HITTITE JOURNAL OF SCIENCE AND ENGINEERING

e-ISSN: 2148-4171
Volume: 12 • Number: 2
June 2025

# Bibliometric Analysis of Publications on Sustainable Renovation of Buildings from 2001 to 2024

**Sema Balçık*[1] | Ruşen Yamaçlı[2]**
[1]Sivas Cumhuriyet University, Department of Urban and Regional Planning, 58140, Sivas, Türkiye.
[2]Eskisehir Technical University, Department of Architecture, 26555, Eskisehir, Türkiye.

## Corresponding Author
**Sema Balçık**
E-mail: semabalcik@cumhuriyet.edu.tr Phone: +90 346 219 1560 / 3393
RORID[1]: https://ror.org/04f81fm77 RORID[2]: https://ror.org/00gcgqv39

## Article Information
**Article Type:** Review
**Doi:** https://doi.org/10.17350/HJSE19030000353
**Received:** 0 1.12.2024
**Accepted:** 10.04.2025
**Published:** 30.06.2025

## Cite As
Balçık S, Yamaçlı R. Bibliometric analysis of publications on sustainable renovation of buildings from 2001 to 2024. Hittite J Sci Eng. 2025;12(2):69-79.

**Peer Review:** Evaluated by independent reviewers working in at least two different institutions appointed by the field editor.
**Ethical Statement:** Not available.
**Plagiarism Checks:** Yes - iThenticate
**Conflict of Interest:** Authors declare no conflict of interest.

**CRediT AUTHOR STATEMENT**
**Sema Balçık:** Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Resources, Supervision, Writing – review and editing. **Ruşen Yamaçlı:** Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Supervision, Visualization, Writing – original draft & editing.

# Bibliometric Analysis of Publications on Sustainable Renovation of Buildings from 2001 to 2024

Sema Balçık*[1] |Ruşen Yamaçlı[2]

[1]Sivas Cumhuriyet University, Department of Urban and Regional Planning, 58140, Sivas, Türkiye.
[2]Eskisehir Technical University, Department of Architecture, 26555, Eskisehir, Türkiye.

## Abstract

Sustainable architecture is becoming increasingly important today, and designs that take into account environmental conditions come to the fore, especially in the life cycle of the existing building stock and in the processes of building new buildings. The principles of sustainable architecture aim to produce buildings that cause the least damage to the environment and consume the least amount of natural resources, minimize the damage to the environment in the existing building stock, and provide sustainable qualities through renovation processes. Not demolishing the existing building stock, not destroying the energy embedded in buildings, not creating waste, and not harming the environment is a sustainable architectural approach. In addition, by renovating buildings to increase their sustainable quality, they are made more sensitive to the environment. This study aims to evaluate the publications on sustainable building renovation by bibliometric analysis method. Within the scope of the study, data obtained from the Web of Science (WoS) database were used. The study retrieved 1058 publications published between 2001 and 2024 from the Web of Science database on November 17, 2024. The data obtained as a result of bibliometric analysis were created visual network maps using the VOSviewer program. This study emphasizes the importance of sustainable renovation of buildings and efficient consumption of resources within the scope of sustainable development. Within the scope of the study, quantitative data on the development of the subject in the world in line with the bibliometric analysis method are included. In this direction, suggestions have been developed on what needs to be done to increase sustainable building renovation studies.

**Keywords:** Sustainable architecture, Sustainable renovation, Sustainable renovation of buildings, Bibliometric analysis, VOSviewer

## INTRODUCTION

The concept of sustainability, which should be given importance and included in every field today, is best known as meeting the needs of the present while not preventing future generations from meeting their needs (1). For this reason, when we consider the rapidly increasing consumption habits, it is necessary to focus on producing sustainable solutions in all areas of life.

The field of architecture should include the principles of sustainability in all its steps with its human-oriented approaches, resource utilization, and the quality of life that needs to be sustained. The principles of sustainable architecture are expressed by Belek and Yamaçlı (2) as focusing on human-centered design, protecting natural resources, and planning the life cycle. As one of the steps of sustainable architecture, the reuse and sustainable renovation of buildings also allows the protection of natural resources and the re-planning of buildings in a human-centered and sustainable way.

In cities, there is a trend towards strengthening and reusing buildings instead of new construction to ensure energy efficiency and reduce environmental impacts, and existing buildings are seen as a resource reserve. Reuse ensures waste reduction, resource recovery, and efficient use (3). According to Elefante (4), the most environmentally sustainable buildings are those that already exist, and repurposing these structures yields significant resource and energy conservation.

Buildings account for approximately 40% of energy consumption (5). Considering this situation, sustainable renovation of buildings should become a necessity in these days when we face the dangers of depletion of natural resources. In their research, Menna et al. (6), state that sustainable retrofitting of existing buildings constitutes an important step in sustainable architecture steps to achieve climate and energy goals. Trachte and Salvesen (7), stated that sustainable renovation of buildings is an option that improves comfort and quality of life for users, as well as contributing to the environment through energy efficiency.

Sustainable renovation of buildings constitutes an important sustainable architecture approach and has become an increasingly important concept. The act of building a building means the use of a lot of materials, a labor-intensive process, and the intervention of a new area in nature. While the reuse of the building eliminates these harmful steps, its sustainable renovation will increase respect for nature in the life process. For this reason, more studies on sustainable renovation of buildings should be conducted and recommendations should be developed.

Bibliometric studies reveal documents related to a specific subject. The bibliometric analysis method, which is widely used in many different fields, provides a quantitative examination of different variables such as publication years, types, languages, countries, and citation analysis (8). This research study seeks to delineate the current state of international literature regarding sustainable building refurbishment from 2001 to 2024. This date range has been determined based on the oldest publication accessed after the categories were identified during the subject-specific search in the Web of Science (WoS) database. The aim is to identify the qualitative characteristics such as the fields of study within the scope of the subject, keywords that would indicate the trend of the subject, the languages of the publications, and the countries where they were published, as well as the quantitative characteristics such as the years of publication, the number of publications, and the number of citations. The study employed bibliometric analysis to elucidate the focus of research and its contemporary significance for the notion of sustainable building refurbishment.

In line with the purpose of the study, the qualitative research method was primarily used, and the importance of the topic

of sustainable building renovation was emphasized. Then, using the bibliometric analysis method, data on the studies produced by searching the keyword "sustainable renovation of buildings" in the Web of Science (WoS) database were accessed (9). As a result of the search, the studies were visualized through tables and the VOSviewer program with the data obtained within the scope of category, year, type, journals, indexes, countries producing the most studies, publication languages, contributions to sustainable development goals, and keywords. This program enables the analysis and visualization of scientific publication studies and citation networks (10). As a result of the study, recommendations were developed based on the findings obtained from the analysis of the tables and visualizations produced within the scope of sustainable building renovation.

## MATERIAL AND METHODS

The material of the research study consists of data obtained through the bibliometric analysis method. Within the scope of the study, the concept of sustainable renovation of buildings is first explained. Then, the Web of Science (WoS) database was selected to obtain data on studies on sustainable renovation of buildings. This database stood out among analytical information and scientific citation search platforms. The selection of the Web of Science database for the analysis was based on the quality and reliability of the research, its advanced search indicators, and its comprehensive data on different disciplines and transitions (11). The data obtained from the Web of Science database was used to conduct a bibliometric analysis of the concept of sustainable renovation of buildings. Bibliometric analysis is widely used to evaluate and analyze large volumes of scientific data and is a method that enables understanding the relationship between the number of citations and publications, keywords, and topic occurrences in the current topic to obtain an overview of the researched topic, to identify knowledge gaps within the scope of the topic, to derive new ideas for research, and to indicate intended contributions to the field (12). The data of the studies obtained through the database were evaluated using the VOSviewer program developed by Nees Jan van Eck and Ludo Waltman (13) at the Center for Science and Technology Studies at Leiden University.

Van Eck and Waltman (14), the founders of the VOSviewer software, state that the software should be used to create bibliometric maps and that this software provides advantages and important contributions to researchers by using different techniques in the analysis. In addition to the Vosviewer program for bibliometric analyses, there are also software programs such as Citespice, BibExcel, Gephi, Scimat, and Histcite for visualization. Among these, VOSviwer is more commonly preferred for analyses such as citation analysis, co-citation, and bibliographic coupling in the structuring of bibliometric networks (15). By evaluating large amounts of bibliographic data, the VOSviewer program allows the invisible concepts in publications to be depicted in the form of maps, to be understandable by transforming them into a visual representation, and to apply thresholds to categorize this data (16). It provides an advantage in the process of analysis analysis to examine and visualize the structures and dynamics of publications. The steps that constitute the method of the study are shown in Figure 1.

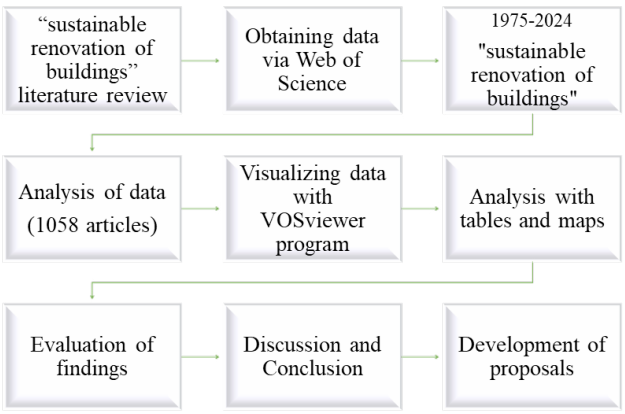


**Figure 1** Methodology of the study

In order to obtain the studies conducted between 1975-2024 in the Web of Science (WoS) database within the scope of sustainable renovation of buildings, "All Fields" was selected in the search section and "sustainable renovation of buildings" was typed as the keyword. The Web of Science (WoS) database includes publications from 1975 onwards. The term "buildings" in the context of renovation encompasses the complete current building inventory, without differentiating between heritage structures. The search through WoS was conducted on November 17, 2024. As a result of this search, 1,720 studies were found. The analysis was limited to articles and when "article" was selected as the document type, 1,139 results were obtained. When only architecture is selected as a category, 67 article studies are revealed. For this reason, the category with at least 10 studies produced in this field was marked. The 21 selected categories and the number of studies are shown in Table 1 and it is seen that the discipline of architecture ranks 8th in terms of the number of studies. It is seen that the highest number of studies is in the field of Construction Building Technology with 370 studies. As a result of the search in line with the selected categories, 1 study from the year 2025 was excluded and bibliometric analysis was performed with 1,058 studies.

The reuse of buildings makes use of the available energy in the building stocks stored in our cities. Guidettia & Ferrara (17), state that in addition to the available energy, the reuse of these buildings should be emphasized in terms of creating the built environment in the future. In addition to the sustainable nature of their reuse, another step is to improve the energy consumption of buildings during their life cycle. According to the European Commission report, buildings are the largest consumers of energy in Europe, and their renovation has an important role in achieving energy and climate targets (18).The ratios mentioned in the report are shown in Figure 2.

**Table 1** Distribution of the articles produced according to categories

| Categories | Number |
|---|---|
| Construction Building Technology | 370 |
| Green Sustainable Science Technology | 359 |
| Energy Fuels | 333 |
| Engineering Civil | 269 |
| Environmental Sciences | 257 |
| Environmental Studies | 225 |
| Engineering Environmental | 103 |
| Architecture | 67 |
| Urban Studies | 34 |
| Economics | 31 |
| Materials Science Multidisciplinary | 31 |
| Thermodynamics | 27 |
| Engineering Multidisciplinary Management | 25 |
| Public Environmental Occupational Health | 20 |
| Physics Applied | 19 |
| Regional Urban Planning Multidisciplinary | 18 |
| Sciences | 17 |
| Chemistry Multidisciplinary | 15 |
| Engineering Chemical | 12 |
| Water Resources | 12 |
| | 11 |

According to the Commission's report (18), approximately 40% of the energy consumed in the EU is used in buildings. The majority of the energy consumed in homes is used for heating, cooling, and hot water, accounting for around 80%. Buildings are responsible for 90% of energy-related greenhouse gas emissions.

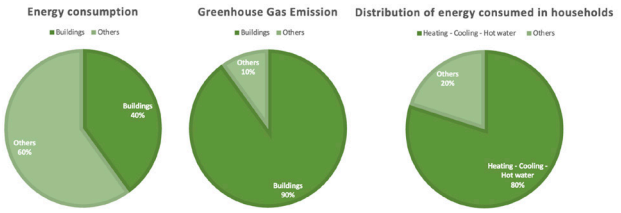


**Figure 2** The role of buildings in energy consumption and greenhouse gas production in the EU (adapted from European Commission (18) report)

Within the scope of sustainable development, architecture aims to contribute to the continuity of life, the efficient use of natural resources, the consideration of spatial and environmental comfort, and the proper management of waste (19). The reuse of buildings, utilizing their embedded energy, and being sensitive during sustainable renovation processes represent a sustainable approach. The efficient use of energy and water resources in buildings, the shift towards renewable energy sources, the importance given to material selection, the management of waste, and the reduction of its formation are processes that increase the environmental sensitivity of structures.

Many studies have been carried out within the scope of reuse and sustainable renovation of buildings, and especially in recent years, the importance of this issue, which also contributes to sustainable development, has been increasing. The use of existing structural elements of buildings, creating a basis for new functions, eliminating the processes of demolishing buildings and building a new structure will allow savings in energy and materials (20). When the results of the articles dealing with the scenarios emerging in the concepts of new building construction and renovation of buildings are evaluated, it is revealed that renovation processes should be preferred in line with the global warming problem (21). Apostolopulos et al. (22), in a study that reveals that sustainable retrofitting of buildings is concretely positive, state that due to the high energy consumption rates of buildings, renovation of building stocks is a mandatory approach to achieve sustainability goals. However, Jimenez-Pulido, Jimenez-Rivero, and Garcia-Navarro (23), emphasize the importance of building renovation processes in line with Europe's carbon neutrality target (by 2050) and the need to develop innovative technologies. In this context, Riuttala, Harala, Aarikka-Stenroos, and Huuhka (24), in a study investigating the reuse of more customized and concrete building components, state that building component reuse is a critical tool to achieve sustainability goals in the construction industry by reducing resource consumption, waste generation, and associated emissions. Caruso et al. (25) emphasize that the renovation and improvement of buildings should aim to minimize the impacts of the building's life cycle by choosing materials that are resistant to natural disasters, reduce energy needs, and low-energy materials. Sustainable building renovation studies aim to provide improvements in the building envelope, extend the life cycle, provide energy efficiency, save on materials, and reduce greenhouse gas emissions (26). Balçık and Yamaçlı (27) recommend increasing studies on water efficiency, waste management, user habits, and country policies within the scope of renovating buildings with sustainable qualities.

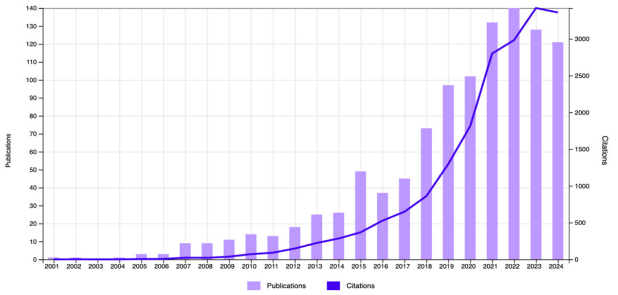


**Figure 3** Publication and Citation Graph between 2001-2024.

Considering the energy consumption and greenhouse gas emission rates in buildings, it is seen that it is inevitable to make improvements to life cycle processes and to renew the buildings with sustainable qualities. In this study, which

aims to reveal the current state of the literature within the scope of this subject and to raise awareness, data from 1058 studies conducted between 1975 and 2024 were used. In line with the analysis of the data, it is seen that the first study on sustainable renovation of buildings was produced in 2001, and most studies with 140 studies were conducted in 2022. Figure 3 shows the publication and citation graph of the studies conducted between 2001 and 2024.

**Table 2** Distribution of studies according to years

| Years | Number |
|---|---|
| 2024 | 121 |
| 2023 | 128 |
| 2022 | 140 |
| 2021 | 132 |
| 2020 | 102 |

Looking at the distribution of studies and citations produced within the scope of the sustainable renovation of buildings by years, 121 studies were produced in 2024, 128 in 2023, 140 in 2022, 132 in 2021, and 102 in 2020 (Table 2). The highest number of citations was made in 2023 (3148).

**Table 3** Distribution of studies according to categories

| Categories | Number |
|---|---|
| Construction Building Technology | 370 |
| Green Sustainable Science Technology | 359 |
| Energy Fuels | 333 |
| Engineering Civil | 269 |
| Environmental Sciences | 257 |

The analysis shows that 96 studies were produced in 96 categories on sustainable renovation of buildings. For this reason, the categories were limited within the scope of the study and those that produced at least 10 studies were selected. Within these categories, the most studies were produced in the fields of Construction Building Technology with 370 studies, Green Sustainable Science Technology with 359 studies, Energy Fuels with 333 studies, Civil Engineering with 269 studies and Environmental Sciences with 257 studies (Table 3). In the field of Architecture, 67 articles were published and ranked 8th among the categories (Table 1).

**Table 4** Distribution of studies according to publication types

| Types | Number |
|---|---|
| Article | 1058 |
| Declaration | 19 |
| Early Access | 16 |
| Book Chapter | 11 |
| Withdrawn publication | 1 |

In the research conducted with the keyword sustainable renovation of buildings, 1720 results were obtained in the WoS database, and the scope of the study was limited according to publication types and categories. In the analysis of the study, in which article-type studies were included in the scope of the study, there were 1058 articles, 19 proceedings, 16 early access publications, and 11 book chapters in line with the determined categories (Table 4).

**Table 5** Distribution of studies according to the journals in which they were published

| Journals | Number |
|---|---|
| Sustainability | 142 |
| Sustainable Cities and Society | 85 |
| Energy and Buildings | 72 |
| Buildings | 54 |
| Energies | 45 |

Upon examining the publications in which the studies studied in the article were published, it was observed that 142 articles appeared in Sustainability, 85 in Sustainable Cities and Society, 72 in Energy and Buildings, 54 in Buildings, and 45 in Energies (Table 5).

**Table 6** Distribution of studies according to the indexes in which they were published

| Indexes | Number |
|---|---|
| Science Citation Index Expanded (SCI-EXPANDED) | 800 |
| Social Sciences Citation Index (SSCI) | 347 |
| Emerging Sources Citation Index (ESCI) | 156 |
| Arts & Humanities Citation Index (A&HCI) | 47 |
| Conference Proceedings Citation Index – Science (CPCI-S) | 18 |

When the academic studies analyzed are considered according to the indexes in which they were published, there are 800 studies with the "Science Citation Index Expanded (SCI-EXPANDED)" index, 347 studies with the "Social Sciences Citation Index (SSCI)" index, 156 studies with the "Emerging Sources Citation Index (ESCI)" index, 47 studies with the "Arts & Humanities Citation Index (A&HCI)" index, and 18 studies with the "Conference Proceedings Citation Index-Science" index. Table 6 shows the distribution of studies according to their indexes.

**Table 7** Distribution of studies according to the countries where they were published

| Countries | Number |
|---|---|
| Italy | 170 |
| People's Republic of China | 154 |
| Sweden | 98 |
| Spain | 93 |
| United States of America | 80 |

When the academic studies are categorized by country, Italy is shown to have the highest number of studies. Italy has 170 studies, China has 154, Sweden has 98, Spain has 93, and the

United States has 80 (Table 7). The UK and the Netherlands scored 6th and 7th with 50 and 46 studies, respectively, while Turkey has 18 studies on sustainable building rehabilitation.

Analysis of academic works by publication language reveals that the predominant language of publication is English. There are 1,031 studies in English, 9 in German and Spanish, and 6 in Italian (Table 8). There is one publication each in Croatian, Dutch, and French.

**Table 8** Distribution of studies by language of publication

| Language | Number |
|---|---|
| English | 1031 |
| German | 9 |
| Spanish | 9 |
| Italian | 6 |
| Croatian | 1 |

When the studies analyzed within the scope of the article are evaluated according to Sustainable Development Goals, 793 studies were produced for Sustainable Cities and Communities (11), 749 for Climate Action (13), 732 for Accessible and Clean Energy (07), 325 for Industry, Innovation, and Infrastructure (09), and 253 for Responsible Production and Consumption (12). Table 9 shows the distribution of the studies produced for the top five sustainable development goals with the highest contribution. Within the scope of all studies, there are publications for all goals except for only 2 sustainable development goals (Gender Equality (05) and Peace, Justice, and Strong Institutions (16)).

**Table 9** Distribution of studies according to Sustainable Development Goals

| Sustainable Development Goals | Number |
|---|---|
| Sustainable Cities and Communities (11) | 793 |
| Climate Action (13) | 749 |
| Accessible and Clean Energy (07) | 732 |
| Industry, Innovation and Infrastructure (09) | 325 |
| Responsible Production and Consumption (12) | 253 |

Using the data obtained as a result of the analysis of the Web of Science (WoS) database, tables were created according to the years, categories, types, journals, indexes, countries, and languages of publication. After the tables, the study data were visualized using the VOSviewer program. The VOSviewer program contributed to the analysis of publications, citations, distribution by countries, keywords, authors, information about publications, and the creation of visual network maps. The statements shown in the maps are represented by a circle. The size of the circles is determined by the weight of the expression, quantitatively its size. The larger the weight, the larger the circle. The lines between the statements express their connectedness (28).

First, the keywords used by the authors were analyzed and visualized through the VOSviewer program. In the co-occurrence analysis/keywords analysis, when 3567 words were limited to at least 3 common words, 279 word results were mapped (Figure 4). The map shows the keywords as circles. While the circle of the most frequently used keyword is the largest, the circles become smaller as the number of uses decreases.

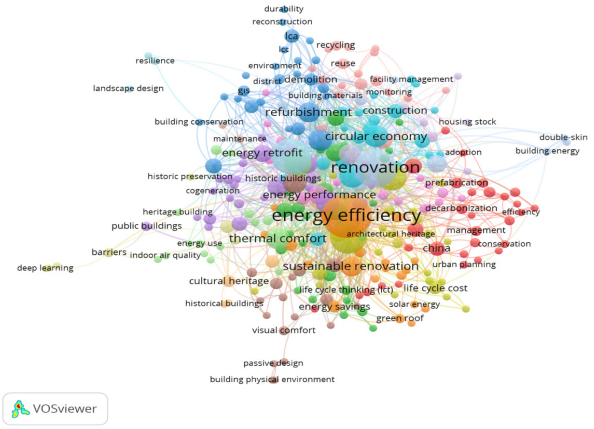


**Figure 4** Network map of the most frequently used keywords

Energy efficiency (111), renovation (85), sustainability (74), building renovation (62), and life cycle assessment (40) are the most frequently used keywords. Table 10 shows the distribution of the most frequently used keywords.

**Table 10** Distribution of the most frequently used keywords

| Keywords | Number |
|---|---|
| energy efficiency | 111 |
| renovation | 85 |
| sustainability | 74 |
| building renovation | 62 |
| life cycle assessment | 40 |
| buildings | 31 |
| building stock | 24 |
| refurbishment | 23 |
| circular economy | 29 |
| energy consumption | 27 |

Within the scope of visualization through the VOSviewer program, the frequency of use of keywords in year intervals is seen with the “overlay visualization” option. In the visual shown in Figure 5, while the keywords in the darkest colors were used before 2016, the color tone lightens as it approaches the present day, and it is seen that the keywords in yellow are frequently used in 2022 and after.

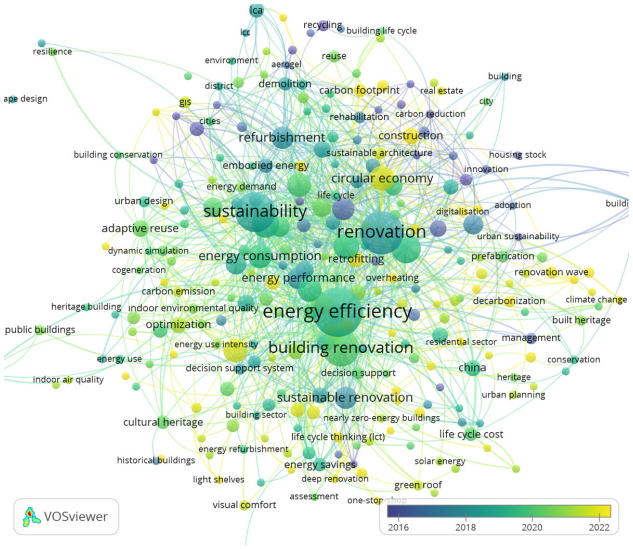


**Figure 5** Visualization of the most frequently used keywords by year

In recent years, the keywords thermal comfort, circular economy, nzeb (nearly zero-energy buildings), overheating, and renovation wave have emerged. The keywords are visualized as in Figure 3, with the most frequently used ones representing the largest circles. Another visual obtained within the scope of visualization through the program is the density analysis of keywords with the "density visualization" option (Figure 6). The intensity of the use of the keywords on the blue background is understood by the size of the yellow spots. It is clear from this visualization that the keywords energy efficiency, sustainability, renovation, and building renovation stand out.

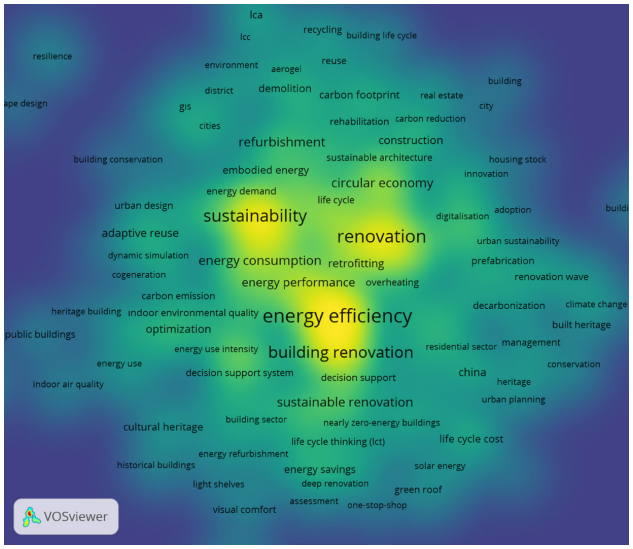


**Figure 6** Visualization of the density of the most frequently used keywords

For the analysis of researchers producing studies within the scope of sustainable renovation of buildings, citation and author options were selected in the VOSviewer program. When 3210 researchers were limited to have at least 2 publications and at least 2 citations, 396 authors were analyzed. As a result of the analysis, the authors who produced the most publications (Table 11) and received the most citations emerged. In Figure 7, the authors who produced the most publications are visualized with the VOSviewer program.

**Table 11** Authors who produced the most publications and the number of publications

| Authors | Number of Publications | Number of Citations |
|---|---|---|
| Mjornell, Kristina | 13 | 237 |
| Serrano-Jimenez, Antonio | 10 | 192 |
| Habert, Guillaume | 10 | 303 |
| Femenias, Paula | 9 | 212 |
| Barrios-Padura, Angela | 8 | 153 |
| Attia, Shady | 8 | 301 |
| Vanoli, Giuseppe Peter | 8 | 139 |
| Malmqvist, Tove | 7 | 191 |
| Marini, Alessandra | 7 | 211 |
| Passoni, Chiara | 7 | 211 |

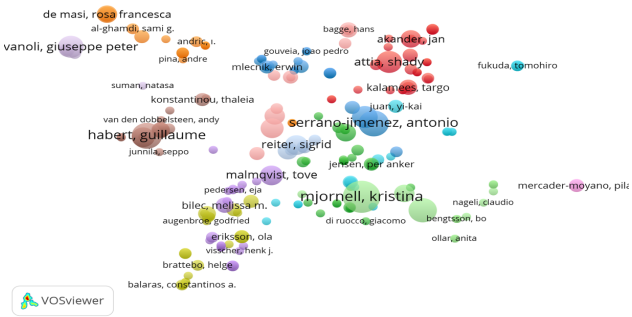


**Figure 7** Visualization of authors who produced the most publications

Analysis of writers in the architecture category reveals that most have a maximum of two publications. Of the 158 authors who published in the architectural category, only those with at least one publication and one citation were considered, resulting in the inclusion of 98 authors in the analysis. Table 12 displays the publication and citation counts for the initial five writers.

**Table 12** Authors who produced the most publications in the field of architecture and the number of publications

| Authors | Number of Publications | Number of Citations |
|---|---|---|
| Pushkar, Svetlana | 2 | 35 |
| Verbitsky, Oleg | 2 | 35 |
| Arumagi, Endrik | 1 | 30 |
| Kalamees, Targo | 1 | 30 |
| Kallavus, Urve | 1 | 30 |

In the same way, the most cited authors were analyzed by

selecting the citation and author options in the VOSviewer program. The most cited authors are shown in Table 13 as a result of the analysis of 396 authors obtained by limiting at least 2 publications and at least 2 citations. Mjornell, Kristina, who has the most publications (13) within the scope of the subject, ranks 11th with 237 citations.

**Table 13** Most cited authors and number of citations

| Authors | Number of Citations | Number of Publications |
|---|---|---|
| Bilec, Melissa M. | 421 | 5 |
| Bocken, Nancy | 374 | 2 |
| Habert, Guillaume | 303 | 10 |
| Attia, Shady | 301 | 8 |
| Juan, Yi-Kai | 289 | 4 |
| Jensen, Per Anker | 270 | 4 |
| Maslesa, Esmir | 268 | 3 |
| Balaras, Ca | 253 | 2 |
| Dascalaki, E. | 253 | 2 |
| Almeida, Manuela | 245 | 4 |

In line with the data of the studies on sustainable renovation of buildings, an analysis of citations by countries (citations/countries) was made. In the program, 66 countries were analyzed over 84 countries when the minimum number of publications and the minimum number of citations of a country were limited to 2. In the analysis, it is seen that Italy, which has the highest number of publications (170), ranks first again with 3284 citations. Italy ranks next in China with 2283 citations, the United States with 2141, Sweden with 2135, and Spain with 1824. The most cited countries are visualized in Figure 8 with the VOSviewer program. As with the number of publications, the UK and the Netherlands follow these countries in 6th and 7th place, respectively. The 18 publications made in Turkey received 160 citations.

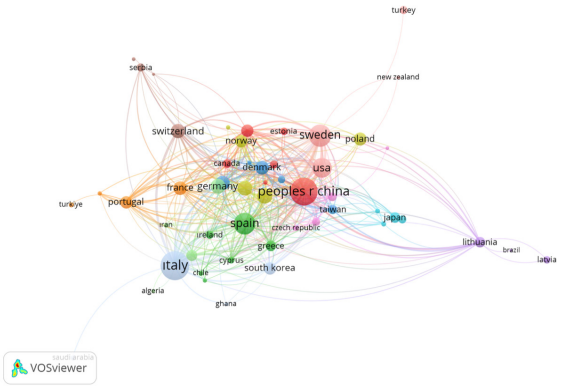


**Figure 8** Visualization of the most cited countries

For the analysis of the sources co-cited in the study, the co-citation analysis/cited source options were selected. 21625 sources were limited to those with at least 10 citations. Among the 348 sources analyzed as a result of the limitation, the journals that stand out with the highest number of citations are Energy Buildings (3753), Building and Environment (1743), Journal of Cleaner Production (1282), Renewable and Sustainable Energy Reviews (1105), and Energy Policy (1070). Figure 9 shows the map of the most co-cited sources visualized with the VOSviewer program.

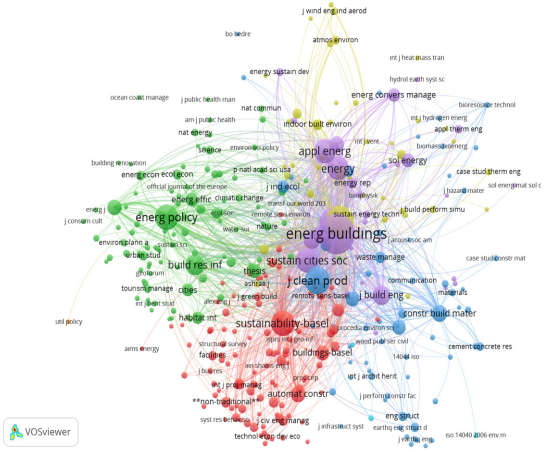


**Figure 9** Visualization of the most co-cited sources

For the analysis of the most cited studies within the scope of sustainable renovation of buildings, citation/document options were selected. The 1058 publications examined within the scope of the study were limited to at least 10 citations, and 491 publications were analyzed. Table 14 shows the most cited publications, and Figure 10 shows the visual network maps.

**Table 14:** Most cited publications and number of citations

| **Yazar** | **Çalışma** | **Atıf Sayısı** |
|---|---|---|
| Gonzalez (2006) | Assessment of the decrease of $CO_2$ emissions in the construction field through the selection of materials: Practical case study of three houses of low environmental impact | 281 |
| Güneralp (2017) | Global scenarios of urban density and its impacts on building energy use through 2050 | 279 |
| Leising (2018) | Circular Economy in the building sector: Three cases and a collaboration tool | 267 |
| Juan (2010) | A hybrid decision support system for sustainable office building renovation and energy performance improvement | 247 |
| Power (2008) | Does demolition or refurbishment of old and inefficient homes help to increase our environmental, social and economic viability? | 230 |

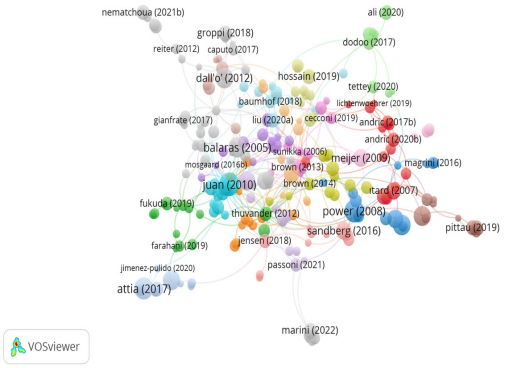


**Figure 10** Visualization of the most cited publications

## FINDINGS

The research study on papers concerning sustainable renovation of building has yielded conclusions regarding publication trends. The characteristics of the studies have been analyzed to elucidate the situation of publication output about the keywords. In the Web of Science (WoS) database, 1720 studies were found by searching with the keyword sustainable renovation of the building. Then, by limiting the category and year options, the research study was continued with 1058 publications. The category, year, type, journals, indexes, countries that produced the most studies, languages of publication, contributions to sustainable development goals, and keywords of these publications were interpreted with the help of tables and the VOSviewer program.

In the analyses made within the scope of sustainable renovation of buildings:
- It has been observed that studies in the article type stand out.
- It is seen that Italy is the leading country with the highest number of studies, followed by China, Sweden, Spain and the United States of America.
- It was found that the studies were mostly published in the journal Sustainability and were mostly scanned in index Science Citation Index Expanded (SCI-EXPANDED).
- The most commonly used keywords were energy efficiency, renovation, sustainability, building renovation, and life cycle assessment.
- When we look at the dates of the research conducted within the scope of the subject, it is seen that studies have been developed since 2001, but have increased as we approach the present day. The most studies within the scope of this subject were conducted in 2021 and 2022.
- Within the scope of the subject, publications were produced in 7 different languages in total, and the most publications were made in English.

Mjornell, Kristina is the author who has produced the most publications in the analysis of the study, and she is working in the field of Building Physics at RISE Research Institutes in Sweden, producing studies on sustainable renovation. The most cited work was produced by Gonzalez, MJ (29), who aimed to quantify the total amount of CO2 emissions saved by the method applied to the choice of materials in the life cycle of a building and showed the possibility of reducing CO2 emissions. Gonzalez, MJ works at the Department of Construction and Rural Roads at the Polytechnic University of Madrid, Spain, where he produces papers on building and construction technologies and sustainable construction. Bilec, Melissa M., the most cited author, works in the field of Civil and Environmental Engineering at the University of Pittsburgh, United States, in the areas of environmental sciences, ecology, construction, and building technology.

The authors in the field of architecture Pushkar, Svetlana Verbitsky, Oleg in their joint LEED-NCV3 Silver and Gold Certified Projects In The Us: An Observational Study (30) and LEED-NC 2009 Silver To Gold Certified Projects In The Us In 2012-2017: An Appropriate Statistical Analysis (31), aimed to identify trends in Silver and Gold LEED for New Construction and Major Renovations (LEED-NCv3) certified projects. In Israel he produces studies in the field of architectural research.

One of the most cited studies in this context is “Assessment of the decrease of CO2 emissions in the construction field through the selection of materials: Practical case study of three houses of low environmental impact.” In the field of Civil Engineering; “Global scenarios of urban density and its impacts on building energy use through 2050” is in the field of Environmental Sciences and Ecology, focusing on the environmental impacts of buildings, carbon dioxide emissions, and energy consumption. These concepts, along with the most commonly used keywords such as energy efficiency, sustainability, and life cycle, indicate the trend of the subject.

## DISCUSSION AND CONCLUSION

In the study, the concept of sustainable renovation of buildings was established, and its importance was emphasized first. Then, it is aimed to investigate the publication studies made in line with this concept and to examine the quantitative characteristics of the publications. In order to obtain the publications to be examined, the Web of Science (WoS) database, which covers qualified and reliable studies and provides access to comprehensive data collection from different disciplines, was utilized.

Sustainable renovation of buildings is an issue that needs to be considered on an international scale and constitutes an inevitable application area, especially due to the increasing building stocks in cities today. Along with the discipline of architecture, studies are being developed in many different fields within the scope of renewal technologies and processes of buildings. It is important to develop innovative technologies that will minimize the environmental damage of buildings and raise awareness.

The significant increase in research on the sustainable renovation of buildings over time constitutes one of the most important findings of the study. It has been determined that these studies, which began in 2001, reached their highest number with 140 publications in 2022. Additionally, the

identification of the most cited publications on sustainable renovation through bibliometric analysis and the provision of a comprehensive overview of the general state of the literature in this field are also among the significant findings. The trend of the most cited studies in the field of construction includes factors such as reducing CO2 emissions, material selection, having a low environmental impact, and energy use in buildings, indicating that sustainable building renovation is becoming increasingly important within the scope of global issues and that more research needs to be conducted. Therefore, it is necessary to increase publications in the field of architecture that contribute to this topic.

In this study, within the scope of sustainable renovation of buildings, not only architecture but also the studies produced by related disciplines are included, and it is aimed to reveal the latest situation and to create a basis for future studies on this subject. In this sense, all relevant disciplines, and especially the discipline of architecture, which is responsible for all stages such as building construction, life process, and demolition, have important duties. When looking at the categories in which work is being done, it is necessary to increase the number of studies in the field o f a rchitecture, which is currently less represented. The design of policies that will bring together architecture and different disciplines will contribute to the development of new technologies and applications.

It is observed that the majority of the studies conducted within the scope of sustainable building renovation (approximately 97%) are published in English. It is recommended that countries also publish high-quality works in their own languages on this subject. In addition to this, it should be emphasized that the studies should be produced with sustainable development goals in mind, and their contribution to sustainable development should be emphasized.

## References


1. WCED. (1987). “Our Common Future”. The World Commision on Environment and Development.: http://www.un-documents.net/our-common-future.pdf
2. Belek, A. N., & Yamaçlı, R. (2023). Ekolojik Binaların Sürdürülebilir Tasarım Kriterleri ve Değerlendirme Süreci. Journal of Architecture and Life, 529-550.
3. Rodrigues, C., & Freire, F. (2021). Environmental impacts and costs of residential building retrofits – What matters? Sustainable Cities and Society, 1-14
4. Elefante, C. (2007). The Greenest Building Is...One That Is Already Built. The Journal of the National Trust for Historic Preservation, 26-38.
5. European Commission. (2020, October 14). Renovation Wave: doubling the renovation rate to cut emissions, boost recovery and reduce energy poverty. ec.europa.eu:https://ec.europa.eu/commission/presscorner/detail/en/IP_20_1835
6. Menna, C., Felicioni, L., Negro, P., Lupisek, A., Romano, E., Prota, A., & Hajek, P. (2022). Review of methods for the combined assessment of seismic resilience and energy efficiency towards sustainable retrofitting of existing European buildings. Sustainable Cities and Society, 1-19.
7. Trachtea, S., & Salvesenb, F. (2014). Sustainable renovation of non residential buildings, a response to lowering the environmental impact of the building sector in Europe. Energy Procedia(48), 1512-1518.
8. McBurney , M. K., & Novak , P. L. (2002). What Is Bibliometrics and Why Should You Care? Proceedings. IEEE International Professional Communication Conference, (s. 108-114). Portland, OR, USA,.
9. Web of Science. (2024). Access Date: 17.11.2024. 11 2024 tarihinde www.webofscience.com: https://www.webofscience.com/wos/woscc/summary/78e1a39c82d7-4824-aafa-0155a725c33e-012ba93e9a/relevance/1
10. VOSviewer. (2023). VOSviewer version 1.6.19. Access Date: 12.10.2023: https://www.vosviewer.com/
11. Dirik, D., Eryılmaz, İ., & Erhan, T. (2023). Post-Truth Kavramı Uzerine Yapılan Çalışmaların VOSviewer ile Bibliyometrik Analizi. Sosyal Mucit Academic Review, 164-188.
12. Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. Journal of Business Research, 285-296.
13. Dereli, A. B. (2024). Vosviewer ile Bibliyometrik Analiz. Communicata, 1-7.
14. Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics, 523-538.
15. Öztürk, N., & Kurutkan, M. N. (2020). Kalite Yönetiminin Bibliyometrik Analiz Yöntemi ile İncelenmesi. Journal of Innovative Healthcare Practices (JOINIHP), 1-13.
16. Mokhtari , H., Mirezati , S. Z., Saberi , M. K., Fazli , F., & Kharabati-Neshin , M. (2019). A Bibliometric Analysis and Visualization of the Scientific Publications of Universities: A Study of Hamadan University of Medical Sciences during 1992-2018. Webology, 197-2011.
17. Guidettia, E., & Ferrara, M. (2023). Embodied energy in existing buildings as a tool for sustainable intervention on urban heritage. Sustainable Cities and Society, 1-15.
18. European Commission. (2024). Energy Performance of Buildings Directive. https://commission.europa.eu/: https://energy.ec.europa.eu/topics/energy-efficiency/energyefficient-buildings/energy-performance- buildings-directive_en
19. Çiğan, A., & Yamaçlı, R. (2020). Doğal Enerji, Sürdürülebilir Kalkınma ve Mimarlık Politikaları. Düzce University Journal of Science & Technologj, 554-571.
20. Doğru, M. (2017). Yesil Binaların Bütüncül Enerji Verimliliği Yaklasımı. ecobuild: https://www.ecobuild.com.tr/post/2017/07/25/ye%C5%9Fil-binalar%C4%B1nb%C3%BCt%C3%BCnc%C3%BCl-enerji-verimlili%C4%9Fiyakla%C5%9F%C4%B1m%C4%B1
21. Leichter, M., & Piccardo, C. (2024). Assessing life cycle sustainability of building renovation and reconstruction: A comprehensive review of case studies and methods. Building and Environment, 1-19.
22. Apostolopoulos, V., Mamounakis, I., Seitaridis, A., Tagkoulis, N., Kourkoumpas, D. S., Iliadis, P., . . . Nikolopoulos , N. (2023). An integrated life cycle assessment and life cycle costing approach towards sustainable building renovation via a dynamic online tool. Applied Energy , 1-21.
23. Jiménez-Pulido, C., Jiménez-Rivero, A., & García-Navarro, J. (2022). Improved sustainability certification systems to respond to building renovation challenges based on a literature review. Journal of Building Engineering, 1-29.

24. Riuttala, M., Harala, L., Aarikka-Stenroos, L., & Huuhka, S. (2024). How building component reuse creates economic value–Identifying value capture determinants from a case study . Journal of Cleaner Production, 1-13.
25. Caruso, M., Buttazzoni, M., Passoni, C., Labò, S., Marini , A., & Pinho, R. (2024). An updated multi-criteria decision- making method for the sustainable renovation of buildings including environmental, economic and social life-cycle metrics. Journal of Building Engineering, 1-15.
26. Amoruso, F. M., Sonn, M.-H., & Schuetze, T. (2022). Carbon-neutral building renovation potential with passive house-certified components: Applications for an exemplary apartment building in the Republic of Korea. Building and Environment, 1-23.
27. Balçık, S., & Yamaçlı, R. (2024). Sürdürülebilir Bina Yenileme Yöntemleri Uzerine Bir İnceleme. Online Journal of Art and Design, 164-178.
28. Eck, N. J., & Waltman, L. (2024). VOSviewer Manual. Access Date: 28.11.2024: https://www.vosviewer.com/documentation/Manual_VOSviewer_1.6.16.pdf
29. González, M. J., & Navarro, J. G. (2006). Assessment of the decrease of CO2 emissions in the construction field through the selection of materials:: Practical case study of three houses of low environmental impact. Building and Environment, 902-909.
30. Pushkar, S., & Verbitsky, O. (2018). LEED-NCV3 Silver and Gold Certified Projects In The Us: An Observational Study . Journal of Green Building, 67-83.
31. Pushkar, S., & Verbitsky, O. (2019). LEED-NC 2009 Silver To Gold Certified Projects In The Us In 2012-2017: An Appropriate Statistical Analysis. Journal of Green Builgind, 83-107.