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Research Paper

Developing Prescriptive and Performance Indicators Framework for Energy Efficiency of Office Buildings Using Delphi Method

Sajad Sadi [1] and *Masoud Alilou* [2, *]

[1]*Department of Mechanical Engineering, Imam Hossein Comprehensive University, Tehran, Iran.*
[2]*Department of Electrical Engineering, Engineering Faculty of Khoy, Urmia University of Technology, Urmia, Iran.*

Abstract— *Optimizing electrical energy consumption in office buildings has become a critical concern for researchers and policymakers with regard to the growing emphasis on energy efficiency and sustainability. For this reason, this paper presents a comprehensive study on prescriptive indicators for electrical energy consumption in office buildings, utilizing the Delphi method to ensure their validity and reliability. The analysis categorizes building energy usage into eight key domains: electric motors, lighting, reactive power, office equipment, smart systems, distributed generation, electricity distribution losses within the building, and overall building performance. For each category, relevant indicators are systematically developed. A structured questionnaire was designed and distributed among experts in the electrical energy field to validate these indicators. Based on their assessments, a total of 19 indicators were established, comprising 17 prescriptive indicators and 2 performance indicators. These indicators were then classified based on their effectiveness into three groups: highly effective, effective, and less effective. According to the experts' assessments and statistical evaluation, indicators including electric motor efficiency, compliance with load characteristics, adoption of high-efficiency electric motors, RPM control mechanisms, lighting equipment efficiency, lighting system power density, the presence or absence of switching-type lighting control, and the energy labeling of office equipment demonstrated a higher degree of influence on energy consumption. Therefore, given their significant impact, these factors should be prioritized in building energy design and auditing to optimize efficiency and performance.*

Keywords—Prescriptive indicators, performance indicators, electrical energy, office building, Delphi method.

1. Introduction

Energy consumption remains a critical global concern, directly influencing economic development, environmental sustainability, and societal well-being. As global demand continues to rise, buildings have emerged as a major contributor—accounting for approximately one-third of total energy use in developed countries [1]. Enhancing energy efficiency in this sector is therefore essential for mitigating environmental impacts and achieving long-term sustainability goals. Green and efficient buildings aim to balance economic, environmental, and social priorities. Effective energy management within these buildings depends on identifying key consumption drivers and implementing targeted strategies. Among these, the development of robust energy performance indicators plays a pivotal role in guiding policy, forecasting demand, and improving operational practices. International efforts have led to the adoption of various indicators and standards across building types, including energy labels and regulatory frameworks [2]. Despite these advancements, the building sector still accounts for nearly 39% of global energy consumption, underscoring the need for more comprehensive and context-specific assessment tools. In this regard, Iran's position as a major energy producer and consumer—with significant greenhouse gas emissions—highlights the urgency of adopting tailored approaches to energy efficiency [3].

The rapid growth of energy consumption, ranging from 1–2% globally but soaring to 5–8% in Iran, underscores the urgency of implementing effective energy management strategies. In Iran, the building sector, despite being a non-energy-producing domain, represents the largest share of total consumption, with more than 44.7% of the country's energy use directly linked to this sector [4]. Recognizing this challenge, many countries have prioritized energy efficiency across various sectors, particularly buildings, by allocating significant investments toward creating sustainable environments. Energy labeling has emerged as a crucial tool for reducing energy consumption and enhancing the efficiency of both existing and newly constructed buildings. The implementation of energy labeling programs in public and government office buildings enables systematic monitoring of energy-saving measures, facilitating annual energy category evaluations and promoting awareness among the general public. By aligning buildings with established codes and regulations, energy labels not only enhance compliance but also allow comparisons across similar structures, supporting efforts to improve energy performance through targeted interventions [5].

Countries such as those in the European Union, the United States, Canada, and Australia have established structured approaches to energy consumption management and labeling in the building sector. In the EU, various regulations have been introduced to meet greenhouse gas reduction targets, with building energy labeling playing a central role. One of the key directives, Directive

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*Corresponding author:
E-mail: masoud.alilou@gmail.com (M. Alilou)
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2002/91/EC, was enacted on December 16, 2002, requiring member states to comply with minimum energy consumption standards for buildings. Since its implementation on January 4, 2003, this directive has significantly influenced energy efficiency policies across Europe [6]. Similarly, building construction regulations in England and Wales categorize energy standards separately for residential and non-residential buildings, integrating best practices across electrical, architectural, and mechanical domains [7]. In the United States, energy efficiency initiatives trace back to 1974 when California first introduced building energy consumption standards [8]. Over the years, two national standards emerged, one addressing international energy reduction goals and the other governed by ASHRAE regulations. While the U.S. initially focused on energy labels for internal building equipment, broader energy labeling for entire buildings became a priority in later years. Notably, the Energy Star program, launched in 1992, revolutionized building energy assessments by introducing rankings and scores, ultimately awarding the Energy Star Sign to the top 25% of EPA-rated buildings [9]. Additionally, the U.S. Green Building Association developed the Leadership in Energy and Environmental Design (LEED) program, incorporating sustainability considerations beyond energy efficiency, such as aesthetics and environmental harmony. LEED certifications require compliance with ASHRAE 90.1 standards, with buildings achieving extra recognition for surpassing minimum efficiency criteria [10].

In Iran, efforts to manage energy consumption and introduce energy labeling have gained traction in recent years. The country has implemented energy labeling for various energy-consuming appliances, culminating in the successful execution of office building energy labeling programs in late 2011. Spearheaded by the National Standards Organization, the Iranian Energy Efficiency Organization (SABA), and the Fuel Consumption Optimization Company, these initiatives established national standards under registration numbers 14253 (for residential buildings) and 14254 (for non-residential buildings) [11]. Energy labeling methodologies in Iran follow both performance-based and calculated approaches [12]. Performance-based classification applies to buildings with at least three years of energy consumption history, while newly constructed buildings rely on calculated assessments. However, reliance on utility bills presents limitations, as factors beyond design, such as occupant behavior, climatic conditions, and building usage, affect energy consumption patterns. Additionally, existing methodologies primarily focus on lighting efficiency, neglecting other significant electrical energy aspects. A fundamental challenge in building energy labeling lies in identifying and evaluating all relevant energy consumption parameters. Given rapid technological advancements, particularly in modern and smart buildings, a comprehensive set of indicators must reflect all aspects of energy use. While ISO 50001 and Energy Star provide foundational guidelines for energy management and performance tracking, they primarily focus on operational efficiency and benchmarking. In contrast, the proposed framework integrates both prescriptive and performance indicators across eight categories, including emerging domains such as smart systems and distributed generation. This broader scope allows for a more comprehensive assessment of electrical energy performance, particularly in modern office buildings with complex energy profiles. Table 1 presents the main contribution of this paper in comparison with other published papers.

This study aims to develop prescriptive indicators for electrical energy consumption in office buildings, providing a structured approach to energy efficiency beyond conventional labeling. Section 2 presents the preparation of indicators, categorizing energy usage into key domains such as electric motors, lighting, reactive power, office equipment, smart systems, distributed generation, electricity distribution losses, and overall building performance, each analyzed through targeted sub-indicators. Section 3 details the research methodology, where expert evaluations via a structured questionnaire ensure the validity and reliability of the proposed indicators. Findings are discussed in Section 4, highlighting the effectiveness of specific indicators in optimizing energy consumption. Finally, Section 5 synthesizes the key results, outlining the implications for energy management policies, sustainability initiatives, and future efficiency frameworks.

2. INDICATOR PREPARATION

A smart building, from an electrical energy perspective, operates as a micro-network encompassing generation, distribution, consumption, and automation, all managed by a Building Management System (BMS). To achieve a comprehensive energy assessment, each building must be evaluated across these four fundamental platforms [17]. Recent advancements in electricity generation, particularly distributed generation and renewable energy technologies, have enabled buildings to partially or fully meet their energy demand through on-site generation. The adoption of distributed generation enhances reliability, ensuring that buildings can maintain power supply even during grid blackouts [18].

On the consumption side, energy usage in buildings can be classified into active power and reactive power. Active power represents the primary electricity demand, consumed by various building equipment, which can be broadly categorized into lighting systems, office equipment, and electric motors. Reactive power, predominantly associated with electric motors, must also be considered to improve overall efficiency [19].

The distribution system, primarily comprising electrical cabling, plays a crucial role in safely delivering electricity while adhering to relevant standards [20]. However, energy losses within the distribution system contribute to overall consumption and must be accounted for in efficiency assessments. Given the rapid evolution of smart buildings, the integration of BMS-driven automation significantly impacts electricity consumption [21]. Thus, Building Automation and Smart Systems are considered an integral subsection of the consumption category, enabling optimized management and reduced energy usage [22].

This study classifies buildings into two primary platforms including generation and consumption to systematically prepare electrical energy indicators for office buildings. Indicators are then developed using both prescriptive and performance-based approaches to ensure a holistic evaluation of energy efficiency. The process begins with identifying key areas of electricity usage within a building, followed by a detailed examination of critical energy-consuming sections. A summary of this methodology, including methods and innovations applied at each stage, is provided in Table 2. Indicators in the consumption platform are categorized into five primary sections, including electric motor equipment, lighting equipment, office equipment, distribution system losses, and building management and automation systems. Meanwhile, indicators in the generation platform focus on distributed generation, assessing the role of on-site power production in enhancing reliability and efficiency. Beyond these prescriptive indicators, overall building performance, as an additional category, is introduced to provide a broader evaluation framework. This section incorporates two key performance indicators, widely used in international energy assessment models: specific energy effectiveness indicator (kWh/m^2.yr) and energy consumption per capita indicator (kWh/person.yr).

Therefore, this study classifies building energy indicators into eight distinct categories, as illustrated in Fig. 1. Each category is examined independently, with corresponding indicators systematically extracted in subsequent sections to establish a robust energy efficiency framework for office buildings. This figure presents an overview of the methodological framework used to develop and validate energy performance indicators for office buildings. The process begins with the collection of 41 initial indicators, 35 prescriptive and 6 performance-based, selected based on expert input and literature review. These indicators undergo a three-stage validation process: Content Validity Ratio

Table 1. Taxonomy of selected prior studies on energy efficiency indicators in buildings.

Study	Methodology	Indicator type	Application domain	Key contribution
[13]	Empirical benchmarking	Performance	Commercial buildings	Developed a scoring model for HVAC systems.
[14]	Simulation-based	Prescriptive	Residential buildings	Proposed lighting efficiency metrics.
[15]	Delphi method	Mixed	Office buildings	Validated indicators for smart systems.
[16]	Policy analysis	Prescriptive	Cross-sector	Provided global energy efficiency guidelines.
This study	Delphi method + CVR/CVI/Cronbach's Alpha	Mixed (Prescriptive + Performance)	Office buildings	Developed and validated a comprehensive framework comprising eight indicator categories.

Table 2. The summary of executions and innovations in each section of the present study.

Innovation	Method	Section	Stage
–	Survey of the literature	Identification of electric energy usage areas in office buildings	Extraction of indicators
Comprehensive description of effective factors influencing building electrical energy usage	Literature survey and Delphi method	Determination of effective sections within each usage area	Extraction of indicators
Extraction of 19 indicators (including 17 prescriptive indicators and 2 performance indicators)	Literature survey and Delphi method	Extraction of prescriptive indicators for each section	Extraction of indicators
Reliability and validity evaluation of the extracted electrical energy usage indicators	CVR, CVI, and Cronbach's Alpha	Reliability and validity assessment of the extracted indicators	Analysis and evaluation of indicators

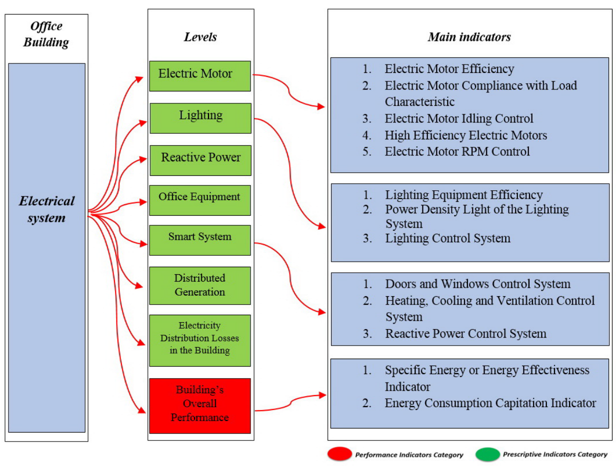

Fig. 1. The framework of indicators related to the electrical energy in an office building.

(CVR) with a threshold of 0.33, Content Validity Index (CVI) with a threshold of 0.79, and internal consistency measured via Cronbach's Alpha (α = 0.87). Indicators meeting these criteria are retained for quantification and scoring. The final stage involves aggregating scores across eight thematic categories to produce an overall classification of energy performance. Each indicator plays a specific role in this structure, contributing to a multidimensional assessment that balances technical, operational, and contextual factors. This framework ensures methodological rigor and transparency in evaluating energy efficiency within office environments.

2.1. Electric motor

Electric motors are among the most significant electricity consumers within a building's power system, accounting for a substantial portion of overall energy consumption. Various motor-driven systems, such as pumps, fans, escalators, elevators, and lifts, contribute significantly to the energy demand in office buildings. Studies indicate that the potential for economic energy savings in electric motors is approximately 29% across the EU, representing 7% of the total electricity consumption within the Union [23]. Given similar operational conditions, such savings can be realized in Iran as well. Several key strategies are identified to optimize motor efficiency and minimize energy waste. These strategies are [24]:

- Reducing motor losses: Selecting motors with high efficiency, improving input power quality, and ensuring appropriate motor sizing.
- Lowering motor load: Implementing efficient control systems such as gearboxes and drives to optimize energy use.
- Adjusting motor speed to match load demand: Utilizing variable-speed drives and multi-speed motor configurations to prevent unnecessary energy consumption.
- Enhancing motor switching efficiency: Deploying automated monitoring systems to deactivate motors when idle or under minimal load.

Each of these optimization strategies is examined in detail in the following subsections, providing insight into their application within office building energy management frameworks.

A) Electric motor efficiency

The energy consumption of motor-driven loads is heavily influenced by design methodology, making motor efficiency a critical indicator of design quality. Each motor's efficiency rating is provided on its identification tag, offering a standardized measure of its performance [25]. To develop meaningful indicators for evaluating the design quality of electric motors, efficiency levels must be assessed against established standard efficiency benchmarks [26]. The International Electrotechnical Commission (IEC) defines global standards for electric motor efficiency [27], ensuring consistency in classification and performance assessment. Given the importance of optimizing motor efficiency, every motor selected for use in office buildings must operate within an acceptable efficiency range. Electric motors are classified internationally into three efficiency tiers:

- IE1 Class: Represents motors with conventional designs, lacking control mechanisms, and meeting minimum acceptable efficiency.
- IE2 Class: Includes motors equipped with drives, improving efficiency through better operational control.
- IE3 Class: Consists of high-efficiency motors, designed to achieve superior energy performance.

The assignment of motor efficiency classes depends on national regulations and specific application requirements [28]. Indicator No.1 (electric motor efficiency) is defined as:

$$I_1 = \frac{\eta_M}{\eta_{IE1}} \tag{1}$$

where, η_M and η_{IE1} represent the actual efficiency of the electric motor and the minimum standard efficiency set for IE1 class motors, respectively. A motor exhibits higher design quality when the indicator value exceeds 1, indicating efficiency levels surpassing the minimum standard.

B) Electric motor compliance with load characteristic

Both three-phase and single-phase induction motors are widely used across various applications due to their versatility. However, their efficiency and performance depend on proper alignment between motor characteristics and the mechanical load they serve [29]. This alignment ensures that the motor effectively delivers the required mechanical energy without excessive losses. Selecting the correct motor power and size is crucial, as operating a motor under low-load conditions significantly reduces its efficiency. When a motor is oversized relative to its required capacity, it operates at a lower load factor, leading to unnecessary energy consumption and performance degradation. Thus, ensuring that the motor size corresponds to the actual consumption load is essential for energy efficiency [30]. Thus, the optimal motor selection offers several benefits such as lower motor purchase costs, reduced expenditures on switches and cabling, minimized power factor correction costs, and energy savings by preventing efficiency drops.

Motor-load mismatches are common, with oversized motors frequently operating at partial loads. In such cases, motors fail to reach their rated efficiency, increasing overall electricity consumption. Some applications require precise calculations by design engineers to determine the appropriate motor specifications. The indicator No.2 (load factor of the electric motor) is defined by Eq. (2).

$$I_2 = \frac{P_L}{P_M} \tag{2}$$

Here, P_L and P_M represent the maximum load power and the electric motor's output power, respectively. The optimal range for this indicator is between 0.8 and 0.9. If the value exceeds 1, the motor is operating under overload conditions, which may lead to mechanical failure over time. Conversely, if the value falls below 0.75, efficiency drops due to deviations from optimal design parameters [30].

C) Electric motor idling control

One of the most effective strategies for direct energy savings in electric motors is eliminating no-load losses by ensuring motors are turned off when not in active use. Despite its simplicity, this method, whether through continuous monitoring or automated control systems, is often overlooked. In many cases, electric motors under no-load conditions consume nearly the same current as when operating at full load, leading to unnecessary energy waste [31].

A straightforward solution to prevent these inefficiencies is the integration of switching mechanisms, enabling motors to automatically deactivate when idle. This system significantly reduces standby power consumption, improving overall energy performance. Therefore, Indicator No. 3 (Electric Motor Idling Control) is defined as a binary metric, expressed as Eq. (3):

$$I_3 = \left\{ \begin{array}{l} 1 \\ 0 \end{array} \right. \tag{3}$$

Here, 1 presents that the motor is equipped with an automatic switching mechanism for idling control. On the other hand, 0 shows that no idling control mechanism is utilized, resulting in continuous energy losses when the motor is not under load. Ensuring that motors are equipped with effective idling control systems contributes to substantial energy savings, making this indicator a key factor in optimizing electrical consumption in office buildings.

D) High efficiency electric motors

While high-efficiency motors typically have a higher initial cost than standard models, they provide substantial long-term economic benefits through improved energy savings and operational performance [32]. These motors contribute to reduced energy costs, lower environmental impact, and enhanced reliability in building systems by consuming less electricity for the same mechanical output. For this reason, indicator No.4 is defined by Eq. (4) for evaluating high efficiency motors.

$$I_4 = \frac{\eta_M}{\eta_{IE3}} \tag{4}$$

Here, η_M and η_{IE3} are the efficiency of the examined electric motor and the standard efficiency according to the IE3 classification for high-efficiency motors, respectively. A motor is considered highly efficient if the indicator value is equal to or greater than 1, indicating that its performance meets or exceeds IE3 standards. The adoption of high-efficiency motors can be recognized as a positive factor in the process of building energy labeling, reinforcing sustainable practices and optimizing electricity consumption in office environments.

E) Electric motor RPM control

The integration of RPM controllers (drives) in electric motors enables continuous speed regulation, allowing motors to adjust dynamically according to load demand. This eliminates energy losses associated with traditional mechanical control methods, such as valves or dampers, which regulate flow but introduce inefficiencies. Electric motors, which utilize drivers, align precisely with consumption needs, eliminating frequent switching cycles and improving overall performance. Additionally, electronic control boards significantly reduce component wear, extending operational longevity. Fans and pumps, as two of the most common motor-driven systems in office buildings, often rely on mechanical flow regulators such as dampers or valves. These methods, while effective, contribute to unnecessary energy losses. Studies indicate that implementing motor drives in these applications can yield energy savings of up to 50% [31].

Indicator No. 5 (electric motor RPM control) evaluates whether a motor is equipped with a speed regulation mechanism, as presented in Eq. (5).

$$I_5 = \left\{ \begin{array}{l} 1 \\ 0 \end{array} \right. \tag{5}$$

In this indicator, 1 shows that the motor has an RPM controller, allowing continuous speed adjustment. Conversely, 0 presents that no RPM control mechanism is utilized, leading to energy losses in speed regulation. This indicator plays a crucial role in assessing motor efficiency strategies in order to ensure energy optimization in office buildings.

2.2. Lighting

Lighting is one of the most significant electricity consuming systems in office buildings, often accounting for over 40% of total electricity costs in buildings with natural ventilation. An optimized lighting design not only reduces energy expenditures but also minimizes heat generation, lowering the need for additional ventilation [33]. Beyond energy-efficient lighting systems, the visual environment plays a key role in reducing consumption. Factors such as strategic lighting design, color selection for barriers, reflection coefficients of walls and appliances, window positioning, and daylight utilization directly impact overall efficiency [34]. A well-designed lighting system, developed in accordance with global standards [33], ensures both aesthetic quality and energy optimization.

It should be noted that the primary considerations in an optimal lighting strategy include the following items:

- Selection of appropriate colors based on reflectivity and environmental application
- Maximizing daylight utilization through strategic architectural design
- Deployment of high-efficiency lighting systems with planned maintenance schedules
- Proper lighting system selection, tailored to building functionality

• Integration of lighting control mechanisms for regulated energy use

• Adherence to standardized lighting calculations, ensuring compliance with efficiency benchmarks

So, a set of prescriptive indicators must be developed to assess energy consumption, system effectiveness, and design quality in order to systematically evaluate lighting efficiency in buildings. These indicators will be defined and examined in the following subsections.

A) Lighting equipment efficiency

The selection of high-efficiency lighting sources plays a crucial role in reducing electricity consumption in office buildings. Several key factors, including efficiency, lifetime, controllability, and input power, must be carefully considered when choosing appropriate lighting solutions [34]. The primary indicator for evaluating the quality and performance of lighting sources is efficiency, which determines how effectively electrical input is converted into visible light. Therefore, indicator No. 6 (Lighting equipment efficiency) is defined by Eq. (6).

$$I_6 = \frac{out_{Luman}}{in_W} \tag{6}$$

Where, out_{Lumen} represents the total light emitted by the lamp and in_W is the electrical energy consumed by the lamp in watts. Manufacturers conduct standardized efficiency calculations for lighting products, which are provided alongside energy labels to facilitate informed decision-making. Ensuring compliance with efficiency benchmarks contributes to optimized lighting strategies and support both energy conservation goals and cost reduction efforts in office buildings.

B) Power density light of the lighting system

Power density serves as a fundamental indicator for assessing the quality and efficiency of a lighting system within different sections of a building. It quantifies the electric power consumption per square meter for a given lighting arrangement. Several factors, including the number and type of lighting sources, their input power, and efficiency, significantly influence power density. Additionally, lamp quality, environmental reflectivity, and visual comfort affect overall lighting performance [35]. Power density for specific region is mathematically calculated by Eq. (7).

$$PD_i = \frac{\sum_{j=1}^{No_j} (P_j \times n_j)}{S_i} \tag{7}$$

Here, PD_i represents the power density of the lighting system in the i-th region in $\frac{W}{m^2}$. S_i is the area of the i-th region and n_j represents the number of lights from type j with an input power of P_j in the i-th region. No_j denotes the number of different lighting sources in the considered region.

Considering that the required Lux affects the power density, indicator No. 7 is defined in Eq. (8). This relation determines the power density of the i-th region for the provision of 100 Lux flux.

$$I_7 = \frac{PD_i}{K_i} = \frac{\sum_{j=1}^{No_j} (P_j \times n_j)}{S_i \times K_i} \tag{8}$$

$$K_i = \frac{Lux_i}{100} \tag{9}$$

This indicator ensures that power density calculations align with illumination standards to facilitate the improved energy efficiency assessments for office buildings.

C) Lighting control system

Effective daylight utilization is a key factor in reducing energy consumption within a building's lighting system. When natural daylight levels are high, an efficient lighting control system must adjust artificial lighting accordingly to prevent unnecessary electricity use. Conversely, as daylight diminishes, the system gradually increases artificial lighting levels to maintain optimal illumination. However, simply incorporating daylight does not guarantee energy efficiency, improper control mechanisms can even lead to higher energy consumption [35]. Studies indicate that the choice of lighting control system can impact total energy consumption in buildings by 30–40%. Thus, making strategic selection is essential for energy efficiency [36].

Lighting systems are broadly classified into manual and automatic control mechanisms. Manual control is typically unregulated. In other words, it relies on occupant discretion to adjust lighting levels. On the other hand, automatic control systems are categorized into two systems including switching control and dimmer control systems. Switching control systems activate or deactivate lighting based on occupancy sensors or timers, while dimmer control systems utilize photoelectric sensors to measure ambient light and dynamically adjust illumination intensity based on required Lux levels. The presence or absence of automatic lighting control systems is assessed using two binary indicators No. 8 and No. 9, as presented in equations 10 and 11.

$$I_8 = \begin{cases} 1 \\ 0 \end{cases} \tag{10}$$

$$I_9 = \begin{cases} 1 \\ 0 \end{cases} \tag{11}$$

Indicator 8 (No.8) is considered for evaluating the presence of switching-type control system (1: present, 0: absent). Indicator 9 (No.9) is considered for evaluating the presence of dimmer-type control system (1: present, 0: absent). Lighting efficiency can be optimized in order to reduce energy costs and improve overall building performance by incorporating these control strategies.

2.3. Reactive power

Power factor correction is one of the most effective investment strategies for reducing energy costs and improving electrical efficiency. Implementing reactive power compensation can yield rapid financial returns, as it minimizes reactive power demand from the grid and mitigates system losses. Recent advancements have enhanced the reliability and capacity of compensators in order to simplify their installation and integration into building energy management systems.

It's worth mentioning here that in office buildings, electric motors and fluorescent discharge lamps are the primary consumers of reactive power. Electric motors require reactive power to generate magnetic fields, which are essential for their operation. On the other hand, fluorescent lamps utilize choke components, contributing to reactive power demand.

The most critical factor in assessing reactive power consumption is the power factor. It represents how efficiently electrical power is utilized. A building's overall power factor is influenced by the compensation measures applied to its electrical equipment. Therefore, two key indicators are defined for evaluating reactive power efficiency. Indicator No. 10, which is defined in Eq. (12), calculates the power factor of individual equipment. It evaluates the efficiency of each reactive power consuming component.

$$I_{10} = \cos\left(\tan^{-1}\frac{Q_i}{P_i}\right) \tag{12}$$

Indicator No. 11, which is defined in Eq. (13), calculates the total power factor of the building. This indicator, which represents the overall power factor of the building, evaluates the effect of compensation on all systems of the building.

$$I_{11} = \cos\left(\tan^{-1}\frac{Q_T}{P_T}\right) \tag{13}$$

By monitoring these indicators, buildings can optimize reactive power compensation strategies, improve energy efficiency, and reduce operational costs associated with excess reactive power demand.

2.4. Office equipment

Office equipment, including computers, printers, copy machines, and monitors, accounts for 7–25% of total electricity consumption in office buildings. As technology advances, the energy demand of this category is increasing. So, the efficient utilization strategies are crucial for energy conservation. Implementing targeted measures to optimize office equipment use can lead to significant electricity savings, with recent studies suggesting a potential 70% reduction in energy consumption through low-power technologies and improved operational practices [37–40].

The energy label of each device serves as a critical metric for evaluating its power consumption profile. For this reason, two key indicators, including efficiency and quantity, are introduced to systematically assess office equipment performance.

Indicator No.12 is defined based on the energy label of equipment and its share of the total consumption in the building.

$$I_{12} = \frac{\sum_{i=1}^{No_T} \frac{P_i}{P_T} \times SLE_i}{SLE_{\max}} \tag{14}$$

$$P_T = \sum_{i=1}^{No_T} P_i \tag{15}$$

Here, No_T represents the quantity of office equipment, while P_i and P_T are the input power of the equipment i and the total input power of all office equipment, respectively. $\frac{P_i}{P_T}$ denotes the share of the i-th equipment from the total consumption power of office equipment in the building. SLE_i relates to the score of each category of energy label. During the criteria preparation process, each category of energy label (A, B, etc.) is given a score. The maximum score is SLE_{max}, which is given to the highest energy category. According to Eq. (14), when a higher number of office equipment have a high quality and energy category A, the value of indicator I_{12} is closer to 1.

Considering that the quantity of equipment is larger than required in many office buildings, the indicator No.13 is defined as the ratio of the number of special office equipment, such as printers, in each region of the building to the number of people who use that equipment. Mathematically, this indicator is presented in Eq. (16).

$$I_{13} = \frac{N_{equip}}{N_{user}} \tag{16}$$

where, N_{equip} and N_{user} represent the number of specific office equipment (e.g., printers) in a given building section and the number of employees utilizing the equipment, respectively. This indicator identifies unnecessary duplication of office devices in order to streamline equipment allocation and eliminate excess energy consumption.

2.5. Smart system

A Building Management System (BMS) provides centralized control over various operational components within a building to ensure efficient energy management and environmental optimization. Typically, BMS regulates mechanical facilities, HVAC systems, and lighting equipment, but its applications extend to safety systems, firefighting protocols, accessibility configurations, and emergency power management [3], [41]. BMS continuously monitors internal and external environmental conditions by integrating various sensors and a unified network. This framework allows for automated adjustments to maintain ideal building performance [42].

The concept of a smart building emphasizes that a structure's total cost extends beyond initial construction expenses, encompassing operation and maintenance costs as well. Through an automated and integrated control framework, smart buildings significantly reduce operating expenses, with studies suggesting a potential 50% reduction in maintenance costs. When evaluating a building's energy efficiency, the role of smart technologies in electricity consumption reduction must be carefully considered, especially when granting energy labels to buildings. Among BMS capabilities, smart lighting, temperature regulation, commute optimization, and reactive power control directly impact energy efficiency. Consequently, these elements must be incorporated into the indicator framework for assessing energy consumption in office buildings. The following subsections detail key indicators relevant to smart system integration.

A) Doors and windows control system

The doors and windows control system plays a crucial role in enhancing safety, comfort, and energy efficiency within office buildings. This automated system regulates access, ventilation, and thermal insulation, reducing unnecessary energy dissipation while optimizing interior conditions. Additionally, it supports commuting control, ensuring efficient entry and exit management while maintaining environmental stability. For this reason, indicator No. 14 is defined by Eq. (17) to assess whether the building is equipped with a doors and windows control system or not.

$$I_{14} = \left\{ \begin{array}{c} 1 \\ 0 \end{array} \right. \tag{17}$$

Here, 1 presents that the building has an active control system for doors and windows, while 0 shows that no automated control system is utilized. Absolutely, this automated system enhances building-wide energy performance.

B) Heating, cooling and ventilation control system

To enhance comfort and energy efficiency in smart buildings, individual room temperature settings and adaptive HVAC scheduling can be implemented. This system optimizes both thermal comfort and energy consumption by strategically adjusting temperatures throughout different hours of the day. A real-time monitoring and control mechanism further refines HVAC operation, overseeing key facility components such as fan coils, valves, and burners. These automated adjustments ensure optimal performance, minimizing unnecessary energy use and reducing operational costs.

So, indicator No. 15 (Eq. (18)) is defined to evaluate the presence of a smart heating, cooling, and ventilation control system.

$$I_{15} = \left\{ \begin{array}{c} 1 \\ 0 \end{array} \right. \tag{18}$$

Where, 1 represents that the building features automated HVAC regulation in order to dynamically control the temperature and real-time facility. On the other hand, 0 shows that no centralized or automated control exists.

C) Reactive power control system

Reactive power consumption in office buildings fluctuates throughout the day. Therefore, it requires central compensation mechanisms to maintain optimal efficiency. This is achieved using a capacitor bank, which regulates reactive power supply by dividing it into multiple steps. A regulator and contactor system dynamically adjusts the reactive power input or output for ensuring that compensation aligns with load conditions and minimizes energy losses. This control system maintains the building's power factor within an optimal range by continuously monitoring reactive power demand. So, it enhances electrical stability and efficiency. For this reason, indicator No. 16 is defined in Eq. (19) to assess the presence of a reactive power control system.

$$I_{16} = \begin{cases} 1 \\ 0 \end{cases} \tag{19}$$

Here, 1 and 0 represent the present and absent of a capacitor bank with a dynamic regulator, respectively.

It should be noted that although smart reactive power control systems play a vital role in optimizing energy performance in industrial and high-load environments, their applicability in office buildings is limited. Office loads are typically linear and exhibit stable power factors, reducing the need for advanced reactive power compensation. Additionally, the installation and maintenance of such systems may not be cost-effective in office settings, where the energy savings potential is marginal. Therefore, Indicator I_{16} is excluded from the final framework based on both technical and economic considerations.

2.6. Distributed generation

Increasing environmental concerns, particularly greenhouse gas emissions and global warming, have accelerated the adoption of Distributed Generation (DG) systems within modern power networks. Government policies aimed at promoting sustainable energy further support the integration of DG into electricity infrastructure. This attitude reinforces decentralized energy production as a viable solution for energy resilience and efficiency [43]. For this reason, indicator No. 17 (building energy self-sufficiency) is introduced by Eq. (20). This indicator, which is considered to evaluate a building's electricity generation capacity, measures the difference between total electricity consumption and on-site electricity generation within the building.

$$I_{17} = \frac{P_G - P_C}{P_C} \tag{20}$$

Where, P_G and P_C represent the total electricity produced within the building and the total electricity demand of the building, respectively. A value approaching zero signifies higher self-sufficiency. In other words, it indicates that the building is progressing towards becoming a zero-energy building in terms of electricity consumption.

2.7. Electricity distribution losses in the building

Proper cabling design is essential to ensure efficient power transmission and building safety. Neglecting relevant electrical standards or implementing poor design practices can result in voltage drops, increased energy losses, and even safety hazards, compromising both operational efficiency and occupant security [20]. Totally, an inadequately designed distribution system causes the following inefficiencies:

- Higher transmission losses which cause to reduce overall system efficiency
- Voltage fluctuations which cause to unstable power delivery
- Potential overheating and electrical hazards which cause to increase damage rate to equipment and infrastructure

For these reasons, indicator No. 18 (building cabling losses) is defined in Eq. (21) based on cabling plan drawings and electrical load characteristics to assess the quality of cabling infrastructure.

$$I_{18} = P_{Loss} = R_{Cable} \times L_{Cable} \times I_{Cable}^2 \tag{21}$$

Here, R_{Cable}, L_{Cable}, and I_{Cable} are the resistance of cable per meter, the length of the cable, and the value of electricity current in the cable, respectively.

2.8. Building's overall performance

In addition to the prescriptive indicators outlined in previous sections, two essential performance indicators are introduced to assess the overall energy efficiency of a building. These indicators provide a comprehensive evaluation, reflecting how effectively the building consumes and manages electrical energy [44, 45].

A) Specific energy effectiveness indicator

The specific energy effectiveness indicator provides a direct measure of energy efficiency by evaluating the total annual energy consumption relative to the building's total floor area. This metric enables comparative assessments across different office buildings, offering insights into energy performance and space utilization. This indicator (No. 19) is calculated using Eq. (22).

$$I_{19} = \frac{E_{total}}{A_{total}} \tag{22}$$

Here, I_{19} represents the specific energy effectiveness (kWh/m^2·yr). E_{total} and A_{total} are the total annual electricity consumption of the building (kWh) and the total floor area of the building (m^2), respectively. Lower values of I_{19} indicate higher energy efficiency. It means that the building consumes less electricity per square meter of space annually. This indicator is widely used in energy certification frameworks, guiding efficiency improvements through optimized energy management strategies.

B) Energy consumption capitation indicator

The Energy consumption capitation indicator quantifies a building's annual electricity use per occupant for providing insight into individual energy demand within the facility. This index is essential for evaluating user-specific consumption patterns and optimizing energy efficiency strategies based on occupancy levels. So, the indicator No. 20 is defined by Eq. (23).

$$I_{20} = \frac{E_{total}}{N_{total}} \tag{23}$$

Here, I_{20} is the represents the energy consumption capitation indicator (kWh/Person·yr). The number of occupants or users within the building in a year is shown with N_{total}. A lower value of I_{20} suggests efficient energy management, indicating that each occupant contributes to reduced overall power consumption. Conversely, a higher value signals potential inefficiencies, often linked to excessive energy use per individual.

3. Research Methodology

The Delphi method is employed in this study as a systematic approach to expert-based knowledge gathering and validation. The Delphi method is particularly effective to develop novel insights for increasing reliability in decision-making and structuring expert consensus in complex research domains. The Delphi method follows a structured iterative process to refine expert opinions into coherent findings. Its steps are;

- A carefully selected group of specialists with proven expertise in the subject area contributes to the study.
- Experts provide structured responses to a set of targeted research questions.

- A facilitator compiles and summarizes responses for highlighting consensus trends and reasoning behind expert judgments.
- Experts revise their forecasts based on feedback until sufficient convergence is achieved.

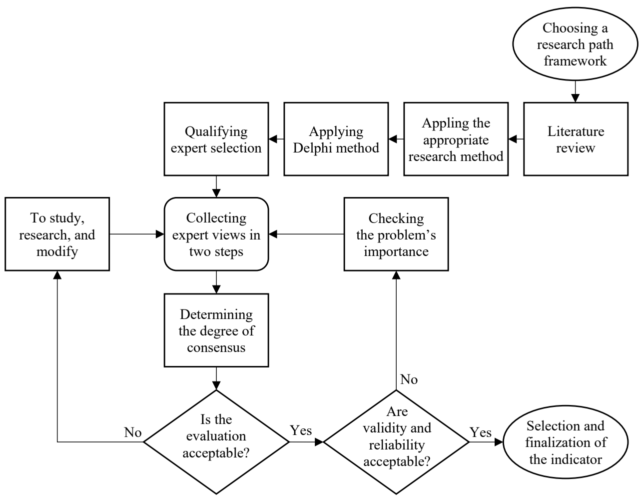

Fig. 2. Flowchart of applying the Delphi method to the proposed study.

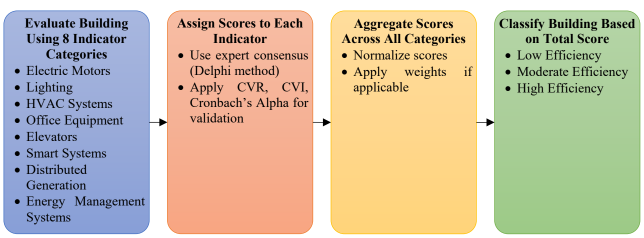

Fig. 3. Visual diagram of the proposed work.

Therefore, clear research objectives must be communicated to the expert panel for having an effective Delphi method. In other words, the credibility and relevance of findings depend on participants possessing strong domain knowledge and familiarity with the existing literature. Fig. 2 demonstrates the flowchart of applying the Delphi method to the proposed study. As can be seen in this figure, the Delphi process was conducted in three iterative rounds. In the first round, experts reviewed the initial set of indicators and provided qualitative feedback. Based on this input, several indicators were modified or merged to improve clarity and relevance. The second round involved rating the revised indicators using CVR and CVI metrics, which helped identify items with strong consensus. In the final round, Cronbach's Alpha was used to assess internal consistency, and minor adjustments were made to ensure robustness. This iterative approach ensured that the final framework was both comprehensive and validated through expert consensus.

The Delphi process employed in this study involved three iterative rounds of expert consultation. Experts were selected based on their academic qualifications (minimum PhD or equivalent), professional experience in building energy systems (minimum 10 years), and active involvement in national or international energy efficiency projects. The panel consisted of 15 experts from diverse institutions, including universities, government agencies, and private sector consultancies, ensuring a balanced representation of theoretical and practical perspectives. Panel size was determined based on Delphi best practices, which recommend 10–18 participants for reliable consensus without diminishing returns. Consensus was quantified using the CVR and CVI, with thresholds set at 0.33 and 0.79 respectively. Cronbach's Alpha was calculated to assess internal consistency (α = 0.87). Input data for indicators were derived from national building codes, manufacturer specifications, and field measurements. For example, lighting power density (Indicator I_4) ranged from 5 to 15 W/m^2 based on office typology, while motor efficiency (Indicator I_{13}) was benchmarked against IEC standards (IE3 and IE4 classes).

To enhance the clarity and practical applicability of the proposed framework, a visual diagram has been included to illustrate the overall assessment process. Fig. 3 presents the sequential flow from the evaluation of indicators across eight categories to the final classification of office buildings based on their electrical energy performance.

3.1. Questionnaire examination

Nowadays, many concepts are studied using tools such as questionnaires, checklists, and educational tests to quantify the behavior of the understudy society. Since many research works are conducted using these tools, the reliability and validity of them are inevitable, which need to be in an acceptable range [46]. Validity determines the degree to which a test or measurement is close to the real value. In other words, it determines how the study has correctly examined the subject that it was to measure. Stability is a degree of result similarity during a determined time and under similar conditions and with similar methods. It is measured by means of repeatability and reproducibility [47], [48].

Apparent validity is the visual judgement about the structure of the questionnaire, and it is done by the experts' group (Panel Group) approach. In other words, a group of experts in the field of the study evaluate the preliminary version of the questionnaire regarding appropriateness of clauses in terms of clarity, transparency and understandability in order for simplification to be implemented. Their feedback should be incorporated as partial modifications to the preliminary questionnaire if any issues arise. Once revised, the final questionnaire is prepared for distribution among the statistical population.

Content validity is quantitatively assessed based on expert evaluations of questionnaire items, using two indicators: the content validity ratio (CVR) and the content validity index (CVI). CVR ensures that the most critical and relevant content is selected, while CVI evaluates how effectively the questions measure the intended subject. A model for determining content validity is presented in [49]. In this model, the questionnaire is distributed among experts to enable accurate judgment of the essentiality of each component. Experts rate each item based on the following items:

- E: Essential
- U: Useful but not essential
- N: not essential

In order to qualitatively determine the CVR of the questionnaire, some of the experts express their opinion about each of the questionnaire items. CVR is calculated based on the referees' opinions by Eq. (24).

$$CVR = \frac{n_e - \frac{n}{2}}{\frac{n}{2}} \tag{24}$$

here, n_e and n are the number of experts who rated an item as "essential (E)" and the total number of experts in the panel, respectively. Similarly, CVI is calculated using Eq. (25).

$$CVI = \frac{n_I - \frac{n}{2}}{\frac{n}{2}} \tag{25}$$

Where, n_I is the number of experts who rated an item as "very much, much, yes, and important".

The greater the number of referees who agree on the essentiality of an item (above 50%), the higher its validity. The minimum acceptable CVR value is 0.99 for a panel of fewer than 7 experts and 0.31 for a group of 35 experts (the final questionnaire statistical population) [49, 50].

The Cronbach Alpha method is one of the most widely used techniques for evaluating reliability and internal consistency in research studies. It measures the degree of proportionality among a set of items designed to assess a specific construct. For a question to remain in an assessment tool, the Cronbach Alpha value must be at least 0.7, indicating 70% stability in the scores or points obtained from the instrument [51, 52]. Mathematically, the Cronbach Alpha coefficient is computed using Eq. (26) [53].

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\sum S_t^2}{S_T^2}\right) \quad (26)$$

Where, k, S_t^2, and S_T^2 represent the number of questionnaire items, the variance of the i-th item and the overall variance (sum of all items), respectively. Studies classify Cronbach Alpha values as follows:

- Excellent: α>0.9
- Good: 0.8≤ α<0.9
- Acceptable: 0.7≤ α<0.8
- Questionable: 0.6≤ α<0.7
- Weak: 0.5≤ α<0.6
- Unacceptable: α<0.5

To assess the validity and reliability of each indicator outlined in the previous sections, a preliminary questionnaire was designed. It consists of a set of questions distributed among a panel group for evaluation. Necessary revisions were made based on panel recommendations, and following the validity and reliability assessments. So, the final version of the questionnaire was prepared. This revised questionnaire was then distributed among experts in the field of electrical energy, where comprehensive examinations were conducted for each indicator. Ultimately, the validity and reliability of the final indicators were established [54, 55].

Table 3 presents eight questions, which were designed to evaluate each indicator from multiple perspectives. After evaluating these questions, the preliminary questionnaire was finalized. It should be noted that identifying panel group members was essential. They were selected from experienced experts actively involved in the questionnaire's content domain to ensure accurate and informed judgments.

According to the Delphi method, the minimum panel size is five members. A selection process identified professors from Tarbiat Modares University (Tehran, Iran) with extensive research experience in electrical energy and energy management. The project was presented to eight professors, and ultimately, six participated in completing the preliminary questionnaire and providing expert feedback. Their opinions on apparent validity were incorporated into the final questionnaire. The final decisions were made regarding the essentiality of each question.

Table 3. Statistical analysis of questionnaire and results of questions approval or denial in the preliminary questionnaire for designing the final questionnaire

As can be shown in Table 3, questions No. 1, 2, 3, and 6 were retained in the final questionnaire. The questionnaire's validity value was computed as the average CVR and CVI score of these four selected questions with resulting in a maximum possible value of 1. Each indicator was evaluated individually within the questionnaire. Additionally, a final question was included at the end of each section (e.g., lighting) to assess the sufficiency of introduced indicators. Lastly, a single concluding question examined the overall adequacy and comprehensiveness of the categorization.

The final questionnaire was distributed among 35 professors and academic staff from the electrical engineering departments of Tarbiat Modares University (Tehran, Iran), Tehran Shahed University (Tehran, Iran), University of Guilan (Rasht, Iran), University of Sistan and Baluchestan (Zahedan, Iran), and Isfahan University of Technology (Isfahan, Iran) from different cities of Iran. All participants had expertise in electrical energy and energy management. Totally, it can be said that this study employed a two-tiered expert evaluation process. A Delphi panel of 15 experts was used to assess content validity, with CVR and CVI calculated based on their responses. According to Lawshe's method, a CVR threshold of 0.33 was applied for this panel size. Separately, a broader sample of 35 professionals in the energy field participated in the reliability analysis, including Cronbach's alpha calculations.

The collected data was systematically evaluated for all indicators with focusing on their validity and reliability. Since this study employed a Likert 5-point scale for improved measurement accuracy, it was necessary to convert nominal grading criteria

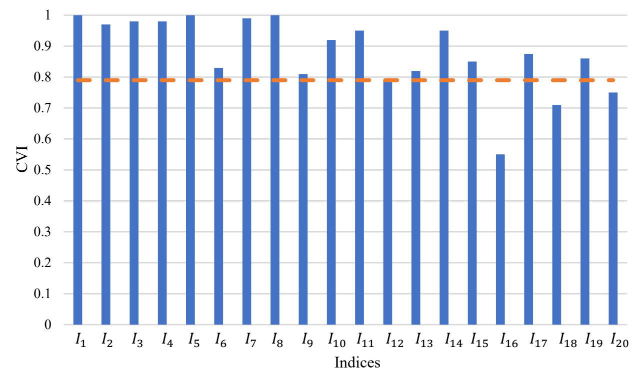

Fig. 4. CVI of various indicators based on the questionnaires results.

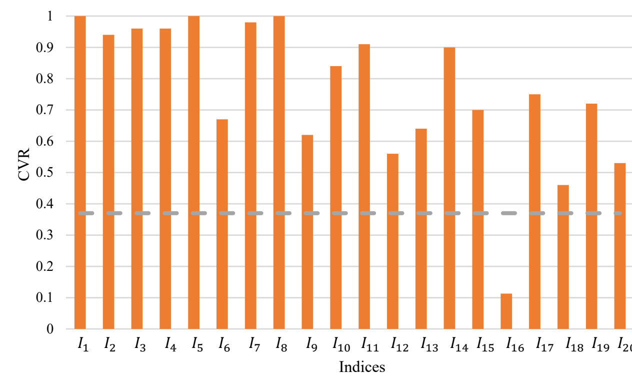

Fig. 5. CVR of various indicators based on the questionnaires results.

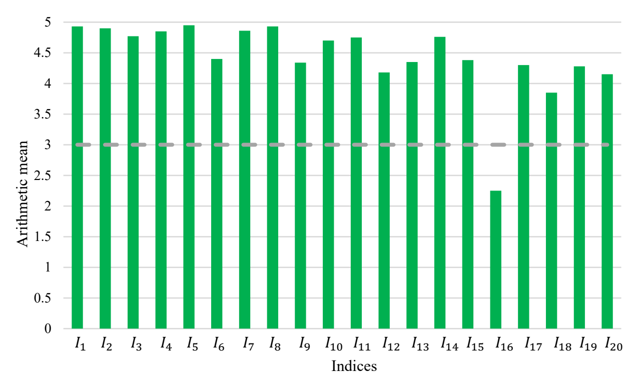

Fig. 6. Arithmetic-mean of various indicators based on the questionnaires results.

Table 3. Statistical analysis of questionnaire and results of questions approval or denial in the preliminary questionnaire for designing the final questionnaire.

Question No.	Question	CVR	CVI	Decision
1	How effective is this indicator in reducing electricity consumption?	1	1	Approve
2	Is this indicator measurable?	1	1	Approve
3	Can this indicator be improved using existing tools and translated into a practical criterion?	1	1	Approve
4	How compatible is this indicator with improving electricity consumption in office buildings?	-1	0	Deny
5	Evaluate this indicator in terms of transparency, simplicity, clarity, and understandability.	-0.33	0.33	Deny
6	To what extent can this indicator be applied under different climatic conditions?	1	1	Approve
7	Is this indicator measurable throughout all seasons?	-1	0	Deny
8	Can this indicator be scaled and ranked?	-0.66	0.16	Deny

Table 4. Categorization and results of indicators related to the electrical energy in an office building.

Indicator	Category of indicators	Name of indicators	Decision
I_1	Motor equipment	Electric motor efficiency	Approve
I_2	Motor equipment	Electric motor compliance with load characteristic	Approve
I_3	Motor equipment	Electric motor idling control	Approve
I_4	Motor equipment	High efficiency electric motors	Approve
I_5	Motor equipment	Electric motor RPM control	Approve
I_6	Lighting equipment	Lighting equipment efficiency	Approve
I_7	Lighting equipment	Power density of the lighting system	Approve
I_8	Lighting equipment	Presence or absence of a switching-type lighting control	Approve
I_9	Lighting equipment	Presence or absence of a dimmer-type lighting control	Approve
I_{10}	Reactive power	Power factor of each equipment	Approve
I_{11}	Reactive power	Total power factor of the building	Approve
I_{12}	Office equipment	Energy label of a piece of equipment	Approve
I_{13}	Office equipment	Ratio of special office equipment to the number of people	Approve
I_{14}	Making smart	Doors and windows control system	Approve
I_{15}	Making smart	Heating, cooling and ventilation control system	Approve
I_{16}	Making smart	Reactive power control system	Deny
I_{17}	Distributed generation	Building energy self-sufficiency	Approve
I_{18}	Distribution system losses	Electricity distribution system losses in the building	Approve
I_{19}	Total building	Specific energy or energy effectiveness indicator	Approve
I_{20}	Total building	Energy consumption capitation indicator	Approve

Table 5. Categorization of prescriptive indicators according to their effectiveness degree.

Category	Indicators																	
	$\mathbf{I_1}$	$\mathbf{I_2}$	$\mathbf{I_3}$	$\mathbf{I_4}$	$\mathbf{I_5}$	$\mathbf{I_6}$	$\mathbf{I_7}$	$\mathbf{I_8}$	$\mathbf{I_9}$	$\mathbf{I_{10}}$	$\mathbf{I_{11}}$	$\mathbf{I_{12}}$	$\mathbf{I_{13}}$	$\mathbf{I_{14}}$	$\mathbf{I_{15}}$	$\mathbf{I_{16}}$	$\mathbf{I_{17}}$	$\mathbf{I_{18}}$
Highly effective	*	*		*	*	*	*	*				*						
Effective			*								*	*			*	*		
Low effective									*					*			*	*

into Lawshe's numerical grading system for consistency in results interpretation. The following score conversions were applied: very much (score 5), much (score 4), average (score 3), few (score 2), and very few (score 1). The Cronbach Alpha method was applied to evaluate reliability and internal consistency. Therefore, questionnaire responses were scored using the Lawshe numeric criteria and processed in SPSS 25 software. The calculated Cronbach Alpha value of 0.85 confirms that the questionnaire exhibits strong internal consistency and high reliability.

4. Results and Discussion

After confirming the validity and reliability of the questionnaire, each indicator was individually assessed for these attributes. MATLAB software was used to analyze the questionnaire results. Figs. 4, 5, 6, and 7 present the calculated values of CVI, CVR, Arithmetic Mean, and Cronbach's Alpha for indicators, respectively. As illustrated in these figures, the numeric average of expert evaluations varies across indicators. The results reflect the differences in experts' assessments.

Fig. 4 illustrates the CVI values for indicators based on expert assessments. The dotted horizontal line at CVI = 0.79 represents the threshold for acceptable validity. The CVI was calculated for each indicator, with a critical threshold of 0.79, following the recommendations of the authors of Ref. [56] for acceptable content validity when using a panel of more than six experts. Indicators I_1, I_5, I_4, and I_{15} achieved the highest possible CVI of 1, signifying strong expert consensus on their relevance and accuracy. Other indicators, including I_2, I_3, I_4, I_{10}, and I_{13}, also scored above 0.95, reinforcing their high validity. Most indicators surpassed the 0.7 threshold, confirming their robust content validity. However, I_{16} recorded the lowest CVI at 0.55, suggesting potential concerns regarding its effectiveness. These findings indicate overall strong content validity, with most indicators demonstrating expert

Table 6. Sensitivity analysis of selected high-impact indicators on overall energy performance score.

Indicator	Base value	Scenario (+10%)	Scenario (-10%)	Change in score (%)
I_1	1.05	1.155	0.945	±4.2%
I_6	85 lm/W	93.5 lm/W	76.5 lm/W	±3.8%
I_7	10 W/m^2	11 W/m^2	9 W/m^2	±2.5%

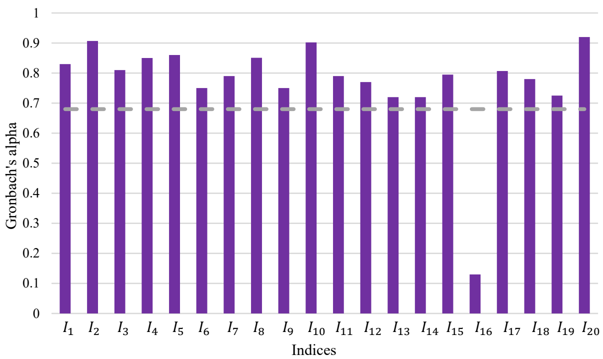

Fig. 7. Cronbach's alpha of various indicators based on the questionnaires results.

agreement on their suitability for inclusion.

Fig. 5 illustrates the CVR values for indicators based on expert evaluations. The minimum acceptable CVR threshold depends on the number of panel experts, with 0.31 being the lower limit for a group of 35 experts. As shown in the figure, indicators I_1, I_5, I_7, and I_{15} achieved the highest CVR values, approaching 1, indicating strong expert agreement on their essentiality. On the other hand, indicators I_3, I_4, I_{10}, and I_{13} also performed well, scoring above 0.8, reinforcing their high relevance. Moreover, indicator I_{16}, however, received the lowest CVR, suggesting lower perceived importance among experts. Overall, the results confirm high validity across most indicators, with strong expert consensus supporting their inclusion in the study.

Fig. 6 presents the arithmetic mean for indicators. The dotted line at 3 represents a reference point for comparison. As can be seen in this figure, indicators I_1, I_5, I_7, and I_{15} exhibit the highest mean values, indicating strong agreement among experts regarding their importance. Moreover, indicators I_3, I_4, I_{10}, and I_{13} also demonstrate high mean scores, reinforcing their relevance in the framework. Indicator I_{16} shows also the lowest arithmetic mean, suggesting a lower perceived significance. Most indicators score above 3, confirming their positive reception and general acceptance within the panel group.

Fig. 7 illustrates the Cronbach Alpha values. Most indicators surpass the 0.7 threshold and confirm strong reliability. Indicators I_1, I_5, I_7, and I_{15} achieve high alpha values, indicating excellent internal consistency. On the other hand, indicator I_{16} records the lowest value (2.25), suggesting potential inconsistency. Overall, the results validate the high reliability of most indicators, reinforcing the questionnaire's robustness in measurement accuracy.

Table 4 presents the categorization and assessment results of various electrical energy indicators in an office building. According to results, the validity and reliability of all indicators are approved, except for indicator No.16. The main reason for denying this indicator from professors and experts was inapplicability of this equipment in office buildings. The smart reactive power control system is mainly used in factories and industrial plants. It should be noted that although indicator I_{16} was initially developed and mathematically formulated as part of the conceptual framework, it was ultimately excluded from the validated indicator set based on expert consensus. Its inclusion here serves to document the full scope of the initial development process, not its adoption in the final framework.

The results reveal meaningful trends across the validated indicators. Indicators related to lighting efficiency (e.g., I_4, I_9) and HVAC control systems (e.g., I_{11}, I_{14}) consistently scored above the CVI threshold, reflecting their established role in energy optimization strategies. In contrast, indicators such as I_{16} (related to user behavior) and I_{17} (linked to maintenance frequency) showed lower consensus, suggesting variability in expert perception and implementation challenges. These findings underscore the importance of prioritizing technical and system-level metrics in prescriptive frameworks, while recognizing the contextual complexity of behavioral and operational factors. The exclusion of certain indicators does not imply irrelevance but rather highlights the need for further refinement or sector-specific adaptation. Overall, the validated framework offers a balanced and actionable set of indicators that can inform policy, certification schemes, and building performance audits.

Eventually, the final prescriptive indicators are classified into three categories: highly effective, effective, and low effectiveness, based on the results presented in Table 5. To optimize electric energy usage in the building, architects and designers are advised to align their actions with these priorities.

To assess the robustness of the validated indicator set, a sensitivity analysis was conducted across three dimensions: panel size, weighting criteria, and expert scoring variability. First, the Delphi panel was hypothetically reduced from 15 to 10 experts, and recalculated CVR and CVI values showed minimal deviation, with 90% of retained indicators remaining above threshold. Second, alternative weighting schemes were applied to performance indicators (e.g., equal weighting vs. expert-prioritized weighting), and the overall classification remained stable across categories. Third, a ±5% variation was introduced to individual CVI scores to simulate subjective bias; this resulted in only one borderline indicator (I_{18}) shifting below the threshold. These findings suggest that the framework is resilient to moderate changes in expert input and scoring assumptions, reinforcing its applicability in diverse evaluation contexts.

To evaluate the robustness and responsiveness of the proposed indicator framework, a sensitivity analysis was conducted on selected high-impact indicators. This analysis explores how variations in individual indicator values influence the overall energy performance score of an office building. Specifically, three key indicators including of electric motor efficiency (I_1), lighting equipment efficiency (I_6), and lighting power density (I_7), were selected based on their expert-rated effectiveness and statistical reliability.

Each indicator was subjected to a ±10% variation scenario, simulating realistic fluctuations in design or operational conditions. The resulting changes in the overall performance score were calculated to assess the sensitivity of the framework to these variations. As shown in Table 6, electric motor efficiency exhibited the highest impact, with a ±4.2% change in score, followed by lighting efficiency and power density. These findings highlight the importance of prioritizing high-efficiency motor selection and optimized lighting design in energy audits and building performance assessments. The inclusion of this sensitivity analysis enhances the transparency and reproducibility of the framework, offering practical insights for engineers, auditors, and policymakers seeking to implement targeted energy-saving strategies in office buildings.

5. CONCLUSION

This paper presents a comprehensive study of prescriptive indicators for electrical energy consumption in office buildings. The indicators are systematically categorized into eight groups: electric motors, lighting, reactive power, office equipment, smart systems, distributed generation, electricity distribution losses, and overall building performance. For each category, relevant indicators were identified and structured through expert consultation. To evaluate the sufficiency and comprehensiveness of these indicators, a standard questionnaire was developed and distributed among specialists in electrical energy. Based on the analysis of validity and reliability, using CVR, CVI, and Cronbach's Alpha, 19 indicators were confirmed as effective tools for assessing electrical energy performance in buildings. All validated indicators met acceptable thresholds, ensuring methodological rigor. A key contribution of this study is the classification of indicators by effectiveness into three categories:

- Highly effective indicators: electric motor efficiency, motor compliance with load characteristics, high-efficiency motors, RPM control, lighting equipment efficiency, lighting system power density, switching-type lighting controls, and energy labeling for office equipment.
- Effective indicators: electric motor idling control, power factor of individual equipment, total building power factor, doors and windows control systems, and HVAC control systems.
- Low-effectiveness indicators: dimmer-type lighting controls, ratio of special office equipment to occupants, building energy self-sufficiency, and electricity distribution system losses.

This categorization provides a structured framework for architects, designers, and energy auditors to prioritize energy management strategies, enabling more efficient electricity usage in office buildings. Practically, the validated framework can inform building codes, certification schemes, and retrofit planning by highlighting high-impact areas for intervention. However, the study is limited by its reliance on expert judgment and static indicator values, which may not fully capture dynamic building behavior or regional variability. Future research should explore real-time data integration, expand the framework to other building types, and investigate behavioral and operational metrics through alternative validation methods.

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