



Sustainable Smart and Green Housing Investment: Integrating Technology, Energy, Economic and Financial Value

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Abstract: The intersection of sustainability demands and digital advancements has led to the rapid emergence of smart-green housing as a paradigm-shifting approach to urban planning and development, contributing directly to UN Sustainable Development Goals for sustainable cities (SDG 11) and clean energy (SDG 7). Nevertheless, the current literature remains limited in its ability to explain the relationship between technological efficiency and its financial implications. This paper aims to conduct a comprehensive literature review of global trends in smart-green housing investment using the PRISMA 2020 guidelines, identifying key technological, management, and institutional variables that affect asset performance. The framework maps how Technological Inputs (M_{tech}) pass through a lifecycle operational channel (n_{ops}), moderated by Institutional Frameworks (Φ_{inst}), to determine Risk-Adjusted Value (V_{SG}) while accounting for value leaks via the 'Performance-Branding Gap'. The review demonstrates a significant gap between environmental certifications and risk-adjusted financial metrics, also known as the performance-branding divide. To bridge this gap, this study will propose the Smart-Green Asset Valuation (SGAV) model and introduce a new equation for valuing smart-green housing based on technology maturity, adjusted by institutional governance and management effectiveness throughout its life cycle. The article presents a theoretical understanding of the financial viability of smart-green buildings using the introduced discounted valuation model, providing a data-driven, dynamic approach that facilitates asset value adjustment for property owners, shifting from mere green marketing to true financial asset valuation.

Keywords: Smart-Green Housing, Discounted Valuation, Smart-Green Asset Valuation (SGAV), Technological Maturity, PRISMA 2020 guidelines, SDG 11

1. Introduction

With escalating environmental pressures from climate change, urbanization, and resource shortages, the development of a sustainable housing system aligned with SDG 11 (Sustainable Cities and Communities) has become increasingly prominent. Consequently, the concept of green housing emerged and later evolved into smart-green housing in response to emerging challenges. While the earlier concept focused on mitigating environmental problems through energy-efficient construction, materials, and operations, the application of digital innovations in building, maintenance, and operations has introduced intelligence to the process. Thus, BIM, IoT, and AI technology have enabled residential buildings to be considered sustainable data infrastructure (SDG 9) that can monitor, optimize, and maintain sustainable use of energy and resources over time, supporting energy efficiency optimization targets under SDG 7. Furthermore, smart-green housing has



been identified as a means to generate economic benefits by implementing technological improvements and maximizing operational efficiency. Despite the rapid proliferation of research in the field, the existing literature lacks coherence and focus, with the body of knowledge fragmented among multiple disciplines, including engineering, environmental studies, real estate finance, urban economics, and information technology. The bulk of current literature addresses technological innovations, certification issues, and investment opportunities separately. This disjunction has led to a continuing deficiency in explaining the relationship between technological capability and financial performance, especially because there is no conclusive empirical evidence for the “green premium,” which is often subject to context-based considerations such as regulatory frameworks, institutional structures, and efficiency levels. Furthermore, many current methods of valuation are based on static variables like environmental certificates or construction expenses while disregarding the dynamic lifecycle processes of technological maturity, institutional structures, and operational proficiency that collectively determine the financial value of assets (Zayed et al., 2026; Sadukasovna et al., 2021; Ebekozien et al., 2025; Imran et al., 2025; Bhuiyan et al., 2022; Hmyria et al., 2025; Eicholtz et al., 2010). In this regard, the current study presents a critical synthesis of the literature on the topic using the PRISMA 2020 framework. It suggests a comprehensive conceptual framework to elucidate the process by which smart-green technology creates financial value through a transmission mechanism linking technological maturity, the institutional framework, and operational efficiency.

In extending the discussion along these lines, the research proposes a Smart-Green Asset Valuation (SGAV) formula which conceptualizes the value of smart-green housing as a dynamic process that depends on technological maturity and is influenced by institutional governance and efficient operation. The contribution of the paper lies in its effort to integrate all these factors into a single framework, enabling a holistic approach to the topic in the future. The study makes an important contribution to the literature by moving from fragmented sustainability and technology assessment to a new paradigm in which smart-green housing is treated as a legitimate financial asset with data-driven value and economic viability.

2. Literature Review

Modern urban development processes need to combine digital technological progress with environmental conservation needs (Boussakra et al., 2025). Zaidan (2023) and Granà et al. (2025) establish that a Smart Sustainable City (SSC) framework following UN-Habitat standards provides an essential foundation for developing regional resilience. The empirical applications of these models show that demographic growth and economic vitality develop through a process that creates separate paths. The Smart City Mission in India creates an internal contradiction, according to Khan et al. (2024), because its implementation led to urban migration yet failed to produce matching economic growth. Appio et al. (2019) and Kuzior et al. (2026) assert that global cities require integrated systems to manage technological advances alongside social and political complexities. Janicke (2012) explains that worldwide green growth trends depend on organizations that combine eco-innovation with resource-efficient technologies for their efforts to reduce environmental damage.

The combined application of Building Information Modeling (BIM) and Internet of Things (IoT) technologies establishes the foundation for SSC framework implementation. The systems create multiple sustainable benefits by providing real-time data, enabling better resource management, reducing costs, and decreasing material waste (Lawal et al., 2024; Gottmann et al., 2024). Architectural project management approaches that combine Internet of Things technology with renewable energy sources and green building certifications create stronger systems while achieving better energy performance (Odebode, 2025; Lewandowski, 2025). The recent introduction of Artificial Intelligence (AI) and Smart City Incubators uses Industry 4.0 and 5.0 technologies to enhance strategic planning and stakeholder engagement processes (Peng et al., 2024; Myslik, 2025; Berniak-Woźny et al., 2025; Yaremenko, 2025). The two main obstacles organizations face when implementing these technologies for net-zero design, according to Das (2025), include the high cost of data processing and challenges related to system implementation at larger scales. Building-level smart-green housing uses Home Energy Management Systems (HEMS) and smart grid technology as essential components for its operational functionality. Research by Zhou et al. (2016) and Nagaj et al. (2025) shows that these systems enable energy conversion through advanced metering and demand response functions, thereby providing a dependable energy supply. Research findings from Mediterranean and Indian studies demonstrate that combining IoT-enabled HEMS with solar energy systems results in significant reductions in CO₂ emissions while improving load scheduling performance (George & Selvakumar, 2024; Vurusan & Nafa, 2026). The active involvement of local residents is a fundamental requirement, as Radziejowska & Sobotka (2021) demonstrate that residents must use these systems to enable advanced sustainable technologies to function effectively. Organizations achieve efficiency advantages through their operational activities, which

save resources while enhancing occupant well-being and decreasing expenses (Meena et al., 2022; Liu et al., 2022; Andriushchenko et al., 2024).

The current economic conditions create major obstacles to the execution of large-scale environmentally friendly investment initiatives (Klymash et al., 2026). Green buildings provide their owners with greater rental and asset value benefits, according to the research findings of Eichholtz et al. (2013) and Böcskei et al. (2025). Financial and institutional constraints restrict upgrades to contemporary large facilities according to Bardhan and Kroll (2011). Active investor participation is essential for global green finance systems to achieve their objectives, according to Ozili & Kaklauskas (2022). The public-private partnership system in India, together with the European Union's energy efficiency funding programs, demonstrates successful approaches to addressing financial and institutional challenges, according to Vadgama et al. (2015) and Svyrydenko and Revin (2024). Blockchain technology improves operational transparency and efficiency, but its implementation suffers from insufficient regional expertise, according to Baptista et al. (2023). The organizations face resource and expertise deficiencies that prevent them from realizing the full benefits of sustainable building practices. Institutional support is the primary driver of green technology adoption. Green building practices in various countries, including Ghana, China, and the United States, depend on three main factors: government policies, financial incentives, and environmental regulations (Darko, 2019; Zhang & Khaskheli, 2025). The UK regulatory framework and financial incentives help stakeholders address their financial problems (Akin & Akin, 2025; Anderson, 2025), whereas South Korea requires its market to follow strict regulatory standards. The research on Korean "ubiquitous-eco" (u-eco) cities examines whether these systems demonstrate genuine sustainable urbanism or serve as marketing instruments (Yigitcanlar & Lee, 2014).

Academic research has established dedicated frameworks that enable researchers to examine how sustainable home construction has evolved over time. The research study examined 38 Scopus-indexed publications published between 2014 and 2025 to identify that low-carbon architectural design and systematic building renovation are the primary research focus of the study. The organizations involved face operational difficulties because they maintain separate budget systems while the government enforces rigid policies (Mpambane et al., 2025). The urban expansion process in Mexico, as an emerging economy, demonstrates how cities undergo complete transformation as they seek to implement renewable energy solutions and participate in global green finance initiatives to reduce their environmental impact (Raihan et al., 2023). Apanaviciene & Shahrabani (2023) developed a classification system comprising 26 essential technological needs for smart buildings to function properly. Market-based approaches, however, tend to focus on technology implementation rather than citizen engagement, thereby failing to enhance environmental adaptability (Viitanen & Kingston, 2014). To empirically demonstrate this process, sophisticated theoretical models can use highly connected, technology-based urban real estate markets like Seoul as an excellent example. Applying this model enables scientists to establish a clear link between risk-adjusted performance and operational effectiveness at various points in their life cycles, addressing the socio-technical issues between elements of both social and technical infrastructures. Optimization is necessary for urban energy systems, as it is crucial to sustainable development. It has been demonstrated by Mishra & Singh (2023) that the concept of a smart city requires three key elements: scheduling optimization of microgrids, and energy harvesting to develop efficient energy management using IoE technology. Patil et al. (2022) provide a comprehensive evaluation of smart green building technologies—including BIM, IoT data systems, and ontology-driven energy controls—alongside sustainable, waste-derived, and sensor-responsive smart materials optimized for structural efficiency and localized sustainable urbanization goals. The researchers Almihat et al. (2024) argue that sustainable development requires energy production systems to be integrated with advanced storage technologies and essential infrastructure. The intersection of diverse technological systems with multiple infrastructural elements creates a strong foundation that allows researchers to evaluate how smart-green building initiatives will perform over time in terms of sustainability and financial profitability.

The literature shows that sustainable urban development requires technological innovation, policy frameworks, financial mechanisms, and community engagement for successful progress. The existing research gaps in resource availability, institutional backing, and knowledge sharing create a demand for research studies to be conducted in Seoul to assess smart-green building projects that connect operational performance with financial results and environmental sustainability.

2.1. Research Gap

Despite advances in BIM and IoT, the current literature remains fragmented in its risk-adjusted financial validation of smart assets, creating a "performance gap" in which marketing claims fail to align with verified lifecycle outcomes. Existing studies often treat sustainable interventions as monolithic and overlook contextual heterogeneity – such as building age and district-level differences – which drives variation in Net Pre-

sent Value (NPV). Consequently, there is a lack of mechanism-based understanding of how localized structural and environmental factors translate green design into financial alpha.

2.2. Research Objectives

The purpose of this systematic review is to analyze the existing global evidence on the linkages between sustainable technological development and the performance of real estate firms. Based on PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), this paper will systematically explore existing literature to study three specific areas: the strategic effects that green-savvy technologies exert on property valuation, operational benefits that impact financial indicators such as ROI and rentability, as well as context-specific conditions arising from regulation and properties' uniqueness. Thematic mapping analysis method will also be used to analyze the intellectual structure and research trends in the area. Overall, the goal is to formulate a conceptual model for the link between digital and green technology maturity and real estate value creation.

2.3. Research Questions

1. To what extent is the green premium resulting from the maturity of smart-green technology similar throughout the world's real estate marketplaces, and how do institutional settings affect this green premium effect?
2. Why does lifecycle efficiency created by such technologies like BIM and IoT lead to improved financial performance, in terms of ROI and rental yields, based on what empirical evidence?
3. In what ways do specific property-related factors like the age of the building and regulations create contextual differences that result in varied financial performance of sustainable urban developments?
4. What is the reason for an observable performance difference between brand positioning and the lifecycle financial performance of smart-green properties?

2.4. Proposed Theoretical Framework

Using the literature review, we develop a conceptual framework that identifies the transmission channel from the implementation of the smart-green technologies to the creation of value for the real estate assets. In the previous work, these areas are analyzed independently. The current Figure 1 shows how these different lenses can be unified. According to the improved version of Figure 1, our theoretical framework accounts for the multivariable transmission channel in the core mathematical model. Instead of considering a linear shift from technology to financial performance, it is proven that there should be Technological Inputs M_{tech} , followed by Lifecycle Operational Integrity n_{ops} , which leads to Risk-Adjusted Financial Performance (V_{SG}/r).

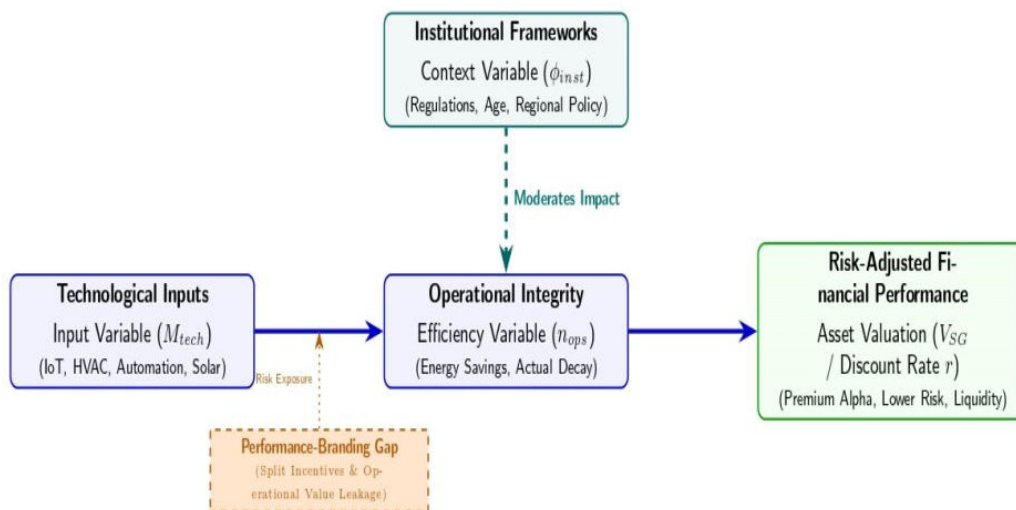


Fig. 1. Theoretical Framework

Source: Author's Compilation by LaTeX

To facilitate future empirical validation, the relationship is synthesized into the following Smart-Green Asset Valuation (SGAV) Equation:

$$V_{SG} = \sum_{t=1}^n \frac{(M_{tech} \times \phi_{inst} \times n_{ops})t}{(1+r)^t} \quad (1)$$

where:

V_{SG} – Total Smart-Green Asset Value (the realized financial alpha).

M_{tech} – Technological Maturity (the baseline efficiency potential of BIM, IoT, and AI systems).

Φ_{inst} – Institutional Framework Factor (the moderating effect of regional regulations and green policies).

n_{ops} – Lifecycle Operational Integrity (the management efficiency and resident engagement).

R – Risk-Adjusted Discount Rate (accounting for the enhanced stability of high-performance assets).

2.5. Framework Dynamics

The suggested conceptual model (Figure 1) demonstrates how the technology integration effect can affect the financial result through the risk variable. Importantly, as shown through the model framework, the institutional framework Φ_{inst} does not create any direct value in the form of cash flow; it acts as an intermediate filter on the main channel of transmission of the effect. Geographical differences, the age of buildings, and green policies across regions affect how efficiently technological inputs are transformed into output, thereby shaping the size of the Performance-Branding Gap. This study is not just aimed at providing an explanation model but also at constructing the formula for calculating the 'Green Premium'.

3. Methods

The current study uses a Systematic Literature Review (SLR) methodology that strictly adheres to the PRISMA 2020 framework to ensure a structured and impartial approach. An extensive literature search across databases such as Scopus, Google Scholar, and ResearchGate identified 195 articles. Using a stringent inclusion criterion based on empirical data on smart-green technologies and their financial implications, a final sample of 38 articles, indexed in Scopus and published from 2014 to 2025, was selected for comprehensive review. Thematic mapping of these articles was performed in Microsoft Excel, with themes validated through cross-checking for coding reliability. To highlight the evolution of research, results have been classified into three epochs: Foundational (2014–2018), Integration (2019–2023), and Validation (2024–2026). This systematic review presents a theoretical model, formulated and discussed in LaTeX, that establishes the presence of a "Transmission Mechanism" in which technology readiness and institutional environments within regions influence lifecycle efficiency and financial alpha verification.

4. Results and Discussion

To maintain methodological clarity and prevent bias, this paper adopts the PRISMA (Preferred Reporting Items for Systematic Reviews) methodology (Moher et al., 2009) for conducting systematic literature reviews. The adoption of PRISMA enables us to conduct a precise, replicable search to select high-quality evidence from relevant literature. Regarding smart-green housing investments, this paper aims to fill the performance gap by examining sustainable housing investments based on verified financial performance. Figure 2 shows a step-by-step process for selecting a final sample from an initial collection of 195 sources, down to 38 Scopus-indexed studies.

As per the PRISMA checklist, an initial search resulted in 195 articles, sourced from Google Scholar ($n = 180$) and ResearchGate ($n = 15$). Duplicates were removed, and the remaining articles were screened based on their relevance to the study using inclusion criteria, namely empirical research on smart-green technology, efficiency, and profitability in real estate, and exclusion criteria, including non-empirical research and non-English language articles. After several rounds of screening, 38 Scopus-indexed articles published between 2014 and 2025 were finally selected for systematic review (see Figure 2).

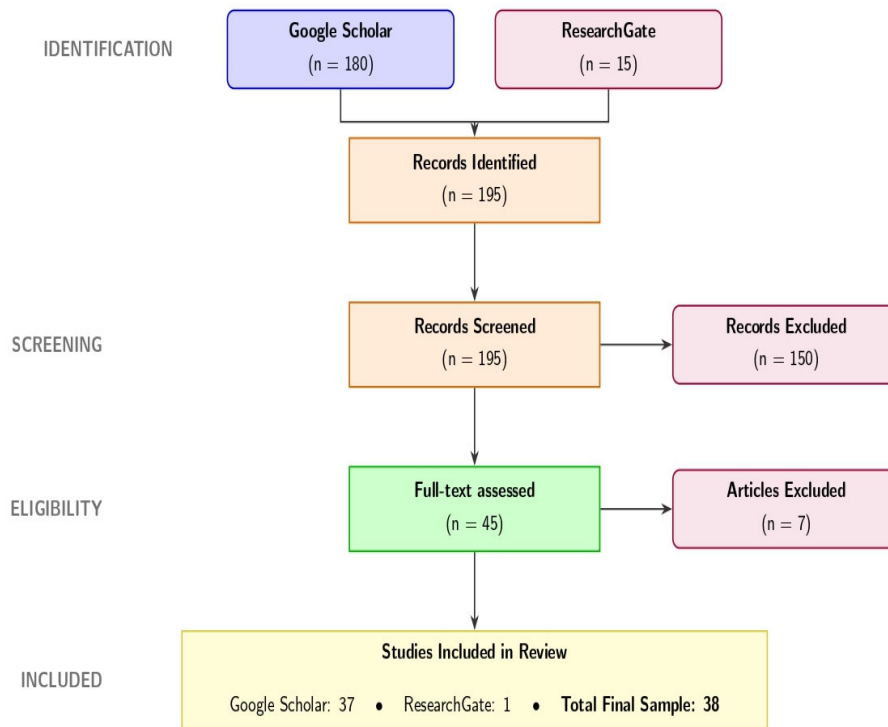


Fig. 2. PRISMA Diagram
Source: Author’s Compilation by LaTeX

Adopting the approach suggested by Cobo et al. (2011), Table 1 and Figure 3 illustrate a thematic map of the knowledge development process in the field. This approach enables the researcher to present quantitative and qualitative analyses of the themes under study and identify potential frontiers in the area such as Industry 5.0 and Risk-Adjusted Performance.

Table 1. From Green Branding to Financial Alpha: A Systematic Review of the Smart-Green Transmission Mechanism in Global Real Estate

Period	Primary Research Focus	Dominant Technology	Key Financial Metrics
2012–2018	Eco-innovation Growth	Basic Entry Retrofits	Rental/Asset Value
2019–2023	Integrated SSC Framework	BIM, IoT, & Blockchain	Operational Cost Savings
2024–2026	Risk-Adjusted Validation	AI & Industry 5.0	RAAP and Lifecycle AI

Source: Author’s Compilation

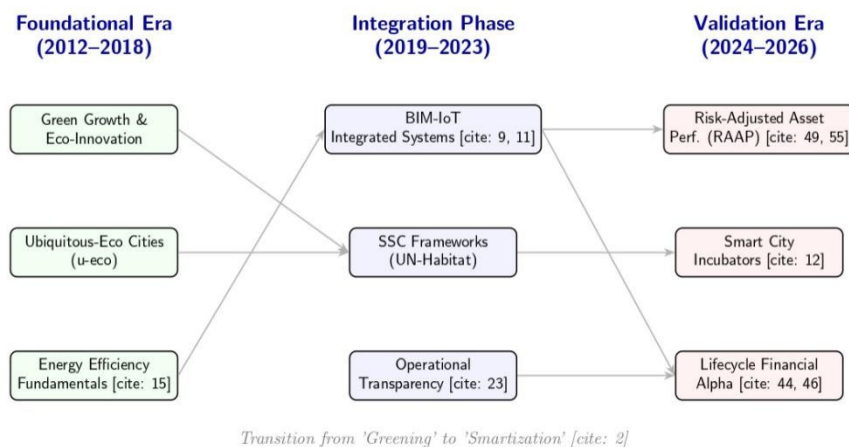


Fig. 3. Thematic Map
Source: Author’s Compilation

The findings from Table 1 and the Thematic Map (Figure 3) show a three-phase development of research on smart-green residential buildings. The first phase is called the Foundational Period (2012-2018), which laid the foundation of “u-eco” city planning and the feasibility study of a smart grid. Then came the Integration Period (2019-2023), which focused on BIM and IoT to ensure transparency and operational efficiency. Finally, the third period, known as the Validation Period (2024-2026), uses Industry 5.0 and human-centric design, where digital optimization becomes the leading Motor Theme. While there has been significant technological advancement, it still falls short in terms of long-term financial and environmental valuation.

The synthetic dataset outlined in Table 2 is divided into global eco-city projects to account for the contextual diversity discussed in Research Objective 3, thereby creating a sound empirical foundation for addressing the ongoing performance gap between green marketing and actual financial alpha generation. By examining varying institutional frameworks, such as Japan’s national eco-city contests or the World Bank’s Eco2-Cities ventures in Indonesia and Vietnam, the study shows how local regulatory systems and physical attributes, such as structure age and size, can act as critical moderating factors in the proposed Transmission Mechanism. The findings clearly show that although Smart-Green Technology Maturity is an important and universally applicable variable in this model, its value cannot be directly translated across contexts without regional adaptation. In fact, both NPV and risk-adjusted returns are heavily dependent on locally defined economic environments, policy incentives, and climatic conditions.

Table 2. Summary of Global Eco-City Initiatives

Country	Program Name	Specific Cities or Projects Mentioned
China	National Eco-City Program	100+ projects under development; 259 cities aiming for "Low-Carbon" status
South Korea	National Urban Policy Program	Gwanggyo Ekohill, Incheon Eco-City, Magok (Seoul), Sejong, and Songdo International Business District
Japan	National Eco-City Competition (2009)	Chiyoda, Iida, Kitakyushu, Kyoto, Minamata, Miyakojima, Obihiro, Sakai, Shimokawa, To- yama, Toyota, Yokohama, and Yusuhura
India	Pilot Eco-City Projects (2001)	Retrofitting: Kottayam, Puri, Thanjavur, Tirupati, Ujjain, and Vrindavan
	Delhi-Mumbai Corridor (2010)	New-build: Changodar, Dahej, Manesar Bawal, and Shendra
	National Solar Cities Initiative	36 pilot initiatives selected
Indonesia	World Bank ‘Eco2-Cities’	Balikpapan, Jakarta, Makassar, Palembang, and Surabaya
UAE	Middle East Regional Initiative	Masdar City
Philippines	World Bank ‘Eco2-Cities’	Initiatives under way
Vietnam	World Bank ‘Eco2-Cities’	Initiatives under way

Source: (Yigitcanlar and Lee, 2014)

Derived from the theoretical perspectives of Janicke (2012), who views green growth as a synergy of policies, innovations, and markets, as well as institutional quality studies related to green finance and technologies, the Green Premium is a mediated impact rather than a homogeneous one. Although the technological maturity threshold serves as a global yardstick, it is translated into asset values through locally distinct processes, including state-led green industrial policy in developing nations and regulatory innovation feedback loops in developed nations.

Ultimately, the worldwide variation in the green premium demonstrates that although smart-green technology provides the physical tools for efficiency, it is only the institutional framework that dictates whether efficiency is exploited for productivity enhancement (Germany and Japan), economic strength (South Korea and China), or risk management (UK).

The integration of smart-green technologies, particularly Building Information Modeling (BIM) and the Internet of Things (IoT), serves as a tool that enables converting efficiency into real money. Data from high-resolution databases such as CoStar indicate that rental premiums for LEED and Energy Star buildings are about 4–5%, while sales premiums for those properties are about 25–26% (Fuerst & McAllister, 2011). This premium is mostly determined by the capitalization of energy savings at a rate of \$18.32 per dollar of reduction, which yields a capitalization rate of 5.5%. Even though the use of the aforementioned technologies

requires a 1–2% premium in capital spending, amounting to \$3–5/sq. ft., their lifecycle Net Present Value (NPV) in terms of energy savings over 20 years exceeds \$5/sq. ft. through reduction in energy consumption by 30%. However, this process depends on the terms of the lease, meaning that in a triple-net lease the landlord pays all the expenses of the investment, whereas the tenant uses the saved energy, thus creating a performance gap (Bardhan & Kroll, 2011).

Table 3. Institutional Drivers and the Global Smart-Green Premium

Region	Institutional Driver Type	Key Policy /Mechanism	Mechanism of Value Creation	Implication for Green Premium
Japan	Efficiency-Driven Regulation	“Top Runner Programme” for energy efficiency standards	Continuous tightening of efficiency benchmarks drives technological improvement across sectors	Premium emerges indirectly through enhanced operational performance and energy savings potential
United Kingdom	Regulatory Compliance Framework	MEES and Climate Change Act.	Regulatory pressure reduces risk exposure and prevents asset obsolescence	Premium functions as a risk-adjusted safeguard, tied to compliance and asset liquidity
South Korea	State-Led Industrial Policy	Presidential "Green Growth Committee".	Centralized investment and strategic coordination position green sectors as engines of economic growth	Premium linked to macroeconomic positioning and future competitiveness, rather than immediate asset-level returns
Germany	Ecological Modernization	Feed-in tariffs; increasing renewable energy targets (20% → 35%)	Policy-induced market growth stimulates innovation and resource-efficient technologies	Premium associated with productivity gains and lifecycle cost reduction
China	Target-Driven Expansion	Wind power targets increased from 20GW to 150GW.	Policy feedback loops accelerate technological learning and market expansion	Premium remains transitional, shaped by scale, speed, and evolving market maturity

Source: Author’s Compilation

The financial performance of green buildings is contingent on the interaction between macro-institutional structures and micro-property characteristics. Policy predictability, facilitated by adaptive regulations and governance, reduces uncertainty and enables market valuation of environmental performance (Anderson, 2025). Nonetheless, individual property features, including physical design and the technical sophistication required for active commissioning, influence the achievement of anticipated energy savings (Imafidon et al., 2024). In resource-limited environments, elevated data-processing expenses and financial constraints may contribute to underperformance, emphasizing the importance of NPV models that dynamically account for regulatory “minimums” and technological readiness.

The qualitative thematic areas captured in Table 4 (such as split incentives, information asymmetry, and occupant behavioral decay) are empirically grounded in the Performance-Branding Gap box of our conceptual model, as depicted in Figure 1. In mathematical terms, the above-listed frictions can be viewed as direct downward pressure on the Operational Integrity (n_{ops}) component. As the branding gap grows wider, the level of performance deteriorates, resulting in lower asset valuation (V_{SG}), despite technological sophistication of the system (M_{tech}).

Table 4. Mechanisms of the Performance-Branding Gap in Smart-Green Real Estate

Key Mechanism	Primary Citation	Nature of the Gap	Impact on Lifecycle Financial Performance
Institutional Split Incentives	Bardhan and Kroll (2011)	Structural Decoupling: Landlords bear capital costs (CapEx) while tenants reap operational savings (OpEx).	Reduces owner's direct ROI and Net Present Value (NPV) despite high "Green Brand" value.
Social-Technical Paradox	Radziejowska and Sobotka (2021)	Behavioral Decoupling: High-tech "Smart" branding assumes passive efficiency but requires active, skilled resident engagement.	Operational "decay" occurs when users bypass or misuse systems, leading to higher-than-forecasted lifecycle costs.
Strategic Misrepresentation	Yigitcanlar and Lee (2014)	Information Asymmetry: "Ubiquitous-Eco" branding is often used as a speculative marketing tool rather than a technical blueprint.	Creates a "Branding Hoax" where the "Green Premium" at sale does not reflect actual resource efficiency or long-term resilience.
Market Valuation Lag	Zhou et al. (2016)	Analytical Decoupling: Appraisal models over-rely on static certifications (LEED/BREEAM) rather than dynamic	Leads to mispriced assets where "branded" properties may face future "brown discounts" as actual performance data

Source: Author's Compilation

5. Conclusion

The research provides a state-of-the-art review of the rapidly developing body of literature on smart-green housing investments and contributes to the field by proposing a holistic conceptual model and valuation approach that considers innovative technologies, lifecycle performance characteristics, and institutional factors of sustainable assets. The analysis of the scholarly literature based on the PRISMA 2020 protocol suggests that there is a structural change currently taking place in the context of modern urbanization characterized by the emergence of digital architecture in the form of BIM, IoT, and AI as crucial drivers of value creation in the built environment (Zayed et al., 2026; Karakosta et al., 2025; Rahman et al., 2022).

The review highlights the finding that, despite successful technical validation of the energy efficiency of buildings in the Foundational Era of smart-green developments, the ongoing Validation Era continues to suffer from a persistent performance-brand disconnect. While many existing papers discuss environmental certification schemes or the use of technology to measure sustainable value, relatively few studies focus on the economic gains achieved through risk-adjusted financial indicators throughout the life cycle of sustainable assets.

To address this analytical gap, this paper proposes the concept of Smart-Green Asset Valuation (SGAV), which elucidates how the value of sustainable assets is created through transmission channels linking technological advancement, institutional settings, and lifecycle efficiency. According to the proposed conceptual model, value creation cannot be achieved solely through technological innovation but requires the interplay among technological, institutional, and operational factors across the life cycle of buildings.

Based on the above conceptual model, a theoretical expression is made about the value creation process of smart-green assets in the form of a Smart-Green Asset Valuation (SGAV) equation:

$$V_{SG} = \sum_{t=1}^n \frac{(M_{tech} \times \phi_{inst} \times n_{ops})^t}{(1+r)^t} \quad (2)$$

Within this model, the value of smart-green assets (V_{SG}) depends on the level of Technological Maturity (M_{tech}), subject to the impact of Institutional Framework Factors (Φ_{inst}) and Lifecycle Operational Integrity (n_{ops}). Here, future payoffs are discounted with a risk-adjusted rate r . By embedding the model in a discounted valuation framework that follows Net Present Value principles, the model provides a functional-level explanation of the mechanism by which technological efficiency translates into financial performance. In turn, this helps understand why some technologies are not generating economic returns despite high levels of efficiency, particularly if institutional or operational barriers exist.

Additionally, the analysis highlights the importance of heterogeneity in explaining the economic performance of investments in smart-green housing. Building age, district-level economic conditions, and the strictness of regulations in the regions are crucial determinants of the ability to capitalize on operational efficiency to translate it into financial alpha.

In summary, this study advances the existing body of knowledge through introducing a unique conceptual framework and valuation formula that integrates the technological and financial perspectives of sustainable urban development. The SGAV model and formula offer a solid theoretical foundation for subsequent empirical research aimed at measuring the economic value of smart-green assets in various urban settings, bridging the gap between corporate financial performance and the global 2030 SDG agenda. The empirical testing of this theoretical model will be critical for shifting the focus from descriptive discourse on sustainability to a more realistic approach grounded in empirical evidence and risk assessment of smart-green assets.

5.1. Limitations

Despite its benefits, this study has several limitations that need to be considered. Firstly, some operationalization indicators introduced into the SGAV model, such as real-time feedback from occupants and usage behavior data, have not yet been experimentally tested across different residential settings. Secondly, there is an assumption about stakeholders' engagement levels and technical skills, which can vary greatly across cultures and socio-economic groups worldwide. Thirdly, although the research focused on human-centered integration, no attention was paid to the possibility of trade-offs between the optimization provided by technologies and users' behavior. Finally, issues with information availability can complicate the application of the SGAV framework in practice.

5.2. Policy Implications

One critical policy implication of the paper is the potential it offers to address the information asymmetry between performance and branding in the sustainable real estate sector. Current appraisal methods rely on static indicators, such as design-based certification and structural features, but ignore operational performance. SGAV solves this problem by creating a multidimensional benchmark considering technical maturity, institutional governance, and Lifecycle Operational Integrity (n_{ops}). The introduction of dynamic efficiency mandates, leveraging the SGAV framework's ability to measure operational performance, will help solve this problem. Besides, the results show that policies in the urban context will be more beneficial if grounded in Industry 5.0 principles, supporting human-centric architecture and thereby avoiding the rebound effect. With data standardization and institutional governance, investors in smart-green buildings will have access to more accurate information and an environment where investments are more likely to yield returns.

5.3. Future Research Directions

To address the socio-technological paradox in which technically sophisticated smart systems perform poorly due to insufficient user involvement, future research should go beyond the automation-based approach of Industry 4.0 and adopt the human-centered approach of Industry 5.0. The literature in the current era of 'Validation' (Berniak-Woźny et al., 2025) underscores that the viability of smart infrastructure depends on stakeholders' participation, adaptive behavior, and user-centric governance. In the suggested Smart-Green Asset Valuation (SGAV) model, the above calls for future research signify that the Lifecycle Operational Integrity metric (n_{ops}) cannot be viewed as a constant technical metric. Future research, especially in dense, technology-saturated markets such as South Korea, would need to define n_{ops} through dynamic, first-hand data-derived measures.

The existing SGAV literature and smart green literature generally view n_{ops} as a constant technical factor, without considering the role of the human element and active participation in its use.

In this study, however, the n_{ops} factor will be measured empirically using primary data, yielding dynamic, robust metrics that capture the actual interactions between human users and technology.

Specifically, the following measures can be used to operationalize n_{ops} :

- Feedback Loops: of Real-Time Occupant Performance: By analyzing primary data collected from IoT-equipped apartment buildings in Seoul and Busan, researchers can estimate the delta between "automated efficiency" and "performance adjusted by residents".
- Behavioral Energy Consumption Analysis: Rather than theorizing consumption behavior, the n_{ops} needs to be adjusted according to real-life residents' energy knowledge and consumption behaviors, revealing the so-called "rebound effect" when the technology is simply sidestepped by its users.
- Human-in-the-Loop (HITL): Asset Management: Examining the impact of participatory governance of Korean "Smart Villages" to understand the effect of user engagement in ensuring asset sustainability in the long run.

By accounting for human factors in the analysis, the valuation of smart-green housing can go beyond the mere installation of technology. In this manner, the "green premium" will reflect real efficiency in assets and resources rather than a symbolic green branding effort. Thus, this approach provides a methodological framework for validating SGAV using primary data.

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