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Development of a Scoring-Based Renewable Energy Readiness Index for Commercial Buildings: An Integrated Framework Based on Energy Audit Findings

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Abstract

The building sector plays a significant role in global energy consumption and carbon emissions, necessitating the integration of renewable energy systems. However, conventional energy audits primarily focus on technical efficiency and do not provide a structured assessment of a building's readiness for renewable energy implementation. This study addresses this gap by developing a Renewable Energy Readiness Assessment Framework (RERAF) and its corresponding Renewable Energy Readiness Index (RERI), which integrate energy audit findings with multidimensional readiness factors. The framework comprises nine dimensions—technical, managerial, economic, regulatory, environmental, social, digital, resilience, and institutional—operationalized through an evidence-based scoring approach using a standardized Likert scale (0–4). To maintain methodological neutrality at the initial development stage, all dimensions and indicators are assigned equal weights (equal weighting scheme), thereby avoiding subjective bias in the absence of expert-based validation. The framework was applied to a commercial office building in Indonesia using energy audit data, supporting documents, and operational information. The results show a RERI score of 2.39 (equivalent to 60.00 on a normalized scale), indicating a moderate level of readiness. The analysis reveals a structural imbalance between relatively strong technical readiness and weaker non-technical dimensions, particularly in managerial, economic, digital, and institutional aspects. These findings highlight that technical feasibility alone is insufficient to ensure successful renewable energy adoption. The proposed framework contributes to bridging the gap between energy audit practices and renewable energy readiness assessment by providing a transparent, evidence-based, and reproducible decision-support tool for stakeholders in the building sector.

1. Introduction

The building sector is one of the primary contributors to global energy consumption and greenhouse gas emissions. Recent reports indicate that buildings account for approximately 30–32% of global final energy consumption and up to 34% of global CO_2 emissions [1], while also representing one of the sectors with the highest potential for energy efficiency improvements [2–4]. In addition, buildings contribute significantly to global electricity demand, largely driven by the requirements of heating, ventilation, and air conditioning (HVAC) systems, lighting, and operational equipment.

In the context of energy transition and climate change mitigation, the building sector has emerged as a critical focal point in global decarbonization efforts [5]. Nevertheless, numerous studies have identified a persistent discrepancy between design performance and actual operational performance, —commonly referred to as the “performance gap”, which constrains the effectiveness of energy efficiency strategies [6]. Furthermore, the inherent complexity of building energy systems necessitates more integrated approaches in both analysis and management [7].

Conventional energy audits generally focus on identifying technical efficiency opportunities, such as energy savings in HVAC systems, lighting, and electrical equipment. However, this approach tends to be limited to technical aspects and does not comprehensively capture the level of building readiness for adopting renewable energy systems. Consequently, audit outcomes often remain confined to technical recommendations, lacking an evaluative framework capable of bridging audit findings with strategic decision-making for renewable energy implementation.

On the other hand, various renewable energy readiness frameworks developed by international organizations such as the International Renewable Energy Agency (IRENA) and the United Nations Development Programme (UNDP) generally operate at the macro level (national or sectoral), with a primary focus on policy, market, and institutional dimensions [8, 9]. While these frameworks provide valuable strategic perspectives, they are less capable of capturing building-specific characteristics and are not grounded in empirical data derived from energy audits. This study aims to develop a building-level Renewable Energy Readiness Assessment Framework (RERAF), construct a Renewable Energy Readiness Index (RERI) based on energy audit findings, and demonstrate its application in a commercial office building in Indonesia.

2. Materials and Methods

2.1. Research Design

This study adopts a mixed-method approach grounded in a methodological development design, complemented by an initial pilot application in a commercial building. The approach integrates empirical data derived from energy audits with a multidimensional assessment framework to develop a renewable energy implementation readiness index. In general, the research is structured into four main stages: a). developing readiness indicators based on a comprehensive literature synthesis; b). assigning dimension weights using an equal weighting scheme as an initial approach; c). evaluating indicators using evidence-based scoring derived from energy audit findings and supporting data; and d). calculating the readiness index through weighted score aggregation. This approach is specifically designed to bridge the gap between the technical analysis typically conducted in energy audits and the need for a structured evaluation of renewable energy implementation readiness at the building operational level.

2.2. Case Study and Data Source

This study employs a single office building as a case study, namely the Graha Surveyor Indonesia Building. The primary data were obtained from energy audit reports spanning the period from 2021 to 2023, which include: monthly electricity consumption data; Energy Consumption Intensity (ECI) values; energy load profiles (e.g., the dominance of HVAC systems); and information on building utility systems.

The audit results indicate that monthly energy consumption ranges between 300,000 and 350,000 kWh, with HVAC systems accounting for approximately 66% of the total energy use [10]. This information serves as the basis for evaluating indicators within the technical dimension, as well as several indicators in other dimensions. In addition to the energy audit data, this study also incorporates: a review of internal documents related to energy management; operational information of the building; and limited interviews with building management and facility personnel. The use of multiple data sources is intended to enhance the completeness and reliability of the information employed in the assessment process. The purpose of the single-case application is not to generalize results statistically, but to demonstrate the operational feasibility and analytical consistency of the proposed framework in a real-world context.

2.3. Development of Renewable Energy Readiness Framework

The RERAF framework developed in this study was not constructed arbitrarily; rather, it was derived through a systematic literature synthesis and thematic extraction of renewable energy readiness factors that consistently emerge across prior studies. These sources include building energy audit studies, renewable energy readiness frameworks, and enabling condition analyses for energy technology adoption. Based on this synthesis, nine principal dimensions of readiness were identified: technical, managerial, economic, regulatory, environmental, social/behavioral, digital/technological, resilience, and institutional. Each dimension is represented by two indicators to ensure conceptual

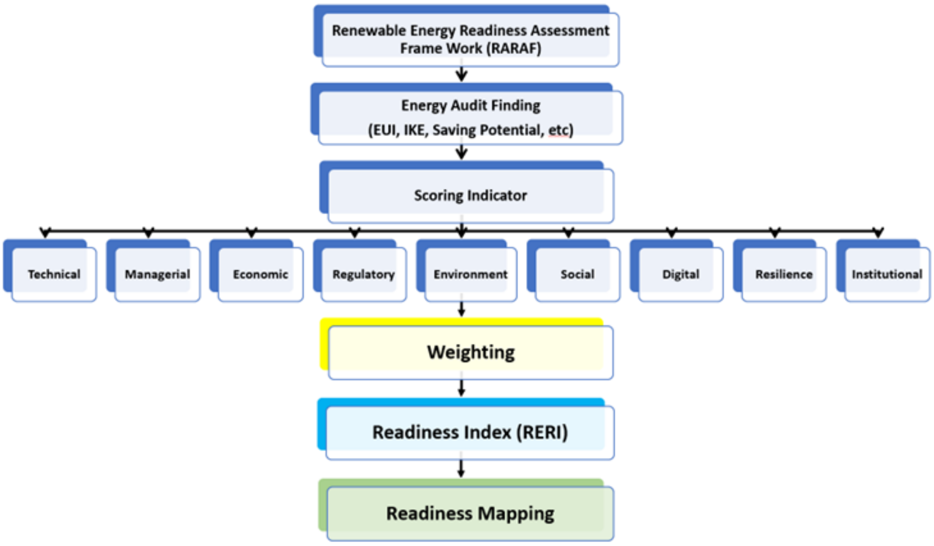

Figure 1. Renewable Energy Readiness Assessment Framework (RERAF).

balance while maintaining model simplicity at the initial stage of development. This structure is positioned as a foundational model that can be further refined and expanded through broader empirical validation.

The RERAF framework is developed as an integrative model to link energy audit outcomes with the assessment of renewable energy implementation readiness in commercial buildings. Conceptually, this framework is structured based on a systematic input–process–output approach, grounded in the principles of multi-criteria decision-making (MCDM), as illustrated in Figure 1.

At the initial stage (input layer), the primary data are derived from building energy audit results, encompassing quantitative performance indicators such as Energy Use Intensity (EUI), Energy Consumption Index (ECI/IKE), and estimated energy-saving potential. These data represent the actual energy performance of the building and serve as the empirical foundation for the readiness assessment process.

At the subsequent stage (process layer), the audit data are translated into nine readiness dimensions, namely: technical, managerial, economic, regulatory, environmental, social, digital/technological, resilience, and institutional aspects. Each dimension is represented by two indicators to ensure conceptual balance while maintaining model simplicity at the initial stage of development. This structure is positioned as a foundational framework that can be further refined through broader empirical validation.

The foundational model of the RERAF is presented in Table 1**.** As shown, a carefully structured set of indicators designed to assess renewable energy readiness at the building level by integrating technical performance metrics with enabling non-technical factors within a unified assessment framework. Each indicator is explicitly defined in terms of its operational scope, unit of measurement, direction of influence, and supporting literature, thereby ensuring methodological transparency, reproducibility, and alignment with established energy assessment standards.

These indicators are systematically organized across nine interrelated dimensions, technical, managerial, economic, regulatory, environmental, social, digital, resilience, and institutional, reflecting the inherently multidimensional nature of renewable energy adoption. While the technical dimension captures baseline energy performance and resource potential, the inclusion of managerial, economic, and institutional dimensions addresses critical constraints related to governance, financing, and coordination that are often overlooked in conventional energy audit practices. Similarly, the regulatory and environmental dimensions provide the foundation for compliance and sustainability considerations, whereas the social and digital dimensions account for behavioral dynamics and technological maturity. The resilience dimension further extends the framework by incorporating risk management and energy security considerations, which are increasingly relevant in the context of climate uncertainty and the ongoing energy transition.

The indicator set combines quantitative metrics (e.g., kWh/m^2/year, kg CO_2/m^2/year) with structured qualitative assessments based on a standardized Likert scale, enabling a more holistic representation of readiness

Table 1. Indicator development.

No.	Indicator Code	Indicator Name	Definition/Operation Description	Unit	Main References
1	T1	Energy Efficiency Baseline (EUI/IKE)	Accessibility and usability of energy consumption data of energy audits (EUI, IKE).	kWh/m²/year	[3, 6, 11]
2	T2	Renewable Energy Potential Study	Techno-economic evaluation of the possibility of installing renewable energy systems (e.g., solar water heater, rooftop photovoltaic system).	% of total energy needs	[3, 6, 11]
3	M1	Energy Management Commitment	The degree of management interest in advancing energy management (organizational structure, assigned individuals).	0–4 Likert scale	[12, 13]
4	M2	Organizational Capacity	The ability of an organization to plan, monitor, and appraise the energy programs internally.	0–4 Likert scale	[12, 13]
5	E1	Financial Readiness	Access to financing and funding options for renewable energy.	% CAPEX or qualitative	[14, 15]
6	E2	Economic Viability	Economic indicators of the renewable energy project (payback period, IRR, NPV, LCOE).	Year / USD/kWh	[14, 15]
7	R1	Regulatory Compliance	Level of compliance with energy regulations, energy conservation, and green building standards.	% compliance	[8, 11]
8	R2	Policy & Incentive Alignment	Extent of conforming to national policy and the use of renewable energy incentives.	Qualitative	[8, 11]
9	L1	Carbon & Emission Reduction	Efforts to emulate and decrease the CO_2 emissions of building operations.	kg CO_2/m²/year	[5, 16]
10	L2	Environmental Management Practice	Introduction of environmental management system (ISO 14001, GBCI).	Qualitative	[5, 16]
11	S1	Energy Awareness & Training	Awareness and amount of energy training to build the staff.	Semester/year	[12, 17]
12	S2	Stakeholder Engagement	Engagement of tenants, residents, or third parties in energy programs.	Qualitative	[12, 17]
13	D1	Digital Energy Monitoring	Digitalization in energy monitoring level (BEMS, IoT, smart meters).	% system integration	[7, 18]
14	D2	Smart & Innovative Technology	The smart technologies (AI-based, automation, smart grids) adoption level.	Qualitative	[7, 18]
15	RS1	Energy Supply Security	There is a backup of renewable energy-based level of energy supply.	% of the guaranteed load	[5, 15]
16	RS2	Climate & Risk Adaptation	The climate risk adaptation plans to sustain energy performance.	Qualitative	[5, 15]
17	K1	Institutional Collaboration	Partnerships with the government agencies, industry players, and universities in the energy sector.	Number of partnerships	[8, 9]
18	K2	Certification & Recognition	Constructing certification guidelines (Greenship, EDGE, ISO 50001).	Certification level	[8, 9]

conditions. This hybrid measurement approach enhances the analytical depth of the framework by capturing both measurable performance outcomes and underlying organizational or institutional capacities.

2.4. Indicator Scoring Procedure

Indicator assessment was conducted using an evidence-based scoring approach with a 0–4 Likert scale, enabling the transformation of qualitative conditions into structured quantitative values. Scores were assigned based on the degree of alignment between the building's actual conditions and the predefined criteria for each indicator. The evaluation process was grounded in the integration of multiple sources of evidence, including energy audit results, supporting documents, and building operational information. Each indicator was systematically mapped to the relevant evidence and assessed according to established criteria. The resulting scores were subsequently reviewed to ensure consistency both across indicators and among dimensions. In cases where data limitations were encountered, the assessment was performed cautiously by relying on the most representative and conservative evidence available. This approach was intended to maintain objectivity, transparency, and reproducibility of the evaluation process.

Table 2. Scoring scale definition.

Score	Readiness Level	General Description
0	Not Ready	No evidence of preparation, implementation, or policy related to the indicator.
1	Initial	Initial awareness or informal actions exist, but without formal structure or documentation.
2	Partial	Partial implementation with limited scope, effectiveness, or institutional support.
3	Managed	Formal implementation supported by procedures, documentation, and regular monitoring.
4	Optimal	Fully integrated, optimized, and continuously improved practices aligned with best practices

The assessment methodology is further illustrated in Table 2, which presents the defined scale used in the evidence-based scoring process to evaluate the level of renewable energy implementation readiness for each indicator within the RERAF framework. The scale adopts a five-level Likert scale (0–4), designed to represent a progressive spectrum of readiness, ranging from not ready to optimal conditions. This approach is consistent with established practices in the development of composite indices and multi-criteria decision-making (MCDM) methods.

This approach is selected as it enables the transformation of descriptive qualitative conditions into structured quantitative values, allowing for systematic analysis within a multidimensional assessment framework. The use of such ordinal scales is also aligned with common practices in composite index construction and MCDM methodologies, where indicator-based assessments are required to represent relative performance levels prior to weighting and aggregation.

Conceptually, each score level within this scale reflects not only the degree of technical achievement but also encompasses institutional, documentation, and implementation sustainability aspects. A score of 0 (Not Ready) indicates the absence of any evidence of readiness, whether in the form of policies, planning, or implementation. A score of 1 (Initial) represents early awareness or informal actions that are not yet supported by adequate organizational structures or documentation. A score of 2 (Partial) reflects partial implementation with limited scope and weak institutional support. A score of 3 (Managed) indicates that practices have been formally implemented, supported by clear procedures, well-documented records, and periodic monitoring mechanisms. At the highest level, a score of 4 (Optimal) represents a condition in which practices are fully integrated into the organizational system, continuously optimized, and aligned with best practices. Each indicator adopts this standardized five-point scoring system (0–4), with responses ranging from not ready (0) to optimal readiness (4). Energy audit data and document reviews support the assignment of these scores, ensuring consistency and reliability. Detailed assessment criteria for each indicator are provided in Appendix A**.**

To enhance objectivity, each score in this study is determined based on empirical evidence obtained from energy audit results, document reviews, and building operational information. Thus, the assessment scale functions not merely as a categorization tool but also as an evaluative mechanism that comprehensively reflects the actual readiness conditions for renewable energy implementation. The indicator assessment process in this study follows an evidence-based approach that systematically integrates multiple sources of information. The data utilized include building energy audit results, supporting document reviews, and interviews with relevant stakeholders to obtain a comprehensive understanding of actual conditions. Each indicator is then mapped to the relevant evidence and assessed based on its conformity with the predefined rubric criteria. The initial assessment results are subsequently reviewed to ensure consistency across indicators and dimensions. In cases of data limitations or uncertainty, assessment decisions are made cautiously by referring to the most representative and conservative evidence. Through this approach, the assessment process not only maintains objectivity but also ensures transparency, consistency, and reproducibility within the renewable energy readiness evaluation framework.

2.5. Index Calculation

The score of each aspect multiplied by the priority weights obtained using the equal weighting approach is added to the scores of other aspects to produce the RERI. Index calculation is conducted in a number of steps that include using aggregate scores of the indicators, scores by aspect, and standardizing the scores.

2.5.1. Calculation of Renewable Energy Readiness Index (RERI)

The formula used to calculate the RERI scores represents the final stage of the indicator development process within the RERAF framework. In this context, the RERI does not function merely as an isolated mathematical computation, but rather as the aggregated outcome of a systematically constructed indicator structure developed in the preceding stages. The renewable energy readiness score is computed using a weighted linear aggregation model, with its values determined in accordance with Equation (1):

$$RERI = \sum_{i=1}^{n} (W_i \times S_i) \quad (1)$$

where W_i denotes the weight of the i-th dimension, S_i represents the composite score of the i -th dimension; and $\boldsymbol{n}$ is the total number of evaluated dimensions. The adoption of this weighted aggregation model is justified by its widespread application in sustainability indices, technology readiness assessments, and multidimensional evaluations within the energy sector [16, 19]. This model offers advantages in terms of transparency, flexibility, and analytical robustness.

2.5.2. Dimension Weighting Scheme (W_i)

In this study, the dimension weights W_i are assigned using an equal weighting approach as an initial scheme in the development of the index. This approach is adopted to maintain neutrality across dimensions and to avoid subjective bias at the early stage of methodological development, particularly given that the study is primarily focused on conceptual framework development and its preliminary application to a single case study. Moreover, the use of equal weighting is a common practice in the early stages of composite index construction, especially when weighting validation based on expert judgment has not yet been adequately established [15, 20].

The RERAF framework in this study comprises nine readiness dimensions, namely technical, managerial, economic, regulatory, environmental, social, digital, resilience, and institutional. As each dimension is considered to have equal importance at this stage, the weight of each dimension is calculated by dividing the total weight of 1 (one) by the number of dimensions, as expressed in Equation (2):

$$W_i = \frac{1}{n} \quad (2)$$

where W_i is the weight of the i-th dimension and $\boldsymbol{n}$ is the total number of dimensions. Furthermore, since each dimension consists of two indicators, and both indicators within each dimension are treated equally, the weight of each indicator is calculated as shown in Equation (3):

$$w_{ij} = \frac{W_i}{m} \quad (3)$$

where w_{ij} denotes the weight of the j-th indicator within the i-th dimension, W_i is the weight of the i-th dimension, and m is the number of indicators within each dimension.

This approach implies that, at the initial stage of development, all dimensions and indicators are positioned equivalently to ensure that the resulting index reflects a balanced contribution from all aspects of readiness. Therefore, this weighting scheme is positioned as a baseline weighting approach, which remains open to further refinement in subsequent studies through more advanced weighting methods, such as expert judgment and statistical techniques. While equal weighting may not fully capture the relative importance of each dimension, it is intentionally adopted as a baseline approach to ensure neutrality and to avoid introducing subjective bias at the early stage of methodological development. This approach is widely recognized in preliminary index construction, particularly in the absence of empirical calibration or expert consensus. Therefore, the weighting scheme in this study is positioned as an initial approximation rather than a definitive representation of dimension importance. Future studies are expected to refine this approach through expert-based methods such as the Analytic Hierarchy Process (AHP) or through statistical techniques, including sensitivity analysis and data-driven weighting.

2.5.3. Calculation of Aspect Scores (S_i)

The use of a Likert scale in this study is consistent with the general approach in multi-criteria decision-making (MCDM) methods for transforming qualitative assessments into structured quantitative values [18, 20]. There are two main steps that are undertaken to derive aspect scores. To begin with, every indicator in a dimension is assessed using a 0–4 Likert scale based on its real degree of preparedness. Second, the scores of the indicators are meant to obtain a composite aspect score, which is depicted in Equation (4):

$$S_i = \frac{1}{m} \sum_{j=1}^{m} s_{ij} \quad (4)$$

where m is the number of indicators in aspect i ; s_{ij} is the score of indicator j in aspect i. This approach ensures that each indicator contributes equally within its respective dimension and prevents any single indicator from disproportionately influencing the final dimension score. All indicator scoring was conducted by the researcher acting as a single assessor to ensure consistency in the evaluation process.

2.5.4. Normalization

To support result interpretation, RERI values are classified into several readiness levels, namely not ready, low readiness, moderately ready, and high readiness. This classification serves as an interpretative boundary to facilitate decision-making rather than as a universal

Table 3. Normalization results.

Score (0–100)	Readiness Category	Meaning & Implications
< 40	Not Ready	The building lacks fundamental readiness conditions and requires substantial improvements in energy management, energy efficiency practices, regulatory compliance, and financial preparedness before renewable energy implementation can be considered.
40 – 60	Moderate / Partial	The building demonstrates partial readiness, with certain enabling conditions already established. However, significant gaps remain, particularly in areas such as digitalization, financial planning, governance, and comprehensive renewable energy feasibility assessment.
61–80	Ready	The building is generally prepared for renewable energy implementation, with most enabling conditions in place. Minor improvements in managerial, technical, or financial aspects are required to support full-scale deployment.
> 81	Highly Ready	The building exhibits a high level of readiness, with technical, regulatory, economic, social, and institutional conditions well established, enabling the effective and large-scale implementation of renewable energy systems.

standard. To enhance readability and interpretability, the RERI values are subsequently normalized to a 0–100 scale using Equation (5):

$$RERI_{norm} = \frac{RERI}{4} \times 100 \quad (5)$$

This normalization is applied because the original scale (0–4) is relatively limited and less intuitive for policy interpretation and decision-making purposes. By converting the index into a 0–100 scale, the results become more accessible, comparable, and easier to classify into readiness level categories.

Table 3 presents the classification scheme used to interpret the normalized RERI scores on a standardized 0–100 scale, providing a clear and actionable framework for assessing building-level readiness. The normalization process translates the original composite scores, derived from a 0–4 Likert-based scale, into a more interpretable metric that aligns with widely adopted benchmarking practices in sustainability and energy performance assessments. The classification thresholds are structured into four distinct readiness categories: Not Ready (<40), Moderate/Partial Readiness (40–60), Ready (61–80), and Highly Ready (>81). These categories are designed to reflect progressive stages of readiness, ranging from the absence of fundamental enabling conditions to a state of full integration and optimization of renewable energy systems. Each category is associated with specific implications in terms of technical capability, governance maturity, financial preparedness, and institutional support.

Importantly, this categorization framework enhances the practical utility of the RERI by enabling stakeholders, including building managers, energy consultants, and policymakers to readily interpret assessment outcomes and identify priority areas for intervention. Moreover, the use of standardized thresholds facilitates cross-building comparisons and supports benchmarking across different contexts, thereby strengthening the decision-support function of the proposed framework.

2.6. Model Validation

Model validation in this study focuses on both conceptual and operational validity, namely the alignment of the framework structure with the literature and its applicability within the case study. In addition, a face validity assessment is conducted to ensure the logical consistency of relationships among the framework components. Given that this study constitutes a methodological development with an initial application to a single building, broader statistical validation requires further research involving a larger sample size. Although statistical validation such as Cronbach's alpha or Delphi-based expert validation was not conducted in this initial study, the framework ensures internal consistency through standardized scoring criteria, structured indicator definitions, and evidence-based evaluation procedures. Future research will incorporate multi-expert validation and sensitivity analysis to enhance robustness and generalizability.

2.7. Avoidance of Circularity Bias

To preserve methodological integrity, this study does not involve external parties in the weighting and assessment processes simultaneously. All indicator evaluations are conducted based on empirical data derived from energy audits and other supporting sources. Accordingly, there is no dependency between the weighting and assessment processes, thereby minimizing the risk of circularity bias and ensuring that the evaluation results remain independent.

3. Results and Discussion

3.1. Energy Audit Results

An energy audit was conducted in 2024 in Jakarta, a city with a hot climate and an average temperature of 27°C,

Table 4. Case-based scoring justification for selected indicators.

No.	Indicator Code	Indicator Name	Empirical Evidence	Scoring Basis	Score
1	T1	Energy Efficiency Baseline (EUI/IKE)	EUI = 138.4 kWh/m²/year; HVAC ~66%	Moderate efficiency (benchmark level); HVAC dominance limits optimality	3
2	T2	Renewable Energy Potential Study	Identified energy-saving potential; rooftop PV technically feasible	Potential identified; no detailed design/implementation study	2
3	M1	Energy Management Commitment	No formal policy / ISO 50001	Awareness exists; not institutionalized	2
4	M2	Organizational Capacity	No dedicated energy management unit	Governance structure not formalized	2
5	E1	Financial Readiness	Energy consumption & cost data available	Basis for analysis exists; no formal investment plan	2
6	E2	Economic Viability	No structured feasibility study	No quantitative assessment (NPV/IRR/LCOE)	2
7	R1	Regulatory Compliance	Compliance with basic energy regulations	Formal compliance established	3
8	R2	Policy & Incentive Alignment	Awareness of RE policies	Aligned externally; not yet implemented	3
9	L1	Carbon & Emission Reduction	Energy efficiency initiatives identified	Partial emission reduction effort	3
10	L2	Environmental Management Practice	Basic environmental practices in place	Not yet fully integrated	3
11	S1	Energy Awareness & Training	Limited internal awareness activities	Informal awareness; no structured program	3
12	S2	Stakeholder Engagement	Limited internal participation	Not systematic	3
13	D1	Digital Energy Monitoring	Partial/manual monitoring system	Not fully digitalized	2
14	D2	Smart & Innovative Technology	No smart energy system	Early-stage adoption	2
15	RS1	Energy Supply Security	Backup generator available	Basic resilience in place	2
16	RS2	Climate & Risk Adaptation	No formal energy risk plan	Not documented	2
17	K1	Institutional Collaboration	No external collaboration	No partnership established	2
18	K2	Certification & Recognition	No external certification	No third-party validation	2

where humidity levels range between 80% and 90%. The audit subject was Graha Surveyor Indonesia Building, a Grade B office building with 19 (nineteen) floors, a total floor area of 20,300 m², and an annual energy consumption of 2,809,276 kWh. This building, which has been in operation since 1996, is equipped with a total of 8 (eight) elevators, with office hours from Monday through Friday, from 7:00 AM to 6:00 PM. The energy audit was conducted in accordance with ISO 50001 (Energy Management Systems, EnMS) and ISO 50002 (Energy Audit) standards, resulting in an Energy Consumption Intensity (ECI) of 138.4 kWh/m² for the data period from 2021 to 2023. The ECI value of 138.4 kWh/m²/year indicates moderate energy performance when compared to typical benchmarks for commercial office buildings in tropical regions. The audit also identified potential energy-saving opportunities, particularly through HVAC optimization and improved operational control.

To enhance the transparency and traceability of the scoring process, this study presents a case-based justification that explicitly links empirical audit findings to indicator-level scores within the RERAF framework, as shown in Table 4. The scoring of each indicator is conducted using an evidence-based approach, where values are assigned based on verifiable data derived from energy audits, supporting documents, and operational information of the building. This approach ensures that the assessment is not solely based on subjective judgment, but grounded in measurable and observable conditions. By providing explicit justification for selected indicators, the table serves to illustrate how empirical evidence is systematically translated into quantitative scores, thereby strengthening the methodological rigor and reproducibility of the RERI calculation. Selected indicators are presented to demonstrate the scoring logic, while maintaining clarity and conciseness in the main manuscript. The following table presents the results

Table 5. Results calculation results for weighting.

Aspect	**Code**	**Indicator**	***Weight* per Indicator (W_{ij})**
Technical	T1	Baseline energy efficiency (EUI/IKE, audit)	0.056
	T2	Renewable energy potential assessment	0.056
Managerial	M1	Energy management commitment	0.056
	M2	Organizational capacity & governance	0.056
Economic	E1	Financial readiness for renewable energy investment	0.056
	E2	Economic viability (NPV/IRR/LCOE)	0.056
Regulatory	R1	Compliance with energy & environmental regulations	0.056
	R2	Policy alignment & incentives	0.056
Environmental	L1	Carbon & emissions reduction program	0.056
	L2	Environmental management practices	0.056
Social	S1	Energy awareness & training	0.056
	S2	Stakeholder engagement	0.056
Digital	D1	Digitalization & energy monitoring	0.056
	D2	Smart technologies & innovation	0.056
Resilience	RS1	Security of supply & backup systems	0.056
	RS2	Climate adaptation & risk strategies	0.056
Institutional	K1	Institutional collaboration	0.056
	K2	External certification & recognition	0.056

of the energy audit and the verification of renewable energy readiness indicators.

3.2. Calculation Results for Weighting Scheme (W_i)

In this study, the dimensional weights (W_i) were initially assigned using an equal-weighting approach as a baseline scheme. Given that the framework comprises nine readiness dimensions, each dimension was assigned an equal weight of 1/9 = 0.111. Furthermore, since each dimension consists of two indicators, the weight of each indicator within a given dimension was calculated as 0.111/2 = 0.056. This approach was adopted to preserve neutrality across dimensions and indicators during the early stage of index development, and to minimize subjective bias prior to further calibration in subsequent research. The detailed calculation results are presented in Table 5.

3.3. Calculation Results for Aspect Scores (S_i)

The aspect score (Si) is determined by the mean of the two indicators of every aspect of renewable energy preparedness. This method is used to keep the contribution of indicators open in a single aspect and to keep a comparison over the aspects.

Table 6 presents the calculated indicator scores across the nine readiness dimensions. The results show that the technical dimension obtained an average score of 2.5, reflecting the availability of energy audit data and the initial identification of renewable energy potential. Regulatory, environmental, and social dimensions recorded relatively higher scores of 3.0, indicating that basic compliance, environmental practices, and internal awareness are already present. In contrast, managerial, economic, digital, resilience, and institutional dimensions remained at a score of 2.0, suggesting partial implementation and limited institutionalization. This pattern indicates that renewable energy readiness in the case study building is constrained less by technical feasibility than by non-technical factors, particularly governance, financial planning, digital monitoring, and institutional collaboration.

3.4. Calculation of the Renewable Energy Readiness Index (RERI)

The assessment of the readiness level for renewable energy implementation at PT Surveyor Indonesia's office building was calculated using the RERI on a scale of 0 to 4, based on the weighting of aspects as specified in the evaluation framework.

Table 7 presents the results of the RERI calculation, obtained through the aggregation of indicator scores across each dimension within the RERAF framework using an equal weighting approach. The total RERI value of 2.390 reflects the building's overall level of readiness to implement renewable energy, based on the proportional contribution of all indicators. Indicator-level analysis reveals variations in scores across dimensions, where the technical, regulatory, environmental, and social aspects tend to exhibit relatively higher scores compared to other dimensions. In contrast, the managerial, economic, digital, resilience, and institutional dimensions remain at a partial implementation level, indicating limitations in organizational support and governance systems.

Table 6. Detailed calculation results for indicator scores.

Aspect	Code	Indicator	Score
Technical	T1	Baseline energy efficiency (EUI/IKE, audit)	**3.0**
	T2	Renewable energy potential assessment	**2.0**
Managerial	M1	Energy management commitment	**2.0**
	M2	Organizational capacity & governance	**2.0**
Economic	E1	Financial readiness for renewable energy investment	**2.0**
	E2	Economic viability (NPV/IRR/LCOE)	**2.0**
Regulatory	R1	Compliance with energy & environmental regulations	**3.0**
	R2	Policy alignment & incentives	**3.0**
Environmental	L1	Carbon & emissions reduction programmes	**3.0**
	L2	Environmental management practices	**3.0**
Social	S1	Energy awareness & training	**3.0**
	S2	Stakeholder engagement	**3.0**
Digital	D1	Digitalisation & energy monitoring	**2.0**
	D2	Smart technologies & innovation	**2.0**
Resilience	RS1	Security of supply & backup systems	**2.0**
	RS2	Climate adaptation & risk strategies	**2.0**
Institutional	K1	Institutional collaboration	**2.0**
	K2	External certification & recognition	**2.0**

Table 7. RERI calculation.

Aspect	Indicator Code	Weight (W_{ij})	Score (s_{ij})	Weighted Score ($W_{ij} \times s_{ij}$)
Technical	T1	0.056	3	0.167
	T2	0.056	2	0.111
Managerial	M1	0.056	2	0.111
	M2	0.056	2	0.111
Economic	E1	0.056	2	0.111
	E2	0.056	2	0.111
Regulatory	R1	0.056	3	0.167
	R2	0.056	3	0.167
Environmental	L1	0.056	3	0.167
	L2	0.056	3	0.167
Social	S1	0.056	3	0.167
	S2	0.056	3	0.167
Digital	D1	0.056	2	0.111
	D2	0.056	2	0.111
Resilience	RS1	0.056	2	0.111
	RS2	0.056	2	0.111
Institutional	K1	0.056	2	0.111
	K2	0.056	2	0.111
Total				**2.390**

These findings highlight the presence of structural imbalances in renewable energy readiness, where technical preparedness is not yet fully complemented by non-technical readiness. Therefore, enhancing overall readiness requires not only technical interventions but also the strengthening of managerial, institutional, and integrated implementation strategies.

3.5. Normalization Results

The RERI calculation results obtained in the previous step range from 0 to 4, corresponding to the indicator rating scale used in this study. Although this range is useful for internal evaluation, it is less practical for interpretation by policymakers, building managers, and other stakeholders. Therefore, normalization is required to express the index on a more intuitive 0–100 scale, which is commonly used in sustainability and energy performance assessment. Using Equation (5) from the Methods section, the RERI value of 2.39 was converted to a 0–100 scale, resulting in a score of 60.00. This places the Graha Surveyor Indonesia Building at the upper limit of the Moderate (Partial) readiness category, with a normalized RERI score of 60.00 out of 100.

3.7. Interpretation

The normalization results indicate that a RERI value of 2.39 on the original 0–4 scale is equivalent to 60.00 on a 0–100 scale. This linear transformation is intended to enhance readability and facilitate comparative interpretation of renewable energy implementation readiness levels. This value suggests that the building is at a moderate level of readiness, indicating that several enabling elements for renewable energy implementation are already in place, yet not fully integrated within the building's operational and governance systems. Substantively, this condition reflects the presence of a reasonably adequate foundation—particularly in technical performance and regulatory compliance, while limitations persist in non-technical dimensions such as organizational capacity, investment readiness, and internal policy integration.

Furthermore, this score represents a transitional phase in which the existing level of readiness is not yet sufficiently robust to drive systematic and sustainable renewable energy implementation. Therefore, improving the RERI value requires not only technical interventions but also the strengthening of managerial and institutional aspects, along with more integrated implementation strategies. A RERI score of 60.00 indicates that renewable energy implementation readiness has reached a functional baseline level, yet still requires significant reinforcement in non-technical dimensions to achieve comprehensive readiness.

3.8. Discussion

This study demonstrates that integrating energy audit findings into a multidimensional readiness framework (RERAF) provides a more comprehensive understanding of renewable energy adoption at the building level. Unlike conventional energy audits, which primarily focus on technical efficiency, the proposed approach captures a broader readiness landscape, including organizational, economic, and institutional dimensions. This is consistent with prior studies indicating that the main barriers to renewable energy adoption are often non-technical in nature [21, 22].

The results indicate that the building achieved a RERI score of 2.39 (60.00 on the normalized scale), reflecting a moderate level of readiness. A key finding is the presence of a structural imbalance between technical and non-technical readiness. While the technical dimension demonstrates relatively stronger performance, supported by the availability of audit data and identifiable renewable energy potential, the managerial, economic, digital, resilience, and institutional dimensions remain underdeveloped.

This imbalance highlights a critical insight: technical feasibility alone is insufficient to ensure successful renewable energy implementation [5, 23]. The findings are aligned with previous studies emphasizing that barriers to renewable energy adoption are frequently dominated by non-technical factors such as governance, financing, and institutional capacity. In this case, the absence of formal energy management policies, limited financial planning, and a lack of structured institutional collaboration significantly hinder the transition from potential to implementation.

From a methodological perspective, the RERAF framework successfully operationalizes the transformation of audit-derived data into a structured readiness index. The use of evidence-based assessment enhances transparency and reduces subjectivity, while the equal weighting scheme ensures neutrality in the absence of validated expert-based weighting. This approach is particularly relevant for early-stage methodological development, where robustness is achieved through clarity and traceability rather than model complexity.

Furthermore, the findings underscore the importance of a multidimensional assessment approach. Dimensions such as regulatory compliance and environmental practices exhibit relatively higher scores, suggesting that external factors, such as policy frameworks and environmental awareness, can function as enabling conditions. However, without corresponding internal readiness, particularly in managerial and institutional domains, these external factors are unlikely to translate into effective implementation.

The practical implication of this study is that building-level energy transition strategies must extend beyond purely technical interventions. Instead, a more integrated approach is required, encompassing governance strengthening, financial readiness, digitalization, and institutional collaboration. Accordingly, the RERAF framework serves not only as an assessment tool but also as a diagnostic instrument to identify priority areas for intervention.

Nevertheless, this study has several limitations. First, The framework was applied to a single case study, thereby limiting the generalizability of the findings. Second, the use of equal weighting, although methodologically justifiable for an initial model, may not fully reflect the relative importance of each dimension. Future research should incorporate datasets covering multiple buildings and explore more advanced weighting techniques, such as expert-based methods or statistical calibration, to enhance the reliability of the index.

4. Conclusions

This study advances the field by introducing the RERAF framework and its associated index, the RERI, as a novel, integrative approach that explicitly bridges the longstanding gap between conventional energy audit practices and renewable energy readiness assessment at the building scale. Existing approaches remain either fragmented or narrowly centered on technical performance, thereby failing to capture the multidimensional nature of readiness. In response, the proposed framework operationalizes nine interrelated readiness dimensions into a unified, evidence-based assessment model that is both analytically rigorous and practically deployable.

Empirical application to a commercial building case study reveals a critical insight: technically adequate buildings may still exhibit constrained readiness (RERI = 2.39; normalized score = 60.00) due to systemic deficiencies in non-technical domains, particularly managerial, economic, digital, resilience, and institutional dimensions. This finding challenges the prevailing assumption that technical performance alone is a sufficient proxy for renewable energy readiness and underscores the structural limitations of conventional audit-centric approaches.

The principal contribution of this study lies in reframing energy audit outputs into a structured, transparent, and replicable decision-support instrument. Beyond its evaluative function, the RERI enables prioritization of targeted, cross-dimensional interventions, thereby enhancing its strategic utility for practitioners and policymakers. While the current study is limited by a single-case design and the adoption of an equal weighting scheme, it establishes a robust methodological foundation for scalable validation and future refinement through expert-informed or data-driven weighting approaches. Consequently, this work positions RERI as a promising candidate for a standardized metric in renewable energy readiness assessment.

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References

1. UNEP. (2025). Global Status Report for Buildings and Construction 2024/2025, UN Environment Programme (UNEP) & Global Alliance for Buildings and Construction (GlobalABC).
2. International Energy Agency. (2023). *Energy Efficiency 2023*.
3. Pérez-Lombard, L., Ortiz, J., and Pout, C. (2008). A Review on Buildings Energy Consumption Information, *Energy and Buildings*, Vol. 40, No. 3, 394–398. doi:10.1016/j.enbuild.2007.03.007.
4. Ürge-Vorsatz, D., Cabeza, L. F., Serrano, S., Barreneche, C., and Petrichenko, K. (2015). Heating and Cooling Energy Trends and Drivers in Buildings, *Renewable and Sustainable Energy Reviews*, Vol. 41, 85–98. doi:10.1016/j.rser.2014.08.039.
5. Santamouris, M. (2016). Innovating to Zero the Building Sector in Europe: Minimising the Energy Consumption, Eradication of the Energy Poverty and Mitigating the Local Climate Change, *Solar Energy*, Vol. 128, 61–94. doi:10.1016/j.solener.2016.01.021.
6. Attia, S., Bilir, S., Safy, T., Struck, C., Loonen, R., and Goia, F. (2018). Current Trends and Future Challenges in the Performance Assessment of Adaptive Façade Systems, *Energy and Buildings*, Vol. 179, 165–182. doi:10.1016/j.enbuild.2018.09.017.
7. Hong, T., Chen, Y., Luo, X., Luo, N., and Lee, S. H. (2020). Ten Questions on Urban Building Energy Modeling, *Building and Environment*, Vol. 168, 106508. doi:10.1016/j.buildenv.2019.106508.
8. International Renewable Energy Agency. (2018). *Renewable Energy Readiness Assessment: Methodology and Case Studies*.
9. United Nations Development Programme. (2019). *Energy Systems Transformation: Building Readiness for Renewable Energy*.
10. PT Surveyor Indonesia. (2024). *Laporan Audit Energi Gedung Graha Surveyor Indonesia*Jakarta, PT Surveyor Indonesia.
11. Green Building Council Indonesia. (2020). *Greenship Existing Building Version 1.1*.
12. Cagno, E., and Trianni, A. (2013). Exploring Drivers for Energy Efficiency within Small- and Medium-Sized Enterprises: First Evidences from Italian Manufacturing Enterprises, *Applied Energy*, Vol. 104, 276–285. doi:10.1016/j.apenergy.2012.10.053.
13. Thollander, P., and Palm, J. (2015). Industrial Energy Management Decision Making for Improved Energy Efficiency—Strategic System Perspectives and Situated Action in Combination, *Energies*, Vol. 8, No. 6, 5694–5703. doi:10.3390/en8065694.
14. International Renewable Energy Agency. (2015). *Renewable Power Generation Costs in 2014*.
15. Stremke, S., and Schöbel, S. (2019). Research through Design for Energy Transition: Two Case Studies in Germany and The Netherlands, *Smart and Sustainable Built Environment*, Vol. 8, No. 1, 16–33. doi:10.1108/SASBE-02-2018-0010.
16. Standardization, I. O. for. (2019). *Greenhouse gases — Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals*.
17. Molepo, P., Mathaba, T. N. D., and Aboalez, K. (2026). Barriers to the Adoption of Solar and Wind Energy Technologies: A Systematic Literature Review, *International Journal of Energy Sector Management*, 1–28. doi:10.1108/IJESM-12-2024-0001.

18. Kabak, M., Köse, E., Kırılmaz, O., and Burmaoğlu, S. (2014). A Fuzzy Multi-Criteria Decision Making Approach to Assess Building Energy Performance, *Energy and Buildings*, Vol. 72, 382–389. doi:10.1016/j.enbuild.2013.12.059.

19. Sovacool, B. K., and Brown, M. A. (2010). Twelve Metropolitan Carbon Footprints: A Preliminary Comparative Global Assessment, *Energy Policy*, Vol. 38, No. 9, 4856–4869. doi:10.1016/j.enpol.2009.10.001.

20. Kumar, A., Sah, B., Singh, A. R., Deng, Y., He, X., Kumar, P., and Bansal, R. C. (2017). A Review of Multi Criteria Decision Making (MCDM) towards Sustainable Renewable Energy Development, *Renewable and Sustainable Energy Reviews*, Vol. 69, 596–609. doi:10.1016/j.rser.2016.11.191.

21. Obuseh, E., Eyenubo, J., Alele, J., Okpare, A., and Oghogho, I. (2025). A Systematic Review of Barriers to Renewable Energy Integration and Adoption, *Journal of Asian Energy Studies*, Vol. 9, 26–45. doi:10.24112/jaes.090002.

22. Painuly, J. . (2001). Barriers to Renewable Energy Penetration; a Framework for Analysis, *Renewable Energy*, Vol. 24, No. 1, 73–89. doi:10.1016/S0960-1481(00)00186-5.

23. Reddy, V. J., Hariram, N. P., Ghazali, M. F., and Kumarasamy, S. (2024). Pathway to Sustainability: An Overview of Renewable Energy Integration in Building Systems, *Sustainability*, Vol. 16, No. 2, 638. doi:10.3390/su16020638.

Appendix

Appendix A: Detailed Scoring Criteria for Renewable Energy Readiness Indicators

This appendix provides a detailed description of the scoring criteria used to evaluate renewable energy readiness indicators in this study. A standardized five-point scale (0–4) was adopted to ensure consistency and comparability across indicators and assessment dimensions.

A.1. Technical Dimension

Table A1. T1 – Energy efficiency baseline (EUI/IKE).

Score	General Description
0	No energy audit conducted and no baseline energy data available.
1	Preliminary energy data collected without structured analysis.
2	Energy audit completed with limited scope or outdated data.
3	Comprehensive energy audit conducted with partial implementation of recommendations.
4	Continuous energy monitoring through BEMS with periodic re-audits and updates.

Table A2. T2 – Renewable energy potential study.

Score	General Description
0	No assessment of renewable energy potential.
1	Technical potential study conducted without financial feasibility analysis.
2	Energy audit completed with limited scope or outdated data.
3	Feasibility study completed and preferred renewable energy option identified.
4	Detailed engineering design and implementation plan prepared.

A.2. Managerial Dimension

Table A3. M1 – Energy management commitment.

Score	General Description
0	No designated responsibility for energy management.
1	Informal initiatives without defined roles or authority.
2	Energy manager appointed with limited mandate.
3	Formal energy policy established with monitoring mechanisms.
4	Certified energy management system implemented (e.g., ISO 50001).

Table A4. M2 – Organizational capacity and governance.

Score	General Description
0	No organizational structure supporting energy management.
1	Energy-related tasks conducted on an ad hoc basis.
2	Partial integration of energy management into facility management.
3	Cross-departmental energy management team established.
4	Fully integrated governance embedded in corporate sustainability leadership.

A.3. Economic Dimension

Table A5. E1 – Financial readiness for renewable energy investment.

Score	General Description
0	No budget allocation or financing mechanism for renewable energy.
1	Initial discussions on financing without formal commitment.
2	Feasibility analysis completed, pending financial approval.
3	Budget allocated for pilot or small-scale renewable energy projects.
4	Long-term renewable energy investments included in CAPEX planning.

Table A6. E2 – Economic viability and cost–benefit analysis.

Score	General Description
0	No economic analysis conducted.
1	Simple payback analysis only.
2	Detailed economic analysis (e.g., LCOE, NPV, or IRR) performed.
3	Renewable energy projects evaluated with risk and sensitivity analysis.
4	Economic evaluation fully integrated into corporate investment decision systems

A.4. Regulatory Dimension

Table A7. R1 – Energy and environmental regulatory compliance.

Score	General Description
0	No awareness of applicable energy or environmental regulations.
1	Awareness exists but compliance is limited.
2	Partial compliance with mandatory standards.
3	Full compliance with applicable regulations and standards.
4	Exceeds regulatory requirements and participates in voluntary green programs.

Table A8. R2 – Policy and incentive alignment.

Score	General Description
0	No alignment with national or local energy policies.
1	Awareness of incentives without utilization.
2	Partial utilization of available incentives.
3	Active participation in government-supported renewable energy programs.
4	Strategic alignment with multiple policy instruments and incentive schemes.

A.5. Environmental Dimension

Table A9. L1 – Carbon and emission reduction practices.

Score	General Description
0	No monitoring or reporting of **emissions**.
1	Baseline emission estimates without systematic tracking.
2	Annual emission data recorded.
3	Formal emission reduction targets established.
4	Continuous carbon accounting integrated into ESG reporting.

Table A10. L2 – Environmental management practices.

Score	General Description
0	No environmental management practice or documented environmental awareness activity.
1	Sporadic environmental awareness activities.
2	Regular environmental training and communication programs.
3	Environmental SOPs and KPIs implemented.
4	Strong environmental culture embedded across the organization

A.6. Social Dimension

Table A11. S1 – Energy awareness and training.

Score	General Description
0	No energy awareness or training programs.
1	Occasional energy-related awareness events.
2	Regular energy awareness campaigns for staff.
3	Energy-efficient behavior integrated into daily operations.
4	Incentive systems and continuous improvement programs implemented.

Table A12. S2 – Stakeholder engagement.

Score	General Description
0	No engagement with tenants, occupants, or external stakeholders.
1	Limited engagement with selected stakeholders.
2	Periodic communication regarding energy initiatives.
3	Regular feedback mechanisms established.
4	Active collaboration and co-creation of renewable energy initiatives.

A.7. Digital Dimension

Table A13. D1 – Digital energy monitoring.

Score	General Description
0	Manual recording of energy data only.
1	Basic digital metering without analytics.
2	Monthly digital energy monitoring.
3	Real-time monitoring with dashboards.
4	Fully integrated IoT-based energy management platform.

Table A14. D2 – Smart and innovative technologies.

Score	General Description
0	No adoption of smart technologies.
1	Pilot smart technology projects under evaluation.
2	Partial adoption of smart control systems.
3	Integrated smart building systems implemented.
4	Advanced analytics and AI-based optimization deployed.

A.8. Resilience Dimension

Table A15. RS1 – Energy supply security and backup systems.

Score	General Description
0	No backup energy systems available.
1	Backup systems rely solely on diesel generators.
2	Limited hybrid or partial backup systems.
3	Backup systems integrated with renewable energy sources.
4	Intelligent hybrid renewable–battery systems with grid support.

Table A16. RS2 – Climate risk and adaptation strategy.

Score	General Description
0	No climate risk assessment conducted.
1	Basic awareness of climate-related risks.
2	Preliminary climate risk assessment performed.
3	Climate risk management plan developed.
4	Adaptive design fully integrated into long-term resilience planning.

A.9. Institutional Dimension

Table A17. K1 – Institutional collaboration.

Score	General Description
0	No collaboration with external institutions.
1	Informal networking with renewable energy vendors.
2	Memoranda of understanding (MoUs) with one or more institutions.
3	Active collaboration with universities or government agencies.
4	Long-term strategic partnerships formally established.

Table A18. K2 – Certification and external recognition.

Score	General Description
0	No certification efforts initiated.
1	Certification planning stage.
2	Certification process ongoing (e.g., Greenship, EDGE).
3	Certified building with periodic reviews.
4	Multiple certifications and participation in international sustainability networks.