# DIVERGING PERSPECTIVES ON ENERGY PERFORMANCE GAPS IN GREEN BUILDINGS: AN EMPIRICAL STUDY OF INDUSTRY EXPERTS

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## ABSTRACT

Green buildings continue to underperform in actual energy use compared to predicted values, revealing persistent energy performance gaps. This study explores the differing perspectives of industry experts on the root causes of and its strategies in this issue. A structured survey was administered to 278 respondents and analyzed using Relative Importance Index (RII) and Kendall's W to measure agreement across three expert subgroups: those uninvolved in green buildings, involved but uncertified, and certified facilitators. Results reveal consistent rankings for major factors such as occupant awareness and leadership commitment but also highlight nuanced differences in how subgroups perceive organisational versus technical contributions. This study informs tailored energy management interventions and highlights the value of expert diversity in shaping sustainable building strategies.

**Keywords:** Building Energy Performance Gap (BEPG), Root Causes of BEPG, Green Buildings, Expert Perspectives, Malaysia.

## 1. INTRODUCTION

In the building industry, one of the most persistent challenges during the operational phase is the performance gap—the discrepancy between the expected (perceived) and actual energy performance of buildings. This issue is especially prevalent in green buildings, which are often criticised for underperforming despite high expectations and certification (Bai et al., 2024; Chiang & Calautit, 2025; Coleman & Robinson, 2018; Thatcher & Milner, 2016; Yen et al., 2016; Zaid & Kiani, 2016). Previous studies highlight that one key criticism is the uncertainty surrounding green investments, making it difficult to justify the higher upfront costs for sustainable features (Aliagha et al., 2013; Zuo & Zhao, 2014). However, some argue that when considering life-cycle costs, incentives, and property value gains, green buildings may not be significantly more expensive than conventional ones (Halim, 2012). Moreover, government subsidies and tax incentives have been shown to influence market acceptance of green buildings, linking economic feasibility to socio-political support (Zhao et al., 2015). From an organisational standpoint, investments in green buildings are also driven by the potential to enhance corporate image, improve employee well-being, and boost satisfaction and productivity (Thatcher & Milner, 2016). While studies consistently show improved air quality and lighting in green buildings, findings on thermal comfort remain mixed (Armitage et al., 2011; Collinge et al., 2014; Wilkinson et al., 2012).

Beyond financial and social concerns, growing evidence questions the real operational energy performance of green buildings. Newsham et al. (2009) found that 28–35% of LEED-rated buildings consumed more energy than conventional ones, despite lower average consumption per floor area. In Malaysia, Zaid & Kiani (2016) reported that a GBI-certified building had a higher Building Energy Index (BEI) than a non-rated one. This apparent contradiction is often attributed to the rebound effect, where increased efficiency leads occupants to use more energy (Azizi & Wilkinson, 2015; Liang & Qiu, 2019). Studies suggest that achieving significant energy reductions is difficult without addressing behavioural factors (Bai et al., 2024; Chiang & Calautit, 2025; Lin & Liu, 2015; Wang et al., 2014).

The transition to green buildings is vital for energy efficiency and climate mitigation. However, many certified green buildings fail to meet expected energy performance, indicating a gap between theoretical and actual efficiency. This study investigates how professionals from different backgrounds perceive the root causes and strategies of this BEPG. Understanding these diverging or converging views is crucial for designing practical and inclusive energy management strategies.

## 2. LITERATURE REVIEW

Numerous buildings, even those integrated with advanced energy-efficient technologies, have been found to underperform in terms of their anticipated energy savings (Bai et al., 2024; Chiang & Calautit, 2025; Zou et al., 2018). In some cases, actual energy use surpasses predicted levels by up to 2.5 times, posing a significant challenge to meet energy efficiency objectives and potentially compromising the credibility of green building certifications. The root causes of the building energy performance gap (BEPG) are generally grouped into three main categories: factors related to design, construction or commissioning, and building operation (see Table 1). This classification helps to systematically understand how various decisions and actions—taken at different stages of the building lifecycle—can negatively impact actual energy performance.

Table 1: Root causes of energy performance gap

| Codes | Causes | References |
|---|---|---|
| **Design-related causes** | | |
| **DRC1** | Overestimation of actual technological performance | Bai et al., 2024; Chiang & Calautit, 2025; P. De Wilde, 2014; Greening et al., 2000; Jones et al., 2015; Liu & Lin, 2016; |

| Codes | Causes | References |
|---|---|---|
| | | Scofield, 2009; Zou et al., 2018 |
| DRC2 | Integration of inefficient or oversized systems | Borgstein et al., 2017; Doty & Turner, 2009; Gordic´ et al., 2010; Jones et al., 2015; Key et al., 1996; Min et al., 2016; Sullivan et al., 2010; Zou et al., 2018 |
| DRC3 | Use of inappropriate parameters in modelling and simulation | Bai et al., 2024; Chiang & Calautit, 2025; De Wilde, 2014; Hong et al., 2015, 2017; Jia et al., 2017; Jones et al., 2015; Newsham et al., 2009; Zou et al., 2018 |
| DRC4 | Design neglects end-user needs and convenience | Bai et al., 2024; Chiang & Calautit, 2025; De Wilde, 2014; Heiskanen et al., 2013; Jones et al., 2015; Venkataraman et al., 2018; Zou et al., 2018 |
| DRC5 | Design overlooks buildability and maintainability considerations | Bai et al., 2024; Chiang & Calautit, 2025; P. De Wilde, 2014; Doty & Turner, 2009; Frank et al., 2015; Greenbuildingindex Sdn Bhd., 2011; Jones et al., 2015;  de P. Wilde & Jones, 2013; Wu et al., 2016; Zainol et al., 2014; Zou et al., 2018 |
| DRC6 | Poor communication between designers and building owners | Bai et al., 2024; Cagno et al., 2013; Chiang & Calautit, 2025; Choi, 2009; P. De Wilde, 2014; Deuble, 2007; Isa et al., 2013; Niu et al., 2016; Shebli, 2016; Tuominen et al., 2012; Zou et al., 2018 |
| DRC7 | Design-stage modifications and change orders | Bai et al., 2024; Chiang & Calautit, 2025; Cross et al., 2017; P. De Wilde, 2014; Zou et al., 2018 |
| DRC8 | Regulatory compliance frameworks omit certain building energy uses | Bai et al., 2024; Chiang & Calautit, 2025; Cohen, 2013; P. De Wilde, 2014; International Energy Agency, 2019; Lewry & Hamilton, 2017; Menezes, 2012; Mulville et al., 2016 |
| **Construction or commissioning-related causes** | | |
| CRC1 | Contractor lacks experience and expertise in implementing advanced green features | Chuen Chan et al., 2017; Doty & Turner, 2009; Valle & Junghans, 2015; Zou et al., 2018 |
| CRC2 | Cost-cutting practices by contractors, including material substitution and non-compliance | Turner & Frankel, 2008; Zou et al., 2018 |
| CRC3 | Poor workmanship and improper construction or installation techniques | Turner & Frankel, 2008; Zainol et al., 2014; Zou et al., 2018 |
| CRC4 | Comprehensive performance testing is limited by time and budget constraints | Bunn & Way, 2010; Jones et al., 2015; Zou et al., 2018 |
| CRC5 | Failure to detect underlying or latent construction issues | Antunes et al., 2014; Bai et al., 2024; Barbetta et al., 2015; Cagno et al., 2013; Chiang & Calautit, 2025; Department of Energy & Climate Change, 2012; Jones et al., 2015; Moezzi & Janda, 2014; Paramonova et al., 2015; Sa et al., 2017;  de P. Wilde & Jones, 2013; Zofia Birgit Brown, 2009; Zou et al., 2018 |
| CRC6 | Insufficient detail and clarity in design documentation provided to contractors | Bai et al., 2024; Bond, 2011; Brown & Cole, 2008; Brunke et al., 2014; Enrico Cagno et al., 2015; Cattaneo, 2018; Chiang & Calautit, 2025;  Chuen Chan et al., 2017; Gou, 2020; Jones et al., 2015; D. Li et al., 2017; D. H. W. Li et al., 2010; Liang & Qiu, 2019; Niu et al., 2016; Ruparathna et al., 2016; Tuominen et al., 2012; Venkataraman et al., 2018;  de P. Wilde & Jones, 2013; Zou et al., 2018 |
| CRC7 | Design changes and variations introduced during the construction stage | Bai et al., 2024; Chiang & Calautit, 2025; Cross et al., 2017; P. De Wilde, 2014; Zou et al., 2018 |
| **Operational-related causes** | | |
| ORC1 | Lack of occupant awareness regarding energy conservation practices | Allouhi et al., 2015; E Cagno et al., 2013; Enrico Cagno et al., 2015; Dioba, 2013; Finnerty et al., 2018; Kormos & Gifford, 2014; Lee & Tanusia, 2016; Liang & Qiu, 2019; Miller, 2013; |

| Codes | Causes | References |
|---|---|---|
| | | Niu et al., 2016; Shrubsole et al., 2019; Trianni & Cagno, 2012; Wimala et al., 2016 |
| **ORC2** | Ineffective occupant interaction with building control systems | Elmualim, 2012; Hong et al., 2016, 2017; Jia et al., 2017; Khashe et al., 2016; Niu et al., 2016; Paone & Bacher, 2018; Robinson et al., 2016; Shi et al., 2019; Shrubsole et al., 2019; Tam, 2018 |
| **ORC3** | Negative peer influence and behavioural interactions among occupants | Carrico & Riemer, 2011; Cattaneo, 2018; Delmas & Lessem, 2014; Elmualim, 2012; Jain et al., 2013; Kano, 2013; Khashe et al., 2016; Lee & Tanusia, 2016; Lo et al., 2012b, 2012a; Mulville et al., 2016; Murtagh et al., 2013; Nilsson et al., 2015; Siero et al., 1996; Staddon et al., 2016 |
| **ORC4** | Inadequate information or guidance on desired energy-efficient behaviours | Allouhi et al., 2015; Brown & Cole, 2008; Cattaneo, 2018; Elmualim, 2012; Hong et al., 2017; Lo et al., 2012a; Nisiforou et al., 2012; Staddon et al., 2016 |
| **ORC5** | Lack of top management commitment and support for energy efficiency initiatives | Ashford, 1996; Brunke et al., 2014; Building Research Establishment, 1995; E Cagno et al., 2013; Engert & Baumgartner, 2016; Finnerty et al., 2018; Land-of-Sky Regional Council, 2006; Sa et al., 2017; A. Trianni & Cagno, 2012; Andrea Trianni, 2020; Zuo & Zhao, 2014 |
| **ORC6** | Facilities management (FM) lacks authority to influence or enforce operational policies | Brunke et al., 2014; Elmualim, 2012; Finnerty et al., 2017; Land-of-Sky Regional Council, 2006; Mineeva, 2016; Posch, 2005 |
| **ORC7** | Ineffective communication and collaboration between FM and occupants | Coleman et al., 2018; Khashe et al., 2016; Leygue et al., 2017; Liang & Qiu, 2019; Niu et al., 2016; Robinson et al., 2016; Xiaoqing Shi & Li, 2019; Shrubsole et al., 2019; Staddon et al., 2016; Zou et al., 2018 |
| **ORC8** | Increase in building occupancy levels beyond original design assumptions | Bai et al., 2024; Chiang & Calautit, 2025; Coleman & Robinson, 2018; P. De Wilde, 2014; Liang & Qiu, 2019; Niu et al., 2016; Robinson et al., 2016; Xiaoqing Shi & Li, 2019; Shrubsole et al., 2019; Staddon et al., 2016; Zou et al., 2018 |
| **ORC9** | Extended building operation hours beyond initial specifications | Liang & Qiu, 2019; Min et al., 2016; Robinson et al., 2016; Shrubsole et al., 2019; van Dronkelaar et al., 2016 |
| **ORC10** | Excessive use of unplanned or additional appliances | A. Elmualim et al., 2010; Lewry & Hamilton, 2017; Liang & Qiu, 2019; Menezes, 2012; Min et al., 2016; van Dronkelaar et al., 2016; Zaid & Kiani, 2016 |
| **ORC11** | Limited financial resources and insufficient incentives for energy efficiency upgrades | Bai et al., 2024; Barbetta et al., 2015; E Cagno et al., 2013; Cao et al., 2015; Chiang & Calautit, 2025; Finnerty et al., 2018; Gillingham & Palmery, 2014; Leygue et al., 2017; Liang & Qiu, 2019; Miller, 2013; Parag & Janda, 2014; Shen et al., 2016; Shrubsole et al., 2019; A. Trianni & Cagno, 2012; de P. Wilde & Jones, 2013 |
| **ORC12** | Policy instruments such as standards, subsidies, and taxes are insufficiently compelling | Cattaneo, 2018; Christen et al., 2016; Cowan & Daim, 2011; Department of Energy & Climate Change, 2012; Epstein & Buhovac, 2010; Geng et al., 2019; Gou, 2020; Introna et al., 2014; Isa et al., 2013; Schulze et al., 2015; Shabrin & Kashem, 2017; A. Trianni & Cagno, 2012; Tuominen et al., 2015 |
| **ORC13** | Energy control systems are bypassed or overridden by building occupants | Jia et al., 2017; Nisiforou et al., 2012; Zofia Birgit Brown, 2009 |
| **ORC14** | Insufficient skills and knowledge in energy monitoring, analysis, and control | Aghili et al., 2016; Aliagha et al., 2013; Brunke et al., 2014; E Cagno et al., 2013; Cole et al., 2008; Duarte et al., 2011; A. Elmualim et al., 2010; Gou, 2020; Parag & Janda, 2014; Paramonova et al., 2015; A. Trianni & Cagno, 2012; Valle & Junghans, 2015; Yen et al., 2016; Zhang et al., 2019 |
| **ORC15** | Absence or inadequacy of sub-metering systems for detailed energy | Bai et al., 2024; Chiang & Calautit, 2025; Coleman et al., 2018; P. De Wilde, 2014; Robinson et al., 2016 |

| Codes | Causes | References |
|---|---|---|
|  | tracking |  |
| **ORC16** | Lack of performance fine-tuning during the initial years of building operating | Borgstein et al., 2017; Demanuele et al., 2010; Jason Palmer, 2016; Sullivan et al., 2010; Zou et al., 2018 |
| **ORC17** | Energy efficiency equipment underperforms relative to manufacturer's specifications | Bai et al., 2024; Chiang & Calautit, 2025; Newsham et al., 2009; Turner & Frankel, 2008; de P. Wilde & Jones, 2013; Yen et al., 2016 |
| **ORC18** | Suppliers fail to meet performance or specification requirements during equipment replacement | Doty & Turner, 2009; Gerarden et al., 2015; Steel & Lewry, 2017; Sullivan et al., 2010 |
| **ORC19** | Incomplete or missing documentation from previous FM contractors | Bosch & Pearce, 2003; Juan et al., 2010; D. Li et al., 2017; Mineeva, 2016; Sa et al., 2017 |
| **ORC20** | External environmental changes (i.e., climate change, urban heat island) impacting building performance | Bai et al., 2024; Chiang & Calautit, 2025; P. De Wilde, 2014; Geng et al., 2019; Hong et al., 2015; Paone & Bacher, 2018; Shaikh et al., 2017; Sullivan et al., 2010; Tam, 2018; Valle & Junghans, 2015; Zhang et al., 2019; Zou et al., 2018 |

## 2.1 Organisational

Institutional and organisational factors play a major role in contributing to the energy performance gap in non-residential buildings (Liang & Qiu, 2019). One common issue is the leasing of spaces to tenants with diverse energy usage patterns driven by individual behaviours, which often leads to inconsistencies in energy consumption and potential conflicts between tenants and landlords. Changes in building operations—such as longer operating hours (Min et al., 2016; Shrubsole et al., 2019), higher occupancy levels (Liang & Qiu, 2019; Xing Shi et al., 2019), and miscellaneous electric loads (Min et al., 2016; Zaid & Kiani, 2016)—can significantly raise actual energy usage. Furthermore, a lack of financial resources and poor managerial dedication to long-term energy planning are closely linked concerns (Mineeva, 2016). While these problems often emerge during the operational stage, they can be effectively addressed through comprehensive energy management practices and proactive involvement from both leadership and building occupants.

## 2.2 Leadership

Effective strategic leadership is crucial for achieving sustained energy efficiency while addressing broader social, environmental, and economic goals. Landlords play a pivotal role in influencing the energy performance gap (Zou et al., 2018). Although facilities managers are key to managing building operations, their duties often span beyond just energy-related tasks (Liang & Qiu, 2019; Myeda et al., 2014). Therefore, assigning dedicated energy managers is essential to ensure focused energy oversight (Staddon et al., 2016). Leadership affects both the underlying causes of energy inefficiencies and the effectiveness of solutions across the entire building lifecycle. Open and transparent leadership enhances stakeholder involvement, creating a continuous feedback loop for performance improvement (Coleman & Robinson, 2018; Shrubsole et al., 2019). Nevertheless, weak communication among stakeholders remains a major barrier to the effective sharing of energy-related information (Zou et al., 2018).

## 2.3 Technological

Technological issues are a common contributor to the energy performance gap. Inaccurate system sizing by designers—whether too large or too small—can lead to inefficient operation and unrealistic energy savings projections (Bai et al., 2024; Chiang & Calautit, 2025; P. De Wilde, 2014; Jones et al., 2015). Additionally, poor installation practices by contractors can further reduce system performance (Benjamin et al., 2020). Even advanced energy-efficient technologies in green buildings often face teething problems during initial use. Many of these systems, particularly complex control mechanisms,

require frequent updates and can be difficult for operators who lack proper training. Technologies like occupancy-based lighting and photosensors are designed to reduce energy use (Guo et al., 2010), but their performance often falls short due to operational complexity and high maintenance needs (Benjamin et al., 2020; Guo et al., 2010). When sensors are incorrectly installed or not properly calibrated, it can lead to occupant frustration and result in systems being overridden or disabled (Benjamin et al., 2020). Ultimately, the success of these technologies depends not only on their design but also on how well they are maintained and how effectively they support occupant comfort.

## 2.4 Behavioural

Occupant behaviour plays a crucial role in a building's energy performance during its operational phase (Zou et al., 2018). Often, occupant actions differ from what designers anticipate, largely due to low awareness or confusing system interfaces. Various factors shape behaviour, affecting both energy use and occupant satisfaction. Educational efforts can encourage more energy-conscious habits (Zurrah et al., 2025), while providing feedback and relevant information can improve accountability and efficiency (Bond, 2011; Liang & Qiu, 2019). Incentive-based approaches, like recognition and rewards, can also support positive change (Staddon et al., 2016). Still, altering behaviour is complex and depends heavily on the surrounding context and the quality of information available (Bond, 2011; Liang & Qiu, 2019).

## 2.5 Skill and Knowledge

With increasing environmental concerns, it is essential to involve facilities management (FM) from the design stage (Jawdeh, 2013). However, FM is often excluded during early planning, leading to expensive modifications after construction (Zou et al., 2018). Poor contractor selection and hiring underqualified staff can also result in design non-compliance and hidden defects (Zou et al., 2018). To overcome these challenges, continuous improvement practices are vital, emphasizing the importance of FM engagement (Min et al., 2016). Yet, many FM professionals lack the necessary skills to effectively manage energy and sustainability goals (Duarte et al., 2011). Skilled energy managers and targeted training—covering technical, managerial, and awareness areas—are crucial. Bridging knowledge gaps among all stakeholders throughout the building lifecycle is key to reducing the energy performance gap. Behaviour plays a crucial role in a building's energy performance during its operational phase (Zou et al., 2018).

## 2.6 Informational

Information is imperative for effective energy management, yet data-related challenges persist throughout a building's lifecycle. Common issues include limited data availability from design to operation, miscommunication among stakeholders (Rajat Gupta & Gregg, 2016), and incorrect data inputs (Zou et al., 2018). Inadequate documentation and improper system usage further reduce performance (Zou et al., 2018). Energy modelling tools often fall short in predicting actual consumption due to changes in equipment, usage patterns, and deviations from original designs. Effective use of these tools requires both technical expertise and accurate interpretation (Bai et al., 2024; Chiang & Calautit, 2025; P. De Wilde, 2014). To improve forecasting accuracy, it's essential to ensure data reliability and build interpretive skills. The "human-in-the-loop" approach addresses this by incorporating occupant feedback through pre- and post-occupancy evaluations into digital models (Zou et al., 2018).

## 2.7 External

External factors play a significant role in building energy performance. These include changing weather conditions (Chen et al., 2020), government regulations (Finnerty et al., 2018), and financial incentives like energy subsidies (Cattaneo, 2018). Weather unpredictability alone can cause energy

performance to vary by as much as 7% from year to year. While national regulations offer standard benchmarks, real-world performance needs to be assessed within its specific context. Incorporating clear measurement and verification processes into policies can help reduce these discrepancies. Supportive policies—such as subsidies and tax breaks—not only encourage energy efficiency but also lower investment risks (Cattaneo, 2018). To maximise impact, these incentives should be inclusive and easily accessible to ensure widespread benefits for society.

Globally, research has identified seven primary strategy elements that influence efforts to reduce the BEPG: organisational frameworks, FM leadership, technological infrastructure, occupant behaviour, skill and knowledge levels, availability of information, and external environmental or regulatory conditions (see Table 2). This table consolidates and categorises the most commonly cited strategies from global literature aimed at mitigating the BEPG, coded under seven thematic groups. Each strategy element has been identified through a comprehensive literature review and aligned with best practices across disciplines in energy management, building performance, and green certification

Table 2: Strategy Elements of Energy Performance Gap

| Codes | Strategy elements | References |
|---|---|---|
| **Organisational Framework** | | |
| ODF1 | Active involvement of top management in energy management | Abdelaziz et al., 2011; Brunke et al., 2014; Doty & Turner, 2009; Gordic′ et al., 2010; Mineeva, 2016; Sa et al., 2017; Schulze et al., 2015; Thollander & Ottosson, 2008; Andrea Trianni, 2020 |
| ODF2 | Top management should have commitment for continuous improvement | Antunes et al., 2014; Deru & Field, 2014; Finnerty et al., 2017; Gordic′ et al., 2010; Mineeva, 2016; Ngai et al., 2013; United Nations Environment Programme, 2006 |
| ODF3 | Energy policy should be short and comprehensive that includes objectives, the authority of energy manager, energy reporting and training requirements | Antunes et al., 2014; Backlund et al., 2012; Building Research Energy Conservation Support Unit (BRESCU), 2006; Building Sector Energy Efficiency Project, 2017; Introna et al., 2014; Mineeva, 2016; Prashar, 2017; Schulze et al., 2015; Shaikh et al., 2017 |
| ODF4 | Energy policy should be reviewed and made recommendations for updating by energy manager and the energy committee | Carbon Trust, 2011; Finnerty et al., 2018; Kano, 2013; Mineeva, 2016 |
| ODF5 | Energy committee should be formed, the members should be rotated once year to bring new people with new ideas | Ashford, 1996; Building Research Energy Conservation Support Unit (BRESCU), 2006; Building Research Establishment, 1996; Building Sector Energy Efficiency Project, 2017; Doty & Turner, 2009; Kano, 2013; Posch, 2005; Schulze et al., 2015; United Nations Environment Programme, 2006 |
| ODF6 | Clear and defined roles of energy management committee | Ashford, 1996; Building Research Energy Conservation Support Unit (BRESCU), 2006; Building Research Establishment, 1996; Building Sector Energy Efficiency Project, 2017; Gordic′ et al., 2010; Natural Resources Canada, 2015; United Nations Environment Programme, 2006 |
| ODF7 | Energy efficiency and energy conservation become the culture in an organisation | (Antunes et al., 2014; Borgstein et al., 2017; R. Bull & Janda, 2017; Endrejat et al., 2017; Engert & Baumgartner, 2016; Leygue et al., 2017; Lutzenhiser, 2014; Miller, 2013; Moezzi & Janda, 2014; Mulville et al., 2016; Prashar, 2017; J. F. Robinson et al., 2016; Sa et al., 2017; Schulze et al., 2015; Staddon et al., 2016; Zofia Birgit Brown, 2009) |
| **FM Leadership** | | |
| LDF1 | Employment of on-site energy manager | Brunke et al., 2014; Building Research Energy Conservation Support Unit (BRESCU), 2006; Carbon Trust, 2011; Finnerty et al., 2017; Goulden & Spence, 2015; Jovanović & Filipović, |

| Codes | Strategy elements | References |
|---|---|---|
|  |  | 2016; Sa et al., 2017; Zou et al., 2018 |
| LDF2 | Energy manager should be positioned high enough in the organisational structure. | Department of Energy & Climate Change, 2012; Gordic´ et al., 2010; Goulden & Spence, 2015; Land-of-Sky Regional Council, 2006; Schulze et al., 2015 |
| LDF3 | Good relationship between stakeholders (e.g. Management team and building occupants) | Goulden & Spence, 2015; Ogino & Tanaka, 2014; D. Robinson et al., 2004; Sarpin et al., 2018; Widyastuti et al., 2019 |
| LDF4 | Energy managers should have capabilities to produce complete comprehensive evaluations of building performance | R. Bull et al., 2015; Carbon Trust, 2011; Doty & Turner, 2009; Dowling, 1998; Goulden & Spence, 2015; Siciliano et al., 2015 |
| **Technological Infrastructure** | | |
| TDF1 | Simplicity in building equipment technology for energy management system | (Chiang & Calautit, 2025)Bai et al., 2024; Bhatia, n.d.; Borgstein et al., 2017; Chiang & Calautit, 2025; Cole et al., 2008; Fedoruk et al., 2015; Jones et al., 2015;  de P. Wilde & Jones, 2013; Zofia Birgit Brown, 2009 |
| TDF2 | Action plans should be grouped into design, construction and commissioning and operation stages | Building Research Energy Conservation Support Unit (BRESCU), 2006; Finnerty et al., 2017; Xing Shi et al., 2019 |
| TDF3 | Well scheduled and informed maintenance of equipment and building sub-systems | Amaratunga, 2001; Kamarazaly, 2007; Kamilaris et al., 2014; D. Lee & Cheng, 2016; Osma et al., 2015; Ruparathna et al., 2016; Sullivan et al., 2010; Wu et al., 2016 |
| TDF4 | Establishment of operational criteria and checklist for energy efficient operations and maintenance | Baharuddin et al., 2011; Caeiro et al., 2012; Dall'O et al., 2012; Fedoruk et al., 2015; Staddon et al., 2016; Sullivan et al., 2010; United Nations Environment Programme, 2006 |
| TDF5 | Energy reduction reduced and continuously improved every year | Antunes et al., 2014; Colby, 2010; Engert & Baumgartner, 2016; Finnerty et al., 2017; Gordic´ et al., 2010; Introna et al., 2014; Jovanović & Filipović, 2016; Leritz et al., 2014; Min et al., 2016; Ngai et al., 2013; Nulty, 2014 |
| TDF6 | Energy audit every year | Abdelaziz et al., 2011; Allouhi et al., 2015; Barbetta et al., 2015; Brunke et al., 2014; Paramonova et al., 2015; Schulze et al., 2015; Thollander & Dotzauer, 2010; Andrea Trianni, 2020 |
| **Occupant Behaviour** | | |
| BDF1 | Get more feedbacks from building occupants on how they can help more in energy saving | Cattaneo, 2018; Fischer, 2008; Jain et al., 2013; Khashe et al., 2016; D. Li et al., 2017; Liang & Qiu, 2019; Miller, 2013; Mulville et al., 2016; Podgornik et al., 2015; Poh & Liang, 2017; Pollard, 2016; Xing Shi et al., 2019; Staddon et al., 2016; Zhao et al., 2015 |
| BDF2 | Promote energy management practices and awareness among building occupants at least twice a year | Engert & Baumgartner, 2016; Finnerty et al., 2018; Jáñez Morán et al., 2016; Lucon et al., 2014; Paramonova et al., 2015; Staddon et al., 2016 |
| BDF3 | Continuously promoting energy target for upcoming years | Boomsma et al., 2016; Carbon Trust, 2011; Fedoruk et al., 2015; Finnerty et al., 2018; Land-of-Sky Regional Council, 2006; Leygue et al., 2017; Siero et al., 1996 |
| BDF4 | Create the feel of ownership among building occupants for energy management | Building Research Energy Conservation Support Unit (BRESCU), 2006; Carbon Trust, 2011; Dowling, 1998; Finnerty et al., 2018; Steel & Lewry, 2017; United States Environmental Protection Agency, 2013 |
| BDF5 | Give reward/recognition to occupants contribute to energy performance improvement | Batista-taran et al., 2009; Building Research Energy Conservation Support Unit (BRESCU), 2006; Engert & Baumgartner, 2016; Finnerty et al., 2018; Jain et al., 2012; Leygue et al., 2017; Schulze et al., 2015; Staddon et al., 2016 |
| **Skill and Knowledge** | | |
| KDF1 | More seminar/workshop for building practitioners to improve their | Backlund et al., 2012; Bhavani et al., 2016; Carbon Trust, 2011; A. Elmualim et al., 2010; Engert & Baumgartner, 2016; |

| Codes | Strategy elements | References |
|---|---|---|
| | understanding and knowledge on green building management | Finnerty et al., 2017; Prashar, 2017; Shen et al., 2016; Staddon et al., 2016; Valle & Junghans, 2015; Waris et al., 2014; Zhang et al., 2019 |
| KDF2 | Good competency level of energy manager | Brunke et al., 2014; Carbon Trust, 2011; Energy Commission of Malaysia, 2013; Energy Institute, 2016; Jovanović & Filipović, 2016; Posch, 2005 |
| KDF3 | Different forms of education training should be conducted such as management training, energy team training and occupants training. | Brunke et al., 2014; Carbon Trust, 2011; Energy Commission of Malaysia, 2013; Energy Institute, 2016; Finnerty et al., 2017; Jovanović & Filipović, 2016; Posch, 2005; Prashar, 2017; Andrea Trianni, 2020/ |
| KDF4 | Full understanding of climate and energy system by both designer and end user. | Bai et al., 2024; Bunn & Way, 2010; Chiang & Calautit, 2025; Coleman et al., 2018; P. De Wilde, 2014; Durosaiye et al., 2019; J. F. Robinson et al., 2016; Valle & Junghans, 2015; Zofia Birgit Brown, 2009; Zou et al., 2018 |
| KDF5 | Assignment of sustainability champion who is willingly and knowledgeable person to help facilities managers to lead sustainable effort | Beacock & Kingham, 2005; Building Research Energy Conservation Support Unit (BRESCU), 2006; Colby, 2010; Consortium for Energy Efficiency, 2016; Department of Energy: Republic of South Africa, 2005; Department of Energy & Climate Change, 2012; Governor's Green Government Council, 2010; Legett et al., 2016; Leritz et al., 2014; Northwest Energy Efficiency Alliance, 2013; Xing Shi et al., 2019; Staddon et al., 2016; Steel & Lewry, 2017; Sullivan et al., 2010 |
| KDF6 | Technical training for Energy Management Committee at least once a year | Building Sector Energy Efficiency Project, 2017; Introna et al., 2014; Natural Resources Canada, 2015; Prashar, 2017; United Nations Environment Programme, 2006 |
| **Information Availability** | | |
| IDF1 | Conduct pre-occupancy data collection and post-occupancy data collection to predict more realistic energy consumption | Amaratunga, 2001; Bai et al., 2024; M. Bull & Brown, 2012; Chiang & Calautit, 2025; Coleman et al., 2018; P. De Wilde, 2014; Leygue et al., 2017; P. Li et al., 2018; Ng & Akasah, 2013; Niu et al., 2016; Xing Shi et al., 2019; Thatcher & Milner, 2016; Valle & Junghans, 2015; Zaid & Kiani, 2016; Zou et al., 2018 |
| IDF2 | Clearly defined and documented purchasing, supply or delivery of energy services and products needs to be energy efficient | Building Research Energy Conservation Support Unit (BRESCU), 2006; E Cagno et al., 2013; Cattaneo, 2018; Kollmuss & Agyeman, 2002; Lopes et al., 2015; Moezzi & Janda, 2014; Pothitou et al., 2016 |
| IDF3 | Energy conservation opportunities should be prioritised and identified its resources, budget and financial returns | Abdelaziz et al., 2011; Antunes et al., 2014; Brunke et al., 2014; E Cagno et al., 2013; Finnerty et al., 2017; Introna et al., 2014; Kollmuss & Agyeman, 2010; Sa et al., 2017; Zhao et al., 2015 |
| **External Environmental Or Regulatory Conditions** | | |
| EDF1 | Government should produce a more comprehensive policy or a guided principle on green buildings operation and maintenance (O&M) | Ahn, 2010; Shen et al., 2016; Xing Shi et al., 2019; Yen et al., 2016; Zhang et al., 2019; Zhao et al., 2015 |
| EDF2 | Detailed information about the different initiatives in different stages should be included in the rating system, benchmarking and standard | Baharuddin et al., 2011; Berardi & Alborz, 2019; Keyvanfar et al., 2014; Poveda & Young, 2015; Zhang et al., 2019; Zhao et al., 2015 |
| EDF3 | To have an open discussion between industry, government, and academia | R. Gupta & Kapsali, 2016; Xing Shi et al., 2019 |

## 3. METHODOLOGY

This study adopts a quantitative approach to investigate diversity perspectives of industry experts from various backgrounds perceive on the root causes and strategies to this BEPG. Expert surveys are particularly valuable in exploring complex, context-dependent issues and allow for the development of comparable indicators across varied settings. The focus on experts stationed in the Klang Valley (Selangor, Kuala Lumpur & Putrajaya) was intentional, as this region hosts the most green-certified office buildings in Malaysia—491 out of the 563 certified nationwide (Green Building Index Sdn Bhd., 2019). Cluster sampling was applied to form three expert subgroups: (1) professionals not involved in green buildings, (2) those involved in green projects but not certified facilitators, and (3) certified green building facilitators. Although expert surveys can be subject to individual judgment biases, using a large and diverse pool of experts helps minimise potential errors and enhances result reliability (C. D. Maestas, 2016). All the selected expert groups were invited to participate in the expert survey via e-mail.

The expert survey questionnaire consists of three sections: respondent demographics (Section A), root causes of the building performance gap (Section B), and strategies to bridge the gap (Section C). Section A collects basic information such as gender, age, education, and years of experience in the building and green industries. Section B includes 35 items across three categories—design (8 items), construction/commissioning (7 items), and operation (20 items)—rated on a five-point Likert scale from "extremely unlikely" to "extremely likely." An open-ended question allows respondents to suggest additional causes. Section C asks respondents to rate the importance of 35 strategies across seven constructs—organisational, leadership, technical, behavioural, knowledge and skill, informational, and external—using a five-point scale from "not important at all" to "extremely important," adapted from Sa et al. (2017)

### 3.1 Perception of Building and Civil Engineering Contractors on Profitability Factors

A survey was carried out in three Malaysian states using cluster sampling to gather input from professionals engaged in green building projects. Out of 795 individuals contacted via email, 278 responded, resulting in a 34.9% response rate. Based on Tan et al. (2005), at least 20 participants per subgroup are needed to justify cluster analysis, and the sample size achieved meets this requirement, ensuring adequate statistical power (Dalmaijer et al., 2020). Cluster sampling was chosen due to the geographic concentration of the target population, which allowed for more efficient respondent grouping and streamlined data collection. The study population included 84 certified Green Building Index (GBI) facilitators, and 711 Registered Electrical Energy Managers (REEM) located in the Klang Valley. The respondents were clustered into three subgroups based on their involvement in green building industry as tabulated in Table 2. The inclusion of these three subgroups aims to identify potential differences in expert opinions.

Table 2: Number of respondents based on subgroup clustering.

| Group A | Not involved in green buildings | 89 Respondents 32%) |
|---------|--------------------------------|---------------------|
| Group B | Involved, but not a certified facilitator | 130 Respondents (47%) |
| Group C | Certified green building facilitators | 59 Respondents (21%) |

### 3.2 Analysis Tools

The responses were analysed using SPSS software, which included descriptive statistics, the Relative Importance Index (RII) analysis to rank the significance of items both within and between groups, and cluster analysis using Kendall's Coefficient of Concordance (W) to evaluate the level of

agreement among the different respondent groups.

RII analysis was employed to rank the key causes and strategies of building energy performance, based on their Relative Importance Index (RII) values, which range from 0 (least important) to 1 (most important) calculated using the Equation *(1)* where $W$ = weight as assigned by each respondent based on the five-point Likert scale from 1 to 5, $A$ = the highest weight in the scale, $N$ = sample size and n = total number responses in each response of scale (Fagbenle, 2011; Kaming et al., 1998).

$$\text{Relative Importance Index (RII)} = \frac{\sum W}{AN} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{5N} - \quad (1)$$

$$(0 \leq RII \leq 1)$$

Using the ranked data sets for root causes and strategies, the researcher conducted an inter-rater reliability test as part of the cluster analysis to assess the level of agreement among the three expert subgroups. Kendall's Coefficient of Concordance (W) was calculated to determine the degree of consensus, with values ranging from 0 (indicating no agreement) to 1 (indicating complete agreement) (Lam et al., 2015; Siegel & Castellan Jr., 1988). This statistic was computed using the formula presented in Equation *(2)* where $S$ is the sums-of-squares of the difference as calculated by Equation (3), $R_i$ is the sums of individual ranks and $\bar{R}$ is the mean of $R_i$, $m$ is the number of raters, $n$ is the numbers of objects being rated and $T$ is a correction factor for tied ranks (Gearhart, Booth, Sedivec, & Schauer, 2013; Herrmann & Bucksch, 2014; Siegel & Castellan, 1988). The value of $T = 0$ where there were no tied ranks within a group. The values of $S$, $\bar{R}$ and $R_i$ were substituted in Equation (4) and Equation (3) for calculating the Kendall's W values.

*Step 1: Calculate Kendall's W,* $\qquad W = \dfrac{12S}{m^2(n^3 - n) - mT}$ $\qquad (2)$

$$S = \sum_{i=1}^{n} (R_i - \bar{R})$$ $\qquad (3)$

There were three steps for evaluating degree of agreement or concordance among the experts which begin with the interpretation of Kendall's W values in this study, as shown in Table 3, is based on a synthesis of interpretation frameworks from the works of Adah & Odeyinka, (2024), Hajghasem et al. (2022), and Abdi, (2006). To measure consistency in the rankings of potential root causes and contributing factors, Kendall's W was employed. This statistical measure reflects the extent to which expert subgroups share similar views.

Table 3 Interpretation of Kendall's W values (Step 1).

| Kendall's (W) | Interpretation | Rank Confidence |
|---|---|---|
| 0.0 to 0.1 | No agreement | No |
| 0.2 to 0.3 | Weak agreement | Low |
| 0.4 to 0.5 | Moderate agreement | Intermediate |
| 0.6 to 0.8 | Strong agreement | High |
| 0.9 to 1 | Perfect agreement | Very high |

To support the conclusion of a complete or very strong agreement using Kendall's W, the p-value must be statistically significant, typically involve Step 2 & Step 3 following the procedures outlined by Legendre (2005) and Siegel & Castellan Jr. (1988):

*Step 2: Calculate Chi square, x & df,*

$$Chi\ square,\ \chi^2 = W \times m \times (n-1) \qquad df = m - 1$$

*Step 3: Calculate P-value.*

$$P\text{-value} = P\ (\chi^2_{(df=m-1)} \geq computed\ value)$$

Table 4: Interpretation of P values, p.

| P-value | Interpretation | Conclusion |
|---|---|---|
| $p < 0.05$ | Statistically significant | Reject $H_0$; agreement exists |
| $p < 0.01$ | Strong evidence of agreement | Strongly reject $H_0$ |
| $p < 0.001$ | Very strong evidence of agreement | Very strong agreement |
| $p \approx 0$ (e.g., $< 0.0001$) | Practically complete agreement | Agreement is near-perfect |

## 4. RESULTS

### 4.1 Background of Respondents

Among the 278 responses collected, engineers made up the largest group (27.3%), followed closely by executives (27%), senior managers (22.3%), directors (15.8%), and lecturers (7.6%) as illustrated in Figure 2.Whereas, Figure 3 shows even though only 35% of the respondents have the experience in green building industry but by combining experience in the building industry and green building industry, more than half of the respondents (78.4%) have at least 6 years' experience generally in the building industry. From the respondents' typologies it reflects the diverse professional backgrounds and varying levels of expertise.
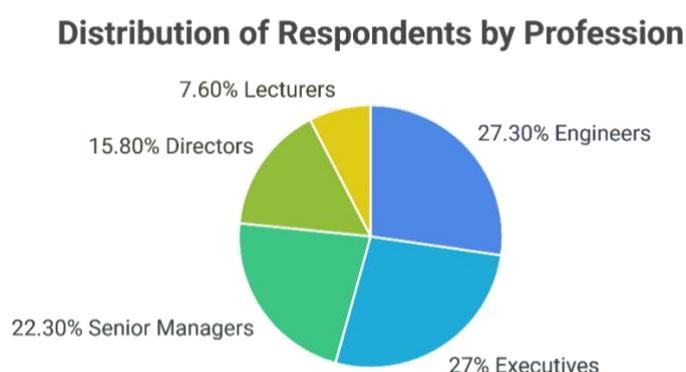


Figure 2: The Job Titles of Respondents.

Figure 3: The respondents' Years of Experience in Industries.

## 4.2  Cluster Analysis

This study examined two hypotheses: the null hypothesis (no agreement among experts) and the alternative hypothesis (experts are in agreement). The results showed a Kendall's W value of 0.87 for the ranking of possible root causes and 0.88 for the ranking of strategies, as detailed in Table 4 and Table 5. These findings suggest a stronger consensus among experts regarding the root causes than for the strategies. Nonetheless, both Kendall's W values were close to 1, and the associated significance levels p ≈ 0 support the rejection of the null hypothesis ($H_o$) in favor of the alternative hypothesis ($H_a$). This confirms that the three expert subgroups exhibited a near-perfect of agreement in their evaluations of the data.

**Degree of agreement: Ranking of Possible Root Causes**

*Step 1: Calculate Kendall's W,*

$$W = \frac{12(25654.5)}{3^2(34^3-34) - 3(0)} \qquad W ≈ 0.87$$

*Step 2: Calculate Chi square & df,*

$$Chi\ square = 0.87 \times 3 \times (34-1) \qquad df = 34-1$$
$$= 86.2 \qquad\qquad = 33$$

*Step 3: Calculate P-value by using Excel computation,*

$$P\text{-value, } p ≈ 0$$

*Conclusion:*

| Root causes | Overall Ranking |
|---|---|
| *Design-related causes* | *3* |
| *Construction/Commissioning-related causes* | *2* |
| *Operational-related causes* | *1* |
| ***p ≈ 0 (e.g., < 0.0001)***     **Practically complete agreement** | **Agreement is near-perfect** |

### Degree of agreement: Ranking of Strategies

*Step 1: Calculate Kendall's W,*

$$W = \frac{12\,(28178)}{3^2(35^3-35)-3(0)} \qquad W \approx 0.88$$

*Step 2: Calculate Chi square & df,*

$$Chi\ square = 0.88 \times 3 \times (35-1) \qquad df = 35-1$$
$$= 89.5 \qquad\qquad = 34$$

*Step 3: Calculate P-value by using Excel computation,*

$$P\text{-value},\ p \approx 0$$

*Conclusion:*

| Strategies Elements | Overall Ranking |
|---|---|
| *Organisational Frameworks* | *1* |
| *FM Leadership* | *2* |
| *Technological Infrastructure* | *6* |
| *Occupant Behaviour* | *3* |
| *Knowledge and Skill* | *7* |
| *Information Availability* | *5* |
| *External Environmental or Regulatory Condition* | *4* |
| **$p \approx 0$ (e.g., < 0.0001)** · **Practically complete agreement** | **Agreement is near-perfect** |

Table 4 The values of S, $\bar{R}$ and $R_i$ calculated for the possible root causes.

| Codes | RII Values | | | Ranking Within Group | | | Sum of Rank $(R_i)$ | D | d² | Overall | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Group A | Group B | Group C | Group A | Group B | Group C | | | | RII Values | Ranking |
| **Design-related Root Causes** | | | | | | | | | | | |
| DRC1 | 0.710 | 0.723 | 0.681 | 27 | 29 | 28 | 84 | 31.5 | 992.3 | 0.727 | 3 |
| DRC2 | 0.751 | 0.752 | 0.776 | 15 | 21 | 9 | 45 | -7.5 | 56.3 | | |
| DRC3 | 0.670 | 0.726 | 0.688 | 32 | 27 | 27 | 86 | 33.5 | 1122.3 | | |
| DRC4 | 0.717 | 0.785 | 0.732 | 25 | 10 | 20 | 55 | 2.5 | 6.3 | | |
| DRC5 | 0.748 | 0.786 | 0.715 | 16 | 9 | 23 | 48 | -4.5 | 20.3 | | |
| DRC6 | 0.724 | 0.724 | 0.724 | 24 | 28 | 22 | 74 | 21.5 | 462.3 | | |
| DRC7 | 0.757 | 0.769 | 0.742 | 12 | 14 | 18 | 44 | -8.5 | 72.3 | | |
| DRC8 | 0.679 | 0.709 | 0.671 | 31 | 30 | 30 | 91 | 38.5 | 1482.25 | | |
| **Construction/Commissioning-related Root Causes** | | | | | | | | | | | |
| CRC1 | 0.732 | 0.757 | 0.773 | 20 | 18 | 12 | 50 | -2.5 | 6.3 | 0.743 | 2 |
| CRC2 | 0.732 | 0.759 | 0.776 | 19 | 15 | 10 | 44 | -8.5 | 72.3 | | |
| CRC3 | 0.764 | 0.772 | 0.783 | 8 | 13 | 6 | 27 | -25.5 | 650.3 | | |
| CRC4 | 0.701 | 0.739 | 0.702 | 29 | 24 | 25 | 78 | 25.5 | 650.3 | | |
| CRC5 | 0.753 | 0.729 | 0.742 | 14 | 25 | 19 | 58 | 5.5 | 30.25 | | |
| CRC6 | 0.733 | 0.757 | 0.695 | 21 | 19 | 26 | 66 | 13.5 | 182.25 | | |
| CRC7 | 0.739 | 0.743 | 0.725 | 17 | 23 | 21 | 61 | 8.5 | 72.25 | | |
| **Operational Root Causes** | | | | | | | | | | | |
| ORC1 | 0.816 | 0.835 | 0.837 | 2 | 1 | 2 | 5 | -47.5 | 2256.3 | 0.753 | 1 |
| ORC2 | 0.789 | 0.805 | 0.810 | 5 | 5 | 3 | 13 | -39.5 | 1560.3 | | |
| ORC3 | 0.735 | 0.754 | 0.749 | 18 | 20 | 17 | 55 | 2.5 | 6.3 | | |
| ORC4 | 0.760 | 0.777 | 0.766 | 11 | 12 | 14 | 37 | -15.5 | 240.3 | | |
| ORC5 | 0.755 | 0.792 | 0.769 | 13 | 7 | 13 | 33 | -19.5 | 380.3 | | |
| ORC6 | 0.717 | 0.758 | 0.712 | 26 | 16 | 24 | 66 | 13.5 | 182.3 | | |
| ORC7 | 0.726 | 0.752 | 0.753 | 23 | 22 | 16 | 61 | 8.5 | 72.3 | | |
| ORC8 | 0.701 | 0.700 | 0.654 | 30 | 31 | 31 | 92 | 39.5 | 1560.3 | | |
| ORC9 | 0.710 | 0.692 | 0.647 | 28 | 32 | 32 | 92 | 39.5 | 1560.3 | | |
| ORC10 | 0.762 | 0.726 | 0.678 | 9 | 26 | 29 | 64 | 11.5 | 132.3 | | |
| ORC11 | 0.840 | 0.831 | 0.756 | 1 | 2 | 15 | 18 | -34.5 | 1190.3 | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ORC12 | 0.800 | 0.791 | 0.773 | 3 | 8 | 11 | 22 | -30.5 | 930.3 |
| ORC13 | 0.728 | 0.757 | 0.783 | 22 | 17 | 7 | 46 | -6.5 | 42.3 |
| ORC14 | 0.773 | 0.808 | 0.841 | 6 | 4 | 1 | 11 | -41.5 | 1722.3 |
| ORC15 | 0.798 | 0.782 | 0.776 | 4 | 11 | 8 | 23 | -29.5 | 870.25 |
| ORC16 | 0.760 | 0.792 | 0.803 | 10 | 6 | 4 | 20 | -32.5 | 1056.25 |
| ORC17 | 0.647 | 0.655 | 0.644 | 34 | 34 | 33 | 101 | 48.5 | 2352.25 |
| ORC18 | 0.658 | 0.689 | 0.624 | 33 | 33 | 34 | 100 | 47.5 | 2256.25 |
| ORC19 | 0.764 | 0.809 | 0.793 | 7 | 3 | 5 | 15 | -37.5 | 1406.25 |
| | | | | **Total Sum** | | | 1785 | **Sum d²(S)** | 25654.5 |
| | | | | **Average Sum ($\overline{R}$)** | | | 52.5 | | |

Table 5 The values of S, $\overline{R}$ and Ri calculated for the strategies.

| Codes | RII Values | | | Ranking Within Group | | | Sum of Rank *(R<sub>i</sub>)* | D | d² | Overall | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Group A | Group B | Group C | Group A | Group B | Group C | | | | RII Values | Ranking |
| **Organisational Framework** | | | | | | | | | | | |
| ODF1 | 0.852 | 0.843 | 0.807 | 5 | 13 | 22 | 40 | -14.0 | 196.0 | 0.849 | 1 |
| ODF2 | 0.892 | 0.938 | 0.908 | 1 | 1 | 1 | 3 | -51.4 | 2643.2 | | |
| ODF3 | 0.861 | 0.880 | 0.898 | 2 | 4 | 3 | 9 | -45.4 | 2062.2 | | |
| ODF4 | 0.858 | 0.902 | 0.861 | 3 | 3 | 10 | 16 | -38.4 | 1475.5 | | |
| ODF5 | 0.818 | 0.865 | 0.875 | 16 | 7 | 8 | 31 | -23.4 | 548.1 | | |
| ODF6 | 0.533 | 0.742 | 0.780 | 35 | 34 | 32 | 101 | 46.6 | 2170.5 | | |
| ODF7 | 0.843 | 0.863 | 0.881 | 9 | 8 | 6 | 23 | -31.4 | 986.7 | | |
| ODF8 | 0.854 | 0.903 | 0.908 | 4 | 2 | 2 | 8 | -46.0 | 2116.0 | | |
| **FM Leadership** | | | | | | | | | | | |
| LDF1 | 0.816 | 0.866 | 0.861 | 18 | 6 | 11 | 35 | -19.4 | 376.8 | 0.847 | 2 |
| LDF2 | 0.816 | 0.834 | 0.817 | 19 | 18 | 17 | 54 | -0.4 | 0.2 | | |
| LDF3 | 0.829 | 0.854 | 0.864 | 12 | 11 | 9 | 32 | -22.4 | 502.3 | | |
| LDF4 | 0.843 | 0.874 | 0.895 | 8 | 5 | 4 | 17 | -37.4 | 1399.6 | | |
| **Technological Infrastructure** | | | | | | | | | | | |
| TDF1 | 0.778 | 0.785 | 0.766 | 34 | 32 | 33 | 99 | 44.6 | 1988.1 | 0.812 | 6 |
| TDF2 | 0.802 | 0.820 | 0.824 | 25 | 22 | 16 | 63 | 8.6 | 73.8 | | |
| TDF3 | 0.845 | 0.854 | 0.888 | 7 | 10 | 5 | 22 | -32.4 | 1050.5 | | |
| TDF4 | 0.840 | 0.855 | 0.875 | 10 | 9 | 7 | 26 | -28.4 | 807.2 | | |
| TDF5 | 0.811 | 0.811 | 0.810 | 21 | 26 | 21 | 68 | 13.6 | 184.6 | | |
| TDF6 | 0.780 | 0.723 | 0.749 | 32 | 35 | 35 | 102 | 47.6 | 2264.6 | | |
| **Occupant Behaviour** | | | | | | | | | | | |
| BDF1 | 0.778 | 0.795 | 0.800 | 33 | 28 | 27 | 88 | 33.6 | 1128.2 | 0.817 | 3 |
| BDF2 | 0.827 | 0.831 | 0.814 | 13 | 20 | 20 | 53 | -1.4 | 2.0 | | |
| BDF3 | 0.818 | 0.834 | 0.793 | 17 | 19 | 30 | 66 | 11.6 | 134.3 | | |
| BDF4 | 0.838 | 0.849 | 0.847 | 11 | 12 | 12 | 35 | -19.4 | 376.8 | | |
| BDF5 | 0.802 | 0.794 | 0.797 | 27 | 29 | 28 | 84 | 29.6 | 875.5 | | |
| **Information Availability** | | | | | | | | | | | |
| IDF1 | 0.825 | 0.812 | 0.817 | 14 | 25 | 18 | 57 | 2.6 | 6.7 | 0.815 | 5 |
| IDF2 | 0.800 | 0.814 | 0.837 | 28 | 24 | 13 | 65 | 10.6 | 112.1 | | |

| IDF3 | 0.804 | 0.840 | 0.827 | 22 | 15 | 15 | 52 | -2.4 | 5.8 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Knowledge and Skill** | | | | | | | | | | | |
| KDF1 | 0.802 | 0.835 | 0.783 | 26 | 17 | 31 | 74 | 19.6 | 383.7 | 0.803 | 7 |
| KDF2 | 0.813 | 0.837 | 0.831 | 20 | 16 | 14 | 50 | -4.4 | 19.5 | | |
| KDF3 | 0.784 | 0.782 | 0.797 | 31 | 33 | 29 | 93 | 38.6 | 1489.1 | | |
| KDF4 | 0.793 | 0.815 | 0.807 | 30 | 23 | 24 | 77 | 22.6 | 510.2 | | |
| KDF5 | 0.804 | 0.791 | 0.817 | 23 | 30 | 19 | 72 | 17.6 | 309.3 | | |
| KDF6 | 0.804 | 0.788 | 0.763 | 24 | 31 | 34 | 89 | 34.6 | 1196.3 | | |
| **External Environmental or Regulatory Condition** | | | | | | | | | | | |
| EDF1 | 0.852 | 0.843 | 0.807 | 6 | 14 | 23 | 43 | -11.4 | 130.2 | 0.816 | 4 |
| EDF2 | 0.825 | 0.798 | 0.800 | 15 | 27 | 26 | 68 | 13.6 | 184.6 | | |
| EDF3 | 0.800 | 0.825 | 0.803 | 29 | 21 | 25 | 75 | 20.6 | 423.9 | | |
| | | | | **Total Sum** | | | 1850 | **Sum d²$(S)$** | 28178 | | |
| | | | | **Average Sum ($\overline{R}$ )** | | | 54.4 | | | | |

## 5.  DISCUSSION

This study confirms a strong consensus among industry experts regarding the key factors contributing to BEPG in green-certified buildings, particularly in Malaysia. Frequently cited factors such as occupant awareness, financial limitations, technological complexity, and lack of leadership commitment were consistently ranked high across expert groups. These findings are consistent with prior studies (Bai et al., 2024; Chiang & Calautit, 2025; Liang & Qiu, 2019; Staddon et al., 2016; Zou et al., 2018), reinforcing the widespread nature of these issues in global green building contexts. The convergence of opinions also supports the validity of expert surveys in addressing complex, context-sensitive topics (C. Maestas, 2016).

Nevertheless, subtle but meaningful differences across expert clusters underscore the importance of differentiated strategies. Experts with limited involvement in green projects (Group A) highlighted operational inconsistencies and low tenant engagement, while experts with facilitator roles (Group C) emphasized gaps in regulatory follow-through and leadership support. This mirrors existing research suggesting that stakeholder roles and experience levels shape how they perceive and address performance issues (Gupta & Gregg, 2016; Bull & Janda, 2017). Such divergence supports the need for tailored interventions that reflect stakeholder-specific perspectives and responsibilities throughout the building lifecycle.

The Relative Importance Index (RII) and Kendall's coefficient of concordance (W) further affirmed high agreement on top-ranked causes and solutions, particularly regarding behavioural and organisational aspects. However, the nuanced variations in how different expert subgroups perceive specific challenges highlight the importance of tailored interventions rather than one-size-fits-all solutions.

I.   For design team: the findings suggest a pressing need to move beyond theoretical performance estimates by integrating more realistic energy simulation models that account for user behaviour and real operational variables. Equally important is embedding occupant education strategies early in the design process to foster user alignment with building performance objectives.

II.  For building operators and facilities managers: the study points to the necessity of strengthening technical capacity through targeted training, particularly in the operation of advanced energy systems. Investments in sub-metering and diagnostic tools would also enhance monitoring precision, allowing more effective energy management and quicker identification of inefficiencies.

III. For policymakers and regulatory bodies: the results advocate for the implementation of mandatory post-occupancy evaluations to verify actual building performance against design expectations. Moreover, adopting performance-based incentives can encourage developers and owners to maintain operational efficiency throughout the building's life cycle, not just at certification.

Collectively, these findings advocate for a participatory and lifecycle-based approach to green building management. Encouraging collaboration between diverse stakeholders—designers, facility managers, and policymakers—can foster more adaptive and resilient building energy strategies. By aligning technical solutions with behavioural insights and regulatory support, the Malaysian green building industry can bridge the persistent energy performance gap and enhance the overall value proposition of sustainable development.

## 6.   CONCLUSION

This study confirms a strong level of agreement among experts regarding the key causes and driving factors behind energy performance gaps in green buildings. At the same time, it reveals important differences shaped by respondents' professional backgrounds and levels of experience with green building projects. These variations highlight the need for nuanced, multi-level strategies that incorporate the perspectives of various stakeholders. Addressing both technological shortcomings and behavioural dynamics is essential for narrowing the gap between predicted and actual building performance.

Based on the findings, several actionable recommendations are proposed. Energy policies should be tailored to reflect the diverse priorities of different stakeholders, ensuring more inclusive and practical implementation. Organisations are encouraged to form interdisciplinary energy committees to foster cross-functional collaboration and accountability. Occupant education should be embedded as a mandatory component within green certification frameworks to promote energy-conscious behaviour. Additionally, post-certification monitoring should be institutionalised to validate ongoing building performance and support continuous improvement.

While this study offers valuable insights, it is geographically limited to the Malaysian context, which may influence the generalisability of the findings. Future research should consider comparative studies across different countries to explore how regional policies, cultures, and market conditions impact energy performance outcomes. Longitudinal studies are also recommended to assess the sustained impact of expert-led energy management practices and post-occupancy evaluations over time. Such investigations would further strengthen the evidence base for bridging the energy performance gap in green buildings globally.

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