Research on the Influencing Factors, Mechanisms, and Optimization Pathways of Building Energy Management: A Structural Equation Modeling and Case Study Approach

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ABSTRACT

Building energy management is influenced by technological, managerial, and external environmental factors. Based on ISO 50001 and socio-technical systems theory, this study integrates SWOT-AHP and interview findings to develop an influencing-factor model. Using 208 valid questionnaires, structural equation modeling is applied to examine the relationships among internal strengths, internal weaknesses, external opportunities, external threats, and energy management performance. An industrial factory case is further used to validate the empirical findings and identify an optimization pathway for energy management. The results provide practical implications for improving energy management systems and supporting low-carbon development.

Keywords: Building Energy Management; Influencing Factors; Structural Equation Modeling; Energy Management Performance; Optimization Pathway

INTRODUCTION

With the increasing global demand for energy and growing requirements for low-carbon development, energy consumption and its environmental impacts in the industrial production sector have attracted increasing attention. Energy Management Systems (EMS) support energy measurement, monitoring, data analysis, and operational management, while enabling continuous improvement of energy performance through systematic management, thereby contributing to energy conservation and improved energy efficiency (International Organization for Standardization, 2018; Fitzgerald et al., 2023). An energy management system not only facilitates the implementation of energy-saving measures but also promotes long-term improvements in organizational energy performance through a continuous improvement mechanism.

Among different types of production buildings, industrial plants are characterized by a large number of production equipment, complex energy systems, and energy loads that are closely associated with production processes. Production processes and building mechanical and electrical systems jointly constitute the major energy-consuming components of industrial plants. Their energy consumption is influenced not only by equipment efficiency but also by production processes, operating conditions, and management practices. China's industrial sector still has considerable potential for improving energy efficiency, and the optimization of industrial energy systems is important for reducing energy consumption and carbon emissions (Yue et al., 2021). As a typical industrial utility system, compressed air systems are affected by equipment performance, operating parameters, system configuration, and maintenance practices, and therefore have considerable potential for energy savings (Kaya et al., 2021).

Meanwhile, energy management in industrial plants is shifting from traditional experience-based practices toward digitalized, refined, and intelligent management. Energy metering, online monitoring, and digital energy management systems can improve energy data transparency and provide support for the management of major energy-consuming equipment, operational optimization, and the evaluation of energy-saving measures (Wang et al., 2024). In recent years, the Internet of Things (IoT) and digital technologies have increasingly been applied to energy monitoring and management in manufacturing, helping identify abnormal energy consumption, improve the utilization of energy data, and support energy-saving decisions (Kumar et al., 2024). At the same time, factory energy management systems are gradually developing into integrated architectures that incorporate data acquisition, data processing, analysis, control, and energy services, providing a new technological foundation for refined energy management in the manufacturing sector (ITU, 2024).

However, investment in energy-saving technologies does not necessarily translate into sustained energy management performance. Smith et al. (2022) and Cagno et al. (2022) indicated that the implementation of industrial energy management is also influenced by organizational capabilities, employee participation, management mechanisms, economic conditions, and the external environment. Consequently, some economically feasible energy-saving measures may not be effectively implemented because of organizational and implementation barriers. Therefore, it is necessary to identify the key factors influencing energy management in industrial plants from multiple dimensions, including internal strengths, internal weaknesses, external opportunities, and external threats, and to further examine the mechanisms through which these factors affect energy management performance.

LITERATURE REVIEW

Research on Energy-Saving Technologies in Buildings and Industrial Plants

Research on energy-saving technologies has mainly focused on building design, lighting, heating, ventilation and air-conditioning, power distribution, production equipment, energy monitoring, and renewable energy. With increasing complexity of energy systems, research has gradually shifted from individual equipment optimization toward integrated system optimization. Variable-frequency control, intelligent monitoring, equipment efficiency optimization, and automated control have become important approaches for improving energy efficiency.

Recent studies indicate that the integration of the Internet of Things (IoT), artificial intelligence (AI), and data-driven technologies is promoting the digitalization and intelligentization of energy management. Real-time energy monitoring, equipment condition monitoring, and intelligent control can improve the ability to identify abnormal energy consumption and optimize system operation (Mischos et al., 2023; Cavalcanti & Pimenta, 2023).

For industrial plants, energy-saving technologies need to be closely integrated with production processes and equipment operation. In addition to building-related systems, production equipment and industrial utilities are important sources of energy consumption. Digital technologies such as energy digital twins can further support energy monitoring, operational optimization, maintenance, and energy-efficiency improvement throughout the industrial production lifecycle (Yu et al., 2022).

Overall, existing studies have established a relatively comprehensive technological foundation for energy conservation. However, most studies still focus on the energy-saving performance of individual technologies or systems, while relatively less attention has been paid to how technological measures interact with organizational management, energy data, and operational mechanisms to generate sustained energy management performance.

Research on Energy Management

Energy management generally involves energy metering, energy planning, energy targets, energy monitoring, energy statistics, data analysis, operational control, and performance evaluation. With the development of digital technologies, energy management systems have gradually evolved from simple monitoring platforms into integrated systems incorporating data acquisition, analysis, optimization, control, and decision support.

Recent research has increasingly emphasized data-driven energy management systems and intelligent energy management. Sievers and Blank (2023), for example, reviewed data-driven energy management systems and highlighted the increasing importance of data acquisition, processing, analysis, and decision-making in both residential and industrial applications. Similarly, Mischos et al. (2023) demonstrated that intelligent energy management systems can integrate real-time monitoring, automation, and optimization to improve energy-use efficiency.

In industrial settings, digitalization provides additional opportunities for energy management. Energy digital twins can connect production processes, energy systems, equipment operation, and energy-performance analysis, thereby supporting more refined industrial energy management (Yu et al., 2022). Industrial digitalization research also shows that the effectiveness of digital technologies depends not only on technological availability but also on organizational capabilities, implementation conditions, and management mechanisms (Culot et al., 2023).

Nevertheless, existing research has largely focused on the functions and technological applications of energy management systems. The ways in which internal organizational capabilities, management deficiencies, and external environmental conditions jointly influence energy management performance remain insufficiently examined. A more systematic perspective is therefore needed to explain the formation mechanism of industrial energy management performance.

Research on Factors Influencing Energy Management Performance

Existing studies indicate that energy management performance is influenced by multiple interacting factors, which can generally be grouped into technological, organizational, behavioral, and external environmental dimensions. Technological factors include equipment efficiency, energy metering, monitoring systems, and intelligent control. Organizational factors involve energy targets, management systems, role responsibilities, operation and maintenance, and performance evaluation. Behavioral factors mainly concern the energy-saving awareness and implementation behavior of managers and equipment operators. External factors include policies, standards, energy prices, technological development, and professional energy services.

Recent industrial energy-efficiency research has increasingly emphasized the importance of organizational and implementation factors. Smith et al. (2022) found that industrial energy management is affected by multiple barriers and drivers, and that the perspectives of frontline employees may differ from those of managers. This indicates that organizational participation and implementation capacity are important conditions for translating energy-saving measures into actual performance. Similarly, Anderson et al. (2022) showed that sustained industrial energy-efficiency improvement depends on both internal drivers and the removal of implementation barriers.

For industrial plants, the relationship between technology and management is particularly important because energy consumption is closely associated with production processes and equipment operation. Energy-intensive equipment such as injection-molding machines, air compressors, fans, pumps, and HVAC systems requires continuous monitoring and operational management. Energy data can only support effective energy management when it is linked with production schedules, equipment operating conditions, energy targets, and performance evaluation. Research on industrial energy management services similarly suggests that energy management can support both energy efficiency and operational productivity, but its implementation is constrained by organizational and operational barriers.

In addition, external conditions can influence the adoption and implementation of industrial energy-efficiency measures. Economic, regulatory, and technological barriers may affect firms' willingness and ability to implement demand-side energy-management measures (Wittmann et al., 2022). Therefore, energy management performance should not be explained solely by technological efficiency. Instead, internal capabilities, internal management deficiencies, external opportunities, and external threats should be considered simultaneously.

Overall, although previous studies have identified numerous factors affecting industrial energy management, there remains a lack of an integrated empirical framework that quantitatively examines the relationships among these factors. This provides the basis for this study to classify influencing factors into internal strengths (ISS), internal weaknesses (IW), external opportunities (EO), and external threats (ET) and further examine their effects on energy management performance using structural equation modeling.

Research Gaps and Research Design

Existing studies have extensively examined technological, organizational, and environmental factors in building energy management. However, two major gaps remain. First, the interactions and synergies among different influencing factors have not been systematically integrated. Second, the pathways through which these factors affect energy management performance have received limited quantitative validation, resulting in a certain disconnect between theoretical research and practical energy management projects.

To address these gaps, this study integrates ISO 50001 and socio-technical systems theory and categorizes the influencing factors of energy management into four dimensions: Internal Strengths (ISS), Internal Weaknesses (IW), External Opportunities (EO), and External Threats (ET). A structural equation model (SEM) is developed to examine the direct and indirect effects of these factors on energy management performance. A typical industrial plant case is further used to validate the practical applicability of the empirical findings. Based on these results, the study further examines the correspondence between the identified influencing factors and actual energy management measures and proposes an optimization pathway for energy management.

The main contributions of this study are to develop an integrated analytical framework for energy management influencing factors, quantitatively examine their underlying mechanisms, and link the SEM findings with a practical industrial plant case, thereby providing theoretical and practical implications for improving energy management systems in buildings and industrial plants.

Research Framework

The research process consists of six main stages, shown as Figure 1.

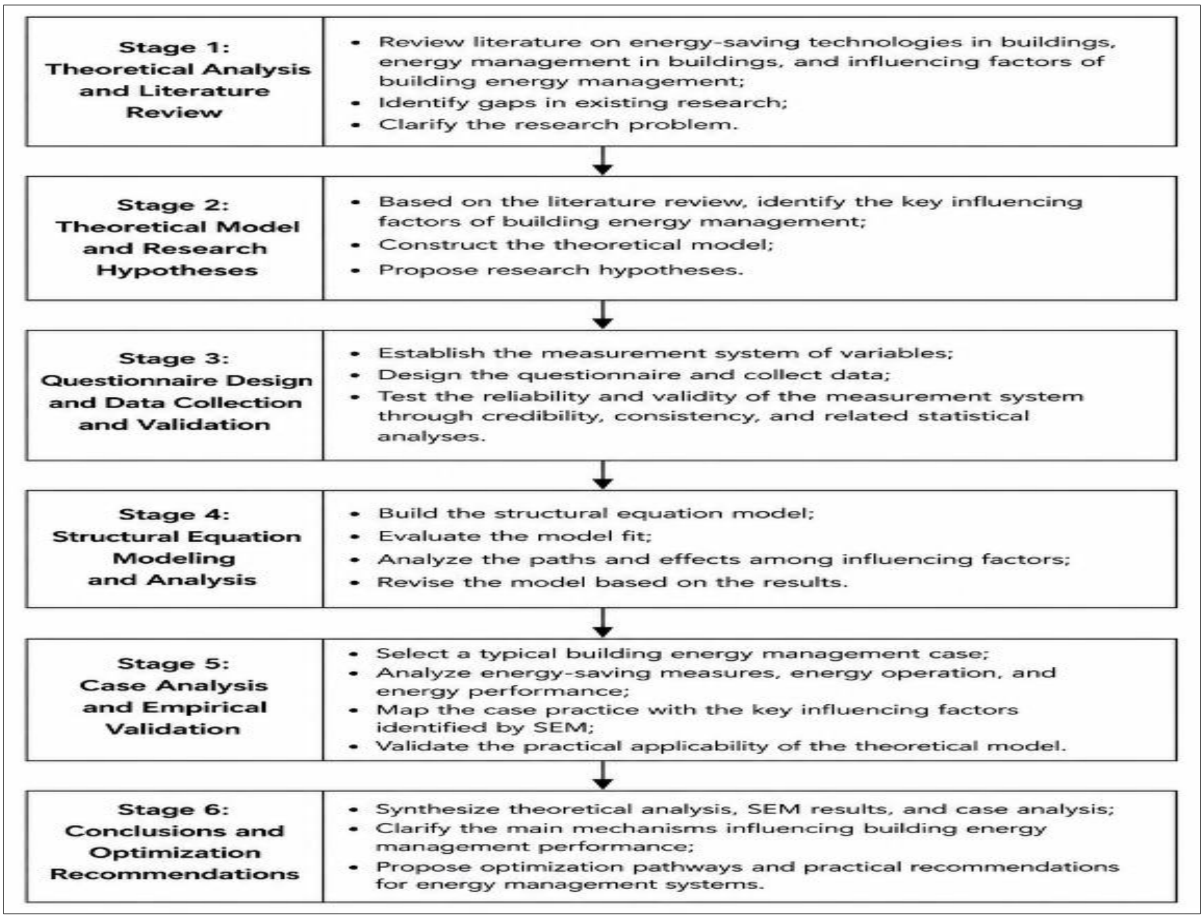

Figure1. Research Framework and Methodology

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Theoretical Foundation And Research Hypotheses

Theoretical Foundation: ISO 50001 and the Socio-Technical Systems Perspective

ISO 50001 provides a systematic framework for organizational energy management. Its core principle is to improve energy performance continuously through energy objectives, energy management implementation, energy performance monitoring, and continual improvement. Recent studies have shown that ISO 50001-based energy management systems can integrate energy performance management into organizational operations and provide a structured basis for monitoring, analysis, decision-making, and continual improvement (International Organization for Standardization, 2018; Pandin et al., 2024).

From this perspective, energy management is not limited to energy-saving technologies or monitoring systems. It also involves organizational management, personnel participation, operational practices, and the conditions surrounding the organization. Recent research on building energy management similarly emphasizes the need to integrate technical and non-technical factors rather than focusing solely on technological solutions.

The socio-technical systems (STS) perspective considers organizational performance to be the outcome of interactions among technical, organizational, human, and environmental subsystems. In building energy management, recent studies have demonstrated that technical systems, management practices, and human factors need to be considered jointly to improve energy-management effectiveness. For example, Andolfi et al. (2024) highlighted the importance of integrating behavioral strategies with technical solutions in building energy management systems, while Zhou et al. (2024) demonstrated the value of incorporating socio-economic factors into technical building-energy analysis.

Based on these two theoretical perspectives, this study views building energy management as a multi-factor socio-technical system. ISO 50001 provides the logic of systematic energy management and continual improvement, while the STS perspective provides a broader framework for understanding interactions among technology, organization, people, and the external environment. Accordingly, this study identifies the key influencing factors of energy management performance from four dimensions: technical factors, management factors, behavioral factors, and external environmental factors, shown as Figure 2. These factors are subsequently incorporated into the structural equation model to examine their relationships with energy management performance.

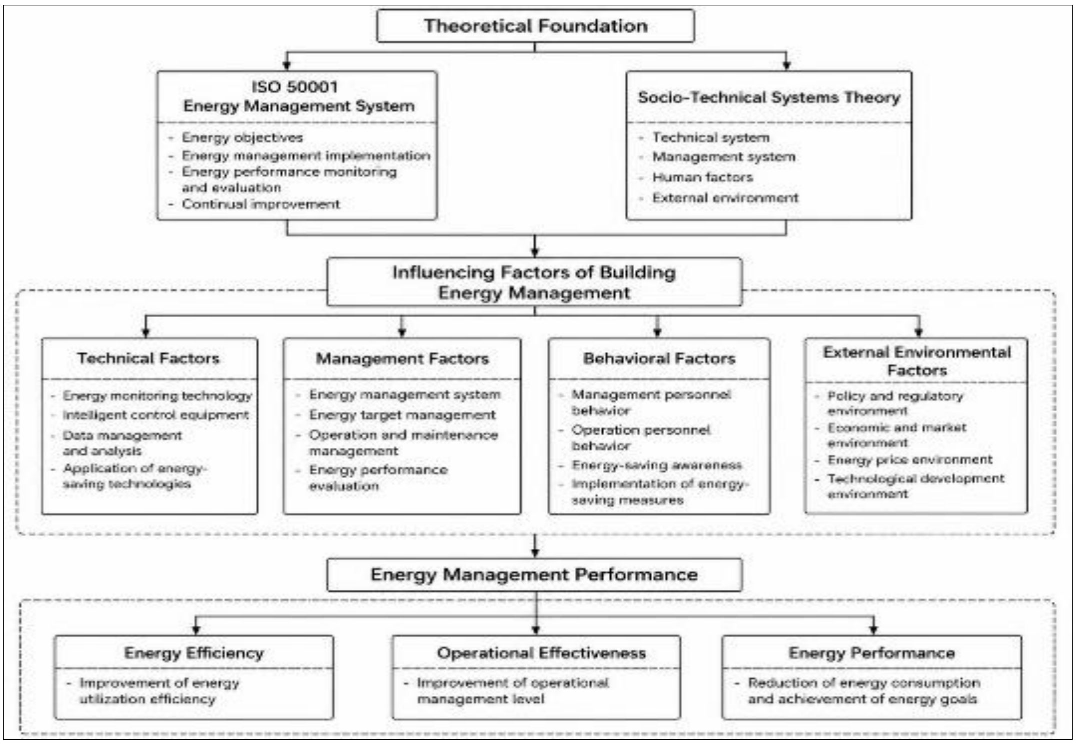

Figure 2. Theoretical Framework for Influencing and Energy Management Performance in Buildings

Research Hypotheses

Direct-Effect Hypotheses

Based on ISO 50001 and the socio-technical systems perspective, building energy management performance is jointly influenced by internal organizational capabilities and external environmental conditions. Internal strengths include human resources, management systems, equipment, technologies, and energy data, which provide essential support for the implementation and continuous improvement of energy management practices. Previous studies have shown that management commitment, organizational resources, technical capabilities, and energy-related expertise are important conditions for effective energy management and the implementation of ISO 50001-based energy management systems (Fuchs et al., 2020; Thollander et al., 2021). Therefore, the following hypothesis is proposed:

H1: Internal strengths (ISS) have a significant positive effect on energy management performance (MEE).

Internal weaknesses mainly include unclear responsibilities, inadequate management processes, insufficient accountability, and deficiencies in technical and data capabilities. These conditions may reduce the effectiveness of energy management implementation and hinder the conversion of energy-saving resources into actual performance improvements. Previous research has identified insufficient resources, human competencies, management support, and organizational capabilities as important barriers to effective energy management (Thollander et al., 2021). Therefore:

H2: Internal weaknesses (IW) have a significant negative effect on energy management performance (MEE).

External opportunities include policy support, technological development, professional energy services, and green financing, which can improve the conditions for implementing energy management and reduce barriers to energy-efficiency improvements. Studies have shown that government incentives, technological development, and external support can facilitate the adoption and implementation of energy management practices. Therefore:

H3: External opportunities (EO) have a significant positive effect on energy management performance (MEE).

External threats mainly include changes in energy prices, adjustments to policies and standards, technological upgrading pressures, and changes in the market environment. These factors may increase energy management costs and organizational adaptation pressures, thereby constraining energy management performance. Research on energy-efficiency implementation has shown that economic, organizational, and external environmental barriers can affect the adoption and implementation of energy-saving measures. Therefore:

H4: External threats (ET) have a significant negative effect on energy management performance (MEE).

Synergistic and Mediating-Effect Hypotheses

Building energy management is not the result of independent effects of individual factors. External policies, technologies, and market resources need to be absorbed and utilized through internal organizational capabilities before they can be transformed into actual energy management outcomes. Therefore, internal strengths may serve as a transmission mechanism between external environmental conditions and energy management performance. This argument is consistent with research indicating that organizational capabilities and management systems can help organizations overcome energy-efficiency barriers and improve the implementation of energy-saving measures.

Internal strengths can enhance an organization's ability to absorb and utilize external policies, technologies, and resources, thereby enabling external opportunities to be more effectively converted into energy management performance. Therefore:

H5: Internal strengths (ISS) mediate the relationship between external opportunities (EO) and energy management performance (MEE).

When external environmental pressures increase, buildings with stronger internal capabilities may respond through technological upgrading, management improvement, and personnel capacity development, thereby reducing the adverse effects of external threats. Accordingly:

H6: Internal strengths (ISS) mediate the relationship between external threats (ET) and energy management performance (MEE).

Based on the theoretical framework and research hypotheses, the variables included in the model and their expected relationships are summarized in Table 1.

Table 1. Research Variables and Expected Relationships

Variable Type	**Variable**	**Expected Effect**
Independent variable	Internal strengths (ISS)	Directly promote energy management performance
Independent variable	Internal weaknesses (IW)	Directly inhibit energy management performance
Independent variable	External opportunities (EO)	Directly promote energy management performance
Independent variable	External threats (ET)	Directly inhibit energy management performance
Mediating variable	Internal strengths (ISS)	Transmit the effects of external environmental factors
Dependent variable	Energy management performance (MEE)	Reflect the overall outcomes of energy management

Theoretical Model

Based on the ISO 50001 energy management system and socio-technical systems theory, and drawing on the preceding analysis of factors influencing building energy management, this study identifies internal strengths (ISS), internal weaknesses (IW), external opportunities (EO), and external threats (ET) as the core influencing factors, with energy management performance (MEE) as the outcome variable. Accordingly, a theoretical model of building energy management is developed.

The model assumes that internal strengths directly contribute to energy management performance, whereas internal weaknesses have a negative effect on performance. External opportunities provide favorable conditions for energy management, while external threats may adversely affect energy management performance. Meanwhile, external environmental factors need to be absorbed and transformed through internal organizational capabilities. Therefore, the mediating role of internal strengths is further considered.

Accordingly, the proposed model follows the logic that "internal and external factors jointly influence energy management performance, while external environmental factors may exert indirect effects through internal organizational capabilities." This theoretical framework provides the basis for subsequent empirical testing using the structural equation model (SEM).

Research Design

Variables and Measurement

Based on ISO 50001, socio-technical systems theory, and the results of the preceding SWOT-AHP analysis and interviews, this study categorizes the factors influencing building energy management into four dimensions: internal strengths (ISS), internal weaknesses (IW), external opportunities (EO), and external threats (ET). Energy management performance (MEE) is used as the outcome variable. Accordingly, a measurement system comprising five latent variables and 19 observed variables is developed, shown as Figure 3.

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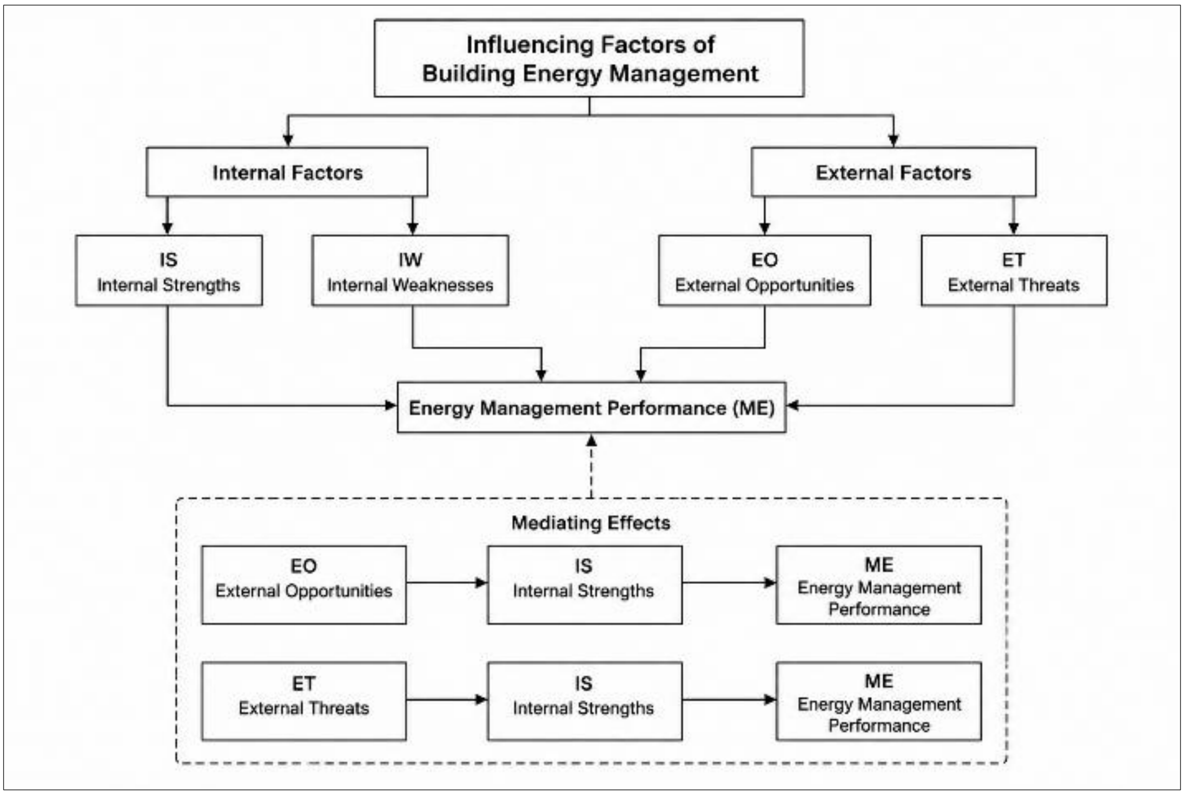

Figure 3. A Theoretical Model of Building Energy Management

ISS consists of five observed variables: team competence, energy management policies and targets, energy equipment and renewable energy application, intelligent technology application, and energy data collection and analysis. IW consists of three observed variables: unclear responsibilities and authorities, inadequate management process coordination, and insufficient accountability for energy performance. EO consists of four observed variables: policy support, intelligent technology development, professional service support, and green financing support. ET consists of three observed variables: energy cost fluctuations, regulatory and standards pressure, and technological upgrading and competitive pressure. MEE consists of four observed variables: energy consumption reduction, efficiency improvement and cost savings, user satisfaction improvement, and improvement in industry certification, shown as Table 2. All measurement items were assessed using a five-point Likert scale, ranging from 1 (“strongly disagree”) to 5 (“strongly agree”).

Table 2. Variable Definitions and Measurement Items

Latent Variable	**Observed Variable**	**Measurement Content**
Internal Strengths (ISS)	IS1	Team professional competence
	IS2	Energy management policies and targets
	IS3	Energy equipment and renewable energy application
	IS4	Intelligent technology application
	IS5	Energy data collection and analysis
Internal Weaknesses (IW)	IW1	Unclear responsibilities and authorities
	IW2	Insufficient coordination of management processes
	IW3	Insufficient accountability for energy performance

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External Opportunities (EO)	EO1	Policy support
	EO2	Intelligent technology development
	EO3	Professional service support
	EO4	Green financing support
External Threats (ET)	ET1	Energy cost fluctuations
	ET2	Regulatory and standards pressure
	ET3	Technological upgrading and competitive pressure
Energy Management Performance (MEE)	ME1	Energy consumption reduction
	ME2	Efficiency improvement and cost savings
	ME3	Improvement in user satisfaction
	ME4	Improvement in industry certification

Questionnaire Design and Data Collection

The questionnaire was primarily targeted at professionals involved in building energy management, including energy management personnel, equipment operation personnel, and relevant management staff. Chengdu, China, was selected as the study area because of its diverse building types, relatively mature energy management practices, and representative characteristics within the regional context.

The formal survey was conducted through field-based data collection. A screening question was included to verify whether respondents were currently engaged in building energy management-related work. Samples that did not meet the target respondent criteria were excluded. A total of 208 valid questionnaires were obtained and used for subsequent measurement-model and structural-model analyses, shown as Table 3.

Table 3. Sample Characteristics

Characteristic	**Categories**
Gender	Male; Female
Age	Below 25; 25–35; 36–45; Above 46
Education	Diploma; Bachelor's degree; Master's degree or above
Work experience	Less than 3 years; 3–5 years; 6–10 years; More than 10 years
Building type	Hospital; School; Office building; Commercial building; Other
Occupation	Managerial staff; Technical staff; Operation and maintenance staff; Other

Data Analysis Methods

The data were analyzed using SPSS 27.0 and AMOS 28.0. First, descriptive statistics were used to summarize the characteristics of the respondents. Second, Cronbach's α was used to assess the internal consistency reliability

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of the measurement scales, while the Kaiser–Meyer–Olkin (KMO) test and Bartlett's test of sphericity were conducted to determine whether the data were suitable for factor analysis.

Subsequently, exploratory factor analysis (EFA) was conducted to examine the underlying structure of the latent variables. Confirmatory factor analysis (CFA) was then performed to evaluate the measurement model, including its convergent and discriminant validity.

Finally, a structural equation model (SEM) was constructed to examine the direct effects of internal strengths, internal weaknesses, external opportunities, and external threats on energy management performance. The mediating role of internal strengths was further examined to determine whether internal capabilities transmit the effects of external opportunities and threats to energy management performance, shown as **Figure 4.**

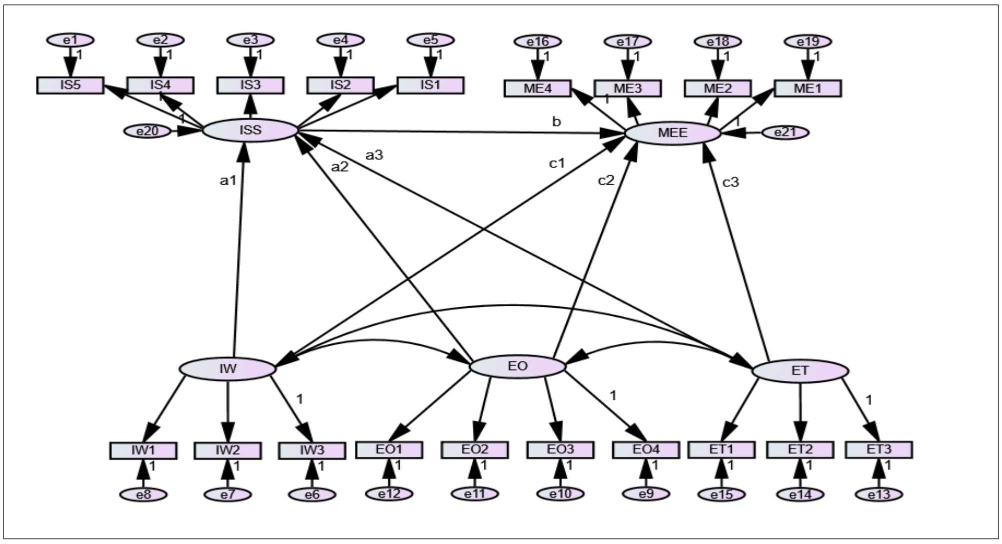

Figure 4. Research Variables and Structural Equation Model Framework

EMPIRICAL RESULTS

Sample Characteristics

A total of 208 valid questionnaires were obtained for this study. The sample covered respondents with different ages, educational backgrounds, years of work experience, and building types. The respondents were mainly engaged in building energy management, equipment operation and maintenance, and related management activities, thereby providing relatively broad coverage of the main participants involved in building energy management practices, shown as Table 4.

Table 4. Descriptive Statistics of Sample Characteristics

Job Title	Count	Percentage (%)
Building Operation Manager	14	7%
Property Project Manager	61	29%
Fire-Facility Operator	12	6%
Building Energy Management Engineer	23	11%
Facility Manager	69	33%
Other BEM-experienced professionals	31	15%

Overall, the sample demonstrated sufficient occupational relevance and diversity in terms of respondent characteristics and building types, providing an appropriate data foundation for the subsequent structural equation modeling analysis.

Reliability and Validity Tests

Reliability Analysis

Cronbach's α coefficients were used to evaluate the internal consistency of each latent variable. The results showed as Table 5. All values exceeded the commonly accepted threshold of 0.70, indicating good internal consistency and satisfactory reliability of the measurement scale.

Table 5. Reliability Test Results

Latent Variable	**Cronbach's α**
ISS	0.850
IW	0.798
EO	0.848
ET	0.802
MEE	0.844

Exploratory Factor Analysis

First, the KMO test and Bartlett's test of sphericity were conducted for the 19 observed variables. The results showed as Table 6. These results indicate significant correlations among the observed variables and confirm that the data were suitable for factor analysis.

Table 6. KMO and Bartlett's Test of Sphericity

Indicator	**Result**
KMO	0.887
Bartlett's χ^2	1832.894
df	171
p	<0.001

A rotated factor analysis was subsequently conducted, extracting five common factors. The results indicated that the 19 observed variables were clearly associated with their respective predefined latent constructs. Factor loadings ranged from 0.692 to 0.843, exceeding the generally acceptable level, and no substantial cross-loadings were identified. Specifically, ME1–ME4 loaded primarily on MEE, IS1–IS5 loaded primarily on ISS, IW1–IW3 loaded primarily on IW, EO1–EO4 loaded primarily on EO, and ET1–ET3 loaded primarily on ET, shown as Table 7.

Table 7. Rotated Factor Loading Matrix

Item	1	2	3	4	5
ME1			.716		
ME2			.801		
ME3			.779		
ME4			.701		
IS1	.736				
IS2	.742				
IS3	.807				
IS4	.692				
IS5	.741				
IW1					.789
IW2					.794
IW3					.763
EO1		.778			
EO2		.785			
EO3		.782			
EO4		.783			
ET1				.843	
ET2				.778	
ET3				.742	

These results demonstrate a good correspondence between the measurement indicators and their theoretically specified dimensions.

Confirmatory Factor Analysis

Based on the EFA results, confirmatory factor analysis (CFA) was further conducted using AMOS 28.0 to evaluate the overall fit of the five-factor measurement model and to assess its convergent and discriminant validity, shown as Figure 5.

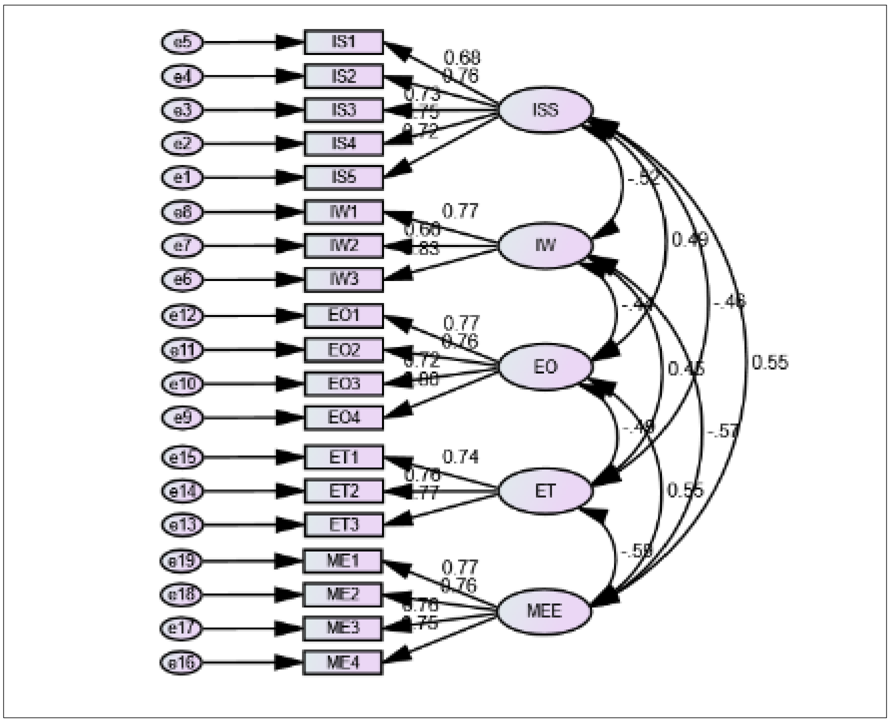

Figure 5. Validation Factor Analysis Model Diagram

Model Fit and Modification

After the measurement model passed the reliability and validity tests, a structural equation model was constructed to examine the relationships among the influencing factors of building energy management and energy management effectiveness.

The initial model was developed according to the theoretical framework and hypotheses H1to H7. It included five latent variables: ISS, IW, EO, ET, and MEE. ISS, IW, EO, and ET were specified as predictors of MEE. In addition, the paths EO to ISS and ET to ISS were specified to examine the mediating role of internal strengths.

Based on the model fit indices and modification indices generated by AMOS 28.0, the model was appropriately modified. To maintain theoretical validity, only error terms with relatively high modification indices and clear theoretical associations were considered for modification, with the aim of improving the overall model fit.

Table 8. Comparison of Initial and Modified Model Fit Indices

Fit Index Category		**Symbol**	**Critical Ratio**	**Test Result**	**Judgment**
Absolute Fit Indices	Chi-square/degrees of freedom	χ^2/df	1–3	1.326	Good
	Root Mean Square Error of Approximation	RMSEA	< 0.06	0.058	Good
Incremental Fit Indices	Comparative Fit Index	CFI	> 0.9	0.973	Good
	Tucker-Lewis Index	TLI	> 0.9	0.968	Good
Parsimonious Fit Indices	Parsimonious Fit Index	PFI	> 0.5	0.683	Good
	Parsimonious Normed Fit Index	PNFI	> 0.5	0.748	Good

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The main fit indices of the modified model met the recommended criteria, indicating that the model provided a satisfactory representation of the observed data and was suitable for subsequent path analysis and hypothesis testing.

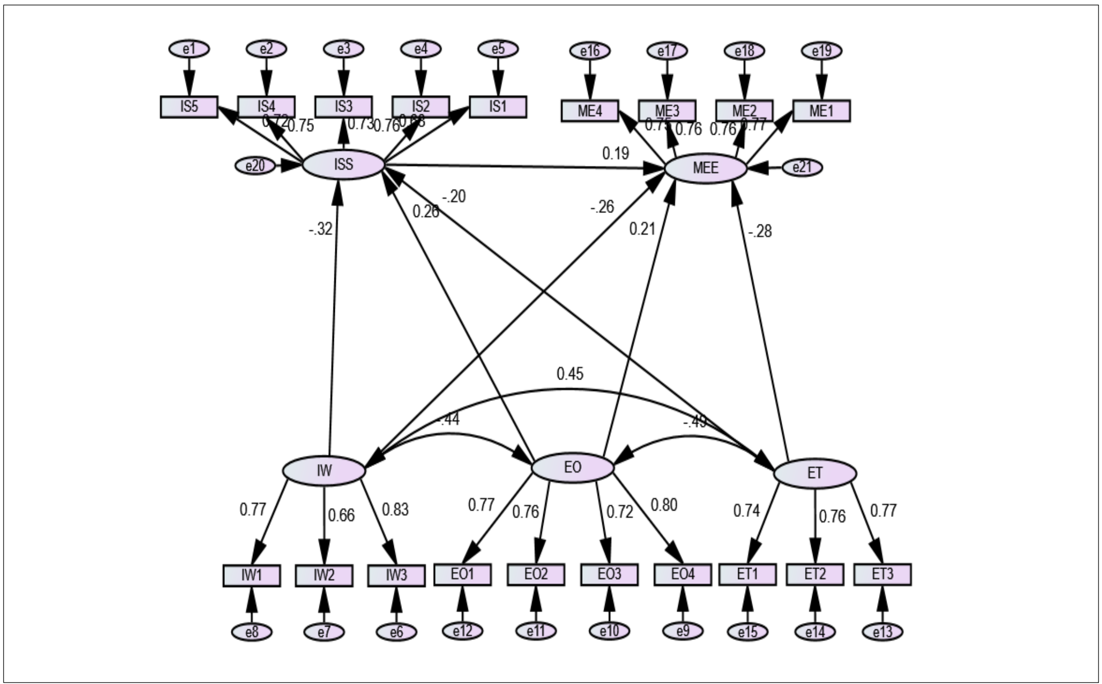

Figure 8. Modified Structural Equation Model

Path Analysis and Hypothesis Testing

Based on the final structural model, standardized path coefficients and significance levels were used to test the proposed hypotheses. A positive path coefficient indicates a positive effect, whereas a negative coefficient indicates a negative effect.

Direct Effects

Table 9. Direct Effect Path Analysis Results

Hypothesis	Path	Standardized β	S.E.	C.R.	P	Result
H1	ISS→MEE	0.187	0.085	2.125	0.034	Supported
H2	IW→MEE	-0.260	0.076	-2.959	0.003	Supported
H3	EO→MEE	0.207	0.076	2.432	0.015	Supported
H4	ET→MEE	-0.284	0.088	-3.206	0.001	Supported

The results focus on the direction and magnitude of the effects of the four types of influencing factors on energy management effectiveness, thereby identifying the major factors affecting energy management performance.

Mediation Effect Analysis

A mediation analysis was further conducted to examine whether internal strengths (ISS) transmit the effects of external factors to energy management effectiveness. The analysis focused on the indirect pathways EO to ISS to ME and ET to ISS to MEE, while also examining the indirect effect of IW to ISS to MEE.

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Table 10. Mediation Effect Test Results

Indirect Path	Coefficient of Antecedent Path	ISS → MEE	Indirect Effect (a×b)	Effect Direction
IW → ISS → MEE	−0.32	0.19	−0.061	Negative
EO → ISS → MEE	0.20	0.19	0.038	Positive
ET → ISS → MEE	−0.20	0.19	−0.038	Negative

The mediation results will be used to determine whether internal strengths serve as a transmission mechanism between external or internal influencing factors and energy management effectiveness, thereby further clarifying the formation mechanism of energy management performance.

Case Analysis And Energy Management Optimization Pathways

Case Background

This study selects a newly constructed industrial plant of a moulding manufacturer as a practical case for building energy management. The company is primarily engaged in the development, design, manufacturing, and sales of automotive components. The project covers an area of approximately 20,000 m², with a total floor area of approximately 21,000 m², and includes six production lines. The main energy types consumed by the project are electricity, natural gas, and fresh water.

After completion, the project is expected to consume approximately 7.5545 million kWh of electricity, 108,500 m³ of natural gas, and 3,700 tonnes of fresh water annually. The total comprehensive energy consumption is approximately 1,060.2 tce (tonnes of coal equivalent, based on the equivalent-value method). Energy consumption is mainly associated with production equipment, compressed-air systems, ventilation, lighting, and air-conditioning systems.

The case incorporates a relatively comprehensive set of building energy-efficiency and energy management measures, including high-efficiency production equipment, variable-frequency control of injection-moulding machines, energy-efficient air compressors, LED lighting, circulating water systems, solar photovoltaic generation, and an energy monitoring system. The project has also appointed dedicated energy management personnel and established an energy management system covering energy planning, energy monitoring, energy statistics, energy consumption analysis, and the management of major energy-consuming equipment. These characteristics provide an appropriate practical setting for examining how the energy management factors identified by the SEM operate in an actual industrial building.

Table 11. Basic Characteristics of the Case Project

Indicator	Basic Information
Building type	Industrial plant and ancillary buildings
Land area	Approximately 20,000 m²
Floor area	Approximately 21,000 m²
Production lines	6
Annual electricity consumption	7.5545 million kWh

Annual natural gas consumption	108,500 m³
Annual fresh water consumption	3,700 t
Comprehensive energy consumption	1,060.2 tce (equivalent-value method)
Energy consumption per unit of output value	0.0365 tce/10,000 yuan
Energy consumption per unit of industrial value added	0.106 tce/10,000 yuan

Major Energy-Using Systems

The energy systems of the case project mainly include production equipment, compressed-air systems, ventilation systems, lighting systems, air-conditioning systems, water supply and drainage systems, and renewable energy systems. Among these, injection-moulding equipment, air compressors, and fans are the major energy-consuming equipment.

The project adopts technologies and measures such as servo motors, variable-frequency speed control, high-efficiency air compressors, energy-efficient lighting, and energy monitoring systems. In addition, measures including circulating water reuse, rainwater harvesting, and solar photovoltaic generation are implemented to reduce energy and resource consumption.

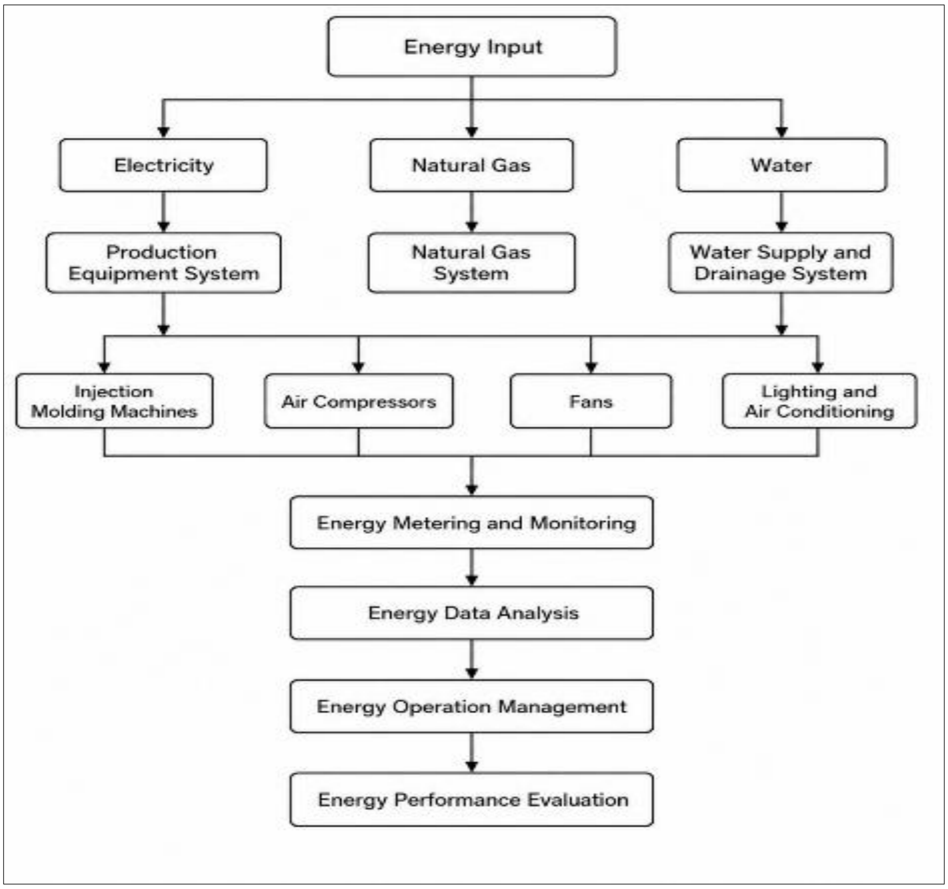

Figure 9. Major Energy-Using Systems and Energy Management System of the Case Industrial Plant

Analysis of Energy Management Measures

The case project has established a relatively comprehensive set of energy-saving technical measures, together with an energy management system and dedicated energy management personnel. These measures provide a practical basis for examining how different influencing factors operate in the actual energy management process.

Internal Strengths: Technical and Management Capabilities

The case project has a relatively strong foundation for energy management in terms of technology and equipment.

In the production process, the project adopts high-efficiency production equipment. Injection molding machines use servo motors and variable-frequency speed control, while production processes and logistics routes are optimized to reduce energy consumption caused by equipment idling and material transportation. The compressed-air system uses variable-frequency screw air compressors that meet Grade 1 energy-efficiency requirements. Fans comply with the relevant energy-efficiency standards, while the lighting system uses LED energy-saving lamps with zonal and grouped control.

In terms of energy management, the project has established an energy management system covering energy planning, energy monitoring, energy statistics, energy consumption analysis, and the management of major energy-consuming equipment. Energy metering devices have also been installed and managed according to a three-level energy metering system.

These measures indicate that the case project has established a relatively strong foundation in terms of equipment, technology, energy monitoring, and energy data management, which is highly consistent with the internal strengths (ISS) identified in the SEM model.

Internal Weaknesses: Gaps in the Energy Management System

Although the project has appointed dedicated energy management personnel and initiated the development of an energy management system, several management weaknesses remain.

According to the case information, the company has appointed an energy management leader and energy management personnel responsible for supervising energy-saving measures, conducting energy statistics, and managing daily energy use. However, the energy management policy and energy targets have not yet been formally established, indicating that the energy management system still requires further improvement.

This situation shows that although the case project has established a certain personnel and institutional foundation, its energy management responsibilities, target system, and continuous improvement mechanisms still have room for improvement.

This finding corresponds well with the negative effect of internal weaknesses (IW) identified by the SEM model. In particular, the absence of clearly defined energy targets may make it difficult to translate energy monitoring results into specific management objectives and improvement measures, thereby limiting improvements in energy management performance.

External Opportunities: Policy and Technological Support

During project development, relevant building energy-efficiency, green building, and energy metering standards were strictly followed, while energy-efficient building design was implemented in consideration of local climatic conditions.

The building design meets the relevant energy-efficiency requirements and incorporates standards related to green industrial buildings and green buildings. The project also adopts measures such as solar photovoltaic systems, sponge-city technologies, and energy-efficient equipment.

These practices indicate that energy-efficiency policies, technical standards, and technological development provide favorable external conditions for enterprises to implement energy management, which is highly consistent with the external opportunities (EO) identified in the SEM model.

External Threats: Cost and Compliance Pressures

The project's energy consumption is primarily electricity-based and also involves natural gas. Therefore, operating costs may be affected by fluctuations in energy prices. In addition, as standards related to building energy efficiency, green buildings, and carbon emissions continue to evolve, enterprises need to continuously adjust their energy management measures and technical solutions.

Therefore, changes in energy prices, increasingly stringent energy-efficiency standards, and rapid technological updates constitute external pressures on energy management. At the same time, these pressures require enterprises to continuously strengthen their internal energy management capabilities, which is consistent with the mechanism of external threats (ET) identified in the SEM model.

Correspondence between SEM Results and Case Practice

Correspondence between SEM Results and Case Practice

To further validate the influencing factors identified by the SEM model, the model results are compared with the actual energy management measures implemented in the case project.

Table 12 Correspondence between SEM Results and Case Practice

Influencing Factor	Effect Identified by SEM	Evidence from Case Practice	Validation Result
Internal Strengths (ISS)	Positive	High-efficiency equipment, energy monitoring, professional personnel, and data management	Supported
Internal Weaknesses (IW)	Negative	Energy targets and the energy management system have not yet been fully established	Supported
External Opportunities (EO)	Positive	Energy-efficiency policies, technical standards, photovoltaic systems, and energy-saving technologies	Supported
External Threats (ET)	Negative	Energy costs, regulatory updates, and technological upgrading pressures	Supported
Mediating effect of ISS	Mediation	External technologies and policies require internal management capabilities for effective implementation	Supported

The case analysis shows that the four types of influencing factors identified by the SEM can be clearly observed in actual energy management practices.

Among them, internal strengths constitute an important foundation for the effective implementation of energy management measures. For example, high-efficiency equipment and energy monitoring systems do not automatically generate energy-saving benefits. They also require energy management personnel to conduct data analysis, optimize equipment operation, and adjust operating conditions. Therefore, the case further demonstrates the fundamental role of internal capabilities in the formation of energy management performance.

At the same time, although the project has dedicated energy management personnel, its energy management policy and energy targets have not yet been fully established. This indicates that having technologies and personnel does not necessarily mean that a complete energy management capability has been established. The absence of appropriate institutional arrangements and targets may reduce the efficiency with which technological investment is translated into improved energy performance.

Transmission Mechanism from External Factors to Energy Management Performance

The case further supports the mediating role of internal strengths.

For example, energy-efficiency policies and green building standards can create favorable conditions for enterprises to adopt energy-efficient equipment, photovoltaic systems, and energy management technologies. However, these external resources must be absorbed and applied through the enterprise's internal personnel, technical capabilities, management systems, and data capabilities before they can generate actual energy-saving outcomes.

This process can be summarized as:

External Policies and Technological Resources to Internal Management and Technical Capabilities to Energy Management Measures to Energy Management Performance

This corresponds well with the SEM pathway:

EO to ISS to ME

Similarly, when facing external pressures such as energy price fluctuations and increasingly stringent energy-efficiency standards, enterprises with stronger internal management capabilities can reduce the impact of these pressures through equipment optimization, energy monitoring, and operational adjustments. Therefore, internal capabilities also serve as an important buffering mechanism for responding to external threats.

Optimization Pathways for Building Energy Management

Based on the SEM results and case analysis, this study further proposes optimization pathways for building energy management.

Strengthening Internal Energy Management Capabilities

The case demonstrates that technological and equipment foundations are important supports for energy management, but they need to be complemented by improved organizational and institutional arrangements.

Therefore, enterprises should further:

Clarify energy management positions, responsibilities, and authorities;

Establish an energy management policy and energy targets;

Improve the energy performance assessment mechanism;

Strengthen the allocation of professional energy management personnel;

Establish mechanisms for energy data analysis, feedback, and improvement.

This can be summarized as:

Personnel Capability to Institutional Development to Data Management to Operational Optimization to Performance Improvement

Improving the Energy Management Closed Loop

In response to the incomplete establishment of energy targets identified in the case, a closed-loop energy management process should be further developed.

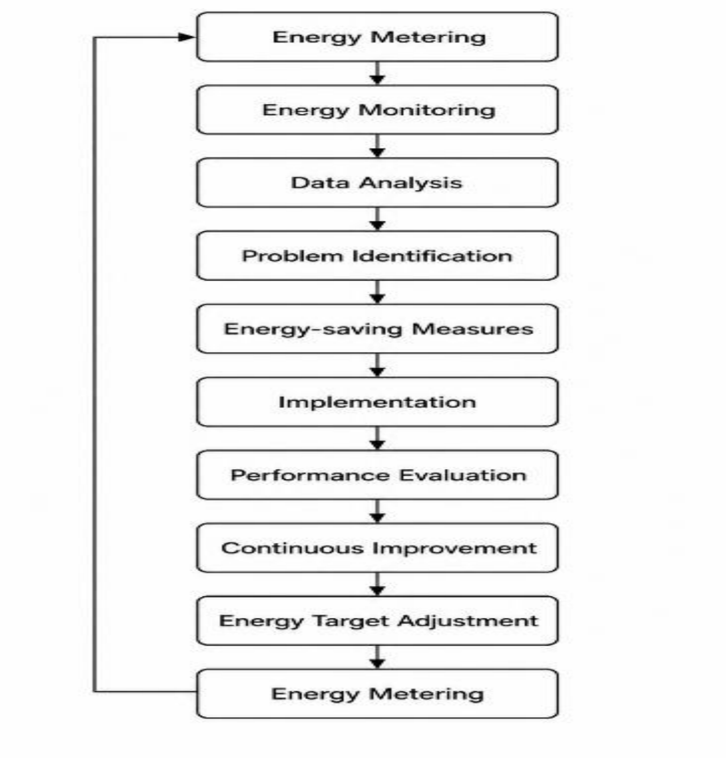

Figure 10. Closed-Loop Optimization Pathway for Building Energy Management

External resources, including energy-saving policies, green finance, technological advances, and professional energy services, should be fully utilized to transform external opportunities into internal energy management capabilities.

Specifically, the following measures should be implemented:

Actively seek policy support for energy-saving retrofits and green building initiatives;

Utilize green financing to reduce the financial burden of energy-saving investments;

Introduce intelligent energy management technologies;

Strengthen cooperation with professional energy service providers;

Promote the utilization of renewable energy;

Optimize energy use strategies in response to changes in energy prices.

Establishing an Energy Risk Prevention and Control Mechanism

In response to external threats such as energy price fluctuations, changes in policies and standards, and technological updates, a dynamic risk identification and management mechanism should be established.

Key measures include:

Monitoring energy price fluctuations;

Tracking energy-saving regulations and standards;

Evaluating emerging energy-saving technologies;

Establishing operational early-warning mechanisms for major energy-consuming equipment;

Analyzing changes in energy costs;

Conducting regular evaluations of energy management performance.

Ultimately, an integrated optimization process can be established as follows:

Strengthening Internal Capabilities to Improving Internal Weaknesses to Utilizing External Resources to Managing External Risks to Continuous Performance Improvement

Final Optimization Pathway

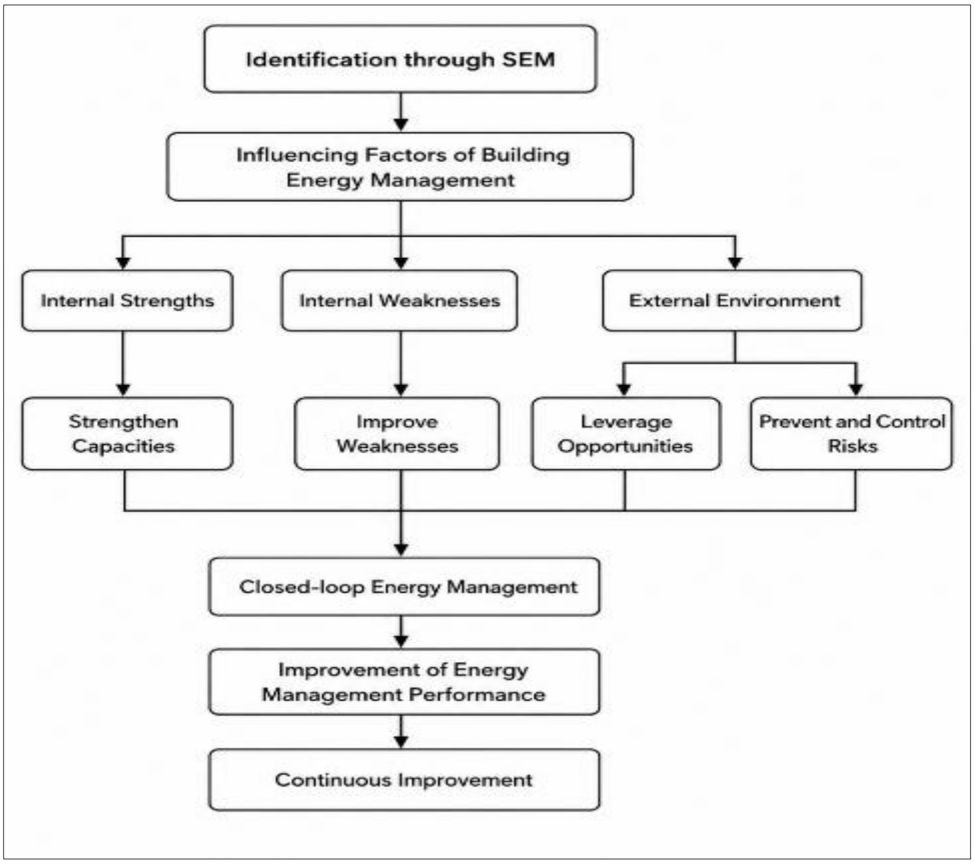

Figure 11. Optimization Pathway for Building Energy Management

CONCLUSIONS

Main Findings

Based on ISO 50001 and socio-technical systems theory, this study integrates SWOT-AHP analysis, questionnaire survey, and structural equation modeling (SEM) to identify the key factors influencing building energy management from four dimensions: internal strengths, internal weaknesses, external opportunities, and external threats. A case study is further employed to examine the applicability of the identified factors in practical energy management. The main findings are as follows.

First, building energy management is a systematic process jointly influenced by technology, management, and the external environment. The study classifies the influencing factors of building energy management into four dimensions: internal strengths (ISS), internal weaknesses (IW), external opportunities (EO), and external threats (ET), with energy management performance (ME) as the outcome variable. The reliability and validity tests indicate that the five latent variables have good internal consistency and construct validity, providing a reliable basis for subsequent SEM analysis.

Second, internal energy management capabilities constitute an important foundation for achieving energy management performance.

Internal strengths are mainly reflected in professional personnel, management systems, equipment infrastructure, technology application, and energy data management capabilities. The case study shows that the enterprise has established an energy management system and assigned dedicated energy management personnel, while implementing energy monitoring, energy statistics, and the management of major energy-consuming equipment. These practices demonstrate that technological infrastructure and organizational capabilities provide fundamental support for implementing energy management measures. However, the energy management policy and energy objectives have not yet been fully established, indicating that internal management capabilities still require further improvement.

Third, internal management weaknesses can constrain the transformation of energy management measures into actual performance. Unclear responsibilities and authority, incomplete energy management processes, and insufficient implementation of performance responsibilities can weaken the practical effects of energy data, technological measures, and management resources. Therefore, building energy management should not rely solely on energy-efficient equipment retrofits. It should also improve management system effectiveness by clarifying responsibilities, strengthening energy management procedures, and ensuring accountability.

Fourth, external policy, technological, and financial conditions can provide important support for energy management, but their benefits need to be realized through organizational capabilities. Low-carbon policies, intelligent energy technologies, professional services, and green finance can reduce external barriers to energy-saving retrofits and energy management implementation. However, external resources alone cannot directly generate improved energy performance. Organizations need adequate technological, personnel, and data-analysis capabilities to absorb and transform these external opportunities into actual energy-saving outcomes.

Fifth, building energy management should establish a continuous closed-loop process of “measurement–monitoring–analysis–improvement–evaluation.” The case study indicates that energy management is gradually shifting from the application of individual energy-saving technologies toward an integrated approach combining energy measurement, online monitoring, data analysis, and operational management. Future energy management should further incorporate energy objectives, performance indicators, operational monitoring, and performance evaluation into an integrated management system, thereby promoting continuous improvement in energy management performance.

Theoretical and Practical Implications

Theoretical Implications

The theoretical implications of this study are mainly reflected in two aspects.

First, the study introduces the ISO 50001 energy management system and socio-technical systems theory into research on the influencing factors of building energy management. By incorporating technology, organizational management, human behavior, and the external environment into an integrated analytical framework, the study extends the traditional research perspective that focuses primarily on energy-efficient equipment and energy-saving technologies.

Second, the combination of SWOT-AHP and SEM establishes a systematic analytical process linking factor identification, importance assessment, and relationship testing. This provides a relatively comprehensive methodological approach for quantitatively examining the mechanisms influencing building energy management performance.

Practical Implications

From a practical perspective, building energy management optimization should focus on the following three aspects.

First, strengthen internal capability development. Organizations should improve their energy management structures, clearly define the responsibilities and authority of energy management positions, assign qualified energy management personnel, and establish energy objectives, performance indicators, and assessment mechanisms.

Second, improve the utilization of energy data. Building on existing energy measurement and monitoring systems, organizations should strengthen energy data collection, analysis, and anomaly identification. The results of data analysis should be incorporated into equipment operation optimization and energy-saving decision-making, thereby promoting a transition from experience-based energy management toward data-driven management.

Third, establish a continuous improvement mechanism. Organizations should make full use of external resources such as policies, technologies, and financing while continuously monitoring changes in energy prices, regulations, standards, and technologies. An integrated energy management mechanism should therefore be established based on the coordinated implementation of internal capability strengthening, internal weakness improvement, external opportunity utilization, and external risk prevention and control.

Research Limitations and Future Research

Although this study develops a model of the influencing factors of building energy management and validates it through questionnaire data and a case study, several limitations remain.

First, the geographical scope of the sample is limited. The survey mainly targeted energy management practitioners in Chengdu and southwestern China. The region has particular characteristics in terms of economic development, energy structure, and policy environment. Therefore, the generalizability of the findings to other regions requires further validation.

Second, the study primarily relies on cross-sectional data. The questionnaire data mainly reflect respondents' perceptions of energy management during a specific period and therefore cannot fully capture the dynamic effects of energy management capabilities over time. Future research could incorporate long-term energy monitoring data to conduct longitudinal analyses.

Third, the measurement of energy management performance could be further refined. The current study primarily measures energy management performance using indicators such as energy consumption reduction, operational efficiency and cost savings, user satisfaction, and industry certification. Future research could incorporate objective indicators, including actual energy consumption, energy use intensity, carbon emissions, and the payback period of energy-saving investments, to improve the accuracy of energy management performance evaluation.

Fourth, comparative research across different building types could be further developed. Buildings include hospitals, schools, office buildings, commercial buildings, and other types, each with different energy-use characteristics and management requirements. Future research could conduct cross-regional and cross-building-type comparisons and integrate actual energy consumption data with data from intelligent energy management platforms to further examine the robustness, applicability, and boundary conditions of the proposed model.

REFERENCE

1. Andolfi, L., Lima Baima, R., Burcheri, L. M., Pavić, I., & Fridgen, G. (2024). Sociotechnical design of building energy management systems in the public sector: Five design principles. Applied Energy, 377, 124628. https://doi.org/10.1016/j.apenergy.2024.124628.
2. Cagno, E., Moschetti, R., Trianni, A., & Pizzocri, M. (2022). How do we learn about drivers for industrial energy efficiency—Current state of knowledge. Energies, 15(7), 2642. https://doi.org/10.3390/en15072642.
3. Cagno, E., Trianni, A., Abeelen, C., Worrell, E., & Miggiano, F. (2022). A novel characterization based framework to incorporate industrial energy management services. Applied Energy, 306, 118891. https://doi.org/10.1016/j.apenergy.2022.118891

4. Cavalcanti, G. O., & Pimenta, H. C. D. (2023). Electric energy management in buildings based on the Internet of Things: A systematic review. Energies, 16(15), 5753. https://doi.org/10.3390/en16155753
5. Culot, G., Nassimbeni, G., Orzes, G., & Sartor, M. (2023). Industrial digitalization: A systematic literature review and research agenda. European Management Journal, 41(1), 47–78. https://doi.org/10.1016/j.emj.2022.01.001
6. Fitzgerald, P., Therkelsen, P., Sheaffer, P., & Rao, P. (2023). Deeper and persistent energy savings and carbon dioxide reductions achieved through ISO 50001 in the manufacturing sector. Sustainable Energy Technologies and Assessments, 57, 103280. https://doi.org/10.1016/j.seta.2023.103280.
7. Fuchs, H., Aghajanzadeh, A., & Therkelsen, P. (2020). Identification of drivers, benefits, and challenges of ISO 50001 through case study content analysis. Energy Policy, 142, 111443. https://doi.org/10.1016/j.enpol.2020.111443
8. International Organization for Standardization (ISO). (2018). ISO 50001:2018 Energy management systems—Requirements with guidance for use. Geneva: International Organization for Standardization.
9. International Organization for Standardization. (2018). ISO 50001:2018 Energy management systems—Requirements with guidance for use. Geneva: International Organization for Standardization.
10. International Telecommunication Union (ITU). (2024). Recommendation ITU-T L.1260: Reference model of a factory energy management system. Geneva: International Telecommunication Union.
11. Kaya, D., Kılıç, F. Ç., & Öztürk, H. H. (2021). Energy efficiency in compressed air systems. In Energy Management and Energy Efficiency in Industry (pp. 395–418). Cham: Springer. https://doi.org/10.1007/978-3-030-25995-2_13.
12. Mischos, S., Dalagdi, E., & Vrakas, D. (2023). Intelligent energy management systems: A review. Artificial Intelligence Review, 56, 11635–11674. https://doi.org/10.1007/s10462-023-10441-3
13. Mischos, S., Dalagdi, E., & Vrakas, D. (2023). Intelligent energy management systems: A review. Artificial Intelligence Review, 56, 11635–11674. https://doi.org/10.1007/s10462-023-10441-3.
14. Mustaffa, N. K., & Kudus, S. A. (2022). Challenges and way forward towards best practices of energy efficient building in Malaysia. Energy, 259, 124839. https://doi.org/10.1016/j.energy.2022.124839
15. Pandin, M., Sumaedi, S., Yaman, A., & Ayundyahrini, M. (2024). ISO 50001 based energy management system: A bibliometric perspective. International Journal of Energy Sector Management, 18(6), 1938–1960. https://doi.org/10.1108/IJESM-08-2023-0001.
16. Sheaffer, P., et al. (2023). ISO 50001-based energy management systems as a practical path for decarbonization: Initial findings from a survey of technical assistance cohort participants. Energies, 16(14), 5441. https://doi.org/10.3390/en16145441
17. Sievers, J., & Blank, T. (2023). A systematic literature review on data-driven residential and industrial energy management systems. Energies, 16(4), 1688. https://doi.org/10.3390/en16041688
18. Sievers, J., & Blank, T. (2023). A systematic literature review on data-driven residential and industrial energy management systems. Energies, 16(4), 1688. https://doi.org/10.3390/en16041688.
19. Smith, K. M., Wilson, S., & Hassall, M. E. (2022). Barriers and drivers for industrial energy management: The frontline perspective. Journal of Cleaner Production, 335, 130320. https://doi.org/10.1016/j.jclepro.2021.130320.
20. Smith, K. M., Wilson, S., & Hassall, M. E. (2022). Barriers and drivers for industrial energy management: The frontline perspective. Journal of Cleaner Production, 335, 130320. https://doi.org/10.1016/j.jclepro.2021.130320
21. Thollander, P., Backlund, S., Trianni, A., & Cagno, E. (2021). Overcoming the efficiency gap: Energy management as a means for overcoming barriers to energy efficiency—Empirical support in the case of Austrian large firms. Energy Efficiency, 14. https://doi.org/10.1007/s12053-021-09954-z
22. U.S. Department of Energy / Lawrence Berkeley National Laboratory. (2022). Organizational Behavior Insights from 50001 Ready Technical Assistance Cohorts. Lawrence Berkeley National Laboratory.
23. Wang, W. B., Wen, Y. S., Xiao, X. D., Guo, G. Q., Wu, Y. J., & Du, Y. (2024). Application and exploration of digital energy management technology in large-scale energy equipment manufacturing enterprises. *Dongfang Electric Review*, 38(6), 80-84.
24. Wittmann, M., et al. (2022). Obstacles to demand response: Why industrial companies do not adapt their power consumption to volatile power generation. Energy Policy, 165, 112876. https://doi.org/10.1016/j.enpol.2022.112876
25. Yu, W., Patros, P., Young, B. R., Klinac, E., & Walmsley, T. G. (2022). Energy digital twin technology

for industrial energy management: Classification, challenges and future. Renewable and Sustainable Energy Reviews, 161, 112407. https://doi.org/10.1016/j.rser.2022.112407.
26. Yue, H., Worrell, E., Crijns-Graus, W., Liu, W., & Zhang, S. (2021). Saving energy in China's industry with a focus on electricity: A review of opportunities, potentials and environmental benefits. Energy Efficiency, 14, 60. https://doi.org/10.1007/s12053-021-09979-4.
27. Zhou, J., Fennell, P., Korolija, I., Fang, Z., Tang, R., & Ruyssevelt, P. (2024). Review of non-domestic building stock modelling studies under socio-technical system framework. Journal of Building Engineering, 97, 110873. https://doi.org/10.1016/j.jobe.2024.110873.