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| RESEARCH ARTICLE

Construction Organization Optimization for Sustainable Green Buildings: The Roles of Energy Efficiency and Environmental Well-Being

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| ABSTRACT
This study develops and tests an integrated explanation of how construction organization optimization is associated with sustainable green building performance through energy efficiency and across varying levels of environmental well-being orientation. Construction organization optimization is conceptualized as the coordinated configuration of governance, information, production planning, supply-chain integration, commissioning, and continuous improvement. The study addresses the continuing gap between green design intentions and realized project and operational outcomes. This cross-sectional quantitative study used a 22-item questionnaire administered to construction professionals. The final sample comprised 421 valid responses measured on a five-point Likert scale. The model was analyzed in SmartPLS 4 using partial least squares structural equation modeling (PLS-SEM) with 5,000 bootstrap resamples, including reliability and validity assessment, mediation analysis, moderation analysis, effect-size assessment, and predictive-relevance evaluation. The results show that construction organization optimization was positively associated with sustainable green building performance ($\beta = .304$, $p < .001$) and energy efficiency ($\beta = .600$, $p < .001$). Energy efficiency was positively associated with sustainable green building performance ($\beta = .483$, $p < .001$), and the specific indirect effect was consistent with complementary partial mediation (indirect $\beta = .290$, $p < .001$). The positive association between energy efficiency and sustainable green building performance was stronger at higher levels of environmental well-being orientation (interaction $\beta = .176$, $p < .001$). The model explains 36.0% of the variance in energy efficiency and 65.0% of the variance in sustainable green building performance, with satisfactory reliability, convergent validity, discriminant validity, and predictive relevance. The study connects construction organization design, energy-performance delivery, and occupant-centered environmental well-being in one model. It reframes green building success as an organizational capability rather than a collection of isolated technologies or certification credits. The findings indicate that optimized coordination is associated with sustainable performance partly through energy-efficiency delivery, while well-being-oriented governance strengthens the relationship between energy efficiency and broader project performance. The 22-item measurement model and integrated PLS-SEM assessment provide empirical evidence for an organizational, technical, and occupant-centered explanation of sustainable green building performance.

| KEYWORDS
Construction organization optimization; sustainable green buildings; energy efficiency; environmental well-being; building performance; PLS-SEM; green construction management

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1. Introduction
The building and construction sector sits at the center of climate mitigation, resource productivity, urban health, and economic development. The most recent global status assessments attribute roughly one-third of final energy demand and more than one-third of energy- and process-related carbon dioxide emissions to buildings and construction, while the Intergovernmental Panel

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on Climate Change identifies substantial mitigation potential in demand reduction, high-performance envelopes, efficient systems, clean energy, material efficiency, and compact urban development (Intergovernmental Panel on Climate Change [IPCC], 2022; United Nations Environment Programme [UNEP], 2024). These pressures have accelerated the use of green building rating systems, low-carbon materials, high-efficiency mechanical systems, building information modeling, prefabrication, commissioning, digital controls, and post-occupancy evaluation. Yet the sector continues to display a persistent implementation paradox: organizations possess more sustainability tools than ever, but design aspirations are frequently diluted by fragmented decisions, late changes, weak information exchange, short-term procurement, incomplete commissioning, and poor operational handover (Darko & Chan, 2017; Doan et al., 2017; Geng et al., 2019; Zou et al., 2018).

A sustainable green building is therefore not simply a technically efficient object. It is the outcome of a temporary multi-organization system that must align owners, designers, contractors, specialist trades, suppliers, commissioning agents, facility managers, and users over a long and uncertain project life cycle. Green performance can deteriorate when energy models are separated from cost and scheduling decisions, when envelope and mechanical designs are coordinated too late, when procurement substitutes products without whole-life evaluation, or when building controls are delivered without usable information for operators. Research on sustainable project management similarly shows that sustainability outcomes depend on governance, stakeholder integration, control systems, decision timing, and organizational learning, not only on the environmental ambition written into a brief (Aarseth et al., 2017; Banihashemi et al., 2017; Kivilä et al., 2017; Martens & Carvalho, 2017). The organizational architecture of delivery is thus a strategic variable in green building performance.

This study introduces construction organization optimization as a project-level capability that integrates six mutually reinforcing practices: clear sustainability governance and decision rights; reliable collaborative planning; digital information integration; coordinated resource and logistics management; life-cycle commissioning and performance verification; and systematic learning across projects. The construct is broader than lean construction, BIM adoption, partnering, or project controls taken separately. It captures how these practices are configured as an operating system for sustainable delivery. BIM can improve visualization and information consistency but create little value when contractual boundaries prevent collaboration; lean routines can stabilize production but neglect operational outcomes; and certification management can secure credits without resolving the building performance gap. Organization optimization concerns the fit among these mechanisms and the extent to which they support sustainability decisions at the point where cost, quality, schedule, carbon, and occupant outcomes are shaped (Ghaffarianhoseini et al., 2017; Mellado & Lou, 2020; Oraee et al., 2019; Sepasgozar et al., 2021).

Energy efficiency is positioned as the principal mediating mechanism. Buildings do not become energy efficient because a single efficient component is specified. Efficiency emerges from the interaction of passive design, envelope continuity, system sizing, equipment selection, controls, commissioning, occupant behavior, maintenance, and feedback. These interdependencies create a socio-technical performance chain in which organizational coordination can either preserve or destroy modeled savings. Reviews of the building performance gap consistently attribute discrepancies to assumptions, construction quality, commissioning deficiencies, control strategies, occupancy patterns, and fragmented responsibility across the life cycle (Delzendeh et al., 2017; Geng et al., 2019; Hafez et al., 2023; Yan et al., 2017; Zou et al., 2018). Energy efficiency therefore represents an observable conversion pathway through which an optimized construction organization translates coordinated decisions into sustainable outcomes.

The study also argues that energy efficiency alone is insufficient as a definition of green building success. Highly sealed envelopes, aggressive setbacks, minimized ventilation, poorly tuned controls, glare-producing daylight strategies, or acoustically hard open spaces can reduce energy use while impairing indoor environmental quality and user experience. A growing body of healthy-building research connects ventilation, air quality, thermal conditions, lighting, acoustics, spatial qualities, and biophilic features with health, comfort, satisfaction, cognitive performance, and perceived productivity (Al Horr et al., 2016; Allen et al., 2016; Awada et al., 2021; Cedeño-Laurent et al., 2018; MacNaughton et al., 2017). Evidence from WELL-certified workplaces and large occupant surveys further shows that certification and design intentions do not automatically guarantee uniformly positive experiences; post-occupancy feedback and adaptive management remain essential (Graham et al., 2021; Ildiri et al., 2022; Licina & Yildirim, 2021; Licina et al., 2021). Accordingly, environmental well-being orientation is modeled as a positive boundary condition that strengthens the contribution of energy efficiency to broader sustainable performance.

The theoretical logic combines dynamic capabilities reasoning, socio-technical systems thinking, and stakeholder-oriented healthy-building principles. From a capability perspective, optimized project organization supports the sensing of sustainability risks, the integration of specialized knowledge, and the reconfiguration of routines when project conditions change. Dynamic capabilities are especially relevant in construction because each project combines novel teams, technologies, regulations, and site conditions; value comes from repeatable coordination capabilities rather than from static assets alone (Teece, 2018). From a socio-technical perspective, energy performance depends on alignment among physical systems, digital information, work processes, operators, and occupants. From a stakeholder perspective, green performance must create value for building users and communities as well as for owners and regulators. These lenses jointly explain why construction organization optimization is expected to be associated with sustainable performance, why energy efficiency may carry part of that association, and why environmental well-being orientation may strengthen the energy-efficiency-to-performance relationship.

The study makes four contributions. First, it develops a multidimensional definition of construction organization optimization suited to sustainable green buildings. Second, it identifies energy efficiency as an indirect delivery pathway rather than treating it only as a final technical outcome. Third, it introduces environmental well-being orientation as a moderator that connects efficient operation with occupant-centered performance. Fourth, it provides empirical evidence from 421 construction professionals using a 22-item questionnaire and a complete PLS-SEM assessment of measurement quality, direct paths, mediation, moderation, effect sizes, and predictive relevance.

The remainder of the article proceeds as follows. The next three sections define the focal variables and their theoretical foundations. The literature review then develops five hypotheses and identifies the research gap. The methodology explains the quantitative design, measurement instrument, and SmartPLS 4 analytical procedure. The results present the measurement and structural models, followed by a discussion of theoretical and practical implications. The article concludes with limitations and directions for future research.

2. Construction Organization Optimization and Capability Theory

Construction organization optimization refers to the deliberate configuration of project governance, roles, workflows, information, resources, controls, and learning mechanisms so that a construction organization can deliver sustainable value with minimum coordination loss. The construct is not equivalent to downsizing, faster scheduling, or isolated process efficiency. Optimization is achieved when decision rights are located where relevant knowledge exists; sustainability targets are translated into work packages and acceptance criteria; cross-disciplinary dependencies are resolved early; information is available in usable form; and feedback from procurement, construction, commissioning, and operation is incorporated into subsequent decisions. In this sense, optimization concerns organizational coherence and adaptability rather than a single technique.

The construction literature provides several partial foundations for the construct. Sustainable project management research emphasizes stakeholder engagement, life-cycle thinking, strategic alignment, and integrated control (Aarseth et al., 2017; Armenia et al., 2019; Carvalho & Rabechini, 2017; Chofreh et al., 2019). Lean construction research emphasizes reliable planning, production flow, constraint removal, visual management, and continuous improvement; systematic reviews show that lean practices can reduce waste and improve coordination when implemented as a management system rather than a collection of tools (Babalola et al., 2019). BIM research emphasizes shared digital representations, clash detection, constructability, information continuity, and integrated analysis, while also warning that technology benefits are constrained by fragmented contracts, unclear responsibilities, and collaboration barriers (Ghaffarianhoseini et al., 2017; Oraee et al., 2017, 2019). The integration of BIM, lean, and sustainability offers stronger performance potential than any one domain in isolation because it connects information accuracy, production reliability, and environmental objectives (Mellado & Lou, 2020; Sepasgozar et al., 2021).

Digitalization expands the optimization opportunity by making project conditions more visible and decisions more traceable. Industry 4.0 technologies, artificial intelligence, digital twins, sensors, and common data environments can connect design intent with site execution and operational verification (Abioye et al., 2021; Boje et al., 2020; Oesterreich & Teuteberg, 2016; Pan & Zhang, 2021). However, digital tools do not remove organizational problems automatically. Poor model ownership, incompatible standards, information overload, weak data governance, and adversarial commercial arrangements can reproduce fragmentation in digital form. Optimization therefore requires complementary governance: agreed information requirements, issue-resolution protocols, model-based decision gates, accountable owners for energy and well-being targets, and incentives that reward life-cycle outcomes.

The capability perspective explains why these organizational arrangements may create sustained performance advantages. Construction firms and project coalitions operate under temporary, uncertain, and path-dependent conditions. They must mobilize dispersed expertise, identify emerging risks, and reconfigure plans as design, procurement, and site conditions evolve. Dynamic capability research argues that organizations create value through their ability to sense change, seize opportunities, and transform routines and resource combinations (Teece, 2018). Applied to green construction, sensing includes recognizing energy, carbon, material, and occupant risks early; seizing includes selecting integrated solutions and allocating resources; and transforming includes learning from commissioning, post-occupancy evidence, and project retrospectives. An optimized organization makes these capabilities routine rather than dependent on individual champions.

Construction organization optimization is also closely linked to project control, but it extends beyond conventional cost and schedule monitoring. Sustainable project control requires leading indicators such as energy-model convergence, envelope-quality inspections, commissioning issue closure, material traceability, waste diversion, and indoor environmental quality readiness. Kivilä et al. (2017) show that sustainability can be embedded through control systems that connect project-level actions to broader objectives. Banihashemi et al. (2017) likewise identify leadership, stakeholder collaboration, knowledge, and integrated processes as critical success factors for incorporating sustainability into construction project management. Consequently, the construct examined here includes both formal systems and relational routines.

Six dimensions operationalize construction organization optimization in the questionnaire. First, integrated governance defines sustainability accountabilities, escalation routes, and decision rights. Second, collaborative production planning translates targets into reliable sequences and removes constraints. Third, digital information integration connects BIM, energy simulation, specifications, procurement, and site records. Fourth, resource and supply-chain optimization manages logistics, prefabrication, material efficiency, and supplier coordination. Fifth, commissioning and handover integration preserves functional intent and provides operators with usable information. Sixth, continuous improvement uses key performance indicators, lessons learned, and post-project feedback. These dimensions are theoretically related because each reduces a different form of coordination loss.

The expected performance effect is multidimensional. Optimized coordination can reduce rework, waste, delay, and unplanned substitutions; strengthen constructability and quality; improve energy and carbon outcomes; and increase stakeholder confidence. Sustainable project success is increasingly understood to include future readiness, stakeholder satisfaction, environmental value, and controlled execution in addition to the traditional iron triangle (Martens & Carvalho, 2017; Sabini et al., 2019; Silvius & Schipper, 2016). Construction organization optimization is therefore expected to improve sustainable green building performance both directly and through specialized capabilities such as energy efficiency.

3. Energy Efficiency and Socio-Technical Performance Theory

Energy efficiency in this study is the organizational and technical capability to provide required building services with lower life-cycle energy demand while maintaining acceptable indoor environmental conditions. It includes passive load reduction, envelope performance, efficient systems, controls, renewable integration where appropriate, construction quality, commissioning, submetering, operational tuning, and evidence-based feedback. This definition distinguishes efficiency from simple equipment efficiency or predicted energy use intensity. A high-performance component can be neutralized by poor sizing, installation, control, or operation; efficiency must therefore be assessed as a whole-building outcome.

Recent reviews show that building energy performance is influenced by design variables, weather, occupancy, behavior, system interactions, and data quality (Amasyali & El-Gohary, 2018; Wei et al., 2018). Simulation enables comparative design decisions, but its results depend on assumptions and information maturity. Occupant behavior studies demonstrate that schedules, thermostat use, window opening, plug loads, and adaptive actions can materially alter consumption (D'Oca et al., 2018; Delzendeh et al., 2017; Hong et al., 2017; Yan et al., 2017). The performance gap literature further identifies incomplete commissioning, control faults, construction defects, changes in use, and weak feedback between operations and design as recurring causes of underperformance (Geng et al., 2019; Zou et al., 2018). These findings make energy efficiency a socio-technical capability rather than a purely engineering variable.

Socio-technical systems theory emphasizes the joint optimization of social and technical subsystems. In a green building project, the technical subsystem includes the envelope, HVAC, lighting, controls, meters, renewable systems, and digital models. The social subsystem includes design teams, trade contractors, commissioning agents, operators, users, routines, incentives, and tacit knowledge. The systems are interdependent. For example, an advanced control sequence will not save energy if it is inadequately tested, poorly documented, overridden by users, or unsupported by facilities staff. Conversely, strong organizational routines can extract more value from modest technologies through careful design, installation, tuning, and maintenance.

Construction organization optimization should influence energy efficiency through several mechanisms. Early multidisciplinary coordination aligns massing, façade, structure, mechanical systems, electrical loads, and control strategies before late-stage lock-in. Model-based design reviews improve visibility of energy consequences and detect conflicts. Reliable planning protects air-barrier quality, insulation continuity, duct sealing, sensor placement, and testing requirements during construction. Supplier integration reduces the risk of substitutions that compromise performance. Commissioning connects design intent to functional verification, while submetering and digital handover support operational learning. Hafez et al. (2023) conclude that energy efficiency in sustainable buildings requires combined policy, technology, design, and management pathways; organizational integration is the mechanism that allows those pathways to reinforce one another.

Energy efficiency also contributes to wider sustainability outcomes. Lower operational demand reduces emissions, utility costs, infrastructure stress, and exposure to energy-price volatility. Efficient systems can improve resilience when they reduce peak loads and extend the usefulness of on-site generation or storage. Better envelope and control performance can improve comfort, although poorly balanced strategies may create indoor environmental trade-offs. At the same time, the relative importance of embodied carbon rises as operational energy decreases, making material efficiency and low-carbon procurement increasingly significant (De Wolf et al., 2017; Pan & Teng, 2021; Röck et al., 2020; World Green Building Council, 2019). Energy efficiency should therefore be interpreted as one central pathway in an integrated life-cycle performance model, not as a substitute for embodied carbon, circularity, water, biodiversity, or social value.

The measurement focuses on five manifestations: use of energy simulation in design decisions; coordination of envelope and building services to reduce loads; commissioning, metering, and verification; life-cycle tracking of energy targets; and control of energy waste during construction and operation. These indicators capture both design intent and delivery capability. They are expected to form a coherent construct because organizations that systematically manage energy are likely to integrate analysis, quality assurance, verification, and feedback rather than rely on a single design-stage calculation.

4. Environmental Well-Being and Stakeholder Theory

Environmental well-being is the condition in which the built environment supports physical health, psychological well-being, comfort, safety, cognitive functioning, social connection, and a positive relationship with the natural environment. The organizational variable used in this study is environmental well-being orientation: the degree to which project governance, design criteria, construction decisions, and operational verification explicitly prioritize these outcomes. The orientation includes indoor air quality, thermal comfort, acoustic quality, visual comfort, daylight, low-emitting materials, water quality, movement, access to nature, inclusivity, and post-occupancy learning.

The well-being literature has broadened the meaning of high-performance buildings. Al Horr et al. (2016) synthesize evidence linking indoor environmental quality with productivity and workplace experience. Controlled and field research indicates that ventilation and pollutant levels can affect cognitive performance and health-related outcomes (Allen et al., 2016; MacNaughton et al., 2017). Cedeño-Laurent et al. (2018) argue that green building research should more explicitly connect physical building conditions with health evidence, while Awada et al. (2021) identify occupant health as a central design and operation issue under both normal and extreme conditions. Biophilic indoor environments may also support stress and anxiety recovery, reinforcing the need to consider restorative experience alongside resource efficiency (Yin et al., 2020).

Certification systems have begun to incorporate these concerns, but empirical findings caution against equating certification with realized well-being. Licina and Yildirim (2021) found improvements in some satisfaction outcomes after relocation to WELL-certified offices, yet effects varied across buildings and outcomes. Ildiri et al. (2022) reported significant gains in workplace satisfaction and perceived health, well-being, and productivity in a larger pre/post evaluation, while Graham et al. (2021) emphasize the value of long-running occupant survey programs for benchmarking and diagnosis. Licina et al. (2021) conclude that future green building certifications must better address individual differences, exposure patterns, temporal variability, and operational evidence. Environmental well-being orientation therefore reflects active organizational attention, not merely the presence of certification credits.

Stakeholder theory supports this emphasis because a building creates or destroys value for multiple groups over time. Owners may prioritize capital cost and asset value; contractors may prioritize production reliability; regulators may prioritize compliance; operators may prioritize maintainability; and occupants may prioritize health, comfort, accessibility, and functionality. Sustainable project management requires these interests to be recognized early and reconciled through transparent trade-offs (Aarseth et al., 2017; Carvalho & Rabechini, 2017). An environmental well-being orientation institutionalizes the occupant and community perspective in project decisions that might otherwise be dominated by short-term capital considerations.

The moderating argument examined in this study arises from complementarity. Energy efficiency may contribute more strongly to sustainable performance when it is pursued within a well-being-oriented system. High-quality envelopes can improve both energy use and thermal stability; right-sized ventilation with heat recovery can protect air quality while limiting energy penalties; daylight and efficient lighting can support visual comfort; passive strategies and biophilic design can reduce loads while enhancing experience; and monitoring can be used to optimize both energy and indoor conditions. By contrast, an organization focused narrowly on energy metrics may accept solutions that reduce consumption at the expense of ventilation, controllability, comfort, or user trust. Well-being orientation changes the quality of energy-efficiency decisions and the range of outcomes they create.

Five indicators capture systematic prioritization of indoor air quality and health; integration of thermal, acoustic, and visual comfort; specification and verification of low-emitting and non-hazardous materials; incorporation of restorative, biophilic, and inclusive spatial features; and use of occupant feedback and post-occupancy evaluation. Together, these indicators represent a governance orientation that can shape design, procurement, quality control, commissioning, and operation.

5. Literature Review

5.1 Construction Organization Optimization and Sustainable Green Building Performance

Green building performance is multidimensional. Rating systems typically combine energy, water, materials, site, indoor environmental quality, innovation, and management criteria, although their weighting, scope, evidence requirements, and regional assumptions differ (Awadh, 2017; Doan et al., 2017; Illankoon et al., 2017; Mattoni et al., 2018). Reviews of global practice show that certification has helped institutionalize sustainability but does not eliminate variation in actual performance (Shan & Hwang, 2018). Regenerative and life-cycle perspectives further argue that sustainable buildings should create positive ecological and social value rather than merely reduce harm (Gou & Xie, 2017). This broad outcome requires organizational integration across design, construction, and operation.

Empirical research on green building adoption identifies management commitment, knowledge, regulation, market demand, economic value, integrated design, and stakeholder collaboration as important drivers (Darko et al., 2017; Darko, Zhang, & Chan, 2017). The corresponding barriers include higher perceived cost, fragmented responsibilities, limited expertise, uncertain benefits, weak incentives, and resistance to change (Darko & Chan, 2017). These drivers and barriers are organizational as much as technical. A project with optimized governance can clarify benefits, coordinate expertise, manage evidence, and control trade-offs; a fragmented project may fail even when individual technologies are available.

Project sustainability research provides complementary evidence. Banihashemi et al. (2017) identify top-management commitment, knowledge, stakeholder engagement, and integrated processes as critical to sustainable construction project management. Kivilä et al. (2017) show how project control can translate sustainability goals into practices, while Martens and Carvalho (2017) demonstrate that sustainability factors extend across economic, environmental, and social dimensions. Carvalho and Rabechini (2017) find that sustainability management can contribute to project success under contingent conditions, and

Sabini et al. (2019) document the evolution from peripheral environmental concerns toward a more integrated understanding of sustainable projects.

Operationally, organization optimization reduces losses that directly affect green performance. Reliable planning reduces rework and material waste. Early coordination prevents oversized systems and façade-service conflicts. Digital information integration improves traceability and constructability. Supplier engagement supports product transparency and low-carbon alternatives. Commissioning closes defects before occupancy. Continuous improvement transfers lessons between projects. Prefabrication and modular strategies can reduce site waste and improve quality, although their benefits depend on logistics, design standardization, and supply-chain readiness (Hong et al., 2018; Kamali & Hewage, 2016; Wuni & Shen, 2020). BIM-enabled waste management and circular design similarly require organizational processes that connect design information with procurement and site decisions (Benachio et al., 2020; Won & Cheng, 2017).

The capability argument therefore predicts a direct relationship. Even after the energy-efficiency pathway is considered, optimized organization should improve sustainable performance through material efficiency, waste reduction, water management, quality, schedule reliability, certification compliance, stakeholder satisfaction, and life-cycle value. The direct effect is expected to remain positive because sustainable performance includes outcomes beyond energy.

H1. Construction organization optimization is significantly and positively associated with sustainable green building performance.

5.2 Construction Organization Optimization and Energy Efficiency

Energy performance is particularly sensitive to organizational fragmentation. Early energy models often depend on incomplete geometry, generic schedules, and default assumptions. As the project develops, cost engineering, value management, procurement, and construction decisions can change envelope assemblies, glazing, system types, controls, and equipment efficiencies. Without an integrated process, changes are not consistently returned to the model, and design teams may lose visibility of cumulative effects. The result is a gap between modeled, as-built, commissioned, and occupied performance (Geng et al., 2019; Zou et al., 2018).

BIM and digital coordination can strengthen the information pathway by connecting energy analysis to geometry, specifications, quantities, and issue management. Ghaffarianhoseini et al. (2017) identify coordination, visualization, and information management as major BIM benefits but also emphasize implementation risks. Oraee et al. (2019) show that collaboration barriers in BIM-based networks include contractual, organizational, process, and technological factors. Mellado and Lou (2020) propose that BIM, lean, and sustainability should be integrated so that information, production, and performance objectives are managed together. Sepasgozar et al. (2021) similarly connect lean practices, BIM, and digital twinning with sustainable construction performance.

Organization optimization also improves the physical realization of energy intent. The quality of insulation, air barriers, glazing installation, ductwork, pipework, controls, sensors, and balancing depends on trade sequencing, supervision, inspection, and testing. Collaborative planning can protect critical quality activities from schedule pressure. Commissioning involvement during design can improve testability and control sequences, while issue tracking can ensure closure before handover. Facility-manager involvement can improve maintainability and operator readiness. These mechanisms are consistent with Hafez et al. (2023), who frame energy efficiency as a multi-pathway challenge involving design, technology, policy, behavior, and management.

The socio-technical literature further supports the link. Occupant behavior, control interfaces, and operational routines shape realized consumption (D'Oca et al., 2018; Hong et al., 2017; Yan et al., 2017). An optimized organization anticipates these interactions by involving operators, defining control narratives, training users, and using meters and feedback. Energy efficiency is therefore expected to be higher where the project organization integrates decisions across the building life cycle.

H2. Construction organization optimization is significantly and positively associated with energy efficiency.

5.3 Energy Efficiency and Sustainable Green Building Performance

Energy efficiency remains one of the most consequential components of green building performance because operational energy affects emissions, costs, peak demand, resilience, and regulatory compliance. The International Energy Agency (2023) identifies efficiency and electrification as central pathways for decarbonizing buildings, while the IPCC (2022) emphasizes demand-side measures and integrated design. Hafez et al. (2023) find that energy-efficient building strategies span passive design, efficient technologies, control systems, renewable energy, policy, and behavioral measures.

Empirical and review studies show that whole-building performance requires coordination among envelope, systems, controls, and users. Data-driven prediction research has improved the ability to forecast consumption and diagnose patterns, but model accuracy depends on high-quality data and contextual variables (Amasyali & El-Gohary, 2018; Wei et al., 2018). Occupant-centric control can yield energy savings while maintaining comfort when sensing and control logic are appropriately designed (Kong et al., 2022). Conversely, efficiency measures that neglect real use may generate rebound, overrides, or dissatisfaction. The sustainable value of energy efficiency therefore depends on delivery quality and alignment with occupant needs.

Energy efficiency contributes directly to certification and asset performance. It can reduce operating expenditure, support decarbonization commitments, lower exposure to energy-price volatility, and improve compliance with performance standards. In high-performance projects, low operational energy also makes embodied carbon more visible as a share of life-cycle impact, encouraging integrated decisions about materials and structural systems (Pan & Teng, 2021; Röck et al., 2020). This does not weaken the importance of efficiency; it expands the performance framework in which efficiency is evaluated.

A positive relationship is therefore expected between energy efficiency and sustainable green building performance. The outcome construct includes operational energy and carbon, but also resource performance, certification, project quality, occupant satisfaction, and life-cycle value. Efficiency should contribute to these dimensions through lower loads, better system integration, stronger commissioning, and more stable indoor conditions.

H3. Energy efficiency is significantly and positively associated with sustainable green building performance.

5.4 The Mediating Role of Energy Efficiency

The mediation hypothesis explains how an organizational capability is linked with a building outcome. Construction organization optimization is an upstream capability: it structures decisions, information, collaboration, and learning. Sustainable green building performance is a downstream result observed in energy, carbon, resources, certification, user outcomes, and life-cycle value. Energy efficiency represents an intermediate delivery capability in the tested model.

This mechanism is consistent with the resource- and capability-based view. Organizational routines do not create value merely because they exist; they create value when they enable specialized capabilities and outcomes. Integrated design reviews, reliable planning, digital coordination, quality assurance, and commissioning should improve energy modeling, system selection, installation quality, control performance, and operational tuning. Those improvements, in turn, contribute to broader green performance. Teece (2018) emphasizes that dynamic capabilities enable organizations to reconfigure resources and routines under changing conditions. In a construction project, energy efficiency is one of the most observable results of that reconfiguration.

The performance-gap literature supports the chain. Zou et al. (2018) show that discrepancies arise across life-cycle stages and stakeholder interfaces. Geng et al. (2019) find that operating performance must be evaluated across energy use, indoor environmental quality, and occupant satisfaction. If organization optimization reduces interface failures, then it should narrow the gap and improve energy efficiency. The mediated path also reflects the integrated BIM-lean-sustainability argument: coordination and flow improvements create environmental value through better decisions and execution (Mellado & Lou, 2020; Sepasgozar et al., 2021).

Partial rather than full mediation is expected. Construction organization optimization can improve material efficiency, waste reduction, water performance, stakeholder engagement, certification management, and schedule-quality outcomes independently of operational energy. Energy efficiency should nevertheless account for a substantial share of the total effect because it is a central, measurable expression of integrated design, construction quality, commissioning, and operational readiness.

H4. Energy efficiency significantly mediates the association between construction organization optimization and sustainable green building performance.

5.5 The Moderating Role of Environmental Well-Being

The fifth hypothesis addresses the conditions under which energy efficiency produces the greatest sustainable value. Energy strategies can be synergistic with well-being, neutral, or harmful depending on how they are designed and operated. A high-performance envelope may improve thermal stability and comfort, while inadequate ventilation may reduce energy use but impair air quality. Daylighting can reduce electric lighting demand and support circadian experience, but uncontrolled glare can reduce satisfaction. Automated controls can optimize systems, but low perceived control may encourage overrides or distrust. Environmental well-being orientation directs the organization to manage these interactions explicitly.

Healthy-building research demonstrates that indoor environmental quality is central to the value proposition of green buildings. Allen et al. (2016) connect ventilation, carbon dioxide, and volatile organic compound conditions with cognitive performance. MacNaughton et al. (2017) report health and cognitive benefits associated with working in green-certified buildings. Cedeño-Laurent et al. (2018) synthesize the evidence base connecting green building strategies with health, while Awada et al. (2021) emphasize resilience and occupant health under normal and extreme events. These studies suggest that efficiency should be evaluated in relation to human outcomes rather than in isolation.

Post-occupancy research further indicates that organizational learning is required. Graham et al. (2021) show how occupant surveys can diagnose patterns that technical measurements alone may miss. Licina and Yildirim (2021) and Ildiri et al. (2022) find positive but context-dependent outcomes in WELL-certified workplaces. Licina et al. (2021) call for greater attention to individual differences, spatial and temporal variability, and exposure. A well-being-oriented organization is more likely to use this evidence to tune systems, revise controls, communicate with users, and prioritize balanced outcomes.

The moderator is expected to be positive because well-being orientation should increase the conversion of energy efficiency into overall sustainable performance. At high levels of orientation, efficient systems are more likely to deliver comfort, health, satisfaction, productivity, and long-term value alongside energy savings. At low levels, energy gains may remain narrow or be offset by complaints, overrides, absenteeism, reputational risks, or retrofit needs. The moderation hypothesis therefore captures complementarity between environmental and human performance.

H5. Environmental well-being orientation significantly and positively moderates the association between energy efficiency and sustainable green building performance, such that the association is stronger when environmental well-being orientation is high.

5.6 Research Gap

The literature is rich in studies of green building technologies, rating systems, BIM, lean construction, energy performance, project sustainability, indoor environmental quality, and circular construction. However, these streams are often separated. Green building adoption research identifies drivers and barriers but rarely models the internal organizational system through which delivery occurs (Darko & Chan, 2017; Darko et al., 2017). BIM and lean research examines collaboration and process improvement but often treats sustainability as a secondary application rather than a multi-dimensional performance outcome (Babalola et al., 2019; Ghaffarianhoseini et al., 2017; Oraee et al., 2019). Energy-performance research explains technical and behavioral determinants but gives less attention to project-organization configuration as an antecedent (Geng et al., 2019; Hafez et al., 2023; Zou et al., 2018). Healthy-building research emphasizes occupant outcomes but is only partially connected to construction governance and energy-delivery mechanisms (Cedeño-Laurent et al., 2018; Licina et al., 2021).

Three specific gaps follow. First, no widely established construct captures the combined optimization of governance, planning, digital information, supply chain, commissioning, and learning for green building delivery. Second, energy efficiency is commonly treated as an outcome or design characteristic, not as a mediator that explains how organizational capability is linked with sustainable performance. Third, environmental well-being is usually modeled as a parallel outcome or certification dimension, not as a boundary condition associated with variation in the value of energy efficiency. The model addresses these gaps by integrating organizational capability, socio-technical energy performance, and occupant-centered well-being.

The model also responds to methodological gaps. Many studies rely on single-domain measures, cross-sectional perceptions, or certification status without linking measurement quality to structural mechanisms. This study uses a multi-construct questionnaire, explicit mediation and moderation hypotheses, measurement-model assessment, effect sizes, and predictive-relevance statistics to evaluate the hypothesized relationships within one quantitative model.

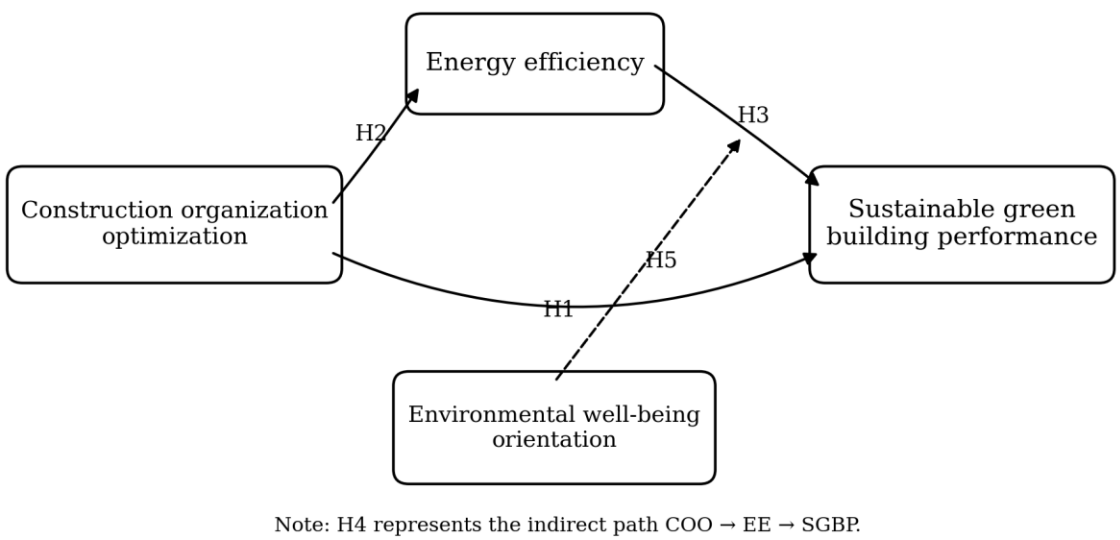

Figure 1. Theoretical Model

6. Methodology

This study used a cross-sectional, explanatory quantitative design to examine associations among organizational and technical mechanisms in sustainable green building delivery. The analytical focus was the focal green building project as reported by a professional respondent with relevant knowledge of design coordination, construction planning, energy systems, commissioning, sustainability certification, procurement, or facilities transition. The sample included project managers, architects and design managers, site and construction managers, mechanical-electrical-plumbing engineers, sustainability specialists, quantity surveyors, procurement personnel, commissioning agents, and facility managers.

The final analytical sample comprised 421 valid questionnaire responses. Respondents answered with reference to one focal green building project, and the resulting measures represent professional perceptions of project-level organizational practices, energy-efficiency delivery, environmental well-being orientation, and sustainable green building performance. The cross-sectional design supports theory-guided association testing but does not establish temporal ordering or causality.

The respondent pool covered design, project management, site delivery, energy engineering, sustainability, procurement, commissioning, and facilities-management roles. This cross-role composition supported assessment of the model across multiple professional perspectives involved in green building delivery.

6.1 Measurement Instrument

The questionnaire contained demographic questions followed by 22 reflective indicators. Construction organization optimization was measured by six items covering governance, collaborative planning, digital integration, lean workflow, supply-chain and logistics optimization, and performance learning. These indicators were adapted from practices highlighted in sustainable project management, BIM collaboration, lean construction, and construction digitalization research (Banihashemi et al., 2017; Babalola et al., 2019; Mellado & Lou, 2020; Oesterreich & Teuteberg, 2016; Sepasgozar et al., 2021). Energy efficiency was measured through five items addressing simulation-informed decisions, envelope and system integration, commissioning and verification, life-cycle target tracking, and corrective monitoring. The items reflect evidence on performance gaps, data-driven energy management, occupant-responsive controls, and operating performance (Amasyali & El-Gohary, 2018; Geng et al., 2019; Hafez et al., 2023; Kong et al., 2022; Zou et al., 2018).

Environmental well-being orientation was represented by five items concerning indoor air quality and health, multi-domain comfort, low-emitting materials, biophilic and inclusive features, and post-occupancy feedback. The scale was grounded in healthy-building and indoor-environmental-quality studies that connect design and operation with satisfaction, health, cognitive outcomes, and perceived productivity (Al Horr et al., 2016; Awada et al., 2021; Cedeño-Laurent et al., 2018; Graham et al., 2021; Licina et al., 2021). Sustainable green building performance was measured by six items covering operational energy and carbon, embodied impacts and resources, certification and compliance, project delivery, occupant experience, and long-term asset value. This multidimensional treatment is consistent with comparative work on rating tools and project sustainability (Doan et al., 2017; Gou & Xie, 2017; Illankoon et al., 2017; Shan & Hwang, 2018). All construct items used a five-point agreement scale ranging from 1, strongly disagree, to 5, strongly agree.

Table 1. **Measurement Constructs and Scale Foundations**

Variable	*Items*	*Scale foundations*
Construction organization optimization	Six	Banihashemi et al. (2017); Babalola et al. (2019); Mellado and Lou (2020); Sepasgozar et al. (2021)
Energy efficiency	Five	Geng et al. (2019); Hafez et al. (2023); Zou et al. (2018)
Environmental well-being orientation	Five	Cedeño-Laurent et al. (2018); Graham et al. (2021); Licina et al. (2021)
Sustainable green building performance	Six	Doan et al. (2017); Gou and Xie (2017); Illankoon et al. (2017); Shan and Hwang (2018)

6.2 Data Analysis Procedure

The questionnaire responses were analyzed using partial least squares structural equation modeling in SmartPLS 4. The procedure assessed indicator distributions, internal consistency, construct scores, and full-collinearity statistics. Reliability was evaluated with Cronbach's alpha, Dijkstra-Henseler's rho_A, and composite reliability. Convergent validity was assessed with indicator loadings and average variance extracted. Values around or above .70 for reliability and .50 for average variance extracted are conventionally interpreted as satisfactory, while indicators should generally load above .70 unless content validity justifies retention (Benitez et al., 2020; Hair et al., 2020; Hair et al., 2022).

Discriminant validity was evaluated using the heterotrait-monotrait ratio and the Fornell-Larcker comparison. HTMT values below .85 provide a conservative indication that constructs are empirically distinct, although interpretation should consider theory and confidence intervals (Franke & Sarstedt, 2019). Potential common-method inflation was screened through full-collinearity variance-inflation factors, using values below 3.3 as an indicative diagnostic rather than proof that bias is absent (Kock, 2017). Because all constructs were measured in a single cross-sectional questionnaire, the findings were interpreted with appropriate caution regarding common-method bias.

The structural analysis estimated standardized direct paths, the specific indirect effect, the total effect, the interaction effect, coefficients of determination, adjusted coefficients, Cohen's f-squared effect sizes, and predictive-relevance statistics. Five thousand bootstrap resamples generated standard errors, t statistics, p values, and percentile confidence intervals. Mediation was evaluated from the bootstrapped specific indirect effect, and moderation was evaluated from the interaction term and simple slopes at low, mean, and high levels of the moderator. Predictive relevance was assessed using Q-squared predict, root mean square error, and mean absolute error in line with PLSpredict guidance (Shmueli et al., 2019). Model quality was also summarized with the standardized root mean square residual, normed fit index, and RMS_theta. These statistics were interpreted jointly with measurement quality, effect sizes, theoretical coherence, and predictive relevance rather than as a single pass-fail test.

6.3 Ethical Considerations

The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. All participants provided informed consent prior to participating in the survey. The survey was completely anonymous, and no personally identifiable data were collected, ensuring the confidentiality and privacy of all respondents.

7. Results

The results are based on 421 valid questionnaire responses. Because the study used a cross-sectional perceptual design, the estimated paths are interpreted as theory-guided associations within the tested model rather than as evidence of temporal or causal effects.

7.1 Respondent Profile

The final sample comprised 421 cases. Men account for 65.8% of the cases, women 33.7%, and 0.5% prefer not to state gender. The largest age groups are 31–40 years (33.5%) and 41–50 years (30.6%). Project managers constitute 22.1% of cases, followed by architects or design managers (18.3%), site or construction managers (17.3%), MEP or energy engineers (15.2%), sustainability specialists (12.6%), quantity-surveying or procurement personnel (7.4%), and commissioning or facility managers (7.1%). A total of 85.3% report at least five years of experience, and 87.2% have participated in two or more green projects. Commercial office and retail projects form the largest project category (31.8%), followed by residential or mixed-use and public or institutional projects (24.9% each). The profile captures professional-role and project-type heterogeneity within the sample.

Table 2. **Respondent Profile**

Characteristic	*Category*	*n*	*%*
Gender	Male	277	65.8
Gender	Female	142	33.7
Gender	Prefer not to say	2	0.5
Age group	31-40	141	33.5
Age group	41-50	129	30.6
Age group	51 and above	78	18.5
Age group	21-30	73	17.3
Professional role	Project manager	93	22.1
Professional role	Architect/design manager	77	18.3
Professional role	Site/construction manager	73	17.3
Professional role	MEP/energy engineer	64	15.2
Professional role	Sustainability/green building specialist	53	12.6
Professional role	Quantity surveyor/procurement	31	7.4
Professional role	Commissioning/facility manager	30	7.1
Professional experience	5-10 years	110	26.1
Professional experience	11-15 years	105	24.9
Professional experience	16-20 years	78	18.5
Professional experience	Above 20 years	66	15.7
Professional experience	Below 5 years	62	14.7
Project type	Commercial office/retail	134	31.8
Project type	Residential/mixed-use	105	24.9
Project type	Public/institutional	105	24.9
Project type	Industrial/logistics	46	10.9
Project type	Healthcare	31	7.4
Organization size	100-499 employees	139	33.0

Characteristic	*Category*	*n*	*%*
Organization size	500-1,999 employees	109	25.9
Organization size	2,000 employees and above	105	24.9
Organization size	Below 100 employees	68	16.2
Green-project experience	7 or more projects	123	29.2
Green-project experience	4-6 projects	122	29.0
Green-project experience	2-3 projects	122	29.0
Green-project experience	1 project	54	12.8

Note. n = 421.

Construct means lie near the scale midpoint: 2.961 for construction organization optimization, 3.012 for energy efficiency, 2.977 for environmental well-being orientation, and 2.980 for sustainable green building performance. Standard deviations range from .962 to .982, indicating adequate dispersion and avoiding an artificially compressed response pattern. Item means range from 2.907 to 3.057, and every response category from one to five is represented.

7.2 Construct Reliability and Convergent Validity

Table 3 reports internal consistency and convergent validity. Cronbach's alpha ranges from .884 to .907, rho_A from .916 to .930, and composite reliability from .915 to .929. All values exceed the .70 benchmark without approaching levels that would suggest extreme item duplication. Average variance extracted ranges from .665 to .688, meaning that each construct explains more than half of the variance in its indicators. Construction organization optimization records alpha = .899, rho_A = .923, composite reliability = .923, and AVE = .665. Energy efficiency records alpha = .886 and AVE = .688. Environmental well-being orientation records alpha = .884 and AVE = .683. Sustainable green building performance has the highest alpha at .907 and an AVE of .684. These statistics support reliability and convergent validity in the sample.

***Table 3.* Construct Reliability and Convergent Validity**

Construct	*Dijkstra-Henseler's rho (ρA)*	*Jöreskog's rho (ρc)*	*Cronbach's alpha (α)*	*AVE*
Construction organization optimization	0.923	0.923	0.899	0.665
Energy efficiency	0.917	0.917	0.886	0.688
Environmental well-being orientation	0.916	0.915	0.884	0.683
Sustainable green building performance	0.930	0.928	0.907	0.684

7.3 Estimated Model

Figure 2 presents the estimated measurement and structural model. The measurement portion shows consistently positive loadings, while the structural portion displays the direct organizational path, the mediated energy-efficiency path, the well-being main effect, and the interaction path. Construction organization optimization correlates .600 with energy efficiency and .660 with sustainable green building performance. Energy efficiency correlates .690 with sustainable performance, while environmental well-being orientation has a more moderate correlation of .411 with sustainable performance. The pattern is theoretically plausible because organizational optimization and energy delivery are related but not interchangeable, and well-being orientation contributes a distinct human-performance emphasis.

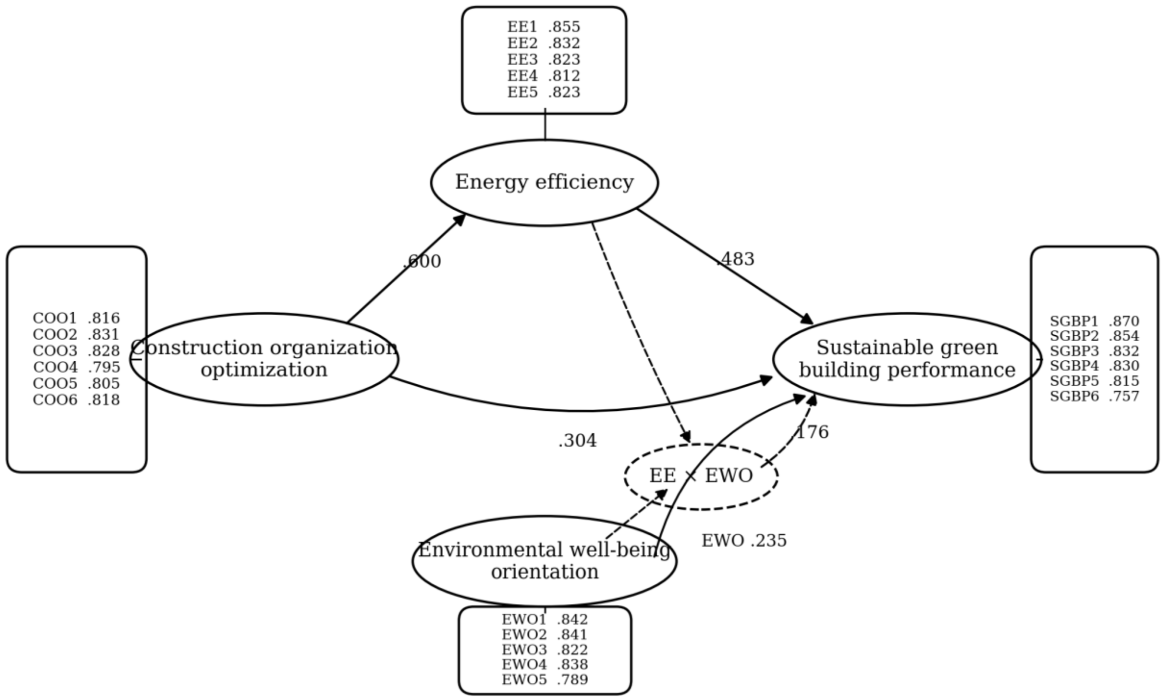

Figure 2. Estimated Measurement and Structural Model

7.4 Indicator Loadings and Collinearity Statistics

All 22 standardized loadings exceed .75. Construction organization optimization loadings range from .795 to .831; energy-efficiency loadings range from .812 to .855; environmental well-being orientation loadings range from .789 to .842; and sustainable green building performance loadings range from .757 to .870. The strongest indicator is SGBP1, representing operational energy and carbon performance, at .870. SGBP6, representing long-term asset value, resilience, and stakeholder confidence, is the lowest at .757 but remains acceptable and preserves the life-cycle value dimension. Indicator VIF values range from 1.834 to 2.821, showing that no item is excessively redundant with the remaining indicators in its construct.

Table 4. **Indicator Loadings and Collinearity Statistics**

Indicator	*Loading*	*Mean*	*SD*	*VIF*
COO1	0.816	3.021	1.194	2.128
COO2	0.831	2.926	1.168	2.277
COO3	0.828	2.974	1.192	2.230
COO4	0.795	2.952	1.160	1.978
COO5	0.805	2.950	1.169	2.052
COO6	0.818	2.941	1.195	2.148
EE1	0.855	3.014	1.161	2.385
EE2	0.832	2.962	1.168	2.156
EE3	0.823	3.026	1.190	2.063
EE4	0.812	3.000	1.242	2.004
EE5	0.823	3.057	1.162	2.076
EWO1	0.842	2.993	1.182	2.226
EWO2	0.841	2.979	1.180	2.218
EWO3	0.822	3.014	1.221	2.055
EWO4	0.838	2.990	1.193	2.199

Indicator	*Loading*	*Mean*	*SD*	*VIF*
EWO5	0.789	2.907	1.129	1.834
SGBP1	0.870	2.952	1.192	2.821
SGBP2	0.854	2.998	1.186	2.555
SGBP3	0.832	3.002	1.127	2.328
SGBP4	0.830	2.907	1.205	2.283
SGBP5	0.815	3.031	1.202	2.152
SGBP6	0.757	2.990	1.121	1.781

7.5 Discriminant Validity

Table 5 displays HTMT statistics. The highest value is .769 between energy efficiency and sustainable green building performance, followed by .731 between construction organization optimization and sustainable performance. Both values are below the conservative .85 threshold. The lowest value is .190 between energy efficiency and environmental well-being orientation, supporting the proposition that technical efficiency and human-centered orientation are distinct constructs. The remaining values range from .356 to .672. Table 6 provides the Fornell-Larcker matrix. Each diagonal square root of AVE, ranging from .816 to .829, exceeds the corresponding inter-construct correlations. Taken together, the HTMT and Fornell-Larcker results support discriminant validity.

***Table 5.* Discriminant Validity: Heterotrait-Monotrait Ratio of Correlations (HTMT)**

Construct	*COO*	*EE*	*EWO*	*SGBP*
COO	—			
EE	0.672	—		
EWO	0.356	0.190	—	
SGBP	0.731	0.769	0.458	—

***Table 6.* Discriminant Validity: Fornell-Larcker Criterion**

Construct	*COO*	*EE*	*EWO*	*SGBP*
COO	0.816	0.600	0.317	0.660
EE	0.600	0.829	0.167	0.690
EWO	0.317	0.167	0.827	0.411
SGBP	0.660	0.690	0.411	0.827

Note. Diagonal values are the square roots of average variance extracted; off-diagonal values are construct correlations.

The full-collinearity VIF values are 1.933 for construction organization optimization, 2.140 for energy efficiency, 1.260 for environmental well-being orientation, and 2.635 for sustainable green building performance. All are below 3.3. This diagnostic reduces concern that a single common response tendency dominates the covariance structure, but it does not eliminate common-method concerns associated with a single-source cross-sectional questionnaire.

7.6 Direct, Indirect, Total, and Effect-Size Results

Table 7 summarizes direct, indirect, total, and effect-size results. Construction organization optimization has a direct path coefficient of .304 with sustainable green building performance and a specific indirect effect of .290 through energy efficiency, producing a total modeled association of .594. The comparable magnitude of the direct and indirect components is consistent with complementary partial mediation: construction organization optimization is associated with sustainable performance both through energy efficiency and through other theoretically relevant routes such as waste prevention, material coordination, certification management, quality, and stakeholder integration. Energy efficiency has the largest direct path coefficient with sustainable performance at .483. Environmental well-being orientation contributes a direct path coefficient of .235, while its interaction with energy efficiency contributes .176.

Cohen's f-squared values further clarify substantive influence. The effect of construction organization optimization on energy efficiency is .562, and the effect of energy efficiency on sustainable performance is .425; both are large relative to conventional guidelines. The direct organizational effect on sustainable performance is .156 and the well-being main effect is .142, representing moderate contributions. The interaction effect is .086, which is smaller but meaningful because moderation effects are often difficult to detect in field settings.

Table 7. **Direct, Indirect, Total, and Effect-Size Results**

Effect	*Direct β*	*Indirect β*	*Total β*	*Cohen's f^2*
Construction organization optimization → Energy efficiency	0.600	—	0.600	0.562
Construction organization optimization → Sustainable green building performance	0.304	0.290	0.594	0.156
Energy efficiency → Sustainable green building performance	0.483	—	0.483	0.425
Environmental well-being orientation → Sustainable green building performance	0.235	—	0.235	0.142
Energy efficiency × Environmental well-being orientation → Sustainable green building performance	0.176	—	0.176	0.086

7.7 Explanatory and Predictive Assessment

Construction organization optimization explains 36.0% of the variance in energy efficiency, with an adjusted R-squared of .358. The full model explains 65.0% of sustainable green building performance, with an adjusted R-squared of .647. The difference between unadjusted and adjusted values is small, indicating that the explanatory power is not an artifact of unnecessary predictors. The Q-squared-predict values are .350 for energy efficiency and .643 for sustainable performance, both above zero. Prediction errors are also reported to facilitate replication: RMSE is .806 and MAE is .655 for energy efficiency, while RMSE is .598 and MAE is .472 for sustainable performance.

The standardized root mean square residual is .043, the normed fit index is .933, and RMS_theta is .072. Considered alongside reliability, validity, explained variance, and predictive-relevance statistics, these values indicate an adequate estimated model. They do not establish that the theoretical structure will generalize to every country, project type, procurement system, or certification regime.

Table 8. **Explanatory and Predictive Assessment**

Construct / statistic	*R^2*	*Adjusted R^2*	*Q^2predict*	*RMSE*	*MAE*
Energy efficiency	0.360	0.358	0.350	0.806	0.655
Sustainable green building performance	0.650	0.647	0.643	0.598	0.472
Model-level fit: SRMR = 0.043; NFI = 0.933; RMS_theta = 0.072	—	—	—	—	—

7.8 Structural Model Results

Figure 3 presents the structural model with standardized coefficients. The strongest structural path is from construction organization optimization to energy efficiency (β = .600). Energy efficiency is positively associated with sustainable green building performance (β = .483), while the direct path from construction organization optimization remains positive (β = .304). Environmental well-being orientation has a positive main-effect path (β = .235), and the energy-efficiency-by-well-being interaction is also positive (β = .176). The pattern is consistent with an indirect organizational pathway through energy efficiency and a stronger energy-efficiency-to-performance association at higher levels of environmental well-being orientation.

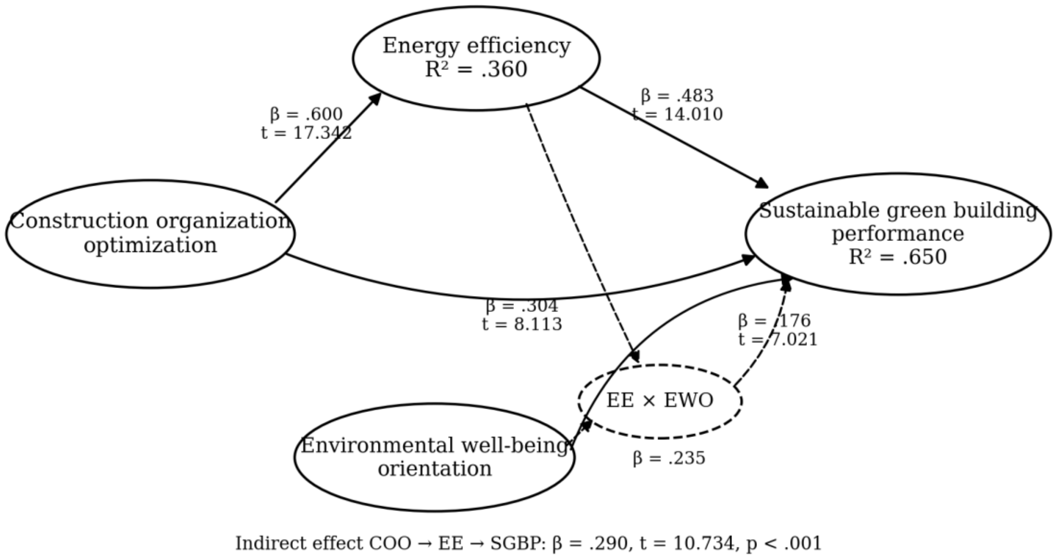

Figure 3. Structural Model Results

7.9 Hypothesis Testing

Table 9 reports the hypothesis tests. H1 is supported because construction organization optimization was positively associated with sustainable green building performance (β = .304, t = 8.113, $p < .001$, 95% CI [.229, .375]). H2 is supported by the positive association between construction organization optimization and energy efficiency (β = .600, t = 17.342, $p < .001$, 95% CI [.534, .669]). H3 is supported because energy efficiency was positively associated with sustainable green building performance (β = .483, t = 14.010, $p < .001$, 95% CI [.417, .551]).

The specific indirect effect for H4 is .290 (t = 10.734, $p < .001$, 95% CI [.240, .345]). Because the direct path remains significant and has the same sign, the pattern is consistent with complementary partial mediation. H5 is also supported: the interaction between energy efficiency and environmental well-being orientation is positive (β = .176, t = 7.021, $p < .001$, 95% CI [.128, .226]). None of the bootstrap confidence intervals includes zero. These results support the hypothesized model but do not establish temporal or causal ordering.

***Table 9.* Structural Path and Hypothesis Tests**

H	*Relationship*	*β*	*STDEV*	*t*	*p*	*95% CI*	*Decision*
H1	Construction organization optimization -> Sustainable green building performance	0.304	0.037	8.113	< .001	[0.229, 0.375]	Supported
H2	Construction organization optimization -> Energy efficiency	0.600	0.035	17.342	< .001	[0.534, 0.669]	Supported
H3	Energy efficiency -> Sustainable green building performance	0.483	0.035	14.010	< .001	[0.417, 0.551]	Supported
H4	Construction organization optimization -> Energy efficiency -> Sustainable green building performance	0.290	0.027	10.734	< .001	[0.240, 0.345]	Supported
H5	Energy efficiency x Environmental well-being orientation -> Sustainable green building performance	0.176	0.025	7.021	< .001	[0.128, 0.226]	Supported

Note. Bootstrap resamples = 5,000.

Simple-slope analysis clarifies the moderation result. At one standard deviation below the mean of environmental well-being orientation, the conditional energy-efficiency slope is .307. At the mean it is .483, and at one standard deviation above the mean it rises to .660. Figure 4 shows the widening difference in predicted sustainable green building performance as energy efficiency increases. The pattern indicates that the positive association between energy efficiency and sustainable performance is stronger when project organizations place greater emphasis on air quality, comfort, materials, inclusiveness, restorative features, user feedback, and post-occupancy learning.

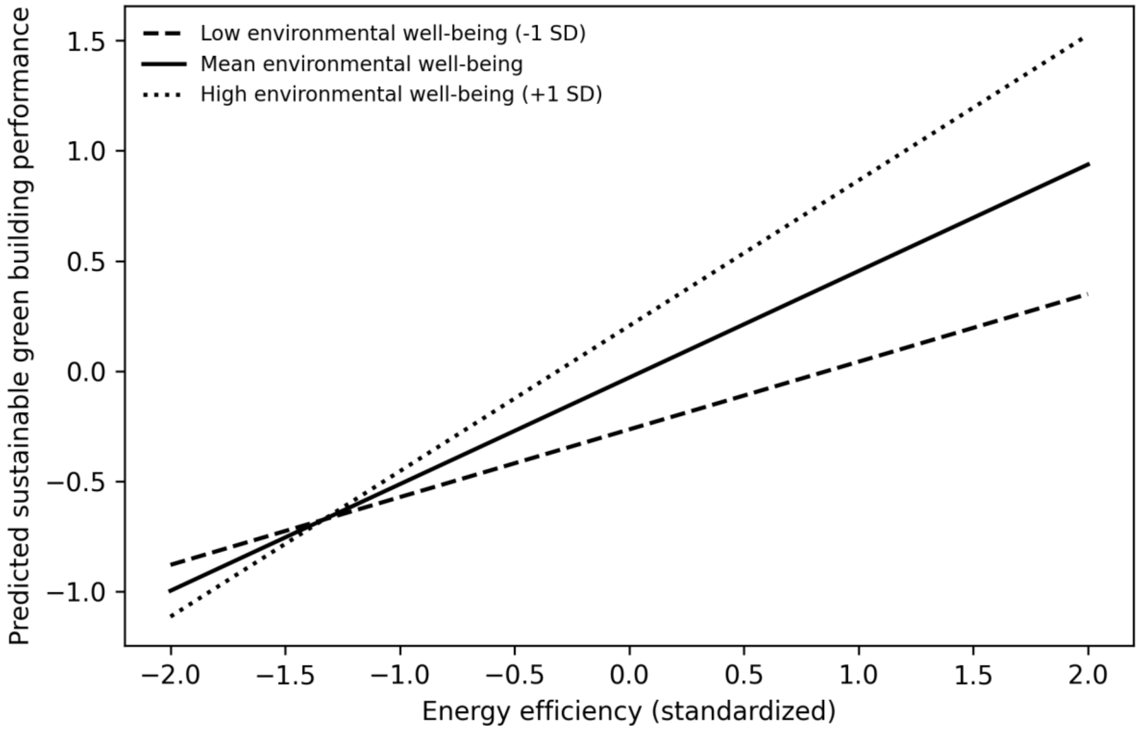

Figure 4. Moderating Effect of Environmental Well-Being Orientation

8. Discussion

The study develops and empirically tests an organizational explanation of sustainable green building performance. The findings support all five hypotheses and connect bodies of research that are commonly treated separately. The central interpretation is not that organization replaces technology. Rather, the observed pattern is consistent with construction organization optimization operating as an integrative capability associated with technical systems, supply chains, commissioning processes, and coordinated professional practices. Energy efficiency functions as an indirect pathway in the tested model, while environmental well-being orientation conditions the strength of the energy-efficiency-to-performance association.

8.1 Discussion of H1

H1 predicted a positive association between construction organization optimization and sustainable green building performance. The supported path is consistent with research showing that sustainability must be embedded in project governance, controls, stakeholder relationships, and decision routines (Aarseth et al., 2017; Carvalho & Rabechini, 2017; Kivilä et al., 2017; Martens & Carvalho, 2017). The result extends that work by treating governance, planning, digital coordination, supply-chain management, commissioning, and learning as a unified capability. Green buildings are delivered by temporary networks whose goals and information are distributed across contractual boundaries. When responsibilities are unclear or decisions are delayed, performance can be lost even when individual organizations possess relevant expertise.

The positive direct association that remained after energy efficiency was included is theoretically important. Construction organization optimization may also be associated with embodied-carbon reduction, waste prevention, circular material use, water stewardship, certification evidence, quality assurance, and life-cycle value. These outcomes depend on early coordination and procurement decisions, as emphasized by studies of construction waste, circularity, prefabrication, and embodied carbon (Ajayi et al., 2017; Benachio et al., 2020; Kamali & Hewage, 2016; Pomponi & Moncaster, 2017; Röck et al., 2020). The finding therefore supports a multidimensional interpretation of sustainable performance rather than reducing green construction to operational energy alone.

8.2 Discussion of H2

H2 linked construction organization optimization with energy efficiency, and this was the strongest path in the model. The finding is consistent with the interdependent nature of building energy performance. Passive design, envelope detailing, mechanical sizing, controls, metering, commissioning, and operator training must be coordinated over time. BIM can support this process through information consistency, clash detection, simulation integration, and digital handover, but collaborative arrangements and data governance are essential to realize the benefits (Ghaffarianhoseini et al., 2017; Oraee et al., 2017; Sacks et al., 2018). Lean planning and constraint removal can further protect the sequence and quality of energy-critical work (Babalola et al., 2019; Mellado & Lou, 2020).

The positive association also aligns with performance-gap evidence. Deviations between predictions and operation often emerge from inaccurate assumptions, construction defects, incomplete commissioning, poor controls, changing use, and fragmented responsibilities (Delzendeh et al., 2017; Geng et al., 2019; Yan et al., 2017; Zou et al., 2018). The observed path is consistent with the argument that clearer ownership of targets, stronger links among simulation, procurement, and construction, verification of installations, and transfer of usable information to operators are associated with better energy-efficiency delivery. Energy efficiency is therefore interpreted as an organizational achievement as well as an engineering property.

8.3 Discussion of H3

H3 showed a positive association between energy efficiency and sustainable green building performance. This finding is expected but should not be interpreted narrowly. Efficient buildings can reduce operational energy demand and emissions while supporting lower operating costs, resilience, regulatory compliance, and asset credibility. Data-driven monitoring, predictive analytics, and occupant-centric controls can help maintain performance after handover (Amasyali & El-Gohary, 2018; Kong et al., 2022; Wei et al., 2018). As operational emissions decline, whole-life assessment becomes increasingly important because embodied impacts account for a larger share of total carbon (De Wolf et al., 2017; Pan & Teng, 2021; World Green Building Council, 2019).

The positive association does not imply that every energy-saving action improves sustainability. Poorly designed strategies may compromise ventilation, comfort, usability, or control. The result is best understood as an association involving integrated energy-efficiency delivery measured through coordinated design, commissioning, monitoring, and correction. This interpretation is consistent with socio-technical research that treats occupants and operators as active components of performance rather than uncontrollable external disturbances (D'Oca et al., 2018; Hong et al., 2017).

8.4 Discussion of H4

H4 yielded a significant specific indirect effect through energy efficiency, consistent with complementary partial mediation between construction organization optimization and sustainable performance. This is the principal theoretical contribution of the model. The indirect pathway explains how organizational practices may be associated with the conditions under which energy targets are maintained across design changes, procurement, installation, controls programming, testing, handover, and operation. The mediated component is almost as large as the direct component, indicating that energy-efficiency delivery is a central but not exclusive pathway. Because the data are cross-sectional, this indirect effect should not be interpreted as proof of temporal or causal mediation.

The indirect association links capability theory to the building performance gap. Dynamic capabilities generate value when they reconfigure resources and routines to support operational capabilities (Teece, 2018). In the tested model, construction organization optimization represents the higher-order coordination capability and energy efficiency represents the intermediate delivery capability. The pattern also supports integrated BIM-lean-sustainability frameworks, which argue that digital information and reliable production are linked with environmental benefits through better decisions and reduced process loss (Mellado & Lou, 2020; Sepasgozar et al., 2021). Additional serial mediators, such as commissioning maturity, digital information quality, or supply-chain integration, require longitudinal or otherwise temporally ordered evaluation.

8.5 Discussion of H5

H5 indicated a positive moderating role for environmental well-being orientation. The simple slopes show that the energy-efficiency-to-performance association is more than twice as strong at high rather than low levels of well-being orientation. The pattern supports the argument that green buildings should optimize energy and human outcomes jointly. Research linking ventilation and pollutant exposure with cognitive function, and green-certified environments with health and performance, provides a basis for this complementarity (Allen et al., 2016; Cedeño-Laurent et al., 2018; MacNaughton et al., 2017). Post-occupancy studies also show that occupant satisfaction is multidimensional and may vary even among certified buildings (Graham et al., 2021; Ildiri et al., 2022; Licina & Yildirim, 2021).

A well-being orientation can shape decisions throughout the project by directing attention to ventilation, air quality, thermal comfort, acoustics, lighting, material emissions, biophilia, accessibility, perceived control, and post-occupancy feedback. These practices may reduce the risk that occupants counteract energy strategies through overrides, supplementary equipment, or space avoidance. The positive interaction is therefore interpreted as a strategic complementarity between energy-efficiency delivery and occupant-centered environmental priorities rather than as evidence of a universal causal effect.

9. Conclusion

This study indicates that sustainable green building performance is associated with the design of the construction organization as well as with the selection of green technologies. Construction organization optimization integrates decision rights, collaborative planning, digital information, lean workflow, supply-chain coordination, commissioning, and continuous learning. The empirical results show positive direct and indirect associations, with energy efficiency serving as the indirect pathway examined in the model. The energy-efficiency-to-performance association is also stronger when environmental well-being is embedded in project priorities and operational feedback.

The model advances green construction research in three ways. First, it establishes construction organization optimization as an integrative construct rather than treating BIM, lean methods, sustainability governance, logistics, or commissioning as isolated practices. Second, it positions energy efficiency as an indirect pathway linking organization optimization with building performance. Third, it identifies environmental well-being orientation as a moderator of the relationship between technical efficiency and wider health, comfort, satisfaction, and asset value. Together, these contributions frame the green building as a socio-technical and organizational system.

The findings provide empirical support for the tested model within the observed sample of construction professionals. Because the evidence is cross-sectional and perception-based, the results are interpreted as theory-consistent associations rather than causal estimates or universal industry benchmarks.

10. Implications of the Study

The theoretical implication is that sustainable project capability should be analyzed as a configuration. Resource-based and dynamic-capability perspectives often emphasize valuable organizational routines, while socio-technical building research emphasizes interactions among systems, controls, and users. The model connects these levels. Organization optimization is the upstream capability, energy efficiency is a technical-operational mechanism, and environmental well-being orientation is a boundary condition associated with variation in realized value. This structure can be extended to embodied carbon, circular procurement, water performance, climate resilience, and digital-twin-enabled operations.

For owners, the results imply that sustainability governance should begin with delivery architecture. Project briefs and contracts should assign target ownership, require cross-disciplinary reviews, connect energy and carbon models with cost and schedule decisions, protect commissioning resources, and define post-occupancy responsibilities. Selecting a certification target without redesigning decision processes is unlikely to eliminate fragmentation. Owners should also require transparent evidence at stage gates rather than relying on end-of-project documentation.

For designers and contractors, organization optimization means integrating BIM, lean planning, procurement, logistics, quality control, and commissioning around shared performance indicators. Energy models should be living decision tools, not compliance documents produced at isolated stages. Energy-critical interfaces—envelope continuity, plant sizing, controls, sensor placement, air balancing, metering, and operator training—should be included in constraint logs, inspection plans, and handover readiness reviews. Digital twins and analytics are most valuable when data ownership, update responsibilities, and operational use cases are defined (Boje et al., 2020; Pan & Zhang, 2021).

For policymakers and rating-system developers, the findings suggest greater emphasis on process assurance and measured outcomes. Credit systems can reward integrated design, embodied-carbon disclosure, commissioning quality, metering, post-occupancy evaluation, and corrective action. Comparable rating tools already contain many relevant criteria, but the weighting and verification of operational and human outcomes remain uneven (Awadh, 2017; Doan et al., 2017; Mattoni et al., 2018). Procurement policy can also support early contractor involvement, performance-based specifications, low-carbon materials, and life-cycle value rather than lowest initial cost.

For facility managers and occupants, environmental well-being should be part of energy management. Dashboards and fault detection should be accompanied by comfort, air-quality, and user-feedback data. Operators need training, authority, and resources to tune systems rather than merely maintain design setpoints. Post-occupancy evaluation should feed both the current building and the next project, creating an organizational learning loop. This approach helps avoid false choices between energy conservation and occupant experience.

11. Limitations and Future Research Directions

The first limitation is the cross-sectional design. Data collected at one point in time do not establish temporal ordering or causality, including for the specific indirect effect. Longitudinal, time-lagged, experimental, or quasi-experimental designs are needed to evaluate temporal mechanisms more directly.

A second limitation is the single-respondent, perception-based measurement approach. Assessments of organizational practices and project outcomes may be influenced by the same respondent and may not fully correspond to objective project records. Future research should combine multiple informants from the same project with objective indicators such as energy-use intensity, commissioning completion, certification scores, embodied-carbon estimates, waste diversion, defect rates, and occupant surveys.

Third, the observed relationships may differ across procurement systems, countries, climates, project types, and organizational sizes. Design-build, integrated project delivery, public-private partnerships, and traditional design-bid-build arrangements distribute authority and risk differently. Multi-group analysis and measurement-invariance testing can compare these contexts.

Healthcare, residential, industrial, education, and commercial buildings may also place different weights on energy, infection control, comfort, process loads, or adaptability.

Fourth, environmental well-being is intentionally broad. Further research can disaggregate indoor air quality, thermal comfort, lighting, acoustics, biophilia, accessibility, and perceived control to identify which dimensions most strongly complement energy efficiency. Objective sensing and experience-sampling methods can connect time-varying environmental conditions with occupant responses. Research should also examine equity because a building can have a favorable average condition while exposing particular zones, shifts, or user groups to poorer environments.

Finally, additional mechanisms deserve testing. Commissioning maturity, digital information quality, psychological safety, sustainability leadership, supplier capability, and facility-management involvement may mediate or moderate the organizational association. Circular procurement and embodied-carbon management could be modeled as parallel mediators to energy efficiency. Qualitative comparative analysis may reveal that different bundles of practices are associated with high performance rather than one universal configuration. These extensions would move the field from lists of green practices toward stronger explanations of how project organizations are linked with low-carbon, healthy, and resilient buildings.

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Appendix A: Questionnaire Items

Respondents should answer with reference to one focal green building project. Unless otherwise noted, use 1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, and 5 = strongly agree.

Table 10. **Questionnaire Measurement Items**

Code	*Measurement item*
COO1	Sustainability responsibilities and decision rights are clearly assigned across project organizations.
COO2	Design, procurement, construction, commissioning, and facilities teams plan work collaboratively.
COO3	BIM or common-data-environment information is integrated with sustainability, cost, schedule, and quality decisions.
COO4	Lean planning and constraint-removal routines are used to stabilize workflows and prevent rework.
COO5	Logistics, suppliers, prefabrication, and material flows are optimized for resource efficiency.
COO6	Energy, carbon, waste, quality, and well-being indicators are reviewed and used for continuous improvement.
EE1	Energy simulation is updated and used at major design and procurement decision points.
EE2	Envelope, HVAC, lighting, and control systems are coordinated to reduce whole-building energy demand.
EE3	Commissioning, functional testing, submetering, and verification are implemented effectively.
EE4	Energy targets are tracked from concept design through construction, handover, and operation.
EE5	Site and operational energy waste is identified and reduced through monitoring and corrective action.

Code	*Measurement item*
EWO1	Indoor air quality and occupant health are treated as core project performance requirements.
EWO2	Thermal, acoustic, lighting, and visual comfort are integrated into design and commissioning decisions.
EWO3	Low-emitting, non-hazardous, and responsibly sourced materials are specified and verified.
EWO4	Biophilic, restorative, accessible, and inclusive environmental features are incorporated where relevant.
EWO5	Occupant feedback and post-occupancy evaluation are used to improve building operation and future projects.
SGBP1	The building achieves lower operational energy use and carbon emissions than conventional alternatives.
SGBP2	Embodied carbon, material consumption, waste, and water impacts are reduced across the life cycle.
SGBP3	Green certification and regulatory performance targets are achieved with reliable evidence.
SGBP4	Sustainability requirements are delivered without unacceptable cost, schedule, or quality deterioration.
SGBP5	Occupants experience satisfactory health, comfort, functionality, and environmental quality.
SGBP6	The building creates strong long-term asset value, resilience, and stakeholder confidence.