

# Artificial intelligence and the internet of things in environmentally building water consumption model: bibliometric analysis

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**Abstract.** Environmentally friendly houses are a solution to reduce the negative impact of buildings on the environment. One of the criteria is water conservation in housing, the implementation of which is heavily influenced by the behaviour of residents. The inhabitants' behaviour varies and affects how much water conservation and conservation are applied in the building. This study performs a thorough bibliometric analysis of the scientific output concerning using artificial intelligence and the Internet of Things in water consumption and conservation in environmentally friendly or sustainable buildings. The research is based on data from Scopus, covering the period from 1996 to 2024. The study found research collaborations among diverse institutions and nations, highlighting prominent research achievements in this sector. The network visualisation analysis was conducted using a VOS viewer. The results of this study can provide valuable insights for scholars, experts, politicians, and funding organisations seeking a comprehensive overview of the current trends and objectives in this field. The results from this study provide a valuable framework for future research directions and underscore the importance of continued investment in implementing Artificial Intelligence and the Internet of Things to achieve water conservation in the future.

## 1 Introduction

The building sector significantly contributes to environmental degradation, accounting for a substantial portion of global energy consumption and greenhouse gas emissions [1], [2]. Environmentally friendly houses have emerged as a solution to mitigate the negative impact of buildings on the environment [3]. These sustainable buildings incorporate various green design principles and technologies to reduce energy and water consumption, minimise waste, and improve indoor environmental quality [4]. Water conservation is one of the critical criteria in environmentally friendly housing [5], [6], as water scarcity is a growing concern

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worldwide [7]. The behaviour of residents heavily influences the implementation of water conservation measures in residential buildings [8]. Inhabitants' behaviour varies and affects the level of water conservation in the building [7], making it essential to understand and model these behavioural patterns to optimise water usage [9]. Artificial intelligence (AI) and the Internet of Things (IoT) have shown promise in modelling and optimising water consumption in buildings [10], [11]. Integrating AI and IoT technologies can lead to the development of smart water management systems that can detect leaks, predict demand, and optimise water allocation [12]. This study presents a comprehensive bibliometric analysis of the scientific output related to the use of AI and IoT in water consumption and conservation in environmentally friendly or sustainable buildings. By applying bibliometric techniques to the literature on AI and IoT in sustainable water management, this study aims to provide valuable insights for researchers, practitioners, policymakers, and funding organisations seeking an overview of current trends and goals in this field.

## **2 Literature Review**

The concept of environmentally friendly buildings has gained significant attention in recent years, with numerous studies focusing on various aspects of sustainable design and construction. [13]. Water conservation is a critical component of green building practices, as it contributes to the overall reduction of environmental impact and promotes the efficient use of resources [14]. Several studies have investigated the factors influencing water consumption in residential buildings, highlighting the importance of occupant behaviour and the need for effective water management strategies [15]. The advent of artificial intelligence (AI) and the Internet of Things (IoT) has opened up new possibilities for monitoring, analysing, and optimising water consumption in buildings [16]. AI techniques, such as machine learning and deep learning, have been applied to develop predictive models for forecasting water demand and identify patterns in water usage data [17]. IoT devices, including smart meters and sensors, have been deployed to collect real-time water consumption data, enabling the development of intelligent water management systems [18]. The integration of AI and IoT technologies has shown promising results in reducing water consumption, detecting leaks, and promoting water conservation in buildings [19].

## **3 Methodology**

To investigate the research topic "Artificial Intelligence and the Internet of Things in Environmentally Building Water Consumption Model: Bibliometric Analysis", this study adopts a quantitative bibliometric methodology. The Scopus database is comprehensively searched using the command "(("home water" OR "grey water" OR "clean water" OR "water consumption" OR "water conservation" OR "consuming water" AND "environmentally building" OR "environmentally friendly building" OR "sustainable building" OR "sustainable home" OR "green building" OR "green home" OR "house" OR "home" OR "building" AND "internet"))", limited to journal and conference proceeding, yielding a dataset of 116 relevant documents spanning from 1996 to 2024. R Studio Biblioshiny software (version 4.4.1) analyses the collected data, generating informative visualisations such as Main Information, Institutions, Most Cited Country, and Co-occurrence network representations. The research incorporates the outcomes of earlier studies to reinforce the reliability and robustness of the findings, creating a solid foundation for recognising essential themes, tendencies, and voids in the present body of knowledge concerning artificial intelligence and IoT in environmentally building water consumption. By employing this methodology, a thorough grasp of the research subject and its numerous facets is achieved.

## 4 Result and Discussion

### 4.1 Main Information

Figure 1 shows the data from 1996 to 2024; 486 unique authors authored 116 documents over the 28-year timespan. The documents have an average of 11.08 citations per document and 4.22 co-authors per document. The average age of these documents is 4.07 years old. There are five single-author documents, which account for 13.79% of international co-authorship. The annual growth rate of the number of documents is 11.09%. Based on the author's keywords and references provided, it appears this dataset contains 397 author's keywords and 3278 references. This data provides valuable insights into the productivity, collaboration patterns, and impact of research in a particular field over time. By analysing these metrics, researchers and institutions can identify trends, evaluate the effectiveness of research programs, and make informed decisions to support and enhance future research endeavours.



Fig. 1. Overview Main Information

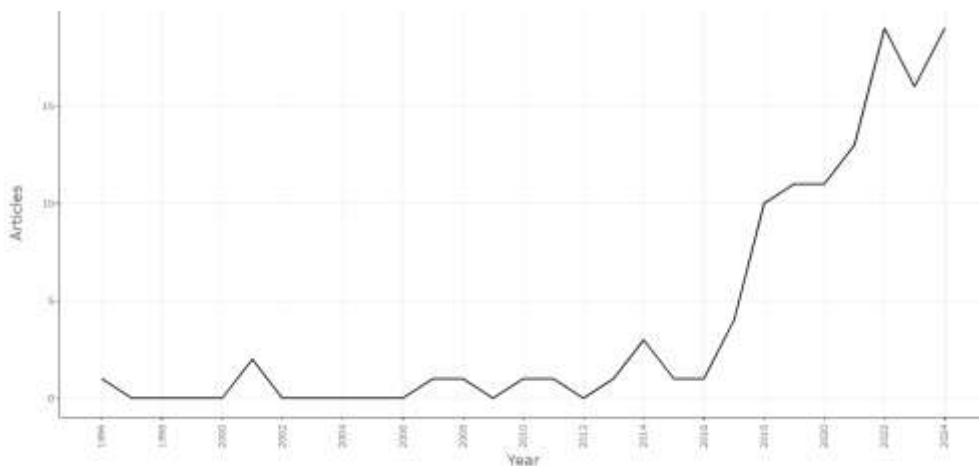
### 4.2 Annual Productions

The line graph in Figure 2 illustrates the annual production of articles from 1996 to 2024. The number of articles published yearly remained relatively low, from 0 to 3, until 2010. From 2010 onwards, there was a notable increase in articles published annually, with the highest peak of 14 articles in 2018. The graph shows an overall upward trend in the yearly output of articles despite some fluctuations and a slight decline after 2018. This data is valuable for researchers and institutions as it provides insights into the growth and development of the field over time. By analysing the annual production trends, stakeholders can identify periods of increased research activity, gauge the field's momentum, and make informed decisions regarding resource allocation and research priorities.

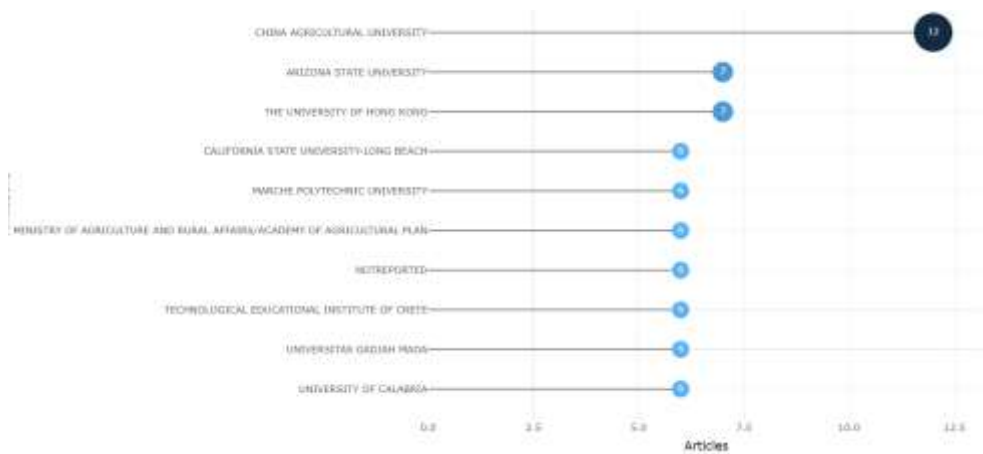
### 4.3 Institutions

Figure 3 displays the number of articles published by various institutions. China Agricultural University leads with 12 articles, followed by Arizona State University with 7. The University of Hong Kong and California State University-Long Beach each contributed six articles. Marche Polytechnic University, the Ministry of Agriculture and Rural Affairs/Academy of Agricultural Plan, and Nottingham Trent University published 5, 3, and 2 articles, respectively. This data provides data on the research output and collaboration

among these institutions. By identifying the most prolific contributors, researchers can explore potential partnerships, funding opportunities, and areas for further investigation within their fields of study.



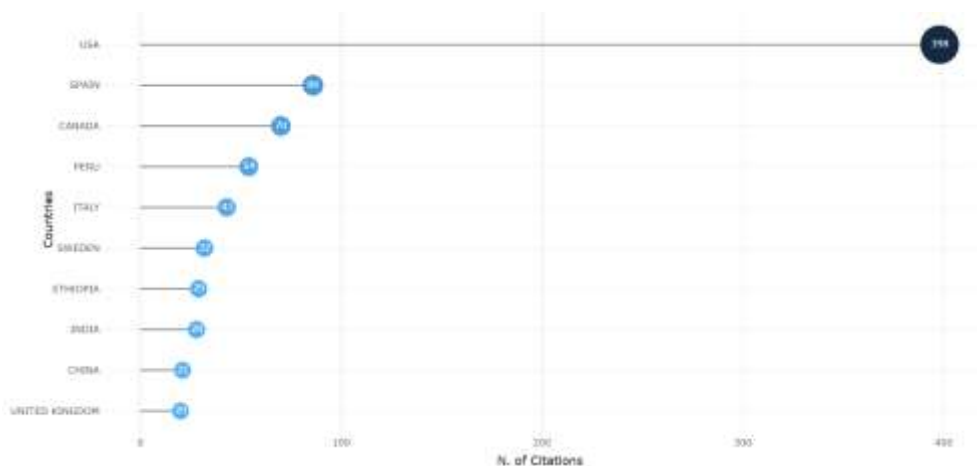
**Fig. 2.** Annual Scientific Production Graph



**Fig. 3.** Most Relevant Affiliations' Graph

#### 4.4 Nations

Figure 4 shows the number of citations received by various countries. The USA stands out as the leader, with 398 citations. Spain and Canada follow, each with around 100 citations. Peru, Italy, and Sweden have between 50 to 100 citations each. Ethiopia, India, China, and the United Kingdom have at most 50 citations. This data highlights the global impact and reach of research from these countries. By identifying the most cited nations, researchers can gain insights into the influence and visibility of work from different regions, potentially guiding future collaborations, funding decisions, and research directions. Moreover, countries with lower citation counts may identify opportunities to enhance their research output and international recognition.



**Fig. 4.** Most Cited Countries' Graph

### 4.5 Co-occurrence Network

Figure 5 reveals the interconnectedness of various terms related to the Internet of Things (IoT) and water conservation. The terms "Internet of Things" and "water conservation" are prominently displayed at the centre, with numerous other terms radiating outwards and forming clusters based on their co-occurrence frequency. Some notable related terms include sustainability, smart city, water management, energy efficiency, big data, remote sensing, and agriculture. The presence of diverse terms highlights the multidisciplinary nature of IoT applications in water conservation. This data is valuable for researchers, policymakers, and industry professionals as it provides a visual overview of the key concepts and their relationships within the IoT and water conservation domain. By identifying the most frequently co-occurring terms, stakeholders can gain insights into current research trends, potential application areas, and opportunities for innovation at the intersection of these fields.



**Fig. 5.** Co-occurrence Network

## 4.6 Journal & Conference Proceeding Sources

Figure 6 presents the number of documents published in various conference proceedings and journals related to the research topic. The ACM International Conference Proceeding Series tops the list with three papers, followed by IET Conference Proceedings and the Indonesian Journal of Electrical Engineering and Computer Science with two documents each. Several other conferences and symposiums have two papers: the IOP Conference Series: Earth and Environmental Science, Sustainability (Switzerland) and the IEEE 7th World Conference on Photovoltaic Energy Conversion (WCPEC). The remaining conferences, including the 13th International Conference and Expo on Emerging Technologies for a Smarter World (CEWIT), the IEEE 7th World Conference on Photovoltaic Energy Conversion (WCPEC), and OCEANS - MTS/IEEE Kobe Techno-Oceans (OTO), each contributed 1 document. This data is valuable for researchers as it highlights the field's most relevant and active publication venues. By identifying these key sources, researchers can stay informed about the latest findings, trends, and developments in their area of study, discover opportunities to present their work and collaborate with peers at these events.

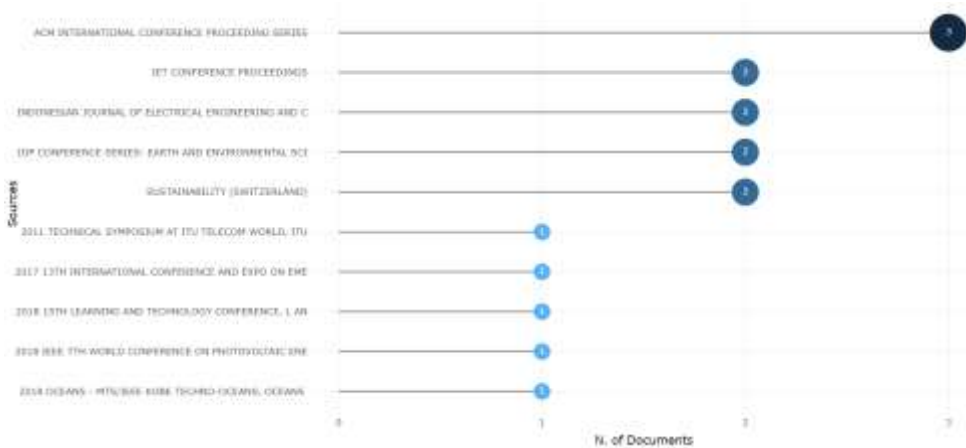


Fig. 6. Most Relevant Sources

## 5 Conclusion

In conclusion, this study provides a comprehensive bibliometric analysis of the scientific output of using artificial intelligence (AI) and the Internet of Things (IoT) in water consumption and conservation in environmentally friendly or sustainable buildings. The analysis, based on data from Scopus from 1996 to 2024, reveals significant research collaborations among various institutions and countries, with China Agricultural University and the USA leading in the number of articles and citations, respectively. The co-occurrence network analysis highlights the multidisciplinary nature of IoT applications in water conservation, with key terms such as sustainability, smart city, water management, and energy efficiency forming clusters based on their co-occurrence frequency. The study also identifies the field's most relevant and active publication venues, including the ACM International Conference Proceeding Series and IET Conference Proceedings. These findings offer valuable insights for researchers, policymakers, and industry professionals, guiding future collaborations, funding decisions, and research directions. The results of this study underscore the importance of continued investment in implementing AI and IoT technologies to achieve water conservation in sustainable buildings. Future research can build upon these

findings to develop more efficient and effective smart water management systems, ultimately contributing to the global effort to mitigate the environmental impact of the building sector.

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