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Review paper

Optimizing the Use of Water, Energy and Waste Resources in Green Buildings: Critical Review, Benefits and Challenges

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ABSTRACT

Research on themes related to green buildings is very important because it relates to building environmentally friendly buildings that prioritize sustainability. However, Green Building and Sustainable Development Goals (SDGs) research tends not to be comprehensive because it only relates to building construction and energy efficiency. For this reason, this research will discuss various things about green buildings and criticize what has been analyzed, whether it is still appropriate or not, considering current conditions that already use wireless and IoT technology. Through literature review techniques, this research examines themes related to the civil sector and the implementation of Green Building goals and SDGs. The Systematic Literature Review (SLR) method is used. Namely, in-depth criticism and evaluation of previous research carried out systematically by applying applicable standards, using the Viosviewer and Publish and Perish applications. This method examines research results published in journals in a particular field. Literature reviews discuss previous research that meets SDGS objectives and is related to the civil sector. This research used 300 earlier studies with a research period ranging from 2010-2023 or 14 years. The research results show that the theme that is often raised is green materials and technology. The use of technology to measure building performance and energy efficiency is the most widely discussed theme. However, the analysis of Green Building and SDGs is rarely linked to IoT technology, saving water use, rainwater utilization, environmentally based wastewater management, and green building education, even though this is closely related to cost efficiency, energy efficiency, and speed, in communicating to achieve SDGs goals.

1. Introduction

Indonesia is committed to sustainable development nationally, especially in the infrastructure distribution program. The government has prepared a National Medium Term Development Plan (RPJMN) 2020-2024, where the vision is "the realization of an advanced Indonesia that is sovereign, independent and has a cooperation personality," as well as several supporting missions."[1]. Efforts to equalize infrastructure have two important missions: fair development and a sustainable environment. The government implements fair development by developing public facilities and infrastructure in the regions so that the areas can experience growth.

A nation's true economic progress can be seen in a growing population, a wider range of infrastructure, and increased available services. However, this progress often comes at a cost to the environment, as economic activity can strain natural resources. While the construction industry booms during development, providing opportunities for workers, it's important to acknowledge the potential environmental impact. [2]. To reduce the environmental impact of the infrastructure development process, a concept called sustainability has emerged. Sustainability is a development concept that seeks to reduce the ecological effects. [3].

Recognizing the global need for sustainable practices, Indonesia's Ministry of Public Works and Housing has issued Ministerial Regulation Number 9 of 2021. This legislation provides guidelines for the construction industry to adopt sustainable practices. The main issues discussed in these legal regulations align with the problems set by The United Nations, namely that the implementation of construction in Indonesia includes three basic pillars: improving the economy and community welfare, maintaining environmental preservation, and reducing social disparities in society. [4].

In recent years, extensive effort has been devoted to

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applying stimuli-responsive smart materials and nanostructures in buildings. These smart materials used in the built environment can be defined as those offering specific functional and adaptable properties in response to thermal, optical, structural, and environmental stimuli [5]. As the green construction phenomenon continues to grow and gain popularity, many problems and issues cast doubt on the development of green construction [6]. The green building movement is now mature enough to demonstrate the value of the green economy in the real estate market for building owners and tenants, as evidenced by the rapid increase in the use of renewable energy and the conversion of information technology and technology development into the development of smart cities, eco-districts, and eco-campuses [7].

Using literature review techniques, we analyzed sustainability research trends related to green construction. This research aims to provide an overview of sustainable construction in Indonesia based on a literature review. The documents analyzed are several studies that discuss sustainable construction in Indonesia. This research will examine literature from Scopus-indexed journals over the last ten years. Based on these journals, it is hoped that trends regarding the discussion of green construction can be found so that further research can be created to discuss other issues that have not been reviewed or discussed much in green building.

2. Method

The research method in this article begins with determining the research objective, namely knowing the implementation of sustainable construction based on a literature review. Before continuing to analyze articles related to sustainable building, an exploration of the map of legislation that has been in force in Indonesia is carried out, which discusses sustainable construction.

The data used in this research is secondary data, namely articles in scientific research journals. The method for collecting related articles is collected in the "Scopus and Elsevier" databases using advanced search tools. The settings in the Scopus database include language settings (in Indonesian) and year of publication from 2010 to 2023. The applications used are Mendeley, Viosviewer, and Publish or Perish.

3. Result and Discussion

3.1. Presenting the Results

The search yielded 20 journals containing the keywords green building, green construction, and sustainability. This study examines how different countries got started with green building initiatives and how far they've progressed. It provides a general picture of green building development around the world. The report explores two key influences on green buildings: external and internal. External factors include government policies that support green building, the economic advantages of green buildings, and green building certification programs. Internal factors focus on the technologies used in green buildings, how well these buildings are managed, and how the people who use them interact with the green technologies. [8].

To truly unlock the potential of green building solutions, we need to consider energy-saving technologies from the beginning of a project through construction. By doing this, green buildings can deliver on their full promise: lower energy bills, cleaner air, and a more comfortable and healthy space for occupants. [9].

The construction included standard and eco-friendly materials, with a plan for disposal at the end of the building's lifespan. Bio-based materials were prioritized from the design stage, with architects acting as designers and green material developers. All three projects incorporated methods for easier deconstruction, promoting this approach for future architects. [10].

This study investigates how to make green roofs more energy-efficient in sustainable buildings. Researchers are looking at the best plants to use and the impact green roofs have on a building's overall energy consumption. The goal is to identify both the advantages and challenges of green roofs.[11].

3.2. Discussion

Based on the results of the review, it can be seen that research on green building or green construction discusses several themes, including the use of technology to regulate the use of electronic equipment in homes or buildings—the use of environmentally friendly materials and saving energy through various designs and lighting.

Ziaee et al. [11], Shen et al. [12], Kaposztasova et al. [13] And Delavar et al. [14] has researched green buildings and technology related to sustainability. meanwhile Dahy [10], Fonseca et al. [15], Czarneki dan Rudner [16]Delgado et al. [17] And Bediako et al. [18] Has researched environmentally friendly materials.

Ahmad et al. [19]Zhang et al. [20], Shen et al. [12] dan Xu [21] has researched water management and the use of technology to help manage clean water. Utomo et al. [7]Jo et al. [22] and Shi et al. [5] has researched waste management. Meanwhile, Zhao dan Gao [23], Kaposztasova et al. [13] and Delavar et al. [14] has researched energy efficiency in buildings.

These results indicate that the research theme often raised is using technology to maintain sustainability. Other themes contained in this review are materials used in construction, design, and the environment. The results of this review also show that the period 2015 to 2019 discusses the themes of using environmentally friendly materials, environmentally friendly design, and the environment itself.

Green building construction is now gaining ground in Singapore's construction industry, and with increasing awareness of environmental issues and growing concerns over climate change, sustainable construction is gradually being promoted globally. However, the construction of environmentally friendly buildings in Singapore still faces obstacles due to the lack of a proper project management framework. Based on survey results and interviews with 31 industry experts, this research aims to identify common barriers faced while managing environmentally friendly construction projects, ultimately proposing several solutions to overcome these obstacles. This research reveals that, although project costs are a major obstacle in green building

construction management, there is no shortage of sustainable knowledge in Singapore's construction industry. To address cost-related issues, the scope of government incentives should be expanded to include environmentally friendly products and technologies. In addition, a project management framework for environmentally friendly building construction should be developed to overcome these barriers and encourage sustainable construction implementation in future projects [24].

To properly understand and use green building technologies, it is important to improve policy and incentive systems, improve the professional quality and technical capabilities of employees and accredited consultants, continuously develop and update evaluation systems, strengthen technological innovation, and integrate design and management. This paper aims to describe a clear roadmap for national standards development, policy formulation, and construction design enterprises, provide solutions to remove barriers, and suggest research directions for future studies. [8].

This research presents a summary of green building research using a bibliometric approach. 2980 articles published in 2000–2016 were reviewed and analyzed. The results show that green building research has been concentrated in the subject categories of engineering, environmental science & ecology, and construction & building technology, and the keywords 'building envelope' and 'living wall' have received many citations in recent years. In addition, based on cluster analysis and content analysis, hot research topics were identified: green and cool roofs, vertical greening systems, water efficiency, occupant comfort and satisfaction, financial benefits of green buildings, life cycle assessment and ranking system, green retrofit, implementation of environmentally friendly building projects, and information and communication technology in environmentally friendly buildings. Knowledge gaps were detected in corporate social responsibility, validating the real performance of environmentally friendly buildings, the application of ICT in environmentally friendly buildings, and safety and health risks in the construction process of environmentally friendly projects. Future research directions are recommended to fill this gap and expand the scope of green building research. [25]. His study examines the influence of Green Star (GS, Australia) on building design compared to Leadership in Energy and Environmental Design (LEED, USA) and Assessment Standard for Green Buildings (ASGB, China). Using the Melbourne School of Design (GS Six Stars certified) as a case study reveals a crucial difference: GS focuses on building performance, while LEED and ASGB offer design guidance. The analysis highlights that LEED prioritizes energy efficiency, while GS takes a more holistic approach, considering both energy and indoor environmental quality. Additionally, GS emphasizes project management. Researchers assessed potential LEED and ASGB certification levels for the case study and design changes needed to achieve the highest levels. The findings demonstrate how different environmental concerns and assessment approaches (performance vs. guidance) impact green buildings' design and overall performance. This research suggests that performance-based rating systems like GS might be more effective in promoting sustainable design practices than measure-based systems like LEED and ASGB.[26].

The analysis results also show that the most important strategies to encourage GBT adoption are further financial and market-based incentives, better availability of information on the costs and benefits of GBT, and eco-labeling and information dissemination. These findings provide a valuable reference for industry practitioners and researchers to deepen their understanding of the key issues influencing GB decision-making and for policymakers aiming to promote the implementation of GBT in the construction industry to develop appropriate policies and incentives. This study expands knowledge about the influences that hinder and promote GBT adoption. [27].

Ranking the level of awareness of the investigated technologies shows that architects in the study area are the most aware of solar energy systems and the least aware of energy-saving windows. The same thing was also expressed in the ranking of technology implementation. Natural lighting strategies were most widely used, while biofuel systems were least used by architects in the 1980s in the study area. The research also shows that client resistance is the main factor preventing architects from implementing environmentally friendly building technology. Based on these findings, this paper recommends intensive awareness efforts to increase client knowledge about the enormous benefits of environmentally friendly building technology compared to conventional technology. [28].

Buildings designed with sustainability in mind, also known as green buildings, bring many advantages to India. These benefits include lower energy consumption and operating costs, improved building air quality, and a healthier work environment for occupants. India has adopted several green building rating methods to promote sustainable construction practices. These methods, including GRIHA, LEED, and IGBC, encourage practices that save energy and water, reduce carbon dioxide emissions, and utilize rainwater harvesting and greywater reuse techniques. However, there are initial hurdles to overcome. Green buildings can have higher upfront construction costs, and there may be a lack of financial incentives to encourage widespread adoption. Despite these challenges, integrating environmentally friendly solutions into building projects remains crucial. By embracing sustainable construction practices, India can create a healthier environment for its people and contribute to a more sustainable future. [9].

Green buildings, constructed with energy-saving systems and sustainable practices in mind, offer significant advantages. These buildings consume less energy during operation and have lower long-term operating and maintenance costs.

However, government involvement is crucial in promoting the wider adoption of sustainable construction practices. Implementing stricter regulations and offering attractive incentives can encourage more stakeholders to participate in this shift towards a greener building sector. [29]. The potential of incorporating renewable energy technologies into architectural design to reduce energy consumption in urban contexts is highlighted by this research. By measuring the impact of green building practices on energy efficiency, planners, architects, and

legislators can obtain important information about the viability and efficiency of sustainable building solutions. The results highlight how important it is for renewable energy and architecture experts to work trans-disciplinary to create environmentally conscious urban environments. [30]. His passage highlights the dual benefit of green buildings. They make a healthier indoor environment for occupants while minimizing their negative environmental impact. This focus on occupant well-being aligns with the growing interest in sustainable architecture's role in promoting overall health.

The review emphasizes the crucial role of green buildings in tackling the global energy crisis. Green buildings offer a win-win solution for both people and the planet by promoting energy efficiency and creating healthier living spaces. [31].

Increasing energy efficiency is the key to achieving sustainability, reducing CO2 emissions, and minimizing air pollution. Utilizing solar energy in water heating can reduce the negative impact of electricity use on the environment. The process of industrialization, urbanization, and advances in social and cultural aspects also increase energy needs, causing energy consumption per person to rise. Given population growth and ever-increasing energy needs, especially due to limited fossil fuels, there is a transition towards renewable energy technologies such as solar panels, concentrated solar power, wave power, fuel cell energy, and other technologies. If managed with careful planning and efficient use, this technology has great potential to become the main solution for sustainable energy use worldwide.

A study by Slawomir Czarnecki and Marlena Rudner (2023) highlights the need to recycle materials resulting from renovating and demolishing building structures in the spirit of sustainable materials engineering. In this way, it is not wasted but can be used for rebuilding buildings, even though some parts cannot be used in the main appearance of the new building. For example, removing con block material can still be used to park motorbikes behind buildings.

Furthermore, Mark Bediako et al. (2016) stated. We must find ways to use cement more sustainably in construction by incorporating eco-friendly materials. This could involve mixing in fly ash or even using leftover industrial waste like bauxite residue in concrete for buildings and roads.

Then Rubio et al. (2024) underlined the importance of using sustainable rooting strategies in the landscape, arranging architecture and soil so that it does not use a lot of material but remains strong, and utilizing the site to highlight the beauty of the natural landscape at that location.

This article explores using smart sensor networks to control building ventilation, air conditioning, and lighting. Researchers can optimize energy use and operational costs by analyzing environmental systems through these sensors. Additionally, real-world applications demonstrate the benefits of controlled ventilation on indoor air quality.

The key takeaway is that integrating smart sensing networks (often called "IoT" - Internet of Things) offers a powerful solution. This technology reduces energy consumption and costs and improves occupant comfort by responding to real-time conditions. Research conducted by Biantoro (2018) regarding electrical audits and energy efficiency shows the efforts made by building managers to implement the green building concept. [32]. Drainage planning and using flood detection tools equipped with sensors are part of water resources management, where knowing when a flood arrives and the amount of water discharge that comes can help managers prepare to reduce the impact of flooding. [33].

The results of topic research from the beginning using the Publish or Perish application with publications from 2010 – 2023 are in **Table 1** below:

Table 1. Data Metrics from Initial Search Results for "Green Building"

No	Description	Data
1	Publication Years	2010 - 2023
2	Citation Years	14 (2010 – 2024)
3	Papers	300
4	Citation	119907
5	Cites / Year	8564.79
6	Cites/paper	399.69
7	Cites / Author	52360.63
8	Papers / Author	125.74
9	Authors/paper	3.04
10	H Index	243
11	G Index	300

Furthermore, after the selection is carried out to suit the topic in question, the results are in **Table 2** below:

Table 2. Data Metrics for Final Search Results for "Green Building"

No	Description	Data
1	Publication Years	2010 - 2023
2	Citation Years	14 (2010 – 2024)
3	Papers	258
4	Citation	101554
5	Cites / Year	7253.86
6	Cites/paper	393.62
7	Cites / Author	43069.46
8	Papers / Author	106.04
9	Authors/paper	3.11
10	H Index	226
11	G Index	258

Next, the research was analyzed and collected, taking into account the many themes chosen related to Green Building SDGs; the results are as follows (**Fig. 1**):

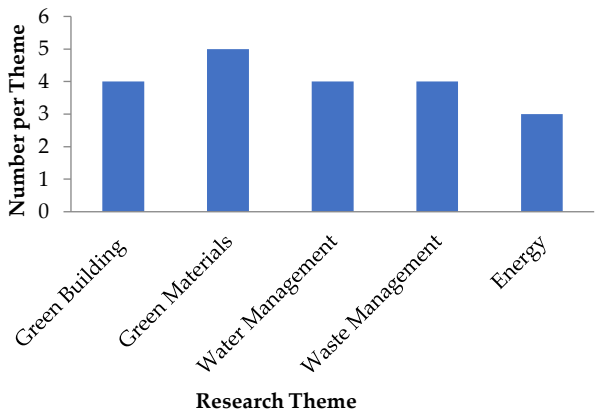

Fig. 1. Review results related to SDGs

The results of the research above show that the green

building concept, which is currently widely discussed, is more directed at reducing excessive energy use, so green technology is needed by using various applications or software to help regulate energy use. On the other hand, the application of green buildings in terms of design, use of waste, management of clean water, use of rainwater (rain harvesting) and wastewater, and related technologies have not yet been widely discussed.

The green building concept leads to efficient use of energy. Building designs that prioritize using natural light and energy-saving electrical equipment are widely used—the idea of saving energy and energy conversion to get savings on energy and other resources.

33 journals were used in this research, where the researchers were related to the themes discussed. Using the Vosviewer application, you can see the mapping results based on the journals used in this literature review.

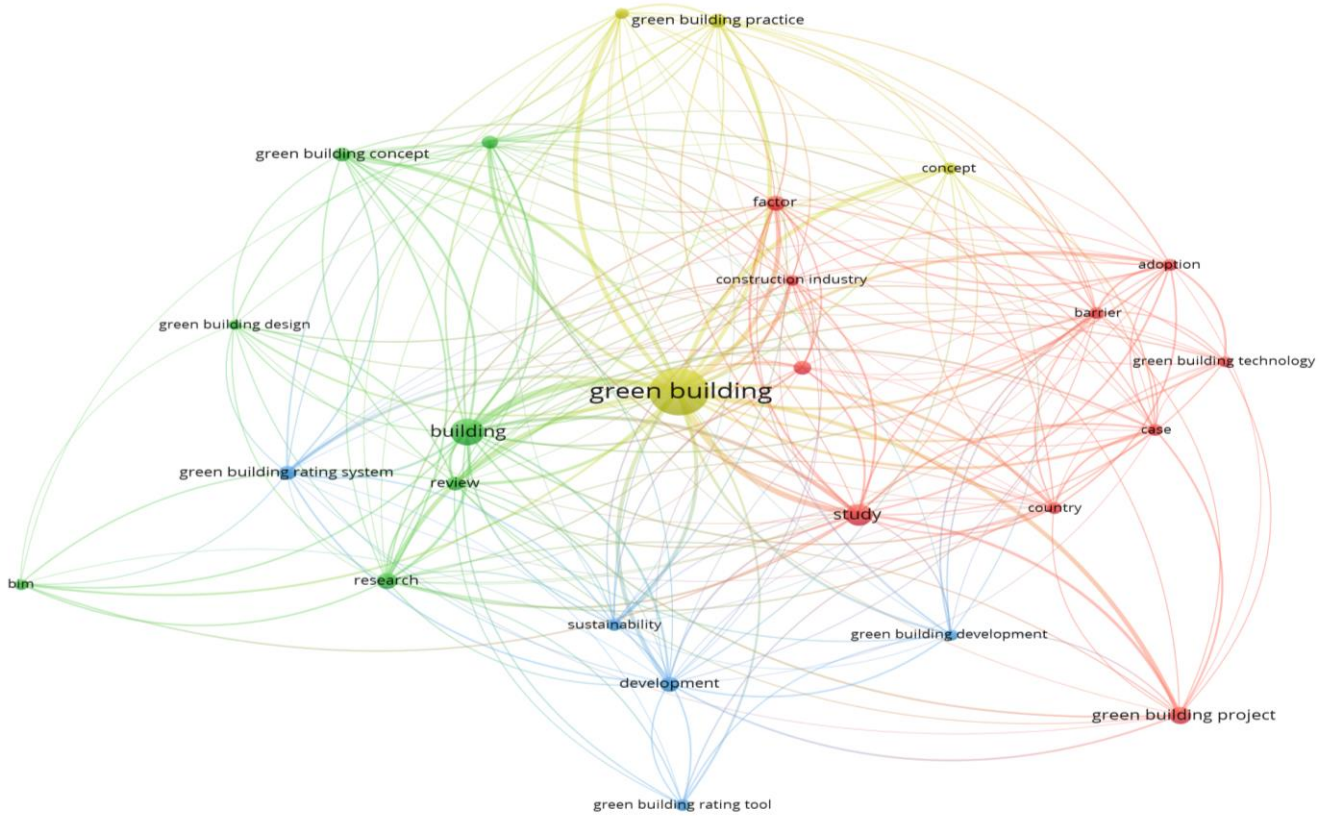

Fig. 2. Mapping results using Green Buiding Network Visualization

The results of the literature review show a strong relationship between several references that are interconnected and differentiated by color. The bigger the circle, the more there is talk about green building. There is quite a lot of research related to keyword study and building. Still, when it comes to BIM, green building design, green building concept, and green building technology, there is little novelty can be extracted from these keywords (Fig. 2). This connection can be in the form of a theme or the use of the same citations or mutual citations. Furthermore, the results of mapping using the Vosviewer application regarding the latest trends in Green Building Overlay Visualization can be seen in **Fig. 3**. The brighter the color in the form of yellow greenish-yellow, the more recent it is, or the topic is still being discussed, conversely, the darker it is, the more it has been discussed. For example, themes related to green building in the form of BIM, study, and green building technology are still being discussed recently.

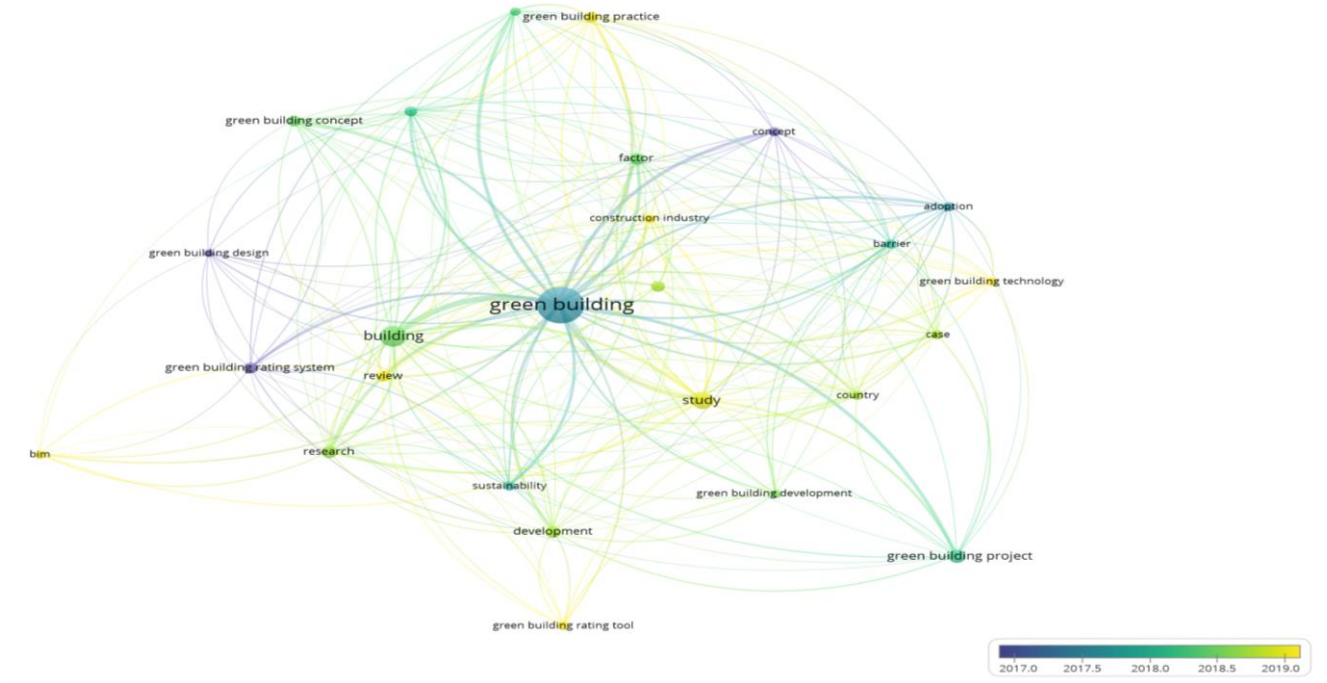

Fig. 3. Mapping results using Green Buiding Overlay Visualization

Green building research related to density is as follows (**Fig. 4**):

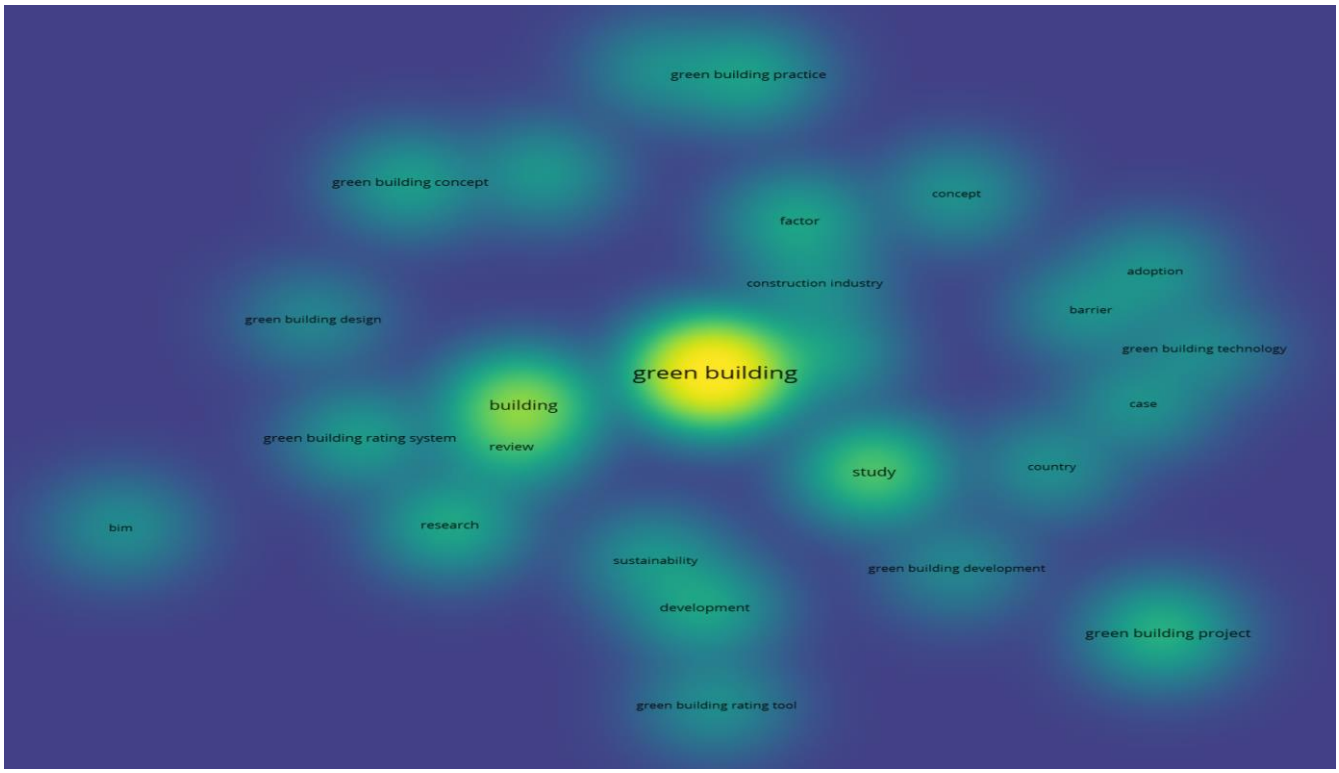

Fig. 4. Mapping results using Green Buiding Density Visualization

The results of mapping using the Vosviewer application regarding Green Building Density Visualization can be seen in **Fig. 4**. The brighter the color in the form of yellow or greenish-yellow, the more recent it is, or the more discussed the topic is, conversely the blurrier it is, the more it is discussed. For example, themes related to green buildings in the form of BIM, studies, and green building technology are still not discussed much.

4. Conclusion

The results of this research show that the green building concept, which is currently widely discussed, is aimed at reducing excessive energy use, so various applications or software are used to help regulate energy use. The application of green building is still widely discussed regarding green technology and environmentally friendly

materials. The use of technology to measure building performance and energy efficiency is also the most discussed theme. However, the analysis of Green Building and SDGs with IoT technology, building design, waste management, wastewater, clean water management, rain harvesting, and related technologies has not yet been widely discussed. This is closely related to cost efficiency, energy efficiency, and speed in communicating and making reports.

Author Declaration

Authors' contributions and responsibilities

The authors made substantial contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation, and discussion of results. The authors read and approved the final manuscript.

Availability of data and materials

All data are available from the authors.

Competing interests

The authors declare no competing interest.

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