

Smart Building Energy Optimization and Green Corporate Strategy: A Structural Equation Modeling Approach

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ABSTRACT

Buildings occupy a strategically important position in corporate sustainability because their energy demand affects operating expenditure, greenhouse-gas emissions, employee experience, asset value, and stakeholder perceptions. Yet smart-building investments are frequently evaluated as technical projects rather than as organizational capabilities embedded in corporate strategy. This article develops a strategy-oriented structural equation modeling (SEM) framework to explain how smart building energy optimization can contribute to green corporate strategy and competitive advantage. Drawing on the resource-based view, dynamic capabilities theory, stakeholder theory, and the natural-resource-based view, the framework connects top-management commitment, digital and energy-management capability, stakeholder pressure, and organizational readiness to smart building energy optimization. It then models energy optimization as a pathway to environmental performance, operational efficiency, green reputation, and sustainable competitive advantage. The framework also considers green strategic integration as a mediator and organizational digital maturity and building-use intensity as potential boundary conditions. An explanatory, cross-sectional survey design is proposed, with building and sustainability managers in commercial, institutional, hospitality, and industrial organizations as the target respondents. The article specifies constructs, measurement principles, hypotheses, and a rigorous SEM analysis protocol without presenting uncollected data as empirical findings. The central argument is that smart-building technologies create strategic value only when data, operational routines, employee practices, and investment decisions are integrated into a coherent sustainability strategy. The contribution is a testable model that bridges building-energy research and strategic-management scholarship while identifying governance, rebound, interoperability, and measurement challenges that can weaken the expected benefits.

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1. INTRODUCTION

Energy use in buildings is both an engineering concern and a strategic management issue. Heating, cooling, ventilation, lighting, plug loads, lifts, and building services consume energy throughout the operating life of commercial and institutional assets. Decisions about these systems influence recurrent expenditure and the environmental footprint associated with electricity and fuel use. The building sector therefore sits at the intersection of climate mitigation, infrastructure investment, workplace quality, and corporate risk management. The International Energy Agency continues to identify buildings and construction as central to global energy and emissions transitions, while international assessments emphasize that operational performance must improve alongside the decarbonization of electricity and construction materials (Fang, 2025; IEA, 2023; UNEP & GlobalABC, 2023, 2024). For organizations, this means that building energy management cannot be isolated from broader decisions about capital allocation, procurement, service delivery, and sustainability disclosure.

Smart buildings use connected sensors, building management systems, analytics, automation, and sometimes artificial intelligence to observe and adjust building operations. Their potential value is not simply that they collect more data. Rather, they can connect operational conditions to decisions: cooling can be matched more closely to occupancy, faults can be detected before they waste energy, equipment schedules can be revised using actual demand, and facility managers can compare performance across sites. Recent

reviews describe a rapidly expanding technical landscape involving Internet of Things (IoT) devices, machine learning, digital twins, predictive control, and integrated building-management platforms (Hafez et al., 2023; Rodríguez-Gracia et al., 2023; Taboada-Orozco et al., 2024; Poyyamozihi et al., 2024). However, the existence of a technology does not guarantee that an organization will use it effectively. Sensor data may be incomplete, legacy systems may not communicate, and managers may lack the authority or incentives to act on recommendations.

This gap between technical potential and organizational realization is consequential for strategy. A building-energy project may deliver measurable utility savings while remaining disconnected from corporate planning, supplier decisions, employee engagement, or external reporting. Conversely, a company may communicate a green-building ambition without changing operating routines or investing in monitoring and verification. The strategic question is therefore not only whether smart-building technologies can reduce energy consumption, but under what organizational conditions their deployment improves environmental and business performance and becomes difficult for competitors to imitate. The distinction matters because competitive advantage arises from the deployment of resources and capabilities in ways that create value, not from the mere possession of widely available equipment or software (Barney, 1991; Teece, 2023).

Research on smart buildings has developed extensively in engineering and computer science, with particular attention to energy forecasting, automated control, fault detection, comfort, and interoperability. In parallel, management research has examined green innovation, environmental capabilities, stakeholder pressure, and sustainable competitive advantage. These streams are related but not always integrated. Building technology studies can understate governance and strategic alignment, while corporate sustainability studies may treat building energy as a generic environmental practice rather than a measurable operational capability. Reviews of data-driven building management and digitalization highlight technical opportunities and persistent implementation challenges, but leave room for an organization-level explanation of how energy optimization becomes strategic value (Asif et al., 2024; Hernández et al., 2024; Taboada-Orozco et al., 2024).

The article addresses three connected research gaps. First, the antecedents of smart-building energy optimization are often discussed as separate technical, financial, or institutional factors, rather than as a coordinated capability system. Second, the mechanisms connecting energy optimization to corporate advantage require clearer theoretical specification: lower energy use may improve costs and emissions, but reputation, resilience, learning, and differentiation depend on how outcomes are measured and strategically used. Third, studies that discuss the value of smart and green buildings do not always distinguish the operational effect of optimization from the broader organizational integration needed to sustain that effect. A strategy-oriented SEM model can test these links simultaneously, including indirect effects and contextual boundary conditions.

The purpose of this article is to develop a theory-grounded, empirically testable framework for explaining the antecedents and consequences of smart building energy optimization. Four research questions guide the analysis: (1) Which organizational and external factors are likely to enable smart-building energy optimization? (2) Through which operational and strategic mechanisms can energy optimization influence environmental performance and competitive advantage? (3) Does green strategic integration mediate the relationship between optimization and sustainable competitive advantage? (4) Under what conditions might technology maturity, organizational readiness, or building-use intensity strengthen or weaken these relationships? The article contributes by integrating building-energy capabilities with resource-based and dynamic-capability perspectives, translating the framework into hypotheses and construct definitions, and proposing an SEM protocol that can be used in a future field study.

The article is organized as follows. The literature review develops the theoretical foundation and synthesizes recent research on smart buildings, green strategy, and performance. The methodology section presents a proposed explanatory survey design and explains the measurement and analysis procedures. The results and discussion section reports the conceptual synthesis and model propositions, rather than fabricated statistical findings. The final section outlines theoretical implications, managerial recommendations, limitations, and priorities for empirical validation.

2. LITERATURE REVIEW

2.1 Smart building energy optimization as an organizational capability

A smart building can be understood as a physical asset whose operating systems are digitally connected and capable of adapting to conditions, objectives, or user requirements. In practice, smartness exists on a continuum. At the lower end, a building may have digital meters and scheduled controls; at the higher end, it may integrate occupancy sensing, weather forecasts, predictive maintenance, renewable generation, storage, demand response, and automated optimization. A building should not be classified as strategically intelligent simply because it contains sensors. The relevant question is whether information is translated into reliable operational decisions and whether the organization learns from the consequences of those decisions.

Recent reviews show that building energy optimization is supported by multiple complementary technologies. IoT sensors enable granular monitoring of temperature, occupancy, equipment status, and electricity consumption. Machine-learning models can forecast demand or identify anomalous patterns, while model predictive control can select operating actions based on predicted future conditions and constraints. Building information modelling, digital twins, and integrated management systems can improve coordination across equipment, design information, and maintenance routines (Hafez et al., 2023; Huotari et al., 2024; Itanola & Whang, 2024; Taboada-Orozco et al., 2024). The value of these technologies depends on context: a complex office tower with variable occupancy has different optimization opportunities from a small retail outlet with fixed opening hours.

Energy optimization is broader than energy conservation. Conservation may involve switching off equipment or reducing operating hours. Optimization seeks to provide the required service—thermal comfort, lighting, ventilation, and productive use of space—with lower energy input, lower emissions, or lower cost. A useful system must therefore balance several objectives. Aggressive reductions in cooling may reduce electricity use but worsen indoor comfort or productivity; ventilation changes can affect indoor air quality; and automation that ignores user behavior can be overridden. Critical reviews of building automation stress the need to balance energy, comfort, adaptability, and control quality rather than maximize one metric in isolation (Building automation systems for energy and comfort management in green buildings, 2023; Hernández et al., 2024).

From a management perspective, energy optimization is best treated as a capability rather than as a hardware inventory. A capability combines technology, human expertise, data governance, maintenance routines, decision rights, and performance feedback. It becomes valuable when an organization can consistently diagnose inefficiencies, select appropriate interventions, implement them, and verify results. This capability view also explains why identical building-management platforms can produce different outcomes across organizations. Differences in managerial attention, workforce competence, procurement, and learning may matter as much as the technology itself.

2.2 The resource-based view and the natural-resource-based view

The resource-based view (RBV) explains performance differences through resources and capabilities that are valuable and difficult to reproduce in combination. A generic building management platform is usually purchasable by competitors, so possession alone is unlikely to provide durable advantage. However, a firm's accumulated operational data, skilled facility teams, supplier relationships, energy-management routines, and ability to embed optimization into capital budgeting may be more distinctive. The strategic asset is not the sensor; it is the organizational system that repeatedly turns sensor information into better decisions, consistent with evidence that green practices create competitive value mainly when combined with organizational capabilities (Phattanaviroj & Pattaradej, 2025).

The natural-resource-based view extends this logic by treating environmental capabilities as potential sources of strategic value. Pollution prevention, product stewardship, and sustainable development require organizations to redesign how they use resources and manage external impacts. In a building context, energy optimization can function as a pollution-prevention capability when it reduces avoidable consumption while maintaining service quality. It may also support stakeholder-facing differentiation when verified performance is relevant to tenants, investors, customers, regulators, and employees. Yet an environmental capability creates advantage only when it is operationally credible and aligned with the organization's

market and cost position. A firm that overinvests in sophisticated controls without a clear operating case may incur cost without generating corresponding strategic benefits.

The RBV also raises an important caution. If energy savings are achieved through a widely available technical solution, competitors can imitate the intervention, and energy savings may be competed away through lower prices or higher service expectations. More defensible value can emerge from complementary capabilities: integration with maintenance planning, building-portfolio benchmarking, employee engagement, carbon accounting, and green procurement. Such complements can make performance improvements more persistent and help translate technical efficiency into organizational learning. This is the logic underlying the proposed links from smart building energy optimization to green strategic integration and, subsequently, to sustainable competitive advantage.

2.3 Dynamic capabilities and organizational adaptation

Dynamic capabilities theory focuses on how organizations sense changes, seize opportunities, and transform assets and routines. Building energy management is inherently dynamic because demand is influenced by weather, occupancy, operating schedules, equipment degradation, energy prices, and grid conditions. A static energy audit may identify a baseline, but sustained performance requires repeated sensing and adjustment. Digital monitoring can support sensing; investment decisions and experimentation can support seizing; and revised workflows, maintenance routines, and staff responsibilities can support transformation (Teece, 2023).

A smart building can therefore be viewed as an operational setting in which dynamic capabilities become observable. For example, an anomaly-detection system may identify that cooling energy rises during periods of low occupancy. The organization must interpret the signal, establish whether the cause is equipment malfunction or control logic, authorize corrective action, and determine whether the intervention should be replicated across other properties. The full cycle includes technical detection and organizational response. If the organization lacks clear accountability or does not review performance after implementation, the sensing function may not translate into improvement.

Dynamic capabilities also explain why optimization should not be reduced to one-time installation. Building systems evolve, tenants change, equipment ages, and business requirements shift. Continuous commissioning, predictive maintenance, and periodic recalibration are therefore strategic routines rather than optional technical extras. The theory predicts that organizational learning and green strategic integration will strengthen the relationship between optimization and competitive outcomes, because they enable the firm to adapt and capture value from operational improvements.

2.4 Stakeholder theory and institutional pressures

Stakeholder theory suggests that organizations must manage relationships with groups that affect or are affected by corporate decisions. In building operations, stakeholders include employees, tenants, customers, property owners, investors, lenders, insurers, utilities, regulators, and local communities. Their expectations can influence the adoption of energy-efficient practices, disclosure quality, and the perceived legitimacy of environmental commitments. A tenant may prefer a building with lower operating costs and credible environmental performance; investors may seek lower transition risk; and employees may expect the workplace to reflect the organization's stated sustainability values.

Institutional pressures also matter. Regulation can establish minimum standards for building performance and disclosure, while professional norms and market expectations can encourage voluntary investment. However, compliance pressure and strategic motivation should be distinguished. An organization may adopt monitoring solely to satisfy a regulation, without using the information to redesign operations. Alternatively, managers may treat external expectations as a signal of future market direction and invest early in capabilities that support innovation. Stakeholder pressure is therefore expected to influence optimization adoption, but its effect on competitive advantage may depend on whether the firm moves beyond symbolic compliance.

Greenwashing risk is particularly relevant. Digital dashboards and certifications can make sustainability claims more visible, but visibility is not the same as verified performance. Organizations need credible

baselines, consistent measurement boundaries, and transparent explanations of changes in occupancy, weather, floor area, or service levels. Where stakeholders are skeptical of environmental claims, the reputational benefit of smart-building investment will depend on the quality of evidence and the consistency between reported and actual operating practices.

2.5 Green corporate strategy and environmental performance

Green corporate strategy refers to the integration of environmental objectives into strategic planning, investment decisions, operations, governance, and performance evaluation. It differs from a collection of isolated environmental initiatives because it links sustainability objectives to resource allocation and organizational accountability. For smart-building energy optimization, strategic integration may be visible when energy performance targets are included in capital expenditure decisions, facility-manager evaluations, procurement specifications, and corporate emissions plans.

Environmental performance should be measured separately from the existence of a strategy. A policy statement does not necessarily reduce emissions. Relevant outcomes include normalized energy consumption, operational greenhouse-gas emissions, peak-demand reduction, equipment efficiency, waste heat or resource losses where measurable, and progress against credible targets. Normalization is important because a building may consume more energy after extending operating hours or increasing occupancy even if its controls improve efficiency. Absolute consumption and energy intensity should therefore be considered together.

The strategic consequences of environmental performance are not automatic. Lower energy use can reduce costs, while verified emissions reductions can improve stakeholder trust and support access to environmentally sensitive customers or capital. Yet the magnitude of these benefits depends on energy prices, lease structures, carbon intensity, building ownership, and market expectations. In some cases, owners pay for equipment while tenants receive the utility savings; in others, the tenant controls operations but cannot approve capital investment. These split incentives can weaken the link between optimization and corporate outcomes. A credible model must therefore recognize that performance is shaped by governance and contractual arrangements, not solely by technology.

2.6 Operational efficiency and sustainable competitive advantage

Operational efficiency includes the ability to deliver required building services with fewer resources, lower avoidable costs, and less operational disruption. Energy optimization may contribute through reduced utility expenditure, better equipment scheduling, early fault detection, fewer emergency repairs, and more informed capital planning. These benefits can release resources for core activities and improve the reliability of the workplace or service environment. However, savings should be calculated net of implementation, integration, training, cybersecurity, maintenance, and software costs. Gross energy savings can overstate economic value if the total cost of ownership is ignored; cost-benefit evidence on renewable-energy adoption among Indonesian SMEs similarly shows that attractive operating savings can be offset by financing, regulatory, and incentive-access barriers (Phan, 2025).

Sustainable competitive advantage is a more demanding construct than short-term cost reduction. It concerns the firm's ability to create value relative to competitors over time. In the proposed model, competitive advantage may appear through a combination of cost position, credible environmental differentiation, resilience to energy-price volatility, asset attractiveness, and improved stakeholder relationships. These outcomes should not be collapsed into a single unexamined claim. A building's energy efficiency may reduce costs, but the resulting advantage may be small if energy represents a minor share of total expenditure or if competitors can replicate the practice rapidly.

Green reputation can mediate or complement operational benefits. Stakeholders may reward firms that demonstrate credible environmental performance, but reputation depends on visibility, trust, and relevance to the stakeholder's decision. In a business-to-business market, energy performance may affect tenant selection, supplier evaluation, or investor assessment. In other markets, it may matter primarily through compliance and cost. Thus, the model treats sustainable competitive advantage as an organizational outcome shaped by operational efficiency and environmental performance, with green strategic integration helping the firm capture and communicate value.

2.7 Recent evidence on smart and green buildings

Recent building-energy reviews converge on several themes. First, data-driven building management is moving from reactive monitoring toward predictive and adaptive operation. Second, the strongest solutions often integrate sensors, control systems, analytics, and building-management processes rather than deploy a single technology in isolation. Third, practical barriers include data quality, interoperability, legacy infrastructure, cybersecurity, uncertain returns, and skills gaps (Asif et al., 2024; Hernández et al., 2024; Poyyamozhi et al., 2024; Taboada-Orozco et al., 2024). These observations support a capability-based interpretation but do not by themselves establish organization-level causal relationships.

The research on artificial intelligence in green and smart buildings also indicates that environmental, economic, and social outcomes can be interdependent. AI-based systems can support prediction and control, but their benefits depend on suitable data and system design. Models trained on historical patterns may perform poorly when occupancy or weather conditions change, and automated control may optimize a proxy that does not fully represent organizational priorities (Rodríguez-Gracia et al., 2023; Huotari et al., 2024). This reinforces the need to examine management support and strategic integration alongside technological capability.

The literature on energy efficiency in sustainable buildings further highlights that technical efficiency is influenced by user behavior, commissioning, maintenance, and the relationship between intended design and actual operation (Hafez et al., 2023). A high-performance design can underperform if systems are poorly commissioned or occupants routinely override controls. Conversely, modest technologies can deliver meaningful savings when paired with disciplined operating practices. These insights motivate the inclusion of organizational readiness and stakeholder engagement as antecedents rather than treating them as peripheral implementation concerns.

2.8 Research gap and conceptual positioning

The reviewed literature provides strong evidence that smart-building technologies can enable more sophisticated energy management, but it leaves three gaps for strategic-management research. The first is an integration gap: technology, managerial support, stakeholder pressure, and organizational readiness are frequently examined in separate discussions. The second is a mechanism gap: efficiency, environmental performance, green reputation, and competitive advantage are often discussed as if one automatically produces the next, although the conversion process depends on strategic routines and measurement credibility. The third is a boundary-condition gap: digital maturity, building complexity, ownership arrangements, and usage intensity can change the economic and environmental returns from optimization.

This article responds by specifying a structural model that distinguishes antecedents, optimization capability, strategic integration, and outcomes. The proposed model is not intended to replace engineering evaluations of specific control algorithms. Instead, it complements them by explaining why technically similar projects can have different organizational outcomes. It also avoids assuming that technology adoption is inherently green. A system may consume energy itself, increase equipment complexity, or encourage additional services that offset some savings. The relevant construct is effective optimization, assessed in terms of service-adjusted energy performance and credible environmental outcomes rather than installation counts alone.

3. METHOD

A quantitative, explanatory research design is proposed to test the relationships among organizational antecedents, smart building energy optimization, environmental performance, operational efficiency, green strategic integration, and sustainable competitive advantage. A survey-based design is appropriate because several constructs—such as management commitment, organizational readiness, and strategic integration—are latent organizational attributes that cannot be observed directly through utility records alone. The design should, however, combine managerial assessments with objective building data wherever feasible. A multi-source design can reduce common-method bias and strengthen the credibility of performance measures.

The unit of analysis is the organization or a clearly defined building-management unit. The preferred respondent is a manager who has sufficient knowledge of building operations and corporate sustainability,

such as a facility manager, energy manager, sustainability manager, property manager, operations director, or senior administrator. Where the organization operates multiple buildings, respondents should answer with reference to a specified building portfolio or site. Mixing site-level and organization-level answers without clear instructions would create a level-of-analysis problem. The survey should therefore define the focal unit at the outset and collect relevant building characteristics separately.

The proposed study is cross-sectional for feasibility, but a time-lagged design would be preferable if resources permit. For example, antecedents could be measured at Time 1, optimization practices at Time 2, and performance outcomes at Time 3. Alternatively, survey responses could be matched to twelve months of energy records before and after a defined intervention. A longitudinal design would improve temporal inference and reduce the risk that respondents retrospectively attribute good performance to the technologies they support. Cross-sectional SEM can estimate associations and indirect effects, but it cannot by itself prove causality.

3.1 Population, sampling, and sample size

The target population consists of organizations operating or managing smart or partially digitized buildings in sectors where building energy is material: commercial real estate, offices, hospitality, healthcare, education, retail, logistics, and selected industrial facilities. Inclusion criteria should require that the organization has at least basic building-energy monitoring or a defined optimization initiative. Including completely non-digital buildings could be useful for an adoption study, but it would complicate the measurement of optimization capability. For the present model, the sample should contain variation in optimization maturity rather than only advanced adopters.

A purposive sampling strategy can identify organizations with relevant building-management responsibilities, followed by stratification by sector, ownership arrangement, building size, and region where feasible. Professional associations, property-management networks, green-building councils, energy-service companies, and facility-management organizations can provide sampling frames. Researchers should record response rates and compare early and late respondents where possible. If multiple respondents are recruited from the same organization, responses should not be treated as independent without accounting for clustering or aggregating them using a justified procedure.

Sample size should be determined through an a priori power analysis based on the smallest substantively meaningful effect, the number of predictors, the expected reliability of measures, and the planned estimation method. A fixed rule such as “ten respondents per item” is insufficient. For covariance-based SEM, the study should seek a sample large enough for stable estimation of the measurement and structural models, including indirect effects and interactions. In many organizational settings, a target in the several-hundred range may be desirable, but the final target must be justified by the model's complexity, anticipated missingness, and power analysis rather than presented as a universal minimum.

3.2 Construct operationalization

All latent constructs should be measured using multiple items adapted from established research where suitable and refined through expert review and pilot testing. The instrument should distinguish perceptions of capability from perceived outcomes. For example, the energy-optimization scale should capture the extent to which the organization uses monitoring, automated control, forecasting, fault detection, and systematic tuning. It should not simply ask whether the building has sensors. Environmental performance items should refer to observed or documented improvement, while competitive advantage items should focus on relative value, differentiation, and resilience rather than general organizational success.

Top-management commitment can be measured through leadership attention to energy objectives, resource allocation, executive review, and accountability. Digital and energy-management capability can capture data integration, analytic competence, system reliability, fault diagnosis, and continuous commissioning. Stakeholder pressure can measure perceived regulatory, tenant, customer, investor, and professional expectations. Organizational readiness can include staff skills, clarity of responsibilities, training, and willingness to modify routines. Smart building energy optimization can assess integrated monitoring, automated or data-informed control, predictive maintenance, demand adjustment, and systematic evaluation of energy interventions.

Environmental performance should ideally combine survey items with normalized objective indicators. Examples include energy-use intensity, operational emissions intensity, peak demand, and progress toward documented energy targets. Energy-use intensity should be calculated using a clear denominator, such as floor area or operating hours, and the study should explain how weather and occupancy are handled. Operational efficiency can include net energy-cost performance, equipment reliability, maintenance efficiency, and resource use per unit of service. Green strategic integration can assess whether building energy metrics influence budgeting, procurement, capital planning, executive review, and sustainability reporting. Sustainable competitive advantage can be operationalized through perceived relative cost position, attractiveness to tenants or customers, credible differentiation, resilience to energy-market volatility, and the ability to sustain performance over time.

A five- or seven-point Likert scale may be used for perception-based items, with consistent anchors and clear reference periods. Respondents should be instructed to assess actual practices over a defined period, such as the preceding twelve months. Objective indicators should be requested separately and only where organizations can provide them. The instrument should avoid double-barrelled items, vague terms such as “highly sustainable,” and items that combine energy savings with reputation in the same statement. Translation and back-translation may be needed for multi-language samples, followed by cognitive interviews to verify that terms such as “optimization,” “green strategy,” and “competitive advantage” are interpreted consistently.

3.3 Content validity and pilot testing

The instrument should undergo expert review involving building-energy specialists, sustainability managers, and researchers familiar with organizational strategy and SEM. Experts should assess item relevance, construct coverage, ambiguity, and the risk of overlap among constructs. A small pilot study can evaluate completion time, missing responses, item distributions, and whether respondents can reliably answer questions about building operations. Cognitive interviews are especially useful for distinguishing system availability from system use and actual outcomes from expectations.

The pilot should also examine whether the items are appropriate across different building types. For example, an occupancy-based control item may be highly relevant to offices and hotels but less meaningful for a continuously operating healthcare facility. The solution is not necessarily to remove context-specific practices; instead, researchers can distinguish common core indicators from sector-specific modules and test measurement invariance before comparing sectors. Any item changes following the pilot should be documented transparently.

3.4 SEM estimation strategy

The choice between covariance-based SEM (CB-SEM) and partial least squares SEM (PLS-SEM) should follow the research objective rather than software preference. CB-SEM is suitable when the purpose is theory testing, assessment of global model fit, and estimation of a prespecified covariance structure. PLS-SEM may be appropriate when prediction is central, the model includes formative composites, or the study is explicitly exploratory and prediction-oriented. Because this article develops a theory-based model with latent constructs and directional hypotheses, CB-SEM is a defensible primary choice if distributional assumptions and sample size are adequate. Robust maximum likelihood or another estimator appropriate to the data should be selected after assessing item scale and distribution.

The analysis should proceed in stages. First, inspect missingness, outliers, response patterns, descriptive statistics, and possible non-response bias. Missing data should be handled using a defensible method, such as full-information maximum likelihood or multiple imputation where assumptions are plausible, rather than indiscriminate mean substitution. Second, assess the measurement model through standardized factor loadings, construct reliability, convergent validity, and discriminant validity. Composite reliability and average variance extracted may be reported alongside coefficient omega or other appropriate reliability indicators. Discriminant validity should be examined using multiple diagnostics, including the heterotrait-monotrait ratio where suitable, while recognizing that no single threshold replaces substantive assessment.

Third, estimate the structural model and report standardized path coefficients, standard errors, confidence intervals, p-values, explained variance, and effect sizes. Overall model fit for CB-SEM can be

evaluated using a set of indices, such as chi-square relative to degrees of freedom, CFI, TLI, RMSEA with confidence interval, and SRMR. Fit indices should be interpreted jointly and in relation to model complexity; they should not be used as mechanical pass/fail rules. Indirect effects should be assessed with bootstrapped confidence intervals or an appropriate distribution-of-products approach. Moderation hypotheses should be tested with latent interaction methods or carefully justified composite interactions, and simple slopes should be interpreted at meaningful values of the moderator.

3.5 Common-method bias and endogeneity

Because several constructs may be measured from the same respondent, common-method bias is a concern. Procedural remedies should be used before statistical tests: assure respondents of confidentiality, separate predictor and outcome sections, vary item wording where appropriate, use objective indicators for performance when available, and avoid leading language. A single-factor test alone is not sufficient evidence that common-method bias is absent. Researchers may compare a theoretically specified measurement model with plausible method-factor alternatives and report the limitations of the chosen diagnostics.

Endogeneity is also possible. Better-performing firms may be more likely to invest in smart-building technologies, meaning that the relationship could run in both directions. Unobserved factors such as management quality, building age, energy prices, and access to capital may influence both optimization and outcomes. The study should include theoretically justified controls, such as building size, age, sector, ownership or lease structure, energy price exposure, occupancy, climate zone, and organizational size. Where data permit, a longitudinal design, instrumental-variable approach, natural experiment, or difference-in-differences design may strengthen causal inference. Controls should not be added indiscriminately; each should have a clear causal rationale.

3.6 Hypothesis development

The model is grounded in complementarity. Top-management commitment provides legitimacy and resources; digital and energy-management capability enables the organization to interpret and act on information; stakeholder pressure shapes priorities; and organizational readiness supports adoption and routine change. These antecedents are related but conceptually distinct. Management commitment concerns leadership attention and resource allocation, while organizational readiness concerns the availability of skills, processes, and change capacity. Digital and energy-management capability concerns the firm's ability to collect, interpret, and use operational information. Stakeholder pressure captures external expectations and demands.

3.6.1 Top-management commitment

Top-management commitment is expected to be a key antecedent because building optimization often requires cross-functional investment and changes in established routines. Senior leaders can connect facilities management with finance, sustainability, information technology, procurement, and human resources. They can also set measurable targets, approve long-term investment, and ensure that managers are not penalized for short-term costs that generate longer-term benefits. Without this support, energy optimization may remain a pilot project that lacks the authority to change operating practices.

H1: *Top-management commitment is positively associated with smart building energy optimization.*

3.6.2 Digital and energy-management capability

Digital and energy-management capability refers to the organization's ability to integrate building data, assess system performance, identify opportunities, and implement corrective action. It includes technical competence, data quality practices, system integration, analytic interpretation, and continuous commissioning. Such capability can improve the accuracy of energy diagnosis and reduce the time between identifying a problem and implementing a response. It can also support comparison across multiple buildings and the transfer of lessons from one site to another.

H2: *Digital and energy-management capability is positively associated with smart building energy optimization.*

3.6.3 Stakeholder pressure

Stakeholder pressure includes regulatory requirements, tenant expectations, investor scrutiny, customer preferences, and professional norms that encourage more sustainable building operations. Such pressure may increase the perceived urgency of optimization and justify investment that would otherwise compete with other capital priorities. Its effect may be strongest when expectations are specific, observable, and connected to contractual or reputational consequences. Nevertheless, pressure may generate symbolic compliance if organizations focus on reporting rather than operational change; the proposed positive relationship should therefore be interpreted as an average expectation, not a universal law.

H3: *Stakeholder pressure is positively associated with smart building energy optimization.*

3.6.4 Organizational readiness

Organizational readiness includes the availability of relevant skills, change-management processes, clear responsibilities, and willingness to use digital recommendations. Readiness reduces implementation friction. Facility teams must understand the system, trust its outputs, and know when human intervention is required. Readiness also includes coordination across departments, since energy optimization can affect comfort, maintenance, security, and service delivery. When organizational readiness is low, advanced analytics may be installed but underused.

H4: *Organizational readiness is positively associated with smart building energy optimization.*

3.6.5 Smart building energy optimization and environmental performance

Effective optimization should improve environmental performance when it reduces energy input per unit of building service and when the energy source has a measurable emissions footprint. It can reduce unnecessary heating and cooling, improve equipment scheduling, identify faults, and support demand response. However, environmental performance should not be inferred from the presence of a digital platform. The effect must be demonstrated through normalized energy and emissions indicators, with adjustments for occupancy, weather, floor area, operating hours, and relevant service requirements.

H5: *Smart building energy optimization is positively associated with environmental performance.*

3.6.6 Smart building energy optimization and operational efficiency

Optimization can improve operational efficiency through lower utility expenditure, fewer avoidable maintenance events, improved scheduling, and better use of facility-management resources. Predictive approaches can identify deterioration before equipment fails, while integrated data can help managers prioritize maintenance and capital upgrades. These effects may be offset by software subscriptions, sensor replacement, integration work, and staff training. Accordingly, operational efficiency should be measured as a net operational outcome rather than simply as a reduction in electricity bills.

H6: *Smart building energy optimization is positively associated with operational efficiency.*

3.6.7 Environmental performance and green strategic integration

Green strategic integration refers to the extent to which environmental goals are embedded in corporate planning, budgeting, performance management, procurement, and disclosure. Better environmental performance can strengthen integration by providing credible evidence that sustainability objectives are achievable and measurable. It can also make energy management more relevant to senior decision-makers. The relationship may be reciprocal over time, because strategic integration can also drive environmental performance; the proposed cross-sectional design tests a directional theoretical association but cannot establish temporal precedence on its own.

H7: *Environmental performance is positively associated with green strategic integration.*

3.6.8 Operational efficiency and green strategic integration

Operational improvements can strengthen strategic integration when energy savings and reliability gains are visible to finance and operations leaders. Verified benefits can make sustainability less likely to be treated as a peripheral compliance function and more likely to be included in investment decisions. Yet operational efficiency alone may not produce a green strategy if savings are captured by one department and not

reinvested or incorporated into broader goals. The hypothesized link therefore depends on the organization recognizing operational performance as strategically relevant.

H8: *Operational efficiency is positively associated with green strategic integration.*

3.6.9 Green strategic integration and sustainable competitive advantage

Strategic integration can help organizations capture value from optimization by coordinating investments, embedding lessons in routines, and communicating credible performance to stakeholders. It may also reduce the risk that energy initiatives are abandoned when managers change or budgets tighten. Integrated environmental objectives can support differentiation, operational resilience, and stronger relationships with tenants, customers, and investors. However, the advantage is more likely to persist when environmental claims are credible and supported by capabilities that competitors cannot reproduce immediately.

H9: *Green strategic integration is positively associated with sustainable competitive advantage.*

3.6.10 Direct effects of environmental performance and operational efficiency

Environmental performance may contribute directly to competitive advantage when customers, tenants, regulators, or investors value verified environmental outcomes. It can also reduce exposure to transition risk and strengthen legitimacy. Operational efficiency may contribute through cost reductions, asset utilization, service reliability, and improved resource allocation. The direct relationships are specified separately because firms can realize financial value from efficiency without strong green differentiation, and they can gain stakeholder value from environmental performance even where immediate cost savings are modest.

H10: *Environmental performance is positively associated with sustainable competitive advantage.*

H11: *Operational efficiency is positively associated with sustainable competitive advantage.*

3.6.11 Mediation through green strategic integration

The model proposes that environmental performance and operational efficiency influence competitive advantage partly through green strategic integration. A firm may achieve energy savings, but the strategic impact is limited if savings are not reflected in capital allocation, procurement, reporting, or market positioning. Integration is the mechanism through which isolated operating gains become organizational routines and stakeholder-facing value propositions. The model therefore expects indirect effects in addition to the direct effects specified in H10 and H11.

H12: *Green strategic integration mediates the relationship between environmental performance and sustainable competitive advantage.*

H13: *Green strategic integration mediates the relationship between operational efficiency and sustainable competitive advantage.*

3.6.12 Contextual conditions

Digital maturity may strengthen the optimization-to-performance relationship because mature organizations can integrate data from multiple systems, maintain analytical quality, and act on insights across sites. Conversely, fragmented infrastructure may constrain value even where sensors are available. Building-use intensity may also shape returns: buildings with variable occupancy, high cooling demand, or energy-intensive services may have greater optimization opportunities, although complexity can increase coordination costs. These moderators should be tested with theoretically justified interaction terms and sufficient sample size.

H14: *Digital maturity positively moderates the relationship between smart building energy optimization and environmental performance.*

H15: *Digital maturity positively moderates the relationship between smart building energy optimization and operational efficiency.*

H16: *Building-use intensity moderates the relationship between smart building energy optimization and environmental performance, such that the relationship differs across levels of use intensity.*

Table 1. Summary of proposed hypotheses

Hypothesis	Proposed relationship	Type
H1	Top-management commitment is positively associated with smart building energy optimization.	Direct (positive)
H2	Digital and energy-management capability is positively associated with smart building energy optimization.	Direct (positive)
H3	Stakeholder pressure is positively associated with smart building energy optimization.	Direct (positive)
H4	Organizational readiness is positively associated with smart building energy optimization.	Direct (positive)
H5	Smart building energy optimization is positively associated with environmental performance.	Direct (positive)
H6	Smart building energy optimization is positively associated with operational efficiency.	Direct (positive)
H7	Environmental performance is positively associated with green strategic integration.	Direct (positive)
H8	Operational efficiency is positively associated with green strategic integration.	Direct (positive)
H9	Green strategic integration is positively associated with sustainable competitive advantage.	Direct (positive)
H10	Environmental performance is positively associated with sustainable competitive advantage.	Direct (positive)
H11	Operational efficiency is positively associated with sustainable competitive advantage.	Direct (positive)
H12	Green strategic integration mediates the relationship between environmental performance and sustainable competitive advantage.	Mediation
H13	Green strategic integration mediates the relationship between operational efficiency and sustainable competitive advantage.	Mediation
H14	Digital maturity positively moderates the relationship between smart building energy optimization and environmental performance.	Moderation
H15	Digital maturity positively moderates the relationship between smart building energy optimization and operational efficiency.	Moderation
H16	Building-use intensity moderates the relationship between smart building energy optimization and environmental performance, such that the relationship differs across levels of use intensity.	Moderation

Source: Authors' elaboration.

The hypotheses form a coherent but deliberately non-deterministic model. The expected positive signs express theory-based predictions that require empirical testing. They should not be interpreted as observed effects until data have been collected and the model has been estimated.

4. RESULTS AND DISCUSSION

4.1 Synthesis of the proposed framework

The conceptual synthesis indicates that smart-building energy optimization is most plausibly understood as a socio-technical capability. Sensors, automation, analytics, and control algorithms provide the technical infrastructure, but organizational routines determine whether the infrastructure changes energy performance. This interpretation aligns with recent reviews showing that smart-building solutions increasingly combine monitoring, prediction, control, and system integration, while implementation barriers remain organizational as well as technical (Hernández et al., 2024; Poyyamozi et al., 2024; Taboada-Orozco et al., 2024). The implication is that adoption and effective optimization should not be treated as equivalent variables.

The model's antecedents perform different functions. Top-management commitment supplies legitimacy and resources; digital and energy-management capability enables diagnosis and intervention; stakeholder pressure influences priority and accountability; and organizational readiness supports execution. Their effects may be complementary. Strong leadership without technical competence can lead to

poorly specified investments, while advanced analytics without leadership support may not trigger operational change. Similarly, external pressure may accelerate adoption but cannot guarantee sustained use if facility teams lack training or decision authority. The framework therefore predicts that optimization is produced by a configuration of conditions rather than one isolated driver.

The distinction between environmental performance and operational efficiency is equally important. A project can reduce energy costs through better scheduling without producing a proportional emissions reduction if the energy supply is carbon intensive or if energy use shifts to another period. Conversely, emissions intensity can improve even when costs do not fall, for example where the organization procures cleaner electricity but pays a premium. Measuring both outcomes avoids treating financial and environmental performance as interchangeable. It also makes the model relevant to organizations whose sustainability obligations extend beyond short-term payback.

Finally, green strategic integration is positioned as the mechanism that converts local gains into organizational value. An energy-management team may identify savings, but the firm captures more durable benefits when the findings influence budgets, maintenance standards, procurement, portfolio investment, and external communication. This strategic translation can support learning across buildings and prevent performance improvements from remaining confined to one site. It is also the point at which energy optimization can contribute to differentiation and resilience rather than merely lower utility bills.

4.2 Why technical adoption is not enough

A recurring risk in smart-building programs is the assumption that more automation necessarily means better energy performance. That assumption overlooks system configuration, commissioning, user behavior, maintenance, and the quality of operational objectives. A building-management system can be technically sophisticated but poorly tuned; sensors can be installed in locations that produce unrepresentative data; and predictive models can rely on historical patterns that no longer reflect occupancy. The resulting system may generate false alarms, control equipment inefficiently, or prompt users to override automation. Technical capability is therefore necessary but not sufficient.

This point has strategic consequences. Procurement decisions often emphasize equipment specifications, software functionality, and projected savings. However, total value depends on whether the organization can sustain system performance after commissioning. Maintenance contracts, cybersecurity updates, staff training, data ownership, and vendor support should be evaluated as part of the business case. The cheapest initial installation may create high long-run costs if the system is difficult to integrate or if critical data become inaccessible when a vendor relationship ends.

The framework suggests that organizations should evaluate the maturity of operating routines before committing to advanced technologies. A staged approach can begin with reliable metering, a baseline, and transparent operating schedules; then introduce fault detection and targeted automation; and only later add more complex predictive or adaptive functions where the data and skills justify them. This sequence can prevent overengineering and allows managers to learn which interventions produce measurable value. It also supports a clearer comparison between the marginal benefit of additional technology and the cost of implementation.

4.3 The role of management commitment

Top-management commitment is not simply an expression of support. It affects resource allocation, accountability, and the time horizon used to evaluate investments. Building-energy projects can involve upfront capital expenditure while savings accrue over several years. If leaders use short payback thresholds without accounting for maintenance, carbon risk, asset value, or service reliability, investments with strategic benefits may be rejected. Conversely, a sustainability narrative without financial discipline can lead to costly projects with weak evidence of performance.

Effective leadership should establish clear but balanced objectives. These may include energy-use intensity, emissions intensity, indoor environmental quality, system reliability, and net financial value. Objectives should be linked to named decision owners and reviewed at intervals appropriate to the building's operating cycle. Leaders also need to resolve conflicts between departments. For example, a facilities team

may seek to reduce cooling demand, while an occupant-facing unit prioritizes comfort or extended operating hours. Without a shared decision framework, optimization goals can be displaced by local performance incentives.

The theoretical implication is that management commitment should influence not only adoption but also the strategic integration of results. Leaders can ensure that evidence from building operations informs capital planning and corporate sustainability reporting. They can also support experimentation and accept that optimization requires iterative adjustment rather than a single installation. This is consistent with a dynamic-capability view: sensing and seizing opportunities require authority to reallocate resources and transform routines, not only access to information.

4.4 Digital capability, data quality, and interoperability

Digital capability is valuable when data are reliable, interpretable, and connected to decisions. Building systems commonly involve equipment from different vendors, different data protocols, inconsistent naming conventions, and varying levels of historical coverage. Integration failures can make portfolio-wide analysis difficult and can increase dependence on specialized vendors. A firm may possess large volumes of data yet remain unable to compare consumption across buildings or identify the operational causes of a change. Data quantity is therefore an inadequate proxy for data capability.

Organizations should establish governance for data quality, access, ownership, retention, and interpretation. A minimum viable data architecture can define common metrics and naming standards, connect energy data with occupancy and weather, and preserve a record of interventions. The architecture should be proportionate to the organization. Small property owners may not need a complex digital twin, but they still need accurate meters, a stable baseline, and an auditable record of operating changes. Large portfolios may benefit from centralized dashboards and common performance definitions, provided local managers retain the context needed to interpret unusual patterns.

Interoperability is strategically significant because it affects switching costs and future investment flexibility. Closed platforms may perform well in the short term but limit integration with future equipment or make data export expensive. Procurement should therefore examine open interfaces, cybersecurity practices, service-level commitments, data portability, and end-of-contract provisions. These issues are not merely IT concerns; they shape long-term operating costs and the organization's capacity to adapt as technologies and standards evolve.

4.5 Stakeholder pressure and the risk of symbolic sustainability

Stakeholder pressure can accelerate investment by making energy performance more visible and consequential. Regulatory requirements can establish a minimum standard, while tenants and investors may reward organizations that demonstrate credible improvement. Yet pressure can also create a reporting-first response in which firms prioritize labels, dashboards, and public commitments over operational performance. The model's positive hypothesis must therefore be understood as conditional on the organization responding substantively to stakeholder expectations.

A credible response requires measurement boundaries and verification. Energy consumption should be normalized where relevant, and the organization should distinguish actual reductions from changes in occupancy, floor area, weather, or operating hours. Renewable electricity procurement should not be confused with lower building demand, and avoided emissions should be reported using a transparent method. If a building's absolute energy use increases while its intensity falls, both measures should be disclosed where material. Transparent reporting may appear less flattering in the short term, but it strengthens the credibility of environmental claims and supports better decisions.

The strategic value of stakeholder pressure is consequently mediated by organizational learning and governance. Firms that use external expectations to improve measurement, procurement, and operating routines may build capabilities that outlast a particular regulatory requirement. Firms that treat pressure as a communications problem may face reputational exposure when claims are challenged. The proposed SEM framework can test the average relationship between stakeholder pressure and optimization, but future

studies should also examine whether pressure interacts with leadership commitment, assurance, or green strategic integration.

4.6 Environmental performance: beyond utility bills

Environmental performance should reflect actual resource use and emissions, not just the presence of green technologies. Energy-use intensity is useful for comparison but can be misleading when buildings provide different services or operate under different climatic conditions. An office, hospital, hotel, and logistics facility have different occupancy patterns and energy requirements. Comparisons should therefore be made within relevant peer groups or adjusted for material differences. Where feasible, the study should combine normalized energy metrics with emissions factors and evidence of system performance.

A further issue is the distinction between operational carbon and embodied carbon. The proposed model focuses on operational energy optimization, but technology investments themselves have material and lifecycle impacts. Replacing equipment prematurely may improve operating efficiency while increasing embodied emissions associated with new equipment and disposal. The appropriate decision depends on the expected life of the equipment, the energy savings, refrigerant impacts, maintenance requirements, and the carbon intensity of energy supply. A strategic sustainability approach should avoid optimizing one boundary while shifting impacts elsewhere.

Rebound effects also deserve attention. Efficiency improvements can reduce the cost of providing a service, potentially encouraging longer operating hours, higher comfort settings, or additional energy-consuming amenities. At the organization level, the rebound may be behavioral or operational rather than a direct response to price. For example, improved cooling efficiency could lead managers to cool previously unconditioned spaces. This does not negate the value of optimization, but it means that post-intervention monitoring is essential. Energy savings should be assessed against a credible counterfactual and interpreted alongside service levels.

4.7 Operational efficiency and the business case

The economic case for smart-building optimization should account for total cost of ownership. Relevant costs include hardware, software licenses, integration, commissioning, training, cybersecurity, data storage, maintenance, and future upgrades. Benefits can include energy savings, lower peak demand, improved equipment life, reduced emergency maintenance, better space utilization, and more reliable operations. Some benefits are easier to monetize than others. Energy bills may be directly observable, while comfort, asset attractiveness, and reduced disruption may require careful estimation or qualitative evidence.

Payback period alone is not a sufficient investment criterion. It ignores the timing of cash flows, risk, changing energy prices, equipment replacement, and strategic externalities. Net present value and scenario analysis can help compare investments, while sensitivity analysis can test assumptions about savings, occupancy, maintenance, and energy tariffs. Where carbon prices or reporting obligations are relevant, the business case should also account for transition risk. However, financial models should not double-count benefits—for example, by counting both energy savings and a separate “efficiency benefit” that represents the same reduction.

The model predicts a positive link between optimization and operational efficiency, but the magnitude should vary by building and organizational context. Buildings with high energy intensity and variable loads may offer larger opportunities, while newer or already optimized buildings may show smaller incremental gains. Ownership and leasing arrangements are especially important. If landlords pay for equipment but tenants pay energy bills, the incentive to invest can be weak. Green leases, shared-savings arrangements, and performance-based service contracts may align incentives, but their effectiveness depends on clear baselines and transparent measurement.

4.8 Green strategic integration as a value-capture mechanism

Green strategic integration is the central management mechanism in the proposed model. It means that energy performance is connected to decisions that shape the organization over time. Examples include prioritizing retrofit investments based on portfolio-wide evidence, incorporating energy criteria into procurement, linking facility performance to management reviews, and using verified outcomes in

sustainability reporting. Integration also requires coordination between sustainability, finance, facilities, procurement, and business-unit leaders.

Integration can improve learning by making building performance comparable across sites. When a portfolio manager can identify why one building performs better than another, the organization can transfer effective routines rather than simply purchase additional equipment. It can also strengthen investment discipline by distinguishing between technologies that perform well in a pilot and those that remain effective under different operating conditions. Over time, these routines may be more difficult for competitors to imitate than the underlying technology.

Nevertheless, strategic integration should not become a reason to overstate the commercial value of environmental performance. Competitive advantage depends on the market context and the ability to appropriate value. A hotel may use energy performance to strengthen its appeal to environmentally conscious guests, while a warehouse operator may derive value primarily through cost and reliability. An office landlord may gain from lower common-area charges or tenant retention, but only if the benefits are visible and relevant to tenants. The model therefore treats competitive advantage as multidimensional and encourages researchers to report its constituent dimensions as well as any overall latent construct.

4.9 Competitive advantage: differentiation, resilience, and imitation

Smart-building energy optimization may contribute to competitive advantage through three broad pathways. The first is cost-based: lower energy and maintenance expenditure can improve operating margins or enable more competitive pricing. The second is differentiation-based: credible environmental performance can strengthen asset attractiveness, tenant preference, or stakeholder trust. The third is resilience-based: better visibility and flexible control can reduce exposure to energy-price volatility, equipment failures, and changing operating conditions. These pathways may reinforce one another, but their relative importance depends on the sector and business model.

The durability of advantage is a separate question. Vendors can sell similar equipment to competing firms, and basic monitoring practices can diffuse rapidly. Advantage is more likely to persist when technology is embedded in organization-specific data, cross-functional routines, workforce competence, and repeated learning. The firm may also benefit from a reputation for credible reporting, but reputation is vulnerable if performance claims are inconsistent with measured outcomes. Competitive advantage is therefore not a guaranteed consequence of digitization; it is an outcome of capability development, implementation quality, and value capture.

The model's mediation hypotheses are particularly relevant here. If environmental performance and operational efficiency have direct effects on competitive advantage, these relationships should remain visible after green strategic integration is included. If integration also carries an indirect effect, it would support the argument that organizational routines help translate operational gains into strategic value. Full mediation should not be assumed in advance. A partial mediation pattern may be more realistic because some cost savings can influence competitiveness immediately, while reputation and strategic learning take longer to develop.

4.10 Boundary conditions and heterogeneity

The value of optimization is unlikely to be uniform across all buildings. Digital maturity can strengthen performance because integrated data and skilled personnel improve the conversion of information into action. Yet maturity can also create diminishing returns: highly optimized buildings may have fewer remaining low-cost opportunities, and complex systems can impose additional maintenance burdens. This suggests that the relationship may be nonlinear, a possibility that future research could examine after the core linear model has been validated.

Building-use intensity can influence both the opportunity and the difficulty of optimization. Buildings with highly variable occupancy or large cooling loads may offer significant opportunities for adaptive control, but they may also require more complex comfort and safety constraints. Healthcare and laboratory buildings, for example, cannot be optimized using the same operating assumptions as a standard office. Sector-level

differences should be tested through measurement invariance and multi-group analysis rather than interpreted solely from separate significance tests.

Other boundary conditions include climate zone, energy tariffs, grid carbon intensity, ownership structure, building age, lease design, and organizational size. In emerging markets, capital constraints and uneven technical support may affect adoption. In mature markets, stricter regulation and more developed energy-service markets may alter the perceived business case. The model can be extended to examine these factors, but the initial study should remain parsimonious and avoid adding moderators without theoretical justification and adequate statistical power.

4.11 Practical interpretation for corporate decision-makers

For managers, the framework implies that an energy-optimization initiative should begin with a strategic problem statement rather than a technology shopping list. The organization should define whether the priority is cost reduction, emissions intensity, peak-demand management, reliability, tenant value, or a combination of objectives. It should establish a baseline and clarify the building services that must be maintained. Only then should it choose sensors, controls, analytics, and integration architecture appropriate to the problem.

The second managerial priority is governance. Energy metrics should have owners, review cycles, and clear links to action. An alert that does not trigger investigation is not a capability. A dashboard that is not connected to investment decisions may improve visibility but have limited strategic effect. Facility teams should have the authority and training to respond, while senior management should review both savings and unintended consequences such as comfort deterioration, cyber incidents, or maintenance backlogs.

The third priority is credible value measurement. Firms should distinguish gross from net savings, normalize energy performance, disclose material assumptions, and avoid claiming carbon benefits that cannot be supported. They should compare the total cost of ownership of alternative solutions and plan for maintenance, upgrades, and data portability. The resulting evidence should feed into procurement, capital planning, sustainability reporting, and portfolio learning. These steps are likely to improve the probability that a building-energy project contributes to durable corporate value rather than a short-lived technical success.

4.12 Implications for research and model validation

The proposed model offers a tractable starting point for empirical research, but validation requires careful measurement. Researchers should first establish whether the antecedent constructs are empirically distinguishable. Management commitment and organizational readiness may correlate strongly, as may digital capability and optimization practices. If discriminant validity is weak, the problem may reflect poor item design or a theoretically meaningful higher-order construct. Researchers should not respond by deleting items solely to improve fit without considering construct meaning.

Second, studies should separate perceptual and objective measures. Managerial perceptions are valuable for assessing strategic integration and capability, but they are less reliable substitutes for energy data. Where objective metrics are unavailable, the limitation should be explicit and the conclusions framed accordingly. Third, replication across sectors and regions is essential. The model may perform differently in owner-occupied offices, leased commercial properties, hotels, hospitals, or public buildings. Measurement invariance is a prerequisite for meaningful comparisons across groups.

Therefore, researchers should consider time and causality. A cross-sectional survey can test whether the proposed covariance pattern is consistent with theory, but it cannot establish that optimization preceded performance. Longitudinal designs, matched energy records, and natural experiments can provide stronger evidence. Future studies could also compare the relative effects of different optimization practices, examine nonlinear returns, and assess whether green strategic integration mediates outcomes over time. These extensions would move the field from broad claims about smart-building potential toward a more precise account of when and how the technology creates strategic value.

5. CONCLUSION

This article has developed a strategic-management framework for understanding how smart building energy optimization can contribute to green corporate strategy and sustainable competitive advantage. Its central argument is that smart-building technology should be treated as an enabling resource whose value depends on complementary organizational capabilities. Sensors, automation, analytics, and predictive control can improve operational visibility and support more adaptive energy management, but the strategic consequences depend on management commitment, digital capability, stakeholder expectations, organizational readiness, and the quality of implementation.

The proposed model connects four antecedents to smart building energy optimization and links optimization to environmental performance and operational efficiency. It further proposes that green strategic integration helps translate these outcomes into competitive advantage. The framework distinguishes the environmental and economic dimensions of performance rather than assuming that they move together in every setting. It also recognizes the potential influence of digital maturity and building-use intensity. Sixteen hypotheses provide a basis for empirical testing, while the methodology outlines how a future study could measure constructs and estimate direct, indirect, and moderated relationships through SEM.

5.1 Theoretical implications

The first theoretical implication is that smart-building energy optimization can be conceptualized as an organizational capability rather than a technology adoption outcome. This perspective extends resource-based reasoning by emphasizing the complementary nature of data, routines, skills, governance, and learning. A technology may be available to competitors, but the ability to use it consistently across a portfolio and integrate results into corporate decisions can be more distinctive.

The second implication is that dynamic capabilities provide a useful explanation of continuous optimization. Buildings are not static systems, and the sources of inefficiency change over time. Sensing, seizing, and transforming are reflected in the ability to detect operational anomalies, authorize interventions, and revise routines after observing results. This approach encourages researchers to examine learning and adaptation rather than relying only on a one-time indicator of technology adoption.

The third implication is that stakeholder pressure should be linked to substantive organizational response. Pressure can motivate investment, but it can also lead to symbolic compliance. By incorporating strategic integration and measured performance, the model distinguishes the external demand for environmental responsibility from the internal capability to deliver it. This distinction can help explain why similar regulatory or market pressures produce different organizational outcomes.

The fourth implication concerns the mechanism connecting sustainability to competitive advantage. Environmental performance and operational efficiency may contribute directly to advantage, but their value can also depend on how they are embedded in strategic decisions. Green strategic integration provides a mechanism for transferring local operational improvements into portfolio-level learning, investment discipline, and credible stakeholder communication. This helps connect building-energy research with the broader question of how sustainability capabilities generate organizational value.

5.2 Managerial implications

Managers should define energy optimization as a business and sustainability capability, not simply as an equipment upgrade. Before investing, organizations should identify the service requirements of the building, establish a credible baseline, and determine which operational problem the intervention is intended to solve. A staged implementation strategy can prioritize reliable metering and basic controls before introducing more complex analytics. Investment decisions should be based on total cost of ownership, expected service-adjusted savings, maintenance requirements, and the ability to integrate with existing systems.

Organizations should also establish cross-functional governance. Facility managers, sustainability teams, finance, IT, procurement, and business-unit leaders need a shared understanding of performance targets and decision rights. Energy metrics should be reviewed regularly and linked to action. Training and change management are essential because staff must understand the system and know when to accept,

question, or override automated recommendations. The organization should preserve human accountability for decisions that affect safety, comfort, and business continuity.

Third, managers should build credible measurement and reporting practices. Absolute energy consumption, energy intensity, emissions intensity, and relevant service indicators should be interpreted together. The organization should document baseline assumptions and account for changes in occupancy, weather, and operating hours. It should avoid treating software installation or certification as proof of environmental improvement. Credible performance data can support investment decisions and stakeholder trust, whereas overstated claims create reputational and regulatory risk.

Fourth, procurement and contracting should account for interoperability, cybersecurity, data ownership, vendor dependence, and end-of-contract portability. The value of a platform can be undermined if the organization cannot export its own data or integrate future equipment. Performance-based contracts and green leases may help align incentives between owners and tenants, but they require clear baselines and transparent verification. Managers should also monitor rebound effects and ensure that efficiency gains are not offset by increased energy demand.

5.3 Policy implications

Policymakers can encourage effective optimization by combining performance standards with practical support for implementation. Building codes and disclosure rules can improve transparency, but smaller organizations may need guidance, technical assistance, financing, and access to trusted energy-service providers. Standardized energy metrics and interoperable data practices can reduce comparison costs and help organizations evaluate performance across assets. Policy should also avoid equating digitalization with decarbonization; monitoring systems are useful only when they support measurable improvements in energy and emissions.

Public procurement can create demand for high-performance building operations by requiring transparent energy data, lifecycle costing, and verification of savings. At the same time, standards should allow context-sensitive approaches because building uses differ. Healthcare facilities, laboratories, schools, offices, and hotels face different service requirements. Policies that reward absolute energy reductions without considering service levels or building conditions may create perverse incentives. A balanced framework should promote measurable performance while protecting occupant health, comfort, and safety.

5.4 Limitations and future research

The principal limitation is that the article proposes a conceptual SEM framework rather than reporting an empirical test. Its relationships are theory-driven and must be validated with data. The proposed model also simplifies a complex socio-technical system into a manageable set of constructs. Other variables such as energy prices, building age, climate, lease structure, employee behavior, and access to capital—may be important in particular contexts. Future research should add such variables selectively and avoid models that become statistically complex without improving theoretical explanation.

Future research should test the model in different sectors and countries, particularly where building ownership, energy markets, and regulatory requirements vary. Multi-group SEM can assess whether measurement and structural relationships differ across building types. Researchers could also examine whether digital maturity has a nonlinear relationship with optimization returns, whether strategic integration develops over time, and whether the benefits of smart buildings extend beyond energy to occupant well-being, maintenance resilience, and asset value. Further work should investigate cybersecurity incidents, vendor lock-in, algorithmic transparency, and the distribution of benefits between owners, tenants, employees, and service providers.

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