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Understanding Divergent Views on Nearly Zero-Energy Buildings between Developers and Procurers in Romania

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Abstract This study investigates the awareness, perceptions, and preparedness of Romanian construction developers and public procurement specialists in relation to nearly Zero-Energy Buildings (nZEBs), focusing on factors that influence their adoption. Employing a mixed-methods approach, the research analyzes 193 validated questionnaire responses and insights from interviews with four industry experts. The findings reveal a significant disparity in familiarity with nZEB, with developers exhibiting greater awareness than procurers. Compliance with regulations emerges as the primary driver for nZEB adoption, while high upfront costs and a scarcity of qualified workforce are major barriers. Additionally, the complexity and fragmentation of Romanian legislation on nZEB standards creates ambiguities and further hinders effective implementation. Despite these challenges, developers express moderate optimism about Romanian construction companies' adaptability to future nZEB demands, whereas procurers remain less confident. The study underscores the critical role of proactive policy interventions, clear public procurement criteria, and collaborative strategies in aligning government-funded projects with energy efficiency goals. By addressing systemic barriers and fostering innovation, this research provides policymakers and stakeholders with actionable insights to facilitate a smooth transition to sustainable building practices in Romania.

Keywords: • sustainable construction • energy efficiency • stakeholder awareness • barriers • strategies

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1 Introduction

Construction, particularly the construction of buildings, plays a pivotal role in addressing climate change (IFC, 2023; IPCC, 2022; UN, 2017). Buildings have a considerable impact on the environment, both through the use of resources during the construction phase and the use of energy during their operational life, which often spans decades (Becqué et al., 2016; Westerholm, 2020). The building sector is a significant contributor to global energy consumption and greenhouse gas emissions, accounting for approximately 36% of global final energy use and 39% of energy-related CO_2 emissions (IEA, 2019, 2023). In the context of the growing global demand for sustainable development, improving the energy efficiency of buildings, reducing greenhouse gas emissions, and ensuring a sustainable future has become increasingly important (Farrow, Grolleau, & Mzoughi, 2018; Amecke et al., 2013; OECD, 2022; Thomas, Gokarakonda, & Moore, 2018). The European Union (EU) has identified energy efficiency as one of its strategic priorities to address the energy trilemma (security of supply, competitive prices, and sustainability) and reduce primary energy consumption. Promoting public awareness and engaging all stakeholders is essential to mitigate the negative impacts of inefficient energy use, such as climate change, resource depletion, and pollution (Sichali & Banda, 2017; Nduka, Ede, Oyeyemi, & Olofinnade, 2019; Abidin, 2010).

Energy efficiency in buildings encompasses more than just cost-effective energy consumption and waste minimization; it is a comprehensive approach that integrates three critical components: employing high-performance materials with enhanced U-values, optimizing the cumulative energy performance of the unit resulting from the combined performance of materials and equipment, and incorporating renewable energy sources. These elements work synergistically to optimize energy efficiency and contribute to a sustainable built environment. Achieving this necessitates a paradigm shift in the construction sector, embracing the holistic integration of optimal design, orientation, high-performance materials, efficient systems, smart controls, passive strategies, regular maintenance, and occupant behavior to radically reduce energy consumption while ensuring comfort, functionality, and sustainability (Amoruso, Donevska, & Skomedal, 2018; EPA, 2019; Amecke et al., 2013; Kibert, 2016; Xu et al., 2016; Yudelson, 2007).

Furthermore, the transition towards energy-efficient buildings is not only an opportunity but an imperative. The EU's Green Deal strategy, through the Fit for 55 package and RePowerEU plan, launched in May 2022, has set binding targets to achieve an EU climate-neutral economy by 2050, reduce fossil fuel use by two-thirds by the end of 2022, and eliminate it entirely by 2030 (EC, 2019a; IEA, 2022b). Buildings are at the heart of these plans, which underscore the need for immediate energy savings through voluntary choices and the acceleration of

structural mid-to-long-term energy efficiency measures (EC, 2019a; IEA, 2022b; UNEP, 2020).

The EU's legislative framework, such as the Energy Performance of Buildings Directive (EPBD), the Energy Efficiency Directive (EED), and the Renewable Energy Directive (RED), provides a solid foundation for enhancing energy performance in buildings. The concept of nZEB serves as a transformative approach used by legislators to promote energy efficiency across the community, ultimately aiming to achieve zero or positive energy-efficient buildings in the EU (EP & CEU, 2010, 2018a, 2018b). Under the EPBD, the nZEB standard became a mandatory legal requirement in December 2018 for public buildings and was extended to all others in December 2020 (EP & CEU, 2010). Furthermore, the EED mandates Member States (MS) to renovate their public building stock to meet the nZEB standard, targeting a renovation rate of 3% annually (EP & CEU, 2018b). Consequently, energy efficiency in buildings has evolved from a mere vision to a binding legislative obligation.

However, despite the progress made through sectoral legislation, the availability of technologically advanced concepts and techniques, and various financial support mechanisms currently in place, the widespread adoption of nZEBs faces numerous barriers that impede the transition to more energy-efficient buildings. These barriers can be broadly categorized into six general categories: strategic and legislative frameworks, institutional, market, and financial constraints, knowledge, awareness, and capacity limitations, industry structure and procurement challenges, digitalization barriers, and regional, local, and cultural barriers (BPIE, 2020; MDLPA, 2020; WB, 2018, 2019a, 2019b; Attia et al., 2022; Otte, Stelmach, Chandan, & Delgado, 2022; Hori, Nogata, Hayabuchi, & Kondo, 2022). As a result, the rate of renovations meeting nZEB standards remains disappointingly low (EC, 2019b), underscoring the urgency of addressing these barriers to accelerate the adoption of nZEBs and achieve the desired energy efficiency goals in the building sector. Addressing these multifaceted barriers requires a comprehensive and integrated approach that focuses on stakeholders' needs at the local level, emphasizing the development of well-designed policies and context-specific solutions (World Bank, 2014; BPIE, 2020; MDLPA, 2020). The importance of raising awareness among key stakeholders, particularly construction developers and procurers, has been highlighted as a vital factor in facilitating nZEB implementation (Bertoldi, Economidou, Palermo, Boza-Kiss, & Todeschi, 2021; Czarnezki, 2019; Economidou, Della Valle, Melica, & Bertoldi, 2024; Alam et al., 2019; BPIE, 2016; Attia et al., 2022; Nduka et al., 2019; Herrando, Gómez, & Fueyo, 2022; Amoruso et al., 2018, INZEB, 2017). This is largely because different stakeholders have different roles and responsibilities during different construction processes (Gao, Koch, & Wu, 2019; Sesana et al., 2021; Demirkesen & Ozorhon, 2017). Understanding and addressing the market failures and

bottlenecks these stakeholders face, especially in the context of public building renovations or new buildings, is essential for accelerating the adoption of nZEBs and energy-efficient building practices (Bertoldi et al., 2021; Czarnezki, 2019; Economidou et al., 2024).

This research aims to explore the barriers and potential solutions for promoting energy efficiency in buildings, with a particular emphasis on Romania as a case study within the EU context. By examining the Romanian context, this study seeks to provide valuable insights into the specific needs and constraints of two critical stakeholder groups: construction developers and procurers. The importance of this study lies in its potential to bridge the gap in the literature by providing a comprehensive analysis of the barriers to nZEB adoption in Romania, focusing on the perspectives of construction developers and procurers. While previous studies have investigated the barriers to energy efficiency in buildings at a broader level (World Bank, 2014; BPIE, 2011, 2016; DECC, 2014; Marquez, McGregor, & Syme, 2012, IPCC, 2007; Otte et al., 2022; Lee & Hess, 2021; Bhattacharyya, Dutta, Samanta, Mukherjee, & Pan, 2021), there is a lack of research specifically targeting the Romanian context and the roles of construction developers and procurers in the adoption of nZEBs.

By addressing the following research questions, the study seeks to shed light on the factors influencing the adoption of nZEB principles in the Romanian context and provide invaluable insights that may pave the way for transformative change in the construction sector:

What is the extent of knowledge and awareness of nZEBs among developers and procurement groups in Romania?

How do these stakeholders perceive the benefits, barriers, and supporters of nZEB construction?

To what degree are Romanian construction companies prepared to respond to the growing demand for nZEBs?

What strategies and interventions can be employed to promote the adoption of nZEBs in Romania, specifically targeting developers and procurement groups?

This research contributes to the scholarly discourse on the challenges and opportunities associated with adopting nZEB principles. While challenges concerning legislation, regulation, and strategic frameworks in the energy efficiency sector in Romania have been detailed by various critics (MDLPA, 2020; WB, 2018, 2019a, 2019b), our focus on Romania offers a more nuanced understanding that has been less explored in the literature. Drawing upon insights from Alam et al. (2019), which emphasized the significant influence stakeholders have on nZEB implementation, and Herrando et al. (2022), who explored energy efficiency planning challenges at the local level, our research offers a comprehensive exploration of the Romanian context. The findings of this study

have the potential to guide policymakers and industry stakeholders, building upon the recommendations by Attia et al. (2022) regarding challenges in Eastern Europe, and addressing concerns raised by critics on Romanian strategies (MDLPA, 2020; WB, 2018, 2019b, 2019a) in designing targeted strategies and interventions for promoting nZEB adoption, overcoming identified barriers, and aligning with the EU's energy efficiency objectives.

The paper is structured as follows: Section 2 offers a literature review, Section 3 delineates the methodology, Section 4 presents the results, Section 5 provides a discussion of the primary findings and their implications, and Section 6 concludes the paper by summarizing the key insights and emphasizing the importance of the research in the context of Romania's energy efficiency objectives.

2 Literature review

2.1 The imperative of addressing unsustainable practices in the construction industry and resulting market failures

The construction industry has a significant environmental impact, with buildings accounting for 36% of global energy-related CO_2 emissions in 2022 from both the operation of existing buildings and embodied emissions from construction materials and new buildings (IEA, 2023). This substantial impact is driven by various factors, including rapidly growing space cooling demand, rebound effects offsetting efficiency gains, lack of building envelope efficiency standards, and rising appliance usage (IEA, 2023; Davis & Gertler, 2015; Architecture 2030, 2022). Space and water heating account for nearly 50% of buildings' energy demand and around 4 $GtCO_2$ annually, making heating decarbonization a critical priority (IEA, 2023; BloombergNEF, 2022). Despite gradual improvements in energy intensity, global energy-related emissions from the building sector have increased by 25% from 2000 to 2017, mainly due to the expansion of the building floor area (UNEP, 2017). Although the COVID-19 pandemic temporarily reduced CO_2 emissions from buildings by 10% in 2020, both energy consumption and emissions rebounded to above 2019 values in 2021 (IEA, 2022a). The building sector's environmental impact extends beyond climate change, encompassing land use, materials consumption, and energy demand, exceeding safe planetary boundaries and undermining sustainable development goals (SDGs) (Architecture 2030, 2022). This multifaceted impact underscores the urgency of addressing unsustainable practices in the construction industry.

Market failures hinder sustainability alignment in the construction industry, externalizing costs onto society (Architecture 2030, 2022). These market failures include public goods, externalities, asymmetric information, monopolies and market power, inequity, and factor immobility (Bator, 1958; Pigou, 2013;

Samuelson, 1954; Lazar & Zai, 2004). While distinct, these market failures are interconnected and collectively contribute to the persistence of unsustainable practices in the construction industry. Public goods possess non-excludability and non-rivalrous consumption, making them unattractive for private investment and leading to under-provision due to free-riding behavior (Samuelson, 1954; Olson, 1971). Externalities arise when economic actions involuntarily spill over to affect uninvolved third parties, not being priced into market transactions (Pigou, 2013; Samuelson & Nordhaus, 2000). Uncoordinated markets fail to address externalities, leading to welfare losses (Nordhaus, 1994; Stern, 2007). Asymmetric information, where one party has more information than the other, leads to adverse selection and moral hazard (Akerlof, 1970; Rothschild & Stiglitz, 1976). Imperfect competition, including monopolies, leads to inefficiencies, reduced output, and higher prices (Samuelson & Nordhaus, 2000). Market mechanisms inherently lead to income and wealth inequalities, even in efficient scenarios (Samuelson & Nordhaus, 2000; Piketty, 2014). Lastly, immobility of labor and capital across sectors or regions leads to inefficient allocation of resources (Molloy, Smith, & Wozniak, 2011; Reinhart & Rogoff, 2009).

These market failures impede energy efficiency in buildings, with information asymmetries and behavioral anomalies, environmental externalities, public goods and free-rider problems, and equity considerations hindering investment and adoption of energy-efficient technologies (Altwies & Nemet, 2013; Gillingham et al., 2009; Allcott & Greenstone, 2012; Auffhammer, 2018; Levesque et al., 2021; McFarlane, Li, & Hollar, 2021; Ürge-Vorsatz et al., 2016). Regulations, incentives, and public investment are needed to correct these market failures and realign the building sector with ecological limits and human well-being (IEA, 2023; Lehne & Preston, 2018). Effectively addressing these market failures and promoting energy efficiency in buildings requires a comprehensive approach that combines regulations, incentives, and public investment is necessary (IEA, 2023; Lehne & Preston, 2018).

2.2 Effective concepts for addressing market failures related to energy in buildings

Sustainable construction and green buildings have emerged as effective concepts for addressing market failures related to energy in buildings. Sustainable construction is a holistic concept that refers to the efficient management and use of natural resources, the promotion of resource efficiency and ecological design, and the enhancement of quality of life, social, economic, and environmental conditions (Kibert, 1994; Ortiz, Castells, & Sonnemann, 2009). It involves a balance between existing technologies, innovative methods, and government policies, while considering environmental, socio-economic, and cultural issues (Vollenbroek, 2002; EC, 2007).

Green buildings, a subset of sustainable construction, aim to reduce negative impacts and create positive impacts on the climate and environment by considering energy use, water use, indoor environmental quality, material content, and site impact (WGBC, 2021; USGBC, 2021). They are healthy, resource-efficient facilities designed using ecologically-based principles (Kibert, 1994). Green buildings adopt a process-focused approach, improving processes throughout the building's life cycle (eco-design) and considering design, construction, operations, maintenance, renovations, and demolitions (Zhong & Wu, 2015; Yun, 2014; Landeta-Manzano, Arana-Landín, Ruiz de Arbulo, & Diaz de Basurto, 2016; Marcelino-Sádaba, González-Jaen, & Pérez-Ezcurdia, 2015).

Various energy-efficient building types have been developed to achieve sustainability and energy efficiency goals. High-performance buildings aim to minimize energy consumption through advanced technologies, innovative engineering solutions, and a holistic, whole-building approach (World Bank, 2014; WBDG, 2021). Nearly Zero Energy Buildings (nZEBs) have exceptionally high energy performance, with minimal energy needs substantially covered by on-site or nearby renewable sources (EP & CEU, 2010; D'Agostino, Zangheri, & Castellazzi, 2017). Net or Zero Energy Buildings (ZEBs) generate the same amount of energy they consume over a year, with different typologies based on site energy, source energy, cost, and emissions (Sartori, Napolitano, & Voss, 2012; Pless & Torcellini, 2010; DOE, 2015). Plus-Energy Buildings generate more energy than they consume, prioritizing passive design, efficient equipment, and large renewable energy systems (Voss, Musall, & Lichtmeß, 2011; Kolokotsa, Rovas, Kosmatopoulos, & Kalaitzakis, 2011). Low-Energy Buildings and Ultra-Low-Energy Buildings achieve significantly lower energy consumption than conventional buildings through passive and active strategies (Torcellini, Pless, Deru, & Crawley, 2006; Ochoa & Capeluto, 2008; Passive House Institute, 2023).

Among these energy-efficient building types, nZEBs have been chosen by many governments as a target concept for promoting energy efficiency in buildings. The EU has been at the forefront of developing and adopting the nZEB concept through its legislative frameworks, as discussed in the following section.

2.3 Barriers towards nZEB adoption

Despite the progress made through sectoral legislation, the availability of technologically advanced concepts and techniques, and various financial support mechanisms currently in place, the widespread adoption of nZEBs faces numerous barriers that impede the transition to more energy-efficient buildings. These barriers can be broadly categorized into six general categories: strategic and legislative frameworks, institutional, market, and financial constraints, knowledge,

awareness, and capacity limitations, industry structure and procurement challenges, digitalization barriers, and regional, local, and cultural barriers (BPIE, 2020; MDLPA, 2020; WB, 2018, 2019a, 2019b; Attia et al., 2022; Otte et al., 2022; Hori et al., 2022). As a result, the rate of renovations meeting nZEB standards remains disappointingly low (EC, 2019b), underscoring the urgency of addressing these barriers to accelerate the adoption of nZEBs and achieve the desired energy efficiency goals in the building sector.

Strategic and legislative framework barriers, such as the lack of agreed-upon scenarios, cost-implementation analyses, progress reporting, and evaluations, as well as insufficient coordination and contribution to other priorities, create a weak policy environment that hinders energy efficiency initiatives (BPIE, 2020; MDLPA, 2020; WB, 2018, 2019a, 2019b). These barriers form the foundation upon which other challenges are built, perpetuating market failures and impeding the widespread adoption of nZEBs.

Institutional, market, and financial barriers encompass a wide range of issues, including the absence of a national database for building stock (BPIE, 2020; Attia et al., 2022), split incentives, unattractive financial returns, high upfront costs (World Bank, 2014; BPIE, 2011, 2017; DECC, 2014), and insufficient funding and financing mechanisms (Ernst, 2015). These barriers exacerbate the challenges posed by market failures, limiting the ability of public authorities and building owners to invest in energy efficiency measures.

Knowledge, awareness, and capacity barriers, such as the lack of information, motivation, and skills among building professionals (Alam et al., 2019; BPIE, 2016, 2017) and insufficient knowledge and low awareness among stakeholders (BPIE, 2011; Marquez et al., 2012), impede the effective planning, implementation, and monitoring of energy efficiency projects. These barriers contribute to persistent information asymmetries and suboptimal decision-making, leading to missed opportunities for energy savings.

Industry structure and procurement barriers, rooted in the fragmented nature of the building industry (IPCC, 2007) and the conservative culture, principal-agent problems, and ineffective procurement methods prevalent in the sector (Dubois & Gadde, 2002, Leiringer, Green, & Raja, 2009; Lim, Zhang, & Oo, 2018), create additional obstacles to the adoption of innovative energy efficiency solutions. Traditional procurement practices that prioritize short-term costs over long-term benefits reinforce the misalignment of incentives and hinder the effective implementation of nZEBs.

Digitalization barriers, including privacy concerns, cybersecurity risks, lack of interoperability, and data availability and analysis challenges (Otte et al., 2022;

Lee & Hess, 2021; Bhattacharyya et al., 2021), impede the adoption of digital technologies crucial for optimizing building performance and reducing energy consumption. These barriers erode consumer trust and confidence, further hindering the widespread implementation of digital solutions in the building sector.

Regional, local, and cultural barriers, such as the large share of old, energy-inefficient buildings (BPIE, 2020), high initial costs of renewable energy systems (MDLPA, 2020), and cultural factors and resistance to change (Amoruso et al., 2018), add another layer of complexity to addressing market failures in nZEB adoption. These barriers underscore the need for tailored, context-specific solutions that address the unique challenges and opportunities present in each setting.

Finally, the assessment of EPBD implementation has revealed some progress in NZEB uptake (EC, 2020), but limitations in data availability, comparability, and uniformity across Member States persist. Addressing these multifaceted barriers requires a comprehensive and integrated approach that focuses on stakeholders' needs at the local level, emphasizing the development of well-designed policies and context-specific solutions (World Bank, 2014; BPIE, 2020; MDLPA, 2020).

2.4 Supportive policies to overcome barriers and promote nZEB adoption

Supportive policies play a crucial role in overcoming barriers and promoting the adoption of nZEBs. To effectively address the complex challenges associated with nZEB implementation, policymakers have employed a diverse array of instruments, which can be categorized into seven main groups: regulatory, financial, information and awareness, qualification, market-based, voluntary, and collaborative policies (Bertoldi et al., 2021; Economidou et al., 2024; Otte et al., 2022).

Regulatory policies, such as the Energy Performance of Buildings Directive (EPBD) and the Energy Efficiency Directive (EED), establish frameworks for implementing energy-saving measures and set minimum energy efficiency requirements (Economidou et al., 2024). Building codes and energy codes, which are essential components of regulatory policies, promote the adoption of energy-efficient technologies and practices (Kontokosta, Spiegel-Feld, & Papadopoulos, 2020a; Baniassadi, Heusinger, Gonzalez, Weber, & Samuelson, 2022). These policies create a solid foundation for driving energy efficiency in the built environment, but their effectiveness depends on factors such as comprehensive coverage, inspection and enforcement, and the use of independently tested and labeled building materials (Evans, Roshchanka, & Graham, 2017).

Financial and fiscal policies, including grants, subsidies, preferential loans, and tax incentives, provide crucial support for overcoming the financial barriers to nZEB adoption (Bertoldi et al., 2021; Economidou et al., 2024). These instruments incentivize investments in energy-efficient technologies and facilitate access to capital, which is particularly important for stakeholders with limited financial resources (Rosenow, Eyre, Bürger, & Rohde, 2013). However, the success of these policies relies on their ability to target specific stakeholder groups, address split incentives, and consider the broader market structure (WB, 2018, 2019a; Schleich, Faure, & Meissner, 2021).

Information and awareness policies, such as energy audits, labeling schemes, and individual metering and billing, play a vital role in raising awareness and encouraging energy-efficient behavior among building owners and occupants (Kontokosta, Spiegel-Feld, & Papadopoulos, 2020b; Fossati, Scalco, Linczuk, & Lamberts, 2016). These policies provide transparent information on energy performance and help identify areas for improvement, but their impact may be limited if not combined with other policy instruments or incentives (Barbetta, Canino, & Cima, 2015).

Qualification policies, focusing on professional training, vocational education, and quality standards, are essential for equipping the workforce with the skills and knowledge needed to design, construct, and operate nZEBs (Stet, Czumbil, Ceclan, Darabant, & Micu, 2017; Clarke, Sahin-Dikmen, & Winch, 2020). These policies address the knowledge and capacity gaps that often hinder the adoption of energy-efficient practices, but their effectiveness depends on the quality and relevance of the training programs and the engagement of key stakeholders (Clarke & Sahin-Dikmen, 2020).

Market-based policies, such as Energy Service Companies (ESCOs), Energy Performance Contracting (EPC), and Energy Efficiency Obligation Schemes (EEOS), harness the power of market forces to drive energy efficiency improvements (Aranda et al., 2023; Augustins et al., 2018; Fawcett et al., 2019). These policies create new business models and financing mechanisms that can help overcome the upfront cost barriers to nZEB adoption, but their success depends on factors such as trust among stakeholders, effective monitoring and verification, and supportive regulatory frameworks (Tsoutsos et al., 2017; Moser, 2017).

Voluntary policies, including certification and labeling programs (e.g., BREEAM, LEED) and green building design and construction methodologies, promote sustainable building practices and encourage the adoption of energy-efficient design and construction techniques (Shan & Hwang, 2018; Zhuang et al., 2021). These policies create market demand for nZEBs and provide recognition for high-

performance buildings, but their impact may be limited if not supported by other policy instruments or regulations (Potoski & Prakash, 2009).

Collaborative policies, such as public-private partnerships, industry task forces, and multi-stakeholder initiatives, foster collaboration among diverse stakeholders and promote innovation in the field of nZEB adoption (Otte et al., 2022). These policies facilitate the development of harmonized standards, best practices, and technological solutions, but their success depends on effective coordination, resource allocation, and the ability to navigate complex stakeholder dynamics (DWG, 2022).

It is essential to emphasize that the analysis of barriers and possible policy solutions is connected to local settings and factors. Understanding local stakeholders' bottlenecks and needs is crucial for progressing towards nZEB goals (OECD, 2003, Bertoldi et al., 2021; Czarnezki, 2019; Economidou et al., 2024).

2.5 The vital role of raising awareness among key stakeholders

The performance of a building is influenced by various stakeholders throughout its life-cycle, with each group having unique roles, needs, and levels of influence (INZEB, 2017). Raising awareness among key stakeholders at the appropriate stage of the building's life-cycle is crucial for achieving the desired energy efficiency performance processes (Gao et al., 2019; Sesana et al., 2021; Demirkesen & Ozorhon, 2017). Construction developers and procurers, who are involved from the design to the use phase of the building, are vital for facilitating nZEB implementation (Bertoldi et al., 2021; Czarnezki, 2019; Economidou et al., 2024). Understanding and addressing the market failures and bottlenecks they face is essential for accelerating the adoption of nZEBs and energy-efficient building practices (Alam et al., 2019; BPIE, 2016; Attia et al., 2022; Nduka et al., 2019; Herrando et al., 2022; Amoruso et al., 2018).

Stakeholders significantly influence the implementation of nZEBs, given their distinct responsibilities, interests, and perspectives (Alam et al., 2019). Therefore, identifying and understanding the level of awareness surrounding nZEBs among these stakeholders is paramount. In Romania, the challenges of embracing energy-efficient building practices, such as nZEBs, can be attributed to various factors, including financial constraints, institutional and administrative obstacles, limited awareness or information, and the presence of split incentives (BPIE, 2016, 2011). This underscores the pressing need to cultivate awareness among stakeholders, ensuring they are well-informed about these barriers and equipped to navigate them effectively.

Achieving nZEBs necessitates innovative solutions, components, and systems (Attia et al., 2022), which can only be actualized by enhancing awareness and addressing market failures at the local level (OECD, 2003). Research on construction developers' perceptions of nZEBs in Nigeria and public strategies for overcoming barriers to public building energy efficiency retrofit projects in Australia revealed that insufficient knowledge, elevated initial costs, lack of demand, insufficient funding, a dearth of technical expertise, and low awareness were the primary obstacles to nZEB adoption (Nduka et al., 2019; Alam et al., 2019). These findings emphasize the importance of comprehending the barriers and opportunities for implementing nZEBs from diverse stakeholder viewpoints.

Energy efficiency planning in public buildings at the local level faces challenges beyond conventional financial barriers, such as a shortage of technical personnel to support decision-making, planning, and execution of energy efficiency measures, and an absence of technical data for buildings, which hinders the development of long-term strategies (Herrando et al., 2022). In Eastern Europe, the most critical barriers to nZEB implementation, besides financial hurdles, were informational and organizational, coupled with a lack of construction skills and quality assurance mechanisms (Attia et al., 2022).

Stakeholder engagement is valuable in promoting energy-efficient building practices, as it can elevate awareness and understanding of nZEB benefits, encourage collaboration, and instill a sense of ownership among stakeholders (Amoruso et al., 2018). Effective communication strategies, such as clear and concise communication, tailored messages, and visual aids, have been found to enhance stakeholders' knowledge and awareness of energy efficiency practices (Nunayon, Olanipekun, & Famakin, 2020).

The crucial role of diverse stakeholders in raising awareness and mobilizing action to tackle climate change is emphasized by Hori et al. (2022), particularly highlighting the significance of non-state actors in achieving climate-related goals. The study suggests the need for a mechanism to incentivize the involvement of these actors, especially within the business sector, and underscores the importance of engaging business associations, international organizations, and third parties in creating institutional arrangements that support a long-term commitment to climate change mitigation. These stakeholders act as norm-setters, shaping expectations and guidelines for businesses pursuing climate change-related objectives, fostering a shared understanding of best practices and standards (Hori et al., 2022).

In summary, raising awareness among key stakeholders is vital for facilitating the adoption of energy-efficient building practices, such as nZEBs. This research will focus on the EU, with a particular emphasis on Romania as a case study, to

explore the barriers and potential solutions for promoting energy efficiency in buildings. By examining the Romanian context, this study aims to provide valuable insights into the specific needs and constraints of two critical stakeholder groups: construction developers and procurers. This understanding is particularly relevant in the context of building renovations or new buildings, where the challenges encountered by procurers' specialists and construction developers are further exacerbated. Consequently, adopting a critical approach to raising awareness and addressing stakeholders' challenges at the local level is indispensable for ensuring the successful implementation of nZEBs in Romania and, by extension, contributing to the broader understanding of energy efficiency in buildings within the EU context.

3 Materials and methods

3.1 The imperative of energy efficiency in EU buildings

The European Commission (EC) acknowledges the indispensable role of the housing and construction sectors in achieving its ambitious sustainability goals, including Europe's commitment to carbon neutrality by 2050 (EC, 2019a). The European Green Deal boldly envisions a just, prosperous, and resource-efficient society that attains zero net greenhouse gas emissions by 2050, all while severing the ties between economic growth and natural resource consumption (EC, 2019a; UNEP, 2020). As critical elements of this vision, buildings hold tremendous potential to transform the EU's energy landscape. The EU has taken decisive action to promote energy efficiency by implementing policies that are aimed at reducing greenhouse gas emissions, improving energy security, and making buildings more sustainable. Key policies such as the EPBD, EED, and RED underscore the emphasis on energy efficiency in buildings (EP & CEU, 2018a, 2018b).

In 2002, the Energy Performance of Buildings Directive (EPBD), also known as Directive 2002/91/EC, was introduced, and it established a robust framework for energy performance in buildings across EU member states. The directive mandated energy performance certificates, promoted minimum energy performance standards, and offered energy-efficient heating and cooling systems incentives.

In 2010, the EPBD underwent a revision with the adoption of Directive 2010/31/EU, also called the recast EPBD. This update introduced stricter energy performance certificates and expanded the directive's scope to include energy performance during the design, construction, and renovation phases. Moreover, the recast of EPBD mandated that buildings demonstrate cost-effectiveness over their life cycle, introducing the Cost-Optimal Methodology as an integral part of

this process (EP & CEU, 2010). Accordingly, this methodology is intended to assist member states in establishing minimum energy requirements for both buildings and their constituent components (Atanasiu, 2011; Ferreira, Almeida, & Rodrigues, 2014; Ferreira, Almeida, Rodrigues, & Silva, 2016). Moreover, the EPBD establishes minimum standards for new and renovated buildings and introduces a pioneering building energy performance certification scheme (EPC) (EP & CEU, 2018b). These certifications empower Member States (MS)to tailor their approaches based on their unique national and regional circumstances. Finally, it introduced the concept of NZEBs, buildings with outstanding energy efficiency and renewable sources that fulfill their remaining energy needs.

The 2018 EPBD III Directive, or Directive 2018/844/EU, has taken significant steps towards achieving a decarbonized building stock by 2050. The EPBD III recognizes deep renovation as a crucial aspect of achieving a decarbonized building stock, making it a vital step towards realizing this goal. Its emphasis on accelerating the renovation of existing buildings and improving their energy performance is essential to achieving this long-term goal. To ensure the success of this objective, the directive has introduced measures such as long-term renovation strategies, financial incentives, and building renovation passports to stimulate the renovation market.

On December 15, 2021, The Commission officially approved a legislative proposal within the Fit for 55 program to update the EPBD. This proposal entails various critical changes, including replacing the nZEBs standard with "zero emissions buildings" for all new public buildings by 2027 and for all other new or undergoing deep renovation buildings by 2030. Additionally, it replaces long-term building renovation strategies with national building renovation plans that outline concrete targets for 2030, 2040, and 2050. In addition, stricter and more uniform regulations for significant renovations and EPCs are being implemented in the EU (EC, 2021). The Commission will develop an EU framework for renovation passports and a Smart Readiness of Buildings indicator. From 2027, Member States cannot subsidize fossil fuel boilers (EC, 2021). The recast EPBD (2021) also includes provisions to safeguard historical buildings while enhancing their energy performance without undermining their technical character and appearance. Starting from 2030, the life-cycle Global Warming Potential (GWP) of all new buildings must be computed, and GWP calculation must be applied to all large new buildings (>2000 square meters) from 2027 onwards. Besides, new buildings must ensure healthy indoor climate conditions, adaptability to climate change, fire safety, seismic activity risk management, carbon removals, and accessibility considerations. While Member States must meet EU-wide minimum energy performance standards (MEPS), they are encouraged to set even more ambitious standards (EC, 2021).

On March 14, 2023, the European Parliament embraced the EPBD proposal, incorporating MEPS as a critical element for existing building infrastructure (EP, 2023). Non-residential buildings must achieve a D-class rating by 2030, while residential buildings must meet the same standard by 2033. A well-balanced compromise was established, emphasizing a transparent investment framework, allowing exemptions, considering national building stock characteristics, strengthening social protections, and ensuring equitable responsibility distribution among Member States (EP, 2023). The general approach foresees that A-class EPCs would apply to zero-emissions buildings, while an A+ class would be created and applied to zero-emissions buildings that also contribute on-site renewable energy to the energy grid. The text incorporates a Whole Life Carbon (WLC) framework to measure and reduce carbon emissions across all building life cycle stages (EP, 2023). This initiative extends energy conservation beyond the usage phase, stimulating innovation in low-carbon materials and enhanced construction waste recycling (EP, 2023). However, significant lobbying efforts have led to an exemption for hybrid systems and boilers partially utilizing renewable fuels, potentially binding citizens to expensive, unreliable, and polluting energy sources for an extended period (EP, 2023).

Moreover, efforts have been made by the EU to promote energy efficiency in buildings by implementing strict standards for various products such as boilers, windows, and lighting. Such standards are enforced through the Energy Labelling Directive (2010/30/EU) and the Ecodesign Directive (2009/125/EC), which ensure that only energy-efficient products are available in the market.

3.2 Current trends and policies on nZEBs in Romania

3.2.1 The non-residential and public building landscape in Romania: A call for urgent action

The non-residential building sector in Romania, a critical component of the nation's infrastructure, accounts for a staggering 67,215,000 m^2 or 12% of the total built area, representing nearly 4% of the overall building stock (MDLPA, 2019). This sector comprises 242,255 non-residential buildings, of which public ownership claims 75,313 structures or an impressive 31% of the total non-residential stock. However, a mere 3,894 of these buildings exceed 250 sqm in size and fall under the jurisdiction of central public authorities (CPAs) (MDLPA, 2020).

A closer examination of these buildings reveals a concerning pattern: an alarming 32% of the CPA-owned buildings, equivalent to 4.3 million square meters, were constructed before 1961—predating the implementation of the first energy standard (MDLPA, 2019). Furthermore, a sizable 65% of the total stock has aged

between 50 to 100 years, urgently necessitating interventions to enhance their efficiency levels. Comparatively, an insignificant 15% of the total stock complies with C107-1997 or later ISO standards or the nZEB standard (MDLPA, 2019).

The European Commission study (2019) paints a similarly bleak picture, highlighting the limited number of renovations in the non-residential sector: a mere 1.9% qualify as medium-depth renovations, while an almost negligible 0.4% are considered deep renovations (EC, 2019b). Additionally, data from new construction permits issued to public authorities (2022) underscores the urgent need for action, as the total number of newly constructed buildings or those undergoing significant renovations accounts for less than 1% of the total building stock in Romania (INS, 2023).

3.2.2 National legislation on energy performance of buildings in Romania

The Romanian legislation governing energy performance in the building sector, Law 372/2005, aligns with Directive 2010/31/EU and has undergone amendments, most recently with Law 101/2020 (Parlamentul României, 2020a). This legislation aims to enhance energy efficiency in buildings while considering external climatic factors, indoor comfort requirements, and cost-effectiveness. It introduces the concept of nZEB and enforces compliance with nZEB standards for public buildings since December 2018 and all other buildings from December 2020 (Parlamentul României, 2020a, 2020b).

A long-term renovation strategy exists for residential and non-residential buildings, overseen by the Romanian Ministry of Public Works, Development, and Administration (Parlamentul României, 2020b). Municipalities with more than 5,000 inhabitants must create local multi-annual plans to increase the number of nZEB-compliant buildings, potentially incorporating differentiated objectives based on climatic zones and building functions. Non-compliance can result in fines (Parlamentul României, 2020b).

Law 121/2014, mirroring EU EED Directive 2012/27/EU, supplements provisions concerning energy efficiency in buildings. It mandates an annual renovation of 3% of the heated and/or cooled building area owned and occupied by the central public administration to meet nZEB standards, with exceptions for historical, military, and religious buildings (Parlamentul României, 2014). Local public administrations with over 5,000 inhabitants must develop short- and medium-term plans for improving energy efficiency. Municipalities with over 20,000 inhabitants must appoint a certified energy manager or sign an energy management contract with an approved company. Public authorities must prepare efficiency plans and submit annual reports on implementation measures and final energy consumption reduction (Parlamentul României, 2014).

3.2.3 nZEB concept and main requirements in Romania

In Romania, the nZEB is established in Art. 3 par. (15) of Law 372/2005 defines nZEB as characterized by extremely high energy performance, close to zero or minimal energy consumption, and at least 30% renewable energy coverage, including energy generated on-site or within a 30 km radius of its GPS coordinates (Parlamentul României, 2020b). The minimum energy efficiency thresholds for primary energy use intensity and CO2 emissions of nZEBs in Romania vary according to the climatic zone and building type (MDLPA, 2020). The thresholds for diverse building types, such as non-residential office buildings, educational buildings, and hospitals, are set for each of the five Romanian climate zones (I to V), with specific values for primary energy (PE) consumption in kWh/m^2 (45-185) and CO2 emissions in kg/m^2 (12-53) (MDLPA, 2020). Energy Performance Certificates (EPCs) in Romania provide provisions for minimum performance thresholds for both heating and cooling demand, classified into seven categories (A to G) based on the energy consumption levels in kWh/ m^2 per annum (MDLPA, 2019). The nZEB framework also considers Life Cycle Assessment (LCA), CO_2 emissions, and airtightness, while provisions for natural ventilation and the assessment of overheating risk are in place (Attia, 2022). However, the legislation does not specify minimum performance requirements for technical systems. Thermal comfort standards are delineated for each of the five climate zones, with efficiency versus renewable energy thresholds set at a minimum of 30% renewable energy sources (RES) (MDLPA, 2019). As for construction quality, the availability of materials and knowledge is classified as high/medium (Attia et al., 2022).

3.2.4 National plans and strategies for nZEB

Romania has developed several strategies and plans in recent years, aiming to fulfill the requirements for nZEB. The country's national plan for increasing the number of nZEB, along with strategies such as the National Energy Efficiency Action Plan (NEEAP), National Long-Term Renovation Strategy (LTRS), and The Integrated National Energy and Climate Change Plan 2021-2030, seek to transform the real estate sector by promoting energy efficiency and decarbonization by 2050 (Guvernul Romaniei, 2020; MDLPA, 2017; Ministry of Energy, 2018). The LTRS Renovation Wave pilar prioritizes enhancing energy efficiency in existing buildings, including multifamily residential, public, and historic buildings. The emphasis is placed on promoting a circular economy, particularly for historic buildings, by creating pilot centers for recovering and reusing historical materials and supporting energy efficiency through innovative solutions (EP & CEU, 2018b). Key objectives involve establishing a funding mechanism, developing a national digital building registry, implementing energy

passports, and strengthening professional capacity through regional training centers.

These initiatives contribute to EU objectives, with Romania's national target aiming to renovate 77% of the total building stock area from 2021 to 2050, doubling the renovation rate by 2025. The 2030 target aims to achieve a primary energy consumption of 32.3 Mtep and a final energy consumption of 25.7 Mtep, with estimated investments of € 13 billion and 18 jobs created per € 1 million invested (Guvernul Romaniei, 2020; MIPE, 2021).

3.2.5 Challenges in enhancing energy efficiency in Romanian buildings: A critique of strategies and regulations

Critics have raised several concerns regarding the general strategies and regulations aimed at enhancing energy efficiency in buildings in Romania (BPIE, 2020; MDLPA, 2020; WB, 2018, 2019b, 2019a). These criticisms can be categorized into different areas, including strategic frameworks, legislation and regulation, institutional and market factors, and financing and implementation issues.

Firstly, critics argue that the strategic frameworks lack certain key elements. These include agreed-upon scenarios, cost-implementation analyses, progress reporting, and evaluations. Without these elements, it becomes challenging to measure the effectiveness of the strategies and make informed decisions regarding their implementation. Insufficient coordination and contribution to other priorities also weaken the overall impact of these frameworks.

Secondly, legislation and regulation in the energy efficiency sector are criticized for their lack of enforcement and evaluation mechanisms. This undermines the effectiveness of the regulations, as non-compliance goes unchecked. Additionally, weak legislation around energy service companies (ESCOs), energy poverty, and prosumers further hampers progress in achieving energy efficiency goals. The lack of support for improving energy efficiency in public procurement is another area of concern, as it represents a missed opportunity to promote sustainable practices.

Institutional and market factors also face criticism for their inadequacy. One key issue is the absence of a national database for building stock, which hinders effective planning and decision-making processes. Insufficient communication and awareness campaigns further limit the reach and impact of energy efficiency initiatives. Addressing these factors is crucial for creating an enabling environment for energy efficiency improvements.

Financing and implementation pose significant challenges as well. Overlapping programs and an overreliance on EU grants can lead to a lack of coordination and inefficiency. A more streamlined and coherent approach is necessary to ensure optimal use of resources. Moreover, the failure to adequately address country-specific challenges, such as a large share of old buildings with low energy efficiency and the high initial costs of renewable energy systems, disproportionately affects marginalized groups. Scarce subsidization of investments in renewable energy systems further exacerbates the situation, limiting accessibility and inclusivity (BPIE, 2020; MDLPA, 2020; WB, 2018, 2019b, 2019a).

In conclusion, Romania's efforts to enhance energy efficiency and decarbonize its building sector could potentially benefit from addressing the criticisms and increasing awareness among key stakeholders. By adopting this approach, Romania may improve the effectiveness of these strategies in achieving its long-term objectives.

3.3 Sample selection and data collection

This study investigated the penetration and adoption of the nZEB concept in the Romanian construction industry through a comprehensive survey of construction developers and procurers. The primary goal was to assess the level of familiarity with nZEB while exploring driving factors, barriers, and potential solutions, hypothesizing that increased awareness would result in higher demand for nZEB. In this regard, the study utilized a mixed-methods approach, drawing on both primary and secondary data sources in 2023.

Primary Data Collection:

Questionnaires

Design and Rationale: The main instrument for primary data collection was a questionnaire, containing both standard and open-ended questions. This approach was chosen because of its cost-effectiveness, capacity to reach a wide audience, and potential for anonymity, thus potentially increasing response rates and reducing social desirability bias (Siva, Nayak, & Narayan, 2019; Wright, 2005).

Distribution and Response: The questionnaire was administered online, inviting voluntary participation. Through collaboration with leading associations and targeted outreach on social media and interest groups, two primary respondent groups were established: construction developers and procurement specialists.

Response Analysis: From the 203 questionnaires returned during February and March 2023, 193 were validated, with 10 discarded due to inconsistencies and incomplete information. The valid responses were segmented into Developers (Gr_1) with 127 participants, and Procurers (Gr_2) having 66 respondents.

Structure: The questionnaire was structured into four parts: nZEB awareness, influencing factors for nZEB adoption, industry's nZEB potential, and recommendations (Table 1 in the Appendix). To maintain respondent engagement and promote clarity, the questionnaire incorporated a balanced mix of Likert-scale, multiple-choice, and open-ended questions. This diversity in question types not only facilitated varied and nuanced responses but also allowed for in-depth analysis during the post-survey phase.

To ensure the comprehensiveness of our measure, the items in the questionnaire were derived from an extensive literature review, consolidating key themes and insights related to nZEB adoption and challenges (Alam et al., 2019; BPIE, 2011, 2016, 2017, 2020; Castleberry, Gliedt, & Greene, 2016; Giorgi, Lavagna, Wang, K., Osmani, Liu, & Campioli, 2022; MDLPA, 2020; WB, 2018, 2019b, 2019a). Additionally, a pilot test was conducted with a select group of industry experts to refine and validate the instrument, ensuring all pertinent topics were appropriately addressed.

Personal Interviews:

Selection and Purpose: Following the survey analysis, in-depth interviews were conducted with four key stakeholders in autumn 2023. This comprised two construction experts/architects known for their nZEB advocacy in Romania, and two procurement specialists. The rationale was to derive deeper insights and contextual explanations from experts in the field.

Procedure: Interviews took place online via platforms like Zoom and Teams. They were based on the questionnaire data, particularly the Mean Rank (MR) or average and Standard Deviation Rank (SDR) of each question. Despite this structure, the talks were open-ended. They addressed noted discrepancies and let experts discuss the wider nZEB landscape, its challenges, opportunities, and future outlooks.

Data Representation: For privacy, interviewees remain unnamed in the findings and are represented using specific codes. Comprehensive details about the interviewees and the discussion guide are available in the appendix (Table 2).

Secondary Data Collection: Extensive desk research was conducted to collect secondary data. This included academic literature, government documents, and industry reports.

3.4 Data analysis techniques

The data analysis process was bifurcated to accommodate both quantitative and qualitative data:

Quantitative Analysis:

Rating System: Participants evaluated their understanding of nZEB practices' benefits and challenges on a five-point Likert scale. The scale ranged from 1 (not beneficial/challenging) to 5 (highly beneficial/challenging) for perceived benefits or challenges, and similarly, 1 (minimum) to 5 (major) for importance.

Descriptive Statistics: Frequencies and percentages were computed to quantify and categorize the responses. By analyzing the proportion of participants who deemed each benefit as crucial or significant, the study could extract dominant perceptions.

Ranking Variables: To methodically rank and interpret the perceived benefits and challenges, the study utilized MR and SDR as pivotal analytical metrics.

Qualitative Analysis:

Content Analysis: This method was employed to decode and understand the qualitative data from the interviews, enabling a deeper dive into the underlying themes and patterns present in the respondents' feedback.

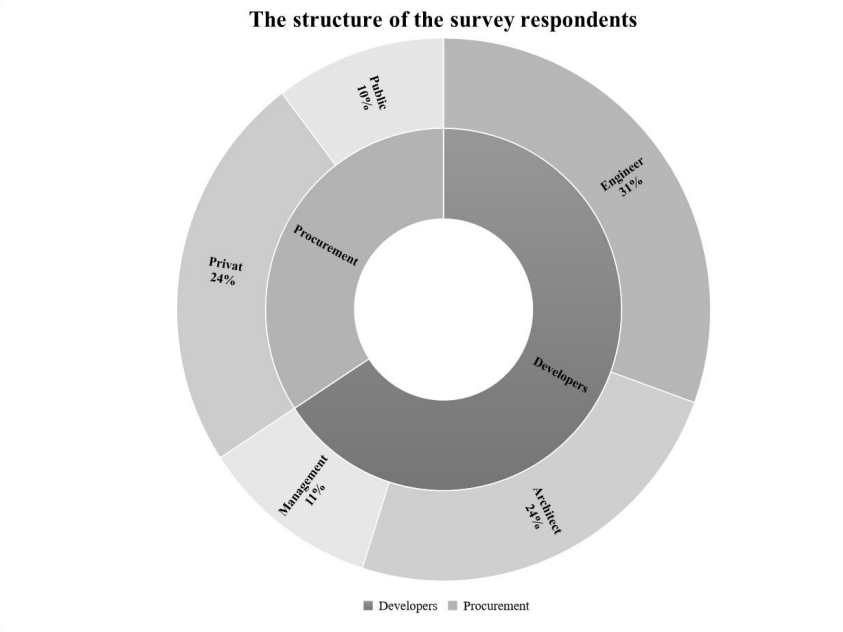
Following the analysis, the interview responses were particularly pivotal in providing depth and context. Their insights, coupled with the post-analysis of the questionnaire responses, were extensively integrated into the discussion section to provide a more holistic understanding of the findings and their implications.

4 Findings and results

The results of the analysis of the completed questionnaires on the status of nZEB in Romania are presented in this section. Figure 1 provides a visual representation of the composition of the respondents who participated in the survey. The configuration illustrates that all relevant stakeholders in the construction process were adequately included, such as builders, architects, engineers, developers,

contractors, and procurers. The survey's broad coverage of stakeholders ensured that the results were comprehensive and representative, with a proportional representation of individual interest groups corresponding to the average distribution of property developers in Romania.

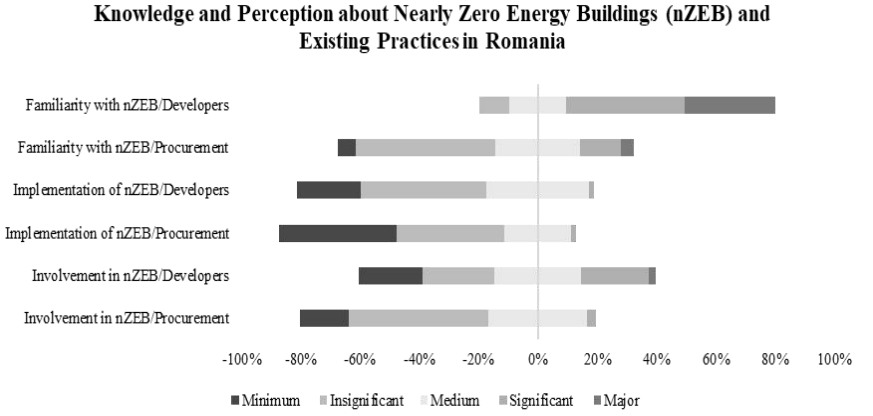
Figure 1: The structure of the survey respondents



4.1 Overview of the respondents' knowledge and awareness of nZEBs

This section examines the general awareness and knowledge about nZEBs and existing practices in Romania, irrespective of the respondents' professional background and profession. Respondents were asked whether or not they were familiar with the concept, implementation level, and involvement in nZEB projects.

Figure 2: Implementation of nZEB practices in Romania



The results from the two groups are presented in Figure 2, which showcases the implementation of nZEB practices in Romania. The data reveal a significant difference in the familiarity level of nZEB between developers and procurers. While 71% of developers have a good understanding of nZEB, only 5% of procurers reported the same. Moreover, most procurers (76%) reported having an intermediate to limited understanding of nZEB, indicating that procurers in Romania have a lower knowledge level about nZEB than developers.

The implementation of nZEB in Romania is suboptimal among both developers and procurers, but developers are more likely to implement nZEB. Out of developers, 35% have implemented nZEB at a moderate to significant level, while only 2% of procurers have implemented nZEB at the same level. Most procurers (39%) have not implemented nZEB, while 21% of developers have not implemented nZEB. These findings suggest that developers are more willing to implement nZEB in Romania than procurers.

Involvement in nZEB projects is another area where developers are more interested and active than procurers. The data indicate that both developers and procurers are not heavily involved in nZEB projects in Romania. Out of developers, 54% have medium to major involvement in nZEB projects, while only 36% of procurers have the same level of involvement. The majority of procuring bodies (47%) have minor involvement in nZEB projects, while 23% of developers have little involvement.

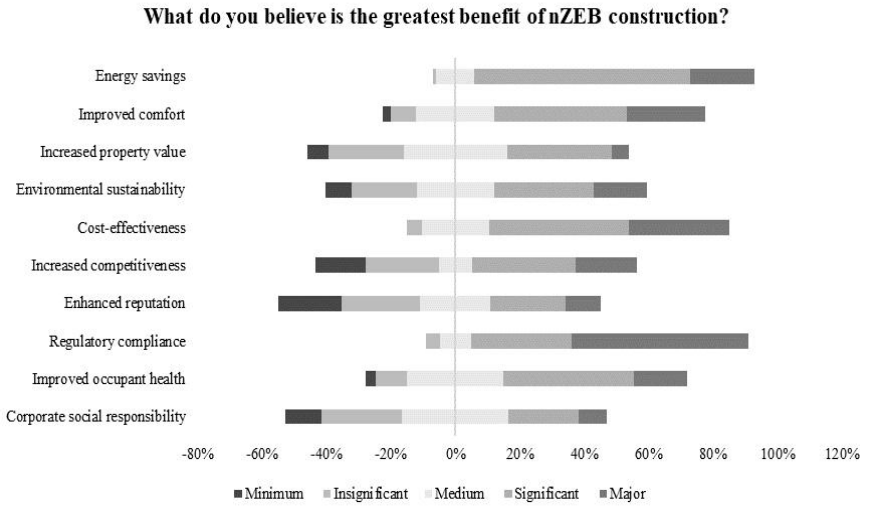
4.2 Factors influencing the adoption of nZEBs

The second set of questions aimed to discern and delineate the primary advantages, impediments, and champions affecting the adoption of nZEBs. Respondents ranked the significance and validity of the proposed alternatives on a scale of 1 (least important) to 5 (most important). The findings are depicted in Figures 3, Figure 4, and Figure 5.

4.2.1 Benefits of nZEB practices in Romania

The survey underscores the broad recognition of the diverse benefits of nZEB construction. Benefits range from tangible advantages, such as energy savings, to intangible enhancements like bolstered reputation. The most pronounced benefits, as perceived by the respondents, include energy savings and reduced utility bills. Notably, 66.84% of respondents found this benefit significant, with an additional 20.21% ascribing major importance to it (Figure 3).

Figure 3: Benefits of nZEB practices in Romania



Enhanced comfort and indoor air quality also received substantial recognition. Specifically, 40.93% of respondents deemed it significant, with 24.35% rating it as major. Other noteworthy benefits include increased property value and market appeal (32.64%), environmental sustainability with a decreased carbon footprint (31.09%), and cost-effectiveness combined with diminished long-term maintenance expenses (43.52% found it significant and 31.09% major).

Comparative Insights: Developers vs. Procurers

A deeper dive into the priorities of each group reveals nuances in their perceived benefits:

Energy Savings & Lower Utility Bills: Both developers and procurers highly valued this benefit, with 87% of both groups regarding it as either significant or major.
Improved Comfort & Indoor Air Quality: This was a top priority for developers, with 76% rating it as significant or major, compared to 46% of procurers.
Cost-Effectiveness & Maintenance Costs: A noteworthy 76% of developers regarded this as a primary benefit, while 71% of procurers echoed similar sentiments.

Conversely, procurers placed slightly more emphasis on "Environmental sustainability and reduced carbon footprint", with 44% deeming it crucial, in contrast to 42% of developers.

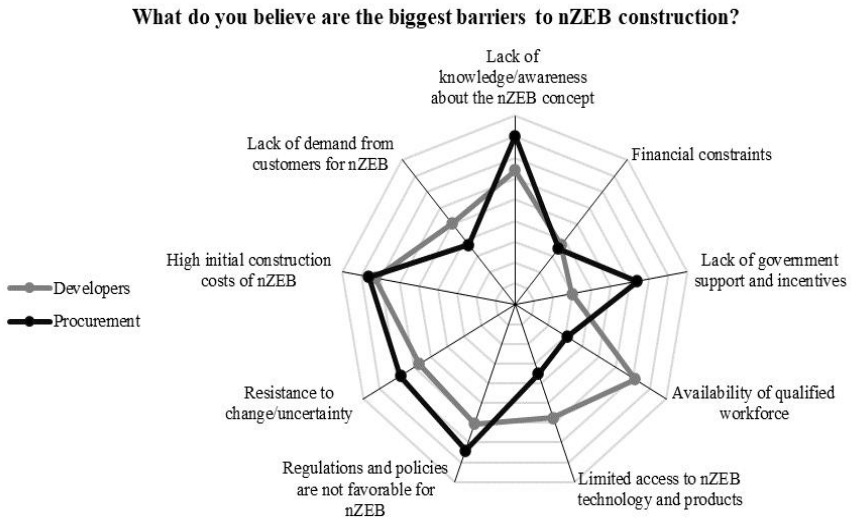
Notably, both groups highlighted the significance of "Compliance with regulations and building codes". Specifically, 88% of developers and 82% of procurers regarded it as a major or significant benefit. Additionally, the "Improved health and well-being of occupants" was identified as a primary advantage by 70% of developers and 56% of procurers.

In summary, while there are certain areas of overlap, distinct priorities emerge when scrutinizing the preferences of developers versus procurers. The shared recognition of the multifaceted benefits of nZEB practices solidifies its importance in the construction landscape of Romania.

4.2.2 Barriers to nZEB construction

The perception of barriers to nZEB construction differs between developers and procurers. Delving into each group's perspective offers nuanced insights into their priorities and concerns.

Figure 4: Obstacles to nZEB Implementation in Romania



Developers' Viewpoints: Developers cite the following as the top barriers to nZEB construction:

Elevated initial construction costs of nZEB (14.56%)

The availability of a qualified workforce (14.26%)

Lack of knowledge/awareness regarding the nZEB concept (12.81%).

These figures reflect developers' challenges in sourcing skilled labor, promoting awareness about nZEB benefits, and managing expenses related to nZEB technology adoption. Close on their heels were concerns regarding unfavorable regulations and policies for nZEB (12.08%), limited access to nZEB technology and products (11.50%), and resistance to change or uncertainty (11.35%). Interestingly, 10.04% of developers perceived customer demand for nZEB as a challenge, hinting at a heightened sensitivity to market demands.

Procurers' Viewpoints: For procurers, the top identified barriers were:

Lack of knowledge/awareness about the nZEB concept (16.05%)

High initial construction costs of nZEB (15.23%)

Unfavorable regulations and policies for nZEB (14.81%).

These percentages suggest procurers face difficulties in understanding the regulatory landscape and addressing supply chain challenges unique to nZEB

construction. Notably, resistance to change/uncertainty (13.58%) and a dearth of government support and incentives (12.76%) were also flagged as significant challenges. A unique concern for procurers was the contractual and legal challenges, coming in at approximately 5%.

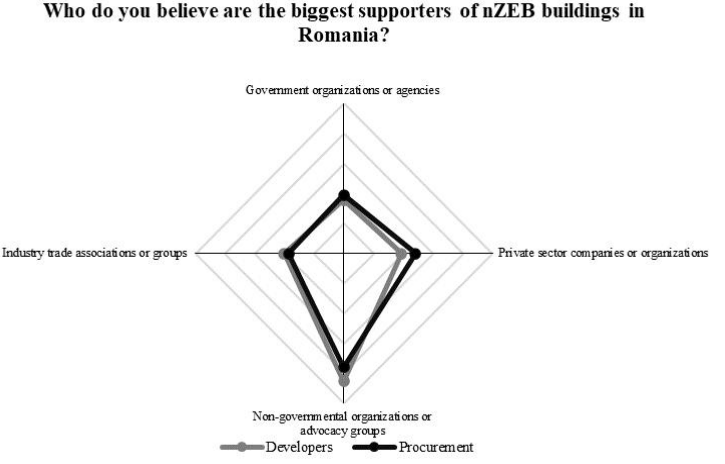
Common Barriers: Both developers and procurers recognized limited access to nZEB technology and products as a substantial obstacle, marked at 11.50% by developers and 7.00% by procurers. Financial constraints were similarly ranked by both groups, with 7.42% of developers and 7.00% of procurers indicating it as a barrier.

These findings elucidate the distinct and shared challenges both developers and procurers encounter in the realm of nZEB construction. Addressing these barriers requires tailored strategies that take into account the specific needs and concerns of each group.

4.2.3 Supporters of nZEB construction

The survey responses concerning the foremost proponents of nZEB buildings in Romania show a general agreement among respondents from both groups.

Figure 5: Survey Responses on the Supporters of nZEB Buildings in Romania (%)



The survey responses highlight the major role of non-governmental organizations (NGOs) and interest groups in promoting the adoption of nZEB buildings in

Romania An impressive 42.64% of developers and 37.96% of procurers identified these entities as the most vigorous supporters of nZEB buildings. This underlines the significant influence that these groups exert in shaping the nZEB landscape, often through a combination of public campaigns, lobbying efforts, and stakeholder education.

At the same time, our results draw attention to the critical participation of the private sector in advancing the nZEB construction agenda. About a fifth of respondents from both groups - 19.38% of developers and 24.07% of procurers - acknowledged the contribution of private companies and organizations. This trend is likely due to the private sector recognizing the economics of NZEB buildings, highlighted by the prospect of reduced energy expenditure and the potential increase in property value.

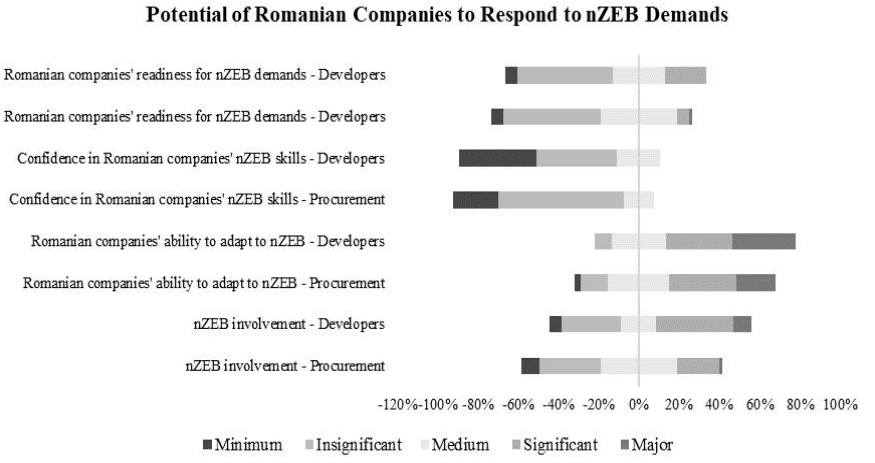
Interestingly, industry trade associations or groups garnered comparatively lesser recognition as champions of nZEB buildings, as expressed by 20.16% of developers and 18.52% of procurers. This suggests a degree of inertia among industry bodies in proactively promoting nZEB buildings. The reasons behind this apparent passivity might require further investigation.

Lastly, the perceived role of governmental organizations or agencies in advocating for nZEB buildings is seemingly moderate. Our survey indicates that only 17.83% of developers and 19.44% of procurers viewed the government as a significant supporter of nZEB buildings. These numbers imply a somewhat subdued governmental push in the promotion of nZEB buildings, perhaps reflecting a wider policy or structural issue that could benefit from further inquiry.

4.3 Romanian companies' potential to address nZEB demands

The third segment of the questionnaire aims to provide insight into Romanian companies' potential in the construction sector to meet the nZEB building requirements, given their current knowledge and practical skills. Question 1 from Section 4 has been included in this analysis to show the perspective between the current status and future plans. Respondents were asked to rate the willingness and confidence of Romanian companies to build nZEB, as well as their intentions to engage in nZEB projects in the near future (Figure 6).

Figure 6: Potential of Romanian companies to address nZEB demands in Romania



According to the questionnaire results, there are differing degrees of confidence among developers and procurers concerning Romanian construction companies' capabilities to address nZEB demands. Developers assess the equipment and preparedness of Romanian construction companies as inferior to procurers' evaluations, with only 26% of developers considering companies significantly equipped, compared to 25% of procurers. In terms of confidence in knowledge and skills, developers exhibit greater optimism than procurers, as 49% of developers rate companies as possessing medium to significant knowledge and skills, while only 41% of procurers share this sentiment.

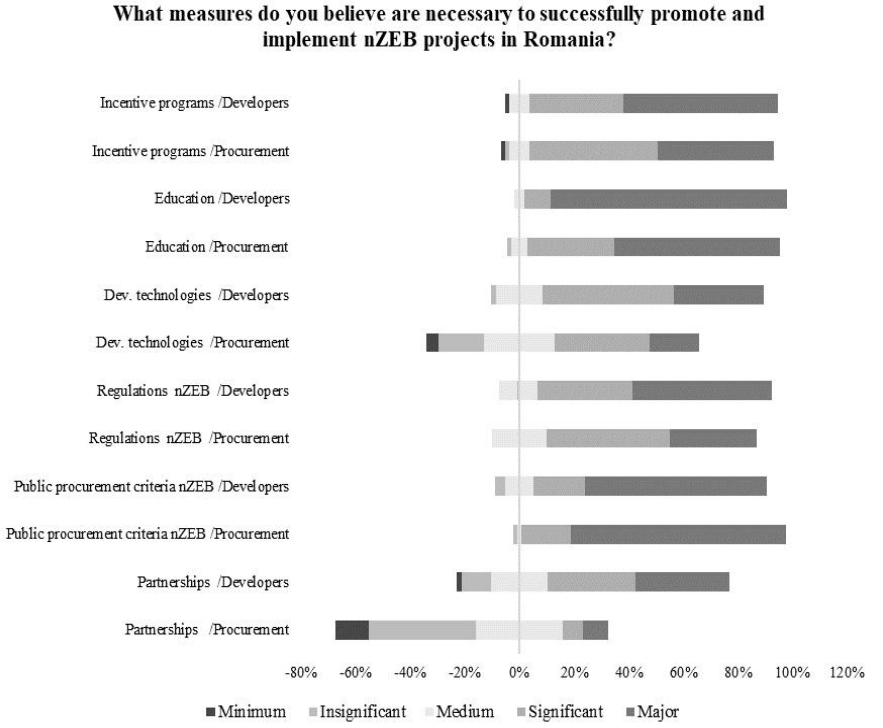
Looking into the future, both groups maintain a positive perspective on Romanian companies' adaptability to nZEB requirements, with the majority of respondents evaluating companies as having medium to significant potential for adaptation. Developers display slightly more optimism, with 42% rating companies as having significant potential for adaptation, compared to 22% of procurers.

Lastly, developers and procurers express intentions to partake in nZEB projects in the near future, with developers demonstrating marginally heightened interest. Most respondents plan to be significantly or majorly involved in nZEB projects, encompassing 49% of developers and 25% of procurers, respectively.

4.4 Necessary support needed for nZEBs in Romania

The last section of the questionnaire dealt with the actions needed to successfully promote and implement nZEB projects in Romania. Given that survey respondents are actively involved in the construction industry, either through building energy efficiency procurement activities or as nZEB developers, respondents were asked to identify the necessary support they could receive to drive nZEB construction forward (Figure 7).

Figure 7: Distribution of responses by group regarding the importance of various actions



The analysis concentrated on each measure, seeking to discern parallels and disparities between the two groups. For example, both groups concurred that government support and incentive programs held considerable importance, with 34.65% of developers and 46.97% of procurers rating them as significant. However, while 56.69% of developers deemed this measure major, a lower 42.42% of procurers considered it equally vital.

Both groups regarded education and training for construction sector employees as critical, with 86.61% of developers and 60.61% of procurers assigning this level of importance. Nonetheless, there were variances between the groups, as 31.82% of procurers rated this measure as significant, compared to a mere 6.06% of developers.

Developers and procurers alike agreed on the importance of developing appropriate technologies, garnering 48.03% and 34.85% of responses, respectively. However, divergences arose in the importance of this measure, with 17.32% of developers rating it as medium level, while 25.76% of procurers did the same.

Both groups concurred that amending regulations and policies to favor nZEB was essential, with 34.65% of developers and 45.45% of procurers assigning this level of importance. Yet, distinctions emerged in the importance attributed to this measure, as 13.39% of developers rated it as medium, compared to 19.70% of procurement.

Clear and consistent policies and criteria for public procurement in support of nZEB were deemed extremely important by both groups, with 67% of developers and 79% of procurers rating them as such. However, discrepancies appeared in the importance assigned to this measure, with 10.24% of developers rating it as medium level, while only 1.52% of procurers agreed.

Ultimately, both groups concurred that forging partnerships with companies and organizations in this field was essential. However, differences manifested in the importance assigned to this measure, with 32.28% of developers and a mere 7.58% of procurers assigning it the same level of importance. Moreover, while 20.47% of developers rated this measure as a medium, 31.82% of procurers considered it medium, and 39.39% insignificant.

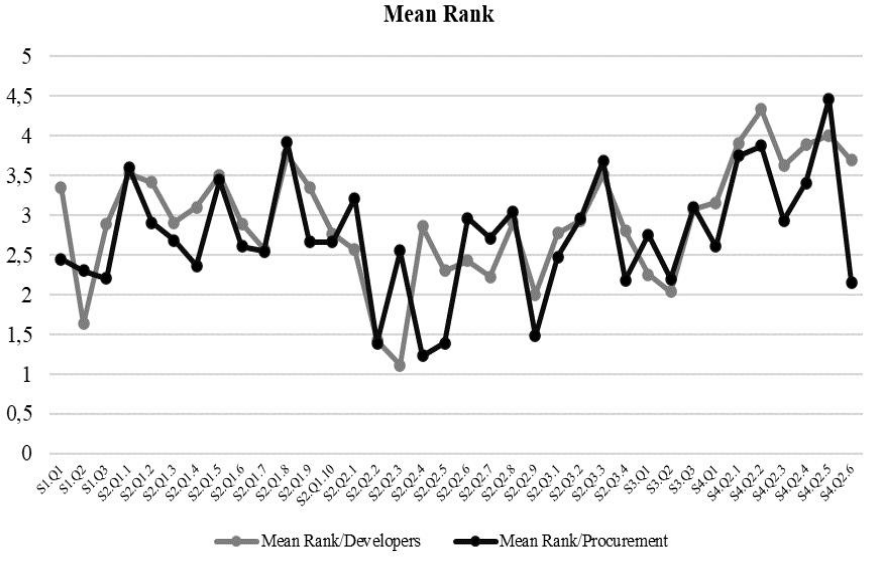
In summary, the analysis indicated that both groups hold similar perspectives on the significance of particular measures, such as government support and incentive programs, education and training, and policy modification. However, disparities emerged in the importance attributed to some measures, including technology development and partnership creation.

5 Discussion

5.1 Comparing developers' and procurers' respondents' views

For the 36 questions, there was a significant difference between respondents representing developers and those representing procurers. The contrast can be seen in the significant differences in assessments between these two groups regarding the obstacles to the current nZEB situation and possible actions needed to overcome it, as shown in Figure 8 below. For a complete list of questions, codes, and results, see Appendix 1. Analysis reveals some notable results and patterns related to Romania's nZEBs. These results can be discussed and interpreted in the context of the research question and the existing literature in the field, allowing for comparisons with previous studies and theoretical frameworks. In addition, the implications of these results for future research and practice are explored. Complementing this analytical endeavor, we also engaged in personal dialogues with experts in the field. These interactions enriched our discussion, furnishing it with profound insights and reflective commentaries.

Figure 8: Familiarity and involvement in nZEB projects



Knowledge and Awareness of nZEBs:
Our findings highlight a significant disparity in understanding the nZEB concept between procurement officials and developers. The latter group demonstrates a

deeper familiarity. This observation aligns with previous research by Nduka et al. (2019), who identified a lack of comprehension as a major hurdle to successful nZEB implementation in Nigeria. The current study extends this finding by revealing a notable awareness gap between two key stakeholder groups in Romania - procurers and developers - suggesting that knowledge disparities can emerge not just across regions, but within the construction ecosystem itself.

The heightened awareness of nZEB among developers likely stems from their professional exposure. This observation aligns with the conclusions of RP1 and RP3, who emphasized the role of professional education in shaping awareness of sustainable building practices, and RP2, who pointed out that professions like engineering and architecture often have in-depth exposure to such advanced concepts. Considering that our respondents are primarily engineers, architects, and upper management members, it's logical to expect their domain-specific knowledge to be more advanced due to their professional responsibilities. As the construction field encompasses a vast array of professionals with varied backgrounds and specialties, effectively disseminating information about new standards, like nZEB, can be a complex undertaking. However, the fragmented nature of the construction industry (IPCC, 2007) can hinder the effective dissemination of nZEB information across all stakeholders, a challenge that is evident in the awareness gap between developers and procurers in the present study. Supporting this notion, RP1 posits, “Two scenarios emerge: respondents either genuinely understand nZEB or believe they do based on superficial knowledge. This crucial distinction warrants further examination.” Delving deeper into this disparity, RP1, “Among all participants, especially developers, there exists a varied and often cursory grasp of intricate standards like nZEB and Passive House. The more candid responses from Group 2 might more accurately reflect the true state of domain knowledge.” This distinction between actual and perceived understanding warrants further examination, as it could have implications for the effective implementation of nZEB principles in practice.

In contrast, the limited awareness of procurers regarding the nZEB concept might be linked to its recent emergence. RP 1 points out, “…low scores in procurement might relate to when legislative changes were mandated, influencing their participation in nZEB projects.” While energy efficiency discussions have been prevalent for over a decade, and mandatory for public buildings in Romania since 2018, the detailed nZEB construction methodology (Mc 001-2022) was only introduced in 2023 (MDLPA, 2023). This timeline raises questions about how sporadic engagements with the construction sector could cultivate an understanding of a standard that was ambiguous to even industry professionals until recently. RP2 offers another perspective: “There’s a possibility that 'familiarity' means that developers are aware, but procurers may only recognize its existence in legislation without truly understanding it. Procurers acknowledge it

but might not have had the opportunity to apply it in their procurement or technical documentation." Building on this, RP3 underscores a critical concern: "If procurers are not well-acquainted with nZEB, how can they effectively prioritize or enforce it during procurement?" This sentiment highlights the tangible challenges that could arise if those in procurement roles don't close the knowledge gap on nZEB standards.

However, among those who undertook such interventions, the specific roles within procurement departments—especially those tasked with drafting technical specifications related to contract objectives—reveal a marked deficiency in detailed understanding concerning the application of nZEB standards, a concern also highlighted by RP3. This limited comprehension largely explains the minimal nZEB implementation, a pattern consistent with Buftic's (2023) analysis. RP2 offers further insight into this challenge, "in public procurement, the initial specification sheet is often minimal, only referencing the laws. Without detailed instructions on how energy efficiency or nZEB standards should be met, achieving these goals becomes unlikely, despite legislative mandates." This trend mirrors earlier research noting the limited nZEB adoption in many European countries, especially those in Eastern Europe (Attia, Kurnitski, et al., 2022; EC, 2019b). This alignment suggests that the challenges faced by Romania in implementing nZEB are not unique, but rather part of a broader pattern of slow uptake in the region. Identifying the common barriers and enablers of nZEB adoption across these contexts could yield valuable insights for accelerating the transition to sustainable building practices.

Interestingly, our data suggests a more optimistic level of engagement in nZEB projects compared to the actual application of nZEB standards. Most developers indicated a moderate to high involvement in nZEB-level energy efficiency projects. This inconsistency might stem from the origins of the nZEB performance standard. As RP1 and RP2 have noted, the nZEB standard effectively merges the well-established passive house standard with other energy performance standards, which have been historically pursued by the private market to create efficient and lucrative spaces.

However, given the nZEB standard's relatively recent introduction, direct comparisons might be misleading. While the origins of the nZEB performance standard traced back to merged longstanding practices, its formal introduction into the market is recent. Consequently, we should approach the perceived inconsistency with caution. Based on our findings, a golden opportunity presents itself for strengthened collaboration between developers and procurers to expedite nZEB adoption in Romania. The expertise of developers, with their background in various energy efficiency standards, could play a crucial role in narrowing the current knowledge chasm, leading to a more widespread procurement of nZEB.

The imperative of augmenting stakeholder participation is also underscored by Hori et al. (2022).

Despite this potential for synergistic collaboration, the observed engagement disparity remains concerning. The apparent lack of engagement, especially among procurers, underscores the pressing need to fortify the understanding and application of nZEB principles. This brings forth the significance of initiating awareness campaigns, specialized education, and training programs – strategies that are strongly advocated by Alam et al. (2019) and Attia, Kurnitski, et al. (2022). The nature of the involvement of procurers, as described by RP3 and RP4, provides further clarity on the issue. RP3 remarked, "…while the procurers might have been involved in a more supervisory or approval capacity," hinting at a possible detachment from hands-on engagement. This sentiment is echoed by RP4, who observed, "Procurers, meanwhile, might have been involved in projects without being deeply engrossed in the technicalities."

Thus, there's an imperative for specialized procurement departments to undergo targeted training. This becomes even more essential as the nZEB performance standard makes building procurement more complex, necessitating a comprehensive understanding not just during the procurement or construction phases, but across the entirety of the building's lifecycle.

Factors influencing the adoption of nZEBs:

Benefits:

Our research unveils nuanced perspectives among different stakeholders with regard to the advantages of nZEB construction in Romania. These findings challenge the notion of a uniform approach to promoting nZEB practices, instead suggesting the need for tailored strategies that account for the diverse viewpoints and priorities of various stakeholder groups. This insight aligns with the World Bank's (2014) emphasis on the importance of understanding local stakeholders' needs and constraints in progressing towards nZEB goals.

A primary finding is the overwhelming importance attached to compliance with regulations and building codes. This observation can be contextualized within the recent legislative changes at the EU level, particularly the EPBD and EE directives, which mandate the adoption of energy-efficient standards like nZEB (EP & CEU, 2018a, 2018b). RP3's note on the strong focus on compliance reflects the growing role of regulations in shaping construction practices, a trend that resonates with the literature on the importance of regulatory policies in driving nZEB uptake (Bertoldi et al., 2021; Economidou et al., 2024). However, the study's findings also suggest that the rapid transition to these new standards may

have inadvertently overemphasized legal compliance at the expense of the broader goal of achieving energy efficiency. The preference for meeting legal requirements rather than fully embracing nZEB principles highlights the need for a more gradual integration of regulations, coupled with adequate support to foster comprehensive understanding. This insight extends the existing knowledge by underscoring the potential unintended consequences of a swift regulatory shift and the importance of a measured approach to policy implementation.

A significant disparity in the perceptions of developers and procurers about compliance with regulations and building codes emphasizes the need to understand the unique experiences and roles of these stakeholder groups. Developers are predominantly guided by construction laws, while procurers' perspectives are shaped by a blend of voluntary and obligatory green procurement directives. RP4 elucidates this by emphasizing the priority many clients, especially procurers, place on immediate cost savings, often sidelining long-term environmental ramifications. This distinct prioritization is grounded in their divergent professional mandates.

Energy savings, reduced utility bills, and long-term cost-effectiveness emerged as focal concerns, resonating with the apprehensions over escalating energy costs and the imperative of energy efficiency in modern architectural designs. These findings align with previous nZEB research that identifies financial savings and improved living conditions as key motivators for adopting nZEB practices (Ardente, Beccali, Cellura, & Mistretta, 2011; Baniassadi et al., 2022; Nduka et al., 2019; Pikas, Kurnitski, Thalfeldt, & Koskela, 2017). The current study reinforces the centrality of these tangible benefits in driving nZEB uptake, as echoed by the insights from RP3, RP4, and RP1.

The importance assigned to improved comfort and indoor air quality by the respondents signifies a growing cognizance of buildings' influence on occupant health and well-being. Developers, as indicated by RP3, appear attuned to these qualitative benefits, appreciating the holistic improvements in the quality of life nZEB offers. This aligns with contemporary research emphasizing the relevance of indoor environmental quality in nZEB buildings (Asere & Blumberga, 2018; De Robles & Kramer, 2017; Frontczak et al., 2012).

Distinct prioritization of benefits between developers and procurers necessitates a subtle approach to policymaking and the design of incentives. Developers predominantly focus on the economic advantages of nZEB, driven by their operational goals oriented towards profitability. In contrast, procurers emphasize attributes that benefit building occupants, reflecting their mandate to serve the public good. However, RP4's insights suggest a nuance to this distinction: while procurers advocate for occupant benefits, they may, at times, prioritize tangible

metrics, potentially undervaluing aspects like occupant comfort. This complex interplay of priorities highlights the diverse motivations that shape each group's approach to nZEB.

Nonetheless, a mutual emphasis on environmental sustainability, carbon footprint reduction, and the improved health and well-being of occupants represents a shared understanding. This common ground, coupled with the growing relevance of nZEB in determining market competitiveness (as noted by RP1, 2, and 3), presents promising opportunities for promoting nZEB in Romania. These findings align with the literature on the potential for collaborative policies and multi-stakeholder initiatives to foster innovation and accelerate nZEB adoption (Otte et al., 2022; DWG, 2022).

To conclude, this study underscores the need for an approach that acknowledges the variety of stakeholder perspectives and seeks to address their unique needs and concerns. A comprehensive, tailor-made strategy that balances regulatory compliance with tangible benefits could potentially bridge the current divide, encouraging broader acceptance and implementation of nZEB standards in Romania.

Barriers:

This research uncovers several significant challenges impeding the implementation of nZEB standards. For developers, the primary obstacles include the increased initial construction costs associated with nZEB, the scarcity of a qualified workforce, and a lack of understanding and awareness of the nZEB concept. These findings align with earlier research conducted in Nigeria and Eastern Europe (Attia, Kurnitski, et al., 2022; EC, 2019b; Nduka et al., 2019), reinforcing the notion that financial constraints, knowledge gaps, and capacity limitations are key barriers to nZEB uptake across diverse contexts. However, the current study extends this understanding by highlighting the interconnectedness of these challenges. RP1's observation that a discrepancy in knowledge levels exists within the industry stakeholders, despite overall high scores in nZEB awareness, suggests that knowledge gaps at grassroots levels can lead to missed opportunities and subpar outcomes. This insight underscores the importance of addressing knowledge disparities at all levels of the construction ecosystem to effectively promote nZEB adoption.

RP1's insights on the cost and availability of technology further illuminate the complex dynamics at play. The observation that attaining nZEB standards can be costly due to market-driven product pricing, coupled with the need for specific expertise to identify and deploy cost-effective alternatives, highlights the interplay between financial constraints, market forces, and knowledge gaps. This finding

extends the existing understanding of the barriers to nZEB adoption by revealing the nuanced ways in which these factors interact and compound each other.

The shortage of a qualified workforce, particularly in specialized areas such as air-tightness, emerges as a significant challenge in the current study. RP2's observation that nZEB standards demand new skills and certified professions that are not yet sufficiently prevalent in the market, especially for procurers, aligns with prior research emphasizing the importance of a skilled workforce and technical expertise in creating energy-efficient buildings (Attia et al., 2022; Attia, Kurnitski, et al., 2022; Nduka et al., 2019). However, the study's findings also highlight the specific skill gaps and training needs in the Romanian context, such as the lack of trained professionals for blower door tests and thermography, despite the mandatory nature of nZEB construction for the past five years.

RP2's insight that the knowledge and skill gap will likely intensify due to regulatory tightening at both the EU and MS levels, particularly with the upcoming amendments to the EPBD recast requiring the consideration and computation of the Whole Carbon Footprint, underscores the urgent need for proactive capacity building. The observation that Romania currently has only a handful of individuals equipped to calculate CO_2 emissions for materials and solutions, coupled with the absence of a dedicated Romanian methodology, highlights the magnitude of the challenge ahead. These findings contribute to a more nuanced understanding of the evolving skill requirements and the importance of anticipating and preparing for future regulatory changes.

The study's findings on the socio-economic factors exacerbating the skilled labor shortage in Romania, including prolonged labor migration and heightened developmental strains on an already burdened industry, provide a context-specific understanding of the barriers to nZEB adoption. These insights align with the observations of RP1 and RP2, emphasizing the need for continuous investment in education and the cultivation of an environment that nurtures learning and skill development.

Restricted access to nZEB technology and products emerges as another significant impediment in the current study, echoing research that underscores the vital role of technology accessibility in promoting eco-friendly construction (Bamgbade Nawi, Kamaruddeen, Adeleke, & Salimon 2019; Hosseini et al., 2017). However, the study's findings also reveal the intrinsic link between this barrier and factors such as awareness, initial costs, and certain business marketing strategies. RP1's insight that numerous enterprises exploit the dynamic of elevated initial costs as a marketing strategy to increase sales, coupled with the observation that equivalent performance levels can be achieved with more budget-friendly technologies,

highlights the importance of comprehensive understanding and informed decision-making in navigating these challenges.

RP3 and RP4's observations on the interconnectedness of limited access to nZEB technology with financial constraints and lack of demand further illuminate the complex web of factors influencing nZEB adoption. These findings suggest that strengthening the nZEB supply chain through collaboration and research support, as advocated by Souley Agbodjan, Wang, J., Cui, Y., Liu, Z., and Luo (2022), could be a promising strategy for overcoming these barriers.

Procurers identify several barriers to nZEB construction, including nZEB regulations and policies, a lack of familiarity with the nZEB concept, and the perceived high upfront construction costs. These challenges align with the literature on the difficulties procurers face when interpreting complex regulatory frameworks and managing supply chain intricacies specific to nZEB projects (Bertoldi et al., 2021; Czarnezki, 2019; Economidou et al., 2024).

Firstly, procurers often perceive nZEB constructions to necessitate sizable initial investments. While the earlier section argued against this notion, highlighting the role of a knowledgeable and adept construction workforce in potentially offsetting these costs, procurers' interaction with nZEB often remains sporadic or supervisory. Such interactions can color their perception, as RP3 articulated, "This uncertainty can be attributed to limited knowledge or awareness. Everything is interconnected." RP3 also emphasized that the daunting nature of these perceived costs is acknowledged by both stakeholder groups. RP4 added that this perception might be influenced by a market that hasn’t yet fully realized the potential benefits of nZEB.

Secondly, these barriers are not isolated but closely interrelated. Although Romania implemented mandates for nZEB construction in the public sector in 2018, comprehensive methodologies for some aspects only materialized in 2023 (MDLPA, 2023). This delay exacerbates existing knowledge gaps among public officials. RP1 and RP2, during their interview, shed light on the legal intricacies, stating, "There are multiple laws with overlapping and sometimes conflicting clauses, which causes disarray among industry participants." They highlighted inconsistencies between Law 372 and Law 50, pointing to specific gaps in energy audit procedures and roles. A prime example is the diverging requirements for nZEB reports and alternative energy feasibility studies. While Law 372 necessitates both, Law 50 only mentions the latter. This disparity creates a fog of ambiguity around legislative compliance, especially in public procurement. Moreover, the newly introduced methodology, Mc 001-2022 (MDLPA, 2023), despite its detail, does not cater adequately to all stakeholder groups. It leaves entities like public procurers or authorities grappling with multiple legislative

texts, trying to extract actionable insights. RP1 emphasized the pressing need for more accessible and actionable guidelines, contrasting Romanian practices with the simpler Anglo-Saxon methods. They also discussed the interplay between Specialists and Procurement departments, suggesting that while specialists draft the technicalities, procurement departments should ensure they're more specific and actionable than a generic preference for 'nZEB-level' construction. RP3 supported this, noting the clear nZEB criteria but lamenting the broader legislative ambiguity. "Legislation should bring clarity, not chaos, particularly in public procurement," they asserted.

RP4's argument that the intertwined nature of these challenges can be traced back to a lack of robust governmental backing aligns with studies emphasizing the crucial role of government policies in promoting energy-efficient buildings (D'Alpaos & Bragolusi, 2018; Matisoff, Noonan, & Flowers, 2016; Schmalensee, 2012). This insight suggests that addressing the barriers to nZEB adoption in Romania may require a more proactive and supportive stance from the government, both in terms of policy formulation and implementation.

Supporters of nZEB Construction: Our survey's findings stress the dominant role of non-governmental organizations (NGOs) and advocacy groups in championing nZEB construction in Romania. RP3's observation resonates with this: "NGOs being ranked high is understandable. They're often the voice pushing for sustainable initiatives. Yet, one wonders if their efforts sometimes remain in the advocacy realm without translating to tangible action." RP4 further adds, "Procurers rate them even higher, possibly seeing them as the main force advocating for nZEB. But there's a risk; if NGOs are the highest supporters, it may mean that the actual stakeholders in construction aren't doing enough on the ground."

The identification of industry entities, such as private sector firms and trade associations, as key supporters of nZEB construction aligns with the prevailing literature on the importance of a cohesive, multi-stakeholder strategy for advancing sustainable building practices (D'Alpaos & Bragolusi, 2018; Matisoff et al., 2016; Nduka et al., 2019; Schmalensee, 2012). This finding reinforces the notion that effective nZEB adoption requires the synergistic efforts of diverse actors across the construction ecosystem, including businesses, industry associations, and professional bodies. However, the study's insights into the specific roles and contributions of these industry entities in the Romanian context offer a more granular understanding of the dynamics at play, highlighting the need for further research on the strategies and best practices employed by these actors in promoting nZEB uptake.

Yet, the governmental role, typically pivotal in endorsing innovative strategies (Ardente et al., 2011; Asere & Blumberga, 2018; EC, 2019b; WB, 2018) appears to be falling short as per our respondents' perceptions. Both developers and procurers assigned a lower rank to governmental support. This concurs with academic writings that highlight the indispensable role of government backing and incentives in spearheading energy-efficient building standards (Amoruso et al., 2018; Fawcett et al., 2019). Moreover, as RP1 shared, there are capacity issues within governmental agencies: "We've dealt with the government's Ministry of Development before, and they are overwhelmed; they don't have enough people." RP1 further mentioned, "The agency responsible for energy efficiency under the Ministry of Development is understaffed. There are only 5 people covering the entire country's building energy efficiency." This paints a picture of the current challenges faced in terms of resources and infrastructure. Furthermore, RP2 stresses the lack of integration of nZEB concepts in education, which demands more robust governmental intervention.

The government's divided approach, as elaborated by RP1, adds layers of complexity. Energy efficiency initiatives fall under different ministries, leading to disjointed efforts. This fragmented structure, combined with potential political interests prioritizing cost over quality in public tenders, further hampers the effective promotion of nZEB. This finding aligns with the growing emphasis on the importance of government policies and incentives in driving the adoption of energy-efficient building standards (Amoruso et al., 2018; Fawcett et al., 2019), highlighting the need for a more integrated and strategic approach to nZEB policy development and implementation in Romania.

These observations underscore a fundamental message: the government's role in reinforcing nZEB standards, both in terms of regulations and leading by example, is currently not living up to expectations. The potential gap left by the government is immense, and while other stakeholders might try to bridge this, as our data shows, the low adoption rate of nZEB and the prevailing knowledge barriers signify the irreplaceable role of the government in offering clear guidelines, robust regulations, and sufficient backing for nZEB adoption. This insight extends the existing understanding of the government's role in promoting sustainable building practices by highlighting the specific areas where enhanced government engagement is most needed in the Romanian context, such as regulatory clarity, consistency, and precedent-setting.

The study's conclusion on the necessity of a robust multi-stakeholder approach and a significant increase in governmental engagement to stimulate nZEB adoption in Romania aligns with the growing emphasis on the importance of collaborative and systemic approaches to promoting energy efficiency in buildings (World Bank, 2014; BPIE, 2020; MDLPA, 2020). However, the specific

recommendations offered by the study, such as enhancing regulatory backing, providing unambiguous and consistent legislation, and setting precedents, provide a more targeted and context-specific roadmap for strengthening government support for nZEB adoption in Romania.

Potential of Romanian Companies and Necessary Support for Advancing nZEB in Romania: The focal point of the present discourse is the preparedness and capabilities of Romanian construction companies to cater to the demands of nZEB construction and the potential support required to navigate hurdles and stride towards energy-efficient building objectives.

The survey results indicating that Romanian developers perceive the domestic construction industry as not adequately equipped to address nZEB requirements resonate with the growing body of research on the barriers to nZEB adoption, particularly in the context of Eastern European countries (Attia, Kurnitski, et al., 2022; EC, 2019b). This finding reinforces the understanding that the lack of technical expertise and capacity limitations within the construction sector can significantly hinder the uptake of nZEB practices, even in the presence of interest and familiarity with such projects.

This lack of confidence in the preparedness of construction firms could be closely linked to the swift pace of evolution in the construction market, specifically legislative changes in the sector. For example, the EPBD directives experience substantial amendments every 5-6 years, with each recast introducing new elements and demands that significantly influence national legislation and construction standards. These quick changes may impose undue strain on the primarily SMEs-driven construction sector, already wrestling with limited profitability margins. The intricate nZEB performance standard requires qualified labor and appropriate equipment, which may not be easily accessible or affordable for many companies. This finding highlights the need for further research on the impact of nZEB policies and regulations on the resilience and competitiveness of construction SMEs, as well as the development of targeted support mechanisms to help these firms adapt to the changing market requirements.

The modest degree of optimism expressed by respondents regarding the potential of Romanian companies to adapt to future nZEB requirements aligns with the literature on the importance of market demand and supply dynamics in driving the adoption of energy-efficient building practices (Ghalebani & Das, 2017; Tsoutsos et al., 2017). The study's findings on the steady growth of the construction market in Romania, the increasing demand from the public sector, and the availability of European and international investment funds suggest that there may be opportunities for the sector to modernize and adapt to nZEB requirements over time. However, the observation that the pace of legislative changes and the

adaptation level of industry players are not in perfect harmony underscores the need for a more systematic approach to addressing the existing obstacles and challenges within the nZEB market, as highlighted by previous research (Attia, Kurnitski, et al., 2022; Hori et al., 2022).

The key areas identified by the survey data demanding enhancement include education and training, policy reforms, transparent public procurement criteria, governmental backing, incentives, and technological advancement align with the growing consensus in the literature on the importance of a multi-faceted and collaborative approach to promoting nZEB adoption (Bertoldi et al., 2021; Economidou et al., 2024; Otte et al., 2022). The study's emphasis on the need for collaborative stakeholder engagement, focusing on disseminating best practices, bridging skills gaps, and establishing clear nZEB implementation guidelines, resonates with the emerging recognition of the transformative potential of multi-actor collaborations in driving sustainability transitions in the built environment (Hori et al., 2022). These challenges could form the essential pillars for public authorities to devise strategies for market expansion within the nZEB sector:

1. Financial incentives: Offering grants, tax incentives, and low-interest loans could potentially mitigate the burden of high upfront construction costs, especially for small and medium-sized enterprises grappling with financial limitations (Ghalebani & Das, 2017).

2. Education and training: Customized programs for developers, procurers, and other stakeholders could boost nZEB knowledge, bridge existing skill gaps, and nurture capacity building (Topriska et al., 2018).

3. Standardization and legal frameworks: Streamlining procurement processes and easing nZEB adoption through the development of standardized contracts, guidelines, legal frameworks, explicit stakeholder roles, and performance benchmarks for nZEB projects could prove highly beneficial (Attia, Kurnitski, et al., 2022; Tsoutsos et al., 2017).

4. Technology transfer and innovation: Encouraging alliances with international organizations, research institutions, and private firms could spur innovation and address the limited access to nZEB products and technologies (Bamgbade et al., 2019; Hosseini et al., 2017; Sanhudo et al., 2018).

5. Public awareness campaigns: Highlighting the long-term economic and environmental benefits of nZEB through public awareness campaigns could underscore energy savings, enhanced comfort, and lower utility bills (Hori et al., 2022). To bolster these campaigns, EU Member States have implemented diverse strategies ranging from simplifying Energy Performance Certificates (EPCs) for

better comprehension to the provision of information and counsel via subsidized energy advisors, to expansive public information initiatives. Such efforts are paramount for elevating the consciousness of the general public, property owners, policymakers, and financiers. Moreover, these campaigns are most effective when integrated with regulatory measures, fiscal incentives, and the monitoring of outcomes through proficient data management (BPIE, 2020).

6. The necessity for transparent and consistent public procurement criteria for nZEB is of utmost importance, as evidenced by a high score among the procurement group and second among developers. The establishment of such criteria reflects the government's commitment to sustainable development, thereby fostering private sector participation. The formulation of these criteria should be an inclusive process, engaging industry stakeholders to ensure practicality and relevance. The implementation of such criteria could stimulate market demand and contribute to energy efficiency goals of government-funded projects, aligning with the EU's emphasis on public procurement as a crucial tool for driving sustainability and energy efficiency in buildings (Lim et al., 2018; Czarnezki, 2019).

5.2 Bridging the divide: A multi-pronged approach to foster nZEB adoption

Bridging the significant divide between construction developers and procurement specialists regarding nZEB adoption in Romania demands a multi-faceted approach that holistically addresses the root causes of this divergence. Fundamentally, capacity building through tailored education and training programs emerges as a pivotal solution to ameliorate the knowledge asymmetry observed between these stakeholder groups.

While developers demonstrate a relatively robust grasp of nZEB concepts, procurers grapple with a lack of familiarity, particularly concerning technical specifications and evaluation criteria. Customized training modules that equip procurers with the requisite expertise to assess nZEB project proposals effectively could empower them to drive market demand through informed decision-making during procurement processes.

Concurrently, fostering cross-sectoral collaboration and knowledge exchange between developers and procurers presents a unique opportunity for synergistic learning. Developers' insights into practical nZEB implementation could complement procurers' regulatory and procedural know-how, facilitating a shared understanding and mitigating knowledge gaps.

However, education and collaboration alone are insufficient without a robust regulatory framework. Stakeholder consultations to identify and address ambiguities, overlaps, and inconsistencies within the existing legislative landscape are crucial for providing clear guidelines and fostering transparency in nZEB procurement criteria across both public and private sectors.

Moreover, enhancing government support through a strategic combination of financial incentives (e.g., grants, tax credits) and non-financial incentives (e.g., expedited permitting) could alleviate perceived cost barriers and stimulate private sector investment in nZEB projects. Simultaneously, the government should lead by example, implementing nZEB standards in public infrastructure to create market demand and catalyze industry-wide adoption.

Furthermore, establishing robust green public procurement (GPP) criteria tailored for nZEB projects could bridge the awareness gap between developers and procurers in Romania. Well-defined GPP guidelines encompassing technical specifications, energy benchmarks, lifecycle costing, and environmental impact assessments would provide procurers with a transparent framework for evaluating nZEB proposals. Concurrently, this clarity offers developers a roadmap for designing compliant, cost-effective nZEB solutions aligned with public sector sustainability goals. An inclusive multi-stakeholder approach to developing GPP criteria ensures practicality and relevance. Ultimately, embedding GPP in nZEB procurements fosters shared understanding, drives innovation, and catalyzes a cultural shift towards an energy-efficient, sustainable construction industry.

Ultimately, a collaborative multi-stakeholder approach, involving government agencies, industry associations, NGOs, research institutions, and private entities, could leverage collective expertise, resources, and networks to drive innovation, technology transfer, and capacity building, thereby accelerating the transition towards a sustainable and energy-efficient built environment in Romania.

5.3 Limitations of the study

This study critically analyzes its limitations, which must be considered when interpreting the results. Firstly, the methodology employed in this study relied on online surveys, which may have affected the accuracy and comprehensiveness of the data collected. Online surveys lack personal engagement and are vulnerable to fraud and manipulation, which may compromise the validity of the data collected. Thus, caution must be exercised when generalizing the findings of this study.

The sample size of 193 participants may not adequately represent the entire population of developers in Romania and may not have captured the opinions of smaller companies or those operating in specific regions. This limitation, coupled

with the high level of professional education and market knowledge of the respondents, may affect the generalizability of the findings. Furthermore, voluntary participation introduces self-selection bias, potentially leading to overestimating or underestimating true familiarity and involvement in nZEB projects.

Social desirability bias may have influenced the self-reported data, with respondents overestimating their familiarity with nZEB or their commitment to environmental sustainability to appear more knowledgeable or responsible. Ambiguous or leading questions and using Likert scales in the questionnaire design could also introduce bias in the responses.

Finally, the study's focus on Romanian participants limits the generalizability of the findings to other regions or contexts. To overcome these limitations, future research could consider using larger sample sizes, diverse respondent groups and validating the adoption and implementation of nZEB practices with objective measures, such as energy consumption data or expert opinions. By acknowledging and addressing these limitations, future research can generate a more comprehensive understanding of the factors influencing nZEB adoption and implementation.

6 Conclusion and recommendation

Our comprehensive research extends and augments the existing theoretical constructs within sustainable construction, explicitly highlighting the impediments in the nZEB realization process in Romania. The observed patterns resonate with the broader scientific literature, highlighting the importance of factors like high upfront costs, skilled labor demand, and the essential role of government support. Unique to the Romanian scenario, our study accentuates the role of NGOs and the requirement of explicit public procurement criteria, adding depth to the intricate nature of nZEB implementation.

The theme of high initial costs as a considerable barrier to nZEB uptake echoes previous research, emphasizing the enduring issue of financial viability. In alignment with numerous studies, our findings confirm the necessity for skilled labor and expertise, thereby underscoring their pivotal role in transitioning to sustainable construction practices. Further, our research reinforces the theoretical standpoint on governmental support, indicating the problems posed by inadequate incentives and regulations.

In contrast, our study presents several novel insights. NGOs and advocacy groups surface as critical players in championing nZEB construction in Romania. The evidence suggests that NGOs may be key in propelling sustainable construction

practices, a perspective often sidelined in the existing literature. Moreover, our study underscores the need for transparent, consistent public procurement criteria for nZEB, emphasizing a potential deficiency in the current policy framework and the practical value of clear policy guidelines.

This research's implications extend to policy and practice, offering essential insights for nZEB promotion. Policymakers should heed the call for better government support, enhanced public procurement criteria, and establishment of targeted education and training programs, as suggested by the study. On a practical level, construction firms can leverage our research to anticipate challenges and identify opportunities. Awareness campaigns orchestrated by procurers, developers, and NGOs could utilize our research to highlight nZEB benefits and stimulate market demand. Our findings also encourage cross-sector collaboration, unveiling potential synergies with research institutions, international organizations, and private-sector enterprises to bolster the nZEB supply chain.

However, potential roadblocks in implementing these recommendations are to be noted. Regulatory changes may be slow due to political and bureaucratic complexities. Economic limitations may limit the breadth of financial incentives, especially under budgetary pressures. Inertia in the construction sector could be a significant barrier, amplified by the high initial costs and unfamiliarity with nZEB projects. Finally, the existing skills gap could delay the application of our findings in real-world contexts.

A salient point is the importance of tailored policy sequences for optimal results. For example, prioritizing financial support policies, absent requisite awareness and expertise, may invite misuse of resources. Unchecked, this could foster corruption, undermining the sustainability of buildings and future initiatives. Policymakers should therefore consider these insights when devising localised policy roadmaps that align with overarching strategies. This strategic planning is critical to any project's success.

Future research should delve into understanding disparities in knowledge and perception of nZEB between developers and procurement stakeholders, scrutinizing specific nZEB adoption barriers, studying the incentives and hurdles in nZEB project participation, and exploring the scope of public-private partnerships and R&D investments in facilitating a transition to sustainable construction. Policies and incentives that cater to diverse stakeholder groups' distinct priorities and interests are pivotal in fast-tracking the adoption of sustainable building practices in Romania.

In conclusion, in its resonance and divergence from prevailing theories, this research sheds light on the complex scenario of nZEB implementation in Romania. The findings lay a robust foundation for driving targeted efforts to promote nZEB, propelling the global shift towards more sustainable and energy-efficient building practices. Despite the potential barriers, the recommendations put forth can serve as key levers in surmounting these challenges and setting the stage for successful nZEB implementation.

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Appendix

Appendix A

Table 1: Survey results on nZEB knowledge, perceptions, and implementation barriers in Romania

Section	Question	Sub-question	Question code	Mean rank (MR)		Standard deviation rank (SDR)	
				Gr_1	Gr_2	Gr_1	Gr_2
Section I: Knowledge and Perception about Nearly Zero Energy Buildings (nZEB) and Existing Practices in Romania	1. To what extent are you familiar with the concept of nZEB?		S1.Q1	3,35	2,44	0,85	1,03
	2. In your opinion, to what extent are nZEB practices currently implemented in Romania?		S1.Q2	1,63	2,3	1,5	1,27
	3. Have you or your company been involved in nZEB projects?		S1.Q3	2,88	2,2	1,02	1,23
Section II: Significant Benefits, Barriers, and Supporters of nZEB Construction	1. What do you believe is the greatest benefit of nZEB construction?	1.1. Energy savings and lower utility bills	S2.Q1.1	3,52	3,6	0,97	1,39
		1.2. Improved comfort and indoor air quality	S2.Q1.2	3,41	2,9	1	0,96
		1.3. Increased property value and market appeal	S2.Q1.3	2,9	2,68	1,16	1,03
		1.4. Environmental sustainability and reduced carbon footprint	S2.Q1.4	3,1	2,36	1,1	0,87
		1.5. Cost-effectiveness and reduced long-term maintenance costs	S2.Q1.5	3,5	3,44	0,99	1,23
		1.6. Increased competitiveness in the building market	S2.Q1.6	2,89	2,6	1,11	1,22
		1.7. Enhanced reputation and brand image	S2.Q1.7	2,57	2,54	1,24	0,93
		1.8. Compliance with regulations and building codes	S2.Q1.8	3,76	3,92	0,69	1,04
		1.9. Improved health and well-being of occupants	S2.Q1.9	3,35	2,66	0,99	0,92
		1.10. Better alignment	S2.Q1.1	2,76	2,66	1,16	0,97

Section	Question	Sub-question	Question code	Mean rank (MR)		Standard deviation rank (SDR)	
				Gr_1	Gr_2	Gr_1	Gr_2
		with corporate social responsibility and ethical values	0				
	2. What do you believe are the biggest barriers to nZEB construction?	2.1. Lack of knowledge/awareness about the nZEB concept	S2.Q2.1	2,56	3,21	1,52	1,48
		2.2. Financial constraints	S2.Q2.2	1,42	1,39	1,61	1,5
		2.3. Lack of government support and incentives	S2.Q2.3	1,11	2,55	1,54	1,56
		2.4. Availability of qualified workforce	S2.Q2.4	2,85	1,23	1,54	1,37
		2.5. Limited access to nZEB technology and products	S2.Q2.5	2,3	1,39	1,72	1,64
		2.6. Regulations and policies are not favorable for nZEB	S2.Q2.6	2,42	2,96	1,44	1,41
		2.7. Resistance to change/uncertainty	S2.Q2.7	2,22	2,71	1,32	1,52
		2.8. High initial construction costs of nZEB	S2.Q2.8	2,91	3,04	1,62	1,62
		2.9. Lack of demand from customers for nZEB	S2.Q2.9	2	1,48	1,43	1,59
	3. Who do you believe are the biggest supporters of nZEB buildings in Romania?	3.1. Government organizations or agencies	S2.Q3.1	2,77	2,47	1,17	1,41
		3.2. Private sector companies or organizations	S2.Q3.2	2,93	2,96	1,23	1,43
		3.3. Non-governmental organizations or advocacy groups	S2.Q3.3	3,51	3,68	1,08	1,3
		3.4. Industry trade associations or groups	S2.Q3.4	2,8	2,18	1,12	1,24
Section III: Potential of Romanian Companies to Respond to nZEB Demands	1. In your opinion, how equipped are Romanian construction companies to respond to nZEB demands?		S3.Q1	2,25	2,75	1,41	1,07
	2. How confident are you in the current level of knowledge and		S3.Q2	2,03	2,19	1,31	1,18

Section	Question	Sub-question	Question code	Mean rank (MR)		Standard deviation rank (SDR)	
				Gr_1	Gr_2	Gr_1	Gr_2
	practical skills of Romanian companies to construct nZEB?						
	3. To what extent do you believe Romanian companies will be able to adapt to nZEB requirements in the future?		S3.Q3	3,07	3,1	0,91	0,95
Section IV: Future Implementation of nZEB in Romania	1. To what extent do you plan to be involved in nZEB projects in the near future?		S4.Q1	3,15	2,6	0,98	1,23
	2. What measures do you believe are necessary to successfully promote and implement nZEB projects in Romania?	2.1. Government support and incentive programs	S4.Q2.1	3,9	3,74	1,05	1,13
		2.2. Education and training for construction sector employees	S4.Q2.2	4,33	3,87	0,88	1,18
		2.3. Development of appropriate technologies	S4.Q2.3	3,62	2,93	1,04	1,18
		2.4. Modification of regulations and policies to favor nZEB	S4.Q2.4	3,88	3,4	1,01	1,17
		2.5. Clear and consistent policies and criteria for public procurement towards nZEB	S4.Q2.5	4	4,46	0,89	0,86
		2.6. Creation of partnerships with companies and organizations involved in this field	S4.Q2.6	3,69	2,15	1,14	1,37

Appendix B

Table 2: Interviews with stakeholders

Code	Type of organization/sector	Job title	Interview date
RP1	nZEB specialist	Architect	04.10.2023
RP2	Architect (Design)	Architect	07.10.2023
RP3	Public (Education)	Public procurement specialist	12.10.2023
RP4	Private (Real Estate/Development)	Procurement specialist	13.10.2023