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Strategies to Advance the Energy Efficiency, Water Efficiency, and Indoor Environmental Quality in New Zealand's Sustainable Building Designs and Practices

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ABSTRACT

Sustainable Building Designs and Practices (SBDPs) are increasingly important for reducing environmental impacts, conserving resources, and improving occupant well-being. This study examines New Zealand building professionals' perceptions of the integration and performance of energy efficiency (EE), water efficiency (WE), and Indoor environmental quality (IEQ) in SBDPs. It assesses whether SBDPs are perceived to outperform conventional buildings, identifies key implementation challenges, and explores strategies to strengthen adoption. A quantitative online survey of 102 New Zealand building professionals was conducted to capture perceptions of SBDP performance, barriers and enablers across the three domains. Data were analysed using reliability testing, one-sample *t*-tests, Kendall's coefficient of concordance, and one-way ANOVA to examine statistical significance, consensus, and stakeholder-group differences. As the study is perception-based, the findings represent perceived rather than empirically measured building performance. The results show that stakeholders perceived SBDPs to outperform conventional buildings across EE, WE and IEQ. EE showed the strongest perceived advantage, while WE was recognised as beneficial but less prominent, suggesting weaker integration within the EE–WE–IEQ nexus. Key barriers included short-term cost priorities, regulatory gaps, and knowledge or coordination deficiencies. Stakeholders favoured passive design, interdisciplinary collaboration, professional training, and incentive-linked regulations, while technology-driven measures were viewed as useful but constrained by cost. The study recommends strengthened building codes, targeted financial incentives, capacity building, and integrated design approaches. By linking stakeholder evidence with practical implementation strategies, this research contributes to SBDP discourse and provides recommendations for policymakers, investors, producers, and practitioners seeking to accelerate sustainable transformation in New Zealand's built environment.

1 | Introduction

The significance of SBDPs has grown in recent years, especially in developed countries, as they provide environmentally friendly and economically feasible construction solutions that also improve inhabitants' quality of life (Poorisat et al. 2024). The World Green Building Council (WGBC) promotes sustainability through Net Zero Energy Buildings (NZEBs), designed to balance annual energy production and consumption from renewable sources (WGBC 2023). SBDPs emphasise energy efficiency (EE), water efficiency (WE), and indoor environmental quality (IEQ), essential for achieving Sustainable Development Goals (SDGs) 3, 6, 7, 12 and 13 (United Nations 2022). EE is vital, aligning with SDG 7 on affordable, sustainable energy (Kim

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et al. 2025; United Nations 2022). Meeting WGBC's net-zero target requires renewable generation and energy-efficient strategies (Hafez et al. 2023). Moreover, EE is a major focus of rating systems such as LEED, Green Star and BREEAM (Vosoughkhosravi et al. 2022). In New Zealand, buildings account for 22% of total energy use and 20% of emissions, making the sector central to decarbonisation (IEA 2023). Despite the high renewable energy uptake (80%) and smart metering (60%) providing a foundation, challenges persist, including the absence of a unified certification system and slow updates to building codes (Cielo and Subiantoro 2021).

WE, another pillar of sustainability, is recognised across global rating tools and supports SDG 6 on water and sanitation (United Nations 2022). It includes WE measures, such as water recycling and reuse (Poorisat et al. 2024). In New Zealand, recurring droughts and events like Cyclone Gabrielle highlight its urgency (Morton 2023). The Three Waters Reform, established in 2020, sought to address systemic issues (MBIE 2021). Nonetheless, there remains a striking lack of technical knowledge and data on water use in non-residential buildings, with the most comprehensive study still dating back to 2012 (Bint 2012). Additionally, the absence of benchmarking frameworks and the complexity of water-related legislation have impeded political momentum and clarity around water policy (Armoudian and Pirsoul 2020). As climate change intensifies the risk of water scarcity, enhancing WE in buildings becomes a critical measure for resilience and sustainability (MBIE 2021). IEQ, covering thermal comfort, air quality, lighting, and acoustics, is fundamental to occupant health (Perera et al. 2025). The COVID-19 pandemic reinforced the importance of indoor air quality (IAQ) in preventing illness (Bennett et al. 2022).

In New Zealand, poor housing quality, with two-thirds lacking insulation, causes serious health issues (Ade and Rehm 2020a). While outdoor air standards are regulated, no IAQ-specific laws exist (Morton 2018). Additionally, the evidence on IEQ in buildings in New Zealand is scarce, underscoring the need for science-based strategies (Bennett et al. 2022). Collectively, EE, WE, and IEQ are paramount for SBDP's performance. In New Zealand, integration is constrained by knowledge gaps, regulatory shortcomings, and slow adoption of rating systems (Doan, Wall, et al. 2021). Accordingly, stakeholders require a more comprehensive understanding of sustainable principles and performance metrics. This study investigates EE, WE, and IEQ in SBDPs in New Zealand, drawing on stakeholder perspectives gathered through an online questionnaire. The overarching aim is to examine the extent to which stakeholders perceive SBDPs in New Zealand to achieve EE, WE and IEQ. To achieve this, the following research questions are explored (RQ1): Do stakeholders perceive that SBDPs in New Zealand have better EE, WE, and IEQ compared to conventional buildings? (RQ2): What are the existing challenges influencing the EE, WE, and IEQ of SBDPs in New Zealand? (RQ3): What are the potential strategies to enhance the EE, WE, and IEQ of SBDPs in New Zealand? The findings from this study's online questionnaire will serve as a valuable resource for policymakers, investors, producers, users, and academics to promote the adoption of more SBDPs.

2 | Previous Studies

SBDPs are commonly evaluated through three interconnected domains: EE, WE and IEQ. Together, these domains capture the environmental, resource-efficiency, and human-centred dimensions of sustainable building performance (Damsari and Sridarran 2025; Poorisat et al. 2024). However, previous studies have frequently examined EE, WE, and IEQ separately or in pairs, with limited attention to the synergies and trade-offs that emerge when the three domains are considered simultaneously. Accordingly, this section first establishes the conceptual basis of the EE–WE–IEQ nexus and subsequently reviews the performance outcomes, implementation challenges, and strategies associated with SBDPs. The section concludes by identifying the research gap addressed by the present study.

2.1 | Conceptual Framework: The EE–WE–IEQ Nexus

EE, WE, and IEQ are widely recognised as essential dimensions of SBDPs (Poorisat et al. 2024). However, previous studies have commonly examined these domains individually or through pairwise relationships rather than as an integrated system (Rodrigues et al. 2020; Wang et al. 2022). Although pairwise studies provide valuable evidence of interdependence, they do not fully explain how improvements in one domain may generate synergistic benefits or unintended trade-offs across the other domains. To address this limitation, the present study conceptualises EE, WE, and IEQ as an integrated water–energy–IEQ nexus, as illustrated in Figure 1.

The causal relationship between EE and WE is particularly well established. Water collection, treatment, distribution, pumping, and heating require substantial energy inputs (Thebuwena et al. 2024). Consequently, reductions in building water demand can lower operational energy consumption. Conversely, energy-efficient building-services, such as efficient pumps, hot-water systems, and smart-control technologies, can reduce the energy required for water provision and use (Pinto et al. 2017). Water-efficient fixtures, rainwater harvesting, greywater-reuse systems, and smart-metering technologies may therefore contribute not only to water conservation but also to reduced energy demand and improved resource resilience (Thebuwena et al. 2024). Nevertheless, EE–WE studies primarily focus on resource efficiency and frequently exclude occupant-health outcomes and broader IEQ considerations (Rodrigues et al. 2020).

EE also has direct and indirect implications for IEQ. Building-envelope design, ventilation systems, passive-design measures, and building-services operation influence both energy consumption and indoor conditions (Perera et al. 2025). For example, high-performance insulation and airtight envelopes can reduce heating and cooling demand, while appropriately designed ventilation systems can improve IAQ and thermal comfort (Hafez et al. 2023; Niza et al. 2022). However, these relationships may involve trade-offs. Increasing ventilation rates to improve IAQ can raise energy demand, while excessively airtight envelopes may adversely affect IEQ when ventilation is inad-

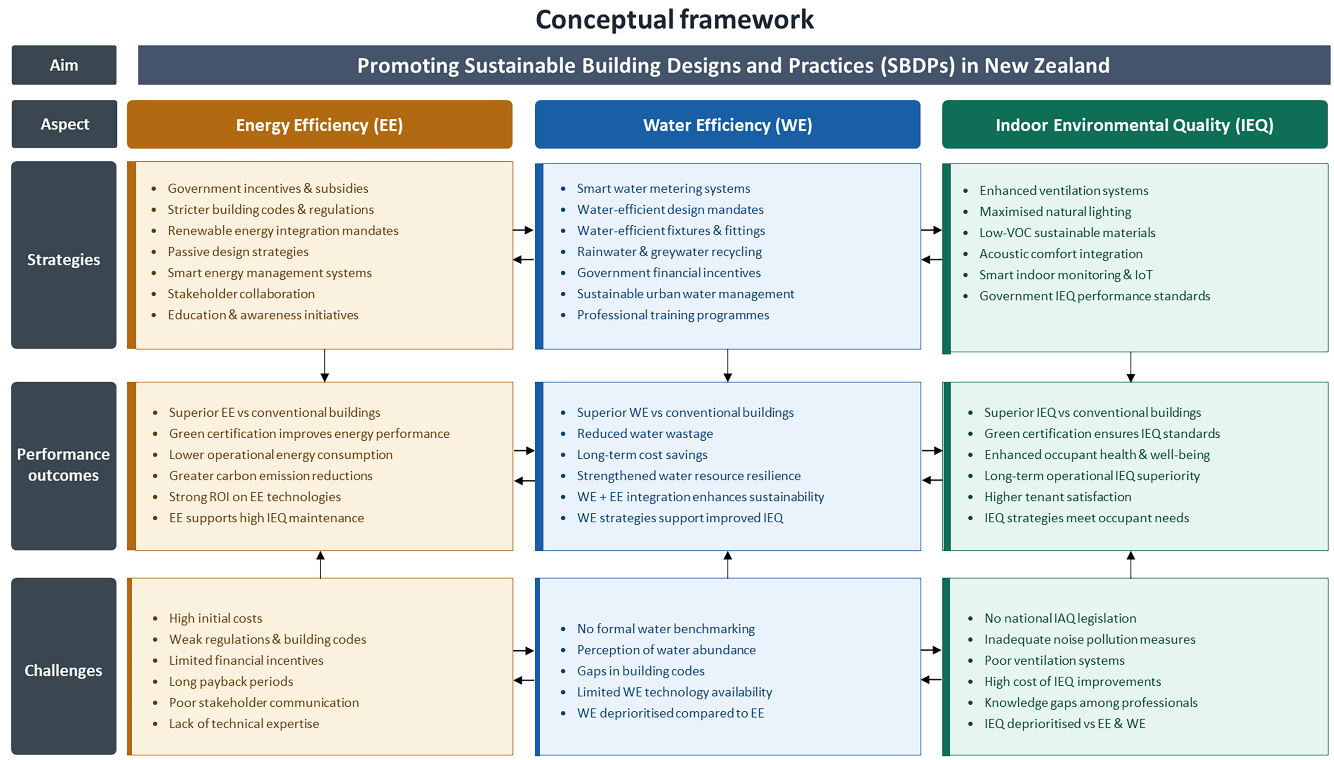


FIGURE 1 | Conceptual framework to promote SBDPs in New Zealand.

equate. Similarly, passive-design measures that reduce energy consumption must be carefully designed to avoid overheating, glare, or insufficient air movement. Vosoughkhosravi et al. (2022) further identified associations between green-building certification, energy performance and occupant satisfaction. These findings demonstrate that EE strategies should not be evaluated solely according to energy savings but also according to their implications for occupant well-being.

Compared with the EE–WE and EE–IEQ relationships, the interaction between WE and IEQ remains comparatively underexplored. Nevertheless, water-management decisions can directly affect occupant health and IEQ because moisture control and plumbing-system design may influence hygiene, mould risks, odour and occupant well-being (Poorisat et al. 2026a). For example, poorly designed or inadequately maintained water systems may increase moisture-related risks, whereas effective water-management strategies can enhance sanitation and support healthier IEQ. WE should therefore be evaluated not only in terms of water savings but also in relation to its potential effects on IEQ. The three domains are consequently linked through multiple causal pathways, as reducing water demand can lower energy use; energy-efficient systems can reduce the energy intensity of water provision; ventilation and envelope strategies can simultaneously improve or constrain energy performance and IEQ; and water-management decisions can influence hygiene, moisture conditions and occupant health (Poorisat et al. 2026a). These pathways demonstrate that improvements in one domain may reinforce outcomes in another, but they may also create trade-offs when implemented without an integrated design and operational approach. A fragmented, pairwise analysis is therefore insufficient to explain the broader system of interactions.

As shown in Figure 1, the proposed conceptual framework integrates EE, WE, and IEQ through three analytical dimensions: strategies, performance outcomes and challenges. Strategies represent the technical, regulatory, financial, and stakeholder-oriented interventions required to improve SBDPs. Performance outcomes reflect the expected environmental, economic, and occupant-related benefits arising from these interventions. Challenges identify the institutional, technical, financial, and knowledge-related barriers that may constrain their implementation and effectiveness. Rather than presenting EE, WE, and IEQ as parallel categories, the framework recognises that the strategies, outcomes, and challenges associated with each domain are causally interconnected. For instance, limited financial incentives and weak regulatory requirements may restrict investment in energy- and water-efficient technologies, while inadequate professional knowledge may result in poorly designed ventilation or water-reuse systems that compromise IEQ (Ebekozien et al. 2024).

Two complementary theoretical perspectives further explain how the EE–WE–IEQ nexus is realised in practice. First, the socio-technical perspective recognises that sustainable building performance is shaped by interactions between technical artefacts, such as building technologies and design solutions, and social structures, including regulations, market incentives, professional norms, stakeholder collaboration, and user behaviour (Poorisat et al. 2026b). Accordingly, the adoption and effectiveness of EE, WE, and IEQ innovations depend not only on technical maturity but also on institutional support and stakeholder alignment (Poorisat et al. 2026b). Second, the building performance gap framework recognises that actual in-use performance may diverge from design expectations because of commissioning deficiencies, operational-management practices, maintenance limitations and occupant behaviour (Moradi et al. 2024). This perspective is particularly important when interpreting stakeholder perceptions, as perceived performance should not automatically be treated as equivalent to verified operational outcomes (Díaz-López et al. 2021). Together, the EE–WE–IEQ nexus, socio-technical perspective, and building performance gap framework provide the conceptual foundation for examining how strategies, challenges, and performance outcomes interact to promote SBDPs in New Zealand. The framework advances beyond the coexistence of three sustainability domains by explicitly recognising their causal relationships, synergies and trade-offs.

2.2 | Existing Challenges Influencing EE, WE, and IEQ for SBDPs

Despite the well-documented benefits of EE, WE, and IEQ, SBDPs continue to face substantial implementation challenges across diverse geographic and policy contexts (Poorisat et al. 2024). EE is central to SBDPs, requiring advanced technologies, regulations, and stakeholder engagement (Poorisat et al. 2024). EE progress is constrained by financial, regulatory, socio-cultural, and environmental barriers, along with challenges in applying energy-efficient technologies (Remeikienė et al. 2021). In Asia, construction is a major Greenhouse Gas (GHG) emitter, with the Asia-Pacific region using 60% of global energy, including China and India (Zhang et al. 2021). The challenges comprise the regulation enforcement gap, high initial costs, long payback period, and lack of educational awareness (Cao et al. 2022; Saha et al. 2022). In Europe, buildings consume 40% of energy and emit 36% of GHGs, while the EU promotes EE, barriers include high initial costs, a lack of education awareness and a lack of funding (Kangas et al. 2018).

In Oceania, New Zealand and Australia face high building energy demand (Moore and Holdsworth 2019). In Australia, buildings account for 45% of national use, with barriers including high costs, weak incentives and limited awareness (Brown et al. 2024; Martek et al. 2019). In addition, New Zealand's sector accounts for 22% of energy use and 20% of emissions (IEA 2023). Despite high renewable penetration, challenges include outdated building codes, absent certification and cost-driven resistance (Bui et al. 2023; Cielo and Subiantoro 2021). These gaps highlight opportunities for stronger policies, incentives, and education to accelerate NZEBs adoption. WE is also hindered by several challenges globally (Poorisat et al. 2024). For example, Ali et al. (2020) mentioned that low-flow fixtures may be impractical in situations where system pressure is insufficient, highlighting the importance of considering local infrastructural conditions when implementing such technologies.

In the context of New Zealand, Bint et al. (2019) pointed out that the absence of clear guidelines limits the capacity of buildings to achieve meaningful water savings consistently. In addition to technical and regulatory barriers, financial concerns also play a significant role. Antão-Geraldes et al. (2023) emphasised that improvements in WE often entail higher upfront costs, which must be carefully weighed against the long-term revenue benefits and potential resource savings. Collectively, these findings suggest that while technological and design strategies for WE exist, their effectiveness is highly context-dependent, shaped by infrastructure, regulatory frameworks and economic considerations.

Despite their recognised benefits, IEQ strategies remain difficult to implement (Poorisat et al. 2024). Key barriers include fragmented design processes, as IEQ is often addressed separately rather than through integrated project delivery, and long payback periods, particularly when health and productivity benefits are difficult to quantify (Afful et al. 2023). A further challenge is balancing IEQ with EE objectives, since measures such as increased ventilation may improve IAQ while raising energy demand (Niza et al. 2023). The COVID-19 pandemic intensified this challenge by increasing expectations for fresh-air supply and filtration (Anand et al. 2022). Accordingly, multidisciplinary education and stronger financial or policy incentives are needed to support the wider adoption of IEQ best practices.

2.3 | Strategies Influencing EE, WE, and IEQ in Sustainable Buildings

Addressing the challenges associated with EE, WE, and IEQ requires a coordinated set of strategic interventions. Although the relative importance of individual measures varies according to climatic, regulatory, economic, and socio-cultural conditions, the literature consistently indicates that effective SBDPs depend on a combination of technical solutions, policy support, financial incentives, professional knowledge and occupant engagement. The following sections examine the principal strategies used to improve EE, WE, and IEQ internationally before considering their relevance to the New Zealand context. Enhancing EE requires a multifaceted approach that integrates technical, governmental, financial, socio-cultural, and knowledge-based measures with common technical strategies, including the adoption of energy-efficient building systems, passive-design principles, and on-site renewable-energy technologies (Hafez et al. 2023). However, the effectiveness of these measures is strongly influenced by the regulatory and climatic contexts in which they are implemented. In Asia, policy, regulatory, and educational interventions are particularly prominent. Cao et al. (2022) emphasised the importance of mandatory green-building requirements, targeted financial incentives and awareness and education programmes. In tropical climates, passive-design measures such as green roofs, solar-energy integration, and strategies to reduce cooling demand are particularly important for improving EE (Lai et al. 2023).

European studies similarly highlight the role of financial returns, incentive mechanisms, regulatory frameworks, and knowledge dissemination. Technological measures such as green façades, solar-thermal systems, and heat pumps are becoming increasingly significant (Carlander and Thollander 2022). Furthermore, Palm and Bryngelson (2023) demonstrated that leadership commitment and long-term organisational strategies are critical for accelerating the adoption of EE measures. In Africa, the literature places greater emphasis on retrofit and passive-design interventions (Nematchoua and Reiter 2021). Key strategies include lighting retrofits, HVAC upgrades, renewable-energy integration, and the adoption of low-energy appliances (Ebekozien et al. 2022; Ezema and Maha 2022). Moreover, Ohene et al. (2022) highlighted the role of daylighting, natural ventilation, and photovoltaic systems in supporting NZEB targets, while emphasising the importance of supportive policies and economic incentives.

Improving WE similarly requires a combination of technological solutions, supportive policies and active occupant engagement (Poorisat et al. 2024). The urgency of these interventions is particularly evident in regions experiencing increasing water insecurity (Nkiaka et al. 2021). In Asia, more than 75% of the region experiences water insecurity, while over 90% of the population is exposed to the risk of an impending water crisis. For example, Thebuwena et al. (2024) demonstrated that dual-flush systems combined with rainwater harvesting and greywater reuse can reduce indoor water consumption by approximately 30%–60%. Similar trends are evident in Australia and New Zealand, where smart water metering has received increasing attention because of its economic and operational benefits (Koech et al. 2021). Water-efficient fixtures are also consistently incorporated into six-star Green Star-rated buildings (Pollard 2022). More broadly, municipalities worldwide are introducing policies that combine efficient fixtures, water-recycling systems, and landscape-management controls to reduce total water demand (Poorisat et al. 2024). Evidence from green-building rating systems supports these findings, with certified projects typically achieving average water savings of approximately 30%–40% (Al-Qawasmi et al. 2019).

Strategies for improving IEQ focus on source control, ventilation, acoustic performance and human-centric design (Poorisat et al. 2024). For IAQ, source control represents a primary strategy. This involves specifying low-emitting materials and furnishings and eliminating hazardous substances such as asbestos and formaldehyde (Afful et al. 2023). Also, Zhang et al. (2024) highlighted the importance of acoustic comfort in supporting occupant performance and satisfaction. Similarly, Asojo and Hazazi (2025) demonstrated that connections with the outdoor environment, including daylight access, external views, and biophilic design elements, can enhance visual comfort and strengthen overall IEQ. When carefully integrated, these strategies can also support EE by reducing reliance on artificial lighting and mechanical conditioning systems (Poorisat et al. 2026a).

New Zealand presents a distinctive context for advancing EE, WE and IEQ. On the one hand, the country benefits from a relatively high proportion of renewable-energy generation (Cielo and Subiantoro 2021) and comparatively abundant freshwater resources (Suazo 2022). On the other hand, several structural and regulatory barriers continue to constrain progress. For EE, the absence of a comprehensive building-certification framework, together with slow updates to building codes for NZEBs, limits the wider adoption of innovative sustainability practices (Doan, Wall, et al. 2021). For WE, urban centres such as Auckland have introduced water-metering and management initiatives, yet the lack of consistent policy support, benchmarking systems, and public awareness continues to restrict broader uptake (Bint et al. 2019). Recurring droughts and water shortages further demonstrate that WE remains important even in a country generally perceived as water-rich (Morton 2023). IEQ is also a significant concern as a substantial proportion of New Zealand's building stock remains inadequately insulated or heated, contributing to respiratory illnesses and excess winter mortality (Ade and Rehm 2020b). While the Resource Management Act establishes outdoor air-quality standards, no equivalent regulatory framework exists for IEQ (Kabir and Morgan 2021). This gap, combined with ageing buildings and limited research on IEQ in commercial properties, increases potential risks to occupant health and well-being (Rasheed and Rotimi 2022).

Although international studies have examined the relationships among EE, WE, and IEQ, the literature remains conceptually fragmented. Existing research has generally investigated individual domains or limited pairwise relationships rather than modelling EE, WE, and IEQ as an integrated system. As shown in Table 1, international studies provide useful but fragmented evidence on the relationships among EE, WE, and IEQ. Pinto et al. (2017) quantified the water–energy nexus in hotels, showing that water use is closely linked to energy demand for pumping, hot-water production, distribution, and building-services. Thebuwena et al. (2024) similarly demonstrated that efficient fixtures, native landscaping, rainwater harvesting, cooling-tower improvements, and condensate-water reuse can reduce water demand in commercial buildings. These studies confirm that EE and WE are interdependent, but they do not fully address occupant-focused IEQ outcomes or explain how resource-efficiency measures affect indoor conditions. Other studies focus more directly on IEQ or EE. Abdulaali et al. (2020) reviewed the effects of IAQ, thermal comfort, lighting, and acoustics on occupant health, well-being, and satisfaction, while Afful et al. (2023) identified economic, capacity-related, process-related, cultural, client-related, and steering barriers to IEQ integration. Hafez et al. (2023) synthesised evidence on EE technologies, policies, passive-design measures, rating systems and broader sustainability considerations.

However, these studies remain largely domain-specific and do not systematically examine EE, WE, and IEQ as co-equal and interdependent performance dimensions. Vosoughkhosravi et al. (2022) provide a closer comparison by examining electricity, natural gas, water consumption, and IEQ-related satisfaction across residential college buildings. The study found that a LEED-certified building did not necessarily outperform non-certified buildings in energy and water use, although it achieved higher comfort satisfaction. This finding shows that improvement in one domain does not automatically produce equivalent gains in others. However, the study was limited to a building-level comparison and did not develop an integrated EE–WE–IEQ framework.

Therefore, the research gap is both geographical and conceptual. EE, WE, and IEQ are often treated as parallel sustainability categories, despite being connected through causal pathways. Reducing water demand can lower energy use for treatment, pumping, distribution and heating (Thebuwena et al. 2024). Ventilation, airtightness, and envelope strategies can improve EE while affecting IAQ and thermal comfort (Perera et al. 2025). Similarly, water-management decisions may influence hygiene, moisture conditions and occupant well-being. Studying these domains separately may therefore obscure synergies, overlook trade-offs, and encourage optimisation of one objective at the expense of another (Poorisat et al. 2026a). This issue is especially relevant in New Zealand. The country presents a distinctive combination of relatively high renewable-energy generation,

TABLE 1 | Comparison of selected international studies relevant to the EE–WE–IEQ nexus.

Study	Country and context of study	Domains examined	Key contribution	Limitations relevant to the present study
Pinto et al. (2017)	Portugal: nine four- and five-star hotels	EE–WE	• Quantifies the water–energy nexus in hotels. • Identifies savings from efficient fixtures, pumps and pipe insulation.	• Sector-specific sample. • Excludes IEQ and occupant-health outcomes. • Does not assess three-way interactions.
Vosoughkhosravi et al. (2022)	United States: eight residential college buildings	EE–WE and IEQ-related satisfaction	• Compares electricity, gas and water use. • Assesses satisfaction with temperature, water services, air quality, lighting and comfort. • Shows that certification does not guarantee improved performance across all domains.	• Includes only one LEED-certified building. • Focuses on building-level comparison. • Does not develop an integrated EE–WE–IEQ framework.
Abdulaali et al. (2020)	International: narrative literature review	IEQ and occupant well-being	• Reviews IAQ, thermal comfort, lighting and acoustics. • Links poor IEQ with health, comfort and satisfaction.	• Focuses on IEQ outcomes. • Does not evaluate EE–WE interactions. • Lacks empirical building-performance analysis.
Hafez et al. (2023)	International: systematic literature review	EE with wider sustainability considerations	• Synthesises EE technologies, policies, passive strategies, rating systems and research gaps. • Highlights environmental, economic and social considerations.	• Predominantly EE-centred. • Does not examine WE and IEQ as co-equal domains • Does not assess cross-domain interactions systematically.
Afful et al. (2023)	International systematic literature review	IEQ-design barriers	• Identifies 24 IEQ-design barriers. • Categorises barriers into six categories. • Illustrates their interrelationships.	• Literature-based findings require empirical validation. • Focuses on IEQ adoption barriers. • Excludes EE–WE interactions.
Thebuwena et al. (2024)	Hot-humid tropical context: high-rise office-building case study	WE with building-services considerations	• Evaluates water-saving measures at the design stage. • Highlights efficient fixtures, rainwater harvesting, cooling-tower improvements and condensate reuse.	• Single-building case study. • Primarily WE-focused. • Excludes occupant-focused IEQ outcomes and three-way interactions.
Present study	New Zealand: survey of 102 building professionals	EE–WE–IEQ	• Examines perceived performance outcomes, challenges, and strategies across all three domains. • Positions EE, WE, and IEQ as interconnected dimensions of sustainable building performance.	• Uses perception-based evidence. • Future studies should triangulate findings with measured POE.

perceived freshwater abundance, recurring water-security concerns, uneven adoption of green-building certification and limited regulation of IEQ (Cielo and Subiantoro 2021; Poorisat et al. 2026a). These contextual characteristics may shape the perceived priorities, barriers, and feasible strategies associated with sustainable building performance differently from those reported internationally. The New Zealand context should therefore not be treated as a simple geographical extension of existing studies.

Rather, it provides an analytically relevant setting in which to examine whether international assumptions concerning EE, WE, and IEQ integration remain applicable under different institutional, climatic and resource conditions. Accordingly, the present study addresses a clearly defined scientific gap by examining EE, WE, and IEQ simultaneously within a unified analytical framework. It evaluates stakeholder perceptions of performance outcomes, implementation challenges, and improvement strategies across all three domains rather than treating them as isolated priorities. Although the findings are perception-based and should subsequently be triangulated with measured post-occupancy evaluation (POE), the study establishes an empirical foundation for understanding where cross-domain synergies are recognised, where trade-offs may arise, and where integrated reasoning remains underdeveloped within the New Zealand built-environment sector.

3 | Materials and Methods

This section outlines the methodological approach used to examine stakeholder perspectives on EE, WE, and IEQ within SBDPs in New Zealand. A quantitative survey method was adopted, using a structured questionnaire informed by prior expert interviews to investigate perceived building performance, implementation challenges and potential strategies. The following subsections detail the research design, questionnaire structure, sampling strategy, data collection procedures, and statistical analyses to ensure methodological transparency, validity and reliability.

3.1 | Research Design

This study adopted a quantitative research design using an online survey to examine stakeholder perspectives on EE, WE, and IEQ in SBDPs across New Zealand. Online surveying was selected due to its capacity to collect quantifiable data efficiently from diverse stakeholder groups within a short timeframe and at relatively low cost (Saharan et al. 2024). This method also strengthens the generalisability of findings and complements earlier qualitative work based on 43 expert interviews (Poorisat et al. 2026a), thereby supporting methodological triangulation and enhancing rigour and comparability (Gray 2021). The questionnaire comprised four sections: (1) demographic information, (2) EE in SBDPs, (3) WE in SBDPs and (4) IEQ in SBDPs. Items relating to EE, WE and IEQ were further organised across three analytical dimensions: (i) performance, (ii) challenges to implementation and (iii) strategies to enhance effectiveness. The demographic section captured information on respondents' professional background, including qualifications, current job title, employment status, stakeholder category, years of experience, highest education level, location of professional experience, building typologies worked with and organisational size.

Guided by findings from prior expert interviews, key variables and measurement items were developed to reflect stakeholder perceptions of these three thematic domains (Poorisat et al. 2026a). Table 2 summarises the measurement constructs used in the online survey, including the perceived performance, challenges, and recommended strategies concerning EE, WE, and IEQ in New Zealand's SBDPs context. All items were rated on a five-point Likert scale (1 = Strongly Disagree; 2 = Slightly Disagree; 3 = Neutral; 4 = Slightly Agree; 5 = Strongly Agree). This scale is widely recognised for its clarity and balance, offering two levels of agreement and disagreement with a neutral midpoint, thereby supporting reliable comparison across items and respondent groups (Aybek and Toraman 2022).

The target population consisted of construction professionals and stakeholders with at least 3 years of practical experience in SBDPs in New Zealand. This included architects, engineers, surveyors, contractors, Green Star Accredited Professionals, Green Star Practitioners, project managers, researchers and facility managers. Their direct involvement in SBDPs positioned them to provide informed insights into the performance, challenges, and strategies of EE, WE, and IEQ. A purposive sampling strategy was adopted to ensure that only qualified and experienced professionals familiar with SBDPs were included, which strengthened the credibility and relevance of the findings by aligning the sample profile with the study's objectives (Campbell et al. 2020).

The online survey was developed and administered using the Qualtrics platform (Qualtrics 2024). Distribution channels included direct email outreach through contact databases from the New Zealand Green Building Council (NZGBC) and the Architectural Designers New Zealand (ADNZ). Over 2 months, 562 invitations were distributed, yielding 102 complete responses retained for the final analysis. This equates to a response rate of 19%, which is considered acceptable in comparable research contexts (Antony et al. 2021; Rodriguez-Nikl et al. 2014). Although the response rate may appear modest, it reflects the niche and emergent nature of SBDPs within the New Zealand construction sector (Doan, Wall, et al. 2021). A sample size of approximately 100 participants is widely considered acceptable for exploratory studies of this type, which is consistent with prior research in construction and environmental studies employing purposive sampling with $n \approx 100$ for specialised professional populations (Eze et al. 2023; Ping Chuen Chan et al. 2017). Such sample sizes are deemed sufficient to yield statistically valid insights when the population is both highly knowledgeable and relatively homogeneous regarding the subject matter. Furthermore, the sample met the minimum requirements for statistical analyses, including descriptive statistics, reliability testing, and Partial Least Squares Structural Equation Modelling (PLS-SEM), as recommended by Hair et al. (2019). The qualifications and experience of respondents, most with over 3 years of direct involvement in SBDPs, further enhanced the credibility of the findings.

3.2 | Data Analysis

Data collected from the online survey were analysed using both descriptive and statistical tests, with the aid of the Statistical Package for the Social Sciences (SPSS) Version 29. To help achieve the research objectives, a structured multi-stage analytical framework was employed to ensure rigour and directly

TABLE 2 | EE, WE, and IEQ: performance, challenges, and strategies in SBDPs.

Aspects	EE	WE	IEQ
Performance comparison	*E1P*: Sustainable buildings in New Zealand perform significantly better in EE than conventional buildings. *E2P*: Green building certifications improve the energy performance of buildings. *E3P*: Sustainable buildings consume less operational energy than conventional buildings. *E4P*: Sustainable buildings reduce carbon emissions more effectively than conventional buildings. *E5P*: Energy-efficient technologies in sustainable buildings deliver strong returns on investment. *E6P*: The gap between the designed and actual energy performance of sustainable buildings is minimal. *E7P*: Improving EE supports the maintenance of high indoor environmental quality.	*W1P*: Sustainable buildings in New Zealand perform significantly better in WE than conventional buildings. *W2P*: Sustainable buildings reduce water wastage more effectively than conventional buildings. *W3P*: Implementing water-efficient strategies in sustainable buildings results in long-term cost savings. *W4P*: Sustainable buildings strengthen water resource resilience, particularly in drought-prone areas. *W5P*: Integrating WE and EE strategies enhances overall building sustainability. *W6P*: Implementing water-efficient strategies supports or improves IEQ.	*I1P*: Sustainable buildings in New Zealand perform significantly better in IEQ than conventional buildings. *I2P*: Green building certifications ensure that IEQ is effectively addressed in building design. *I3P*: Sustainable buildings enhance occupant health and well-being through improved IEQ. *I4P*: The long-term operational performance of SBDPs ensures superior IEQ *I5P*: Tenant satisfaction is generally higher in sustainable buildings compared to conventional buildings. *I6P*: Existing IEQ strategies in sustainable buildings effectively meet occupant needs.
Challenges	*C1E*: High initial costs hinder the adoption of energy-efficient measures. *C2E*: Weak regulations and building codes limit the enforcement of energy-efficient practices. *C3E*: Limited financial incentives reduce stakeholder motivation to implement EE solutions. *C4E*: Long payback periods discourage investment in energy-efficient technologies. *C5E*: Poor communication among stakeholders impedes energy-efficient project implementation. *C6E*: A lack of technical expertise among stakeholders limits the adoption of energy-efficient measures.	*C1W*: The absence of formal water benchmarking in non-residential buildings limits the adoption of water-efficient measures. *C2W*: The public perception of water abundance in New Zealand reduces the urgency to implement water efficiency strategies. *C3W*: Gaps in building codes and regulations hinder the adoption of water-efficient practices. *C4W*: The limited availability of water-efficient technologies restricts their implementation in buildings. *C5W*: WE is often deprioritised in building design compared with EE.	*C1I*: The lack of national legislation on IAQ limits the enforcement of IEQ standards. *C2I*: Sustainable buildings in New Zealand often fail to adequately address noise pollution. *C3I*: Poor ventilation systems contribute to low IEQ. C4I: The high cost of sustainable IEQ improvements limits their adoption. *C5I*: Knowledge gaps among building professionals affect the optimal design of IEQ strategies. *C6I*: IEQ is often deprioritised in favour of EE and WE
Strategies	*S1E*: Government incentives and subsidies promote the adoption of energy-efficient measures. *S2E*: Stricter building codes and regulations improve the implementation of energy-efficient practices. *S3E*: Mandating the integration of renewable energy sources in new buildings promotes EE. *S4E*: Applying passive design strategies enhances EE. *S5E*: Smart energy management systems significantly reduce energy consumption in buildings. *S6E*: Stakeholder collaboration is essential for the successful adoption of energy-efficient solutions. *S7*E: Education and awareness initiatives support the implementation of EE practices.	*S1W*: Installing smart water metering systems supports WE in buildings. *S2W*: Mandating water-efficient designs and recycling techniques improves water conservation. *S3W*: Adopting water-efficient fixtures and fittings enhances WE. *S4W*: Mandating rainwater harvesting and greywater recycling increases water reuse in buildings. *S5W*: Providing government financial incentives encourages the adoption of water-efficient measures. *S6W*: Implementing sustainable urban water management strategies supports WE. *S7W*: Offering training programmes for building professionals strengthens knowledge and application of water-efficient practices.	*S1I*: Enhancing ventilation systems should be prioritised in sustainable buildings. *S2I*: Maximising natural lighting improves occupant well-being and productivity. *S3I*: Mandating the use of sustainable building materials, including low-VOC paints and non-toxic finishes, improves IEQ. *S4I*: Integrating acoustic comfort into building design enhances IEQ. *S5I*: Implementing smart indoor environment monitoring systems and IoT technologies improves building performance. *S6I*: Government policies should establish minimum IEQ performance standards for sustainable buildings.

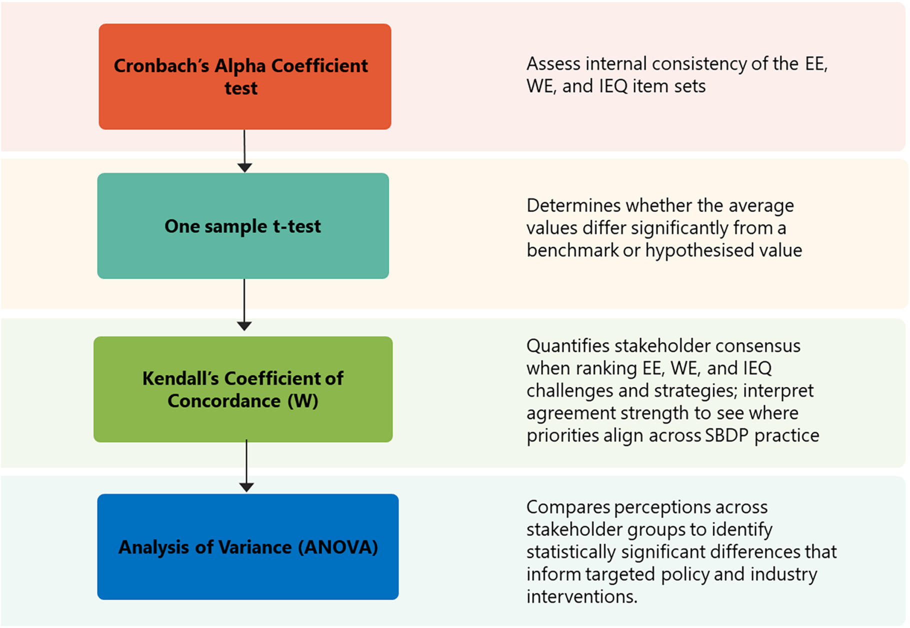


FIGURE 2 | Sequential data analysis procedure used to validate the survey instrument and examine stakeholder perceptions of EE, WE, and IEQ in relation to SBDPs in New Zealand.

address the research objectives, as shown in Figure 2, which consisted of four sequential stages.

First, Cronbach's Alpha was employed to assess the internal consistency of the grouped Likert-scale items across EE, WE, and IEQ, as well as the identified performance factors, challenges and strategies. Only constructs with $\alpha \geq 0.70$ were considered sufficiently reliable for further analysis (García-García et al. 2024). The results demonstrated strong reliability across all three main constructs, with EE showing good internal consistency ($\alpha = 0.828$) and both WE ($\alpha = 0.867$) and IEQ ($\alpha = 0.858$) achieving very good internal consistency. These coefficients confirm that the scales measuring EE, WE, and IEQ are internally consistent, thereby validating the use of the questionnaire data for subsequent statistical analyses (García-García et al. 2024). Second, one-sample t-tests were conducted as the primary inferential analysis to determine whether the mean responses to each item significantly differed from the neutral midpoint of the five-point Likert scale ($\mu = 3$). This established whether stakeholders perceived SBDPs in New Zealand as performing better than conventional buildings and whether challenges and strategies were genuinely endorsed (Marzban et al. 2023).

Null Hypothesis H_0. *$\mu = 3$ (neutral perception).*

Decision rule: H_0 was rejected if $p < 0.05$, indicating that stakeholder perceptions significantly deviated from neutrality.

In addition, Kendall's Coefficient of Concordance (W) was used to assess the level of agreement among stakeholders when ranking the relative importance of challenges, strategies and influence (Franceschini and Maisano 2021). Finally, one-way Analysis of Variance (ANOVA) was applied to examine whether significant differences existed between stakeholder groups. This analysis identified variations in perceptions linked to professional roles, with consideration of effect sizes (Kore et al. 2023). Together, this analytical framework ensured both the reliability of measures and the robustness of results, while keeping the one-sample t-test as the central hypothesis-driven test supported by group comparison and consensus analysis (Franceschini and Maisano 2021; Marzban et al. 2023).

The analytical techniques were aligned with the descriptive and comparative nature of the research questions. The one-sample t-test was used because RQ1–RQ3 examine whether stakeholders endorsed each performance, challenge, and strategy item relative to a defined point of indifference. The neutral midpoint of the five-point Likert scale ($\mu = 3$) was therefore used as the benchmark; means significantly above 3 indicate endorsement rather than neutrality (Ross and Willson 2017). Kendall's coefficient of concordance (W) was selected to assess agreement in rankings across respondents within stakeholder groups (Franceschini and Maisano 2021), while one-way ANOVA, with η^2 effect sizes, was used to examine differences by professional role. Together, these tests provide evidence of central tendency, consensus, and between-group variation appropriate for an exploratory, perception-based study (Hassan et al. 2024). The full structural PLS-SEM model was not estimated in this paper because the aim was to assess stakeholder endorsement and group consensus rather than test latent causal pathways. A separate companion PLS-SEM analysis examines the hypothesised EE–WE–IEQ relationships, focusing on the structural relationships and path estimation. For each indicator, Cohen's d and its 95% confidence interval were reported alongside the t statistic to convey both the magnitude and precision of the deviation from neutrality; the complete per-indicator statistics are provided in Supporting Information A (Tables S9–S11).

Beyond internal consistency, assessed using Cronbach's α, content and face validity were established before data collection. The survey items were developed from a systematic review of SBDP literature and informed by 43 prior expert interviews

(Poorisat et al. 2024, 2026a). The draft questionnaire was also reviewed by domain experts and pilot-tested with practitioners to improve wording, sequencing and clarity. The full survey instrument is provided as Supporting Information B to support transparency and replication. Only fully completed responses were retained ($n = 102$); therefore, listwise treatment was applied, and no missing-value imputation was required. Effect sizes, including η^2 for ANOVA and Cohen's d for one-sample tests, are reported alongside significance values to support interpretation of practical magnitude as well as statistical significance. Full item-level results, effect sizes, and 95% confidence intervals are provided in (Supporting Information A, Tables S9–S11).

3.2.1 | Supplementary Measurement-Model Assessment

To strengthen instrument validation, a supplementary PLS-SEM measurement-model assessment was conducted using the same survey dataset ($n = 102$). Two models were estimated separately: a strategy-driven model examining EE, WE, and IEQ strategies with their corresponding performance constructs, and a challenge-driven model examining implementation barriers with the same performance domains. This distinction reflects the conceptual difference between enabling interventions and barriers, while avoiding unnecessary model complexity (Ahmad et al. 2024). For the reflective constructs, indicator reliability was assessed through outer loadings, internal consistency through Cronbach's α, ρ_a and ρ_c, convergent validity through Average Variance Extracted (AVE), and discriminant validity through Fornell–Larcker and HTMT criteria. HTMT inference was further examined using one-tailed bootstrapping with bias-corrected confidence intervals based on 10,000 subsamples (Hair et al. 2021). Indicators with weaker loadings were not removed automatically. Retention decisions considered loading strength, the effects of item removal on reliability and AVE and theoretical coverage. While item-level analyses, including one-sample t-tests and stakeholder-ranking analyses, used the full survey instrument, the supplementary PLS-SEM assessment evaluated only the retained reflective indicator sets. Excluded items may therefore be interpreted as standalone perception items but not as components of the validated latent constructs.

Across both models, composite reliability exceeded 0.78 for all constructs ($\rho_c = 0.784–0.922$), supporting internal consistency. Although some AVE values were marginally below 0.50, particularly for strategy and challenge constructs, convergent validity was retained because composite reliability remained above 0.70, consistent with Fornell and Larcker (1981) and Hair et al. (2021). Discriminant validity was supported by Fornell–Larcker results and HTMT ratios below 0.90; the highest HTMT value was 0.851 between WE Strategies and IEQ Strategies. All bootstrapped confidence-interval upper bounds remained below 1.00, confirming discriminant validity. Tables S1–S8 report the full measurement-model results, while the structural model is presented separately in a companion study.

4 | Results and Discussion

This section presents and interprets the results of the online survey administered to stakeholders involved in SBDPs across New Zealand. The findings combine descriptive and inferential analyses to examine respondents' demographic and professional attributes, alongside their perceptions of the influence, challenges, and strategies associated with EE, WE and IEQ. Statistical techniques, including one-sample t-tests, Kendall's coefficient of concordance (W), and ANOVA, were applied to assess levels of stakeholder consensus, differences across respondent groups, and interrelationships among the three domains. Together, these analyses reveal areas of alignment and divergence that inform opportunities to strengthen integrated SBDPs within New Zealand's built environment.

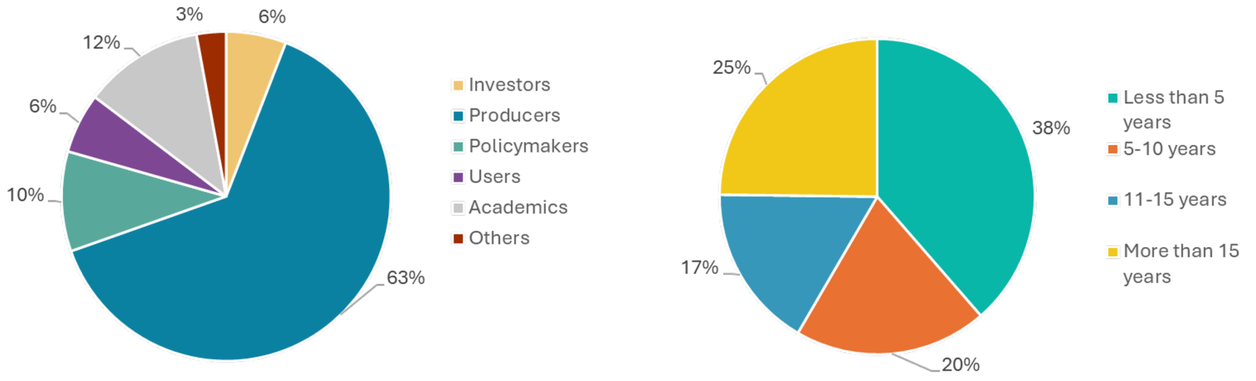
4.1 | Respondents' Profile

The demographic and professional profile of survey participants is presented in Figure 3, while Figure 4 outlines their project involvement, organisational scale and geographic distribution. Together, these figures provide a comprehensive overview of the stakeholders engaged in SBDPs. The majority of respondents identified as designers/engineers (41%) and consultants (26%), followed by decision-makers (15%), policy development (7%), and researchers (2%), with 9% categorised as other, which indicates that technical and advisory professionals dominate the SBDP landscape, highlighting the emphasis on practical insights of SBDPs. Stakeholder categories were defined based on the stakeholder characterisation developed in an earlier phase of this research (Poorisat et al. 2026b), which identified the key stakeholder groups involved in SBDP decision-making. In terms of stakeholder categories, producers were most represented (63%), while users (12%), policymakers (10%), academics (6%) and investors (6%) featured less prominently.

Respondents were generally well-qualified, with 33% holding a bachelor's degree, 24% a master's, and 15% a doctorate, alongside smaller proportions with postgraduate diplomas (6%), polytechnic training (16%), college (2%) and high school (4%). This educational profile reflects the multidisciplinary expertise needed to address EE, WE, and IEQ within SBDPs. Professional experience was also well distributed: 38% had fewer than 5 years, 20% had 5–10 years, 17% had 11–15 years, and 25% had more than 15 years of involvement. This balance indicates contributions from both emerging practitioners and seasoned experts.

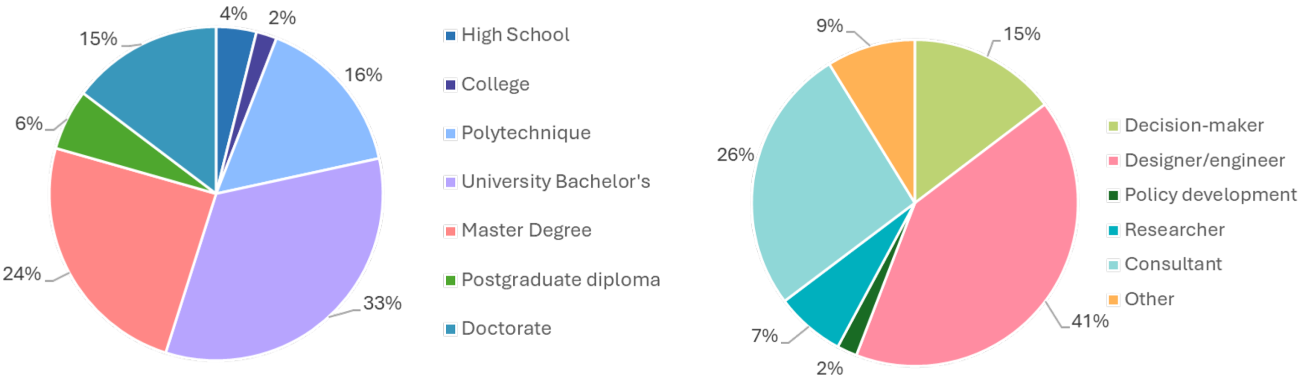
As shown in Figure 4, most respondents were involved in residential (84%) and commercial (83%) projects, mirroring dominant national development trends. Engagement in institutional (68%) and industrial (57%) sectors was also substantial, indicating growing uptake of sustainability in specialised fields such as healthcare, education and manufacturing. Only 11% reported involvement in other building types. Organisation size was evenly represented, with 39% from large firms, 36% from small enterprises, and 25% from medium-sized companies, suggesting that SBDPs are not confined to specific market segments. Regionally, Auckland accounted for 36% of responses, followed by Wellington (14%) and Christchurch (10%), with the remaining 40% distributed nationwide.

Auckland's prominence reflects major development activity, while Wellington's representation aligns with its policy role. Christchurch's share highlights sustainability considerations in



a: Respondent category

b: Years of experience



c: Highest Degree

d: Involvement of stakeholders in SBDPs

FIGURE 3 | Demographic and professional profile of respondents ($n = 102$), including stakeholder category, SBDP experience, education level, and professional involvement.

post-earthquake redevelopment. Overall, the sample comprises a technically skilled, practice-oriented respondent group, spanning varied career stages, project types, organisational sizes, and regions, providing a robust basis for analysing stakeholder perceptions of EE, WE and IEQ in subsequent sections.

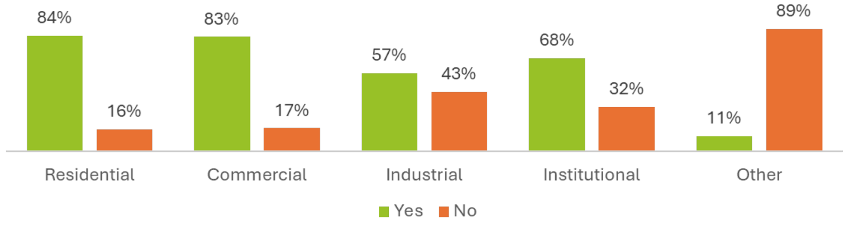
4.2 | Comparing EE, WE, and IEQ in SBDPs to Conventional Buildings in New Zealand

A one-sample *t*-test was performed to assess whether stakeholders perceived the performance of SBDPs in New Zealand to be significantly higher than that of conventional buildings, using a test value of 3 (neutral) as the benchmark. The mean ranking analyses were also conducted to determine the relative importance of indicators within each domain. These analyses jointly reveal both the statistical significance and perceived strength of performance differences across EE, WE and IEQ (see Figure 5).

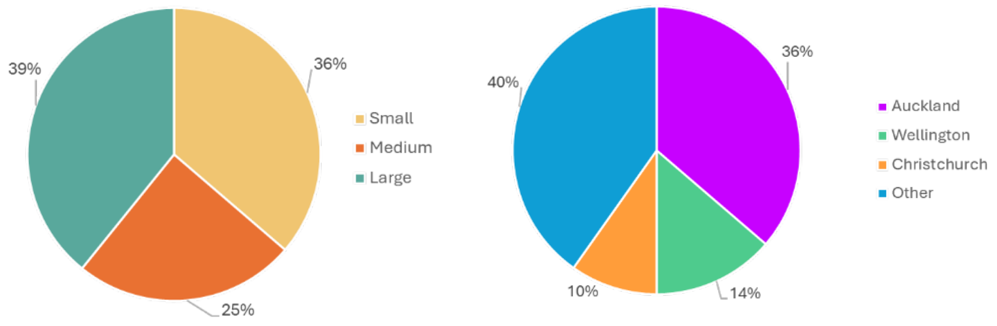
4.2.1 | EE Influence

Across the 19 influence indicators, effect sizes ranged from small to very large (Cohen's $d = 0.18–1.87$), the strongest being *E1P* ($d = 1.87$, 95% CI [1.55, 2.19]) and *E3P* ($d = 1.60$ [1.31, 1.90]); only *W6P* did not differ significantly from neutral ($d = 0.18$ [−0.02, 0.37]). Full statistics are reported in Table S9. The EE domain showed strong perceived performance, with mean values ranging from 3.75 to 4.43. *E1P* recorded the highest mean score ($M = 4.43$), indicating strong stakeholder agreement that SBDPs outperform conventional buildings in overall energy performance. This was followed by *E3P* ($M = 4.28$) and *E4P* ($M = 4.24$), reflecting perceived improvements in operational efficiency and climate resilience. *E2P* ($M = 4.16$) and *E7P* ($M = 4.04$) also received high ratings, suggesting that stakeholders recognise the role of rating systems and the interdependence between EE and IEQ. In contrast, *E6P* ($M = 3.75$) received the lowest score, indicating concerns about the gap between design intent and actual operational performance. Similarly, *E5P* ($M = 3.82$) suggests more moderate confidence in the financial payback of EE measures. Overall, these findings position EE as a key domain distinguishing SBDPs from conventional buildings, while highlighting the need for monitoring and feedback to close the design–operation gap.

As this study did not collect objective building performance data, the perception-based findings were interpreted alongside empirical evidence from the existing literature. Given the limited availability of New Zealand-specific measured studies comparing SBDPs with conventional buildings, international evidence was used as contextual triangulation rather than direct verification.



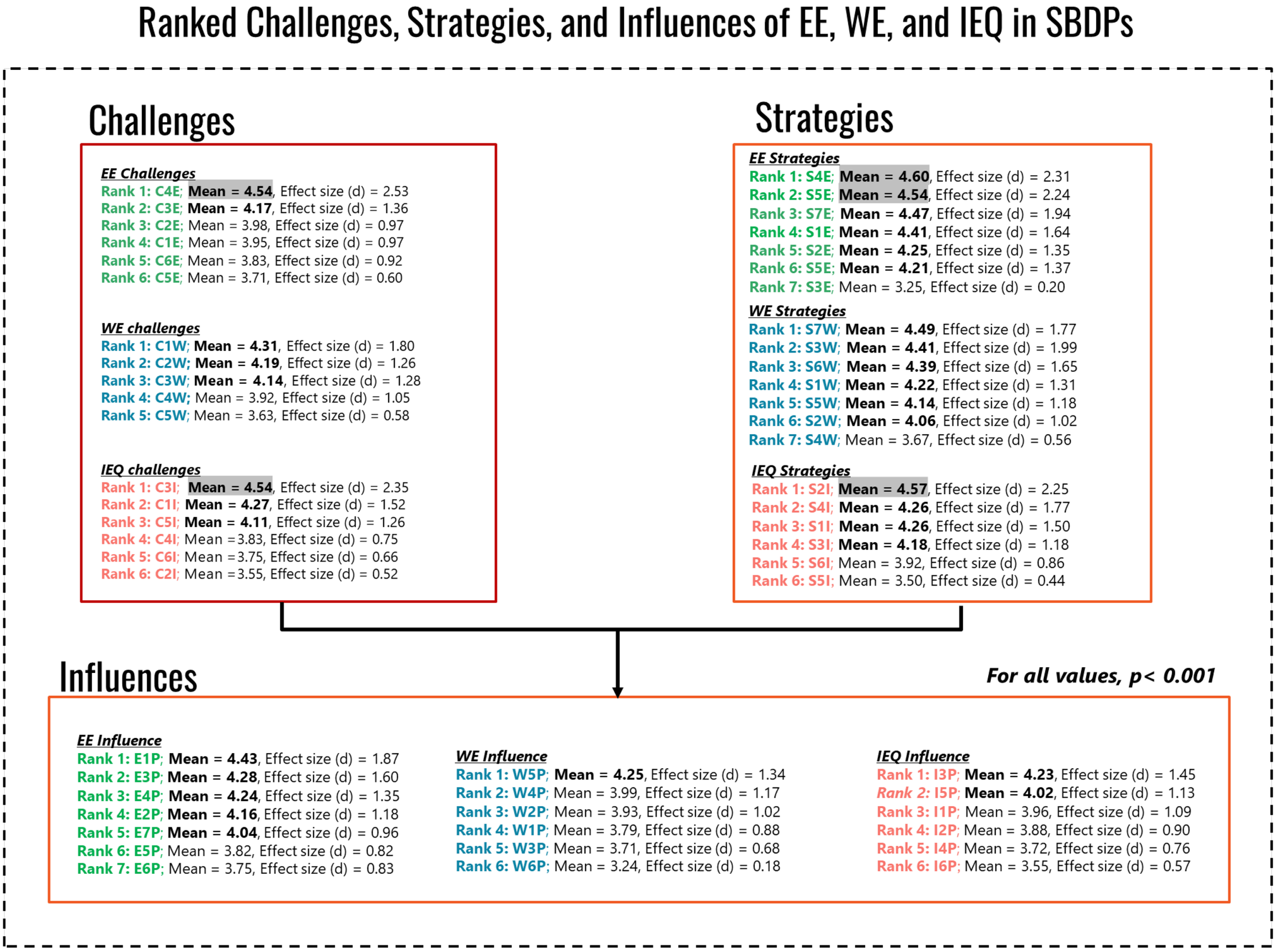
4a: Stakeholder involvement by building types



4b: Company Size

4c: New Zealand work location

FIGURE 4 | Professional and organisational profile of respondents, including building-type involvement, company size, and New Zealand work location.



Ranked Challenges, Strategies, and Influences of EE, WE, and IEQ in SBDPs

Challenges

EE Challenges
Rank 1: C4E; **Mean = 4.54**, Effect size (d) = 2.53
Rank 2: C3E; **Mean = 4.17**, Effect size (d) = 1.36
Rank 3: C2E; Mean = 3.98, Effect size (d) = 0.97
Rank 4: C1E; Mean = 3.95, Effect size (d) = 0.97
Rank 5: C6E; Mean = 3.83, Effect size (d) = 0.92
Rank 6: C5E; Mean = 3.71, Effect size (d) = 0.60

WE challenges
Rank 1: C1W; **Mean = 4.31**, Effect size (d) = 1.80
Rank 2: C2W; Mean = 4.19, Effect size (d) = 1.26
Rank 3: C3W; **Mean = 4.14**, Effect size (d) = 1.28
Rank 4: C4W; Mean = 3.92, Effect size (d) = 1.05
Rank 5: C5W; Mean = 3.63, Effect size (d) = 0.58

IEQ challenges
Rank 1: C3I; **Mean = 4.54**, Effect size (d) = 2.35
Rank 2: C1I; **Mean = 4.27**, Effect size (d) = 1.52
Rank 3: C5I; **Mean = 4.11**, Effect size (d) = 1.26
Rank 4: C4I; Mean =3.83, Effect size (d) = 0.75
Rank 5: C6I; Mean =3.75, Effect size (d) = 0.66
Rank 6: C2I; Mean =3.55, Effect size (d) = 0.52

Strategies

EE Strategies
Rank 1: S4E; **Mean = 4.60**, Effect size (d) = 2.31
Rank 2: S5E; **Mean = 4.54**, Effect size (d) = 2.24
Rank 3: S7E; **Mean = 4.47**, Effect size (d) = 1.94
Rank 4: S1E; **Mean = 4.41**, Effect size (d) = 1.64
Rank 5: S2E; **Mean = 4.25**, Effect size (d) = 1.35
Rank 6: S5E; **Mean = 4.21**, Effect size (d) = 1.37
Rank 7: S3E; Mean = 3.25, Effect size (d) = 0.20

WE Strategies
Rank 1: S7W; **Mean = 4.49**, Effect size (d) = 1.77
Rank 2: S3W; **Mean = 4.41**, Effect size (d) = 1.99
Rank 3: S6W; **Mean = 4.39**, Effect size (d) = 1.65
Rank 4: S1W; **Mean = 4.22**, Effect size (d) = 1.31
Rank 5: S5W; **Mean = 4.14**, Effect size (d) = 1.18
Rank 6: S2W; **Mean = 4.06**, Effect size (d) = 1.02
Rank 7: S4W; Mean = 3.67, Effect size (d) = 0.56

IEQ Strategies
Rank 1: S2I; **Mean = 4.57**, Effect size (d) = 2.25
Rank 2: S4I; **Mean = 4.26**, Effect size (d) = 1.77
Rank 3: S1I; **Mean = 4.26**, Effect size (d) = 1.50
Rank 4: S3I; **Mean = 4.18**, Effect size (d) = 1.18
Rank 5: S6I; Mean = 3.92, Effect size (d) = 0.86
Rank 6: S5I; Mean = 3.50, Effect size (d) = 0.44

Influences

For all values, p< 0.001

EE Influence
Rank 1: E1P; **Mean = 4.43**, Effect size (d) = 1.87
Rank 2: E3P; **Mean = 4.28**, Effect size (d) = 1.60
Rank 3: E4P; **Mean = 4.24**, Effect size (d) = 1.35
Rank 4: E2P; **Mean = 4.16**, Effect size (d) = 1.18
Rank 5: E7P; **Mean = 4.04**, Effect size (d) = 0.96
Rank 6: E5P; Mean = 3.82, Effect size (d) = 0.82
Rank 7: E6P; Mean = 3.75, Effect size (d) = 0.83

WE Influence
Rank 1: W5P; **Mean = 4.25**, Effect size (d) = 1.34
Rank 2: W4P; Mean = 3.99, Effect size (d) = 1.17
Rank 3: W2P; Mean = 3.93, Effect size (d) = 1.02
Rank 4: W1P; Mean = 3.79, Effect size (d) = 0.88
Rank 5: W3P; Mean = 3.71, Effect size (d) = 0.68
Rank 6: W6P; Mean = 3.24, Effect size (d) = 0.18

IEQ Influence
Rank 1: I3P; **Mean = 4.23**, Effect size (d) = 1.45
***Rank 2:* I5P**; **Mean = 4.02**, Effect size (d) = 1.13
Rank 3: I1P; Mean = 3.96, Effect size (d) = 1.09
Rank 4: I2P; Mean = 3.88, Effect size (d) = 0.90
Rank 5: I4P; Mean = 3.72, Effect size (d) = 0.76
Rank 6: I6P; Mean = 3.55, Effect size (d) = 0.57

FIGURE 5 | Ranked challenges, strategies, and influences of EE, WE, and IEQ.

Almeida et al. (2023) broadly support the positive EE ratings, showing that a certified green building consumed 15.1% less site energy than a comparable non-green building under present conditions, increasing to 21.9% under the 2090 high-emission scenario. The green building also produced 14.7% fewer GHG emissions at present and up to 22.0% fewer under future conditions. In relation to the EE–IEQ interaction, it maintained better thermal comfort, with cooling unmet hours increasing from 24 to 246.5 h/years, compared with 842–1429.5 h/years for the non-green building. These findings support the high ratings for *E1P*, *E3P*, *E4P*, and *E7P* by showing that green buildings can deliver stronger EE, lower emissions, and better resilience to future climate conditions.

However, Clay et al. (2023) provide a more cautious interpretation. Their causal analysis of LEED-certified federal retrofits found no statistically significant average energy savings from certification alone, with an estimated effect of −3.0% and a possible range from −12.0% to +6.0%. Nevertheless, buildings with a one-standard-deviation higher LEED energy score achieved 12.6% lower energy use overall and 13.9% lower use in office buildings. These findings suggest that certification alone does not guarantee superior operational performance, but energy-focused certification components can produce measurable savings when effectively implemented. Therefore, Clay et al. (2023) qualify rather than contradict the present findings and support the lower score for *E6P*, confirming that design–operation gaps, certification trade-offs, and operational practices can limit realised EE outcomes. Overall, the literature supports the positive interpretation of EE performance while reinforcing the need for New Zealand-specific POE and performance-based verification.

4.2.2 | WE Influence

The WE domain demonstrated moderate-to-high performance, with mean scores ranging from 3.24 to 4.25, and five of six indicators scoring significantly above-neutral. The highest rating was recorded for *W5P* ($M = 4.25$), indicating strong stakeholder recognition of the synergy between WE and EE. *W4P* ($M = 3.99$) and *W2P* ($M = 3.93$) followed, highlighting the perceived importance of WE measures in enhancing resilience and reducing water wastage. Mid-range results for *W1P* ($M = 3.79$) and *W3P* ($M = 3.71$) indicate medium-to-large effects, suggesting moderate confidence in the comparative performance and cost benefits associated with WE initiatives. The lowest score, *W6P* ($M = 3.24$), suggests that respondents do not strongly perceive WE strategies as directly contributing to IEQ enhancement. Overall, WE outcomes were regarded positively; however, their wider variability compared with EE highlights an opportunity to strengthen WE integration across other performance domains.

As this study did not collect objective water performance data, these perception-based findings were interpreted alongside modelled evidence from the existing studies. Given the limited availability of New Zealand-specific measured studies comparing SBDPs with conventional buildings, this evidence is used as contextual triangulation rather than direct verification; notably, both supporting studies are simulation- and life-cycle-based rather than POE. Recent studies broadly support the positive WE findings. Oneda and Ghisi (2025) simulating rainwater harvesting across five building typologies reported potable-water savings ranging from 18.55% to 50.83% and quantified the associated water–energy nexus, with sector-level energy savings of 245 kWh/day for public buildings, 209 kWh/day for industrial buildings, 8 kWh/day for commercial buildings, 25 kWh/day for single-family houses, and 15 kWh/day for multi-family residential buildings (135,426–240,900 kWh annually). By directly linking reduced potable-water consumption to lower energy use in water treatment and distribution, this evidence supports the high stakeholder rating for *W5P* and aligns with *W2P* and *W4P* by demonstrating reduced water demand and enhanced resilience to water scarcity.

Complementing this, Souza et al. (2025) applied a Life Cycle Sustainability Assessment to decentralised water-reuse systems that integrate constructed-wetland greywater treatment with rainwater harvesting, and found that these systems reduced environmental impacts, largely through lower energy demand, reduced transport emissions, and on-site treatment, and achieved overall sustainability scores up to 4.8 times higher than conventional centralised supply-and-treatment models. Overall, these modelled studies support stakeholders' positive perceptions of WE performance, while reinforcing the need for New Zealand-specific POE and measured water-performance verification.

4.2.3 | IEQ Influence

The findings reveal that all six IEQ indicators scored above the neutral value (3.55–4.23). The highest score, *I3P* ($M = 4.23$), reflects strong agreement that SBDPs enhance occupant health and well-being. Similarly, *I5P* ($M = 4.02$) and *I1P* ($M = 3.96$) indicate high tenant satisfaction and superior IEQ compared with conventional buildings. *I2P* ($M = 3.88$) highlights the importance of integrating IEQ during the design phase, while *I4P* ($M = 3.72$) and *I6P* ($M = 3.55$) show moderate confidence in maintaining long-term performance. The IEQ findings are broadly consistent with recent POE, particularly for occupant-facing outcomes. The high ratings for *I1P*, *I2P*, and *I3P* suggest that respondents perceived SBDPs as contributing positively to IEQ and user experience. This aligns with Asojo and Hazazi (2025), who claimed that where occupants reported high satisfaction with the physical environment, improved work performance and positive health outcomes. Their findings support the view that well-integrated IEQ strategies, such as daylighting, IAQ, and material connections with nature, can enhance occupant well-being.

However, the comparatively lower scores for *I4P* and *I6P* indicate more cautious confidence in IEQ performance. This is consistent with the POE conducted by Jin and Wallbaum (2020) in a BREEAM Silver office in Sweden, where certification did not fully ensure occupant satisfaction, particularly regarding thermal comfort, fresh air, noise and daylight. Similarly, Rasheed and Rotimi (2022)'s New Zealand study showed that office workers preferred more fresh air, mixed-mode ventilation, and lighting, better acoustic conditions and partial control over IEQ conditions. These findings suggest that design intent, certification, or green-building status alone may not guarantee comfort in use. Taken together, the evidence indicates that SBDPs are perceived to improve IEQ and occupant well-being, but sustained IEQ performance remains vulnerable to a perception–performance gap. Thermal comfort, acoustic quality, ventilation, daylight, and occupant control appear especially important for translating design-stage IEQ intentions into positive in-use experiences.

4.3 | Existing Challenges Influencing the EE, WE, and IEQ of SBDPs in New Zealand

A one-sample *t*-test was conducted to identify the most critical challenges perceived by stakeholders in advancing SBDPs across the domains of EE, WE and IEQ. All comparisons were statistically significant at $p < 0.001$, indicating that stakeholders broadly recognised these factors as key challenges to the implementation of SBDPs (see Figure 5). Effect sizes for the 17 challenge indicators ranged from medium to very large ($d = 0.52–2.53$), the largest being *C4E* ($d = 2.53$, 95% CI [2.13, 2.93]) and *C3I* ($d = 2.35$ [1.97, 2.73]); the full results are shown in Table S10.

4.3.1 | EE Challenges

The EE domain reveals persistent systemic, financial, and capability-based barriers that continue to constrain progress toward SBDPs in New Zealand. The highest mean score was recorded for *C4E* ($M = 4.54$), indicating that short-term financial decision-making remains deeply entrenched within the sector. This suggests limited industry willingness to prioritise lifecycle energy savings over immediate capital cost reductions. *C3E* ($M = 4.17$) further underscores the inadequacy of current policy settings, highlighting the need for clearer, more enforceable regulations to drive widespread EE uptake. Economic and regulatory constraints were reinforced by strong effects for *C1E* ($M = 3.95$) and *C2E* ($M = 3.98$) with $d = 0.97$, illustrating how limited financial support and fragmented policy frameworks jointly hinder implementation. *C5E* ($M = 3.86$) emphasises weak stakeholder coordination, signalling gaps between policy intent and operational delivery. Meanwhile, *C6E* ($M = 3.71$) reflects ongoing skill shortages and insufficient technical capacity to deploy advanced EE solutions at scale. Taken together, these findings indicate that advancing EE within SBDPs requires simultaneous strengthening of financial mechanisms, regulatory alignment and professional capability. These challenges are consistent with Cielo and Subiantoro (2021), who identified inadequate incentives, weak policy drivers, and high upfront costs as major impediments to EE adoption. Their findings reinforce the prominence of *C4E* and *C3E* in the present study, confirming that overcoming financial, legislative, and capability constraints is fundamental to accelerating EE integration in New Zealand's built environment.

4.3.2 | WE Challenges

The WE domain presents several substantial barriers, with mean values ranging from 3.63 to 4.31. The most pronounced challenge, *C1W* ($M = 4.31$), is the absence of formal water-use benchmarking for non-residential buildings, which limits systematic performance assessment and informed decision-making. *C2W* ($M = 4.19$) and *C3W* ($M = 4.14$) further highlight entrenched public perceptions of water abundance and regulatory gaps within building codes, indicating that cultural attitudes and weak policy frameworks inhibit the establishment of robust WE practices. Moreover, *C4W* ($M = 3.92$) reflects the limited availability and monitoring of water resources, reinforcing concerns about inadequate infrastructure and data collection. Meanwhile, *C5W* ($M = 3.63$) suggests that WE considerations remain secondary to EE initiatives, likely due to greater market visibility and perceived economic returns associated with energy savings. Collectively, these findings indicate that perceptual and regulatory shortcomings pose more significant barriers than technological limitations. This aligns with Bint et al. (2019), who noted the lack of comprehensive national guidelines for alternative water-supply systems, and Challies et al. (2022), who linked prevailing attitudes of freshwater abundance to the longstanding neglect of WE issues. However, Suazo (2022) observed that increasing population pressures and climate-change impacts are elevating the strategic importance of WE, underscoring the need for proactive policy development and integration within SBDPs.

4.3.3 | IEQ Challenges

The IEQ domain demonstrated consistently high mean scores, ranging from 3.55 to 4.54, with all challenges significantly above the neutral threshold. The most critical barrier was *C3I* ($M = 4.54$), underscoring fundamental design and maintenance deficiencies in achieving effective IEQ management. This finding highlights persistent issues in both the commissioning and operational stages of buildings. Similarly, *C1I* ($M = 4.27$) pointed to policy-level shortcomings that hinder the systematic integration of IEQ into national building performance frameworks. Additionally, *C5I* ($M = 4.11$) further emphasised the need for enhanced professional training and stakeholder awareness, indicating that technical competence and knowledge dissemination remain essential to advancing IEQ outcomes. Financial and comparative barriers, reflected in *C4I* ($M = 3.83$) and *C6I* ($M = 3.75$), suggested that while IEQ is acknowledged as important, it continues to be secondary to energy and water priorities in both policy and practice. Finally, *C2I* ($M = 3.55$) recorded the lowest mean, illustrating limited stakeholder recognition of acoustic quality within the broader sustainability discourse. These findings align with Arya et al. (2024), who observed that New Zealand's Designing Quality Learning Spaces (DQLS) guidelines for IAQ lag behind Organisation for Economic Co-Operation and Development (OECD) standards, particularly regarding CO_2 concentration limits and ventilation performance. Supporting this, Al-Rawi (2021) found through in situ monitoring of indoor conditions in a Waikato home that thermal comfort and ventilation were often inadequate. Furthermore, simulation analyses revealed that even modern dwellings fail to meet ASHRAE and NZS 4246:2016 standards, underscoring a widespread gap between design expectations and realised indoor environmental performance. Overall, these results emphasise that improving IEQ in New Zealand buildings requires an integrated approach, one that combines stronger regulatory frameworks, enhanced professional education, and evidence-based performance monitoring to ensure that design intent translates into healthier indoor environments.

4.4 | Existing Strategies Influencing the EE, WE, and IEQ of SBDPs in New Zealand

A one-sample *t*-test was conducted to assess stakeholder agreement on strategies considered most effective for enhancing EE, WE, and IEQ within SBDPs in New Zealand (see Figure 5). All comparisons, except for *S3E*, were statistically significant ($p < 0.001$), demonstrating a strong consensus among stakeholders on the importance of these strategies in advancing effective SBDPs. Effect sizes for the 20 strategy indicators spanned small to very large ($d = 0.20–2.31$), with the maximum for *S4E* ($d = 2.31$, 95% CI [1.93, 2.68]) and *S2I* ($d = 2.25$ [1.88, 2.62]), with *S3E* showing the smallest, near-negligible effect ($d = 0.20$ [0.00, 0.40]); full results are provided in Table S11.

4.4.1 | EE Strategies

EE strategies achieved the highest overall ratings, reflecting strong stakeholder consensus on the value of integrated and practical energy approaches. The top-rated strategy, *S4E* ($M = 4.60$), reaffirmed passive design as the cornerstone of energy reduction. Close behind, *S6E* ($M = 4.59$) emphasised the importance of coordinated collaboration in driving energy performance, while *S7E* ($M = 4.47$) highlighted the continued value of capacity-building and professional training. *S1E* ($M = 4.41$) and *S2E* ($M = 4.25$) further underscored the complementary roles of policy and market mechanisms, and *S5E* ($M = 4.21$) revealed growing confidence in technology-driven monitoring systems. The only weakly supported item, *S3E* ($M = 3.25$), likely reflects cost and integration challenges. Overall, the results demonstrate uniformly strong statistical support for EE strategies, suggesting that combining design, governance, and human-capital measures is essential for sustained energy transformation. These findings align with those of Besen et al. (2017), who found that passive houses outperform conventional homes in both thermal comfort and EE, reinforcing the primacy of passive design. However, Brougham-Romney (2022) observed that even in buildings meeting advanced Passive House and Homestar standards, user behaviour and occupancy management significantly influenced performance outcomes. This contrasts with the *S4E* finding, indicating that while *S6E* and *S7E* are critical, behavioural factors can still undermine their potential benefits.

4.4.2 | WE Strategies

The mean ratings for WE strategies ranged from 3.67 to 4.49, with all items statistically significant ($p < 0.001$), demonstrating strong overall stakeholder support. The highest rating, *S7W* ($M = 4.49$), underscores the crucial role of professional training and capacity building in achieving WE outcomes. Comparable support for *S3W* ($M = 4.41$) and *S6W* ($M = 4.39$) reflects stakeholder endorsement of practical technological interventions and integrated urban water-management approaches, suggesting that technical solutions and system-level planning are viewed as highly effective and actionable. *S1W* ($M = 4.22$) and *S5W* ($M = 4.14$) further demonstrate recognition of smart metering and financial incentives as important enablers of informed decision-making and adoption. By contrast, *S2W* ($M = 4.06$) received a lower relative ranking, implying that while compliance mechanisms are valued, stakeholders perceive them as less impactful than technology- or skills-based approaches. The lowest rating was observed for *S4W* ($M = 3.67$), relating to rainwater harvesting and greywater reuse, signalling ongoing concerns about implementation cost, maintenance demands and technical feasibility. Despite this, its above-neutral score indicates that such systems remain relevant, albeit with strategic and financial barriers. Overall, the findings indicate that stakeholders favour capacity building, technology deployment, and systemic planning over regulatory or mandated interventions, reflecting a preference for strategies perceived as practical, scalable, and adaptable to diverse project contexts.

These results align with Sarpong and Amankwaa (2022), who emphasised the pivotal role of training and awareness in fostering sustainable water practices. Likewise, strong support for *S3W* and *S6W* is consistent with Poorisat et al. (2024), who highlighted the value of water-efficient technologies and integrated water-management systems in improving building-level sustainability. However, the comparatively lower rating for *S4W* diverges from findings by Bint et al. (2019), who reported that rainwater and greywater systems can be cost-effective and widely accepted under favourable regulatory and pricing conditions. This suggests that implementation challenges, rather than system inefficiency, may limit their adoption in the New Zealand context.

4.4.3 | IEQ Strategies

Stakeholders demonstrated substantial alignment regarding strategies to improve IEQ, with mean ratings ranging from 3.50 to 4.57, all significantly above the neutral benchmark. The highest-rated strategy, *S2I* ($M = 4.57$), underscores strong support for design approaches that enhance both occupant well-being and productivity. Similarly, *S4I* and *S1I* ($M = 4.26$) reflect prioritisation of measures that promote thermal comfort and air quality, reaffirming the centrality of user-focused design considerations. Further support was observed for *S3I* ($M = 4.18$), demonstrating stakeholder confidence in improving IEQ through health-oriented material standards, signalling a strong commitment to reducing harmful exposures and supporting healthy indoor environments. Moderate endorsement of *S6I* ($M = 3.92$) indicates recognition of the role that policy baselines and compliance mechanisms play in safeguarding IEQ outcomes.

In contrast, *S5I* received the lowest rating ($M = 3.50$), suggesting persistent concerns regarding cost, technical complexity, and practical feasibility associated with monitoring-driven approaches. Taken together, these results point to a clear preference for design- and comfort-driven interventions over technologically intensive solutions. This is consistent with findings by Rasheed and Rotimi (2022), who reported strong preferences among New Zealand stakeholders for fresh air, natural daylighting, and acoustic comfort, closely mirroring the high support for *S1I*, *S2I* and *S4I* in this study.

However, emerging literature indicates additional nuance around the highest-rated strategy, which is *S2I*, where Wang et al. (2023) found that in the New Zealand context, natural ventilation alone was insufficient during winter, resulting in poor thermal conditions and elevated CO_2 levels in classrooms. Their study demonstrated that a hybrid ventilation approach increased indoor temperatures and enhanced air exchange rates, underscoring the need for mechanical or solar-assisted ventilation systems to maintain adequate IEQ during colder months. These findings suggest that while natural ventilation remains highly valued, hybrid systems may be essential for achieving year-round performance.

4.4.4 | Cross-Domain Reflections

Across performance perceptions, challenges, and strategic responses, stakeholders consistently perceived SBDPs to outperform conventional buildings across EE, WE and IEQ. However, the magnitude and reliability of these benefits varied across domains, revealing important cross-domain dynamics. Among the three domains, EE demonstrated the strongest perceived performance, particularly through indicators *E1P, E2P*, *E3P and E4P*, suggesting that EE represents the most mature dimension of SBDPs in New Zealand (Abdelaal and Guo 2021). This reflects stronger technical standardisation, clearer benchmarking systems, and greater regulatory familiarity. These findings align with previous research showing that higher certification levels are generally associated with improved energy performance. For example, analyses of thousands of buildings within the National Australian Built Environment Rating System indicate that higher ratings correspond to lower energy use and emissions (Gui and Gou 2020).

Nevertheless, certification does not always guarantee consistent operational outcomes. Leite Ribeiro et al. (2025) reported that certified buildings may exhibit variations in actual energy performance, particularly at lower certification levels, where realised outcomes may diverge from predicted performance. IEQ was also viewed positively, particularly through indicators *I1P*, *I3P* and *I5P*, reflecting strong confidence in improvements to occupant health, comfort and satisfaction (Al-Rawi 2021).

In contrast, WE demonstrated moderate but positive performance. While *W4P, W2P and W5P* indicate recognition of resource conservation and resilience benefits, weaker ratings for *W6P* and *W3P* suggest uncertainty regarding long-term IEQ linkages and cost justification. This pattern produced the study's most unexpected result: although stakeholders strongly endorsed the EE–WE synergy (*W5P*), they were markedly more sceptical that water-efficiency strategies support IEQ (*W6P*), the lowest performance rating recorded. This asymmetry is theoretically notable because it indicates that the water–energy–IEQ nexus is only partially internalised in professional reasoning: the resource-to-resource (water–energy) link is well recognised, whereas the resource-to-health (water–IEQ) link is not, even though both are integral to the nexus. The finding runs counter to the integrated framing promoted in the sustainability literature and signals a specific cognitive and educational gap that targeted training and guidance could address. A second tension concerns the EE–IEQ relationship: stakeholders simultaneously rated the EE–IEQ interaction highly (*E7P*) and identified ventilation as the most critical IEQ challenge (*C3I*), implicitly acknowledging the ventilation–energy trade-off that the conceptual framework anticipates but that the performance ratings tend to gloss over. Across all three domains, several common concerns emerged, particularly regarding performance realisation, long-term economic justification and lifecycle monitoring and verification. These findings are consistent with Hafez et al. (2023) and Moradi et al. (2024), who argued that commissioning and verification gaps often undermine expected sustainability performance. Consequently, although stakeholder confidence in SBDPs remains strong, optimisation is constrained by limited performance verification, weak cross-domain integration and institutional uncertainty.

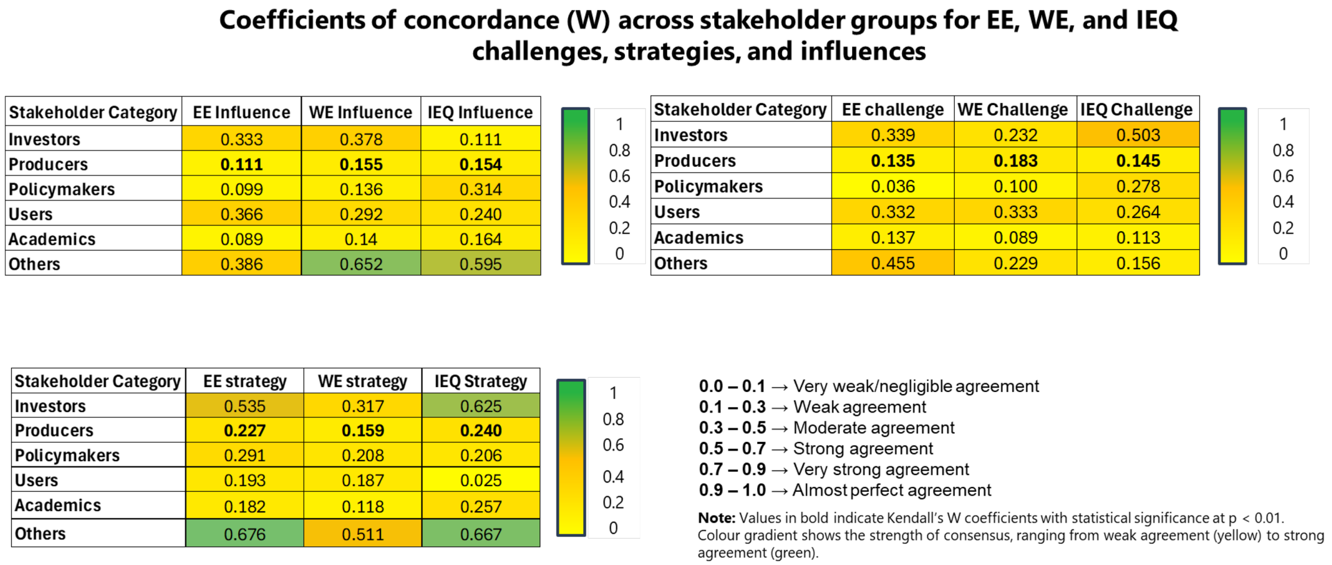
Cross-domain challenge analysis further suggests that structural barriers are systemic rather than domain-specific. Short-term economic considerations, reflected in *C4E*, *C3W* and *C4I*, discourage investment in lifecycle benefits and reinforce prioritisation of upfront cost savings over long-term value. Regulatory weaknesses are similarly pervasive. Insufficient or poorly enforced requirements across *C2E*, *C3W* and *C1I* limit consistent adoption, benchmarking, and compliance. At the same time, *C1W* and *C1I* illustrate fragmentation in WE and IEQ governance, resonating with Poorisat et al. (2024) and Ebekozien et al. (2024), who mentioned that the lack of mandatory regulations hinders the adoption of SBDPs. Professional capability gaps, including *C6E*, *C5W* and *C5I*, further hinder effective design, implementation, and monitoring of EE, WE and IEQ strategies, highlighting the need for targeted training, improved knowledge transfer, and stronger commissioning expertise (Ebekozien et al. 2024).

Strategic responses reflect these structural challenges. Design- and human-centred approaches received the strongest support, with high-scoring items such as *S4E* and *S2I* indicating strong stakeholder confidence in early-stage design integration (Li et al. 2022). Capacity-building initiatives, including *S7E*, *S7W* and *S5I*, further highlight the perceived importance of professional education and skills development as scalable pathways to improved performance (Poorisat et al. 2024). Policy incentives and collaborative governance were also viewed as critical enablers. Support for incentives and compliance mechanisms, including *S1E*, *S5W*, *S2E*, *S2W*, *S6I* and collaborative frameworks, including *S6E* and *S7W*, underscores the importance of coordinated governance and regulatory alignment (Cao et al. 2022; Cole 2021).

By contrast, advanced technologies and mandated systems received comparatively lower support. Lower ratings for *S3E*, *S5E*, *S5I* and *S4W* suggest that cost, complexity, and uncertain value continue to constrain the adoption of EE, WE and IEQ technologies despite their recognised potential. Overall, these cross-domain findings indicate that progress in SBDPs is constrained more by institutional, economic, and cultural factors than by technological limitations. While stakeholders recognise clear benefits across EE, WE, and IEQ, stronger regulation, lifecycle value frameworks, improved monitoring and verification systems, enhanced professional capability, and better design–operation feedback loops are required to support deeper integration of sustainability principles within New Zealand buildings (Abdelaal and Guo 2021; Doan, GhaffarianHoseini, et al. 2021).

4.5 | Stakeholder Consensus on EE, WE, and IEQ Assessed Using Kendall's Coefficient of Concordance (*W*)

Kendall's Coefficient of Concordance (*W*) was employed to assess the degree of alignment among stakeholder groups regarding the



Coefficients of concordance (W) across stakeholder groups for EE, WE, and IEQ challenges, strategies, and influences

Stakeholder Category	EE Influence	WE Influence	IEQ Influence
Investors	0.333	0.378	0.111
Producers	**0.111**	**0.155**	**0.154**
Policymakers	0.099	0.136	0.314
Users	0.366	0.292	0.240
Academics	0.089	0.14	0.164
Others	0.386	0.652	0.595

Stakeholder Category	EE challenge	WE Challenge	IEQ Challenge
Investors	0.339	0.232	0.503
Producers	**0.135**	**0.183**	**0.145**
Policymakers	0.036	0.100	0.278
Users	0.332	0.333	0.264
Academics	0.137	0.089	0.113
Others	0.455	0.229	0.156

Stakeholder Category	EE strategy	WE strategy	IEQ Strategy
Investors	0.535	0.317	0.625
Producers	**0.227**	**0.159**	**0.240**
Policymakers	0.291	0.208	0.206
Users	0.193	0.187	0.025
Academics	0.182	0.118	0.257
Others	0.676	0.511	0.667

0.0 – 0.1 → Very weak/negligible agreement
0.1 – 0.3 → Weak agreement
0.3 – 0.5 → Moderate agreement
0.5 – 0.7 → Strong agreement
0.7 – 0.9 → Very strong agreement
0.9 – 1.0 → Almost perfect agreement

Note: Values in bold indicate Kendall's W coefficients with statistical significance at $p < 0.01$. Colour gradient shows the strength of consensus, ranging from weak agreement (yellow) to strong agreement (green).

FIGURE 6 | Coefficient of concordance (W) across stakeholder groups for EE, WE, and IEQ.

perceived influence, challenges, and strategies associated with EE, WE, and IEQ in SBDPs. Values range from 0 (no agreement) to 1 (complete agreement), with bolded values indicating statistical significance ($p < 0.01$). Figure 6 visualises the intensity of agreement, where yellow denotes low consensus and green indicates strong consensus.

4.5.1 | Influence of EE, WE, and IEQ on SBDPs

Consensus on the perceived influence of EE, WE, and IEQ varied considerably across stakeholder groups. For EE, producers showed weak but significant alignment ($W = 0.111$), while users demonstrated moderate agreement ($W = 0.366$), suggesting shared recognition of energy-related benefits, for example, *E4P* and *E5P*. For WE, producers ($W = 0.155$) and investors ($W = 0.378$) revealed the greatest alignment, particularly around *W2P* and *W3P*, indicating readiness for collaborative uptake of WE initiatives. Conversely, policymakers, users, and academics displayed inconsistent views, reflecting the absence of unified WE-driven priorities. Moreover, consensus on IEQ influence was most evident among policymakers ($W = 0.314$) and producers ($W = 0.154$), whereas the remaining groups showed fragmented perspectives. Overall, WE and IEQ generated stronger cross-group alignment than EE, though fragmentation across all domains points to persistent divergence in perceived performance benefits. Increased inter-stakeholder engagement could support a more cohesive understanding of EE, WE, and IEQ contributions within SBDPs (see Figure 6).

4.5.2 | Challenges of EE, WE, and IEQ

Consensus on challenges was domain-dependent. For EE, producers reported weak yet significant alignment ($W = 0.135$), recognising persistent market and cost barriers. Investors ($W = 0.339$) and users ($W = 0.332$) showed moderate but non-significant agreement, while policymakers ($W = 0.036$) and academics ($W = 0.137$) showed minimal convergence, signalling limited shared problem recognition. For WE challenges, producers demonstrated the strongest and most significant concordance ($W = 0.183$), consistently ranking *C2W* and *C3W* as primary barriers. Other groups exhibited lower alignment, indicating that WE remains comparatively under-prioritised at a policy and practice level. IEQ challenges generated the highest consensus overall, with investors showing strong, significant agreement ($W = 0.503$), prioritising *C1I* and *C3I*. Policymakers ($W = 0.278$) and producers ($W = 0.145$) also showed significant alignment. These findings suggest broad acknowledgment of IEQ-related operational and policy shortcomings and greater clarity regarding required improvement measures relative to EE and WE.

4.5.3 | Strategies Enhancing EE, WE, and IEQ in SBDPs

Consensus on strategies largely mirrored patterns observed for challenges. For EE strategies, producers showed weak but significant agreement ($W = 0.159$), emphasising passive design and capacity-building, including *S4E*, *S6E* and *S7E*. Investors ($W = 0.317$) and policymakers ($W = 0.208$) presented partial alignment around policy and market-supporting strategies *S1E* and *S3E*, whereas users and academics demonstrated low convergence. For WE strategies, producers again displayed the highest significant alignment ($W = 0.159$), prioritising *S2W*, *S4W* and *S7W*. Investors and policymakers showed moderate but non-significant agreement, revealing continued inconsistency in strategic direction. Consensus was strongest for IEQ strategies. Investors showed strong and significant alignment ($W = 0.625$), endorsing measures focused on health and material standards, including *S2I* and *S3I*. Producers ($W = 0.240$) and academics ($W = 0.257$) showed moderate, significant agreement, while policymakers ($W = 0.206$) and other groups ($W = 0.667$) were moderately aligned. In contrast, users ($W = 0.025$) demonstrated negligible agreement, likely reflecting variable personal experiences and limited technical awareness. Collectively, IEQ strategies gained the most uniform support, followed by moderate alignment around EE and WE strategies. The particularly

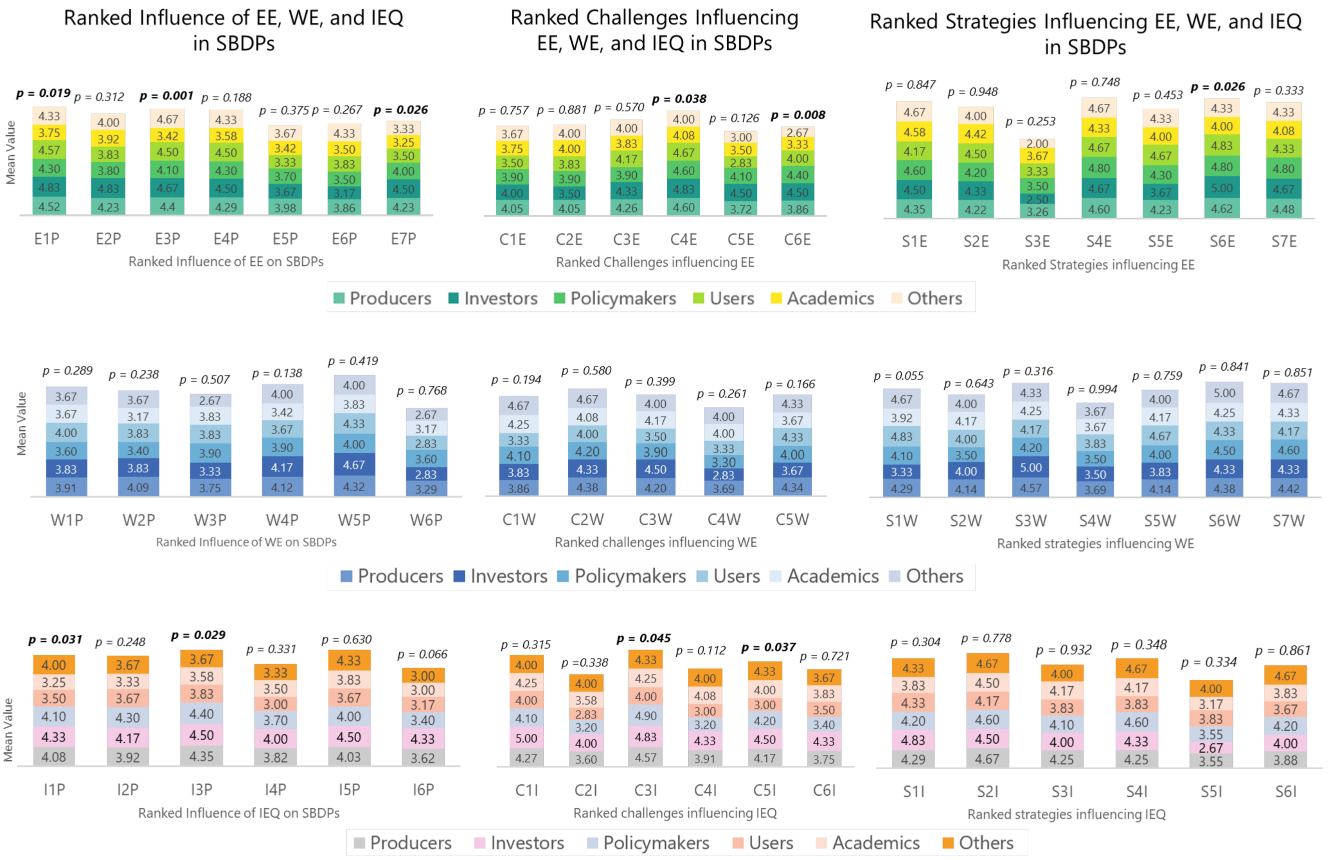


FIGURE 7 | Comparative evaluation of influence, challenges, and strategies across EE, WE, and IEQ domains by stakeholder groups in SBDPs using ANOVA.

strong consensus between investors and academics indicates growing recognition of health-driven, occupant-centred design, while producers' consistent but weaker agreement reflects their focus on practical, regulation-supported solutions.

4.6 | Analyses of Variance (ANOVA) Results: Stakeholder Variation in Perceptions of EE, WE, and IEQ

To examine whether stakeholder perceptions differed across groups, a series of one-way ANOVA tests was conducted for the three performance domains: EE, WE and IEQ. The analysis assessed stakeholder variation in relation to the perceived influence, challenges, and strategies associated with each domain. Given the unequal distribution of stakeholder groups, particularly the dominance of producers within the sample, the results are interpreted as segmented exploratory evidence rather than population-representative estimates. Although weighting was considered, it was not applied because reliable population-level proportions for SBDP stakeholder groups in New Zealand were unavailable. Applying arbitrary weights could have further distorted the results, especially for smaller stakeholder groups. Instead, group-specific differences were examined using ANOVA, supported by η^2 effect sizes, to determine whether aggregate trends concealed meaningful stakeholder variation.

For indicators with a significant omnibus ANOVA result, Games–Howell post hoc comparisons were conducted to identify which stakeholder groups differed significantly. Group-level descriptive statistics, including means and standard deviations, are also reported to support interpretation of the results. Games–Howell was selected because it does not assume equal variances or equal group sizes, making it appropriate for the characteristics of this sample (Agbangba et al. 2024; Games and Howell 1976). However, because the test is conservative, particularly when some groups are small, such as investors ($n = 6$), users ($n = 6$) and others ($n = 3$), a significant omnibus effect was not always accompanied by a significant pairwise contrast. In such cases, group-level patterns are discussed descriptively, while avoiding overinterpretation of non-significant pairwise differences (Agbangba et al. 2024; Games and Howell 1976). The following subsections present stakeholder comparisons across EE, WE, and IEQ in terms of their perceived influence, implementation challenges, and strategies for promoting SBDPs in New Zealand, as summarised in Figure 7.

4.6.1 | EE, WE, and IEQ Influence

Across the seven EE indicators, significant differences were found for *E1P* ($F(5, 96) = 2.85$, $\eta^2 = 0.129$), *E3P* ($F(5, 96) = 4.292$, $\eta^2 = 0.183$) and *E7P* ($F(5, 96) = 2.662$, $\eta^2 = 0.122$), indicating moderate-to-large effects. These variations suggest that stakeholder groups differed in how strongly they perceived sustainable buildings to outperform conventional buildings in operational energy performance and integrated design outcomes. Producers and investors tended to rate EE impacts more favourably, whereas academics were more cautious, reinforcing the need to interpret aggregate results in light of stakeholder composition. The remaining EE indicators showed non-significant effects, suggesting broader agreement on several EE benefits. However, the moderate variation observed for *E4P* and *E6P* indicates the continued need for POE and transparent performance evidence among investors, producers and academics.

For *E1P*, investors reported the highest mean ($M = 4.83$, $\mathrm{SD} = 0.41$), followed by users ($M = 4.67$, $\mathrm{SD} = 0.82$), producers ($M = 4.52$, $\mathrm{SD} = 0.61$), others ($M = 4.33$, $\mathrm{SD} = 1.16$), policymakers ($M = 4.30$, $\mathrm{SD} = 0.68$) and academics ($M = 3.75$, $\mathrm{SD} = 1.22$). Although the omnibus ANOVA was significant ($F(5, 96) = 2.847$, $p = 0.019$, $\eta^2 = 0.129$), Games–Howell post hoc comparisons did not confirm any significant pairwise difference, indicating overall variation without a confirmable between-group contrast; academics were nonetheless the most reserved group. For *E3P*, investors ($M = 4.67$, $\mathrm{SD} = 0.52$) and others reported the highest means ($M = 4.67$, $\mathrm{SD} = 0.58$), followed by users ($M = 4.50$, $\mathrm{SD} = 0.84$), producers ($M = 4.40$, $\mathrm{SD} = 0.68$), policymakers ($M = 4.10$, $\mathrm{SD} = 0.74$) and academics ($M = 3.42$, $\mathrm{SD} = 1.08$). The omnibus ANOVA showed the largest effect among the EE-influence indicators ($F(5, 96) = 4.295$, $p = 0.001$, $\eta^2 = 0.183$). Games–Howell comparisons confirmed that investors rated this item significantly higher than academics (mean difference $= 1.250$, $p = 0.042$), with a similar non-significant trend between producers and academics (mean difference $= 0.983$, $p = 0.083$). Investors thus expressed significantly stronger confidence than academics that sustainable buildings achieve lower operational energy use. For *E7P*, investors again reported the highest mean ($M = 4.50$, $\mathrm{SD} = 1.23$), followed by producers ($M = 4.23$, $\mathrm{SD} = 0.95$), policymakers ($M = 4.00$, $\mathrm{SD} = 1.16$), users ($M = 3.50$, $\mathrm{SD} = 1.05$), others ($M = 3.33$, $\mathrm{SD} = 0.58$) and academics ($M = 3.25$, $\mathrm{SD} = 1.36$). Despite a significant omnibus ANOVA ($F(5, 96) = 2.670$, $p = 0.026$, $\eta^2 = 0.122$), Games–Howell post hoc comparisons did not identify significant pairwise differences, so the variation in views on the EE–IEQ relationship should be interpreted as a general trend rather than a specific group contrast.

For WE, no statistically significant group differences were observed across the six indicators, indicating stronger alignment in stakeholder perceptions of WE influence than was found for EE and IEQ. The ANOVA results were non-significant for *W1P* ($F(5, 96) = 1.257$, $p = 0.289$, $\eta^2 = 0.061$), *W2P* ($F(5, 96) = 1.382$, $p = 0.238$, $\eta^2 = 0.067$), *W3P* ($F(5, 96) = 0.867$, $p = 0.507$, $\eta^2 = 0.043$), *W4P* ($F(5, 96) = 1.717$, $p = 0.138$, $\eta^2 = 0.082$), *W5P* ($F(5, 96) = 1.006$, $p = 0.419$, $\eta^2 = 0.050$) and *W6P* ($F(5, 96) = 0.509$, $p = 0.768$, $\eta^2 = 0.026$). Games–Howell post hoc comparisons further confirmed that no pairwise stakeholder contrasts reached statistical significance. Although these differences were not statistically significant, the descriptive results indicate modest variation for *W4P*, *W2P* and *W1P*. For *W4P*, investors and producers reported relatively higher means ($M = 4.17$ and $M = 4.12$, respectively), whereas academics reported the lowest mean ($M = 3.42$). For *W2P*, producers reported the highest mean ($M = 4.09$), while policymakers reported the lowest mean ($M = 3.40$). For *W1P*, users ($M = 4.00$) and producers ($M = 3.91$) reported slightly higher means, whereas academics again reported the lowest mean ($M = 3.25$). However, because none of these descriptive differences was confirmed by Games–Howell comparisons, they should be interpreted only as indicative patterns rather than statistically supported stakeholder contrasts. Overall, the WE findings suggest comparatively stronger consensus among stakeholder groups regarding the influence of WE on SBDPs' outcomes, possibly reflecting clearer technical solutions and policy expectations for WE measures in the New Zealand building sector.

IEQ indicators showed moderate stakeholder differences. Significant effects were found for *I1P* ($F(5, 96) = 2.587$, $\eta^2 = 0.119$) and *I3P* ($F(5, 96) = 2.624$, $\eta^2 = 0.120$), while *I6P* ($F(5, 96) = 2.153$, $\eta^2 = 0.101$) approached significance. These findings indicate that stakeholder perceptions varied in relation to the perceived influence of IEQ on occupant health, comfort and well-being. In contrast, *I2P*, *I4P* and *I5P* showed small, non-significant effects ($\eta^2 = 0.035–0.066$), suggesting more consistent views on design integration, indoor performance and user satisfaction. For *I1P*, investors reported the highest mean ($M = 4.33$, $\mathrm{SD} = 0.52$), followed by policymakers ($M = 4.10$, $\mathrm{SD} = 0.74$), producers ($M = 4.08$, $\mathrm{SD} = 0.71$), others ($M = 4.00$, $\mathrm{SD} = 1.00$), users ($M = 3.50$, $\mathrm{SD} = 1.05$) and academics ($M = 3.25$, $\mathrm{SD} = 1.42$). The omnibus ANOVA was significant ($F(5, 96) = 2.587$, $p = 0.031$, $\eta^2 = 0.119$), but Games–Howell post hoc comparisons identified no significant pairwise differences. This indicates overall stakeholder variation without a statistically confirmed between-group contrast.

Descriptively, investors, policymakers, and producers expressed stronger confidence that sustainable buildings provide better IEQ than conventional buildings, whereas academics and users were more reserved. For *I3P*, investors again rated this indicator highest ($M = 4.50$, $\mathrm{SD} = 0.55$), followed by policymakers ($M = 4.40$, $\mathrm{SD} = 0.70$), producers ($M = 4.35$, $\mathrm{SD} = 0.57$), users ($M = 3.83$, $\mathrm{SD} = 1.17$), others ($M = 3.67$, $\mathrm{SD} = 1.53$) and academics ($M = 3.58$, $\mathrm{SD} = 1.50$). Despite a significant omnibus ANOVA ($F(5, 96) = 2.624$, $p = 0.029$, $\eta^2 = 0.120$), no Games–Howell pairwise contrast reached significance. The descriptive pattern nevertheless suggests broadly shared but unevenly held confidence in IEQ-related health and well-being benefits, with academics again reporting the lowest mean. Overall, stakeholder divergence was greatest for EE, moderate for IEQ and lowest for WE. This pattern suggests that perceptions vary more strongly where perceived benefits depend on operational performance, user behaviour and post-occupancy verification. Taken together, the findings indicate that stakeholder perceptions of SBDP influence require stakeholder-sensitive interpretation, particularly for EE and IEQ, where stronger empirical validation and post-occupancy evidence are needed to substantiate perceived performance benefits.

4.6.2 | EE, WE, and IEQ Challenges

Significant differences were found for EE challenges *C4E* ($F(5, 96) = 2.472$, $\eta^2 = 0.114$) and *C6E* ($F(5, 96) = 3.352$, $\eta^2 = 0.149$), indicating moderate effects. These results suggest that stakeholder perceptions diverged most strongly on short-term cost prioritisation and expertise-related barriers. Investors and producers appeared more exposed to immediate financial decision-making pressures, while investors also appeared to perceive the lack of expertise as a more pronounced constraint to EE implementation. Conversely, no significant differences were detected for

C1E, *C2E*, *C3E* and *C5E*, where small-to-moderate η^2 values (0.018–0.084) suggest broader agreement that structural, regulatory, and resource-related barriers affect EE progress across groups.

For *C4E*, investors reported the highest mean ($M = 4.83$, $SD = 0.41$), followed by users ($M = 4.67$, $SD = 0.52$), producers and policymakers (both $M = 4.60$; $SD = 0.58$ and 0.52, respectively), academics ($M = 4.08$, $SD = 0.67$) and others ($M = 4.00$, $SD = 1.00$). Although the omnibus ANOVA was significant ($F(5, 96) = 2.472$, $p = 0.038$, $\eta^2 = 0.114$), Games–Howell post hoc comparisons confirmed no significant pairwise difference; the largest contrast, investors versus academics (mean difference = 0.750, $p = 0.087$), was a non-significant trend. The pattern indicates that market-facing groups perceived short-term cost prioritisation as a more pressing barrier than academics did.

For *C6E*, the omnibus ANOVA was significant and showed the largest effect among the EE challenges ($F(5, 96) = 3.352$, $p = 0.008$, $\eta^2 = 0.149$), indicating moderate stakeholder variation in perceptions of lack of expertise as a barrier to EE implementation. Based on the group pattern, investors rated this challenge highest, followed by policymakers, producers, academics, others and users. However, Games–Howell post hoc comparisons did not identify any statistically significant pairwise differences. The strongest non-significant contrasts were investors versus users (mean difference = 1.667, $p = 0.106$), investors versus producers (mean difference = 0.777, $p = 0.117$), investors versus academics (mean difference = 1.000, $p = 0.122$), and investors versus others (mean difference = 1.500, $p = 0.378$). This suggests that investors perceived the *C6E* as a more pronounced EE barrier than several other stakeholder groups. However, the absence of significant pairwise contrasts means that the result should be interpreted as overall stakeholder variation rather than a confirmed between-group difference.

For WE challenges, ANOVA revealed no statistically significant group differences across the five indicators, suggesting comparatively stronger alignment in how stakeholders perceived obstacles to WE implementation. The results were non-significant for *C1W* ($F(5, 96) = 1.508$, $p = 0.194$, $\eta^2 = 0.073$), *C2W* ($F(5, 96) = 0.762$, $p = 0.580$, $\eta^2 = 0.038$), *C3W* ($F(5, 96) = 1.039$, $p = 0.399$, $\eta^2 = 0.051$), *C4W* ($F(5, 96) = 1.324$, $p = 0.261$, $\eta^2 = 0.065$) and *C5W* ($F(5, 96) = 1.606$, $p = 0.166$, $\eta^2 = 0.077$). Games–Howell post hoc comparisons also confirmed that no pairwise stakeholder contrasts reached statistical significance. These results indicate that, unlike EE challenges, WE-related barriers were perceived more consistently across stakeholder groups.

Although no WE challenge showed statistically significant stakeholder variation, the descriptive patterns provide useful practical insight. For *C1W*, others reported the highest mean ($M = 4.67$, $SD = 0.58$), followed by academics ($M = 4.25$, $SD = 0.75$), policymakers ($M = 4.10$, $SD = 0.99$), producers ($M = 3.86$, $SD = 0.85$), investors ($M = 3.83$, $SD = 1.17$) and users ($M = 3.33$, $SD = 0.82$). This suggests broad recognition of benchmarking gaps, particularly among academics and policy-oriented stakeholders. For *C2W*, all groups reported relatively high means, ranging from users ($M = 4.00$, $SD = 0.63$) to others ($M = 4.67$, $SD = 0.58$), indicating strong cross-group agreement that the perception of abundant water remains a barrier to WE prioritisation. For *C3W*, investors rated this challenge highest ($M = 4.50$, $SD = 0.84$), while users rated it lowest ($M = 3.50$, $SD = 1.05$), suggesting some descriptive variation in perceived regulatory constraints, although this was not statistically confirmed.

For *C4W*, academics and others reported the highest means (both $M = 4.00$; $SD = 0.74$ and 1.00, respectively), followed by producers ($M = 3.69$, $SD = 1.03$), users ($M = 3.33$, $SD = 0.82$), policymakers ($M = 3.30$, $SD = 1.57$) and investors ($M = 2.83$, $SD = 1.47$). This pattern suggests that academics and technical stakeholders may perceive technological limitations as more important than investors, although Games–Howell comparisons did not support a significant group contrast. For *C5W*, producers, users, and others reported similarly high means ($M = 4.34$, $M = 4.33$ and $M = 4.33$, respectively), followed by policymakers ($M = 4.00$), while investors and academics reported lower means (both $M = 3.67$). The relatively higher η^2 value for *C5W* indicates modest descriptive divergence around the continued prioritisation of EE over WE, but the absence of significant post hoc differences suggests that this issue is still broadly recognised across groups. Overall, the WE challenge results suggest shared recognition that weak benchmarking, limited policy support, perceived water abundance, and the lower prioritisation of WE compared with EE constrain WE adoption in New Zealand buildings.

For IEQ challenges, significant differences appeared for *C3I* ($F(5, 96) = 2.366$, $\eta^2 = 0.110$) and *C5I* ($F(5, 96) = 2.482$, $\eta^2 = 0.114$), indicating moderate effects. Stakeholders involved in practice and operations appeared more likely to view ventilation as a direct comfort and performance issue, whereas academics and policymakers placed stronger emphasis on informational and regulatory deficiencies. No other IEQ challenges showed significant variation ($\eta^2 = 0.029$–0.088), indicating broader agreement on financial, structural, and implementation-related constraints. For *C3I*, policymakers reported the highest mean ($M = 4.90$, $SD = 0.32$), closely followed by investors ($M = 4.83$, $SD = 0.41$) and producers ($M = 4.57$, $SD = 0.61$), with others ($M = 4.33$, $SD = 1.16$), academics ($M = 4.25$, $SD = 0.87$) and users ($M = 4.00$, $SD = 0.63$) somewhat lower. Despite a significant omnibus ANOVA ($F(5, 96) = 2.366$, $p = 0.045$, $\eta^2 = 0.110$), Games–Howell post hoc comparisons identified no significant pairwise differences, indicating broad agreement on the centrality of ventilation with only modest variation in emphasis.

For *C5I*, investors gave the highest rating ($M = 4.50$, $SD = 0.55$), followed by others ($M = 4.33$, $SD = 0.58$), policymakers ($M = 4.20$, $SD = 1.03$), producers ($M = 4.17$, $SD = 0.84$) and academics ($M = 4.00$, $SD = 0.95$), while users rated it markedly lower ($M = 3.00$, $SD = 0.63$). The omnibus ANOVA was significant ($F(5, 96) = 2.482$, $p = 0.037$, $\eta^2 = 0.114$). Games–Howell post hoc comparisons confirmed that users rated this barrier significantly lower than investors (mean difference = 1.500, $p = 0.013$) and producers (mean difference = 1.169, $p = 0.033$), indicating that building users perceived the IEQ knowledge gap as substantially less pronounced than investors and producers did, plausibly reflecting their more limited technical exposure to IEQ management.

Taken together, the challenge results indicate that stakeholder divergence was strongest for EE, moderate for IEQ, and weakest for WE. This pattern suggests that perceptions differ more where sustainability barriers involve financial decision-making, stakeholder coordination, technical complexity and operational responsibility. In contrast, WE challenges were more consistently recognised across stakeholder groups, suggesting broader consensus around the need for stronger benchmarking, clearer regulatory support, and greater sectoral attention to water efficiency. These findings reinforce the need for integrated communication, regulatory consistency, and cross-sector knowledge exchange to align stakeholder priorities across EE, WE and IEQ (Poorisat et al. 2026b).

4.6.3 | EE, WE, and IEQ Strategies

Among the EE strategies, only *S6E* showed significant group differences ($F(5, 96) = 2.685$, $\eta^2 = 0.123$), indicating a moderate-to-large effect. This suggests differing views on the role of collaboration in achieving EE outcomes. Investors and users placed stronger emphasis on shared communication and accountability, whereas academics rated this strategy lower, possibly reflecting their greater distance from direct implementation. The remaining strategies, *S1E–S5E* and *S7E*, showed no significant variation, indicating broader alignment on established EE measures such as passive design, renewable-energy integration, and stronger building-code requirements. Collaboration, therefore, remains the main point of divergence, highlighting the need for mechanisms that improve coordination, trust, and accountability between design intent and operational performance (Poorisat et al. 2026b).

For *S6E*, investors expressed strong agreement ($M = 5.00$, $SD = 0.00$), followed by users ($M = 4.83$, $SD = 0.41$), policymakers ($M = 4.80$, $SD = 0.42$), producers ($M = 4.62$, $SD = 0.60$), others ($M = 4.33$, $SD = 0.58$) and academics ($M = 4.00$, $SD = 1.28$). The omnibus ANOVA was significant ($F(5, 96) = 2.685$, $p = 0.026$, $\eta^2 = 0.123$). Games–Howell comparisons indicated that investors rated collaboration significantly higher than producers (mean difference $= 0.385$, $p < 0.001$); this contrast should be interpreted with caution, however, because the investor group showed zero variance (all rated 5.00), which inflates the apparent precision of the comparison. Overall, investors, users, and policymakers placed the strongest value on collaboration, whereas academics, who are more removed from delivery, rated it lower.

For WE strategies, only *S1W* approached significance ($F(5, 96) = 2.252$, $\eta^2 = 0.105$), suggesting moderate but non-significant variation. Policymakers and producers rated this strategy higher, reflecting their stronger involvement in compliance, data-driven management and implementation processes. All other WE strategies (*S2W–S7W*) recorded small η^2 values (0.020–0.059), indicating strong consensus around conventional approaches such as efficient fittings, recycling and incentive-based programmes. Overall, smart metering appears to represent a transitional area where stakeholder readiness for digital innovation varies, while WE strategies more broadly benefit from relatively accessible technologies and clearer implementation pathways (Thebuwena et al. 2024).

Across all IEQ strategies, no significant differences were found ($p > 0.05$), with small-to-moderate effect sizes ($\eta^2 = 0.014–0.060$). Slightly higher variation appeared for *S1I* ($F(5, 96) = 1.224$, $p = 0.304$, $\eta^2 = 0.060$) and *S5I* ($F(5, 96) = 1.162$, $\eta^2 = 0.057$), suggesting some differences between practitioners, who may prioritise feasibility and cost, and policymakers or academics, who may emphasise regulation and technology integration. Overall, stakeholders showed broad agreement on IEQ improvement measures such as ventilation, lighting and material selection. Remaining divergence centred mainly on digital monitoring tools, indicating the need for capacity-building, demonstration projects, and clearer evidence of value to support wider adoption of IoT-based IEQ systems in New Zealand's sustainable building sector.

Taken together, the ANOVA results provide useful segmented evidence on stakeholder variation while also addressing the potential influence of producer dominance in the sample. The findings show that aggregate perceptions were not uniform across all domains: divergence was most evident in EE, moderate in IEQ and lowest in WE. However, because producers were overrepresented and some stakeholder groups were relatively small, these subgroup findings should be interpreted cautiously. The results therefore indicate patterns of stakeholder perception rather than statistically representative estimates for the entire New Zealand SBDP sector.

4.7 | Limitations and Future Research

Several limitations should be considered when interpreting the findings. First, this study is subject to an important methodological limitation because it examined stakeholder perceptions rather than objectively measured building performance. Metered energy use, water consumption, and monitored IEQ parameters were not collected. The findings therefore represent perceived, rather than verified, advantages of SBDPs over conventional buildings. Although perception-based evidence is useful for identifying professional consensus, priorities, and sectoral barriers, perceived benefits may not fully correspond with operational outcomes because of the design–operation performance gap across EE, WE and IEQ (Moradi et al. 2024). The cross-sectional, self-reported nature of the survey also introduces potential methodological biases. Social-desirability bias may have encouraged respondents to provide favourable assessments of SBDPs, particularly because many were professionally involved in sustainable building design and delivery. Self-selection bias may also have occurred, as professionals with stronger sustainability interests may have been more likely to participate. In addition, although the 19% response rate reflects the difficulty of recruiting a specialised professional population, non-response bias cannot be excluded because non-respondents may hold different views from respondents.

Second, the sample composition limits representativeness and generalisability. Producers represented 63% of respondents, whereas building users and occupants accounted for only 12%, and independent third-party stakeholders were underrepresented. As producers are directly involved in SBDP design and delivery, aggregate findings may partly reflect producer-oriented perspectives. To reduce over-reliance on aggregate results, stakeholder-group differences were examined using one-way ANOVA and η^2 effect sizes. However, the small size of some groups limits the precision of subgroup comparisons. Weighting was considered but not applied because reliable population-level proportions for each SBDP stakeholder group in New Zealand were not available; applying arbitrary weights could have distorted the results, particularly for smaller groups. Third, the modest sample size ($n = 102$) was adequate for the exploratory purpose of this perception-based study but limits transferability beyond comparable climatic, regulatory and market contexts. Internal consistency was assessed using Cronbach's α; however, convergent and discriminant validity were additionally assessed through a supplementary measurement-model analysis (Section 3.2.1). The structural relationships among EE, WE and IEQ are examined separately through a companion PLS-SEM analysis.

Accordingly, future research should triangulate stakeholder perceptions with objective post-occupancy data, including metered energy use, water-consumption records, and monitored IEQ indicators such as temperature, relative humidity, carbon-dioxide concentration, ventilation, lighting and acoustic comfort. Larger and more balanced samples should include stronger representation from occupants, facility managers and independent third-party stakeholders. Longitudinal and comparative studies across building types, regions, and climatic conditions could further assess cost-effectiveness, payback periods, and the evolution of EE–WE–IEQ relationships across design, construction, commissioning and operation.

5 | Implications of Research Findings

SBDPs have evolved from optional design aspirations to a critical mechanism for achieving environmental, economic and social resilience. They align directly with SDGs 3, 6, 7, 12, and 13 and represent a practical route for New Zealand to decarbonise its built environment while enhancing occupant well-being (Poorisat et al. 2024; United Nations 2022). To achieve this transformation, coordinated action is required among policymakers, producers, investors, users, and academics, each playing a distinct but interdependent role in shaping SBDPs' outcomes. First of all, policymakers hold the most decisive leverage as they play an important role in the transition from voluntary to mandatory sustainability certification, ensuring that all new public and large private developments adhere to recognised green building rating tools such as Green Star, LEED and NABERSNZ. Strengthening regulatory frameworks would also demand regular revisions of the New Zealand Building Code to include prescriptive EE, WE, and IEQ provisions comparable to leading international benchmarks. Specifically, EE requirements must enforce high-performance building envelopes, insulation, and HVAC standards that align with global best practices (Hafez et al. 2023).

Additionally, WE should be advanced through clear national benchmarks and the mandatory incorporation of reuse technologies, such as water recycling systems and green roofs (Greer et al. 2019). For IEQ, policymakers should collaborate to establish enforceable IAQ standards supported by regular post-occupancy evaluations, guided by international frameworks (Licina and Yildirim 2021). Producers should also invest in professional training, upskilling, and interdisciplinary collaboration to close the persistent communication and knowledge gaps between design, construction and operations. The integrated practice would not only enhance project delivery but also strengthen confidence among clients and regulators in the credibility of sustainable performance outcomes. Investors also play a pivotal role in financing and normalising these practices. Moving beyond short-term capital expenditure considerations, they should prioritise whole-life cost analysis and sustainable finance models that reward long-term operational efficiency. Incorporating frameworks such as NABERS, Green Star, and BREEAM within due diligence and valuation processes can help quantify performance risk and attract green investment (Debrah et al. 2022). Close collaboration between investors, policymakers, and design teams is also essential to implement outcome-based procurement models, in which financial incentives are directly linked to verified EE, WE, and IEQ performance data.

Equally, users play a critical role in sustainability demand; for example, educational and behavioural programmes, facilitated by local authorities, should aim to improve user understanding of EE, WE, and IEQ metrics, fostering behavioural change and promoting informed choices in leasing, occupancy and maintenance. When users are aware of building performance data and its implications for comfort and health, they can influence market preferences and regulatory priorities from the bottom up (Poorisat et al. 2024). Academics are uniquely positioned to bridge the persistent gap between research and practice. By generating open-access databases, academics can support data transparency and the development of locally calibrated performance metrics (Elnaklah et al. 2021). Their collaboration with policymakers and producers can ensure that scientific findings are translated into practical tools, standards, and training materials that inform both regulation and professional development. Finally, simplifying certification procedures, standardising performance reporting, and aligning design approval processes would further accelerate adoption and reduce the transaction costs currently associated with sustainable development (Moradi et al. 2024). Accordingly, the findings of this study underscore that advancing SBDPs in New Zealand demands a coordinated roadmap where every stakeholder has both a role and a responsibility. Policymakers must create the enabling environment through mandatory standards and incentives; producers must deliver integrated, performance-driven designs; investors must fund and reward sustainability outcomes; users must sustain demand through awareness and engagement, and academics must support this ecosystem with credible, accessible evidence. Together, these interconnected actions can transform New Zealand's built environment into a resilient, low-carbon system that embodies the principles of long-term environmental stewardship, social well-being and economic sustainability.

6 | Conclusion

This study investigated whether SBDPs in New Zealand are perceived to deliver superior outcomes in EE, WE, and IEQ and identified the challenges and strategies associated with their implementation. Drawing on survey responses from 102 built-environment professionals ($n = 102$), the study examined 19 influencing factors, 17 challenges and 20 strategies. Overall, stakeholders perceived SBDPs as outperforming conventional buildings across EE, WE and IEQ domains. EE was strongly associated with reduced energy consumption, lower operating costs, lower emissions, and improved occupant-related outcomes. WE was also viewed positively, although it remained comparatively underemphasised because of persistent perceptions of water abundance and weaker recognition of the WE–IEQ relationship. The main barriers identified were short-term financial priorities, inconsistent regulation and enforcement, and knowledge and coordination gaps across EE, WE and IEQ. In the WE domain, the lack of benchmarking frameworks and policy clarity continues to limit investment despite growing climate-related risks. In the IEQ domain, inadequate ventilation and the absence of comprehensive legislation emerged as major concerns. ANOVA results showed stakeholder variation, with investors, producers, and users expressing stronger confidence in realised EE and IEQ outcomes, while academics adopted a more cautious, evidence-based position.

WE perceptions were more consistent across stakeholder groups. Kendall's *W* analysis further indicated stronger consensus around IEQ challenges and strategies, moderate agreement for EE, and weaker alignment for WE. The findings contribute empirically, theoretically and practically. Empirically, the study provides a New Zealand-specific, cross-domain perspective on EE, WE and IEQ integration, identifying areas of stakeholder consensus and divergence. Theoretically, it operationalises the water–energy–IEQ nexus as an integrated, perception-based construct and shows that practitioners recognise the EE–WE relationship more clearly than the WE–IEQ linkage. It also suggests that sustainable-building diffusion in New Zealand is shaped more by institutional, behavioural, and capability-related barriers than by technical limitations alone. In addition, the prominence of the design–operation gap extends building-performance-gap discussions beyond energy to a broader EE–WE–IEQ framing.

Practically, the study provides an actionable pathway for improving SBDPs through stronger benchmarks, outcome-based procurement, whole-life cost assessment, streamlined certification and continuous professional learning. While the findings are based on a purposive and perception-based sample, they offer useful insights for New Zealand and other contexts with similar policy and climatic conditions. Future research should verify these perceptions through longitudinal post-occupancy data, cost–benefit analysis, and pilot testing of policy and financial instruments. Methodologically, complementary PLS-SEM analysis and focus group validation can further examine causal linkages, prioritise strategies, and strengthen the empirical basis for EE–WE–IEQ integration. In conclusion, SBDPs in New Zealand are perceived to offer clear benefits for building performance and occupant well-being. However, realising their full potential requires moving from intention to verification through clearer regulation, collaborative delivery, informed users, and transparent performance data. With coordinated action among policymakers, producers, investors, users, and academics, SBDPs can become a practical pathway toward a low-carbon, water-efficient and health-promoting built environment.

Author Contributions

Tharaya Poorisat: formal analysis, writing – original draft, data curation, methodology. **Itohan Esther Aigwi:** writing – review and editing, supervision. **Dat Tien Doan:** writing – review and editing, supervision. **Ali GhaffarianHoseini:** writing – review and editing, supervision.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Table S1:** Measurement model evaluation (for the strategies model). **Table S2:** Discriminant validity of constructs (for the strategies model—Fornell-Larcker criterion). **Table S3:** Discriminant validity of constructs (for the strategies model—HTMT). **Table S4:** Discriminant validity of the strategy-driven measurement model: HTMT ratios with bias-corrected bootstrap confidence intervals ($n = 102$; 10,000 subsamples; one-tailed). **Table S5:** Measurement model evaluation (for the challenges model). **Table S6:** Discriminant validity of constructs (for the challenges model—Fornell-Larcker criterion). **Table S7:** Discriminant validity of constructs (for the challenges model—HTMT). **Table S8:** Discriminant validity of the challenge-driven measurement model: HTMT ratios with bias-corrected bootstrap confidence intervals ($n = 102$; 10,000 subsamples; one-tailed). **Table S9:** Perceived influence of EE, WE, and IEQ (one-sample *t*-tests). **Table S10:** Challenges to EE, WE and IEQ (one-sample *t*-tests). **Table S11:** Strategies for EE, WE and IEQ (one-sample *t*-tests). **Data S1:** Supporting Information B.