UNIVERSIDADE ESTADUAL PAULISTA - UNESP
Faculdade de Engenharia e Ciências – Câmpus de Guaratinguetá

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MEASURES TO OVERCOME THE BARRIERS THAT HINDER THE ADOPTION OF ENERGY-EFFICIENT TECHNOLOGIES IN THE BRAZILIAN BUILDING SEGMENT

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Thesis Co-advisor: Otávio José de Oliveira, DSc.

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IMPACTO POTENCIAL DESTA PESQUISA

Ao propor medidas para superar barreiras à adoção de tecnologias energeticamente eficientes em edificações, a pesquisa oferece um guia prático para formuladores de políticas. Os resultados impactam na eficiência e sustentabilidade dos edifícios, estimulando o crescimento econômico e aumentando a competitividade do Brasil. Além disso, pavimentam o caminho para benefícios e progresso a longo prazo.

POTENTIAL IMPACT OF THIS RESEARCH

By proposing measures to overcome barriers to the adoption of energy-efficient technologies in buildings, the research provides a practical guide for policymakers. The results impact the efficiency and sustainability of buildings, stimulating economic growth and enhancing Brazil's competitiveness. Furthermore, they pave the way for long-term benefits and progress.

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TALITA MARIANE CRISTINO

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I dedicate this research, in a special, to my family.

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“Whatever you do, work at it with all your heart…”.

Colossians 3:23a - Bible

ABSTRACT

The imminent global energy crisis combined with an uncertain climate future highlights the urgency to mitigate undesirable concerns about excessive energy consumption and its environmental impacts. This scenario has led to the development of several actions to reduce global energy consumption. For decades, these actions were directed towards to the industrial segment, since it was the greatest energy consumer in society. However, as time went by, residential, commercial, and public buildings have gained prominence, since they have become responsible for one-third of global final energy consumed and for 15% of greenhouse gas emissions. This scenario is not quite different in Brazil. The energy consumption of this segment has also been growing consistently over the last decades. Therefore, it is important to find ways to reduce the energy consumption of this segment without affecting the comfort and well-being of society. Energy efficiency is the key to solving this issue, in other words, the adoption of energy-efficient (EE) technologies is the best way to deal with this challenge. However, despite the benefits and positive projections linked to such technologies, they have not been widely adopted in buildings, due to the existence of barriers that hinder their adoption. In the literature, there are many publications aimed to identify such barriers. But, just a small portion of them focus on measures to overcome them. And none is dedicated to the Brazilian reality. Therefore, this research aimed to fill this gap. Firstly, it was important to develop a conceptual framework that provides a comprehensive understanding of the barriers that hinder the adoption of EE technologies. Thus, as a result, this framework enabled the delineation of the process of EE technology adoption, highlighting its necessary steps and the stakeholders involved. Notably, the adoption process was subdivided into four stages (Motivation, Information, Planning/Execution, and Results) shaped by both the government and the market. This result still allowed for a meticulous mapping of the barriers specific to the Brazilian context within the adoption process, thus identifying the process stages at which each barrier may emerge. Subsequently, it was possible to study the interrelationships between the barriers that emerge at each stage of the adoption process. This analysis was performed using the ISM (Interpretative Structural Modelling) technique. As a result, it was possible to construct hierarchical structures among the barriers that emerge in each stage of the adoption process, enabling the identification of the critical ones: lack of knowledge on energy efficiency by regulators and legislators (Government Support); lack of financial incentives ("Motivation" phase); lack of demonstration projects ("Information" phase); lack of technical competence and lack of adequate technologies ("Planning/Execution" phase); and lack of good marketing strategies (Market Expansion). From the identification of these critical barriers, it was possible to propose measures to overcome them. Initially, a literature review was conducted to identify such measures. Subsequently, these measures were proposed specifically for the Brazilian context. And although this research had suggested measures to overcome the critical barriers, it was also important to present additional suggestions to overcome the remaining barriers that hinder the adoption of EE technologies in the Brazilian building segment. This strategy ensures that not only the critical barriers are addressed, but also the less prominent ones, thereby facilitating a more effective transition to energy-efficient practices across the entire segment. By proposing measures to overcome barriers to the adoption of EE technologies in the building segment, this research contributes significantly to enhancing the efficiency and sustainability of Brazilian buildings. Additionally, it stimulates economic growth and enhances the country's competitiveness regarding energy issues in the building segment. Thus, the suggested measures not only address immediate challenges but also pave the way for long-term benefits and progress in the Brazilian building segment.

KEYWORDS: energy efficiency; building energy efficiency; energy-efficient technologies; barriers; overcoming measures.

RESUMO

A iminente crise energética global, combinada com um futuro climático incerto, destaca a urgência de mitigar preocupações indesejáveis atreladas ao consumo excessivo de energia e seus impactos ambientais. Este cenário tem levado ao desenvolvimento de diversas ações para reduzir o consumo global de energia. Durante décadas, essas ações foram direcionadas ao segmento industrial, já que é o maior consumidor de energia. Porém, com o passar do tempo, os edifícios residenciais, comerciais e públicos ganharam destaque, uma vez que se tornaram responsáveis por um terço do consumo global de energia e por 15% das emissões totais de gases de efeito estufa. Esse cenário não é muito diferente no Brasil. O consumo de energia deste segmento também tem crescido de forma consistente nas últimas décadas no país. Portanto, é importante encontrar um caminho para reduzir o consumo de energia deste segmento sem afetar o conforto e o bem-estar da sociedade. A eficiência energética é a chave para resolver esta questão, ou seja, a adoção de tecnologias energeticamente eficientes (EE) é a melhor forma de lidar com este desafio. No entanto, apesar dos benefícios e das projeções positivas atreladas a tais tecnologias, elas não têm sido amplamente adotadas, devido à existência de barreiras que dificultam a sua adoção. Na literatura, existem diversas publicações destinadas a identificar tais barreiras. Mas, apenas uma pequena parte delas se concentra em medidas para superar-lás. E nenhuma é dedicada à realidade brasileira. Portanto, esta pesquisa teve como objetivo preencher essa lacuna. Primeiramente, foi importante desenvolver uma estrutura conceitual que proporcionasse uma compreensão abrangente das barreiras que dificultam a adoção de tecnologias EE. Assim, como resultado, foi possível delinear o processo de adoção de tecnologias EE, destacando suas etapas necessárias e os principais envolvidos. Notavelmente, o processo de adoção foi subdividido em quatro etapas (Motivação, Informação, Planejamento/Execução e Resultados) moldadas tanto pelo governo quanto pelo mercado. Esse resultado ainda permitiu um mapeamento meticuloso das barreiras específicas do contexto brasileiro dentro do processo de adoção, identificando assim as barreiras que podem surgir em cada uma das etapas do processo de adoção das tecnologias EE. Posteriormente, as interrelações entre essas barreiras foram analisadas por meio da aplicação da técnica conhecida como Modelagem Estrutural Interpretativa. Como resultado, estruturas hierárquicas das barreiras que podem surgir em cada etapa do processo de adoção foram construídas, permitindo assim identificar cinco barreiras críticas dentro desse processo, que são: falta de conhecimento sobre eficiência energética por parte dos reguladores e legisladores (Apoio Governamental); falta de incentivos financeiros (Fase de “Motivação”); falta de projetos de demonstração (Fase de “Informação”); falta de competência técnica e falta de tecnologias adequadas (Fase de “Planejamento/Execução); e falta de boas estratégias de marketing (Expansão de Mercado). A partir dessa identificação das barreiras críticas foi possível então propor medidas para superá-las. Inicialmente, foi realizada uma revisão de literatura para identificar tais medidas. Posteriormente, essas medidas foram propostas especificamente para o contexto brasileiro. E embora esta pesquisa tenha em um primeiro momento sugerido medidas para superar as barreiras críticas, também foi importante apresentar sugestões adicionais para superar as barreiras restantes que dificultam a adoção de tecnologias EE no segmento de edificações brasileiro. Esta estratégia garante que não só as barreiras mais críticas sejam abordadas, mas também as menos proeminentes, facilitando assim uma transição mais suave e eficaz para práticas de eficiência energética em todo o segmento. Ao propor medidas para superar barreiras à adoção de tecnologias de EE, esta pesquisa contribui significativamente para melhorar a eficiência e a sustentabilidade das edificações no Brasil. Além disso, pode estimular o crescimento econômico e aumenta a competitividade do país em questões energéticas nesse segmento. Assim, as medidas sugeridas não apenas abordam desafios imediatos, mas também podem abrir caminho para benefícios e progresso a longo prazo no setor de edificações brasileiro.

PALAVRAS-CHAVE: eficiência energética; eficiência energética em edificações; tecnologias energeticamente eficientes; barreiras; medidas de superação.

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LIST OF ABBREVIATIONS AND ACRONYMS

ABESCO	Brazilian Association of Energy Conservation Service Companies
ABNT	Brazilian Association of Norms Techniques
ACEEE	America Council for an Energy Efficient Economy
ANEEL	National Electric Energy Agency
BASF	*Badische Anilin- & Soda-Fabrik*
BDCES	Building Disegn Criteria for Energy Saving
BENEFIT	Buildings Energy Efficiency Frontiers & Innovation Technologies
BMZ	Federal Ministry for Economic Cooperation and Development
BNDES	Brazilian Development Bank
BPAs	Building Performance Awards
BPIE	Building Performance Institute Europe
BRICS	Russia, India, China, and South Africa
CAF	Development Bank of Latin America
CAPES	Improvement of Higher Education Personnel
CB3E	*Centro Brasileiro de Eficiência Energética Edificações*
CET	Technical Building Code
CHP	Community Housing Partners
CNPQ	National Council for Scientific and Technological Development
CO_2	Carbon Dioxide
EE	Energy-Efficient
EEDUS	Energy Efficiency in Urban Development Social Housing Focus
EECS	Energy Efficiency Certification Scheme
EEQuest	Energy Efficiency Quick Estimation
EERA	European Energy Research Alliance
EIB	European Investment Bank
EIE	*Espace Info Énergie*
ELETROBRÁS	ELETROBRÁS Centrais Elétricas Brasileiras S.A.
ENCON	Energy Conservation
ENCE	National Energy Conservation Label
EPB	Energy Performance of Buildings
EPC	Energy Performance Certification

EPE	Energy Research Office
EPDB	Energy Performance of Buildings Directive
EPG	Energy Performance Standard for Buildings
ESCO	Energy Services Company
EU	European Union
EXCEN	*Centro de Excelência em Eficiência Energética*
GBIC	Green Buildings Innovation Cluster
GIS	German Agency for International Cooperation
GWh	Gigawatt-hour
HVAC	Heating, Ventilation, Air-Conditioning
IEA	International Energy Agency
FIT	Feed-In Tariff
IECC	International Energy Conservation Codes
ICT	Information and Communication Technologies
INI-C	INMETRO Normative Instruction for Energy Efficiency Classification of Commercial, Service and Public Buildings
INI-R	INMETRO Normative Instruction for Energy Efficiency Classification of Residential Buildings
INMETRO	Institute of Metrology, Quality, and Technology
ISM	Interpretative Structural Modelling
IPTU	Tax on Urban Property and Territorial Property
LED	Light Emitting Diode
LabEEE	Laboratory of Energy Efficiency in Buildings
Low-E	Low Thermal Emissivity
MME	Ministry of Mines and Energy
MURE	*Mesures d'Utilisation Rátionelle de l'Energie*
NBR	Brazilian Technical Standards
NEERMAN	National Energy Efficiency Roadmap for Movement towards Affordable and Natural Habitat
NZEB	Near Zero Energy Building
OIA	Accredited Inspection Bodies
PATH	Partnership for Advancing Technology in Housing
PBE	Brazilian Labelling Program

PEEB	Programme for energy efficiency in buildings
PF4EE	Private Finance for Energy Efficiency
PROCEL	National Electric Energy Conservation Program
R&D	Research and Development
RM	Reachability Matrix
RT2012	*Réglementation Thermique*
RTQ-C	Brazilian Energy Labelling Schemes for Commercial, Public, and Service Buildings
RTQ-R	Brazilian Energy Labelling Schemes for Residential Buildings
SANS	South African National Standard
SNH/MDR	Ministry of Regional Development
SSIM	Structural Self-Interaction Matrix
STEO	Short-Term Energy Outlook
TWh	Terawatt-hour
UFSC	Federal University of Santa Catarina
UK	United Kingdom
USA	United States
USAID	United States Agency For International Development
WOS	Web of Science

SUMMARY

1 INTRODUCTION

The eminent global energy crisis, faced since the mid-1970s, coupled with an uncertain climate future, highlights the urgent need to mitigate the undesirable concerns related to excessive energy use and their environmental impacts, i.e., exhaustion of energy resources, depletion of fossil fuels, global warming, waste accumulation, etc. (PÉREZ-LOMBARD; ORTIZ; POUT, 2008; SHARMA *et al.*, 2011; CABEZA *et al.*, 2014; TETRI, SARVARANTA; SYRI, 2014; ALAM *et al.*, 2019; BELUSSI *et al.*, 2019; SILVERO; RODRIGUES; MONTELPARE, 2020; VENKATRAJ; DIXIT, 2022).

Due to these concerns, reducing energy consumption has been widely recognised as a key challenge to be faced worldwide (HÄCKEL; PFOSSER; TRANKLER, 2017; SILVERO; RODRIGUES; MONTELPARE, 2020). This scenario has led to the development of many actions to reduce the global energy consumption (OIKONOMOU *et al.*, 2009; HÄCKEL PFOSSER; TRANKLER, 2017; KALANGOS, 2017; PETERMAN; KOURULA; LEVITT, 2020; SILVERO; RODRIGUES; MONTELPARE, 2020).

Initially, after the energy crisis of the mid-1970s, these actions were directed mainly at the industrial sector, since it was considered the largest global energy consumer (ALAM *et al.*, 2019). However, as time went by, residential, commercial, and public buildings have been recognised as the greatest contributor to global warming and excessive energy consumption, surpassing the consumption of the industrial segment in the last years (RAMESH; PRAKASH; SHUKLA, 2010; ZHANG; WANG, 2013; GREENOUGH; TOSORATTI, 2014).

According to the International Energy Agency (IEA, 2022), buildings consume one-third of the global final energy and are responsible for 15% of greenhouse gas emissions. Furthermore, the Sixth Report of the Intergovernmental Panel on Climate Change (IPCC, 2022) of the United Nations points out that these rates could still double or triple by 2050 if the efficient use of energy is not a priority of this segment.

Thus, once the global energy demand for buildings is expected to grow steadily, there is a substantial push toward reducing the energy consumption of buildings (MONDOL; KOUMPETSOS, 2013; STREIMIKIENE *et al.*, 2020; FENG *et al.*, 2023).

According to the literature, the best way to achieve this goal is the adoption of energy-efficient (EE) technologies (VAN DOREN *et al.*, 2016; POLZIN; NOLDEN; VON FLOTOW, 2018; ALAM *et al.*, 2019; SILVERO; RODRIGUES; MONTELPARE, 2020).

A lot of research reports that the adoption of EE technologies besides lead to substantial energy reductions in both new and old buildings, also provide saving in energy bills, besides thermal, visual, and acoustic comfort for the building occupants (KORDJAMSHIDI; KING, 2009; MIHIC *et al.*, 2012; LIU *et al.*, 2014; VAN DOREN *et al.*, 2016; GUPTA; ANAND; GUPTA, 2017; PRETE *et al.*, 2017; SOARES *et al.*, 2017; BERTONE *et al.*, 2018; LIU; REN, 2018).

Because of these benefits, the adoption of such technologies has become a strategic target of energy policies around the world (PALMER *et al.*, 2013; DONG; HUO, 2017; DOOLEY, 2017; CRISTINO; FARIA NETO; COSTA, 2018; SOLNØRDAL; FOSS, 2018; VERGERIO *et al.*, 2018; RÖCK *et al.*, 2020; SILVERO; RODRIGUES; MONTELPARE, 2020).

For example, to improve the number of energy efficiency projects, some Member States of the European Community have provided incentives for the adoption of certain EE technologies in buildings, such as heat recovery systems, biomass boilers, heat pumps, solar thermal and photovoltaic collectors (EUROPEAN COMMISSION, 2021). Moreover, many European countries are about to introduce mandatory requirements that encourage the adoption of EE technologies so that new buildings can consume little energy from the electricity grid (EUROPEAN COMMISSION, 2021).

In the United States, there are several incentives to reduce energy consumption and ensure that buildings can generate and manage their demand according to the needs of the occupants using highly efficient heating and cooling equipment, insulators, and intelligent controls connected to the grid, etc. (LANGEVIN *et al.*, 2021).

The Chinese building segment has also adopted EE technologies to substantially reduce the heating energy consumption of their buildings, such as replacing traditional HVAC (heating, ventilation, and air-conditioning) systems with more efficient ones, and changing the materials used in the building envelope (TENG *et al.*, 2021).

Brazil has sought alternatives to reduce the energy demand of their buildings through government initiatives that support the adoption of EE technologies (BERARDI, 2017). It is estimated that new buildings that adopt such technologies can achieve savings of 50% in energy consumption (PROCEL, 2023c). Furthermore, retrofitting existing buildings with EE technologies can lead to energy savings of up to 30% (PROCEL, 2023c).

However, despite the benefits and positive projections around EE technologies, they have not been widely adopted in buildings, so the expected reduction of energy consumption is not fully achieved, thus creating the energy efficiency gap (HIRST; BROWN, 1990; PALMER *et al.*, 2013; PELENUR; CRUICKSHANK, 2014; ZHAN; ZHOU, 2015; YEATSS *et al.*, 2017; HROVATIN; ZORIĆ, 2018; STREIMIKIENE *et al.*, 2020). This phenomenon has received a lot of attention from the academic community and several studies have pointed out that the energy efficiency gap arises due to the existence of barriers that hinder the adoption of such technologies (FASNA; GUNATILAKE, 2019; STREIMIKIENE *et al.*, 2020).

So, to fill this gap, it is necessary to overcome the existing barriers, but first, it is important to know them. Therefore, many studies have been carried out over the years aiming to identify and classify such barriers (TUOMINEN *et al.*, 2012; ADDY; ADINYIRA; KORANTENG, 2014; DJOKOTO; DADZIE; OHEMENG, 2014; DU *et al.*, 2014; GLIEDT; HOICKA, 2015; GERARDEN; NEWELL; STAVINS, 2017; KANGAS; LAZAREVIC; KIVIMAA, 2018; ZHANG *et al.*, 2018; HESSELINK; EMILE; CHAPPIN, 2019).

The recent research conducted by Cristino *et. al.* (2021a) identified 26 barriers through an extensive literature review. These barriers were categorised into six groups based on their similar nature, that is, according to governmental, financial, market, behavioural, professional, and technological aspects. Later, the same authors published a new study where the adherence to barriers identified in the literature was verified for the Brazilian scenario (CRISTINO *et al.*, 2021b).

As a suggestion for future research, the authors highlighted the need to study possible measures for overcoming such barriers (CRISTINO *et al.*, 2021b). This research opportunity reaffirms what was previously said by Fasna and Gunatilake (2019), “no efforts have been taken to identify appropriate strategies that can be taken at different levels to avoid or better manage specific types of barriers”.

Alam *et al.* (2019) also pointed out that there is not enough information on how to implement measures to address barriers. In addition, it is important to study the proposition of such measures for a specific country (FASNA; GUNATILAKE, 2019).

Therefore, it is evident that there is a research opportunity that is still little explored by the scientific community, since only a small portion of the studies focus on measures to overcome barriers to the adoption of EE technologies. In addition, there are no findings specifically for the Brazilian scenario.

Therefore, in the face of such arguments and highlighted opportunities, the questions that guide the development of this research can be formulated as follows: What are the measures to overcome barriers to the adoption of EE technologies in buildings? And how is it possible to propose them for the Brazilian scenario?

1.1 OBJECTIVES

The main objective of this research is to propose measures to overcome the barriers that hinder the adoption of EE technologies in the Brazilian building segment.

1.1.1 Specific objectives

The following specific objectives are proposed to achieve the main objective of the research:

a) To build a framework of barriers to the adoption of EE technologies;
b) To analyse the interrelationship between the barriers;
c) To find out the critical barriers;
d) To find out, in the literature, measures for overcoming such barriers;
e) To find out examples of how such measures have been adopted.

1.2 RESEARCH DELIMITATION

This research is restricted to identifying measures that can be implemented to overcome barriers that hinder the adoption of EE technologies. Therefore, to increase the feasibility and applicability of its results, sought to restrict the scope of analysis to the object of study (barriers and overcoming measures); the types of buildings (residential, commercial, and public); and in regarding the geographical focus (Brazil).

1.3 RESEARCH JUSTIFICATION

Initially, this research supports the current need to improve the energy performance of buildings, given the eminent concerns related to high energy consumption and environmental impacts (BELUSSI *et al.*, 2019; VENKATRAJ; DIXIT, 2022). This scenario points to the growing need to find ways that can be adopted to ensure a sustainable energy future for this sector (ALAM *et al.*, 2019).

From an academic point of view, this research carried out a brief bibliometric study to analyse the scientific community's interest in the theme and its contemporaneity. Table 1 presents the results of the searches conducted in Scopus and Web of Science (WoS).

Table 1 – Results of searches carried out in the Scopus and WoS databases.

Searches	**Key terms**	**Results**	
		Scopus Publications	WoS Publications
#1	("energy efficiency" OR "energy conservation" OR "energy consumption" OR "energy demand" OR "energy management" OR "energy model" OR "energy performance" OR "energy saving" OR "energy use" OR "low consumption" OR "low energy" OR "nearly zero energy" OR "net-zero energy" OR "zero energy")	758,278	431,224
#2	… AND "building sector" OR "buildings"	54,964	31,203
#3	… AND "barriers"	1,665	361
#4	… AND "strategies" OR "drivers" OR "measures"	498	20
#5	…AND "Brazil"	6	0

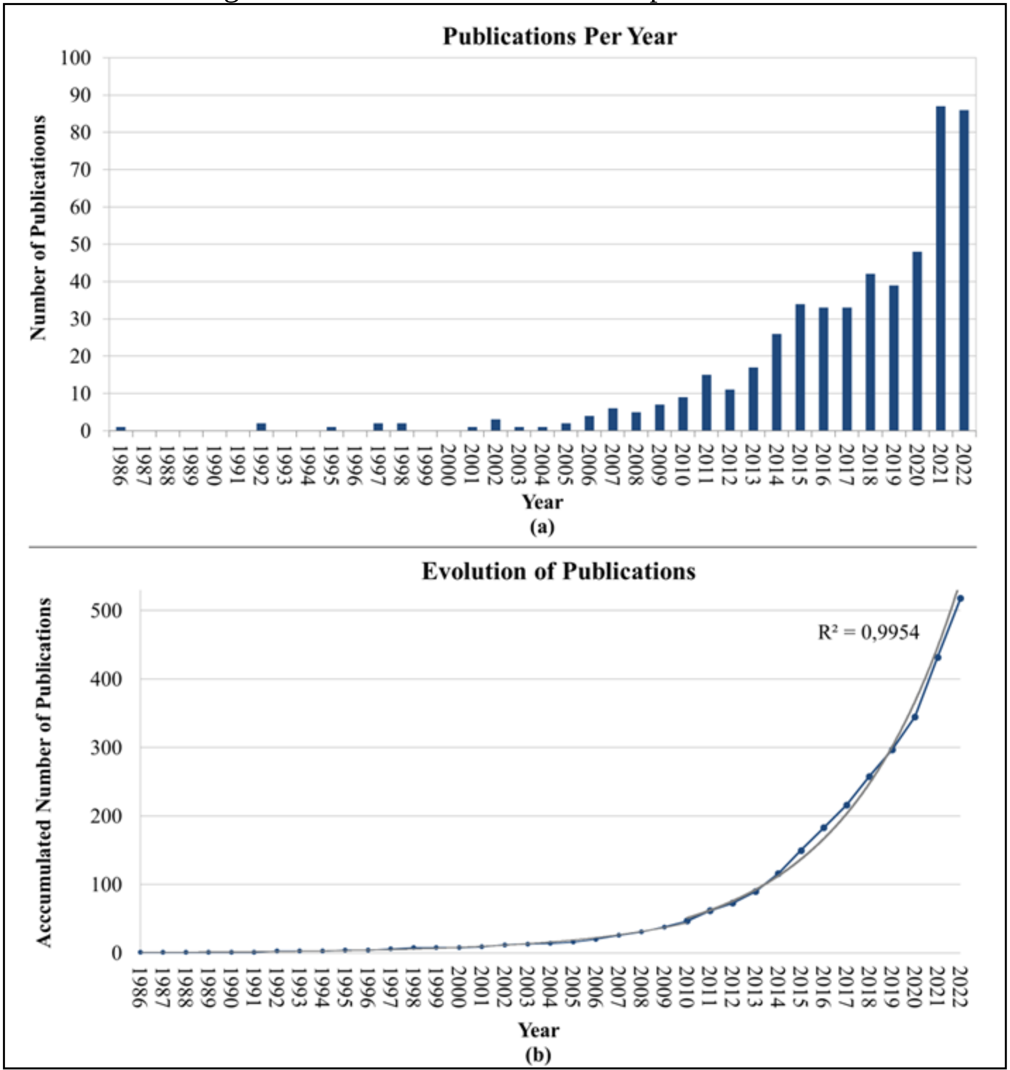
Source: The author.

Analysing the results in Table 1, it is possible to see that the first searches show great interest from the scientific community in studying energy efficiency, mainly in the building segment, since there are more than 80,000 articles published within this field of research.

When the terms related to "barriers" and "strategies" were inserted in the searches, it was possible to limit the research to articles that deal directly with the central theme of this research. A total of 576 articles were filtered through the databases. Figure 1 shows the evolution of publications of these articles to understand if the subject is still at the forefront with a trend of opportunity for new research.

In Figure 1, it is possible to see that the first publication occurred in 1986 (COLTRANE; ARCHER; ARONSON, 1986). However, it was only from the 2000s onwards that the number of publications grew more consistently. It is worth mentioning that the publications of the last four years (2019-2022) represent 50% of the total number of articles that deal with the research topic, which shows the contemporaneity of the subject.

Figure 1 – Time distribution of the publications.



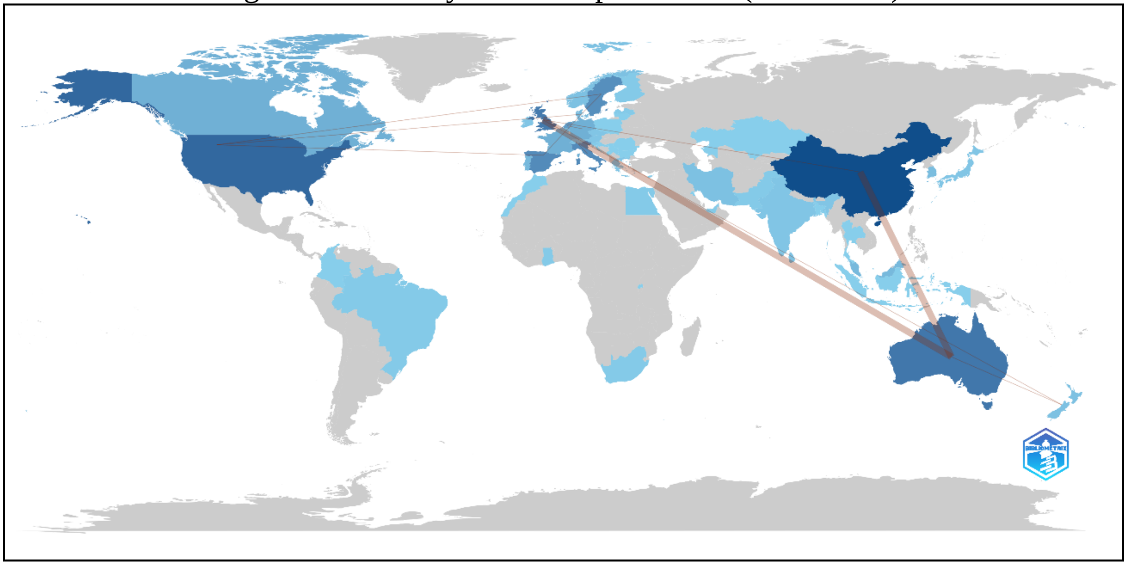
Source: The author.

Furthermore, according to Price's Law (PRICE, 1986) “every field of knowledge grows exponentially until it reaches an inflection point". And when this point is reached, the aspect of the curve changes from exponential to logistic, thus signalling that the maturity of this field of knowledge has been reached, that is, the interest of the scientific community in the subject has cooled down. Thus, looking at Figure 1(b), it is possible to see that the scientific production associated with the subject under study has been growing exponentially, and its turning point has not yet been reached. This indicates that the maturity of the subject has not been attained, showing that there are still research opportunities related to the central theme of this study.

In addition, to provide more evidence on the theme relevance, the articles published between 2019-2022, which represent 50% of published articles, were analysed in more detail to highlight research opportunities supported by Price's Law (PRICE, 1986). This analysis was performed with the support of the Biblioshiny software, from RStudio.

Figure 2 presents the distribution of the number of articles by country.

Figure 2 – Country scientific production (2019-2022).



Source: R software.

Figure 2 shows that the United States and China are the most productive countries, which suggests that these two countries are the most advanced in the subject matter. It is worth mentioning that only three articles were published in Brazil in the last few years, which shows that it is still important to study measures to overcome existing barriers in the Brazilian scenario, since there are still few studies in the country.

Figure 3 presents the cloud of the main authors' keywords of the articles published in the last four years.

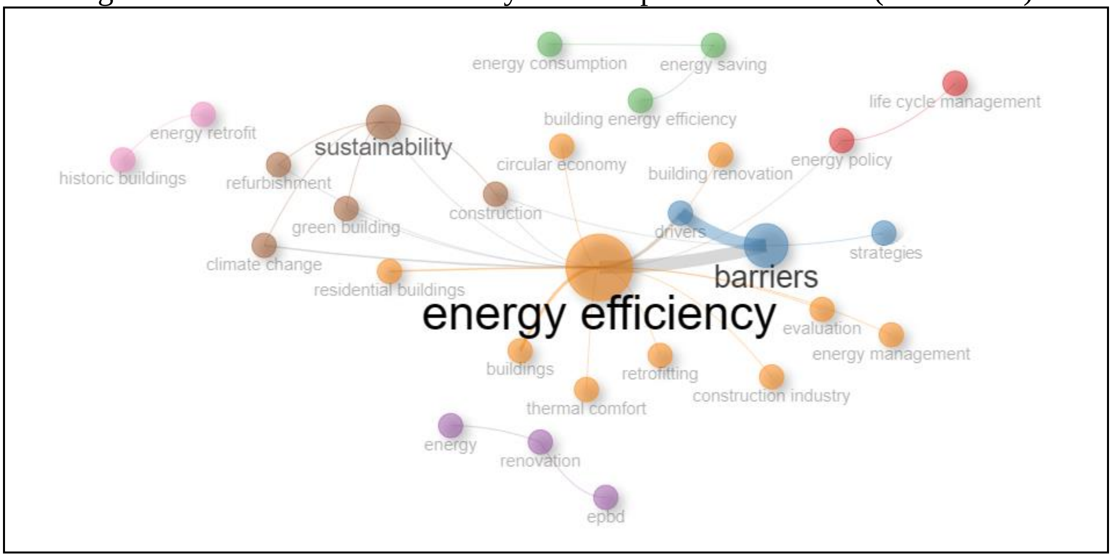
Figure 3 – Cloud of authors' keywords of published articles (2019-2022).

Source: R software.

Figure 3 presents a graphic representation of the frequency of the most prominent words within the research field studied. The larger the keyword in the word cloud, the more common the word is among the keywords. Thus, it can be seen that the terms "energy efficiency" and "barriers" are the terms adherent to this research that are highlighted in the word cloud. In addition, the terms "drivers" and "strategies", which are strictly related to the research objective, also appear in Figure 3. Thus, this result highlights, one more time, the current interest in studying measures for overcoming the barriers that hinder the adoption of EE technologies.

Figure 4 shows the network between these main terms presented in the word cloud.

Figure 4 – Network of authors' keywords of published articles (2019-2022).

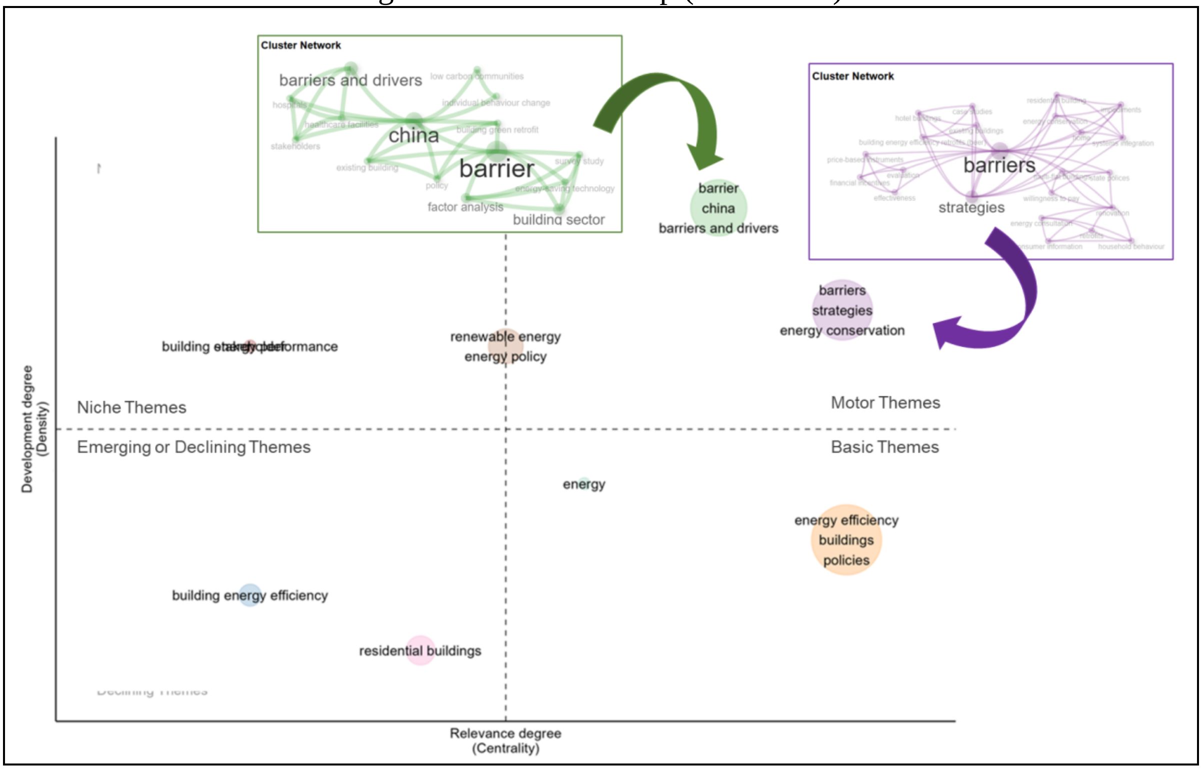


Source: R software.

Looking at the authors' keyword network, it is possible to see that “energy efficiency”, “barriers” and “strategies” are strongly interconnected, which further reinforces the relevance of this study, since it is a subject that is at the forefront within the field of knowledge studied.

Figure 5 shows the thematic map of the research field, which is divided into four quadrants (Q1 to Q4). This result was obtained from a semi-automatic algorithm by reviewing the titles of all references and the relevant author’s keywords to capture deeper variations.

Figure 5 – Thematic map (2019-2022).



Source: R software.

The upper right quadrant (Q1) represents motor themes, the lower right quadrant (Q4) is basic themes, the upper left quadrant (Q2) is the very niche themes, and the lower left quadrant (Q3) is emerging or declining themes.

The motor theme (Q1) is characterised by high density and centrality, that is, grouped the themes that need to be developed in further research. Therefore, looking more closely at Q1, it is possible to see themes that the adherent terms to this research are highlighted in the motor topics identified, showing one more time its relevance.

Finally, it was possible to find, by briefly analysing the articles published between 2019-2022, some research opportunities that this study seeks to fill, as shown in Table 2.

Table 2 – Identified research opportunities.

Research Opportunities	Reference
"To develop measures and strategies that emphasise the adoption of EE technologies"	Camarasa; Kalahasthi; Rosado (2021).
"To identify effective ways to resolve the existing obstacles"	Makvandia; Safiuddin (2021).
"To identify appropriate measures that can be adopted at different levels to avoid or better manage specific types of barriers"	Fasna; Gunatilake (2019)
"To provide information on how to implement strategies to face existing barriers"	Alam *et al.* (2019)
"To study the measures to better manage barriers to a specific context or country"	Fasna; Gunatilake (2019)
"To identify strategies to overcome the barriers that hinder the adoption of EE technologies in Brazil"	Cristino *et al.* (2021b)

Source: The author.

From the bibliometric results and the research opportunities highlighted, it is possible to see that this research still contributes to the maturation of studies that deal with measures for overcoming existing barriers, mainly for the Brazilian scenario. As a practical contribution, the proposition of overcoming measures can support Brazilian managers to direct their strategic choices to overcome the barriers that hinder the adoption of EE technologies in buildings. Furthermore, it is expected that the final results be useful for effectively overcoming existing barriers, and consequently, contributing to the expansion of the energy efficiency market, especially for the building segment.

1.4 THESIS STRUCTURE

The research was structured into eight chapters. Chapter 2 brings a theoretical overview of the concepts concerned with energy efficiency in buildings, and a brief overview of its energy consumption, mainly for the Brazilian scenario.

Chapter 3 details the methodological approach adopted to carry out this research, exposing their classification and methodological flowchart.

Chapter 4 presents the results of the conceptual framework built for a better understanding of the main concepts around the barriers that hinder the adoption of EE technologies in the Brazilian scenario.

Chapter 5 shows the results of Interpretative Structural Modelling (ISM) performed to identify the interrelationships between the barriers.

Chapter 6 presents the measures, identified in the literature, to overcome the critical barriers that hinder the adoption of EE technologies, along with their respective recommendations for the Brazilian scenario.

Chapter 7 shows the measures suggested in the literature, to address the remaining barriers, accompanied by propositions for their implementation in Brazil.

Finally, the discussion and main conclusions of the research are presented in Chapter 8.

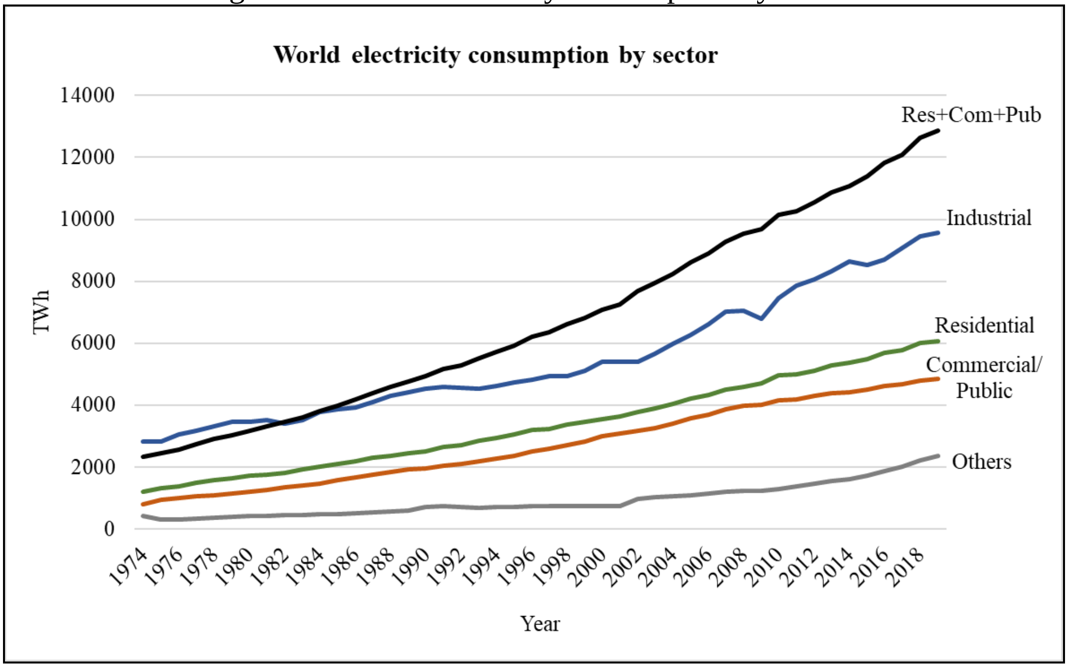
2 OVERVIEW OF BUILDING ENERGY EFFICIENCY

This chapter is dedicated to presenting a brief overview of the electric energy consumption of buildings. Next, the concepts around building energy efficiency are also presented. Some reflections on policy instruments developed for the building segment are also commented on both for the world scenario and Brazil. Finally, the EE technologies adopted in buildings are also commented.

2.1 ELECTRICITY CONSUMPTION OF THE BUILDING SEGMENT

According to the International Energy Agency (IEA, 2022), the electricity consumption of the building segment has been growing consistently over the years, as illustrated in Figure 6.

Figure 6 – World electricity consumption by sector.

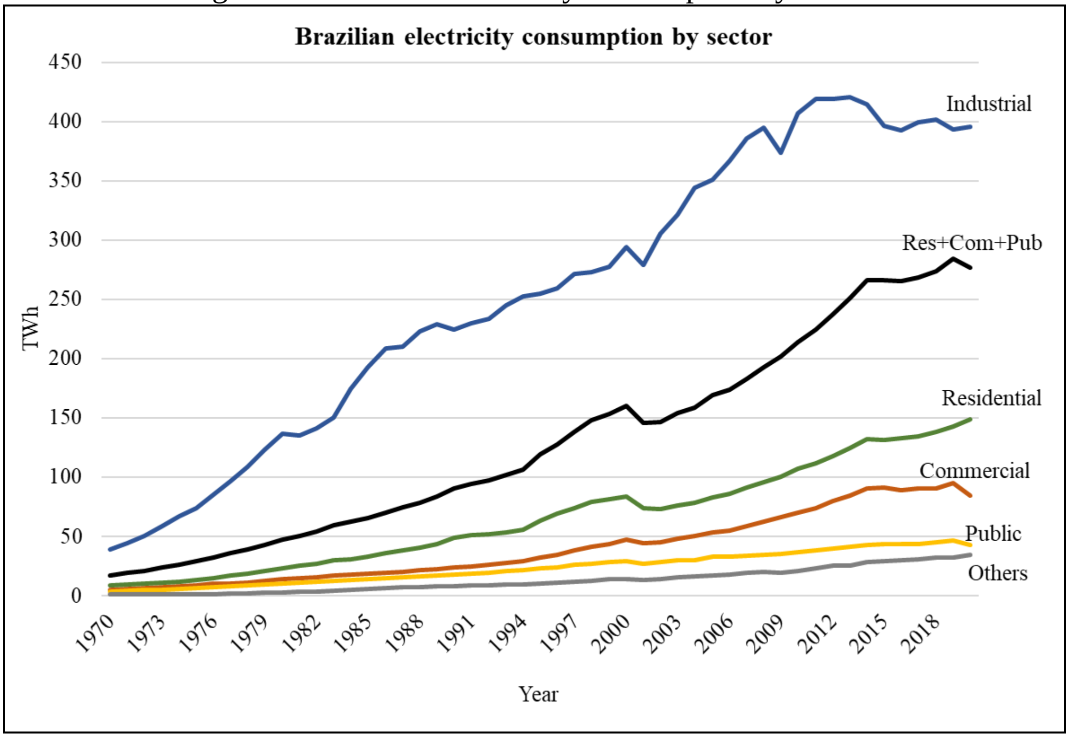


Source: based on the International Energy Agency (IEA, 2022).

In the mid-1980s, the electrical energy consumption of the building segment exceeded the consumption of the industrial sector.

Looking at the Brazilian scenario, it is worth mentioning that electrical energy consumption has also increased over the years, as shown in Figure 7.

Figure 7 – Brazilian electricity consumption by sector.



Source: based on EPE (2022).

The electrical energy consumption of the Brazilian building segment has shown an upward growth since the years '70s. This consumption has been around 250 TWh/per year in the last four decades.

This panorama shows that the building segment has been gaining prominence concerning their electric energy consumption, both worldwide and in Brazil, which suggests the urgency of finding ways to improve the energy performance of buildings that consequently leads to a reduction in energy consumption and its environmental impacts (CRISTINO *et al.*, 2021a).

2.2 BUILDING ENERGY EFFICIENCY

Energy efficiency has been an effective way to improve the energy performance of buildings (OIKONOMOU *et al.*, 2009). Its concept is related to using less energy to obtain the same results, either in a product or service (OIKONOMOU *et al.*, 2009; DUNLOP, 2022). Based on that, energy-efficient buildings are known as those that can satisfactorily meet, with minimal energy consumption, the demands of their occupants (DI ESTEFANO, 2000).

Due to their importance, several programs and actions began to be developed both by political institutions and scientific communities to promote the energy efficiency of buildings (BERARDI, 2013; PRETE *et al.*, 2017; JIA *et al*., 2018; CUNHA *et al.*, 2020; HIMEUR, 2020).

2.2.1 International scenario

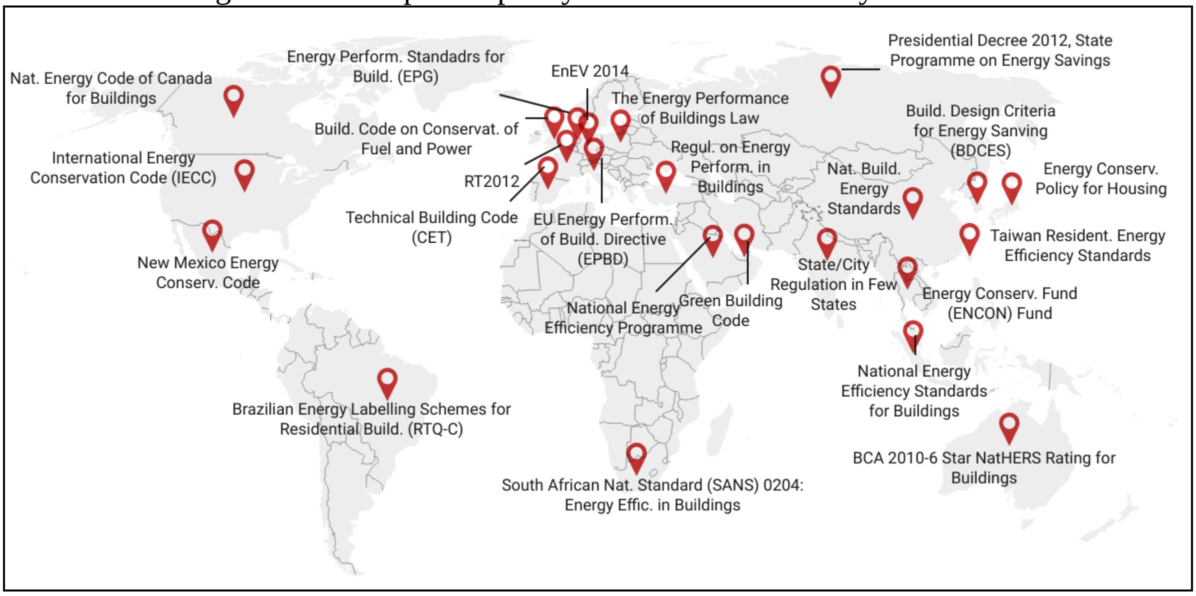
Due to the growth in energy consumption, political institutions began to focus on developing policy instruments (codes, standards, and guidelines) to ensure the energy security of the building segment (GOLBAZI; AKTAS, 2018; BELUSSI *et al*., 2019; ECONOMIDOU *et al*., 2020). Since then, the need to include such instruments in the regulatory framework has spread throughout the world due to their increasing contribution to the energetic development of this sector (CHANDEL; SHARMA; MARWAHA, 2016; LOPES *et al.*, 2016; BELUSSI *et al.*, 2019).

Despite having the same final objective, different policy instruments have been created worldwide to establish energy targets and encourage the adoption of EE technologies for this segment (GOLBAZI; AKTAS, 2018). Figure 8 exemplifies some policy instruments created by countries with the highest building energy efficiency scores, according to the Statista Research Department (2023), which is a company provider of market data in different areas. The source uses several metrics that impact the energy efficiency in buildings to calculate the score, such as energy intensity, building codes, retrofit policies, appliances, equipment standards/labelling, etc.

According to the data provided by Statista Research Department (2023), the first five positions in the ranking are the Netherlands, France, Spain, Germany, and the United Kingdom.

The energy policy instruments created in these countries are based on guidelines implemented by all Member States of the European Union (ANNUNZIATA; FREY; RIZZI, 2013; ECONOMIDOU *et al.*, 2020). One of the main directives adopted is the Energy Performance of Buildings Directive (EPBD), which establishes the minimum requirements for new and retrofitted buildings (ANNUNZIATA; FREY; RIZZI, 2013; BURMAN; MUMOVIC; KIMPIAN, 2014).

Figure 8 – Examples of policy instruments created by countries.



Source: based on International Energy Agency (IEA, 2023) and Statista Research Department (2023).

It is also worth noting that in addition to the EPBD, these countries still have specific policy instruments to support building energy efficiency (ANNUNZIATA; FREY; RIZZI, 2013). For example, the Netherlands created the Energy Performance Standard for Buildings (EPG) which establishes the minimum energy performance for new buildings constructed in the country (IEA,2023).

Another example is the *Réglementation Thermique* (RT2012) (FRANCE, 2023) created in France to also establish minimum performance requirements in terms of building design, thermal comfort, and energy consumption.

Spain, Germany, and the United Kingdom also have some policy instruments capable of boosting the adoption of technologies that improve building energy performance.

In China, the National Building Energy Standards were created to promote energy conservation and renewable energy adoption in buildings, performing actions aimed at energy efficiency and environmental protection for the building segment (HONG, 2009).

In the United States, one of the main policy instruments created was the International Energy Conservation Codes (IECC), which established the minimum requirements for energy efficiency projects in buildings with a focus on how to reduce energy consumption and its environmental impacts (GOLBAZI; AKTAS, 2018; KOIRALA; BOHARA, 2021).

Thus, it is fair to say that the main policy instruments concerned with energy efficiency seek to establish requirements to promote the adoption of EE technologies in the building segment. This highlights, even more, the great interest in increasing building energy efficiency to decrease the energy consumption.

2.2.2 Brazilian scenario

With the oil crises that alarmed the entire world scenario, the Brazilian government also began to show concern about the unbridled energy consumption in the country (FOSSATI *et al*., 2016).

Thus, since the 1980s, several policy initiatives aimed at energy efficiency have been developed to reduce and make energy consumption more efficient in the country (ROSA; LOMARDO, 2004). Such as the CONSERVE Program which was created in 1981 to promote energy conservation in the industrial segment (LOPES *et al*., 2016).

In 1985, the National Electric Energy Conservation Program (PROCEL) was instituted to promote the development of energy efficiency actions (PROCEL INFO, 2023a).

In 2001, the country faced an energy crisis that affected the supply and distribution of electricity throughout the territory, which led to the publication of the Energy Efficiency Law, which promotes the National Policy for Conservation and Rational Use of Energy in the country (SCALCO; FOSSATI; VERSAGE, 2012).

Due to the increasing energy demand for buildings, the government has begun to focus on this segment and has developed specific policy programs and instruments to reduce its energy consumption (LOPES *et al*., 2016). One of these actions was the creation, in 2003, of a Technical Group for Improving Energy Efficiency in Buildings (*GT-Edificações*) which was responsible for developing and regulating procedures to evaluate energy efficiency in buildings (SCALCO; FOSSATI; VERSAGE, 2012).

In 2003, the PROCEL subprogram was launched, known as PROCEL EDIFICA, to implement the concept of building energy efficiency (SCALCO; FOSSATI; VERSAGE, 2012). It is worth noting that this program, besides encouraging the use of more efficient equipment, was also created to promote the development of projects and practical actions to reduce energy consumption in this segment (LOPES *et al.*, 2016).

At the end of 2005, the Technical Secretariat of Buildings (*ST-Edificações*) was created by GT-*Edificações,* whose main responsibility was to discuss technical issues involving energy efficiency indicators in buildings (PBE EDIFICA, 2023).

From that, through PROCEL EDIFICA and the Brazilian Labelling Program, the Brazilian Energy Labelling Schemes for Commercial, Public, and Services Buildings (RTQ-C) and the Brazilian Energy Labelling Schemes for Residential Buildings (RTQ-R) were developed to establish the requirements for obtaining the National Energy Conservation Label issued by the Institute of Metrology, Quality, and Technology (INMETRO) (PROCEL INFO, 2023b).

In 2014, the PROCEL Seal was instituted to identify the level of energy efficiency of buildings to encourage the real estate market to promote buildings with greater energy efficiency (PROCEL INFO, 2023c).

The procedure for obtaining the ENCE (National Energy Conservation Label) and the PROCEL Seal can occur both for commercial, service, and public buildings and for residential buildings (PROCEL INFO, 2023d). Furthermore, they can be granted both at the design stage and after the building construction (PROCEL INFO, 2023d). However, it is expected that the ENCE will be required already in the design phase, as labelled projects, when implemented, can achieve energy consumption savings of up to 50% (PROCEL INFO, 2023c).

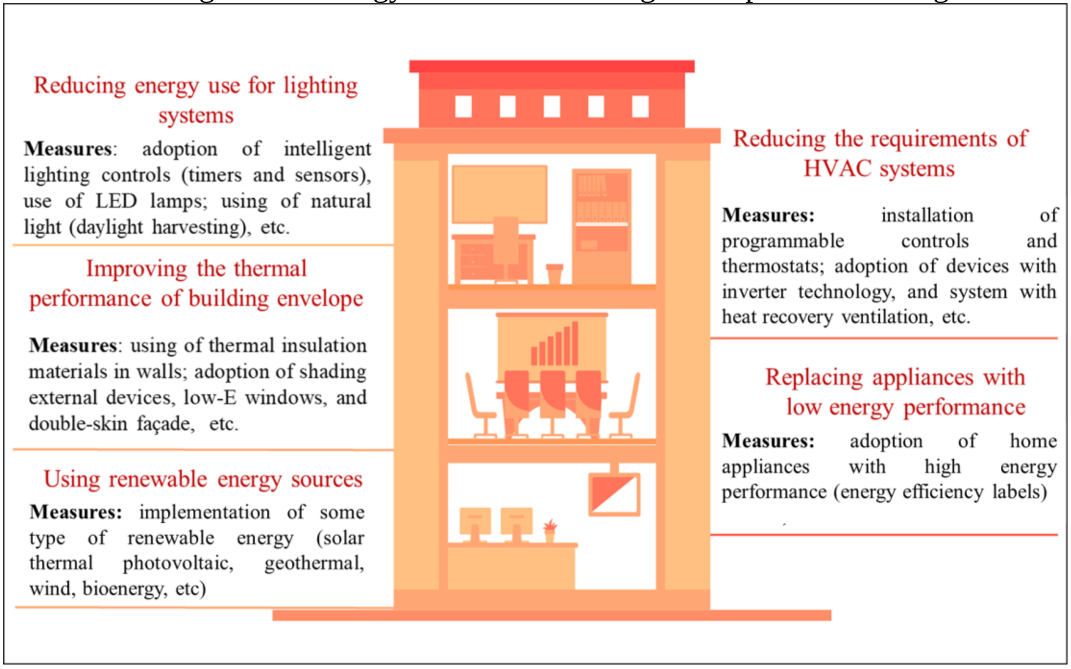
In 2014, the PROCEL Seal became mandatory only for Federal Public Administration buildings (PROCEL INFO, 2023d).

Despite the policy actions related to energy efficiency created in the country, there is still little adherence in buildings, which demonstrates that there is still room for the creation of new instruments that encourage the implementation of measures to promote the adoption of EE technologies.

2.3 ENERGY-EFFICIENT TECHNOLOGIES ADOPTED IN THE BUILDING SEGMENT

Several EE technologies can be considered to improve the energy performance of buildings (GUPTA; ANAND; GUPTA, 2017). Figure 9 summarises the main technologies that can be adopted to achieve this objective.

Figure 9 – Energy-efficient technologies adopted in buildings.



Source: The author.

It can be seen that the technologies presented in Figure 9 were divided into five groups aimed at different targets concerned with energy saving.

The first group is aimed to adopt technologies for reducing the energy use of lighting systems. According to Hinnells (2008), the adoption of new technologies for lighting systems has the potential to significantly reduce the electricity consumption of a building. Among the lighting technologies, it is important to highlight the use of intelligent lighting control, occupancy sensors, and LED (light emitting diode) lamps, besides strategies to take advantage of natural light (HINNELLS, 2008; TETRI; SARVARANTA; SYRI, 2014; KIM; BROWN, 2019). The adoption of these technologies not only reduces energy consumption but also can improve the visual comfort of the occupants (TETRI; SARVARANTA; SYRI, 2014).

Improving the thermal performance of the building envelope is another important target for reducing energy consumption (SOZER, 2010). Since the building envelope is associated with the design and construction of a physical barrier comprised of various components (roof, walls, windows, doors, facades, etc.) that collectively form the structure of the building, it is important to adopt technologies that enhance thermal resistance (SADINENI; MADALA; BOEHM, 2011). A good example is passive technologies such as the thermal insulation materials used in the walls and facades; shading devices to reduce the absorption of solar radiation, and windows made of Low-E glass (low thermal emissivity) (SOZER, 2010).

Another important measure towards energy saving is the use of renewable sources to generate energy locally. The types of renewable energies most used in buildings are solar thermal, photovoltaic, wind, geothermal, and biomass (LI; YANG; LAM, 2013; WU; SKYE, 2021).

HVAC systems are responsible for a large part of the energy consumed in a building (TEKE; TIMUR, 2014; GONZÁLEZ-TORRES *et al*., 2022). Therefore, there are examples of technologies that can reduce the energy demand of this system, such as heat recovery systems; inverter technology incorporated in air conditioners; use of natural ventilation; and combined use of air conditioners and ceiling fans (HUANG; NIU, 2016; RÍOS-FERNÁNDEZ, 2020). Besides saving energy, these technologies can also improve the thermal comfort of the building occupants (TEKE; TIMUR, 2014).

Furthermore, it is important to replace low-energy performance appliances (refrigerators, freezers, washing machines, TVs) with more energy-efficient ones (KELLY, 2021; GONZÁLEZ-TORREZ *et al.*, 2022; VÉREZ; BORRI; CABEZA, 2022).

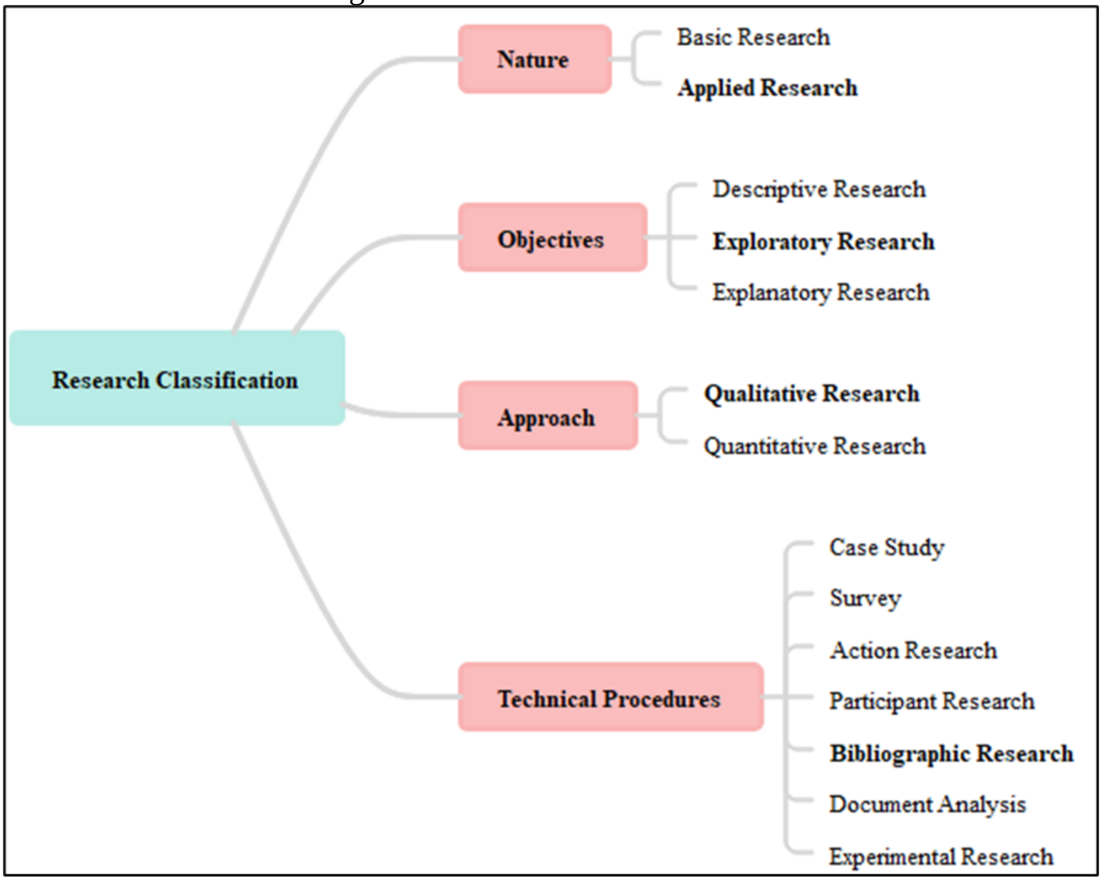
3 METHOD

This chapter aimed to detail the classification of the research and its methodological flow.

3.1 RESEARCH CLASSIFICATION

Scientific research can be classified according to its nature, approach, objectives, and technical procedures (PRODANOV; DE FREITAS, 2013). Figure 10 presents the possibilities for the classification of scientific research, highlighting the classification of this study.

Figure 10 – Research classification.



Source: Adapted from Prodanov and Freitas (2013).

The nature of this research is applied, since it is characterised to generate useful knowledge for practical application to solve specific problems, and its approach is qualitative (GIL, 2008; MIGUEL *et al.*, 2012; KOTHARI, 2013; PRODANOV; DE FREITAS, 2013).

Furthermore, this research, concerned with their objectives, is classified as exploratory for providing greater familiarity with the problem, aiming to make it scientifically explicit

(GIL, 2002; JUPP, 2006).

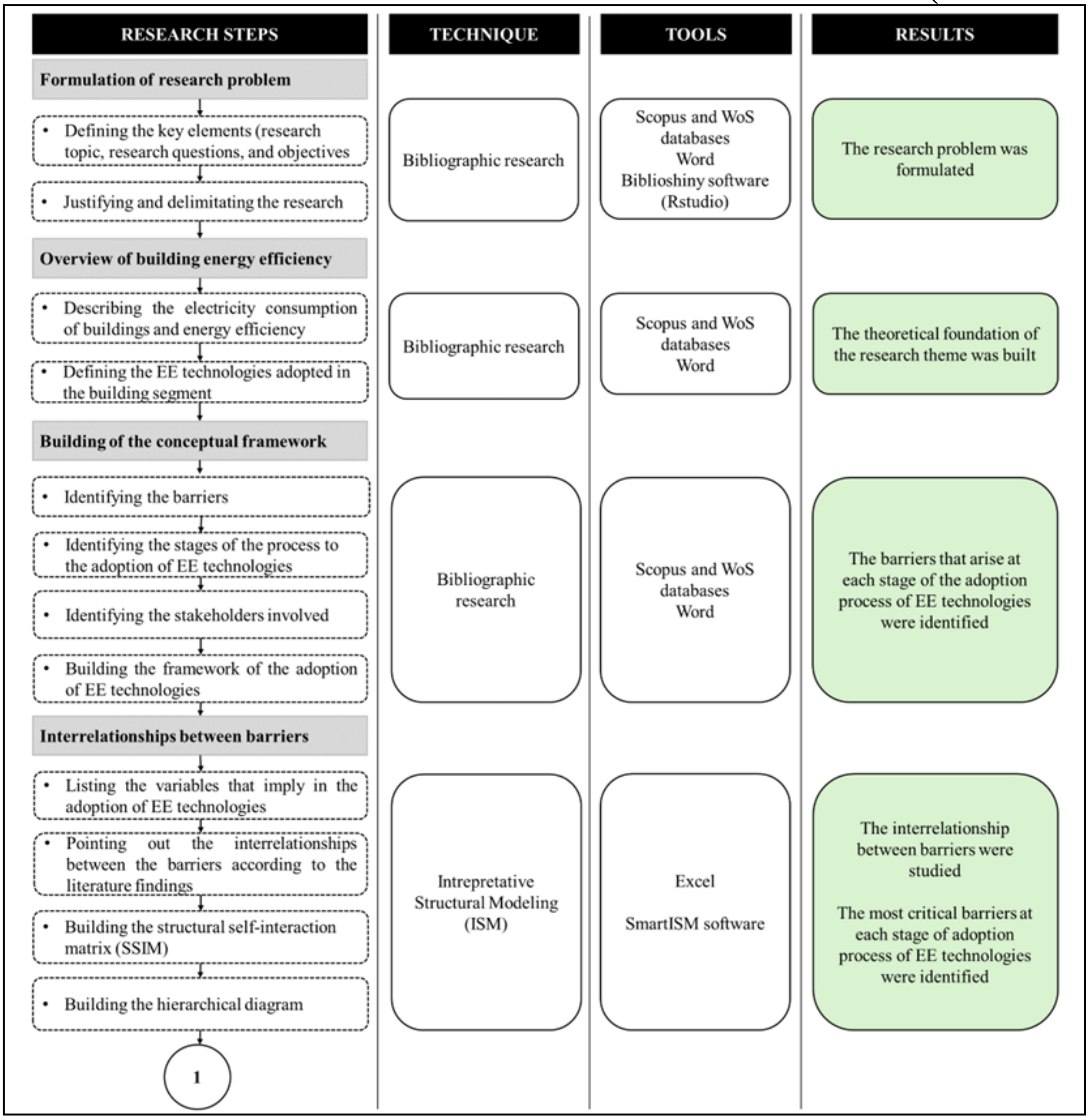
Regarding the technical procedures to be used, the research can be classified as bibliographic research, since it presents conceptual discussions from literature findings (PROVDANOV; DE FREITAS, 2013).

3.2 METHODOLOGICAL FLOWCHART

The research followed the methodological flow outlined in Figure 11. It was subdivided into six detailed steps, described as follows.

Figure 11 – Methodological flowchart.

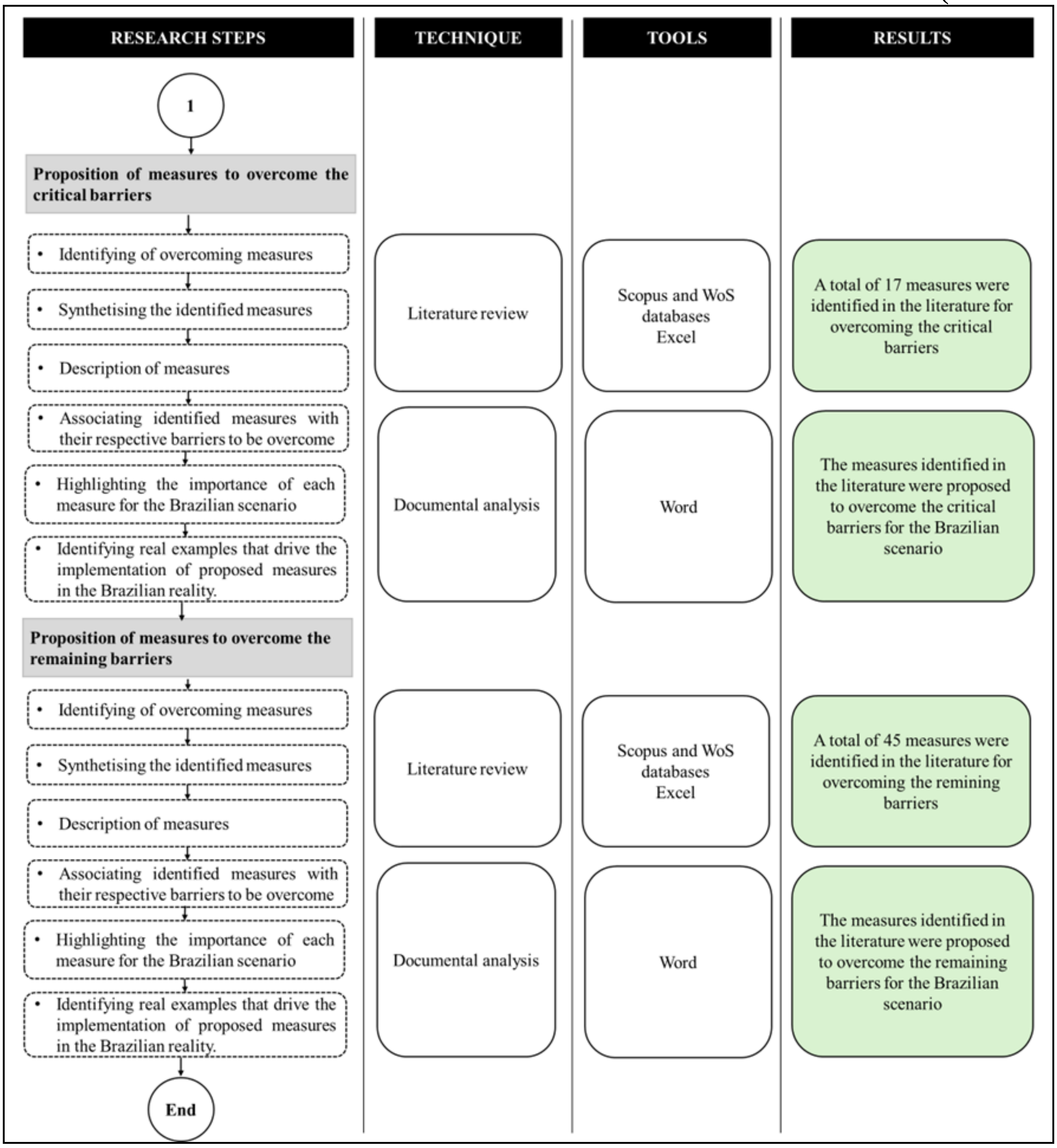
(to be continued)



Source: The author.

Figure 11 – Methodological flowchart.

(conclusion)



Source: The author.

- **Formulation of the research problem**

The inital step in the research process involved establishing the key elements of the study. Firstly, the central theme of the research was defined. Next, research questions and objectives were formulated to guide the investigation. Additionally, the scope of the study was delineated to achieve the proposed objectives. And finally, the justification for the study was provided by explaining its relevance, importance, and potential contributions.

- **Overview of building energy efficiency**

In this phase, a solid theoretical foundation for the research was built by delving into the main concepts related to the theme under study. It was important to comprehensively examine various aspects, including data on electrical energy consumption in buildings, initiatives towards promoting energy efficiency in this sector, and the set of EE technologies that have been implemented. The theoretical foundation was built based on scholarly publications, primarily sourced from databases such as Scopus and Web of Science (WoS), as well as, information provided by relevant government agencies. This comprehensive exploration allowed for a nuanced understanding of the complexities surrounding building energy efficiency, thereby guiding the subsequent stages of this research.

- **Building of the conceptual framework**

This step was carried out to provide a comprehensive understanding of the barriers that hinder the adoption of EE technologies. Given the various approaches existing in the literature to study these barriers, the conceptual framework was constructed based on a barrier model proposed by Weber (1997) in the literature.

Using this model, the process of EE technology adoption was delineated, illustrating its necessary steps and identifying the stakeholders involved. Furthermore, specific barriers to the Brazilian context were meticulously mapped across each stage of the adoption process. It is noteworthy that the conceptual framework was built based on insights obtained from the extensive bibliographic review.

- **Interrelationship between barriers**

The next step of the research was concerned with the application of Interpretative Structural Modelling (ISM) to better understand the interrelationship among barriers that hinder the adoption of EE technologies in the Brazilian building segment. This technique, as elucidated by Attri, Dev, and Sharma (2013), offers a systematic approach to analysing how these barriers interact and mutually influence each other throughout the adoption process. Thus, throught ISM, it was possible to construct a hierarchical structure delineating the relationships between the barriers, highlighting their relative significance and impact on the adoption process. Notably, this hierarchical framework facilitated the identification of the critical barriers in the Brazilian context. For a comprehensive understanding of the ISM methodology utilised in this step, a detailed procedure is provided in Appendix A.

- **Proposition of measures to overcoming the critical barriers**

This step aimed to propose measures to overcoming the critical barriers identifed in the previous step of the research. For that, firstly, a literature review was conducted to identify such measures in the literature.

Therefore, Scopus and WoS databases were chosen for this purpose, given their extensive collection of scientific articles. From that, a research query was formulated to gather a significant sample of publications addressing the central theme.

The keywords used were defined from the delimitation of the research. For example, the query was formulated using terms related to "energy efficiency" and other similar terms; "buildings" and "building sector; "barrier" or "obstacles"; and "drivers", "strategies", "measures", "recommendations", "suggestions". The period covered by the research was considered until 2022. No starting date was defined, thus allowing the database to gather the oldest articles in the literature. Furthermore, the search was limited to the title, abstract, and keywords. Only articles and reviews written in English and published in journals were considered. By the searches, it was possible to identify 503 publications in the Scopus and 63 articles in the WoS database, totalising 566 publications.

From the selected publications, duplicates were excluded, resulting in a total of 518 publications. Subsequently, the title and abstract of each article were read to identify those that addressed measures for overcoming barriers to the adoption of EE technologies, excluding those where the terms related to "measures" were only incidental. At the end of this step, the number of eligible papers for further analysis dropped to 339.

The next step was to gather the measures from these articles. Thus, the 339 publications were read in detail, and the measures were collected from 46 articles.

After identifying such measures in the literature, they were linked with the corresponding barriers to be overcoming. Subsequently, the measures were proposed specifically for the Brazilian context.

In formulating these proposals, it was important to develop a comprehensive scheme aimed at facilitating their implementation in the Brazilian scenario. Thus, beyond simply outlining the barriers and their respectives measures, it was crucial to emphasise the significance of each measure as delineated in the literature for the Brazilian building segment. This involved assessing whether similar initiatives have been previously implemented in Brazil and highlighting how the proposed measures can be adopted in the Brazilian context.

Furthermore, to facilitate the effective implementation of these proposals, real examples of measures implemented in different geographical contexts were also presented.

- **Proposition of measures to overcoming the remaining barriers**

Although the previous step had suggested measures to overcome the critical barriers, it was important to present additional suggestions to overcome the remaining barriers that hinder the adoption of EE technologies in the Brazilian building segment.

These new suggestions are crucial for a comprehensive approach to barrier mitigation. Thus, they can be considered in a second implementation phase, following the initial phase focused on the critical barriers.

Based on that, in this step, the measures to overcome the remaining barriers that hinder the adoption of EE technologies in the Brazilian building segment were presented. It is worth mentioning that these suggestions were proposed following the same method used in the previous step. Firstly, a literature review was conducted on the 46 articles retrieved from the Scopus and WoS databases. After that, the identified measures were linked with the corresponding barriers to be addressed.

Finally, these measures were proposed for the Brazilian scenario, following the same scheme previously presented to propose measures to overcome the critical barriers.

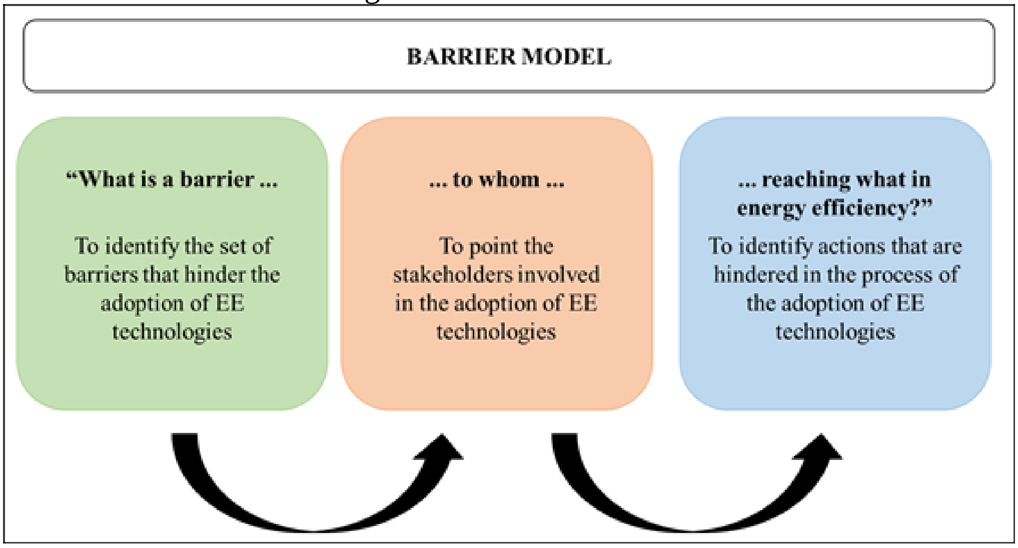
4 CONCEPTUAL FRAMEWORK

The adoption of EE technologies in the building segment is a complex process that requires a collective understanding of the many factors that influence its adoption. The existing literature provides valuable and extensive insights into the barriers that hinder the adoption of such technologies. Therefore, to connect these different insights, this section built a conceptual framework that can provide a clear overview of the main concepts around the barriers that hinder the adoption of EE technologies.

4.1 BARRIER MODEL

The literature reveals different ways to study the barriers that inhibit the adoption of EE technologies. Weber (1997) built a model that addressed three specific characteristics to understand the barriers that hinder energy-efficient use: the objective obstacle, the subject hindered, and the hindered action. Furthermore, the methodological question, designed by Weber (1997), to determine a barrier model is: what is an obstacle to whom reaching what in energy efficiency? Thus, the barrier model is presented in Figure 12.

Figure 12 – Barrier Model.



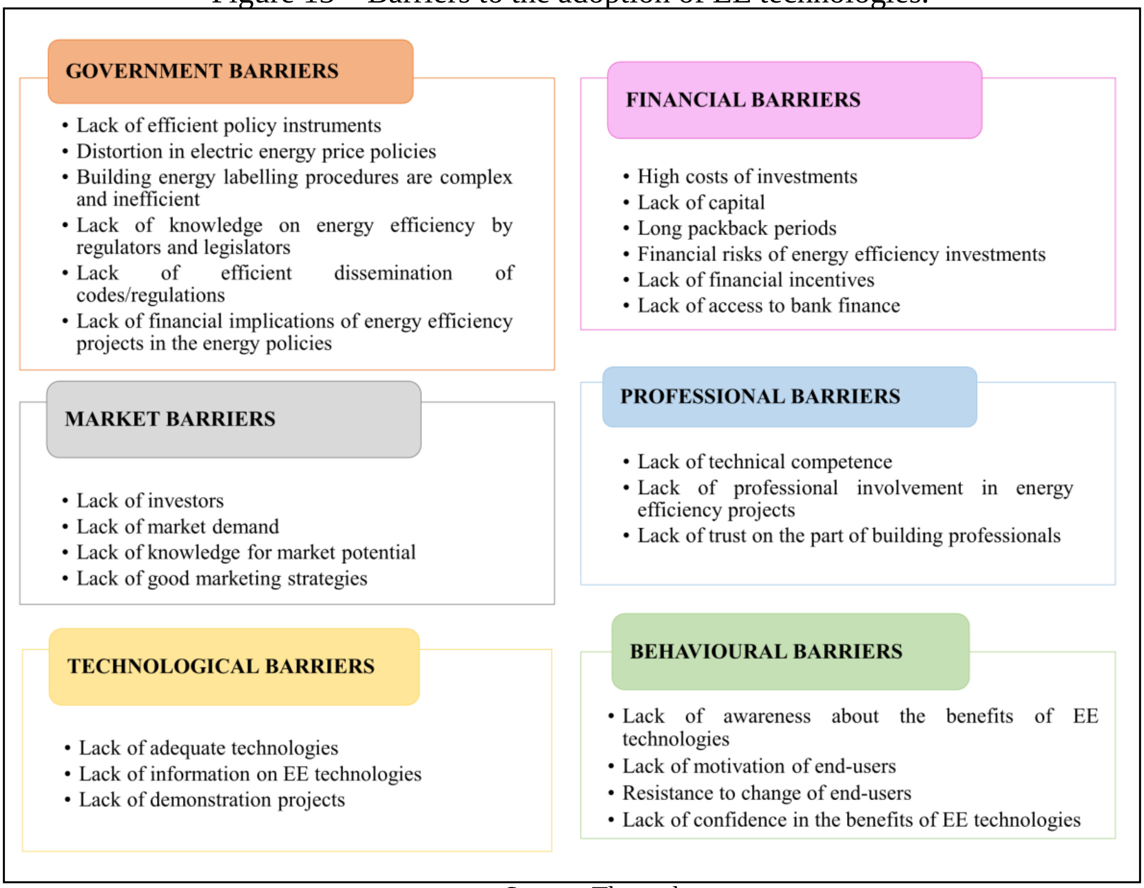
Source: The author.

Therefore, following the barrier model built by Weber (1997), the first pillar presented is the set of barriers that hinder the adoption of EE technologies in the context studied. Besides, it is important to find out who the stakeholders are involved in the adoption of EE technologies. Finally, the hindered actions in the process that led to the adoption of EE technologies are investigated too. From this, it is possible to build a conceptual framework for the adoption of EE technologies to understand better when existing barriers arise before proposing measures.

4.2 BARRIERS THAT HINDER THE ADOPTION OF ENERGY-EFFICIENT TECHNOLOGIES IN THE BUILDING SEGMENT

In the literature, it is possible to find a range of publications dealing with barriers that hinder the progress of building energy efficiency in light of several considerations (GUPTA; ANAND; GUPTA, 2017; PALM; REINDL, 2018; HESSELINK; EMILE; CHAPPIN; 2019, FASNA; GUNATILAKE, 2020). Recent research, developed by Cristino *et. al.* (2021a), identified 26 barriers in the literature. These barriers were categorised into six groups, as shown in Figure 13.

Figure 13 – Barriers to the adoption of EE technologies.



Source: The author.

It is worth mentioning that these barriers and the proposed taxonomy were previously ratified for the Brazilian scenario. Thus, the rest of this subsection is devoted to analysing each group.

4.2.1 Barriers related to government aspects

The government plays an important role in supporting the adoption of EE technologies, through policies and instruments that help to reduce costs and increase the demand for energy-efficient buildings. According to Djokoto, Dadzie, and Ohemeng (2014), this support encourages stakeholders to incorporate such technologies in their building projects. However, despite its importance, the ineffective actions of the governments give rise to barriers to the adoption of EE technologies of different natures, as shown in Table 3.

Table 3 – Barriers related to governmental aspects.

(to be continued)

Barrier	Implications
Lack of efficient policy instruments - There is a lack of functional policy instruments to promote the adoption of EE technologies (QIAN; CHAN, 2010; WANG *et al.*, 2016).	- It makes policy instruments difficult to implement (QIAN; CHAN, 2010; WANG *et al.*, 2016); - It leads to low adherence to existing policy instruments (KANGAS; LAZAREVIC; KIVIMAA, 2018).
Distortion in electric energy price policies - Conventional energy prices do not fully reflect the real external costs (environmental and social) associated with their production, resulting in being energy costs not as high as they really are (HIRST; BROWN, 1990; DU *et al.*, 2014; GLIEDT; HOICKA, 2015).	- It decreases the motivation of owners to adopt EE technologies to save energy (TUOMINEN *et al.*, 2012; BERTONE *et al.*, 2016); - It increases the perception of financial risks associated with the adoption of EE technologies (WEBER, 1997; KANGAS; LAZAREVIC; KIVIMAA, 2018); - It reduces the possibility of access to bank financing (TRAVEZAN; HARMSEN; TOLEDO, 2013). - It extends the payback period of the capital invested (DURDYEV *et al.*, 2018).

Source: The author.

Table 3 – Barriers related to governmental aspects.

(conclusion)

Barrier	Implications
Building energy labelling procedures are complex and inefficient - The guidelines for obtaining energy efficiency labels for buildings are often complex and difficult to comprehend (DURDYEV *et al*., 2018; ALAM *et al.*, 2019; LI; COLOMBIER, 2019).	- It constrains the adoption of EE technologies (PERSSON; GRÖNKVIST, 2015).
Lack of knowledge on energy efficiency among regulators and legislators - Regulators and legislators responsible for developing policy instruments for the building segment do not have sufficient knowledge regarding energy efficiency (ALAM *et al*., 2019).	- It leads to the malfunction and misinterpretation of policy instruments (AMETEPEY; AIGBAVBOA; ANSAH, 2015; IQBAL *et al.*, 2021); - It leads to the creation of inefficient policy instruments (KANGAS; LAZAREVIC; KIVIMAA, 2018).
Lack of efficient dissemination of codes/regulations - There is a lack of mechanisms for the dissemination of the policy instruments related to building energy efficiency (GOODIER; CHMUTINA, 2014; FASNA; GUNATILAKE, 2020).	- It decreases the public knowledge around the policies that govern created to promote the adoption of EE technologies (FASNA; GUNATILAKE, 2020).
Lack of financial implications of energy efficiency projects in the energy policies - Energy policies fail to provide evidence of the costs associated with investments for the development of energy efficiency projects (ADEYEYE; OSMANI; BROWN, 2007; CURTIUS, 2018).	- It reduces market interest in adopting EE technologies (ADEYEYE; OSMANI; BROWN, 2007).

Source: The author.

4.2.2 Barriers related to financial aspects

To incentivise the adoption of EE technologies, it is very important to provide evidence of the economic benefits linked to the adoption of such technologies. However, financial obstacles like the ones present in Table 4 can arise.

Table 4 - Barriers related to financial aspects.

(to be continued)

Barrier	Implications
High costs of investments - The initial costs associated with energy efficiency projects are higher than the conventional ones (ZHOU; LI; CHIANG, 2013; JAGARAJAN *et al.,* 2017).	- It extends the payback period on invested capital (ADEYEYE; OSMANI; BROWN, 2007; WANG *et al.*, 2016; DADZIE *et al.*, 2018; IQBAL *et al.*, 2021); - It discourages potential investors from adopting EE technologies in their building projects (WANG *et al.*, 2016; ASSYLBEKOV *et al*., 2021; IQBAL *et al.*, 2021); - It increases financial risks associated with the adoption of EE technologies (LIU *et al*., 2020, CARLANDER; THOLLANDER, 2023); - It limits access to bank financing (TRAVEZAN; HARMSEN; TOLEDO, 2013); - It makes owners more resistant to adopting EE technologies (ALAM *et al.*, 2019).
Lack of capital - Owners do not have enough capital to cover the costs associated with the adoption of EE technologies in their buildings (ZHOU; LI; CHIANG, 2013; JAGARAJAN *et al.*, 2017; IQBAL *et al.*, 2021).	- It increases perceptions of financial risks linked to energy efficiency investments (CARLANDER; THOLLANDER, 2023); - It reduces owner interest in opting for EE technologies in their projects (IQBAL *et al.*, 2021); - It is difficult to access banking alternatives to financing energy efficiency projects (CARLANDER; THOLLANDER, 2023).
Long payback periods - The financial returns on invested capital in energy efficiency projects are gradual, accumulating in the medium and long term (SAHA *et al.*, 2021).	- It introduces financial risks for investors (PERSSON; GRÖNKVIST, 2015; CARLANDER; THOLLANDER, 2023); - It decreases the confidence of owners in the economic benefits of EE technologies (IQBAL *et al*., 2021); - It discourages owners from adopting EE technologies in their buildings (ASSYLBEKOV *et al*., 2021); - It complicates access to bank financing (TRAVEZAN; HARMSEN; TOLEDO, 2013).
Financial risks of energy efficiency investments - There are some uncertainties and risks associated with the adoption of EE technologies, that can be seen as a possibility of financial loss (THOLLANDER, OTTOSON, 2008).	- It discourages owners from considering EE technologies in their buildings (ASSYLBEKOV *et al*., 2021); - It makes owners reluctant to adopt EE technologies (ZHOU; LI; CHIANG, 2013; KANGAS; LAZAREVIC; KIVIMAA, 2018); - It impedes access to bank finance (TRAVEZAN; HARMSEN; TOLEDO, 2013).

Source: The author.

Table 4 - Barriers related to financial aspects.

(conclusion)

Barrier	Implications
Lack of financial incentives - The absence of monetary mechanisms such as subsidies, financial rewards, special funds, tax benefits, and discounts to support owners in investing in EE technologies is evident (WANG *et al.,* 2016; GUPTA; ANAND; GUPTA, 2017; SAHA *et al.,* 2021).	- It increases capital costs and payback periods associated with the adoption of EE technologies (WHITNEY; DREYER; RIEMER, 2020; IQBAL *et al.*, 2021); - It increases the need for a larger amount of capital to cover the costs linked to the adoption of EE technologies (IQBAL *et al.*, 2021); - It increases the possibility of financial risks in the adoption of EE technologies (WHITNEY; DREYER; RIEMER, 2020); - It is difficult to create bank financing to facilitate the adoption of EE technologies (TRAVEZAN; HARMSEN; TOLEDO, 2013; AMETEPEY; AIGBAVBOA; ANSAH, 2015; PAIHO; AHVENNIEMI, 2017; IQBAL *et al.*, 2021); - It discourages owners from investing in EE technologies (AHVENNIEMI, 2017; IQBAL *et al.*, 2021; PAIHO; SAHA *et al.*, 2021); - It increases resistance among owners to opt for EE technologies (CARLANDER; THOLLANDER, 2023).
Lack of access to bank finance - It is difficult to access financing provided by bank institutions to facilitate investments in energy efficiency projects (TRAVEZAN; HARMSEN; TOLEDO, 2013).	It discourages owners from adopting EE technologies in their building projects (CHAN *et al.*, 2018; ALAM *et al.*, 2019).

Source: The author.

4.2.3 Barriers related to market aspects

The adoption of EE technologies can directly result in an impressive reduction of energy consumption in buildings. However, despite the proven cost-effectiveness, there are potential EE technologies that are not adopted due to market barriers, as presented in Table 5.

Table 5 - Barriers related to market aspects.

Barrier	Implications
Lack of investors - There is a lack of investors willing to incorporate EE technologies in their building projects (ADDY; ADINYIRA; KORATENG, 2014).	- It limits the expansion possibilities of the energy efficiency market (HÄKKIEN; BELLONI, 2011; DJOKOTO; DADZIE; OHEMENG, 2014; KANGAS; LAZAREVIC; KIVIMAA, 2017).
Lack of market demand - There is a low demand for technologies that enhance the energy performance of buildings (HÄKKINEN; BELLONI, 2011; DJOKOTO; DADZIE; OHEMENG, 2014; DARKO *et al.*, 2017).	It decreases the adoption of EE technologies (HÄKKINEN; BELLONI, 2011; DJOKOTO; DADZIE; OHEMENG, 2014; DARKO *et al.*, 2017).
Lack of knowledge of market potential - There is insufficient understanding of the real potential of the energy efficiency market to impact the reduction of consumption and environmental impacts in buildings (GUPTA; ANAND; GUPTA, 2017; YEATTS *et al.*, 2017).	- It reduces the number of investors and low demand for EE technologies (DJOKOTO; DADZIE; OHEMENG, 2014).
Lack of good marketing strategies - Effective marketing strategies are lacking to increase public acceptance of EE technologies (GLIEDT; HOICKA, 2015; DADZIE *et al.*, 2018).	- It decreases the knowledge levels associated with the energy efficiency market (DADZIE *et al.*, 2018); - It reduces the public acceptance of EE technologies adoption (DADZIE *et al.*, 2018); - It inhibits market expansion (GLIEDT; HOICKA, 2015; WANG *et al.*, 2016; DADZIE *et al.*, 2018).

Source: The author.

4.2.4 Barriers related to behavioural aspects

The behaviour of end-users is crucial to achieving the energy-saving targets expected for the building segment. However, as outlined in Table 6, some barriers can hinder building end-users from actively participating in energy-saving initiatives.

Table 6 - Barriers related to behavioural aspects.

Barrier	Implications
Lack of awareness about the benefits of EE technologies - Owners and occupants remain unaware of the benefits associated with the adoption of EE technologies (REDDY; PAINULLY, 2004).	- It increases the resistance of owners and occupants to choose new and innovative EE technologies (PAN; PAN, 2019; LIU, *et al.*, 2020; IQBAL, *et al.*, 2021; CARLANDER; THOLLANDER, 2023); - It decreases the confidence of the owners and occupants about the benefits of EE technologies (LIU *et al.*, 2020); - It reduces the motivation of owners and occupants to adopt EE technologies (LIU *et al.*, 2020).
Lack of motivation of end-users - The owners and occupants are not motivated to incorporate EE technologies in their buildings (YEATTS *et al.*, 2017; ALAM *et al.*, 2019).	- It increases the resistance of owners and occupants to the adoption of EE technologies (ALAM *et al.*, 2019).
Resistance to change of end-users - Occupants and owners are inert in adopting technologies, preferring conventional ones instead of investing in unfamiliar ones (CHAN *et al.*, 2018).	- It discourages owners and occupants from selecting more efficient technologies over the conventional ones they are used to using (IQBAL *et al.*, 2021).
Lack of confidence in the benefits of EE technologies - There is no confidence in the benefits that EE technologies can add to buildings on the part of owners and occupants (YEATSS *et al.*, 2017).	- It increases resistance to change of the owners and occupants (HOPKINS, 2016); - It decreases interest from owners and occupants in adopting EE technologies in their buildings (GOODIER; CHMUTINA, 2014).

Source: The author.

4.2.5 Barriers related to professional aspects

The EE technologies are evolving very fast. Thus, building professionals must be technically qualified to implement energy-saving solutions. However, the labour qualification is still low, raising several barriers that hinder the diffusion of EE technologies, as presented in Table 7.

Table 7 - Barriers related to professional aspects.

Barrier	Implications
Lack of technical competence - The professionals do not have the specific expertise or technical skills to implement EE technologies in the developed projects (GUPTA; ANAND; GUPTA, 2017; JAGARAJAN *et al*., 2017; DURDYEV *et al*., 2018).	- It reduces the involvement of the professionals, since they become more confident in getting involved in projects that they are used to developing (IQBAL *et al*., 2021; CARLANDER; THOLLANDER, 2023); - It increases mistrust regarding the benefits of EE technologies for their building projects (AMETEPEY; AIGBOVBOA; ANSAH, 2015; CARLANDER; THOLLANDER, 2023).
Lack of professional involvement in energy efficiency projects - There is a lack of interest among professionals in participating in energy efficiency projects (DJOKOTO; DADZIE; OHEMENG, 2016; KANGAS; LAZAREVIC; KIVIMAA, 2018).	- It reduces the level of adoption of EE technologies, since these professionals prefer to work on conventional projects (DJOKOTO; DADZIE; OHEMENG, 2016).
Lack of trust on the part of building professionals - The professionals do not trust in the benefits that EE technologies can bring to their building projects (DJOKOTO; DADZIE; OHEMENG, 2016; HOPKINS, 2016).	It decreases the professional interest in developing energy efficiency projects (KANGAS; LAZAREVIC; KIVIMAA, 2017).

Source: The author.

4.2.6 Barriers related to technological aspects

Major advances in reducing the energy consumption in buildings are achieved by improving energy management. However, there are certain concerns, like those in Table 8, that make it difficult.

Table 8 - Barriers related to technological aspects.

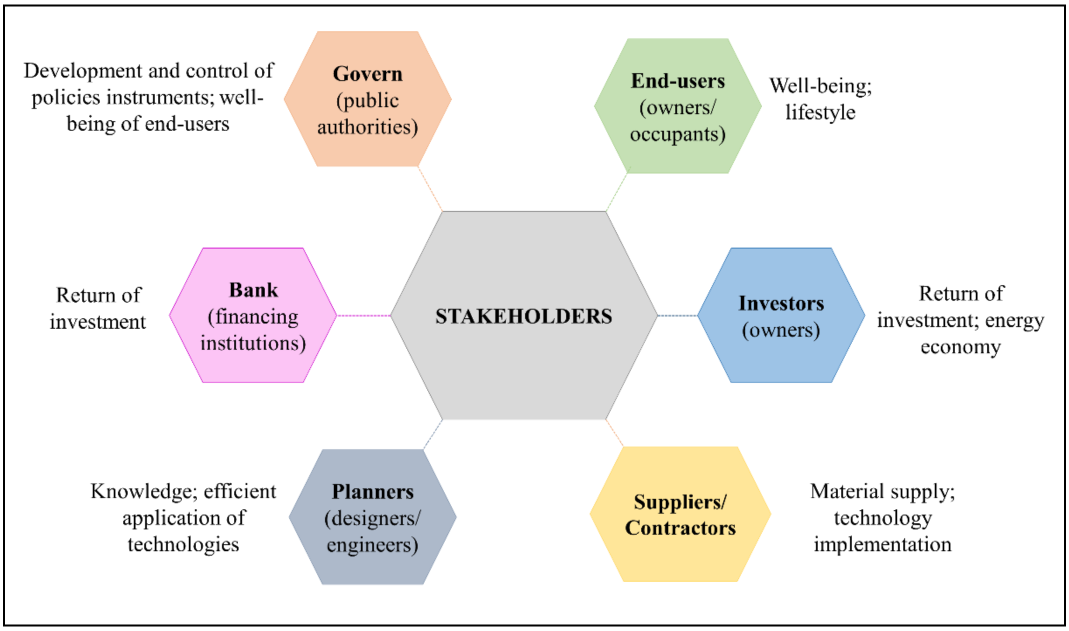
Barrier	Implications
Lack of adequate technologies - Some of the available technologies present compatibility issues with the building structure, or still they are difficult to integrate into buildings (DU *et al*., 2014; WANG *et al*., 2016; GUPTA; ANAND; GUPTA, 2017).	- It leads to the rejection of EE technologies by those who design energy efficiency projects (WANG *et al.*, 2016); - It decreases the confidence of professionals in implementing EE technologies in their building projects (DU *et al.*, 2014; WANG *et al*., 2016).
Lack of information on EE technologies - There is no sufficient information available on the costs, quality, and benefits of EE technologies (THOLLANDER, OTTOSON, 2008; PELENUR; CRUICKSHANK, 2014).	- It increases the lack of knowledge about EE technologies among stakeholders (THOLLANDER; OTTOSON, 2008).
Lack of demonstration projects - There is a lack of successful demonstration projects that show innovation, economic and technical viability, and new opportunities for energy efficiency in the building segment (WANG *et al*., 2016; PAIHO, AHVENNIEMI, 2017).	- It increases the lack of information on the safety and stability of energy efficiency projects (WANG *et al*., 2016); - It decreases the dissemination of the economic benefits of EE technologies among stakeholders (WANG *et al.*, 2016); - It makes difficult the dissemination of specific information about EE technologies among stakeholders (THOLLANDER; OTTOSON, 2008).

Source: The author.

4.3 STAKEHOLDERS INVOLVED IN THE ADOPTION OF ENERGY-EFFICIENT TECHNOLOGIES

The second pillar in Weber's model is concerned with the stakeholders. In the literature, it is possible to find several definitions of the stakeholders involved in the adoption of EE technologies in the building segment. Thus, besides knowing the barriers to the adoption of EE technologies, it is important to identify who are the stakeholders that can be responsible for or impacted by the existence of one determined barrier. This information can help to develop measures to overcome the barriers, since they can be implemented also considering the stakeholders involved in each stage of the adoption process. Thus, Figure 14 presents, according to Feige, Wallbaum, and Krank (2011), the main stakeholders involved in the adoption of EE technologies, as well as their main concerns related to energy efficiency projects.

Figure 14 – Main stakeholders involved in the adoption of EE technologies.



Source: Adapted from Feige, Wallbaum and Krank (2011).

The government has the responsibility to support the process that leads to the adoption of EE technologies. Its responsibility is to develop and control policy instruments that establish goals and strategies to reduce energy consumption and greenhouse gas emissions.

Financial institutions are responsible for providing upfront funding to support the adoption of EE technologies.

The planners are the professionals who work on the required project for the adoption of EE technologies. They are responsible for obtaining all information necessary to estimate the costs and potential savings of the project. Its main concerns are related to knowledge and the efficient application of technologies.

The contractors and suppliers are the professionals responsible for ensuring the efficient implementation of such technologies. Its main concerns are focused on material/technology supply to execute energy efficiency projects.

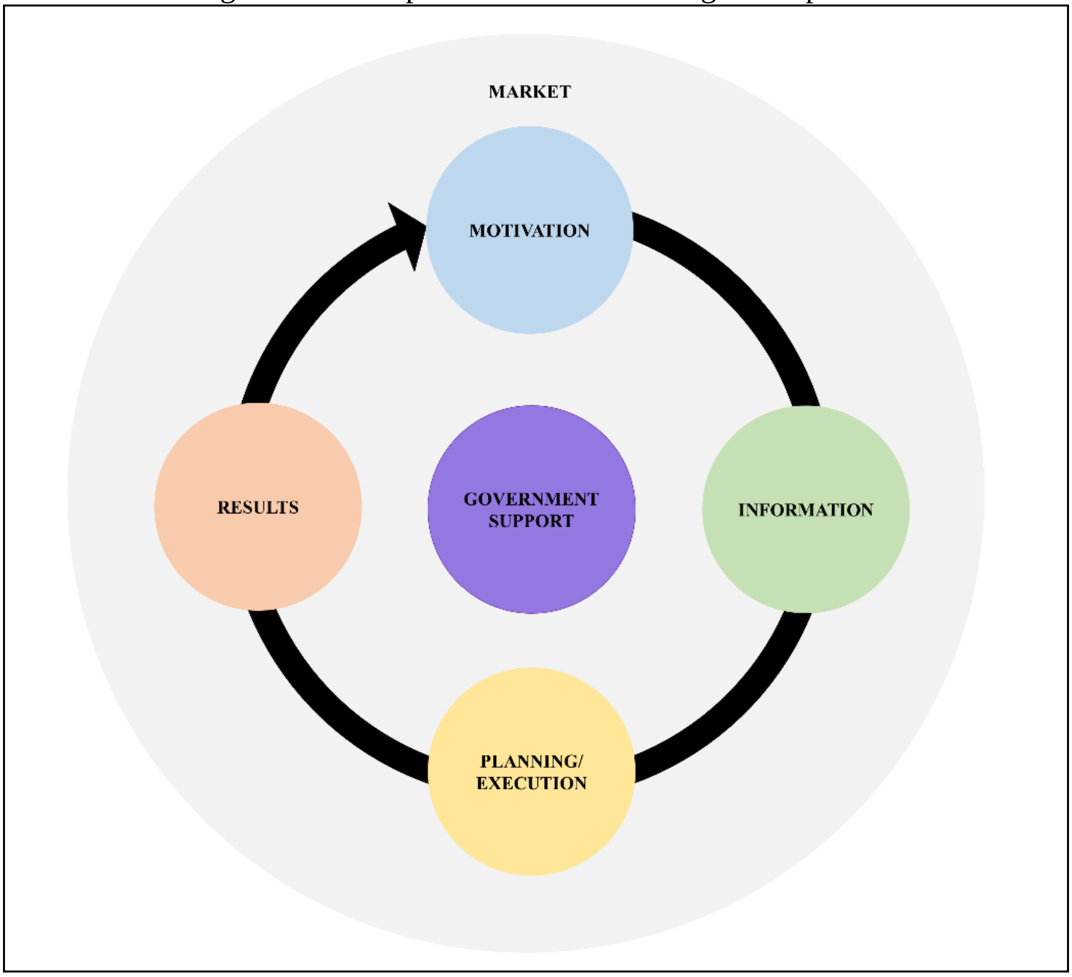
The investors are owners interested in adopting EE technologies in their buildings. Thus, their expectations regarding energy efficiency projects must be met at the end of the process.

Finally, end-users are those who enjoy the results of the adoption of EE technologies. Their main concerns are related to well-being and lifestyle.

4.4 THE PROCESS OF THE ADOPTION OF ENERGY-EFFICIENT TECHNOLOGIES IN THE BUILDING SEGMENT

The adoption of EE technologies can be described as a multiphase process shaped by the government and the market, as illustrated in Figure 15.

Figure 15 – The process of EE technologies adoption.



Source: The author.

The government is responsible for driving the adoption of EE technologies during all its phases.

The adoption of EE technologies starts to be considered by owners and investors when they feel motivated, mainly, by financial savings arising from energy consumption reduction.

Once the stakeholders feel motivated, they start wondering for more information on EE technologies, like cost performance, whether there are demonstration projects available, etc.

As soon as the decision has been made to adopt EE technologies, planning and execution measures should be taken, such as hiring specialised professionals in energy efficiency.

After the installation of EE technologies, the results are measured, that is to say, the electric energy bills are followed to see if the investment was worth it.

Negative results reduce market demand and the number of new investors, reducing in such a way the expansion of the market for EE technologies.

4.5 FRAMEWORK OF THE ADOPTION OF ENERGY-EFFICIENT TECHNOLOGIES IN THE BUILDING SEGMENT

Several barriers to the adoption of EE technologies can arise during this process. Cristino *et al.* (2021a) have gathered 26 barriers from the literature review and classified them into six categories (governmental, financial, professional, market, technological, and behavioural). However, to suggest measures to overcome them it is worth understanding how these barriers fit into the framework of the adoption of EE technologies. Thus, Figure 16 is an evolution of Figure 15, in which it is possible to see the steps in the process of adopting EE technologies, along with the barriers that may emerge in each of their steps.

The government can drive the adoption of EE technologies during all its phases.

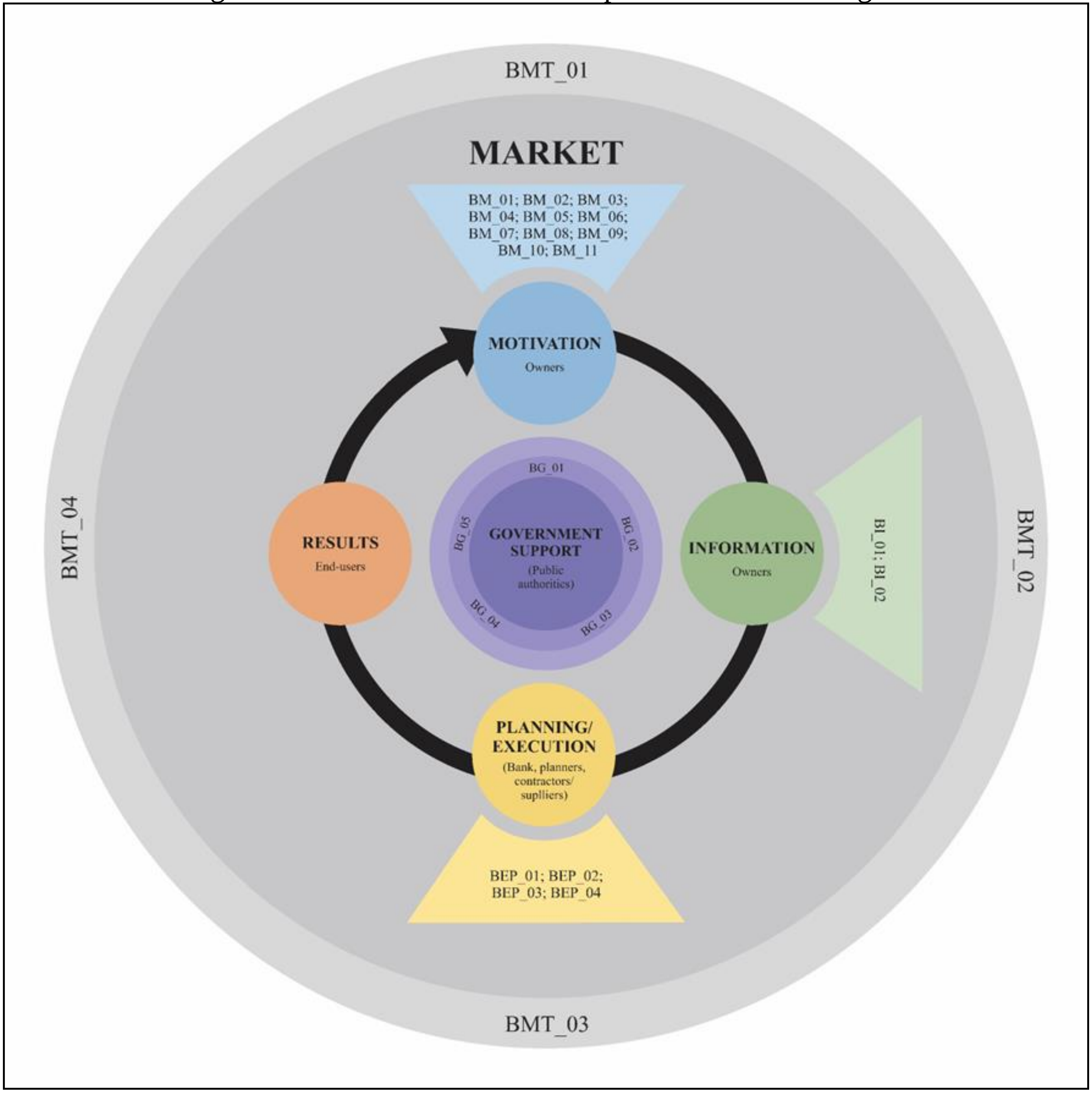
The lack of <u>legislations, codes, and regulations</u> (BG_01) that establish a minimum standard of energy efficiency for buildings in general, added to the <u>lack of dissemination of the few existing ones</u> (BG_04) decreases the motivation of the whole society to invest in EE technologies.

Furthermore, the <u>financial implications linked to the investment of energy efficiency projects in the energy policies</u> (BG_05) should be better understood.

Energy labelling could be a great motivator for adopting EE technologies, since they help consumers to choose the most energy-efficient buildings, lowering energy bills and reducing the environmental impacts. However, <u>the inefficiency and complexity of the labelling procedures</u> (BG_02) can discourage the adoption of such technologies.

The effects of these barriers could be mitigated, or even, overcome, were it not for the <u>lack of knowledge on energy efficiency by regulators and legislators</u> (BG_03).

Figure 16 – Framework of the adoption of EE technologies



Source: The author.

During the motivation phase, several barriers such as the high costs of investments (BM_01), lack of capital (BM_02), and lack of financial incentives (BM_05), lead the owners/investors to reconsider whether this type of investment is truly worthwhile.

Investments in EE technologies have long payback periods (BM_03) and are very sensitive to distortions in energy price policies (BM_07), which increases the financial risks (BM_04), leading to a lack of bank financing (BM_06).

Some end-users are not aware of the benefits arising from EE technologies (BM_08), others do not trust this kind of technology (BM_11), and still, others are resistant to change (BM_10).

All these obstacles decrease the motivation (BM_09) to adopt EE technologies.

If, despite these barriers, owners and investors are still considering the adoption of EE technologies, further technical information regarding costs, performance, etc., will be needed. However, they can face obstacles like lack of information (BI_01) and lack of demonstration facilities (BI_02).

Once these barriers are overcome, it is time to consider the efficient technologies in the projects. However, a great part of building professionals do not trust EE technologies (BEP_03), perhaps because they do not have the technical competencies (BEP_01) required by the job, consequently, they do not get involved with this sort of project (BEP_02).

Sometimes, new technologies seem to fit a given situation. However, in real situations, it proves they are inadequate (BEP_04).

According to the literature, no barriers emerge while measuring the results, because the results can be seen directly in the electric bill.

It is fair to say that the barriers that emerge during the process of adoption of efficient technologies shape the energy efficiency market, in such a way, that additional barriers to the adoption of EE technologies, beyond those mentioned above, arise as a consequence of the market itself. For example, the lack of marketing strategies (BMT_04) is responsible for the lack of knowledge of the energy-efficient market (BMT_03), hindering its development. This lack of awareness subsequently leads to the lack of investors (BMT_01) willing to adopt such technologies, ultimately resulting in a lack of market demand (BMT_02).

Based on the results presented in this chapter, it is possible to illustrate the process of adoption of EE technologies, showing its necessary steps, as well as, those stakeholders involved. Furthermore, the barriers identified for the Brazilian scenario have been distributed throughout each stage of the adoption process. Thus, this conceptual structure has allowed the visualisation of how overcoming a particular barrier can improve the flow of the adoption process, and still identify those impacted by this. These results are useful for achieving the objectives of this research, since the measures proposed to overcome a given barrier can be directed towards the stage of the adoption process in which it arises, as well as, considering who will be impacted by such a measure proposed. This is valuable to ensure the continuity of the flow of the EE technologies adoption process.

5 INTERRELATIONSHIPS BETWEEN THE BARRIERS TO THE ADOPTION OF ENERGY-EFFICIENT TECHNOLOGIES

Before proposing measures to overcome the barriers that hinder the adoption of EE technologies, it is important to understand how these barriers influence each other. This can be achieved using the Interpretative Structural Modelling (ISM) approach. Developed by Warfield in 1974, this technique has been widely used to analyse and structure complex relationships among a set of variables.

In this study, ISM allows for identifying the relationships between the barriers, making it possible to visualise their interdependencies and mutual influences (AZEVEDO; CARVALHO; CRUZ-MACHADO, 2013; SHARMA; GROVER; SHARMA, 2017). The technique results in the construction of a hierarchical model (KHABA; BHAR, 2018). By understanding this hierarchy, it is possible to identify the critical barriers that have the potential to influence other barriers (SHARMA; GROVER; SHARMA, 2017; IQBAL *et al.*, 2021).

It is important to understand that the influence identified through ISM does not necessarily imply that one barrier is the direct cause of the existence of another. Instead, this influence may increase the intensity or impact of another barrier. For example, if it is found that Barrier A influences Barrier B, this does not mean Barrier A is the reason Barrier B exists, but it may intensify the severity or difficulty associated with overcoming Barrier B.

From that, it is possible to identify which barriers have more influence over others. This helps to prioritise the barriers that need to be urgently overcome, as they may be causing or potencialising the existence of others.

Therefore, the analysis using ISM technique allows us to identify which barriers have the greatest influence on the others. This is crucial to prioritise the barriers that need to be overcome urgently, as they may be contributing to the existence or severity of others. By understanding these interactions, it is possible to more effectively target the efforts to overcome the most impactful barriers and thus facilitate the adoption of EE technologies in the building segment.

Accordingly, this section applies the ISM technique to analyse the relationship among the barriers that emerge at each stage of the adoption process of EE technologies, aiming to identify the barriers that require priority attention to be overcome. The following subsections present the results of the interrelationships between the barriers studied for the Brazilian scenario, emphasising the critical ones identified through the ISM technique.

Further and detailed information on this technique can be found in Appendix A.

5.1 INTERRELATIONSHIPS BETWEEN THE BARRIERS THAT HINDER THE GOVERNMENT SUPPORT

Five barriers can arise during the process of adopting EE technologies, hindering the government from supporting those interested in adopting such technologies.

Thus, for better visualisation of the results obtained by the ISM technique, these barriers were coded as shown in Table 9.

Table 9 – Barriers that hinder the government support.

Code	Barrier
BG_01	Lack of efficient policy instruments
BG_02	Building energy labelling procedures are complex and inefficient
BG_03	Lack of knowledge on energy efficiency by regulators and legislators
BG_04	Lack of efficient dissemination of codes/regulations
BG_05	Lack of financial implications of energy efficiency projects in the energy policies

Source: The author.

The relationship between the barriers shown in Table 9 was studied, thus resulting in a structural self-interaction matrix (SSIM), as shown in Table 10.

Table 10 – SSIM for Table 9.

Barriers	BG_01	BG_02	BG_03	BG_04	BG_05
BG_01	-	V	A	O	O
BG_02	-	-	A	O	O
BG_03	-	-	-	V	V
BG_04	-	-	-	-	O
BG_05	-	-	-	-	-

Source: The author.

where,

V = Barrier *i* implies in Barrier *j*;

A = Barrier *j* implies in Barrier *i*;

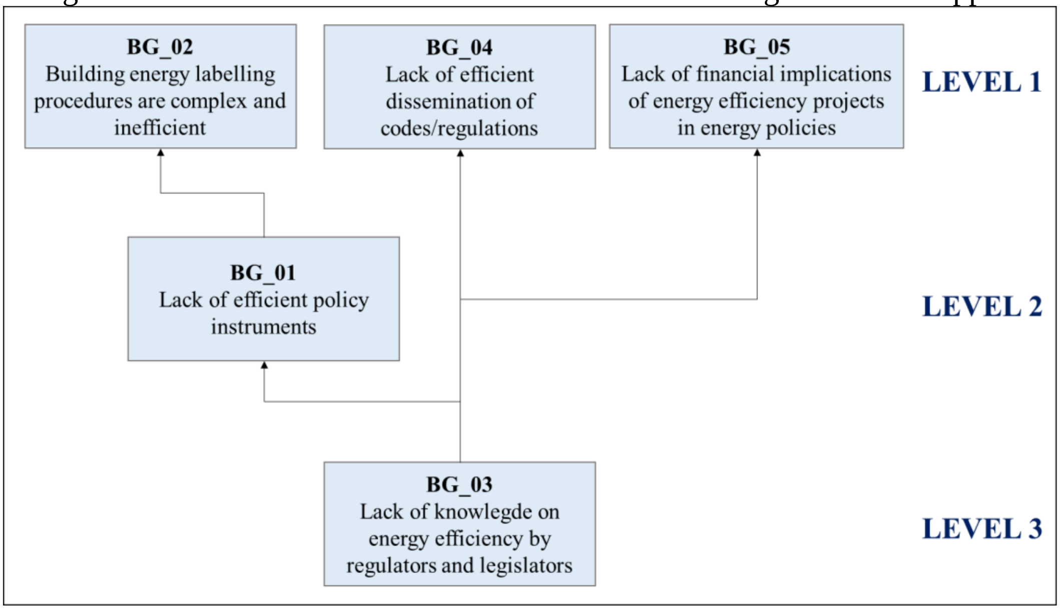
X= Barrier *i* and *j* imply in each other;

O = Barriers *i* and *j* are unrelated.

The nature of these relationships was obtained directly from the literature.

The submission of Table 10 to the procedure detailed in Appendix A resulted in the hierarchical model, as shown in Figure 17, that was obtained from SmartISM (*http://www.smartism.sgetm.com/ISM.aspx/*).

Figure 17 – Hierarchical structure of barriers that hinder government support.



Source: The author.

According to Iqbal *et al.* (2021), the barriers considered the least important are the ones at the topmost level, whereas those listed at the very bottom are the critical ones. However, it is worth mentioning that as cited by Tan *et al.* (2019), the hierarchy model classifies the barriers by influence, therefore, the barriers at the base of the hierarchy are considered the critical because they imply the barriers at the levels above. Those at the topmost level are the least important due to their weak influence on other barriers.

Based on that, the BG_03 ("lack of knowledge on energy efficiency by regulators and legislators") is considered the critical barrier. This barrier occupied Level 3 of the ISM model, and its importance is due to its direct or indirect influence on the other four barriers of this group.

On Level 2 is the barrier BG_01, which refers to the lack of efficient legislation, codes, and regulations regarding energy efficiency in building projects, consequently leading to the existence of barrier BG_02.

On Level 1 there are three barriers (BG_02, BG_04, and BG_05), which are considered the least important, as they do not imply the existence of any other barrier.

5.2 INTERRELATIONSHIPS BETWEEN THE BARRIERS THAT ARISE IN THE "MOTIVATION" PHASE

In this phase, eleven barriers were identified as being those that can discourage owners from opting for EE technologies in their buildings. To study the relationship between them, through the ISM technique, they were first coded as shown in Table 11.

Table 11 – Barriers that arise in the "Motivation" phase.

Code	Barrier
BM_01	High costs of investments
BM_02	Lack of capital
BM_03	Long payback periods
BM_04	Financial risks of energy efficiency investments
BM_05	Lack of financial incentives
BM_06	Lack of access to bank finance
BM_07	Distortion in electric energy price policies
BM_08	Lack of awareness about the benefits of EE technologies
BM_09	Lack of motivation of end-users
BM_10	Resistance to change of end-users
BM_11	Lack of confidence in the benefits of EE technologies

Source: The author.

The relationship between these barriers shown in Table 11 is presented in Table 12.

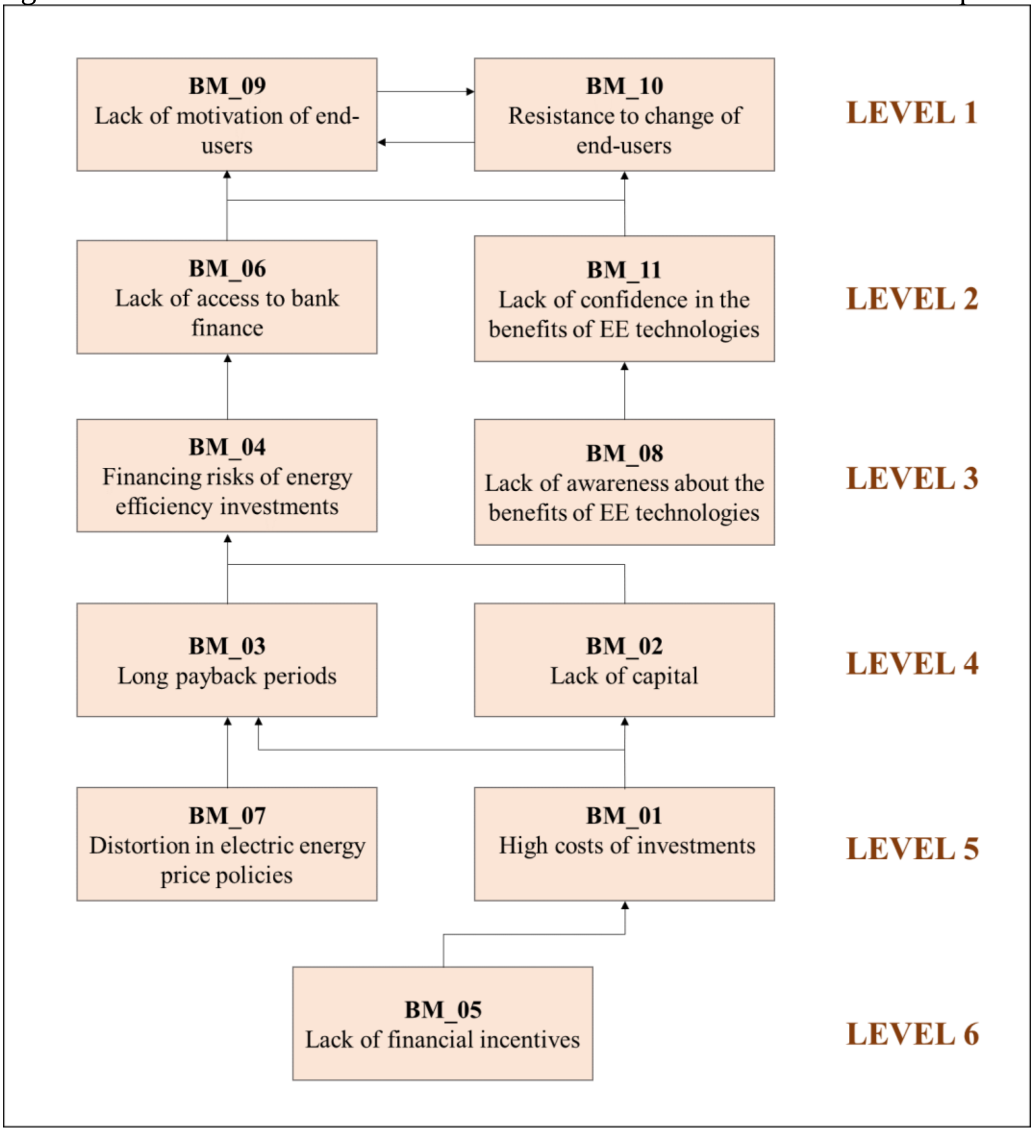
Table 12 – SSIM for Table 11.

Barriers	**BM_01**	**BM_02**	**BM_03**	**BM_04**	**BM_05**	**BM_06**	**BM_07**	**BM_08**	**BM_09**	**BM_10**	**BM_11**
BM_01	-	O	V	V	A	V	O	O	V	V	O
BM_02	-	-	O	V	A	V	O	O	V	O	O
BM_03	-	-	-	V	A	V	A	O	V	O	V
BM_04	-	-	-	-	A	V	A	O	V	V	O
BM_05	-	-	-	-	-	V	O	O	V	V	O
BM_06	-	-	-	-	-	-	A	O	V	O	O
BM_07	-	-	-	-	-	-	-	O	V	O	O
BM_08	-	-	-	-	-	-	-	-	V	V	V
BM_09	-	-	-	-	-	-	-	-	-	X	A
BM_10	-	-	-	-	-	-	-	-	-	-	A
BM_11	-	-	-	-	-	-	-	-	-	-	-

Source: The author.

Based on Table 12, and following the process shown in Appendix A, a hierarchical model for these barriers, Figure 18, was reached.

Figure 18 – Hierarchical structure of barriers that arise in the “Motivation” phase.



Source: The author.

According to the ISM model, the higher the level occupied by the barrier, the more important it is, since it directly or indirectly implies the barriers above it. Therefore, while BM_05 (lack of financial incentives) is the critical barrier in Figure 18, since it implies directly all other barriers (but BM_07 and BM_08). The barriers BM_09 (lack of motivation of end-users) and BM_10 (resistance to change of end-users) are the least important ones. It is noteworthy that there is a mutual influence between them, suggesting that the emergence of one can lead to the existence of the other.

5.3 INTERRELATIONSHIPS BETWEEN THE BARRIERS THAT ARISE IN THE "INFORMATION" PHASE

Only two barriers were identified as being those that may hinder information about EE technologies from reaching those interested in adopting them.

For the application of the ISM, these barriers were coded, as shown in Table 13.

Table 13 – Barriers that arise in the "Information" phase.

Code	Barrier
BI_01	Lack of information on EE technologies
BI_02	Lack of demonstration projects

Source: The author.

Table 14 presents the SSIM concerned with these barriers.

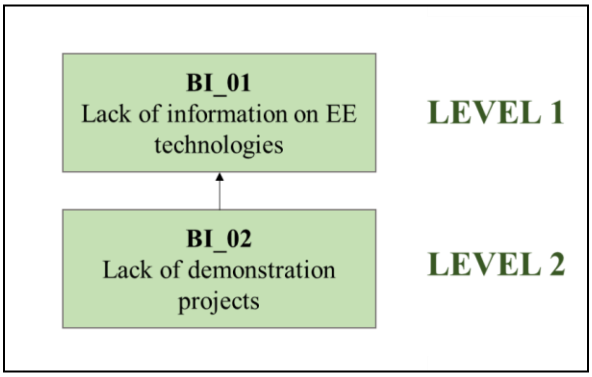
Table 14 – SSIM for Table 13.

Barriers	BI_01	BI_02
BI_01	-	A
BI_02	-	-

Source: The author.

The hierarchical structure between these two barriers was built, as illustrated in Figure 19.

Figure 19 – Hierarchical structure of barriers that arise in the "Information" phase.



Source: The author.

The lack of demonstration projects demonstrating the benefits and opportunities related to EE technologies (BI_02) is a critical barrier as it is located on the base of the ISM hierarchy.

5.4 INTERRELATIONSHIPS BETWEEN THE BARRIERS THAT ARISE IN THE "PLANNING/EXECUTION" PHASE

A total of four barriers (Table 15) can arise over the planning and execution stage of energy efficiency projects.

Table 15 – Barriers that arise in the "Planning/Execution" phase.

Code	Barrier
BEP_01	Lack of technical competence
BEP_02	Lack of professional involvement in energy efficiency projects
BEP_03	Lack of trust on the part of building professionals
BEP_04	Lack of adequate technologies

Source: The author.

The contextual relationships between such barriers are presented in Table 16.

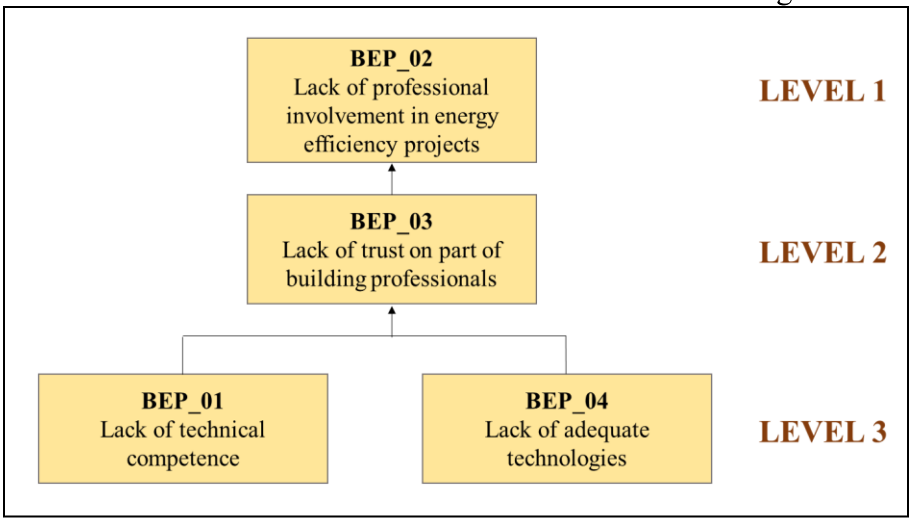
Table 16 – SSIM for Table 15.

Barriers	BEP_01	BEP_02	BEP_03	BEP_04
BEP_01	-	V	V	O
BEP_02	-	-	A	O
BEP_03	-	-	-	A
BEP_04	-	-	-	-

Source: The author.

The hierarchical model for these barriers can be viewed in Figure 20.

Figure 20 – Hierarchical structure of barriers that arise in the "Planning/Execution" phase.



Source: The author.

The barriers related to the lack of technical competence of the professionals involved in energy efficiency projects (BEP_01) and the lack of adequate technologies (BEP_04) form the basis of the hierarchical structure, therefore they can be considered the most impactful ones.

Finally, it can be seen that the lack of involvement of these professionals (BEP_02) appears at the top of the hierarchy, suggesting that is the least important barrier.

5.5 INTERRELATIONSHIPS BETWEEN THE BARRIERS THAT HINDER THE MARKET EXPANSION

Table 17 presents the barriers that hinder the expansion of the adoption of EE technologies in the building segment.

Table 17 – Barriers that hinder the market expansion.

Code	Barrier
BMT_01	Lack of investors
BMT_02	Lack of market demand
BMT_03	Lack of knowledge of market potential
BMT_04	Lack of good marketing strategies

Source: The author.

Table 18 shows the SSIM concerned with the barriers in Table 17.

Table 18 – SSIM for Table 17.

Barriers	BMT_01	BMT_02	BMT_03	BMT_04
BMT_01	-	V	A	A
BMT_02	-	-	A	A
BMT_03	-	-	-	A
BMT_04	-	-	-	-

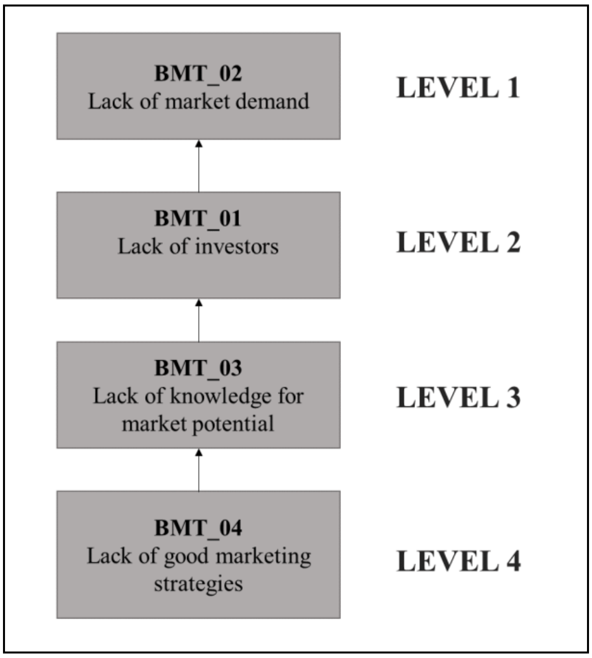
Source: The author.

The hierarchical structure of these barriers is shown in Figure 21.

It is possible to see that the lack of good marketing strategies to promote the adoption of EE measures (BMT_04) has a direct or indirect influence on the other barriers, of this group, which makes it the critical barrier.

The lack of market demand is the least important barrier, once it was influenced by the others in the group.

Figure 21 – Hierarchical structure of barriers that hinder the market expansion.



Source: The author.

This chapter employed the Interpretative Structural Modelling (ISM) approach to study the interrelationships between the barriers classified into different categories. The hierarchical structure resulting from the ISM showed the relationship between the barriers, highlighting the critical ones, that is to say, those that are influential factors that can drive the existence of the others. Figure 21 summarises the critical barriers that arise at each stage of the adoption process of EE technologies.

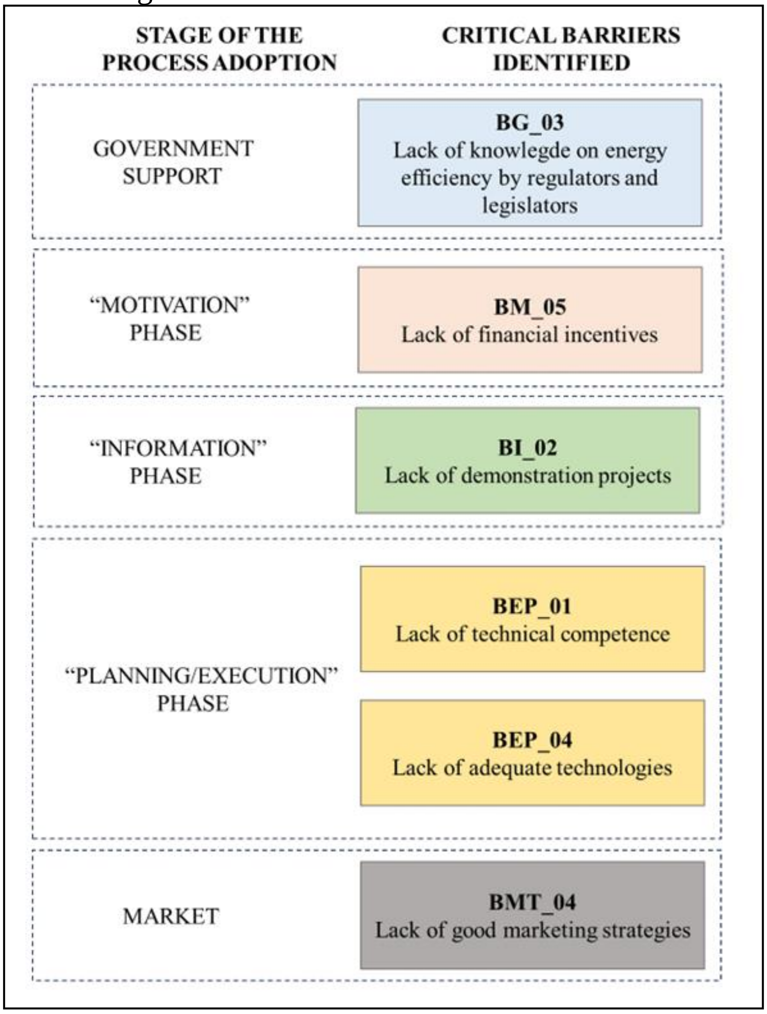
The analysis revealed that the "Lack of knowledge on energy efficiency by regulators and legislators" barrier was the critical barrier identified among five barriers that hinder government support during the process of adopting EE technologies.

In the "Motivation" phase, it was identified that the "Lack of financial incentives" stands as the foremost obstacle, causing or potencialising the existence of the other barriers that discourage the owners from opting for EE technologies.

Transitioning to the "Information" phase, the "Lack of demonstration projects" barrier has been highlighted, directly influencing the availability of information about EE technologies.

In the subsequent "Planning/Execution" phase, two critical barriers were identified: "Lack of technical competence" and "Lack of adequate technologies", both representing significant challenges to effective implementation.

Figure 21 – The critical barriers identified.



Source: The author.

The barrier "Lack of good marketing strategies" was identified as the critical barrier that influences the other three barriers that hinder market expansion.

These findings are valuable for achieving the objectives of this research. By utilising the hierarchical structures built from the ISM technique, it is possible to prioritise the proposed measures based on the positioning of their respective barriers within the hierarchy. This means that barriers identified as more critical can be addressed first.

By focusing on these critical barriers first, it is possible to create a ripple effect that reduces the intensity or impact of other related barriers. This strategic prioritisation is essential for effectively promoting the adoption of EE technologies. By ensuring that efforts and resources are first allocated to overcome the critical barriers, it is possible to make more efficient and impactful progress toward widespread adoption.

6 MEASURES FOR OVERCOMING THE CRITICAL BARRIERS IDENTIFIED IN THE BRAZILIAN SCENARIO

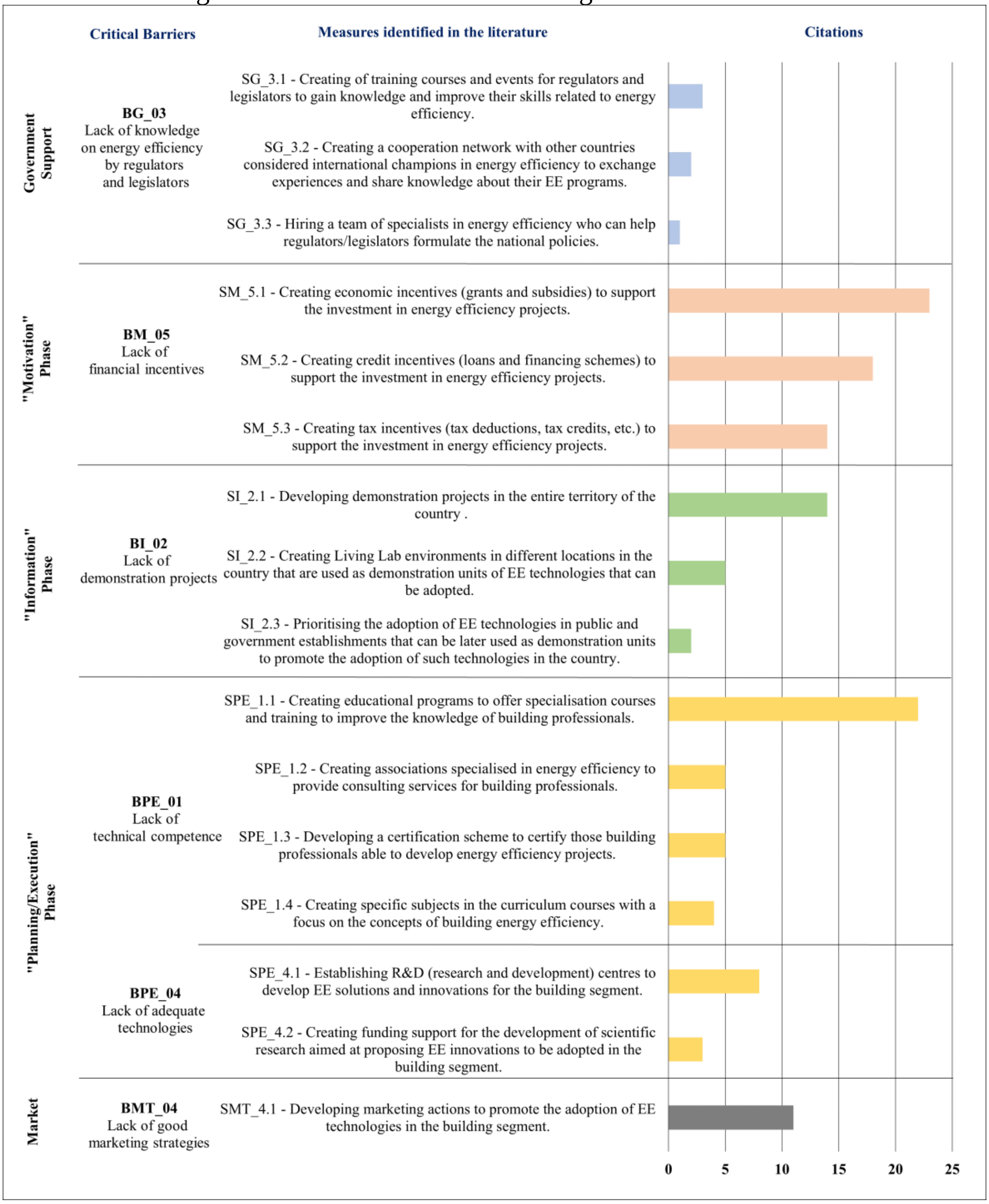
This chapter aims to propose measures for overcome the five critical barriers, identified through the ISM technique, that hinder the adoption of EE technologies in the Brazilian scenario. To achieve this, a literature review was initially conducted to identify the measures point out in articles indexed in the SCOPUS and WoS databases. Subsequently, these identified measures were proposed for the Brazilian scenario. They were systematically organised to highlight the actions to address each critical barrier. This approach aimed to establish a direct relationship between the challenges faced and their corresponding solutions.

6.1 IDENTIFYING MEASURES FOR OVERCOMING THE CRITICAL BARRIERS IN THE LITERATURE

The measures to overcome the five critical barriers were identified through the analysis of 46 articles retrieved from the Scopus and WoS databases. From the reading of these articles, a collection of overcoming measures was identified. However, many of them presented a similar meaning, for example, the overcoming measure “Creating demonstration projects focusing on the costs and benefits of the different technologies adopted” and “Developing demonstration projects, specify their guidelines and pro-energy saving results” are similar solutions; “Developing innovation centres to support relevant R&D projects and research” means the same as “Creation of centres that can be combined with companies and universities to establish a production, learning, and research platform”; “develop fiscal incentives” and “create fiscal financial support schemes” are the same thing. Thus, it was necessary to group similar measures. Therefore, after several rounds of reading, the number of identified measures was reduced to 17.

After identifying the measures, it was possible to associate each one with its respective barrier to be overcome. Figure 23 presents these results with the number of citations of each suggestion identified in the literature.

Figure 23 – Measures for overcoming the critical barriers.



Source: The author.

It can be seen that to overcome the barrier BG_03 ("Lack of knowledge on energy efficiency by regulators and legislators") that hinders effective government support, three measures were identified in the literature. Among these measures, it was emphasised the creation of training courses and events to improve the knowledge and skills of regulators, agents, and policy officials about energy efficiency in buildings. This particular measure has been highlighted three times in the literature.

To overcome the barrier BM_05 (“Lack of financial incentives”), which stands out as a critical issue in the “Motivation” phase, three suggestions have been identified in the literature. Among these measures, the most frequently cited involves the creation of specific economic incentives, such as grants and subsidies, to financially support energy efficiency investments. This measure was referenced 23 times in the literature.

To address the barrier BI_02 (“Lack of demonstration projects”) in the “Information” phase, three measures were identified. Among them, the most cited highlights the importance of developing a range of projects to demonstrate the real examples of EE technologies that can be adopted in buildings. These demonstration projects can present readily available technologies in the market; demonstrate effective methods of acquisition and utilisation; highlight the results achieved through their adoption (both technical and economic benefits); and elucidate challenges that can be mitigated or avoided. This recommendation was cited 14 times in the literature.

Moreover, it was possible to identify measures to overcome the two critical barriers, BPE_01 (“Lack of technical competence”) and BPE_04 (“Lack of adequate technologies”), in the “Planning/Execution” phase. To overcome the barrier BPE_01, four measures were identified in the literature. The most cited measure, with 22 citations, is the creation of educational programs to teach energy efficiency concepts in different training centres and educational institutions. Furthermore, to address the barrier BPE_04, two measures were pointed out in the articles. Notable, the creation of R&D centres to promote the development of innovative technological solutions for energy efficiency was highlighted in eight publications.

Lastly, in addressing the critical barrier (BMT_04 – "Lack of good marketing strategies") hindering market expansion, only one measure was identified in the literature. This measure was cited 13 times and points out the importance of developing marketing initiatives to stimulate the adoption of EE technologies in the building segment.

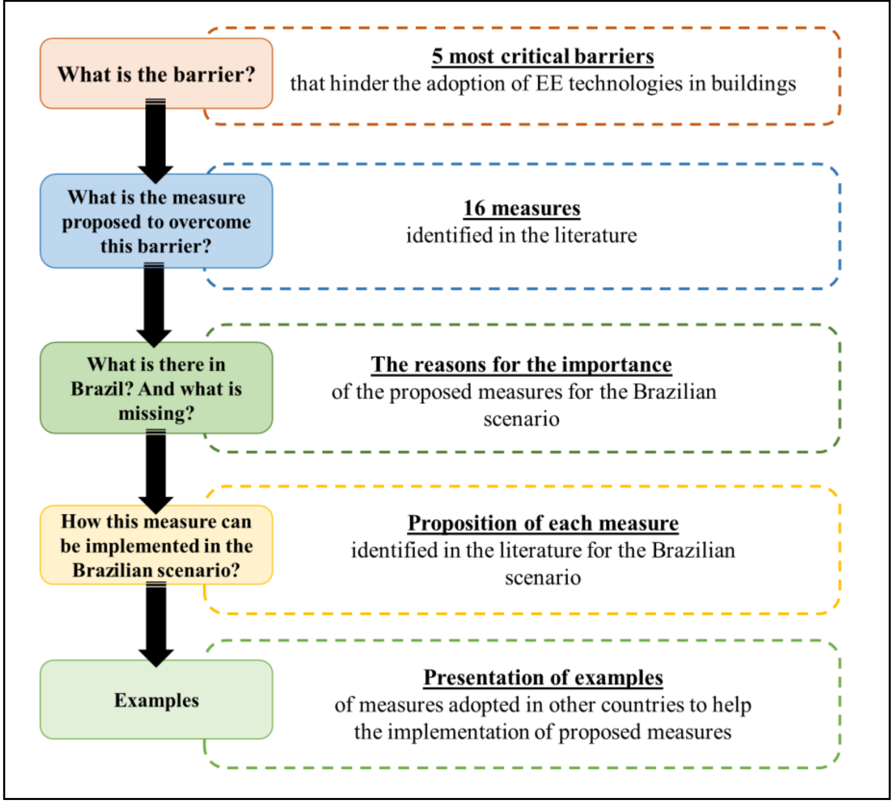
These results significantly enhance the depth of this research, highlighting a comprehensive set of measures found in the literature to overcome the critical barriers to the adoption of EE technologies in the building segment. From that, these identified measures can be proposed to the Brazilian context, ensuring that the proposed measures are not only relevant but also feasible for the Brazilian building segment.

6.2 PROPOSITION OF MEASURES TO OVERCOME THE CRITICAL BARRIERS IN THE BRAZILIAN BUILDING SEGMENT

The literature review pointed out a set of measures to overcome the five critical barriers. So, as these barriers identified are adherent to the Brazilian scenario, after identifying their respective overcoming measures, it was important to propose them for the Brazilian scenario. Therefore, this subsection aims to present the proposition of measures identified in the literature for the Brazilian scenario.

Figure 24 shows a diagram illustrating how the proposed measures are presented for better visualisation.

Figure 24- Scheme of the proposition of overcoming measures.



Source: The author.

Based on Figure 24, it as possible to propose the measures identified in the literature for the Brazilian scenario to accelerate the adoption of EE technologies in the building segment.

Table 19 presents the proposition of measures to overcome the barrier BG_03 (“Lack of knowledge on energy efficiency by regulators and legislators”). Regarding these proposed measures, it was possible to observe that they have the potential to improve the understanding of policymakers in relation to the country's energy issues, which could lead to more impactful governmental support for energy efficiency initiatives in the building segment of Brazil.

Table 20 describes the measures proposed to overcome the barrier BM_05 (“Lack of financial incentives”). The proposed measures focus on the creation of specific economic incentives in Brazil to promote investment in energy efficiency projects. These initiatives encompass different incentive models and opportunities to mobilise financial resources, aiming to encourage investors and property owners to adopt EE technologies in their buildings.

The measures proposed to overcome the barrier BI_02 (“Lack of demonstration projects) are detailed in Table 21. It was proposed that is important to develop different types of demonstration projects in Brazil to disseminate best practices and encourage the adoption of EE technologies. These initiatives offer tangible examples showcasing the technical and economic benefits of EE technologies for stakeholders engaged in the adoption process.

Table 22 presents the measures proposed to address the barrier BPE_01 (“Lack of technical competence”). These measures underscore the importance of establishing educational programs and institutions that provide training for professionals involved in energy efficiency projects in buildings. Furthermore, the suggestions include the creation of certification programs and the inclusion of specific subjects in undergraduate courses, aimed at these professionals. These initiatives help Brazilian professionals improve their technical skills, ensuring the effective implementation of EE technologies in buildings.

Table 23 outlines the proposed measures to overcome the barrier BPE_04 (“Lack of adequate technologies”). To overcome this barrier, the suggestions propose the creation of research and development initiatives, alongside funding incentives, to promote technological innovation of energy efficiency buildings in the Brazilian context. These actions have the potential to accelerate the technological advance of EE technologies in the country.

Finally, Table 24 outlines one suggestion to overcome the barrier BMT (“Lack of good marketing strategies”). The proposed measure suggests the development of marketing strategies to attract new investors interested in integrating EE technologies into their building projects. These initiatives should not only consider technical and financial aspects but also prioritise consumers' perceptions and stakeholders' attitudes toward building energy efficiency. By focusing on these factors, initiatives can be created to expand the energy efficiency market. Together, these actions provide a comprehensive roadmap to raise awareness and promote energy efficiency in the Brazilian building segment.

This proposition of measures was developed to serve as a practical guide for Brazilian policymakers. Therefore, by focusing on the critical barriers, the proposed measures help policymakers make strategic decisions that can have a significant impact on the adoption of EE technologies. By addressing these key barriers first, they can create a foundation for broader and more effective implementation of EE technologies across the building segment.

Table 19 – Proposed measures to overcome the “Lack of knowledge on energy efficiency by regulators and legislators” barrier.

What is the barrier?		**BG_03 -** LACK OF KNOWLEDGE ON ENERGY EFFICIENCY BY REGULATORS AND LEGISLATORS				
What is the measure proposed to overcome this barrier?		**Measure 1:** Creation of training courses and events, for regulators and legislators to gain knowledge and improve their skills related to energy efficiency.		**Measure 2:** Creation of a cooperation network with other countries considered international champions in energy efficiency to exchange experiences and share knowledge about their energy efficiency programs.		**Measure 3:** Hiring a team of specialists in energy efficiency who can help regulators and legislators formulate national policies
What is there in Brazil? And what is missing?		There are educational actions to improve the knowledge of the general public, such as the “Online Course on Energy Efficiency in Buildings for Brazil” promoted by the Ministry of Mines and Energy (MME), International Energy Agency (IEA), and Development Bank of Latin America (CAF). However, there are no specific educational actions for policymakers that develop energy efficiency.		There is a lack of involvement with emerging countries in energy efficiency to share knowledge and experiences, one of the main international cooperation networks with Brazil is with the other countries belonging to BRICS (Russia, India, China, and South Africa), which have been committed to finding political solutions that support the transition to a more sustainable energy matrix in the country.		Few professionals specialised in energy efficiency work directly with political bodies to develop national policies related to energy efficiency, the majority of professionals at the MME are specialised in policy areas or macro-areas of direct impact on society.
How this measure can be implemented in the Brazilian scenario?		**Proposition 1:** Offering training and qualification courses focused on energy efficiency for Brazilian policymakers	**Proposition 2:** Participation of Brazilian policymakers in events/congress on energy efficiency	**Proposition 1:** Creating an interactive tool for policymakers to know policy instruments developed in other countries.	**Proposition 2:** Seeking partnerships with countries that offer technical assistance to the Brazilian policymakers.	**Proposition 1:** Creating a career program to hire professionals willing to help policymakers formulate national policies to promote the adoption of EE technologies in Brazil.
Examples	**Example-Action**	Free Training Courses - Green Building Professional	Energy Efficiency Policy Training Week	Building energy efficiency policy explorer	USAID's Energy Efficiency for Development program	Career in Clean Energy
	Geographical Context	Denmark	Global	Global	United States (USA)	USA
	Objective	To offer free online courses to governmental representatives that explain the latest trends in energy efficiency (COPENHAGEN CENTRE, 2024).	To build capacity among policymakers to help them develop effective EE initiatives in their respective countries (IEA, 2024b).	To offer an interactive dashboard where policymakers can see a range of EE actions being implemented around the world (C40 KNOWLEDGE HUB, 2024).	To provide technical assistance to policymakers of partner countries to overcome challenges associated with implementing EE programs (USAID, 2024).	To provide job opportunities for specialists with different skills to help accelerate the country's transition to 100% clean energy (U.S. DEPARTMENT OF ENERGY, 2024b).

Source: The author.

Table 20 – Proposed measures to overcome the “Lack of financial incentives” barrier.

What is the barrier?		**BM_05 -** LACK OF FINANCIAL INCENTIVES				
What is the measure proposed to overcome this barrier?		**Measure 1:** Creating economic incentives (grants and subsidies) to support the investment in EE projects.	**Measure 2:** Creating credit incentives (loans and financing schemes) to support the investment in energy efficiency projects.		**Measure 3:** Creating tax incentives (tax deductions, tax credits, etc.) to support the investment in energy efficiency projects.	
What is there in Brazil? And what is missing?		Although there are subsidised loans offer financial support at an interest rate lower than the market rate offered by financial institutions, such as the initiatives of BNDES FINEM and Federal Savings Banking (Caixa), it is important to develop new forms of subsidies/grants.	Although there are credit incentives made available by financial institutions, such as “*BB Crédito Energia Renovável*” of the Bank of Brazil, it is important to increase the number of incentives offered to promote the adoption of EE technologies in the building segment.		Fiscal incentives are needed to help offset the upfront costs that owners have in adopting EE technologies in their buildings.	
How this measure can be implemented in the Brazilian scenario?		**Proposition 1:** Creation of economic incentives to support Brazilian owners to pay for the EE technologies in their building projects.	**Proposition 1:** Creation of specific loans for the adoption of EE technologies in Brazilian buildings.	**Proposition 2:** Creation of a credit financing system for incentivising the adoption of EE technologies in Brazil.	**Proposition 1:** Creation of tax credits to support the adoption of EE technologies in the Brazilian building segment.	**Proposition 2:** Offering tax deductions to offset the technology costs for Brazilian owners that adopt EE technologies in their buildings.
Examples	**Example-Action**	Energy Efficiency Grants	Special programme for large-scale building renovations	Credit financing for EE improvements to existing homes	Tax credit for energy efficiency in new buildings	Commercial Building Tax Deduction
	Geographical Context	Ireland	Switzerland	USA	France	USA
	Objective	To allocate grants/subsidies for projects delivering best practices in the design, construction, and management of EE buildings (IEA, 2024k).	To offer loans for owners can carry out renovation energy on favourable terms, ensuring that building costs remain affordable (IEA,2024l).	To offer credit financing to apply to EE improvements in the building envelope and for the purchase of high-efficiency heating and cooling equipment (IEA, 2024m).	To introduce a tax credit equivalent to 15% of investment costs in EE technologies installed in residential buildings (IEA, 2024n).	Building owners that adopt EE technologies in their properties will be able to request a tax deduction to offset some of the costs of the equipment (IEA, 2024o).

Source: The author.

Table 21 – Proposed measures to overcome the "Lack of demonstration projects" barrier.

<table>
<tr><th colspan="2">What is the barrier?</th><th colspan="4">BI_02 - LACK OF DEMONSTRATION PROJECTS</th></tr>
<tr><td colspan="2">What is the measure proposed to overcome this barrier?</td><td colspan="2">Measure 1: Developing demonstration projects in the entire territory of the country.</td><td>Measure 2: Creating Living Lab environments in different locations in the country that are used as demonstration units of EE technologies that can be adopted.</td><td>Measure 3: Prioritising the adoption of EE technologies in public and government establishments that can be later used as demonstration units to promote the adoption of such technologies in the country.</td></tr>
<tr><td colspan="2">What is there in Brazil? And what is missing?</td><td colspan="2">Although there are public initiatives, such as the NZEB public calls coordinated by PROCEL/ELETROBRÁS, there remains a lack of sufficient incentives for the development of demonstration projects showcasing energy efficiency results in the building segment.</td><td>There are a few Living Lab projects, such as the "Projeto Casa Eficiente" created in partnership between the Federal University of Santa Catarina (UFSC), Eletrosul and Eletrobrás, which served as a demonstration laboratory for efficient buildings.</td><td>As energy efficiency labelling, promulgated by PROCEL/Eletrobrás, is mandatory in federal public buildings, these establishments could be used as demonstration projects to present the thermal and financial viability of EE technologies.</td></tr>
<tr><td colspan="2">How this measure can be implemented in the Brazilian scenario?</td><td>Proposition 1: Creation of incentives for the development of demonstration projects in many local regions of Brazil.</td><td>Proposition 2: Creation of demonstration projects in different locations to present the EE technologies that have not been widely adopted.</td><td>Proposition 1: Creation of a Living Lab that can be used as a demonstration unit of EE technologies that can be adopted in the Brazilian building segment.</td><td>Proposition 1: Prioritisation of the adoption of EE technologies in Brazilian public buildings that can be used as demonstration units.</td></tr>
<tr><td rowspan="3">Examples</td><td>Example-Action</td><td>Energy Technology Development and Demonstration Program</td><td>GBIC Demonstration (GBIC-Demo)</td><td>Living Lab for Energy Efficient Public Buildings based on ICT Solutions</td><td>Municipal Energy Efficiency Project</td></tr>
<tr><td>Geographical Context</td><td>European Union (EU)</td><td>Singapore</td><td>Denmark</td><td>Mexico</td></tr>
<tr><td>Objective</td><td>To provide fund alternatives to encourage enterprises and universities to develop demonstration projects of new energy technologies (EUDP, 2024).</td><td>To provide building owners and developers the opportunity to strive for greater energy savings by demonstrating innovative EE technologies that have not been widely implemented locally in upcoming projects or existing buildings (BCA, 2024).</td><td>To help foster new solutions to improve energy efficiency and education and to disseminate information about the new solutions and results to increase the energy efficiency of buildings (SDU,2023).</td><td>To support the demonstration of large-scale energy efficiency investments in the municipal service sector and public buildings, and to improve national and local capacity in designing and implementing municipal energy efficiency programmes (IEA,2024e).</td></tr>
</table>

Source: The author.

Table 22 – Proposed measures to overcome the “Lack of technical competence” barrier.

What is the barrier?		**BPE_01 -** LACK OF TECHNICAL COMPETENCE			
What is the measure proposed to overcome this barrier?		**Measure 1:** Creating educational programs to offer specialisation courses and training to improve the knowledge of building professionals.	**Measure 2:** Creating associations specialised in energy efficiency to provide consulting services for building professionals.	**Measure 3:** Developing a certification scheme to certify those building professionals able to develop energy efficiency projects.	**Measure 4:** Creating specific subjects in the curriculum courses with a focus on the concepts of building energy efficiency.
What is there in Brazil? And what is missing?		There are few educational initiatives aimed at enhancing the skills and knowledge of builng professionals. Most existing courses, such as the "EtiqEEE" course offered by the Federal University of Santa Catarina (UFSC), primarily focus on introducing the most relevant elements for building labelling.	Although there are associations like ABESCO to provide support to encourage and promote actions and projects that benefit their members, there is a lack of an association dedicated to offering energy efficiency consultancy to building professionals.	There is no certification program for specialised professionals in building energy efficiency, unlike in the industrial sector, where the Energy Efficiency Specialist Certification Course is offered by SENAI (National Service of Industrial Learning) in partnership with the PotencializEE program.	There are specialisation and undergraduate courses focused on energy efficiency in buildings in the country, however, there is a lack of specific subjects that concentrate on energy efficiency concepts and technologies to be offered in undergraduate courses in related areas of building construction and energy systems.
How this measure can be implemented in the Brazilian scenario?		**Proposition 1:** Creation of a qualification program to improve the technical skills of Brazilian building professionals.	**Proposition 1:** Creation of an association specialised in building energy efficiency to provide consulting services to the Brazilian building professionals.	**Proposition 1:** Creation of a certification scheme to certify the Brazilian building professionals able to develop energy efficiency projects.	**Proposition 1:** Development of a specific module on building energy efficiency in the courses specially directed to building professionals in Brazilian Universities.
Examples	**Example-Action**	Train-to-NZEB	Building Energy Services Consulting	Energy Efficiency Certification Scheme (EECS)	PEEB Project - Module on Energy-Efficient Buildings
	Geographical Context	EU	USA	Australia	Israel
	Objective	To provide training on energy efficiency in buildings to improve the knowledge/skills of building professionals through practical training, demonstrations, and consulting services (EUROPEAN COMMISSION, 2024d).	To provide energy consulting services tailored to the needs of builders, property managers, architects, and others in the building industry who work with energy efficiency projects (GDS ASSOCIATES, 2013).	To certify professionals that can lead integrated building energy retrofits of commercial buildings (ENERGY EFFICIENCY COUNCIL, 2023).	To incorporate energy-efficient building design into the curricula of the architectural programs (MUHAISEN, 2006).

Source: The author.

Table 23 – Proposed measures to overcome the "Lack of adequate technologies" barrier.

What is the barrier?		**BPE_04 -** LACK OF ADEQUATE TECHNOLOGIES	
What is the measure proposed to overcome this barrier?		**Measure 1:** Establishing R&D (research and development) centres to develop solutions and innovations in energy efficiency for the building segment.	**Measure 2:** Creating funding support for the development of scientific research aimed at proposing EE innovations to be adopted in the building segment.
What is there in Brazil? And what is missing?		There is a need to develop more R&D centres to encourage the development of technologies focused on reducing energy consumption in buildings, such as the Laboratory of Energy Efficiency in Buildings (LabEEE) of the Federal University of Santa Catarina (UFSC).	There is a need to increase the number of research projects focused on energy efficiency in buildings, beyond those already funded by renowned development agencies such as the Improvement of Higher Education Personnel (CAPES) and the National Council for Scientific and Technological Development (CNPQ).
How this measure can be implemented in the Brazilian scenario?		**Proposition 1:** Establishing R&D centres in partnerships between Brazilian companies and universities to develop EE technologies to be adopted in the building segment.	**Proposition 1:** Creation of funding support for the development of scientific research dealing with energy efficiency innovations for the Brazilian building segment.
Examples	**Example-Action**	EERA (European Energy Research Alliance) JP Smart Cities	Buildings Energy Efficiency Frontiers & Innovation Technologies (BENEFIT) – 2022/23
	Geographical Context	EU	USA
	Objective	To contribute significantly to research and innovation in smart cities – both in the development of fundamental research, innovation, and co-creation with city and industry partners, and in showcasing the importance of research and innovation (EERA, 2024).	To offer a funding opportunity of investment across five topic areas to research and develop high-impact, cost-effective technologies and building retrofit practices that will reduce carbon emissions, improve flexibility and resilience, and lower energy costs (U.S. DEPARTMENT OF ENERGY, 2024d).

Source: The author.

Table 24 – Proposed measures to overcome the “Lack of good marketing strategies” barrier.

	What is the barrier?	**BMT_04 -** LACK OF GOOD MARKETING STRATEGIES	
	What is the measure proposed to overcome this barrier?	**Measure 1:** Developing marketing actions to promote the adoption of EE technologies in the building segment.	
	What is there in Brazil? And what is missing?	Although several different marketing strategies have been developed by public bodies in Brazil, such as by the Eletrobrás Company and the MME, it is important to improve them and create new ones to attract potential investors in adopting EE technologies.	
	How this measure can be implemented in the Brazilian scenario?	**Proposition 1:** Developing marketing actions to promote the adoption of EE technologies in the Brazilian building segment.	
Examples	**Example-Action**	ENERGY STAR Partner - Marketing Resources for Partners	Buildings Performance Institute Europe (BPIE)
	Geographical Context	USA	EU
	Objective	To provide a variety of resources at no cost that will help educate homebuyers and residents about the value of energy efficiency (ENERGY STAR, 2024a).	To develop action to support and speed up the improved energy performance of the buildings sector with data-driven analysis, innovative policy solutions, and convincing transformation pathways (BPIE, 2024).

Source: The author.

7. MEASURES FOR OVERCOMING REMAINING BARRIERS IDENTIFIED IN THE BRAZILIAN SCENARIO

As previously highlighted, the overcoming of the critical barriers does not ensure that these remaining barriers will be resolved. Instead, addressing the critical barriers can reduce the intensity or impact of these other barriers, but it may not eliminate them. Therefore, although measures had already been previously suggested to overcome the critical barriers, it was important to present additional suggestions to overcome the remaining barriers that hinder the adoption of EE technologies in the Brazilian building segment.

These new suggestions are crucial for a comprehensive approach to barrier mitigation. Thus, they can be considered in a second implementation phase, following the initial phase focused on the critical barriers. By doing so, policymakers and stakeholders can ensure a more thorough adoption of EE technologies in Brazil.

Based on that, this chapter presents the measures to overcome the remaining barriers that hinder the adoption of EE technologies in the Brazilian building segment. These suggestions were proposed following the same method used in the previous chapter. Firstly, a literature review was conducted, and overcoming measures were identified in 46 articles indexed in the Scopus and WoS databases. Subsequently, these measures were proposed for the Brazilian scenario, following the scheme previously presented in Figure 24.

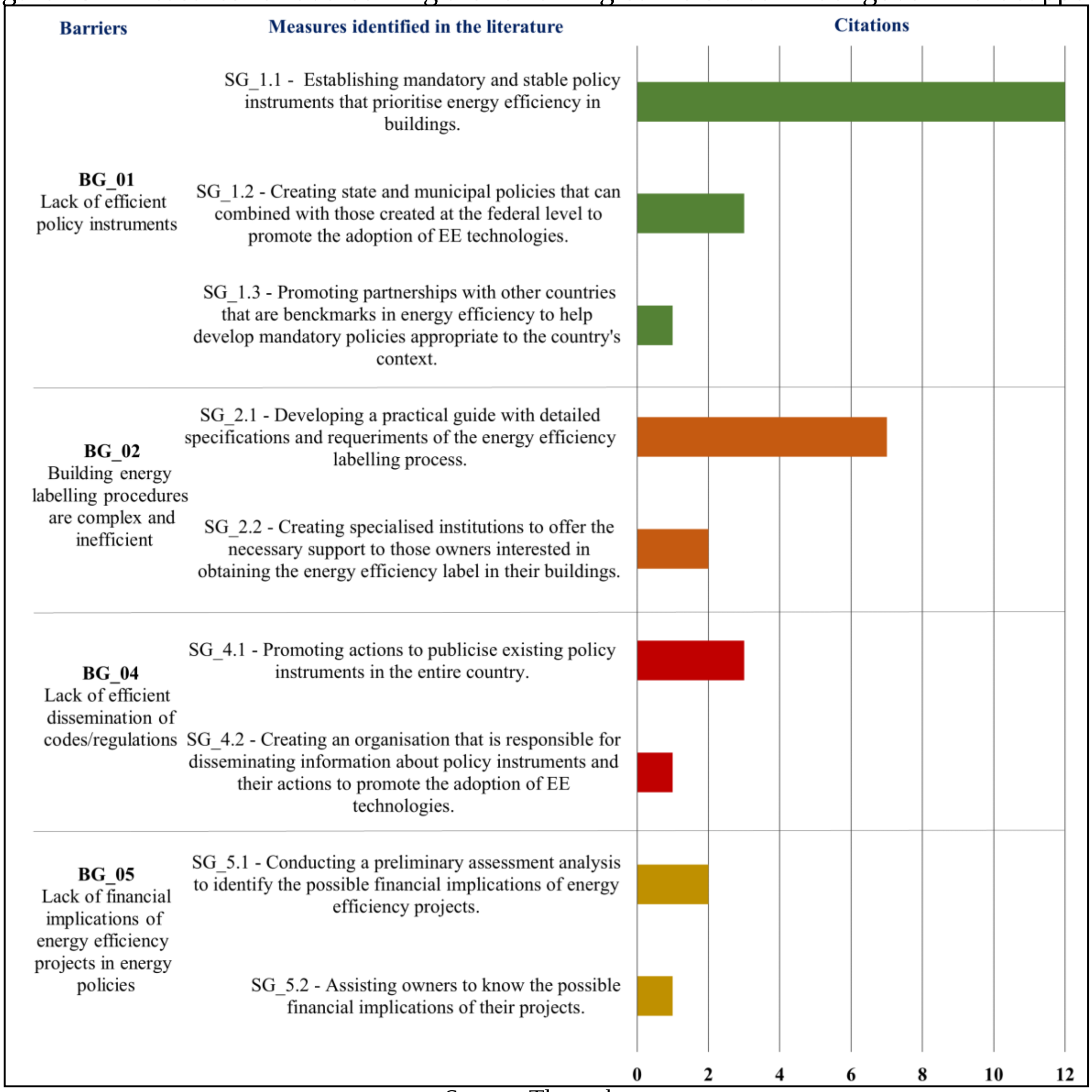
The following subsections detail the measures to overcome the remaining barriers and their respective propositions for the Brazilian scenario. For better visualisation, these results were subdivided considering the groups of barriers that may arise at each stage of the process of adopting EE technologies in the building segment.

7.1 PROPOSED MEASURES FOR OVERCOMING THE REMAINING BARRIERS THAT HINDER THE GOVERNMENT SUPPORT

Eight measures have been identified to address the four remaining barriers that may hinder government support in the adoption of EE technologies in the building segment. It is worth mentioning that these identified measures were associated with their respective barrier to be overcome. Figure 25 presents such measures with their number of citations.

To address the barrier BG_01 ("Lack of efficient policy instruments"), which hinders effective government support, three measures were identified in the literature. Among these measures, it is emphasised that establishing mandatory policy instruments aimed at promoting the adoption of EE technologies in the building segment is crucial. This particular measure was cited 10 times in the literature.

Figure 25 – Measures for overcoming the remaining barriers that hinder government support.



Source: The author.

Two measures have been proposed to address the barrier BG_02 ("Complex and inefficient building energy labeling procedures"). The measure with the highest number of citations recommends the development of a practical guide describing detailed specifications and directives to facilitate energy efficiency labeling of buildings (7 citations).

Another two measures have been identified to overcome the barrier BG_04 ("Lack of efficient dissemination of codes/regulations"). One of these measures suggests the strategic promotion of initiatives to disseminate, on a nationwide scale, the policy instruments specifically created to address energy efficiency in the building segment.

To address the barrier BG_05 ("Lack of financial implications of energy efficiency projects in energy policies"), two measures were highlighted in the literature. The most frequently cited measure involves a preliminary assessment to understand the financial implications associated with energy efficiency investments. This suggestion was referenced two times in the literature.

With this set of measures identified in the literature for overcoming the barriers that hinder the government support in the adoption process of EE technologies, it was possible to proposed them in more detail for Brazilian scenario.

Table 25 presents the proposed measures identified to overcome the barrier BG_01, which pertains to the "Lack of efficient policy instruments." Regarding these proposed measures, it was possible to see that they have the potential to improve the quality of Brazilian policy instruments, promoting a more conducive regulatory environment that encourages and facilitates energy efficiency practices in the Brazilian building segment.

Table 26 describes the measures proposed to address the barrier BG_02 ("Complex and inefficient building energy labeling procedures"). The proposed measures focus on initiatives to facilitate the process of obtaining energy efficiency labels for Brazilian buildings. This is significant because simplifying the process to obtain energy efficiency labels encourages building owners to invest in energy efficiency solutions for their buildings. Consequently, this contributes to the wider promotion and adoption of EE technologies across Brazil.

The measures proposed to overcome the barrier BG_04 (“Lack of efficient dissemination of codes/regulations”) are detailed in Table 27. These measures are designed to become the codes/regulations concerned with building energy efficiency known among the Brazilian owners. By ensuring comprehensive disclosure of such information, these measures aim to equip building owners with a thorough understanding of relevant codes and regulations. Consequently, this initiative seeks to ensure compliance with and to promote the adoption of energy efficiency practices in the Brazilian building segment.

Finally, Table 28 outlines suggestions to overcome the barrier BG_05 ("Lack of financial implications of energy efficiency projects in energy policies"). These proposed initiatives helped Brazilian owners understand the possible financial implications that can emerge from the adoption process, which empowers them to prioritise and allocate resources effectively, thereby facilitating the uptake of such solutions in their buildings.

Table 25 – Proposed measures to overcome the “Lack of efficient policy instruments” barrier.

(to be continued)

What is the barrier?		**BG_01 -** LACK OF EFFICIENT POLICY INSTRUMENTS			
What is the measure proposed to overcome this barrier?		**Measure 1:** Establishment of mandatory and stable policy instruments that prioritise energy efficiency in buildings			
What is there in Brazil? And what is missing?		Despite there are specific standards for the building segment and their energy consumption, for example, the ABNT NBR 15.575 that deals with the minimum quality and comfort requirements for residential buildings, and the INI-R (INMETRO Normative Instruction for the Energy Efficiency Classification of Residential Buildings) that establishes the requirements for classifying the energy efficiency level of buildings, there is still a lack of specific policy instruments to promote the adoption of EE technologies in the building segment.			
How this measure can be implemented in the Brazilian scenario?		**Proposition 1:** Creation of a national standard or code of energy efficiency in buildings to promote the adoption of EE technologies in Brazil.	**Proposition 2:** Establishing a guidebook that presents an overview of the key elements of the policy instruments created to promote building energy efficiency in Brazil.	**Proposition 3:** Developing specific policy instruments that present realistic targets that can be achieved to help reduce energy consumption in the Brazilian building segment.	**Proposition 4:** Creating databases to monitor the energy performance of buildings to know whether the energy targets established in policy instruments are being achieved.
Examples	**Example-Action**	Energy performance of buildings directive	A guidebook to European building policy: key legislation and initiatives	Roadmap for Building Energy Codes and Standards for Mexico	EU Building Stock Observatory
	Geographical Context	EU	EU	Mexico	EU
	Objective	To promote the improvement of the energy performance of buildings, considering climate requirements and cost-effectiveness (EUROPEAN COMMISSION, 2024a).	To provide an overview of EU building policies, with a focus on the Energy Performance of Buildings Directive (EPBD) and Clean Energy Package for all Europeans (BPIE, 2024).	To develop a Roadmap for Building Energy Codes and Standards to promote the use of Cleaner Technologies and Fuels to achieve substantial reductions in the electricity consumption of buildings by 2050 (IEA, 2024a).	To provide transparent information on the EU’s building stock, to support the monitoring of current EU energy policies and measures, and to contribute to future policy-making processes (EUROPEAN COMMISSION, 2024b).

Source: The author.

Table 25 – Proposed measures to overcome the "Lack of efficient policy instruments" barrier.

(conclusion)

	What is the barrier?	**BG_01 -** LACK OF EFFICIENT POLICY INSTRUMENTS	
	What is the measure proposed to overcome this barrier?	**Measure 2:** Creation of state and municipal policies that can be combined with those created at the federal level to promote the adoption of EE technologies.	**Measure 3:** Promotion of partnerships with other countries that are benchmarks in energy efficiency to help develop mandatory policies appropriate to the country's context.
	What is there in Brazil? And what is missing?	Although there are state or municipal policy instruments that present the requirements for the construction and renovation of buildings with a focus on sustainability premises that impact the reduction of building energy consumption, for example, the Law N°9,725 promulged in the Municipality of Belo Horizonte, still, there is a lack of specific local policies to promote the adoption of EE technologies.	Although there are mutual partnerships with other countries to promote energy efficiency, such as the "German-Brazilian Energy Partnership", which provides a forum for high-level political dialogue supporting the energy transition of both countries, there remains a need for more collaborations with international organizations that offer support in the development of policy instruments to promote the adoption of EE technologies in the Brazilian building segment.
	How this measure can be implemented in the Brazilian scenario?	**Proposition 1:** Creation of state and national policy instruments that promote the adoption of EE technologies in buildings, considering the characteristics of the Brazilian region in which they will be implemented.	**Proposition 1:** Searching for partnerships with other countries that are benchmarks in energy efficiency to offer technical assistance to help policymakers better develop appropriate policy instruments to promote the adoption of EE technologies in Brazil.
Examples	**Example-Action**	Local Policy Program	Programme for energy efficiency in buildings (PEEB) - International Climate Initiative
	Geographical Context	USA	Germany
	Objective	To support the state and municipal governments to increase energy efficiency in their communities through local policy instruments that promote the adoption of EE technologies in their building segment (ACEEE,2024a; ACEEE, 2024b).	To support partner countries in improving their energy efficiency policies, climate targets, and investment conditions for buildings to ensure that energy efficiency projects are replicated in these partner countries (IKI, 2024).

Source: The author.

Table 26 – Proposed measures to overcome the "Building energy labelling procedures are complex and inefficient" barrier.

What is the barrier?		**BG_02 -** BUILDING ENERGY LABELLING PROCEDURES ARE COMPLEX AND INEFFICIENT	
What is the measure proposed to overcome this barrier?		**Measure 1:** Development of a practical guide with detailed specifications and requirements of the energy efficiency labelling process.	**Measure 2:** Creation of specialised institutions to offer the necessary support to those owners interested in obtaining the energy efficiency label in their buildings.
What is there in Brazil? And what is missing?		There are normative instructions that specify the criteria and methods (INI-C and INI-R) for obtaining the PBE EDIFICA (label that classifies buildings according to their energy efficiency), however, these normative instructions are very extensive and technical. Therefore, there is a need to create a guide that presents in the most practical format the steps necessary to obtain the energy efficiency label.	In the country, there are Accredited Inspection Bodies (OIA) by INMETRO with technical competence to work in the evaluation and execution phase of building certification. However, there is a lack of specific institutions to assist the owners throughout the process to obtain the energy efficiency label for their buildings.
How this measure can be implemented in the Brazilian scenario?		**Proposition 1:** Creating a practical guide that presents the necessary information for energy efficiency labelling for Brazilian buildings in a simple, accessible, and easy-to-use way without the need for additional interpretation.	**Proposition 1:** Promoting the creation of private institutions to offer consultancy services for assisting owners in the process of obtaining the energy efficiency label for their buildings.
Examples	**Example-Action**	Energy Efficiency Technical Guide: Standards, Rating and Labeling	Consultancy and Services on the Energy Performance of Buildings
	Geographical Context	USA	Netherlands
	Objective	To outline the essential components of standards, rating, and labelling schemes for products and buildings, highlighting key concepts and common challenges (U.S. DEPARTMENT OF ENERGY, 2024a).	To offer consultancy services for assisting in the process of implementing and using EPB (Energy Performance of Buildings) Standards (EPB, 2024).

Source: The author.

Table 27 – Proposed measures to overcome the “Lack of efficiency dissemination of codes/regulations” barrier.

What is the barrier?		**BG_04 -** LACK OF EFFICIENT DISSEMINATION OF CODES/REGULATIONS		
What is the measure proposed to overcome this barrier?		**Measure 1:** Promotion of actions to publicise existing policy instruments in the entire country.		**Measure 2:** Creation of an organisation that is responsible for disseminating information about policy instruments and their actions to promote the adoption of EE technologies.
What is there in Brazil? And what is missing?		Although the policy instruments designed to promote the energy efficiency of buildings are available on government platforms, such as on the websites of the MME and the National Energy Conservation Programme (PROCEL), they are not widely disseminated to the general public.		General information about policy instruments is available on government platforms. However, there is a lack of a specific organisation to manage and disseminate information about the policy instruments enacted to promote the adoption of EE technologies in the building segment.
How this measure can be implemented in the Brazilian scenario?		**Proposition 1:** Developing a tool to provide information about the policy instruments enacted to promote building energy efficiency in Brazil.	**Proposition 2:** Creation of exchange forums between the Brazilian country's regions to share the policy instruments created to promote building energy efficiency.	**Proposition 1:** Creation of an organisation that is responsible for helping the Brazilian government to promote the main policy instruments and actions enacted to encourage the adoption of EE technologies in the country.
Examples	**Example-Action**	MURE (*Mesures d'Utilisation Rationnelle de l'Energie*) database	India’s Building Energy Efficiency Program Dashboard	America Council for an Energy Efficient Economy (ACEEE)
	Geographical Context	EU	India	USA
	Objective	To provide information on energy efficiency policies and measures that have been carried out in the Member States of the European Union (EUROPEAN UNION, 2024a).	To provide, for policymakers and others, transparent and accessible data, increasing understanding of the energy system and supporting energy policy decisions at the highest level (IEA, 2024c).	To help national, state, and local governments develop, implement, and adopt solutions to make known the policy instruments that significantly promote the energy efficiency of existing buildings (ACEEE,2024c).

Source: The author.

Table 28 – Proposed measures to overcome the "Lack of financial implications of energy efficiency projects in energy policies" barrier.

	What is the barrier?	**BG_05 -** LACK OF FINANCIAL IMPLICATIONS OF ENERGY EFFICIENCY PROJECTS IN ENERGY POLICIES	
	What is the measure proposed to overcome this barrier?	**Measure 1:** Conduction of a preliminary assessment analysis to identify the possible financial implications of energy efficiency projects.	**Measure 2:** Assisting owners to know the possible financial implications of their projects.
	What is there in Brazil? And what is missing?	There is no preliminary assessment developed by public bodies responsible for promoting energy efficiency in buildings that can help identify the possible financial implications that may arise during the process of adoption of EE technologies.	There is no support offered by government bodies to help owners understand the possible financial implications of their projects.
	How this measure can be implemented in the Brazilian scenario?	**Proposition 1:** Performing a rigorous financial analysis that will determine the economic implications of energy efficiency projects developed in the Brazilian building segment.	**Proposition 2:** Creating educational ways to help Brazilian owners know the possible financial implications linked to their projects.
Examples	**Example-Action**	Guide to cost-benefit analysis of investment projects	Alaska Housing Finance Corporation Programs -Energy Efficiency Education
	Geographical Context	EU	USA
	Objective	To illustrate common principles and rules for the application of cost-benefit analysis that can help to give a complete picture of the possible financial implications of energy efficiency projects (EUROPEAN COMMISSION, 2024c).	To develop tools and education to help non-residential building owners to understand the financial implications of energy efficiency retrofits (US ARCTIC RESEARCH COMMISSION, 2024).

Source: The author.

The proposed measures have the potential to create a regulatory environment that is not only more conducive, but also more stable for the adoption of EE technologies in the Brazilian building segment, providing a supportive governmental structure for the implementation and utilisation of EE technologies in buildings across Brazil.

7.2 PROPOSED MEASURES FOR OVERCOMING THE REMAINING BARRIERS THAT ARISE IN THE “MOTIVATION” PHASE

A total of 22 measures were identified in the literature for overcoming the remaining barriers that arise in the "Motivation" phase of the adoption process of EE technologies. These measures are associated with their respective barrier to be overcome. Figure 26 presents these measures with their citation frequency in the literature.

Two measures were collected in the articles to overcome the barrier BM_01 (“High costs of investments”) in adopting EE technologies. The literature emphasises the importance of developing financial incentives, such as targeted subsidies, to reduce the initial investment costs of energy efficiency projects. This measure was cited three times.

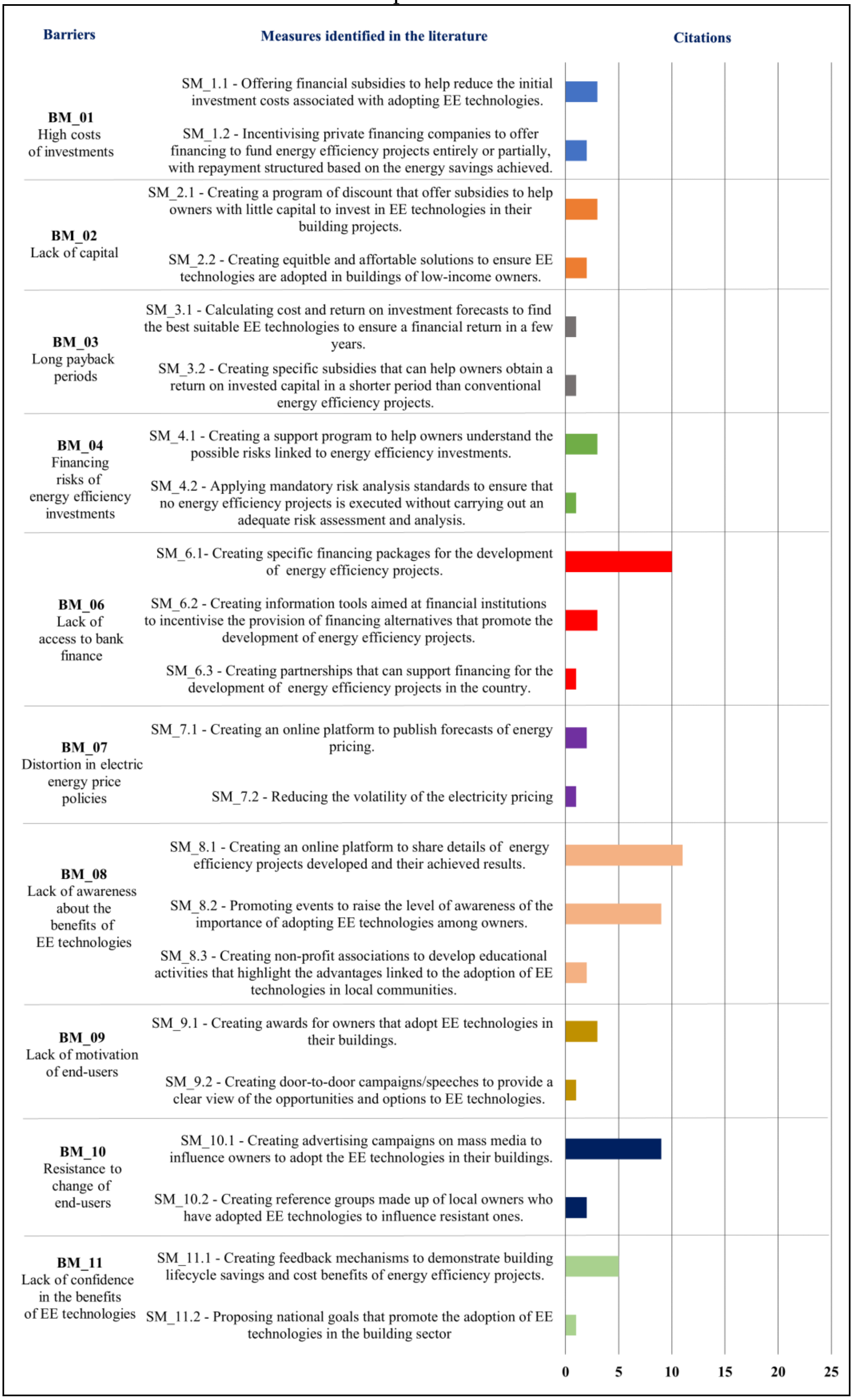
Other two measures have been identified to address the “Lack of capital” (BM_02) barrier. One of these suggestions involves establishing a discount program that provides subsidies to lower the project costs, facilitating potential owners in covering the expenses associated with adopting EE technologies. This measure was mentioned three times.

To overcome the barrier BM_03 (“Long payback periods”), two measures were pointed out. One of them points out the importance of calculating cost and return on investment forecasts to find the most appropriate technology for adoption, thereby ensuring a timely financial return within a few years. This measure was referenced one time in the literature.

The literature highlights two key measures to overcome the barrier “Financial risks energy efficiency investments” (BM_04). For instance, there is an emphasis on implementing mandatory risk analysis standards prior to the adoption of EE technologies. This approach enables owners to proactively address potential risk scenarios that may arise during investment in such technologies. This measure was cited only one time.

Three measures are found to address the barrier BM_06 (“Lack of access to bank finance”). The most cited suggestion involves the development of specific financing packages aimed at incentivising financial institutions to provide support for investments in EE technologies (10 citations).

Figure 26 – Measures for overcoming the remaining barriers that arise in the "Motivation" phase.



Source: The author.

Two measures were pointed out to overcome the barrier “Distortion in electric energy price policies” (BM_07). One of these measures involves the suggestion of creating an online platform capable of continuously updating real forecasts for energy prices in the country. This measure received two citations in the literature.

A total of three measures were identified to overcome the barrier “Lack of awareness about the benefits of EE technologies” (BM_08). Among these, one of the most cited solutions, with nine citations, involves the development of events aimed at incorporating energy efficiency topics among building owners. These events can be used as platforms to disseminate knowledge and raise awareness about the benefits of EE technologies.

Two measures have been delineated to address the barrier BM_09 (“Lack of motivation of end-users”). To enhance motivation, it is suggested to create awards to recognise and reward the owners that effort in adopting EE technologies in their buildings, as indicated by four citations in the literature.

A total of two measures have been proposed to overcome the barrier BM_10 (“Resistance to change of end-users”). Among these measures, the most cited solution, with nine citations, deals with the development of advertising campaigns tailored to influence owners’ beliefs and behaviour change. These campaigns employ persuasive messaging and targeted communication strategies to overcome resistance to change, thereby promoting the adoption of EE technologies.

Two measures have been highlighted to mitigate the barrier “Lack of confidence in the benefits of EE technologies” (BM_11). To instill confidence, it was suggested to establish feedback mechanisms to share real data on the benefits derived from the adoption of EE technologies. This suggestion was presented by five articles in the literature.

From these results, which was proposed such measures identified in the literature for overcoming the barriers that hinder the “Motivation” phase in the adoption process of EE technologies, it was possible to proposed them in more detail for Brazilian scenario.

Table 29 presents the proposed measures identified to overcome the barrier BM_01, which pertains to the “High costs of investments”. Regarding these proposed measures, it was possible to see that they have the potential to reduce the value of the investment required for EE technology adoption. This reduction in investment value can encourage the Brazilian owners to consider these technologies in their building projects.

The measures proposed to overcome the barrier BM_02 (“Lack of capital”) are detailed in Table 30. These measures are designed to offer viable alternatives and support mechanisms to reduce the financial constraints faced by Brazilian building owners in adopting EE technologies.

Table 31 describes the measures proposed to address the barrier BM_03 (“Long payback periods”). The proposed measures are centered on initiatives to reduce the duration of investment return. This is significant because it directly impacts the financial viability and attractiveness of EE technology adoption. By reduction the payback period, Brazilian owners can recover their initial investment in EE technologies more quickly, thereby incentivising greater uptake of energy saving practice in the Brazilian building segment.

Table 32 outlines suggestions to overcome the barrier BM_04 ("Financial risks of energy efficiency investments"). These proposed initiatives helped Brazilian owners understand the potential financial risks associated with EE technology adoption. This understanding empowers them to strategically prioritise and allocate resources effectively, thereby facilitating the uptake of such solutions in their buildings.

The measures proposed to address the barrier BM_06 (“Lack of access to bank finance”) are detailed in Table 33. These suggestions are designed to enhance or expand the availability of financing options offered to banking institutions. This can accelerate the adoption of EE technologies in the Brazilian building segment.

Table 34 presents the proposed measures identified to overcome the barrier BM_07, which pertains to the “Distortion in electric energy price policies”. By implementing these measures, such as regulatory reforms or pricing mechanisms, it becomes possible to reduce these distortions. This, in turn, promotes a more conducive environment for EE technology adoption by ensuring that energy prices accurately reflect the true costs and benefits of energy consumption in Brazil.

Table 35 highlights suggestions to overcome the barriers BM_08 (“Lack of awareness about the benefits of EE technologies”). By implementing these measures, it becomes possible to raise awareness among Brazilian owners about the advantages of EE technologies. Without a clear understanding of the benefits, owners may be hesitant to invest in these solutions. Thus, this increased awareness can lead Brazilian owners to better appreciate the potential cost savings, environmental benefits, and improved comfort associated with EE technologies, thereby motivating them to prioritise EE initiatives in their buildings.

The measures proposed to address the barrier BM_09 (“Lack of motivation of end-users) are presented in Table 36. The suggestions can be used as an instrument to cultivate a culture of energy efficiency among Brazilian owners, driving positive behavioural changes, and ultimately contributing to the overall promotion of EE technologies in the country.

Table 37 shows the proposed measures to overcome the barrier BM_10 (“Resistance to change of end-users”). These measures are crucial because overcoming resistance to change is valuable for the successful implementation and utilisation of EE technologies. By addressing this barrier, the acceptance of EE technologies among Brazilian users becomes more achievable.

Finally, Table 38 outlines suggestions to overcome the barrier BM_11 (“Lack of confidence in the benefits of EE technologies”). By implementing the suggested measures, it becomes possible to increase the confidence of Brazilian owners in the efficacy of the energy efficiency solutions. This increased confidence is crucial for encouraging Brazilian owners to invest in and implement EE technologies, leading to substantial energy savings in their built environment.

The proposed measures for overcoming the barriers that arise in the “Motivation” phase have the potential to increase the owners’ interest in opting for EE technologies in their buildings, as various factors contributing to owners' motivation can be enhanced. Overall, Brazilian building owners can be encouraged to explore and adopt EE technologies, leading to a greater uptake of energy saving practices and improved energy performance of their buildings.

Table 29 – Proposed measures to overcome the "High costs of investments" barrier.

<table>
<tr><th colspan="2">What is the barrier?</th><th colspan="2">BM_01 - HIGH COSTS OF INVESTMENTS</th></tr>
<tr><td colspan="2">What is the measure proposed to overcome this barrier?</td><td>Measure 1: Offering financial subsidies to help reduce the initial investment costs associated with adopting EE technologies.</td><td>Measure 2: Incentivising private financing companies to offer financing to fund energy efficiency projects entirely or partially, with repayment structured based on the energy savings achieved.</td></tr>
<tr><td colspan="2">What is there in Brazil? And what is missing?</td><td>Although financial subsidies already exist to help partially cover the costs of measures to reduce energy consumption, for example, the "BB Crédito Energia Renovável" offered by Bank of Brazil, it is still necessary to create more financial subsidies to help cover the costs associated with the adoption of EE technologies in building projects.</td><td>Although there are specific lines of credit for energy efficiency that are offered by private financial institutions in the country, such as "Santander Financiamentos" from Santander Bank which directs resources to finance technologies and projects to improve energy efficiency, most of them part of the public initiative.</td></tr>
<tr><td colspan="2">How this measure can be implemented in the Brazilian scenario?</td><td>Proposition 1:
Creation of financial subsidies to cover a partial percentage of the investment's cost in the energy efficiency in Brazilian buildings</td><td>Proposition 2:
Creation of financing, supported by Brazilian private financing companies, to repay the project costs.</td></tr>
<tr><td rowspan="3">Examples</td><td>Example-Action</td><td>Federal subsidy for energy-efficient buildings – single measures</td><td>Energy Performance Certification (EPC)</td></tr>
<tr><td>Geographical Context</td><td>EU</td><td>EU</td></tr>
<tr><td>Objective</td><td>To subsidise the scheme deployment of renewable heating and cooling installations in existing buildings, offering subsidies that can cover part of the percentage of the investment's costs (EUROPEAN COMMISSION, 2024f).</td><td>To offer "creative financing" where an external organisation (ESCO) implements an energy efficiency project that uses the stream of income from the cost savings, to repay the costs of the project (EUROPEAN COMMISSION, 2024e).</td></tr>
</table>

Source: The author.

Table 30 – Proposed measures to overcome the "Lack of capital" barrier.

What is the barrier?		**BM_02 -** LACK OF CAPITAL	
What is the measure proposed to overcome this barrier?		**Measure 1:** Creating a program of discount that offers subsidies to help owners with little capital to pay for EE technologies in their building projects.	**Measure 2:** Creating equitable and affordable solutions to ensure EE technologies are financially accessible for low-income owners.
What is there in Brazil? And what is missing?		In the country, there are public policies to encourage more sustainable buildings, such as the "IPTU Verde" implemented by several municipal governments to grant small percentages of discounts in city tax for owners who promote certain socio-environmental measures in their buildings. However, there is no specific discount program to provide subsidies for reducing the costs of energy efficiency projects.	While there are initiatives in the country to help low-income homeowners adopt energy efficiency measures in their buildings, such as the Post-Occupation Evaluation Methodology for Social Housing Buildings developed by the "Energy Efficiency in Urban Development Social Housing Focus (EEDUS)" project—a collaboration between the National Housing Secretariat of the Ministry of Regional Development (SNH/MDR) and Germany's Federal Ministry for Economic Cooperation and Development (BMZ)—these efforts remain limited.
How this measure can be implemented in the Brazilian scenario?		**Proposition 1:** Creation of a program to offer discounts in subsidy formats for Brazilian owners that can perform energy improvements in their buildings.	**Proposition 1:** Creation of resources and strategy to ensure EE technologies are adopted for low-income Brazilian owners.
Examples	**Example-Action**	Home Efficiency Rebates	Affordable Home Energy Shot
	Geographical Context	USA	USA
	Objective	To award grants to State energy offices for providing rebates that reduce the price of energy-saving retrofits in single-family and multi-family buildings (U.S. DEPARTMENT OF ENERGY, 2024f).	To ensure equitable and affordable solutions to reduce the upfront cost of upgrading a home by at least 50% while reducing energy bills by 20% within a decade. (U.S. DEPARTMENT OF ENERGY, 2024g).

Source: The author.

Table 31 – Proposed measures to overcome the "Long payback periods" barrier.

What is the barrier?		**BM_03 -** LONG PAYBACK PERIODS	
What is the measure proposed to overcome this barrier?		**Measure 1:** Calculating cost and return on investment forecasts to find the best suitable EE technologies to ensure a financial return in a few years.	**Measure 2:** Creating specific subsidies that can help owners obtain a return on invested capital in a shorter period than conventional energy efficiency projects.
What is there in Brazil? And what is missing?		There are no public initiatives to help owners calculate costs and make realistic forecasts on the return on invested capital. It is worth mentioning that there is a lack of data to calculate the return on investment, such as the price of technologies, labour, the interest rate on project financing, the electric energy price, the value of energy saved, etc.	Although there are subsidised loans in the country, such as loans subsidised for efficiency by BNDES, it is still important to improve existing ones and incorporate specific subsidies that support energy efficiency projects with greater clarity, ensuring a return on capital investment.
How this measure can be implemented in the Brazilian scenario?		**Proposition 1:** Creation of a calculation tool to estimate the return on investment for energy efficiency projects developed in Brazil.	**Proposition 1:** Creation of specific subsidies to decrease the return on investment of energy efficiency projects developed in the Brazilian building segment.
Examples	**Example-Action**	Cost calculator – EDGE App	Poland's "My Electricity" programme
	Geographical Context	United Kingdom (UK)	Poland
	Objective	To decide the best green options, estimate the incremental costs of building green and the payback period through estimated utility savings (UK GOVERNMENT, 2024).	To offer subsidies to support the share of distributed solar photovoltaic in the production of electricity, which was expected to shorten the payback period on the installation of photovoltaic panels for a half-time (IEA, 2024j).

Source: The author.

Table 32 – Proposed measures to overcome the "Financial risks of energy efficiency investments" barrier.

What is the barrier?		**BM_04 -** FINANCIAL RISKS OF ENERGY EFFICIENCY INVESTMENTS	
What is the measure proposed to overcome this barrier?		**Measure 1:** Creating a support program to help owners understand the possible risks linked to energy efficiency investments.	**Measure 2:** Applying mandatory risk analysis standards to ensure that no energy efficiency project is executed without carrying out an adequate risk assessment and analysis.
What is there in Brazil? And what is missing?		Although there are public initiatives developed, for example, by the MME, PROCEL, and Eletrobrás that help to identify financial instruments that can help to deal with the financial risks of energy efficiency projects, it is still important to develop public initiatives that directly help building owners deal with such risks.	Although there are tools for assessing the level of energy efficiency and energy performance in buildings, such as assessment methods proposed by PROCEL Edifica, it is difficult to identify tools that help assess the risks of investing in and financing energy efficiency projects.
How this measure can be implemented in the Brazilian scenario?		**Proposition 1:** Creation of a support program to help Brazilian owners know the possible risks linked to energy efficiency investments.	**Proposition 1:** Evaluation of the financial risks of the energy efficiency projects developed in the Brazilian scenario.
Examples	**Example-Action**	Project EFFECT4 buildings	Building Upgrade Value Calculator
	Geographical Context	EU	USA
	Objective	To develop, in collaboration with public building managers, a comprehensive decision-making support toolbox with a set of financial instruments to unlock the investments and lower the risks of implementing EE measures in buildings owned by public stakeholders (EUROPEAN UNION, 2024e).	To evaluate the financial impacts of energy efficiency improvements of buildings, and the financial value of efficiency-related capital investments in the commercial real state (ENERGY STAR, 2024b).

Source: The author.

Table 33 – Proposed measures to overcome the "Lack of access to bank finance" barrier.

What is the barrier?		**BM_06 -** LACK OF ACCESS TO BANK FINANCE		
What is the measure proposed to overcome this barrier?		**Measure 1:** Creating specific financing packages for the development of energy efficiency projects.	**Measure 2:** Creating information tools aimed at financial institutions to incentivise the provision of financing alternatives that promote the development of energy efficiency projects.	**Measure 3:** Creating partnerships that can support financing for the development of energy efficiency projects in the country.
What is there in Brazil? And what is missing?		There is a need to expand the types of financing, since the majority of financing packages, offered by public and private financial institutions, are for specific improvements in buildings, such as the "*BB Crédito Energia Renovável*" from Bank of Brazil and the "*Crédito Pessoal Caixa - Energia Renovável*" offered by CAIXA Bank.	There is no specific tool that can be used as an informational initiative to encourage financial institutions to provide financing alternatives to support the adoption of EE technologies in the building segment.	Although there are existing incentives through government collaborations, such as the partnership between PROCEL and BNDES to provide financial resources for the "*Programa de Garantias de Crédito para Eficiência Energética (FGEnergia)*", it is important to further expand the government's partnership with financial institutions.
How this measure can be implemented in the Brazilian scenario?		**Proposition 1:** Creation of financial packages that are directed toward the adoption of EE technologies in Brazilian buildings.	**Proposition 1:** Creation of an information tool to support the Brazilian financial institutions to provide financial support for the adoption of EE technologies.	**Proposition 1:** Creation of partnerships that can help the availability of financing alternatives to support the adoption of EE technologies in the Brazilian building segment.
Examples	**Example-Action**	European Investment Bank (EIB) financing to energy efficiency projects of a specific real estate company	Energy Efficiency Quick Estimation (EEQuest)	Private Finance for Energy Efficiency (PF4EE) – Join the initiative between the European Investment Bank and the European Commission
	Geographical Context	EU	EU	EU
	Objective	To offer capital to a specific real estate company to enhance the energy efficiency of its building stock (IEA,2024p).	To support financial intermediaries in marketing dedicated to energy efficiency finance, raises awareness, and facilitates on-lending for energy efficiency, allowing to estimate of a preliminary value of potential energy savings (EUROPEAN COMMISSION, 2024g).	To increase the availability of debt financing for eligible energy efficiency investments and to make energy efficiency lending a more sustainable activity with European institutions (EUROPEAN COMMISSION, 2024h).

Source: The author.

Table 33 – Proposed measures to overcome the "Distortion in electric energy price policies" barrier.

	What is the barrier?	**BM_07 -** DISTORTION IN ELECTRIC ENERGY PRICE POLICIES	
	What is the measure proposed to overcome this barrier?	**Measure 1:** Creating an online platform to publish forecasts of energy prices.	**Measure 2:** Reducing the volatility of the electricity pricing.
	What is there in Brazil? And what is missing?	There is no initiative in this regard in the country, despite the National Electric Energy Agency (ANEEL) estimating electricity tariff prices on its data platform.	There is no specific pricing in the country that can be offered to owners who adopt EE technologies, despite energy concessionaires establishing a fixed charge rate for the use of renewable energy generation systems (minimum rate of light).
	How this measure can be implemented in the Brazilian scenario?	**Proposition 1:** Creation of an online platform to publish forecasts of electricity pricing of the Brazilian building segment.	**Proposition 1:** Creation of fixed electricity pricing for energy efficiency projects developed in Brazil.
Examples	**Example-Action**	Short-term Energy Outlook (STEO) – Real Price Viewer	Feed-in tariffs for electricity produced from Renewable Energy Sources
	Geographical Context	USA	Lithuania
	Objective	To provide near-term electricity real prices data, analysis, and forecasts from the time of publication through December of the next calendar year (U.S. ENERGY INFORMATION ADMINISTRATION, 2024).	To set feed-in tariff (FIT) levels for a determined period for installations that adopt renewable energy sources for electricity production (IEA, 2024q).

Source: The author.

Table 35 – Proposed measures to overcome the "Lack of awareness about the benefits of EE technologies" barrier.

What is the barrier?		**BM_08 -** LACK OF AWARENESS ABOUT THE BENEFITS OF EE TECHNOLOGIES		
What is the measure proposed to overcome this barrier?		**Measure 1:** Creating an online platform to share details of energy efficiency projects developed and their achieved results.	**Measure 2:** Promoting events to raise the level of awareness of the importance of adopting EE technologies among owners.	**Measure 3:** Creating non-profit associations to develop educational activities that highlight the advantages linked to the adoption of EE technologies in local communities.
What is there in Brazil? And what is missing?		There is a deficiency in information and dissemination of results achieved in energy efficient projects, since the information disclosed is linked mainly to the results of the PROCEL Edifica Energy Efficiency Labeling Program.	There are no local public initiatives, specifically targeting the building segment. Existing initiatives, such as those managed by the MME, focus on general energy efficiency issues across various energy sectors in the country.	Although some non-profitable associations support the energy efficiency of buildings throughout the country, such as the Brazilian Association of Energy Conservation Service Companies (ABESCO), there is a need to create municipal non-profitable institutions to develop activities closer to the local public.
How this measure can be implemented in the Brazilian scenario?		**Proposition 1:** Creation of an online platform to share the results of the energy efficiency projects developed in the Brazilian building segment.	**Proposition 1:** Creation of events to raise the awareness of Brazilian owners about the need to adopt EE technologies in their buildings.	**Proposition 1:** Creation of associations to provide free local advice on energy saving and EE technologies to the Brazilian owners.
Examples	**Example-Action**	National Ujala Dashboard	Energy Efficiency Day	*Service Info Énergie en Isére*
	Geographical Context	India	USA	France
	Objective	To display the number of LED lights installed by region in real-time, along with the respective annual cost savings, annual CO_2 reductions, etc. (IEA, 2024r).	To share tips, tools, and stories that promote the multiple benefits of energy efficiency, from lower costs to healthier buildings (ACEEE, 2024e).	To provide local advice and information on energy renewal issues, such as available technologies, technical assistance, list of professionals, eligibility for financial assistance, etc. (FRANCE RÉNOV', 2024).

Source: The author.

Table 36 – Proposed measures to overcome the "Lack of motivation of end-users" barrier.

What is the barrier?		**BM_09 -** LACK OF MOTIVATION OF END-USERS	
What is the measure proposed to overcome this barrier?		**Measure 1:** Creating awards for owners that adopt EE technologies in their buildings.	**Measure 2:** Creating door-to-door campaigns/speeches to provide a clear view of the opportunities and options for EE technologies.
What is there in Brazil? And what is missing?		There are no initiatives in this regard in the country, the most prominent recognition for owners is the Brazilian Labelling Program (PBE Label) developed in partnership between Inmetro and Eletrobras/PROCEL Edifica.	There are few initiatives in this sense in the country to represent a clear overview of the opportunities of EE technologies, such as the *"Programa de Eficiência Energética da Cosern*", which was regulated by ANEEL, to offer door-to-door awareness activities to certain locations in the country.
How this measure can be implemented in the Brazilian scenario?		**Proposition 1:** Creating awards to recognise outstanding energy-efficient building designs in Brazil.	**Proposition 1:** Creating campaigns to provide Brazilian owners with a clear overview of building energy efficiency.
Examples	**Example-Action**	National Energy Efficiency Roadmap for Movement Towards Affordable and Natural Habitat (NEERMAN) Awards	Door-to-door campaigns – Community Housing Partners (CHP)
	Geographical Context	India	USA
	Objective	To acknowledge and encourage exemplary building designs complying with Energy Conservation Building Codes (GOVERNMENT OF INDIA, 2024).	To distribute flyers/door hangers and offer free services to connect no-cost homes energy efficiency programs with owners and occupants (COMMUNITY HOUSING PARTNERS, 2024).

Source: The author.

Table 37 – Proposed measures to overcome the "Resistance to change of end-users" barrier.

What is the barrier?		**BM_10 -** RESISTANCE TO CHANGE OF END-USERS	
What is the measure proposed to overcome this barrier?		**Measure 1:** Creating advertising campaigns on mass media to influence owners to adopt the EE technologies in their buildings.	**Measure 2:** Creating reference groups made up of local owners who have adopted EE technologies to influence resistant ones.
What is there in Brazil? And what is missing?		There are few campaigns aimed at influencing the adoption of EE technologies, there are mainly public initiatives developed by PROCEL, ELETROBRÁS, and the MME to publicise Energy Efficiency Labelling for Buildings.	There are no public initiatives in this sense in the country, where owners can act as agents of change in their local communities.
How this measure can be implemented in the Brazilian scenario?		**Proposition 1:** Creating advertising campaigns on mass media to influence Brazilian owners to adopt the EE technologies in their buildings.	**Proposition 1:** Creating reference groups made up of local owners to influence resistant ones in adopting the EE technologies in their buildings.
Examples	**Example-Action**	Better Buildings Residential Network – Social Media Toolkit	Pilot project – The UK Green Open Homes Programmes
	Geographical Context	USA	UK
	Objective	To help residential energy efficiency programs learn to engage the owners through social media (U.S. DEPARTMENT OF ENERGY, 2024h).	To create a program where owners who made energy efficiency improvements to their homes open them to visitors to explain why they have done it, and their benefits achieved (EUROPEAN UNION, 2024c).

Source: The author.

Table 38– Proposed measures to overcome the "Lack of confidence in the benefits of EE technologies" barrier.

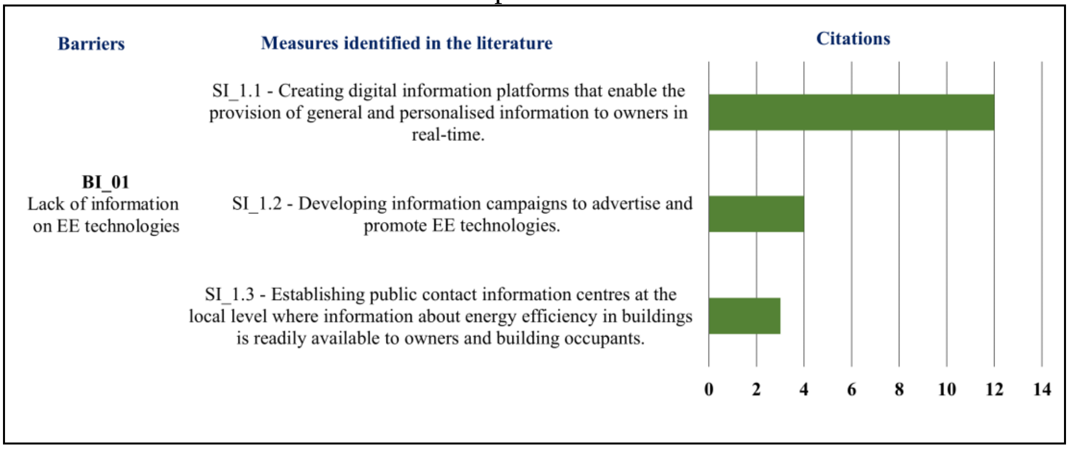
What is the barrier?		**BM_11** - LACK OF CONFIDENCE IN THE BENEFITS OF EE TECHNOLOGIES	
What is the measure proposed to overcome this barrier?		**Measure 1:** Creating feedback mechanisms to demonstrate building lifecycle savings and cost benefits of energy efficiency projects.	**Measure 2:** Proposing national goals that promote the adoption of EE technologies in the building segment.
What is there in Brazil? And what is missing?		Although feedback mechanisms already exist in the country, there is a need to increase the use of these mechanisms and energy performance indicators that drive the development of a national energy management program for building energy efficiency.	Although there are national plans with goals to promote building energy efficiency, such as the "Ten-Year Energy Efficiency Plan" developed by PROCEL/Eletrobrás, it is important to improve the existing plans, mainly in the presentation of annual reports about achieved results.
How this measure can be implemented in the Brazilian scenario?		**Proposition 1:** Creation of benchmarking mechanisms to demonstrate the performance of the technologies adopted in the Brazilian buildings.	**Proposition 1:** Proposition of realistic goals in the national plans to the aim of promoting the adoption of EE technologies in the Brazilian building segment.
Examples	**Example-Action**	Online building-based electricity utilization – Index Benchmarking tool	National action plans and annual progress reports
	Geographical Context	Hong Kong	EU
	Objective	To facilitate the comparison and review of building electricity utilisation performance, thereby allowing building owners to benchmark their electricity consumption performance with others having similar building usage (EMSD, 2024).	To develop national energy efficiency action plans that set out estimated energy consumption, planned energy efficiency measures, long-term renovation strategies, and the improvements that individual EU countries expect to achieve to reach the EU 2020 target of 20%. (EUROPEN COMISSION, 2024i).

Source: The author.

7.3. PROPOSED MEASURES FOR OVERCOMING THE REMAINING BARRIER THAT ARISE IN THE "INFORMATION" PHASE

The "Information" phase, only one remaining barrier is considered. Therefore, from the literature review, it was possible to identify three measures to overcome this barrier, as presented in Figure 27.

Figure 27 – Measures for overcoming the remaining barriers that arise in the "Information" phase.



Source: The author.

Among the three measures identified, the most cited measure for overcoming barrier BI_01, which relates to the "Lack of information of EE technologies," involves establishing an online platform and electronic devices for real-time dissemination of all pertinent information to the adoption of EE technologies. These platforms can be used as comprehensive repositories of information, focusing on various aspects essential for EE technology adoption. This includes publicising technological options and their potential energy savings, detailing available financing options for developing energy efficiency projects, showcasing real case studies developed within the country, and providing reliable techniques and procedures to maximize energy efficiency. This measure was cited 12 times in the literature.

Considering the importance of the proposed measures for overcoming the barrier BI_01, they have been detailed for the Brazilian context, as delineated in Table 39. It's noteworthy that the implementation of these measures plays an essential role in addressing the informational gaps that hinder the adoption of EE technologies. By providing accessible and up-to-date information, Brazilian building owners can make informed decisions and navigate the complexities associated with EE technology adoption more effectively.

Table 39 – Proposed measures to overcome the "Lack of information on EE technologies" barrier.

	What is the barrier?	**BI_01 -** LACK OF INFORMATION ON EE TECHNOLOGIES		
	What is the measure proposed to overcome this barrier?	**Measure 1:** Creating digital information platforms that enable the provision of general and personalised information to owners in real-time.	**Measure 2:** Developing information campaigns to advertise and promote EE technologies.	**Measure 3:** Establishing public contact information centres at the local level where information about energy efficiency in buildings is readily available to owners and building occupants.
	What is there in Brazil? And what is missing?	There is no dedicated information platform for energy efficiency in buildings. The information provided by public and private entities linked to the government, such as the Energy Research Office (EPE) and Eletrobrás, is general and focuses on various energy sectors rather than specifically on buildings.	There is little dissemination of information related to building energy efficiency in publicise campaigns, since the main information is made available on the platforms of companies and government agencies such as PROCEL.	There are no physical environments where it is possible to access information about energy efficiency in buildings, as the information available is mostly present on government online platforms, such as the site of the MME.
	How this measure can be implemented in the Brazilian scenario?	**Proposition 1:** Creation of an online platform to present information about the advanced EE technologies and the practices to reduce building energy consumption in Brazil.	**Proposition 1:** Development of information campaigns to advertise and promote EE technologies in the entire Brazilian territory.	**Proposition 1:** Creation of information centres at the local level to provide advice and information on energy efficiency to the owners and occupants of Brazilian buildings.
Examples	**Example-Action**	Partnership for Advancing Technology in Housing (PATH)	Campaign: "Energy Efficiency: Doing more with less."	*Espace Info Énergie* (EIE)
	Geographical Context	USA	EU	France
	Objective	To create an online resource where the best information on advanced building technologies, best practices, case studies, links to articles and publications, and tips for owners can be included (IEA,2024d).	To launch an information campaign on energy efficiency under the slogan "Doing More with Less" to promote the benefits of energy efficiency, showcase the projects that impact the communities and environment they live in, and motivate change (EUROPEAN UNION, 2024b).	To create a network of local information centres to provide free, impartial, practical advice and information on energy efficiency to owners and occupants (AGEDEN, 2024; UNDP,2024).

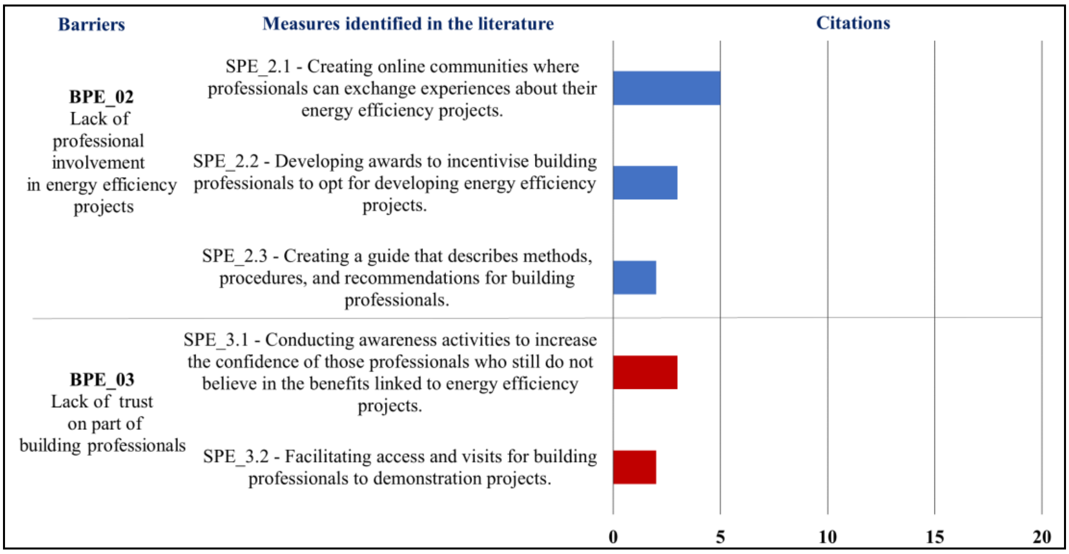
Source: The author.

Thus, examining the Brazilian scenario, it is important to highlight that implementing the proposed measures improves the owners' access to the necessary information, which facilitates the adoption of EE technologies. This, in turn, has a positive impact on the increase in the number of building projects focused on reducing energy consumption and promoting environmental sustainability in the country.

7.4. PROPOSED MEASURES FOR OVERCOMING THE REMAINING BARRIERS THAT ARISE IN THE “PLANNING/EXECUTION” PHASE

Two additional barriers were identified to potentially emerge during the “Planning/Execution” phase of the adoption of EE technologies. Based on the findings of the literature review, a total of five measures were identified to overcome these barriers. Figure 28 presents the identified measures and their corresponding number of citations.

Figure 28 – Measures for overcoming the remaining barriers that arise in the “Planning/Execution” phase.



Source: The author.

The literature explores three specific measures aimed at overcoming the barrier BPE_02, which concerns the “Lack of professional involvement in energy efficiency projects”. Among these measures, one noteworthy measure involves instituting specific awards to acknowledge building professionals engaged with energy efficiency initiatives. This suggestion has been referenced in three publications, and have the potential to stimulate the participation of other professionals who may currently lack enthusiasm for integrating EE technologies into their building projects.

To address the barrier BPE_03 ("Lack of trust on the part of building professionals") was collected two barriers in the literature. One of these suggestions emphasises the organisation and implementation of awareness activities aimed at sharing experiences relevant to energy efficiency projects. This measure, cited in three articles, focus on promoting trust among building professionals by providing opportunities to learn from and engage with successful EE technologies.

From these results, which was proposed such measures identified in the literature for overcoming the barriers that hinder the "Planning/Execution" phase in the adoption process of EE technologies, it was possible to refine them for Brazilian scenario.

Table 40 presents the proposed measures identified to address the barrier BPE_02 ("Lack of professional involvement in energy efficiency projects"). The proposition of these measures reveals their significance in potentially increasing the interest of Brazilian professionals in undertaking building projects incorporating EE technologies. Because of their potential to stimulate greater engagement and interest among Brazilian professionals, these measures also contribute to broader efforts in advancing the adoption of EE technologies with building projects across Brazil.

The measures proposed to overcome the barrier BPE_03, which concerns the "Lack of trust on the part of building professionals", are detailed in Table 41. These suggestions are important for enhancing the trust of Brazilian building professionals by means of strategies that can be directed for this public. As results, the implementation of these measures can providing Brazilian professionals with the resources, support, and confidence that they need to prioritise the effectively adoption of energy efficiency initiatives in their building projects.

These measures aimed at overcoming the barriers that arise in the "Planning/Execution" phase have the potential to generate greater interest and active involvement of Brazilian building professionals in projects that integrating EE technologies. Additionally, as professionals prioritise these projects, they also encourage their clients, emphasising the importance and advantages of implementing EE technologies in their buildings. This, in turn, makes clients more inclined to prioritise such projects in their buildings.

Table 40 – Proposed measures to overcome the "Lack of professional involvement in energy efficiency projects" barrier.

What is the barrier?		**BPE_02 -** LACK OF PROFESSIONAL INVOLVEMENT IN ENERGY EFFICIENCY PROJECTS		
What is the measure proposed to overcome this barrier?		**Measure 1:** Creating online communities where professionals can exchange experiences about their energy efficiency projects.	**Measure 2:** Developing awards to incentivise building professionals to opt for developing energy efficiency projects.	**Measure 3:** Creating a guide that describes methods, procedures, and recommendations for building professionals.
What is there in Brazil? And what is missing?		There is no initiative in this regard in the country, where building professionals can exchange experiences when it comes to energy efficiency in buildings.	There is no specific award that can be used as an incentive tool for building professionals who work with the development of energy efficiency projects in the country.	There is a need to complement the materials already existing in the country, such as the "Interactive Guide to Energy Efficiency in Buildings" created by the MME, together with SindoCon-SP and German Cooperation for Sustainable Development, to be used as a support tool and provision of technical knowledge to professionals in the building market.
How this measure can be implemented in the Brazilian scenario?		**Proposition 1:** Creation of an online community focused on building energy efficiency where Brazilian building professionals involved with energy efficiency projects can encourage the involvement of other professionals through sharing their experiences.	**Proposition 1:** Creation of awards aimed at recognizing Brazilian building professionals who develop successful projects in the country.	**Proposition 1:** Creation of a guide that describes procedures and recommendations that can help to ingrain an emerging professional culture of energy saving and sustainability among Brazilian building professionals uninterested in these issues.
Examples	**Example-Action**	Home Energy Pros	CIBSE Building Performance Awards (BPAs) – Project of the Year	The guide to sustainable construction
	Geographical Context	USA	UK	Germany
	Objective	To create a global online community for home performance and weatherisation professionals to share resources, experiences, knowledge, and opportunities (U.S. DEPARTMENT OF ENERGY, 2024c; ACEEE,2024d).	To reward building projects that effectively demonstrate high levels of comfort, while also providing excellent energy performance (CIBSE, 2024).	To describe methods and procedures for the implementation of sustainability measures in buildings and to present recommendations for structural and architectural building quality, technical building equipment, and energy supply (IEA,2024f).

Source: The author.

Table 41 – Proposed measures to overcome the "Lack of trust on the part of building professionals" barrier.

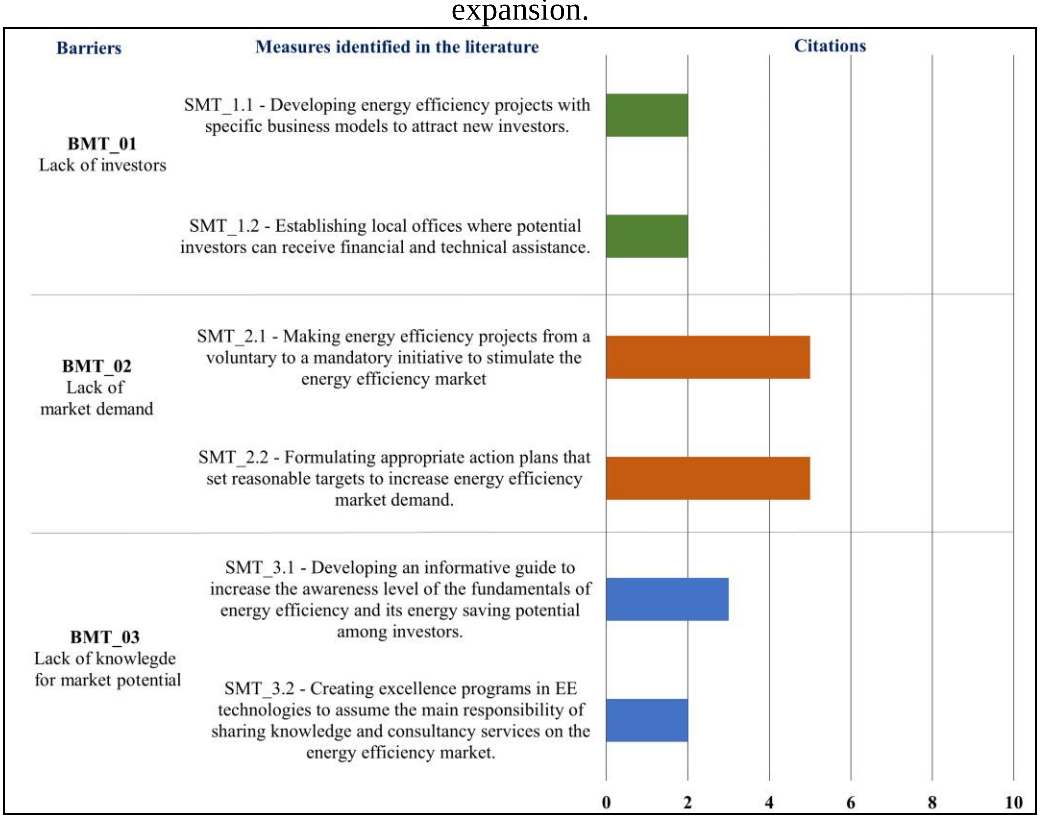
What is the barrier?		**BPE_03 -** LACK OF TRUST ON PART OF BUILDING PROFESSIONALS	
What is the measure proposed to overcome this barrier?		**Measure 1:** Conducting awareness activities to increase the confidence of those professionals who still do not believe in the benefits linked to energy efficiency projects.	**Measure 2:** Facilitating access and visits for building professionals to demonstration projects.
What is there in Brazil? And what is missing?		There is a need to carry out awareness-raising activities for professionals working in the building segment, similar to those developed in the country for the industrial sector, such as the educational events of the PotencializEE Program (Transformative Investment Program in Energy Efficiency) led by the MME and the German Agency for International Cooperation (GIZ) that promoting energy efficiency between professionals of medium and small enterprises.	There is a need to encourage building professionals to visit demonstration projects similar to the promotion of technical visits to the "*Primeira Casa Eoeficiente em Termos Eenergéticos*" (First Energy-Efficient House) established by the BASF Company in 2013, which in the first five years of the project, it received visits from more than 18,000 professionals in the field.
How this measure can be implemented in the Brazilian scenario?		**Proposition 1:** To establish awareness initiatives aimed at promoting energy efficiency among Brazilian building professionals who do not believe in the benefits of EE technologies.	**Proposition 1:** To encourage technical visits for Brazilian building professionals to demonstration projects, providing them with practical experience of the adoption of EE technologies in buildings.
Examples	**Example-Action**	*Edifici a Energia Quasi Zero Verso IL 2020*	*Suedtirol - Enertour4*
	Geographical Context	Italy	Italy
	Objective	To raise awareness among building professionals on the viability and importance of energy efficiency of existing buildings, both public and private type (EUROPEAN UNION, 2024c).	To offer building professionals technical visits to *CasaClima* buildings so they can have explanations about the technical and economic aspects of the installations of renewable energy systems and municipal systems (EUROPEAN UNION, 2024d).

Source: The author.

7.5. PROPOSED MEASURES FOR OVERCOMING THE REMAINING BARRIERS THAT HINDER THE MARKET EXPANSION

A total of six measures were identified in the literature for overcoming the remaining barriers that hinder the expansion of the market in building energy efficiency. Figure 29 presents the overcoming measures identified.

Figure 29 – Measures for overcoming the remaining barriers that hinder the market expansion.



Source: The author.

Three measures were identified for overcoming the barrier BMT_01, which pertains to the “Lack of investors” issue. Each mentioned measure was cited twice in the literature. One of these measures centers on the strategic planning of energy efficiency projects, incorporating a detailed business plan to guide their execution. By emphasising the importance of a specific business plan, this measure aims to provide potential investors with a clear roadmap for the project's implementation and expected outcomes. This increases the attractiveness of the project to investors, as they can better understand the potential return on their investment and the benefits of improving energy efficiency in buildings.

To address the barrier BMT_02 barrier (Lack of market demand”), two measures were collected in the literature. One suggestion highlighted involves transitioning energy efficiency programs from voluntary to mandatory initiatives. This measure aims to stimulate the energy efficiency market by progressively introducing energy efficiency targets. This measure was cited five times in the literature.

In the literature, two measures were pointed out to overcome the barrier BMT_03 ("Lack of knowledge for market potential"). One suggestion, with five citations, involves the development of an informational guide. This guide can be used as a comprehensive resource, offering references, guidelines, case studies, and manuals about EE technologies. The primary aim is to increase awareness among investors about the fundamentals of building energy efficiency and its potential for energy savings.

From these identified measures for overcoming the barriers that hinder the expansion of the market in building energy efficiency, it was possible to proposed them, in more detail for Brazilian scenario.

Table 42 describes the measures proposed to address the barrier BMT_01 ("Lack of investors"). Such measures focus on initiatives to increase the number of Brazilian investors interested in adopting EE technologies in their buildings. By increasing the number of investors, these measures can significantly enhance the pace and scale of adoption, leading to widespread improvements in the energy efficiency of the Brazilian building segment.

The measures proposed to overcome the barrier BMT_02 (Lack of market demand") are detailed in Table 43. These measures are strategically stimulate demand within the energy efficiency market. Advancing the market for energy efficiency holds substantial benefits for the Brazilian building segment, so besides to increase the adoption of EE technologies, these measures still creates opportunities for innovation, investment and competitiveness in this segment.

Finally, Table 44 outlines suggestions to overcome the barrier BMT_03 ("Lack of knowledge for market potential"). These proposed initiatives are designed to bridge the gap in understanding and awareness regarding the market potential for energy efficiency. By implementing the proposed initiatives, Brazilian investors can make more informed decisions regarding investments and strategic planning. This, in turn, can lead to increased confidence and willingness to engage in energy efficiency projects in Brazil.

The proposed measures have the potential to establish an energy efficiency market that experiences continuous growth and stability in the Brazilian building segment. For the implementation of these measures, the market can become a driving force for the widespread adoption of EE technologies in the building segment, promoting sustainability, innovation, and economic growth in the country.

Table 42 – Proposed measures to overcome the "Lack of investors" barrier.

What is the barrier?		**BMT_01 -** LACK OF INVESTORS	
What is the measure proposed to overcome this barrier?		**Measure 1:** Developing energy efficiency projects with specific business models to attract new investors.	**Measure 2:** Establishing local offices where potential investors can receive financial and technical assistance.
What is there in Brazil? And what is missing?		There are no specific business models presented by public initiatives that can be used to attract new investors who choose EE technologies in their buildings.	There is a need to offer consultancy services in different geographical regions for technical support for investors, such as the consultancy service of LabEEE at the Federal University of Santa Catarina.
How this measure can be implemented in the Brazilian scenario?		**Proposition 1:** Development of business models to attract new Brazilian investors to adopt the EE technologies in their buildings.	**Proposition 1:** Creation of local offices where Brazilian investors can receive financial and technical assistance for energy efficiency projects.
Examples	**Example-Action**	National Action Plan on Energy Efficiency	Energy Conservation Assistance Program
	Geographical Context	Germany	USA
	Objective	To develop business models for energy saving with a new approach for promoting close-to-market and cost-effective EE solutions (U.S. DEPARTMENT OF ENERGY, 2024e).	To provide financial and technical assistance to owners implementing energy efficiency updates (FAIRFAX COUNT VIRGINIA, 2024).

Source: The author.

Table 43 – Proposed measures to overcome the “Lack of market demand” barrier.

What is the barrier?		**BMT_02 -** LACK OF MARKET DEMAND	
What is the measure proposed to overcome this barrier?		**Measure 1:** Making energy efficiency projects from a voluntary to a mandatory initiative to stimulate the energy efficiency market.	**Measure 2:** Formulating appropriate action plans that set reasonable targets to increase energy efficiency market demand.
What is there in Brazil? And what is missing?		There is no obligation to adopt EE technologies in all types of buildings, since the improvements in energy efficiency are only mandatory for labelling public buildings.	Although there are general plans, such as the "*Plano Decenal de Eficiência Energética*", that propose energy efficiency actions on the most diverse final consumption sectors in the country, it is important to create specific action plans for energy efficiency considering each type of building.
How this measure can be implemented in the Brazilian scenario?		**Proposition 1:** Imposition of mandatory energy consumption and saving limits for buildings in Brazil.	**Proposition 1:** Proposition of action plans to increase the adoption of EE technologies in Brazilian buildings.
Examples	**Example-Action**	Danish Energy Efficiency Obligation	More with less Programme
	Geographical Context	Denmark	Netherlands
	Objective	To institute an energy efficiency obligation to achieve an energy savings per year of 3,384 GWh and an incremental energy savings of 2,2% in comparison to total fuel consumption, achieving between 2015-2020 (IEA, 2024g).	To improve the annual energy performance of a majority of their buildings, focusing on enabling owners to save energy with the least possible effort, since they can receive contractor support whether for certified energy advice or to install the required EE technology (IEA, 2024h).

Source: The author.

Table 44 – Proposed measures to overcome the "Lack of knowledge for market potential" barrier.

What is the barrier?		**BMT_03 -** LACK OF KNOWLEDGE OF MARKET POTENTIAL	
What is the measure proposed to overcome this barrier?		**Measure 1:** Developing an informative guide to increasing the level of awareness of the fundamentals of energy efficiency and its energy-saving potential among investors.	**Measure 2:** Creating excellence programs in energy efficiency technologies to assume the main responsibility of sharing knowledge and consultancy services on the energy efficiency market.
What is there in Brazil? And what is missing?		Although there are some general guidelines to support and provide knowledge about energy efficiency in buildings, such as the Interactive Guide created by the MME, there is no specific guide focused on raising awareness among potential investors.	There are some programs of excellence in energy efficiency in buildings in the country, such as CB3E *(Centro Brasileiro de Eficiência Energética Edificações)* and EXCEN *(Centro de Excelência em Eficiência Energética)* that can be improved to provide customised services to promote the adoption of EE technologies.
How this measure can be implemented in the Brazilian scenario?		**Proposition 1:** Development of an informative guide with orientations that can help new Brazilian investors in adopting EE technologies.	**Proposition 1:** Creation of excellence programs to help Brazilian owners adopt EE technologies in their buildings.
Examples	**Example-Action**	Guidelines for future building owners on how to build new NZEB	First Nations Conservation Program
	Geographical Context	Belgium	Canada
	Objective	To produce a "practical guide for building your nZEB house" to support future homeowners through the process of preparing, designing, executing, and using an nZEB dwelling (EUROPEAN COMMISSION, 2024c).	To provide customised conservation services designed to help communities reduce their electricity use in residential housing, and in commercial and institutional buildings (IEA, 2024i).

Source: The author.

The proposition of suggestions to overcome the remaining barriers plays a crucial role in addressing the challenges faced by the Brazilian building segment regarding the adoption of EE technologies. By targeting barriers that may hinder progress at different stages of the adoption process, these measures offer a comprehensive approach to addressing the complexities associated with EE technology adoption. This comprehensive approach can promote a culture of continuous improvement and innovation in the Brazilian building segment. This not only enhances the efficiency and sustainability of buildings but also drives economic growth and competitiveness of the country concerning energy issues.

8 CONCLUSION

This research was developed to answer the following questions: What are the measures to overcome barriers to the adoption of EE technologies in buildings? How is it possible to make them fit the Brazilian scenario?

Firstly, to answer these questions, it was important to develop a framework that provides a comprehensive understanding of the barriers that hinder the adoption of EE technologies. Thus, as a result, this framework enabled the delineation of the process of EE technology adoption, highlighting its necessary steps and the stakeholders involved. Notably, the adoption process was divided into four stages (Motivation, Information, Planning/Execution, and Results) shaped by both the government and the market. This framework also allowed for meticulous mapping of the barriers specific to the Brazilian context within the adoption process, identifying the stages at which each barrier may emerge.

As a significant contribution, these results enabled us to visualise at which stage each barrier in the Brazilian scenario might arise, and identify the stakeholders impacted by its existence. This is particularly useful because the proposed measures can be directed toward the specific stage of the adoption process where the barrier emerges. This approach enhances the continuity of the EE technology adoption process by overcoming barriers more effectively and maintaining the flow of adoption of EE technologies in the building segment.

Subsequently, the interrelationships between the barriers that emerge at each stage of the adoption process were studied using the ISM technique. This analysis resulted in the construction of hierarchical structures among the barriers that emerge in each stage of the adoption process, enabling the identification of the critical ones. The critical barriers identified were: lack of knowledge on energy efficiency by regulators and legislators (Government Support); lack of financial incentives ("Motivation" phase); lack of demonstration projects ("Information" phase); lack of technical competence and lack of adequate technologies ("Planning/Execution" phase"; and lack of good marketing strategies (Market Expansion).

These findings are valuable for achieving the objectives of this research. By identifying the critical barriers, it becomes possible to prioritise the implementation of the proposed measures. Overcoming the critical and influential barriers first can create a ripple effect that reduces the intensity or impact of other related barriers. This strategic prioritisation is essential for effectively promoting the adoption of EE technologies, ensuring that efforts and resources are first allocated to overcome the critical barriers, leading to more efficient and impactful progress toward widespread adoption of EE technologies in the building segment.

From the identification of the critical barriers, it was possible to propose measures to overcome them. Initially, a literature review was conducted to identify such measures. As a result, 17 measures were collected from 46 articles indexed in the Scopus and WoS databases. After identifying these measures in the literature, they were associated with their corresponding barriers, ensuring a clear visualisation of the critical barriers and their respective solutions.

Subsequently, these measures were proposed specifically for the Brazilian context. To formulate these proposals, a comprehensive scheme was developed to facilitate their implementation in Brazil. Beyond outlining the barriers and their corresponding measures, it was crucial to emphasise the significance of each measure for the Brazilian building segment. This involved assessing whether similar initiatives had been previously implemented in Brazil and highlighting how the proposed measures could be adopted in the Brazilian context. Furthermore, real examples of measures implemented in different geographical contexts were presented to facilitate their effective implementation.

These propositions can serve as a practical guide for Brazilian policymakers to overcome the critical barriers identified in this research. By focusing on these measures, policymakers can make strategic decisions that significantly impact the broader and more effective adoption of EE technologies across the Brazilian building segment.

Although this research suggested measures to overcome the critical barriers, it was important to present additional suggestions to overcome the remaining barriers that hinder the adoption of EE technologies in the Brazilian building segment. Therefore, a total of 45 measures were identified in 46 articles. It is worth mentioning that such measures were proposed to the Brazilian scenario following the same method used to propose measures for the critical ones. These new suggestions can be considered in a second implementation phase, following the initial phase focused on the critical barriers.

The proposition of suggestions to overcome the remaining barriers plays a crucial role in addressing the challenges faced by the Brazilian building segment regarding the adoption of EE technologies. By targeting all barriers that may hinder progress at different stages of the adoption process, these measures offer a comprehensive approach to dealing with the complexities associated with EE technology adoption. This holistic strategy ensures that not only the critical barriers are addressed, but also the less prominent ones, thereby facilitating a more effective transition to energy-efficient practices across the entire segment.

Therefore, by proposing measures to overcome barriers to the adoption of EE technologies in the building segment, this research significantly contributes to enhancing the efficiency and sustainability of buildings. Additionally, it stimulates economic growth and enhances the country’s competitiveness regarding energy issues in the building segment. Thus, the suggested measures not only address immediate challenges but also pave the way for long-term benefits and progress in the Brazilian building segment.

Despite the richness of this research, some suggestions can be considered for future studies. Firstly, it is recommended that the identified measures be studied more deeply, as some of them can be useful for overcoming multiple barriers.

Another suggestion is the development of a survey to analyse the degree of difficulty in implementating the proposed measures in the Brazilian scenario, based on specialists' perceptions. This suggestion is important to categorise the proposed measures for each barrier according to their implementation difficulty, from easier to more difficult.

Lastly, it is noteworthy that the academic results of the research are presented in Appendix D.

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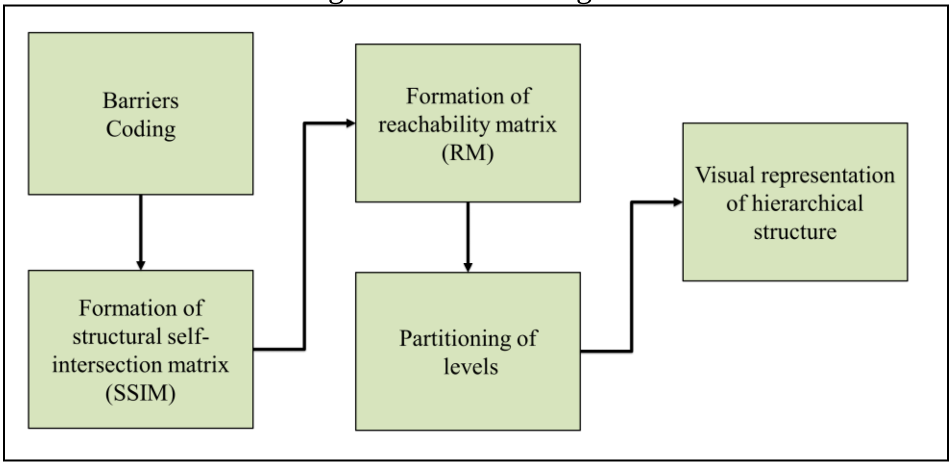
APPENDIX A - INTERPRETATIVE STRUCTURAL MODELLING (ISM)

Interpretative structural modelling (ISM) is an interactive learning process that structures elements, directly and indirectly, related, into a comprehensive systematic model. The resulting model depicts the structure of a complex problem in graph form (ATTRI; DEV; SHARMA, 2013).

The ISM technique can be represented by the following block diagram presented in Figure A.1.

Figure A.1 – ISM diagram.



Source: The author.

ISM starts with the identification and coding of variables. Then, a contextually relevant subordinate relation is chosen based on a pairwise comparison of the variables and represented in a matrix called structural self-interaction matrix (SSIM). In the next step, the SSIM is converted into a matrix called the reachability matrix (RM). The RM is analysed and the transitivity embedding is completed resulting in a final version of the reachability matrix. The next step is the partitioning of the reachability matrix into different levels, suggesting a hierarchy. The last step in the ISM is the visual representation of the hierarchical structure derived from the final version of the reachability matrix.

To illustrate this technique it will be applied in richness of detail to study the interrelationships between barriers that hinder government support in the process of adoption of EE technologies.

Thus, firstly, the barriers identified as those that hinder government support were coded, as presented in Table A.1.

Table A.1 – Barriers that hinder the government support.

Code	Barrier
BG_01	Lack of efficient policy instruments
BG_02	Building energy labelling procedures are complex and inefficient
BG_02	Lack of knowledge on energy efficiency by regulators and legislators
BG_04	Lack of efficient dissemination of codes/regulations
BG_05	Lack of financial implications of energy efficiency projects in the energy policies

Source: The author.

The codes are to make easier the identification of the barriers in figures and diagrams.

Based on the literature, it was possible to establish a contextual relationship between the barriers as can be seen in Table A.2.

Table A.2 – Developed SSIM.

Barriers	BG_01	BG_02	BG_03	BG_04	BG_05
BG_01	-	V	A	O	O
BG_02	-	-	A	O	O
BG_03	-	-	-	V	V
BG_04	-	-	-	-	O
BG_05	-	-	-	-	-

Source: The author.

Four symbols are used to denote the relationship between two barriers (barrier *i* and barrier *j*);

V = Barrier *i* implies in Barrier *j*;

A = Barrier *j* implies in Barrier *i*;

X= Barrier *i* and *j* imply in each other;

O = Barriers *i* and *j* are unrelated.

After the development of the SSIM, the initial reachability matrix was built by transforming the SSIM into a binary matrix, according to the rule in Table A.3.

Table A.3 – Rule adopted for substitution.

SSIM	Reachability Matrix	
	$(i \rightarrow j)$	$(i \leftarrow j)$
V	1	0
A	0	1
O	1	1
X	0	0

Source: The author.

The reachability matrix was prepared considering these rules. For example, Table A.2 shows that the relationship between the BG_01 and BG_02 is V, that is, the existence of Barrier BG_01 implies the emergence of Barrier BG_02. Therefore, according to Table A.3, the relationship between them ($i \rightarrow j$) is 1, and the inverse direction ($i \leftarrow j$) is 0.

Thus, based on the previous rules, the conversion of the SSIM into the initial reachability matrix was achieved, as presented in Table A.4.

Table A.4 – Reachability matrix.

Barriers	BG_01	BG_02	BG_03	BG_04	BG_05
BG_01	1	1	0	0	0
BG_02	0	1	0	0	0
BG_03	1	1	1	1	1
BG_04	0	0	0	1	0
BG_05	0	0	0	0	1

Source: The author.

The next step is to apply the property of transitivity in the initial reachability matrix. According to the transitivity rule, if barrier *i* implies a barrier *j*; and if barrier *j* implies a third barrier *k*, then even indirectly barrier *i* implies barrier *k* (SOTI; SHANKAR; KAUSHAL, 2010). Thus, the transitivity property is incorporated into the reachability matrix by inserting 1* entries where there is an indirect relationship between two barriers.

In this case, however, analysing the initial reachability matrix, no transitivity was incorporated. Thus, after this analysis, the final reachability matrix was obtained, as shown in Table A.5.

Table A.5 – Final reachability matrix.

Barriers	BG_01	BG_02	BG_03	BG_04	BG_05	Driving Power	Ranking
BG_01	1	1	0	0	0	2	II
BG_02	0	1	0	0	0	1	II
BG_03	1	1	1	1	1	5	I
BG_04	0	0	0	1	0	1	III
BG_05	0	0	0	0	1	1	III
Dependence Power	2	3	1	2	2		
Ranking	II	I	III	II	II		

Source: The author.

In Table A.5, it is possible to see the driving and dependence power of each barrier. According to Attri, Sev, and Sharma (2013), the drive power of a variable is derived by summing up the number of relationships in the rows, and its dependence power is obtained by summing up the number of relationships in the columns. From that, it was possible to rank the barriers based on their driving and dependence on power.

Thus, once the final reachability matrix was achieved, the time has come to partition it into levels. For that, it is necessary to figure out three sets, i.e., the reachability, antecedent, and intersection sets (WARFIELD, 1974).

For a given barrier, the reachability set is composed of a barrier itself, and the others that are directly or indirectly implied by it, while the antecedent set consists of the barriers themselves and the other barriers that directly or indirectly imply it (IQBAL *et al.*, 2021). The intersection set is a common barrier between the accessibility set and the intersection set (TAN *et al.*, 2019). Table A.6 presents the partition of Table A.5 into three levels.

Table A.6 - Level Partitions.

Interaction	Barriers	Reachability Set	Antecedent Set	Intersection Set	Level
Interaction I	BG_01	1,2	1,3	1	
	BG_02	2	1,2,3	2	I
	BG_03	1,2,3,4,5	3	3	
	BG_04	4	3,4	4	I
	BG_05	5	3,5	5	I
Interaction	**Barriers**	**Reachability Set**	**Antecedent Set**	**Intersection Set**	**Level**
Interaction II	BG_01	1	1,3	1	II
	BG_03	1,3	3	3	
Interaction	**Barriers**	**Reachability Set**	**Antecedent Set**	**Intersection Set**	**Level**
Interaction III	BG_03	3	3	3	III

Source: The author.

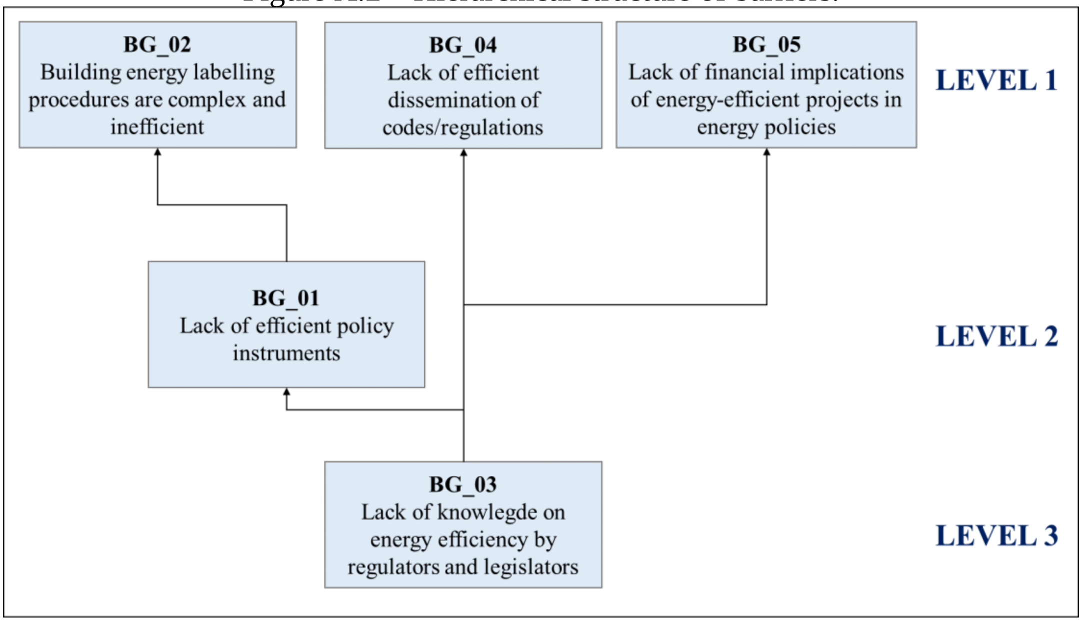
For a better understanding of how the levels were partitioned, Interaction I can be taken as an example. It is possible to see that the five barriers that hinder government support are presented in Interaction I, with their respective reachability and antecedent sets.

According to Farooq *et al.* (2020), to find the topmost level of the interaction matrix model, it is necessary to identify the barriers with the same intersection and reachability sets. Therefore, it is possible to see that the barriers BG_02, BG_04, and BG_05 are those that formed the highest level of the hierarchy.

With the barriers of the first level identified, the next step was to remove them from the reachability set. And so, the process was repeated in the same way until all possible level partitions were formed (TAN *et al*., 2019).

Based on the levels partitioned in Table A.7, it was possible to build the hierarchical model presented in Figure A.2.

Figure A.2 – Hierarchical structure of barriers.



Source: The author.

APPENDIX B- REFERENCES OF MEASURES IDENTIFIED IN THE LITERATURE FOR OVERCOME THE CRITICAL BARRIERS.

(to be continued)

Barrier	Measure Codes	References
BG_03 Lack of knowledge on energy efficiency by regulators and legislators	SG_3.1	GBONEY, 2008; GUPTA; ANAND; GUPTA, 2017; PAN; PAN, 2019.
	SG_3.2	RIAZI; HOSSEYNI, 2011; BERTONE *et al.*, 2018.
	SG_3.3	GUPTA; ANAND; GUPTA, 2017.
BM_05 Lack of financial incentives	SM_5.1	BROWN; SOUTHWORTH, 2008; SHIPKOVS *et al.*, 2011; SOPIAN; ALI; ASSIM, 2011; GOLUBCHIKOV; DEDA, 2012; DU *et al.*, 2014; LU *et al.*, 2014; HOU *et al.*, 2016; GUPTA; ANAND; GUPTA, 2017; YEATTS *et al.*, 2017; HROVATIN; ZORIĆ, 2018; ZHANG *et al.*, 2018; FASNA; GUNATILAKE, 2019; LING-CHIN *et al.*, 2019; YANG *et al.*, 2019; XU *et al.*, 2019; LIU *et al.*, 2020; SILVERO; RODRIGUES; MONTELPARE, 2020; STREIMIKIENE *et al.*, 2020; STREIMIKIENE; BALEZENTIS, 2020; XU; ZHOU, 2020; BERTOLDI *et al.*, 2021; KAZEMI; KAZEMI, 2022; MUSTAFFA; KUDUS, 2022.
	SM_5.2	ADEYEYE; OSMANI; BROWN, 2007; BROWN; SOUTHWORTH, 2008; SHIPKOVS *et al.*, 2011; SOPIAN; ALI; ASSIM, 2011 ; GOLUBCHIKOV; DEDA, 2012; LU *et al.*, 2014; HUSSAINI; ABDUL MAJID, 2015; VAN DOREN *et al.*, 2016; ZHANG *et al.*, 2018; FASNA; GUNATILAKE, 2019; XU *et al.*, 2019; FIGUEIREDO *et al.*, 2020; LIU *et al.*, 2020; STREIMIKIENE; BALEZENTIS, 2020; XU; ZHOU, 2020; BERTOLDI *et al.*, 2021; KAZEMI; KAZEMI, 2022; MUSTAFFA; KUDUS, 2022.
	SM_5.3	BROWN; SOUTHWORTH, 2008; SHIPKOVS *et al.*, 2011; SOPIAN; ALI; ASSIM, 2011; GOLUBCHIKOV; DEDA, 2012; LU *et al.*, 2014; ZHANG *et al.*, 2018; FASNA; GUNATILAKE, 2019; LIU *et al.*, 2020; STREIMIKIENE *et al.*, 2020; STREIMIKIENE; BALEZENTIS, 2020; XU; ZHOU, 2020; BERTOLDI *et al.*, 2021; KAZEMI; KAZEMI, 2022; MUSTAFFA; KUDUS, 2022.

Source: The author.

APPENDIX B- REFERENCES OF MEASURES IDENTIFIED IN THE LITERATURE FOR OVERCOME THE CRITICAL BARRIERS.

(continuation)

Barrier	Measure Codes	References
BI_02 Lack of demonstration projects	SI_2.1	YIK; LEE, 2002; CHEN *et al.*, 2011; SOPIAN; ALI; ASSIM, 2011; GOLUBCHIKOV; DEDA, 2012; VAN DOREN *et al.*, 2016; WANG *et al.*, 2016; YEATTS *et al.*, 2017; BERTONE *et al.*, 2018; ZHANG *et al.*, 2018; FASNA; GUNATILAKE, 2019; LIU *et al.*, 2019; FIGUEIREDO *et al.*, 2020; LIU *et al.*, 2020; SILVERO; RODRIGUES; MONTELPARE, 2020.
	SI_2.2	SHIPKOVS *et al.*, 2011; HUSSAINI; ABDUL MAJID, 2015; WANG *et al.*, 2016. YEATTS *et al.*, 2017; HROVATIN; ZORIĆ, 2018.
	SI_2.3	XU *et al.*, 2019; XU; ZHOU, 2020.
BPE_01 Lack of technical competence	SPE_1.1	YIK; LEE, 2002; RIAZI; HOSSEYNI, 2011; SOPIAN; ALI; ASSIM, 2011; HUSSAINI; ABDUL MAJID, 2015; YANG, 2015; GUPTA; ANAND; GUPTA, 2017; YEATTS *et al.*, 2017; BERTONE *et al.*, 2018; TOPRISKA *et al.*, 2018; FASNA; GUNATILAKE, 2019; LING-CHIN *et al.*, 2019; LIU *et al.*, 2019; PAN; PAN, 2019; XU *et al.*, 2019; FIGUEIREDO *et al.*, 2020; KAZEMI; KAZEMI, 2022; LIU *et al.*, 2020; SILVERO; RODRIGUES; MONTELPARE, 2020; MAKVANDIA; SAFIUDDIN, 2021; ZHANG *et al* , 2021; XU et al. 2022.
	SPE_1.2	YANG, 2015; WANG *et al.*, 2016; YEATTS *et al.*, 2017; PAN; PAN, 2019; LIU *et al.*, 2020.
	SPE_1.3	ALAM *et al.*, 2019; FASNA; GUNATILAKE, 2019; TOPRISKA *et al.*, 2018; PAN; PAN, 2019; FIGUEIREDO *et al.*, 2020.
	SPE_1.4	CHEN *et al.*, 2011; SOPIAN; ALI; ASSIM, 2011; YEATTS *et al.*, 2017; MAKVANDIA; SAFIUDDIN, 2021.

Source: The author.

APPENDIX B- REFERENCES OF MEASURES IDENTIFIED IN THE LITERATURE FOR OVERCOME THE CRITICAL BARRIERS.

(conclusion)

Barrier	Measure Codes	References
BPE_04 Lack of adequate technologies	SPE_4.1	SOPIAN; ALI; ASSIM, 2011; GOLUBCHIKOV; DEDA, 2012; HUSSAINI; ABDUL MAJID, 2015; ZHANG *et al.*, 2018; LING-CHIN *et al.*, 2019; XU *et al.*, 2019; LIU *et al.*, 2020; SOVACOOL; DEL RIO, 2020.
	SPE_4.2	HUSSAINI; ABDUL MAJID, 2015; PAN; PAN, 2019; XU; ZHOU, 2020.
BMT_03 Lack of knowledge of market potential	SMT_3.1	SOPIAN; ALI; ASSIM, 2011; BERTONE *et al.*, 2018 LING-CHIN *et al.*, 2019.
	SMT_3.2	SOPIAN; ALI; ASSIM, 2011; XU *et al.*, 2022;

Source: The author.

APPENDIX C- REFERENCES OF MEASURES IDENTIFIED IN THE LITERATURE FOR OVERCOME THE REMAINING BARRIERS.

(to be continued)

Barrier	Measure Codes	References
BG_01 Lack of efficient policy instruments	SG_1.1	HUANG *et al.*, 2015; HOU *et al.*, 2016; GUPTA; ANAND; GUPTA, 2017; YEATTS *et al.*, 2017; ALAM *et al.*, 2019; PAN; PAN, 2019; AZAR *et al.*, 2020; FIGUEIREDO *et al.*, 2020; LIU *et al.*, 2020; XU; ZHOU, 2020; ZHANG *et al.*, 2021; KAZEMI; KAZEMI, 2022.
	SG_1.2	RIAZI; HOSSEYNI, 2011; HOU *et al.*, 2016; GUPTA; ANAND; GUPTA, 2017.
	SG_1.3	GBONEY, 2011.
BG_02 Building energy labelling procedures are complex and inefficient	SG_2.1	ADEYEYE; OSMANI; BROWN, 2007; RIAZI; HOSSEYNI, 2011; WANG *et al.*, 2016; YEATSS *et al.*, 2017; LIU *et al.*, 2020; SILVERO; RODRIGUES; MONTELPARE, 2020; MUSTAFFA; KUDUS, 2022.
	SG_2.2	HUANG *et al.*, 2015; MAKVANDIA; SAFIUDDIN, 2021.
BG_04 Lack of efficient dissemination of codes/regulations	SG_4.1	HUANG *et al.*, 2015; CAPUTO; PASETTI, 2015; FIGUEIREDO *et al.*, 2020.
	SG_4.2	RIAZI; HOSSEYNI, 2011
BG_05 Lack of financial implications of energy-efficient projects in the energy policies	SG_5.1	FASNA; GUNATILAKE, 2019; PAN; PAN, 2019.
	SG_5.2	ZHANG *et al.*, 2021.
BM_01 High costs of investments	SM_1.1	SOPIAN; ALI; ASSIM, 2011; FIGUEIREDO *et al.*, 2020; BERTOLDI *et al.*, 2021.
	SM_1.2	YEATTS *et al.*, 2017; BERTOLDI *et al.*, 2021.
BM_02 Lack of capital	SM_2.1	GOLUBCHIKOV; DEDA, 2012; MAKVANDIA; SAFIUDDIN, 2021; STREIMIKIENE *et al.*, 2020.
	SM_2.2	GOLUBCHIKOV; DEDA, 2012; FASNA; GUNATILAKE, 2019
BM_03 Long payback periods	SM_3.1	BERTONE *et al.*, 2018
	SM_3.2	HOU *et al.*, 2016

Source: The author.

APPENDIX C- REFERENCES OF MEASURES IDENTIFIED IN THE LITERATURE FOR OVERCOME THE REMAINING BARRIERS.

(continuation)

Barrier	Measure Codes	References
BM_04 Financial risks of energy-efficient investments	SM_4.1	BERTONE *et al.*, 2018; PAN; PAN, 2019; STREIMIKIENE *et al.*, 2020.
	SM_4.2	GUPTA; ANAND; GUPTA, 2017.
BM_06 Lack of access to bank finance	SM_6.1	YIK; LEE, 2002; SOPIAN; ALI; ASSIM, 2011; LU *et al.*, 2014; ALAM *et al.*, 2019; FASNA; GUNATILAKE, 2019; LIU *et al.*, 2020; SILVERO; RODRIGUES; MONTELPARE, 2020; RANA *et al.*, 2021; KAZEMI; KAZEMI, 2022; MUSTAFFA; KUDUS, 2022.
	SM_6.2	LU *et al.*, 2014; YEATTS *et al.*, 2017; FASNA; GUNATILAKE, 2019.
	SM_6.3	SILVERO; RODRIGUES; MONTELPARE, 2020.
BM_07 Distortion in electric energy price policies	SM_7.1	GOLUBCHIKOV; DEDA, 2012; KAZEMI; KAZEMI, 2022.
	SM_7.2	KAZEMI; KAZEMI, 2022.
BM_08 Lack of awareness about the benefits of EE technologies	SM_8.1	CHEN *et al.*, 2011; JIANG *et al.*, 2013; HUSSAINI; ABDUL MAJID, 2015; FASNA; GUNATILAKE, 2019; LIU *et al.*, 2020; XU; ZHOU, 2020; MAKVANDIA; SAFIUDDIN, 2021; MUSTAFFA; KUDUS, 2022; YEATTS *et al.*, 2017; XU *et al.*, 2022; ZHANG *et al.*, 2021.
	SM_8.2	RIAZI; HOSSEYNI, 2011; SOPIAN; ALI; ASSIM, 2011; GOLUBCHIKOV; DEDA, 2012; YEATTS *et al.*, 2017; BERTONE *et al.*, 2018; FASNA; GUNATILAKE, 2019; FIGUEIREDO *et al.*, 2020; ZHANG *et al.*, 2021; KAZEMI; KAZEMI, 2022.
	SM_8.3	YEATSS *et al.*, 2017; LIU *et al.*, 2020.
BM_09 Lack of motivation of end-users	SM_9.1	YEATTS *et al.*, 2017; SILVERO; RODRIGUES, MOTELPARE, 2020; XU *et al.*, 2022.
	SM_9.1	FASNA, GUNATILAKE, 2019.

Source: The author.

APPENDIX C- REFERENCES OF MEASURES IDENTIFIED IN THE LITERATURE FOR OVERCOME THE REMAINING BARRIERS.

(continuation)

Barrier	Measure Codes	References
BM_10 Resistance to change of end-users	SM_10.1	JIANG *et al.*, 2013; HROVATIN; ZORIĆ, 2018; YEATTS *et al.*, 2017; FASNA; GUNATILAKE, 2019; PAN; PAN, 2019; XU *et al.*, 2019; XU; ZHOU, 2020; SILVERO; RODRIGUES; MONTELPARE, 2020; ZHANG *et al.*, 2021.
	SM_10.2	SANTANGELO; TONDELLI, 2017; YEATTS *et al.*, 2017.
BM_11 Lack of confidence in the benefits of EE technologies	SM_11.1	YEATTS *et al.*, 2017; FASNA; GUNATILAKE, 2019; PAN; PAN, 2019; LIU *et al.*, 2020; STREIMIKIENE *et al.*, 2020.
	SM_11.2	SOPIAN; ALI; ASSIM, 2011.
BI_01 Lack of information on EE technologies	SI_1.1	SOPIAN; ALI; ASSIM, 2011; GOLUBCHIKOV; DEDA, 2012; WANG *et al.*, 2016; KOSONEN; KIM, 2017; YEATSS *et al.*, 2017; HROVATIN; ZORIĆ, 2018; FASNA; GUNATILAKE, 2019; LIU *et al.*, 2020; STREIMIKIENE; BALEZENTIS, 2020; XU; ZHOU, 2020; KAZEMI; KAZEMI, 2022; XU *et al.*, 2022.
	SI_1.2	HUSSAINI; ABDUL; MAJID, 2015; KOSONEN; KIM, 2017; PAN; PAN, 2019; LIU *et al.*, 2020.
	SI_1.3	GBONEY, 2011; HUSSAINI; ABDUL MAJID, 2015; XU; ZHOU, 2020.
BPE_02 Lack of professional involvement in energy-efficient projects	SEP_2.1	YEATTS *et al.*, 2017; ALAM *et al.*, 2019; FASNA; GUNATILAKE, 2019; TOPRISKA *et al.*, 2018; FIGUEIREDO *et al.*, 2020.
	SEP_2.2	HUSSAINI; ABDUL MAJID, 2015; FASNA; GUNATILAKE, 2019; XU *et al.*, 2019.
	SEP_2.3	HUSSAINI; ABDUL MAJID, 2015; PAN; PAN, 2019.
BPE_03 Lack of trust on the part of building professionals	SPE_3.1	YEATSS *et al.*, 2017; FASNA; GUNATILAKE, 2019; XU *et al.*, 2022.
	SPE_3.2	FASNA; GUNATILAKE, 2019; LIU *et al.*, 2020.
	SMT_3.2	SOPIAN; ALI; ASSIM, 2011; XU *et al.*, 2022;

Source: The author.

APPENDIX C- REFERENCES OF MEASURES IDENTIFIED IN THE LITERATURE FOR OVERCOME THE REMAINING BARRIERS.

(conclusion)

Barrier	Measure Codes	References
BMT_01 Lack of investors	SMT_1.1	CHEN *et al.*, 2011; YEATTS, *et al.*, 2017.
	SMT_1.2	VAN DOREN *et al.*, 2016; FASNA; GUNATILAKE, 2019.
BMT_02 Lack of market demand	SMT_2.1	LU *et al.*, 2014; DENG *et al.*, 2018; FASNA; GUNATILAKE, 2019; LIU *et al.*, 2019; PAN; PAN, 2019; MUSTAFFA; KUDUS, 2022.
	SMT_2.2	SOPIAN; ALI; ASSIM, 2011; DU *et al.*, 2014; BERTONE *et al.*, 2018; FASNA; GUNATILAKE, 2019; PAN; PAN, 2019.
BMT_03 Lack of knowledge of market potential	SMT_3.1	SOPIAN; ALI; ASSIM, 2011; BERTONE *et al.*, 2018; LING-CHIN *et al.*, 2019.

Source: The author.

APPENDIX D - ACADEMIC RESULTS OF THE RESEARCH

The research received funding support by the São Paulo Research Foundation (FAPESP) – process number: 2021/01423-9. Furthermore, the research received the award of the best doctoral research in the field of Mechanics at the VI Workshop of the Graduate Program in Engineering organised by the Faculty of Engineering and Sciences of Guaratinguetá.

The academic results achieved in the research development were published in articles in internationally indexed journals:

- **CRISTINO, T.M.;** NETO, A.F.; COSTA, A.F.B. *Energy efficiency in buildings: Analysis of scientific literature and identification of data analysis techniques from a bibliometric study*. ***Scientometrics***, v. 114, p.1275–1326, 2017. Available in: https://doi.org/10.1007/s11192-017-2615-4.
- **CRISTINO, T.M.;** LOTUFO, F.; DELINCHANT, B.; WURTZ, F.; NETO, A.F. *A comprehensive review of obstacles and drivers to building energy-saving technologies and their association with research themes, types of buildings, and geographic regions.* ***Renewable Sustainable Energy Reviews,*** v. 135, 110191, 2021. Available in: https://doi.org/10.1016/j.rser.2020.110191.
- **CRISTINO, T.M.;** FARIA NETO, A.; WURTZ, F.; DELINCHANT, B. *Barriers to the adoption of energy-efficient technologies in the building sector: A survey of Brazil.* ***Energy and Buildings***, v. 252, 111452, 2021. Available in: https://doi.org/10.1016/j.enbuild.2021.111452.
- **CRISTINO, T.M.;** FARIA NETO, A.; WURTZ, F.; DELINCHANT, B. *The evolution of knowledge and trends within the Building Energy Efficiency field of knowledge.* ***Energies***, v. 15, n. 3, 691, 2022. Available in: https://doi.org/10.3390/en15030691.

Furthermore, two more articles were published in partnership with the research group coordinated by Prof. Dr. Antonio Faria Neto:

- DA SILVA, M.B.; **CRISTINO, T.M.;** NETO, A.F.; LOTUFO, F.A. *Barriers to the application of energy conservation measures in the industrial sector: A literature review.* **Sodebrás,** v.19, n. 217, 2024. https://doi.org/10.29367/issn.1809-3957.2024.01.217.34.

- COSTA, J.C.L.; **CRISTINO, T.M.;** CASSULA, A.M.; NETO, A.F.; LOTUFO, F.A. *Energy optimization in conditioning: integration of air conditioners and ceiling fans – A literature review.* **Sodebrás,** v.19, n. 218, 2024. https://doi.org/10.29367/issn.1809-3957.2024.02.218.27.

The study was partially presented at three international congresses related to the research area:

- CRISTINO, T.M.; FARIA NETO, A.; OLIVEIRA, O.J. *Barriers that hinder the adoption of building energy-efficient technologies in Brazil.* ***7th Edition of Global Energy Meet (GEM-2023)***, Boston, United States.
- CRISTINO, T.M. FARIA NETO, A.; OLIVEIRA, O.J. *Obstacles to the Adoption of Energy-Saving Measures in the Building Sector: A Survey in Brazil.* ***International Meet on Renewable and Sustainable Energy (RENEWABLEMEET2023)***, Rome, Italy.
- CRISTINO, T.M. OLIVEIRA, O.J.; FARIA NETO, A. *Barriers to the Adoption of Energy-Efficient Technologies in the Brazilian Building Sector.* ***5th International Conference on Renewable Energy, Resources and Sustainable Technologies (ENERGYTECH-2023),*** Paris, France.

Finally, it is important to highlight that more than three articles based on the results of this research are being prepared for submission to international journals (Qualis Capes A1) relevant to the studied research area.