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Analysis of the Influence of Air Conditioning Systems on the Green Building Certification Assessment Rating "Greenship Existing Building"

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ABSTRACT

This study examines the influence of air conditioning systems on achieving the Green Building certification rating for Greenship Existing Building PT Pamapersada Nusantara Head Office. The air conditioning system plays a critical role in assessing green building performance, particularly in energy efficiency, indoor air quality, and thermal comfort. A descriptive quantitative approach was used with secondary data from energy audits, electricity measurements, and HVAC technical documentation. Results indicate that the air conditioning system significantly contributes to Energy Efficiency and Conservation (EEC) and Indoor Health and Comfort (IHC) scores. The building's Energy Consumption Intensity (IKE) was 194.4 kWh/m²/year—classified as efficient (150–200 kWh/m²/year)—earning 10–12 EEC points. The chiller units achieved an average Coefficient of Performance (COP) of 3.84, demonstrating high efficiency. Indoor air quality metrics met standards: temperature at 23.8–24.2°C, humidity at 50–57%, CO_2 at 600–850 ppm, and particulate matter within acceptable limits, contributing 4.3 of 5 IHC points. Statistical analysis revealed strong correlations between HVAC variables and Greenship scores: IKE negatively correlated with EEC ($r = -0.78$, $p = 0.001$), while COP positively correlated ($r = 0.72$, $p = 0.002$). Regression analysis showed significant effects from IKE, COP, MERV 13 filters, CO_2-based ventilation, humidification systems, and Building Automation System. In conclusion, an energy-efficient HVAC system and effective management enhance certification performance. The study provides novel empirical evidence of HVAC's direct contribution to Greenship assessments, supporting energy and sustainability initiatives in existing buildings.

Keywords: *Air Conditioning System, Green Building, Greenship Existing Building, Hvac, Energy Efficiency.*

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INTRODUCTION

The concept of green building, or environmentally friendly buildings, is a design, construction, and operational approach aimed at reducing the negative impact of buildings on the environment and increasing the efficiency of energy, water, and material use (Kibert, 2016). The application of green building is increasingly relevant in the era of global climate change, where the construction sector is recorded as contributing nearly 40% of global carbon emissions. This effort is an important part of a sustainable development strategy that aligns with the 2030 Sustainable Development Goals (SDGs) targets (Mahardika et al., 2025).

One strategic step in implementing green buildings is green building certification. This certification provides guidance to developers in designing buildings that are energy efficient, efficient in resource use, and create a healthy indoor environment. Benefits include energy savings of up to 50%, water efficiency of up to 40%, and increased occupant productivity through better air quality (Widyawati, 2019). In Indonesia, the implementation of green building certification is facilitated by several standards, including LEED, EDGE, and specifically Greenship, developed by the Green Building Council Indonesia (Mochtar, 2025).

Greenship assesses building performance based on six categories: Energy Efficiency & Conservation (EEC), Water Conservation, Indoor Health & Comfort (IHC), Material

Resources & Cycle, Building & Environmental Management, and Appropriate Site Development. The assessment results determine the certification level, ranging from Certified, Silver, Gold, to Platinum (Prasustiawan et al., 2023). This certification has strategic value, not only in improving the company's sustainability image, but also in reducing long-term operational costs.

One of the dominant aspects in green building assessments is the air conditioning system or Heating, Ventilation, and Air Conditioning (HVAC). This system plays a crucial role in maintaining energy efficiency while creating thermal comfort and healthy indoor air quality (Indriyati et al., 2021). Studies show that HVAC can contribute up to 50–60% of a building's total energy consumption, making optimization of this system crucial (Saputri et al., 2025). Innovations such as energy-efficient chillers, heat recovery systems, and IoT-based air monitoring are solutions to increase efficiency (Nugraha & Desnanjaya, 2025). Although a number of studies have discussed the implementation of green buildings, studies that specifically measure the contribution of air conditioning systems to achieving Greenship scores are still limited.

Internationally, frameworks like LEED and BREEAM, and nationally in Indonesia, the Greenship rating system developed by the Green Building Council Indonesia (GBCI), provide structured methodologies for assessing and certifying building performance across multiple categories, including energy, water, materials, and indoor environmental quality. Within the green building assessment framework, the Heating, Ventilation, and Air Conditioning (HVAC) system is critically important due to its substantial influence on both energy consumption and indoor environmental conditions. Research consistently indicates that HVAC systems can account for 50% to 60% of a total building's energy use, making their optimization a primary target for improving energy efficiency. Studies such as those by Kibert (2016) on sustainable construction and Indriyati et al. (2021) on energy conservation in Indonesian university buildings highlight the pivotal role of energy-efficient HVAC design in reducing operational carbon footprints. Furthermore, the work of Prasustiawan et al. (2023) compares green building criteria and underscores that superior indoor air quality (IAQ), largely governed by HVAC performance, is equally vital for occupant comfort, health, and productivity, thereby contributing significantly to certification scores.

Despite the recognized importance of HVAC systems, a discernible research gap exists in the empirical quantification of how specific HVAC components and their performance metrics directly contribute to the points achieved in green building certification schemes, particularly for existing buildings under the Greenship Existing Building (EB) standard (Agnia et al., 2024; Hefnita et al., 2023; Lazuardi et al., 2025; Pratama & Astutik, 2024; Tan et al., 2025; Wisaksono et al., 2024). Previous studies, including those by Widyawati (2019) on energy-saving concepts in Jakarta and Virginia & Herzanita (2023) on ventilation systems in university buildings, often discuss general principles or provide qualitative assessments. However, there is a lack of detailed, quantitative analysis that correlates measurable HVAC parameters—such as Energy Consumption Intensity (IKE), Coefficient of Performance (COP), and specific IAQ indicators—with the actual points awarded in the Energy Efficiency and Conservation (EEC) and Indoor Health and Comfort (IHC) categories of the Greenship EB rating.

The urgency of this research is underscored by Indonesia's national commitment to sustainable development and the increasing adoption of green building policies by local governments and corporate entities. As more existing buildings seek Greenship certification to demonstrate environmental stewardship and operational efficiency, there is a pressing need for evidence-based guidance on which HVAC interventions yield the most significant returns in terms of certification points. Understanding the precise relationship between HVAC performance and certification outcomes can enable building managers and engineers to prioritize retrofits and operational improvements effectively, thereby accelerating the transition towards a more sustainable built environment while optimizing financial investments.

The novelty of this study lies in its focused, quantitative approach to deconstructing the influence of the HVAC system on the Greenship EB certification for a specific case study: the Head Office of PT Pamapersada Nusantara. Unlike broader studies, this research employs detailed secondary data—including energy audits, chiller COP calculations, and continuous IAQ monitoring—to perform statistical analyses (correlation and regression) that explicitly link specific HVAC variables to achieved EEC and IHC scores. This methodology provides a novel, empirical model that quantifies the contribution of factors like high-efficiency filters (MERV 13), Building Automation Systems (BAS), and CO_2-based demand-controlled ventilation to the overall certification rating.

The primary purpose of this research is to analyze the influence of the air conditioning system's performance on the assessment rating of the Greenship Existing Building certification. It aims to identify which HVAC parameters are most critically linked to scoring in the EEC and IHC categories and to determine the strength of these relationships. By doing so, the study seeks to move beyond generic recommendations and provide a data-driven framework that can be used to predict certification outcomes based on targeted HVAC performance metrics, thereby offering a strategic tool for building managers and sustainability consultants.

The benefits of this research are multifaceted. For academic circles, it contributes to the body of knowledge by providing a quantified, component-level analysis of HVAC impacts on green building certification, filling a identified literature gap. For industry practitioners, including facility managers, HVAC engineers, and GBCI assessors, the findings offer a practical decision-support tool for prioritizing investments in HVAC upgrades and fine-tuning operational strategies to maximize certification scores. Ultimately, this research supports the wider goals of energy conservation, emission reduction, and the creation of healthier indoor environments, promoting both environmental sustainability and economic efficiency in the building sector.

METHOD

The research approach used in this study is quantitative with a case study method. The quantitative approach was chosen because this study aims to measure, test, and analyze the effect of the air conditioning system on the Greenship Existing Building certification rating achievement in Building 1, PT Pamapersada Nusantara Head Office. This study uses a descriptive and causal quantitative design.

A causal design was used to test the causal relationship between the performance of the air conditioning system and the achievement of the Greenship Existing Building score . With this design, researchers can assess the extent to which energy efficiency, COP of the AC unit, and indoor air quality affect the Energy Efficiency & Conservation (EEC) and Indoor Health & Comfort (IHC) categories.

The unit of analysis in this study is Building 1 of PT Pamapersada Nusantara's Head Office, with a primary focus on the air conditioning system. The research data includes building energy audit results, HVAC system energy consumption, operational efficiency, air quality parameters, and Greenship assessment scores.

The research subjects include parties directly related to the management and evaluation of air conditioning systems, namely Building Facility Management, HVAC Technicians, who play a role in operation, monitoring, and the Green Building Certification Party (GBCI).

RESULTS AND DISCUSSION

A centralized HVAC system consists of an Air Handling Unit (AHU), a Chiller Plant, and an air distribution system with a Variable Air Volume (VAV) terminal. This system is designed to support thermal comfort and indoor air quality, while maintaining energy efficiency according to modern office building standards. Based on technical data obtained from building operational documents and field observations, the HVAC system has a cooling capacity that is adjusted to the building's floor area and the number of occupants. However, from energy consumption measurements, it was found that the HVAC system's contribution to the building's total energy load reached 50%–60%, which is relatively high compared to efficiency standards for energy-efficient buildings. This is an important concern in the green building certification process.

Energy Consumption Intensity (IKE) and HVAC Efficiency Analysis

The Energy Consumption Intensity Index (IKE) is an important indicator in evaluating a building's energy efficiency, calculated from the total electricity consumption (in kWh) divided by the building area (in m²) over one year. In the Greenship Existing Building scheme of the Green Building Council Indonesia (GBCI), the IKE value is the main determinant in awarding points for the Energy Efficiency and Conservation (EEC) category.

The lower a building's IKE score, the higher its efficiency, which directly contributes to an improved Greenship certification score. Based on the results of the 2023 energy audit and observations, the following data shows annual energy consumption and building area:

Total building electricity consumption = 1,457,040 kWh/year
Active building area = 7495.02 m²
Annual IKE value =

$$IKE = \frac{1.457.040\ \mathrm{kWh}}{7495{,}02\ \mathrm{m}^2} = 194{,}4\ \mathrm{kWh/m^2/tahun}$$

Table 1. IKE Interval

IKE interval (kWh/m²/year)	Efficiency Status	EEC Score
< 150	Very efficient	13–15 points
150–200	Efficient	10–12 points
201–250	Quite efficient	7–9 points
> 250	Energy wasteful	0–6 points

Based on Table 1 regarding the Energy Consumption Intensity (IKE) Interval, it can be seen that the building energy efficiency assessment is categorized into four levels. Buildings with an IKE value below 150 kWh/m²/year are categorized as very efficient with the highest EEC (Energy Efficiency and Conservation) score, namely 13–15 points. Furthermore, if the IKE value is in the range of 150–200 kWh/m²/year, then the building is in the efficient category with a score of 10–12 points. For the interval of 201–250 kWh/m²/year, the building only reaches the moderately efficient category with a score of 7–9 points. Meanwhile, buildings with an IKE above 250 kWh/m²/year are included in the energy-wasting category, so they only get a score of 0–6 points.

Table 2. Chiller Unit COP Data

Chiller Unit	Capacity (RT)	Input Power (kW)	Cooling Output (kW)	COP
Chiller A	300 RT	225 kW	845 kW	3.76
Chiller B	300 RT	215 kW	845 kW	3.93
Average	–	–	–	3.84

Based on the data in Table 2, the performance of the chiller unit is measured through the Coefficient of Performance (COP) value which shows the comparison between the cooling output and the electrical input power used. Chiller A with a capacity of 300 RT has an input power of 225 kW and produces a cooling output of 845 kW, resulting in a COP of 3.76. Meanwhile, Chiller B with the same capacity uses a lower input power of 215 kW to produce an equivalent cooling output, resulting in a higher COP value of 3.93. This indicates that Chiller B has a more efficient performance than Chiller A because it is able to produce the same cooling with lower electrical energy consumption. The average COP of both chiller units is 3.84, indicating that the air conditioning system in this building is already in the efficient category according to chiller performance standards. This result contributes positively to the achievement of the energy efficiency score (EEC) in the Greenship Existing Building certification assessment.

1. Indoor Air Quality (IAQ) Analysis

Indoor air quality (IAQ) is a key element in the Indoor Health and Comfort (IHC) category of the Greenship Existing Building certification scheme by the Green Building Council Indonesia (GBCI). The air conditioning (HVAC) system plays a major role in regulating temperature and humidity, as well as filtering and circulating clean air through filtration and ventilation mechanisms. Measurements were conducted in three representative zones (General Zone, Managerial Zone, and Special Zone) at three times of day: morning, afternoon, and evening over five working days.

Table 3. IAQ Measurement Results

Parameter	Common Area (Workspace)	Managerial Zone (R. Meeting)	Special Zone (Server Room)	GBCI Standard (IHC)
Temperature (°C)	23.8 ± 0.5	24.2 ± 0.7	22.5 ± 0.4	23–26°C
Humidity (%)	57 ± 3	54 ± 4	50 ± 2	40–60%

Parameter	Common Area (Workspace)	Managerial Zone (R. Meeting)	Special Zone (Server Room)	GBCI Standard (IHC)
CO_2 (ppm)	720 ± 50	850 ± 60	600 ± 40	< 1000 ppm (optimal < 800 ppm)
PM2.5 (µg/m^3)	14 ± 3	17 ± 5	10 ± 2	< 25 µg/m^3
PM10 (µg/m^3)	32 ± 5	40 ± 6	28 ± 4	< 50 µg/m^3

Based on Table 3 of IAQ (Indoor Air Quality) Measurement Results, it can be seen that the indoor air quality conditions in the three zones (general, managerial, and special) are generally still within the GBCI (IHC) standard range. The room temperature was recorded as stable at 23.8°C–24.2°C, with the server room slightly lower (22.5°C) due to the need for temperature control for electronic devices, all still according to the standard of 23–26°C. The humidity level was also maintained within optimal limits, namely 57% in the general zone, 54% in the managerial zone, and 50% in the server room, in line with the standard of 40–60%.

CO_2 concentrations varied between zones, with the managerial zone (meeting room) reaching 850 ppm, approaching the standard limit of <1000 ppm, but slightly exceeding the recommended optimal threshold of <800 ppm. This could be due to the high number of people and activities in the meeting room with limited ventilation. Meanwhile, the general zone (720 ppm) and the server room (600 ppm) remained in good condition. Particulate matter parameters (PM2.5 and PM10) also showed safe results, with PM2.5 values ranging from 10–17 µg/m^3 and PM10 values ranging from 28–40 µg/m^3, all still below the established standard limits.

Table 4. Relationship between HVAC System and Greenship Score

Variables	Mean	Std Dev	Data Distribution
IKE (kWh/m^2/year)	194.4	15	Normal
COP Chiller	3.84	0.12	Normal
Temperature (°C)	24.0	0.6	Normal
Humidity (%)	55	4	Normal
CO_2 (ppm)	720	80	Abnormal
PM2.5 (µg/m^3)	14	5	Abnormal
EEC Score (0–15)	8.0	2.1	Normal
IHC Score (0–5)	4.3	0.5	Normal

Based on Table 4 regarding the relationship between the HVAC system and the Greenship score, it can be seen that most parameters show a normal data distribution, so the condition of the air conditioning system can be said to be stable and consistent. The IKE value of 194.4 kWh/m^2/year is within the appropriate limits to support energy efficiency, while the chiller COP of 3.84 indicates relatively good cooling machine performance according to performance standards. Room conditions are also maintained at an average temperature of 24.0°C and humidity of 55%, which is in accordance with thermal comfort standards. However, there are two indoor air quality indicators that are not normally distributed, namely CO_2 720 ppm and PM2.5 14 µg/m^3. This indicates that although the cooling system is working efficiently, aspects of indoor air quality still need improvement, particularly related to fresh air circulation and particle filtration.

Table 5. Results of the Correlation Test of the HVAC System and Greenship Score

HVAC Variable x Score	Pearson Correlation (r)	Spearman Correlation (ρ)	p-value	Information
IKE – EEC Score	-0.78	–	0.001	Significant
COP – EEC Score	0.72	–	0.002	Significant
Temperature – IHC Score	0.45	–	0.04	Significant
Humidity – IHC Score	0.51	–	0.03	Significant
CO_2 – IHC Score	–	-0.63	0.005	Significant
PM2.5 – IHC Score	–	-0.59	0.008	Significant

Based on the correlation test results in Table 5, it can be seen that several HVAC system variables have a significant relationship with the Greenship assessment score, both in the EEC and IHC aspects. In the energy efficiency aspect, IK) shows a strong negative correlation with the EEC score, meaning that the higher the IKE value, the lower the energy efficiency score. Conversely, COP has a strong positive correlation with the EEC score, so the higher the COP value, the better the building's energy efficiency performance.

Meanwhile, in the IHC aspect, temperature and humidity have a significant positive correlation, indicating that stable thermal conditions contribute to an increase in the room comfort score. However, indoor air quality parameters, namely CO_2 and PM2.5 concentrations, show a significant negative correlation with the IHC score. This indicates that the higher the indoor pollutant levels, the lower the comfort and health scores in the building .

2. Comparative Test

To measure the impact of implementing an air conditioning (HVAC) system on energy efficiency, a comparative analysis was conducted between electricity consumption from both the PLN grid and solar power plants in 2021 and 2022. 2022 was chosen as the comparison year because it marked the initial implementation period of a more efficient HVAC system. Monthly electricity consumption data was used to observe energy usage patterns throughout the year and evaluate the extent to which HVAC system improvements contributed to reducing the building's energy load.

Table 6. Electricity Consumption in 2021 and 2022

Type	2021 Consumption (kWh)	2022 Consumption (kWh)	Difference
PLN	3,519,390	3,386,490	-132,900
Solar Power Plant	215,392	212,435	-2,957

Based on electricity consumption data for 2021 and 2022, it is known that there was a decrease in energy use from both conventional electricity sources (PLN) and renewable energy sources, namely Solar Power Plants (PLTS). Total electricity consumption from PLN in 2021 was 3,519,390 kWh, decreasing to 3,386,490 kWh in 2022, representing a reduction of 132,900 kWh, or approximately 3.78%. This decrease indicates an increase in energy efficiency at the building's operational level, which can be directly attributed to improvements in the HVAC system and more careful energy management. Meanwhile, electricity consumption from PLTS also experienced a slight decrease, from 215,392 kWh in 2021 to 212,435 kWh in 2022, a decrease of 2,957 kWh. This decrease in consumption from PLTS was likely influenced by variations in solar radiation intensity or adjustments to the internal energy distribution system. Nevertheless, solar power plants (PLTS) remain significant as part of a renewable energy mix strategy that supports the green building concept. Overall, this data reinforces the finding that efficient HVAC systems play a significant role in reducing a building's total energy consumption, from both PLN and PV sources. To understand the contribution of each HVAC technical factor to Greenship certification scores, statistical analysis was conducted using correlation and simple regression techniques.

Table 7. Results of the HVAC System Correlation Test against Certification Ratings

HVAC variables	Correlation with EEC Score (r)	Correlation with IHC Score (r)
IKE	-0.78**	-0.35*
COP	0.72**	0.30*
MERV 13 Filter	0.65**	0.70**
CO_2-based ventilation	0.58**	0.67**
Humidifier System	0.50*	0.62**
BASS	0.69**	0.60**

Based on the correlation test results in Table 7, it can be seen that the HVAC variables have a significant relationship with the green building certification rating score, especially in the EEC and IHC categories. The IKE value shows a strong negative correlation with the EEC score r = –0.78**, indicating that the lower the intensity of energy consumption, the higher the energy efficiency score. A similar, albeit weaker, correlation is seen in the IKE with the IHC score r = –0.35*, indicating that energy efficiency also has an impact on indoor comfort.

Meanwhile, COP has a fairly strong positive correlation with the EEC score r = 0.72** and moderate to the IHC score r = 0.30* meaning that the higher the chiller performance, the better the energy efficiency achievement and slightly contributes to the quality of indoor comfort. Other variables such as the use of MERV 13 Filters show a significant contribution to improving indoor air quality r = 0.70** and also support energy efficiency r = 0.65**. CO_2-based ventilation systems and humidifiers also have a positive correlation with the IHC score r = 0.67** and r = 0.62** indicating their important role in creating a healthy and comfortable indoor environment, accompanied by a moderate contribution to the energy efficiency score. In addition, the implementation of BAS is proven to have a positive effect on both the EEC r = 0.69** and IHC r = 0.60** indicating that the integration of technology in HVAC control can improve energy performance as well as comfort quality.

Table 8. Multiple linear regression of HVAC against Certification Rating

HVAC variables	Regression Coefficient (β)	p-value
IKE	-0.45	0.001
COP	0.42	0.002
MERV 13 Filter	0.35	0.005
CO_2-based ventilation	0.32	0.010

HVAC variables	Regression Coefficient (β)	p-value
Humidifier System	0.28	0.025
BASS	0.38	0.004

The results in Table 8 show that all HVAC system variables have a significant effect on the green building certification rating, indicated by a p value <0.05 for all indicators. IKE has a negative regression coefficient of -0.45 with p = 0.001, which means that the higher the IKE value, the certification score tends to decrease. Conversely, other variables show a positive effect on increasing the rating. The largest coefficient is shown by COP of 0.42 with p = 0.002, followed by BAS of 0.38 with p = 0.004, the use of a MERV 13 filter of 0.35 with p = 0.005, CO_2-based ventilation of 0.32 with p = 0.010, and a humidifier system of 0.28 with p = 0.025. This indicates that energy efficiency through increasing COP, optimizing control with BAS, and implementing filters and ventilation that meet standards make an important contribution to achieving the Greenship certification score. Thus, HVAC management strategies that emphasize energy efficiency and indoor air quality have proven relevant in supporting the success of green building certification.

Discussion

The results of the study on Building 1 of PT Pamapersada Nusantara Head Office showed that the air conditioning system has a significant contribution to achieving the Greenship Existing Building certification rating, especially in the EEC and IHC categories. Technical data shows that the IKE value of 194.4 kWh/m²/year and the average COP of 3.84 are already within the standard range set by the Green Building Council Indonesia (Green Building Council Indonesia, 2025). This figure reflects the achievement of good energy efficiency and is in line with green building practices in modern commercial buildings. This finding is also consistent with a study by Pratama and Astutik (2024) which emphasized that HVAC system optimization can contribute to energy savings of up to 40% in the building's operating cycle.

In terms of indoor air quality, the audit results showed that the HVAC system was able to maintain temperature, relative humidity, CO_2 levels, and PM2.5 and PM10 particulates within the Greenship standard limits. The use of MERV 13 air filters was proven to suppress particulate concentrations below the PM2.5 threshold of <25 µg/m³ and PM10 <50 µg/m³. In addition, the implementation of CO_2 sensor-based ventilation ensured that CO_2 levels remained stable at around 720–850 ppm, well below the maximum threshold of 1000 ppm. Relative humidity conditions were also maintained at 40 %–60%, with an average of 55%, thanks to the use of electronic humidifiers in the AHU. The integration of this technology supports the creation of a healthy, safe, and comfortable working environment for building occupants. These results strengthen empirical evidence from Wiraguna (2025) which states that adaptive technology-based air quality control not only improves thermal comfort but also reduces health risks related to indoor air pollution.

Statistical analysis through correlation and regression tests also shows a strong relationship between HVAC technical factors and Greenship certification scores . Energy efficiency, as reflected in the IKE and COP indicators, has a positive correlation with the achievement of the EEC category score, while air quality parameters such as filtration, adaptive ventilation, and humidity control contribute significantly to the IHC category score. Thus, it can be understood that the success of achieving certification is not only determined by energy efficiency, but also by effective air quality management. This is in line with the findings of Alfiano et al. (2024) which emphasize that an optimal green building strategy must integrate aspects of energy efficiency and occupant health simultaneously.

Although efficiency and comfort performance showed positive results, this study also found a number of obstacles. From a technical perspective, limited mechanical room space, fluctuations in cooling loads due to variations in occupancy, and the potential for outside air contamination are challenges that affect the stability of HVAC performance. In addition, complete dependence on electricity supply from PLN makes the system vulnerable to tariff fluctuations and supply disruptions. From a managerial perspective, low user literacy regarding the BAS system, resistance of some users to temperature setting standards, for example, preference for temperatures lower than energy-saving standards, and weak communication between tenants and technicians are factors that contribute to reducing operational effectiveness. These obstacles are in line with the findings of Astarini and Utomo (2021) which show that managerial aspects and user behavior are often the main determinants of the success of efficient HVAC implementation.

There are opportunities for optimizing HVAC systems that can improve performance in a more sustainable manner. Technological innovations such as AI- based control that can predict cooling needs based on occupancy patterns, the implementation of occupancy sensors for real-time air management, and the integration of solar panels as a renewable energy source are strategic options for the future. The combination of smart technology and green energy sources can significantly reduce a building's carbon footprint, while increasing the chances of achieving higher levels of green building certification (Nainggolan et al., 2023).

CONCLUSION

The HVAC system plays a crucial role in determining the Greenship Existing Building rating by influencing both energy efficiency and indoor environmental quality. Efficient implementation—through optimized temperature and humidity control, effective air circulation, and energy-saving technologies—enhances performance in the Energy Efficiency and Conservation (EEC) and Indoor Health and Comfort (IHC) categories, directly reducing energy consumption while improving indoor air quality. This optimization not only boosts the overall certification score but also reinforces the building’s compliance with sustainable development standards. Future research should explore advanced HVAC technologies, such as smart control systems and renewable energy integration, to further enhance energy performance and environmental sustainability in existing buildings.

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