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Smart building trend, role, and position: a systematic literature review

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ABSTRACT

Property growth, especially in high-rise buildings in developed and developing countries, has experienced a significant increase. The increasingly expensive resources and the development of information technology encourage the growth of smart buildings in almost all countries, especially in developed and developing countries, and become a trend. The Internet of things (IoT) is the main driver in the development of smart buildings. Property businesses are competing to adopt and implement smart buildings on their properties. This is further strengthened by the development of smart cities in almost all cities around the world, one of the criteria is a smart community. The purpose of implementing smart buildings is to make property management effective and efficient. Using the systematic literature review, this paper will discuss what components must be met for a property called a smart building, then what is the role of smart buildings for an area or community, and how the current smart building trend will be in the future.

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1. INTRODUCTION

The demand for efficiency and effectiveness in property management with the help of technology is currently a concern for property businesses around the world, especially in countries with strong economies. Since information communication and technology (ICT) was introduced, it has changed the aspect of our life [1]. Property as a very large value must be calculated very carefully and accurately. The role of government in several countries plays a very important role as a regulator that regulates matters relating to investment, including in the property industry [2]. The expensive and high resources needed in property management and the trend of implementing industry 4.0 are the basis for the property to be directed to become a Smart Building. Smart Building consists of various technologies including data analysis, data acquisition, and data visualization, and all are integrated to provide high-quality, safe, guaranteed, and cost-effective services to all residents [3]. Although it is still being debated and not very clear in the use of the term smart building with Intelligence Building, the difference between the terms according to Hoy is not too important, the point is to integrate different types of technology on the property/building [4]. According to Buckman *et al*. [5], the depiction of smart building can be seen in Figure 1.

From Figure 1, it can be concluded that a smart building is a building or property that integrates and takes into account Intelligence, a company or institution (as the owner of the building), materials and design, and control as a comprehensive system with the ability to adapt, able to follow advancements and technology, and has been prepared to be able to face change at all timeframes [5]. Klynveld Peat Marwick Goerdeler

(KPMG) provides an overview of smart building [6] the future and the relationship between technology and the internet in Figure 2.

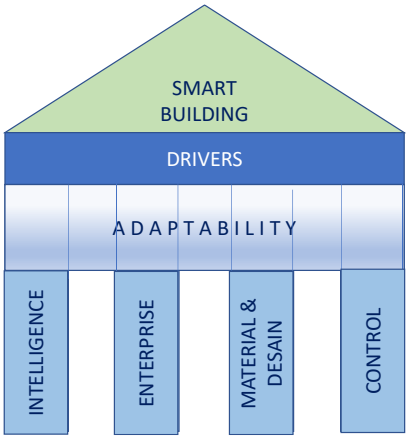

Figure 1. Features of smart building [5]

Figure 2. KPMG creating the building of the future through internet of things (IoT) technology [6]

According to KPMG, there are 4 points in developing and integrating smart buildings with IoT technology, namely: i) safety and security, in the future, safety and security will be a major concern, especially with the COVID-19 pandemic condition sweeping across the world and has not been fully overcome and other threats that can threaten the lives of the occupants of the building or property, ii) tenant experience is an important part of how they feel comfortable while occupying the building where they live or where they work, point, and iii) sustainable environment, the contents of the environment, and our participation in protecting nature so that resources nature can be sustainable in the long term is an issue in all countries preventing global warming, smart building is expected to contribute actively to save and be efficient in the use of electrical energy, lighting and all resources used [7]. The fourth point is the smart system, which is the demand to use the latest technology to make it easier to control all the technology components used, including being part of the smart city [8].

This systematic literature review explores this subject to find answers to the research questions posed by the author. 4 research questions are proposed, namely:
RQ1: how is the grouping of themes in articles about smart building?
RQ2: which country is the research location for smart building?
RQ3: on what type of property is the smart building research conducted?
RQ4: what is the current trend of smart building research?

2. LITERATURE REVIEW

Smart building has become an integral part of the development of smart city [9], [10]. The components that build a smart city are smart people, smart environment, smart living (smart property/smart building), smart mobility, smart economy, and smart governance. But in smart building, the variations are quite a lot to be able to explain the existing components. Several articles have tried to create component groupings in smart building [11]-[13]. But in general, there are still many differences from the components that have been made regarding what conditions a property or building is called a smart building.

Smart building is a general term used to describe the integration between different technologies in a property or building. But until now there is no clear definition to differentiate between smart building and intelligence building [14]. According to Buckman *et al*. [15], explaining as follows "there is something unclear/confusing about the difference between smart building and intelligence building". Buckman gives an illustration that the sequence of technological developments in buildings or properties starts from “primitive”, then becomes “simple”, then changes to “automatic”, then becomes “intelligent”, until the highest is a “smart” building [15].

Smart buildings can collect data about how and when a building is being used and provide a real-time view of the status and condition of the building. By using a network of sensors and cameras, smart building can calculate how many visitors and occupants are in a building at any given time. By using data from sensors, the latest technologies such as big data, machine learning, artificial intelligence, and augmented reality can be used. The simple concept of a smart building is to make a building or property adaptable to time and technology with the aim of efficiency and effectiveness [16].

3. MATERIAL AND METHOD

This systematic literature review (SLR) refers to the SLR concept from Kitchenham [17] which divides it into three stages starting from the first stage, planning, then the second stage is conducting the review and the third stage is reporting the review. These three stages can be seen in Figure 3. At the planning stage, there will be 2 main jobs, namely identifying the need for a review and developing a review protocol during the research. In the development of this review protocol, a research question for this study was raised. Conducting the review stage consists of 4 parts: identification research, study selection, data extraction, and result analysis the final result will be presented in stage 3: reporting the review.

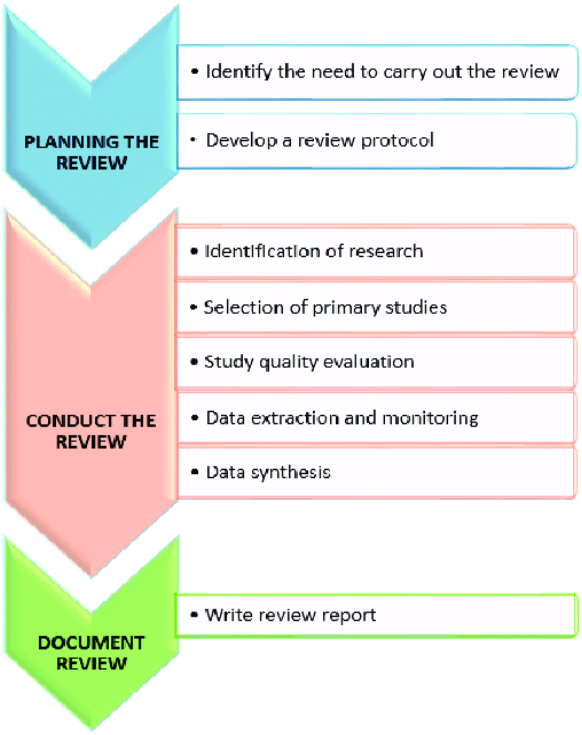

Figure 3. Kitchenham SLR stages

The articles that will be used in this SLR are taken from the Scopus database. As an article database that has been recognized as having a world reputation with thousands of journals and conference proceedings, it is very feasible to source articles from the Scopus database [18]. The selection and screening of articles that will be used for SLR in the Scopus database are based on the PRISMA method [19] which provides a clear description of each stage in screening articles, as shown in Figure 4.

The first stage is to filter the Scopus database based on article titles containing the words "smart building" or "smart property" and 1,483 documents are obtained. From all these documents, the next stage was screened with the criteria of only choosing English articles, the source type was only journals and conference proceedings, and 327 documents were found. From a total of 327 documents, only documents published in 2018 to 2021 because the content of smart building articles will become irrelevant if it takes too long, so it is only taken 4 years, 2022 is deliberately not included because there are still too few that are included in the 2022 publication. The results obtained from the selection of documents from 2018 to 2021 found 224 documents that met these criteria.

The next stage is to filter documents that have been cited by other authors with the number of citations per document above 3 citations. This is to provide confidence that the article has been proven to be known and cited by other authors. From this filter, 122 documents were found. Furthermore, from 122 documents, an abstract filter was carried out according to the writing theme regarding components, roles, and trends, obtained 78. The last filter sorted out the suitability of 78 documents from full-text and obtained 56 documents to be reviewed.

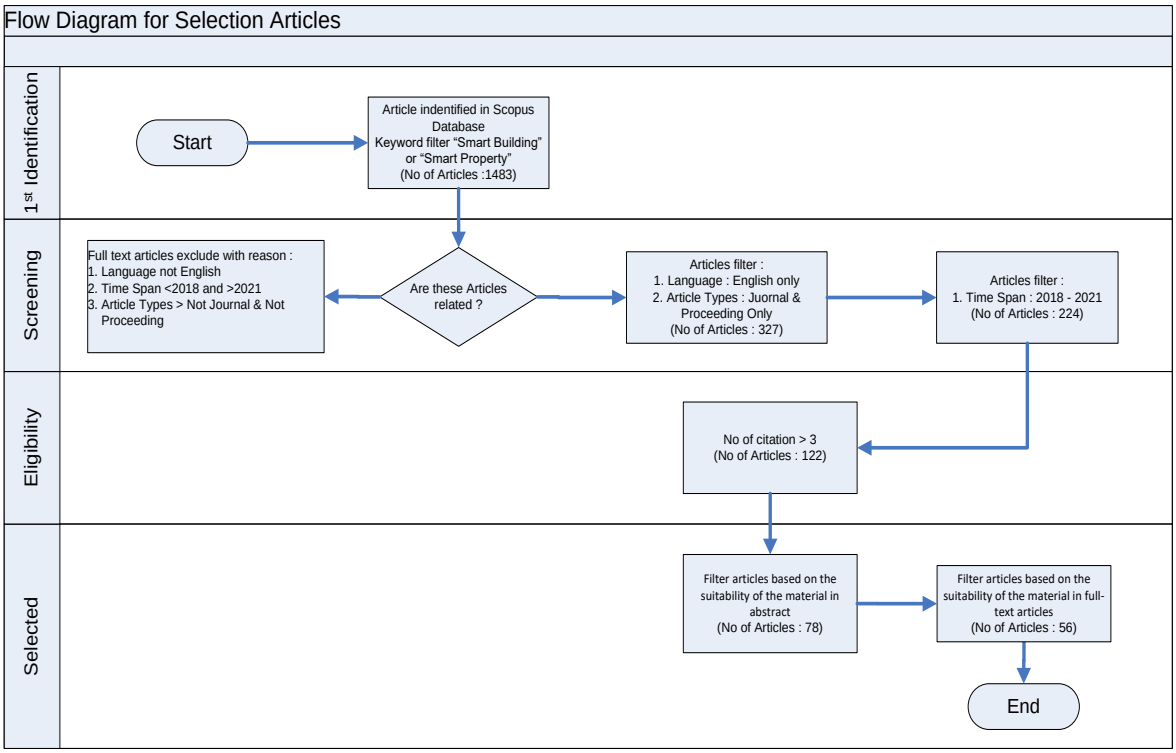

Figure 4. Articles selection in Scopus database

The number of selected papers as many as 56 are papers published in the Scopus database according to the filter carried out with the criteria previously mentioned and based on the year of publication between 2018 and 2021. The graph of published papers per year can be seen in Figure 5. In 2018 there were 14 articles, in 2019 there were 21 articles which was the highest number in 4 years, in 2020 there were 16 articles and in 2021 there were only 5 articles that met the screening criteria according to Figure 4. The number of articles in 2021 the number decreased drastically possibly. This is due to the COVID-19 pandemic conditions around the world, so that a lot of research on smart buildings is expected because they cannot freely collect data, are limited to conducting interviews with respondents and there are lots of buildings or properties for their activities during the COVID-19 pandemic.

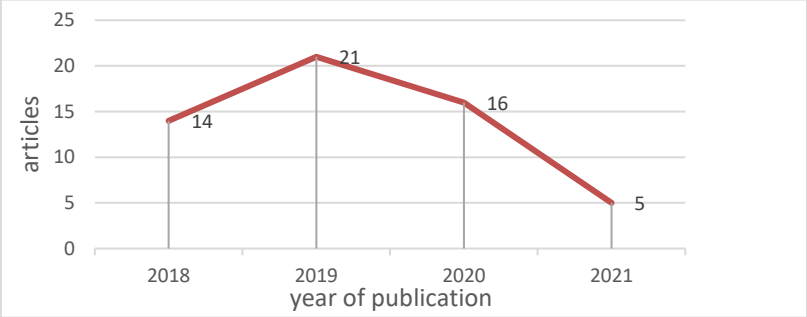

Figure 5. Number of articles from 2018-2021

4. RESULT AND DISCUSSION

4.1. Discussion topics and clustering in smart building articles

To see what components are contained in smart building, the relationship between keywords is used and the keyword used is the author keyword contained in the 56 full-text documents reviewed. As a tool for mapping the keywords used in 56 full-text documents, the VOSviewer application [20] is used. This VOSviewer application can provide a view of the relationship between keywords from export files such as RIS and CSV. In this study, the file used is an imported file from the Scopus database in CSV format. Before the author keyword mapping process, improvements were made to combine several of the same keywords. In one article the author keyword wrote "internet of things" some wrote "IoT", the author combined if there were conditions such as to obtain keywords that were not duplicated.

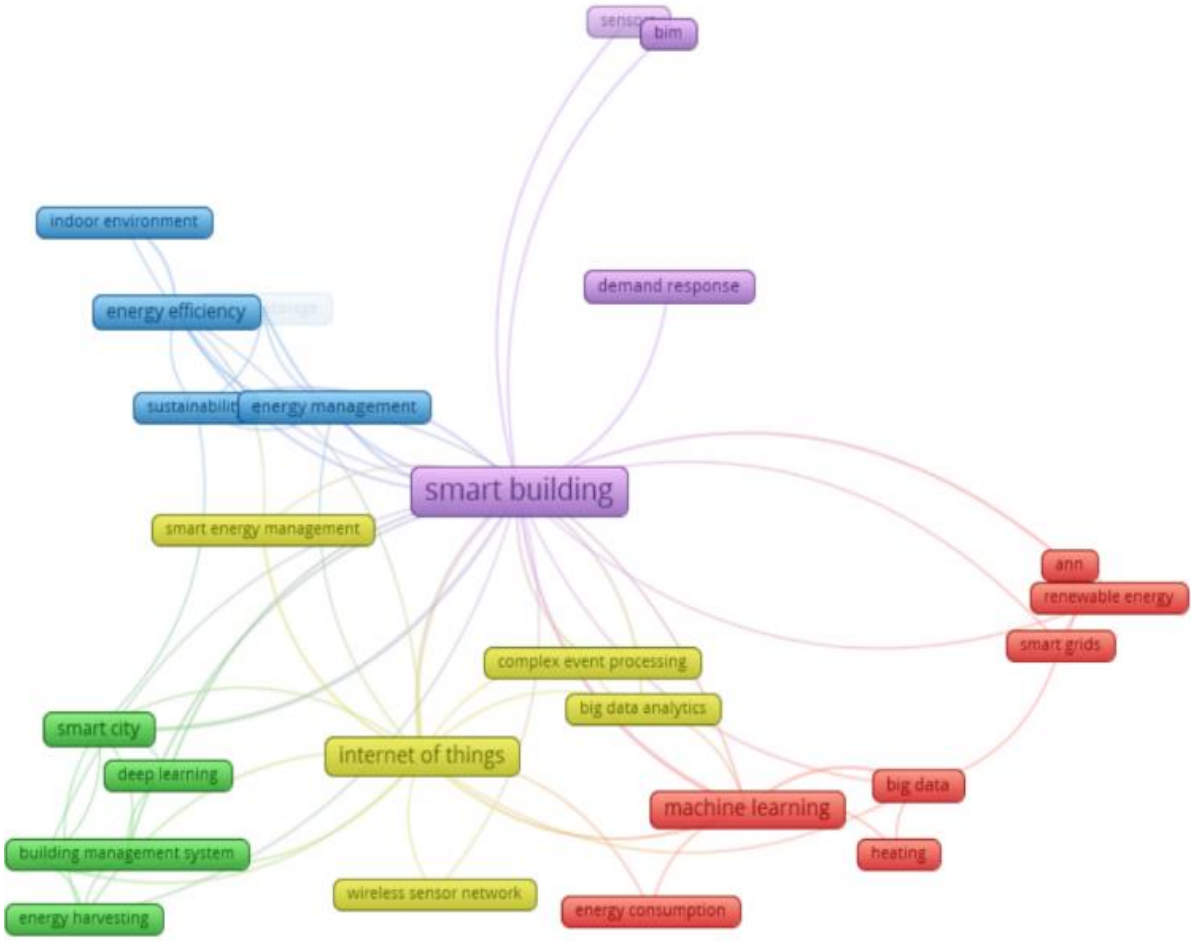

Figure 6. Keyword mapping in VOSviewer

From all articles, 196 keywords are obtained and the VOSviewer application has a function to set parameters for more flexibility. One of its features is to carry out the process of mapping keywords that have a minimum relationship of 2 keywords between articles and the results can be seen in Figure 6. The VOSviewer application can also provide information on author keyword clustering. Clustering results are displayed in different colors to distinguish 1 cluster from other clusters. In this study, 5 clusters were obtained as the basis for grouping components for smart building. Each cluster is identified in different colors with different components in each cluster. Table 1 provides an overview of the resulting clusters.

Table 1. Keyword clustering using VOSviewer application

Cluster name	Color	Component
Cluster 1	Red	ANN, big data, energy consumption, heating, machine learning, renewable energy, smart grids
Cluster 2	Green	Building management system, deep learning, energy harvesting, fault-tolerant control, smart City
Cluster 3	Blue	Energy efficiency, energy management, energy storage, indoor environment, sustainability
Cluster 4	Yellow	Big data analytics, complex event processing, internet of things, smart energy management, wireless sensor network
Cluster 5	Purple	Building information management, demand response, sensors, smart building

The clustering of keywords above is based on the proximity between keywords. Keywords in the same color are closer together than keywords in different color clusters. Smart building is placed in cluster 5 with purple color, one cluster with building information management, demand response, and sensors. This provides information that smart buildings have various roles in the discussion on building information management, demand response, and sensors. In cluster 1 in red, there are the keywords heating, renewal energy and smart grid, meaning that there is a close relationship between the keywords in the discussion of heating, renewal energy and smart grid, which are closely related to artificial neural network (ANN), big data and machine learning. The green color represents cluster 2 in which some keywords play a role and are close together, namely building management system, deep learning, energy harvesting, fault-tolerant control, smart city.

Cluster 3 in blue shows the proximity of keywords that are mostly related to energy, namely the keywords energy efficiency, energy management, and energy storage. And things related to this energy are widely used and associated with indoor environment and sustainability and become a part that is always discussed together in various articles. The keyword group big data analytics, complex event processing, internet of things, smart energy management, and wireless sensor network is in the 4th cluster.

4.2. Countries where smart building research is conducted

From the full-text 56 articles reviewed, the countries where the smart building research was conducted were identified and obtained in Table 3. The distribution of the countries where the research was conducted was 17 countries from 3 regions. This illustrates that most research on smart building comes from only 3 regions, namely: Europe and Central Asia, East Asia and Pacific, and North America, covering 17 countries involved as a place for smart building research.

Table 3. Countries where smart building research is conducted

No.	Country name	Country category (World Bank)	Region	Articles
01	Australia	High income	East Asia and Pacific	[21], [22]
02	China	Upper middle income	East Asia and Pacific	[23]-[25]
03	Czech Rep.	High income	Europe and Central Asia	[26]
05	Finland	High income	Europe and Central Asia	[27], [28]
06	France	High income	Europe and Central Asia	[29], [30]
07	Hongkong	High income	East Asia and Pacific	[31]
08	Indonesia	Lower middle income	East Asia and Pacific	[32], [33]
09	Italy	High income	Europe and Central Asia	[34], [35]
10	Korea Rep.	High income	East Asia and Pacific	[36]
11	Malaysia	Upper middle income	East Asia and Pacific	[37]-[39]
12	Romania	Upper middle income	Europe and Central Asia	[40]
13	Singapore	High income	East Asia and Pacific	[41]-[43]
14	Slovak Rep.	High income	Europe and Central Asia	[44]
15	Spain	High income	Europe and Central Asia	[45]-[47],
16	UK	High income	Europe and Central Asia	[48], [49]
17	USA	High income	North America	[50], [51]
18	N/A	-	-	[12], [52]-[58], [59]-[66], [67]-[75]

31 papers specifically mention the country where the research was carried out and 25 papers do not mention it, Figure 7. Of the 31 papers spread across 17 countries where smart building research was conducted, there are only 3 regions. Regions Europe and Central Asia, East Asia and Pacific and North America as ranked by the World Bank [76] most of them are countries with income levels at the “high income” and “upper middle income” levels and in Figure 8 it can be seen that there are 71% of countries that occupy the “high income” position and 23% of countries with “upper middle income” category and only 6% occupy the position as a country with the income category of "lower middle income". It means that the country where smart building is currently being researched is dominated by countries with a good economy and in terms of income, the country with a minimum level is "lower middle income".

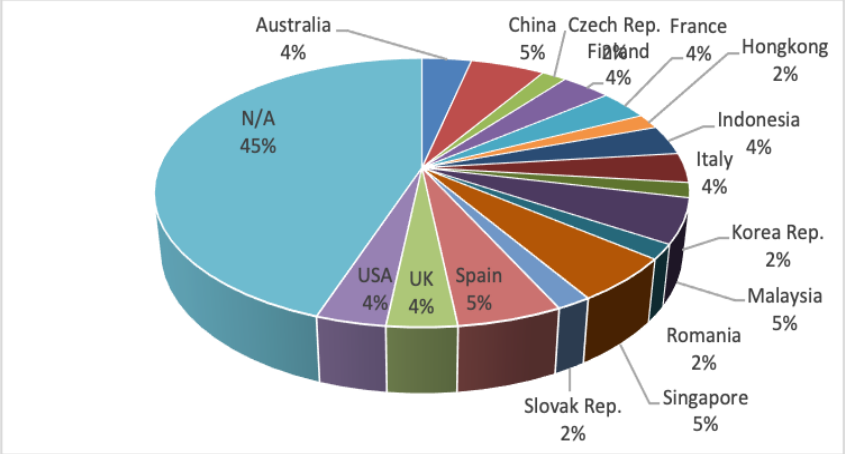

Figure 7. The country where the smart building research is conducted

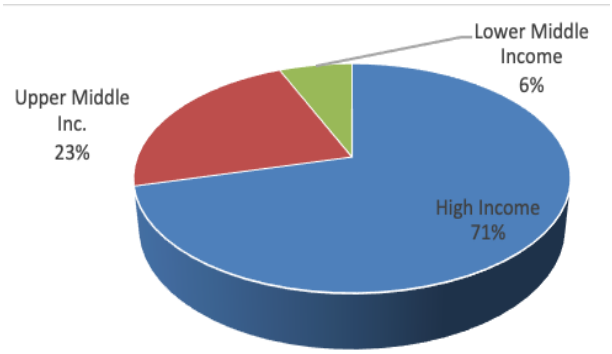

Figure 8. Category based on the income of the country where the smart building research is conducted

4.3. Implementation of smart building in the property industry

The grouping of properties or buildings is generally divided into 2 types, namely: i) residential property (single-family homes and multi-family homes such as apartments, condominiums), and ii) commercial property (office buildings, retail facilities, educational buildings, healthcare facilities). There is a clear difference in the use of smart building for the two types of property. The development of the IoT in smart buildings in commercial buildings gets more attention than residential buildings and will continue to develop in commercial property [77]. Because commercial buildings are highly demanded to follow the latest technological developments, are used as a means of business, research and must support many other facilities.

The results of a systematic literature review provide information that smart building research is indeed carried out on both types of property, namely residential which consists of residential buildings, apartments, condominiums, and family houses. In the commercial building, the places used for smart building research consist of hotels, office buildings, and campus/school buildings. In Table 4, the smart building research on commercial building has 11 articles consisting of 1 article for hotel, 4 for office building, and 6 for

campus/school building. Meanwhile, in the smart building research that uses residential property as the research location, there are 6 articles.

Table 4. Smart building research locations by property type

Property type	Property category	Articles	Total
Residential	Residential/apartment/family house	[28], [36], [44], [52], [65],[68]	6
Commercial	Hotel	[31]	1
	Office building	[22], [29], [37], [49]	4
	Campus/school building	[32], [34], [40], [45], [52],[78]	6

The grouping of research location data based on the type of property in Figure 9 displays information with 2 types of large groups, namely residential and commercial shown in Figure 8. Research using non-commercial properties as much as 41% and commercial properties as much as 59%. Residential properties consist of residential/apartment/family house has 6 papers and government building has 1 paper. As for commercial property, there are 3 types, namely hotels with 1 paper, campus/school building with 6 papers, and office building with 4 papers.

From the number of articles per property type, a graph is made to be able to see the percentage of the smart building research location grouping. The results of the percentage per property type can be seen in Figure 9. Research with the location of commercial building as much as 65%, namely there are 11 articles from 17 articles and residential property as much as 35% or 6 articles from 17 articles which inform the location of the smart building research.

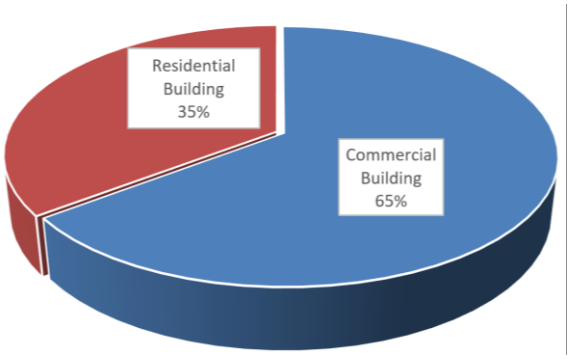

Figure 9. Category based on property type where the smart building research is conducted

From the results above, it can be concluded that the research location is still dominated by commercial buildings. This means that research using commercial property is still very open to getting more precise and real results. Smart building research in commercial building is very challenging because of the demands for flexibility and the conditions that occur in it. Unlike residential property which tends to be stagnant and fixed, smart buildings applied to commercial buildings must be able to adapt to internal and external conditions [79].

4.4. Trends in smart building research

Of the 56 selected articles, there were 196 keywords. Based on these keywords that will be used as a basis for seeing the current trend in research on smart building. The selected keywords are keywords that are contained in more than 1 article, while keywords that are only found in 1 article are not included. The special keyword "smart building" is also not included because it is the main keyword. The list of keywords, the total number of keywords in the article, and which articles the keywords were used in is in Table 5.

The 24 keywords are then grouped again based on keywords that have the same meaning. The purpose of grouping keywords with the same meaning is to determine the trend of discussion in research in smart building. In Table 5, several keywords have the same or similar meaning. The keywords that have the same or the same meaning are combined to form a new group and produce information about the most widely discussed trends in smart building research. The keyword cluster "energy" is a combination of the keywords "energy management", "energy efficiency", "energy consumption", "energy harvesting", "energy storage", "smart

energy management" and the combination of these 6 keywords becomes the total energy keyword. 20 keywords and ranks 1 of all keywords.

Table 5. Grouping of keywords in smart building articles

No.	Author Keywords	Total	Article-No
01	Internet of things	12	[12], [21], [27], [34], [39] [52]-[55], [57], [59], [62],
02	Machine learning	11	[12], [37], [44], [45], [48], [54], [57], [62], [64],[70],[80]
03	Big data	5	[12], [48], [57], [58], [62]
04	ANN	5	[25], [55], [64], [78], [81]
05	Energy management	5	[27], [37], [46], [52], [54],
06	Energy efficiency	5	[27], [31], [42], [46], [68]
07	Smart city	4	[21], [41], [60], [66]
08	Heating	4	[28], [34], [35], [48]
09	Energy consumption	4	[37], [39], [45], [64]
10	Demand response	3	[23], [47], [65]
11	Fault tolerant control	3	[21], [27], [59]
12	Indoor environment	3	[31], [42], [68]
13	Smart grid	3	[23], [58], [64]
14	Deep learning	3	[32], [41], [54]
15	Building management system	2	[21], [32]
16	Energy harvesting	2	[21], [50]
17	Energy storage	2	[29], [46]
18	Sensors	2	[73], [78]
19	Sustainability	2	[46], [60]
20	Building information modeling	2	[43], [73]
21	Wireless sensor network	2	[25], [55]
22	Big data analytics	1	[12]
23	Complex event processing	2	[12], [38]
24	Smart energy management	2	[27], [52]

This means that the keyword "energy" is the most discussed in the "smart building" article compared to the others. The keyword “big data” is combined with the keyword “big data analytics”, the total number of articles that use a combination of these keywords is 8 and the last combination of keywords is “sensor” combined with “wireless sensor network” a total of 8 keywords, the results can be seen in Table 6.

Table 6 and Figure 10 illustrate that the most discussed trends in smart building are about energy as much as 24%, this is very relevant because in smart building one of the main goals is efficiency and energy is the main issue. The number of articles that discuss energy in smart buildings is because the cost of providing energy to a property or building is one of the biggest costs and is a routine cost in operations. The second order in the smart building article is a discussion of the IoT by 16%. The development of information technology, the internet, and other technologies, especially those applied in the property industry, causes all devices to be operated easily and integrated. And this is the reason why the IoT in smart building is widely discussed and becomes a trend.

Machine learning in smart building occupies the 3rd position with 12%, the 4th position is a discussion of big data with 10% and the last position in the top 5 is the discussion of ANN as much as 6%. machine learning, big data, and ANN are quite surprising in positions 3, 4 and 5 because the issue is an issue that has not been too long ago but has been discussed quite a lot in the smart building article, meaning that the property world is very fast in adopting the latest technology and issues in the technology world information.

Tabel 6. The results of combining similar keywords in smart building research

No.	Author Keywords	Total
01	Energy	20
02	Internet of things	13
03	Machine learning	10
04	Big data	8
05	ANN	5
06	Smart city	4
07	Heating	4
08	Demand response	3
09	Fault-tolerant control	3
10	Indoor environment	3
11	Smart grid	3
12	Deep learning	3
13	Building management system	2
14	Sensors	2

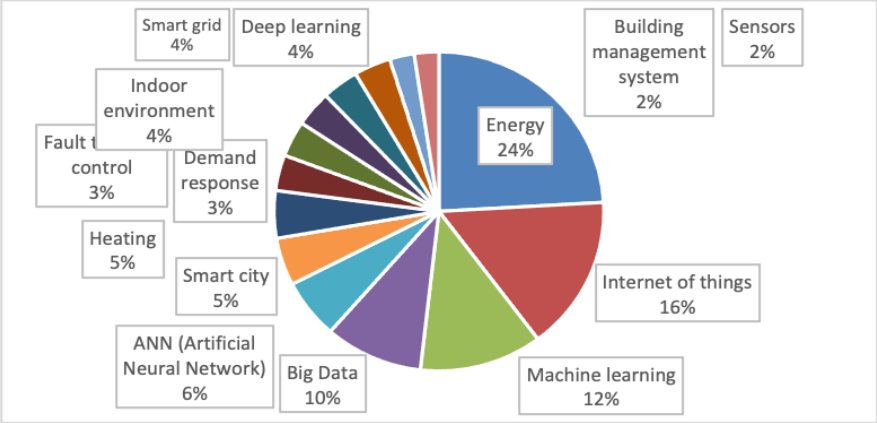

Figure 10. Research discussion trends in smart building

5. CONCLUSION AND FUTURE WORK

The discussion topics in the smart building article are based on keyword grouping and mapping from 56 articles and by using the VOSviewer application, an image is obtained that there are 5 clusters created, in VOSviewer they are given in different colors for each cluster. This cluster indicates the grouping for any components contained in the smart building. Research on smart building has not been carried out evenly in all countries in the world, the results of the SLR analysis provide an overview only in 3 regions, namely East Asia Pacific, Europe and Central Asia, and North America, and in countries with minimal income, "lower middle income". Countries in the Europe and Central Asia region rank highest as countries that have the highest research in smart building. This concludes that smart building has not been widely used as an option for research in low-economy countries.

This systematic literature review also provides information that most smart building research is conducted on non-commercial properties, such as campus buildings, apartments, family homes, and government buildings. Places of research conducted on commercial property types such as malls, hotels, and commercial office buildings only 24% of the total research conducted on non-commercial property types. Trends in current smart building research continue to make "energy" and its derivatives a part that is widely discussed and has become a trend in recent years. This is because many researchers from multiple disciplines are trying to find ways to use energy as efficiently and effectively as possible. An interesting trend is that smart buildings also adopt the latest technologies such as the application of big data, machine learning, and artificial neural networks.

This research is expected to contribute theoretically and practically. Research in smart building in the future will certainly continue to develop and be integrated with the latest information technology. The components in a Smart Building will be an important point that must be considered in determining a Smart Building. Smart building research is carried out in economically strong countries with the country's average income in the "lower middle income" category and currently, the research conducted has involved the category of non-commercial property and commercial property. The need for a smart building model in each country or region with its peculiarities is deemed necessary so that the development of Smart Buildings can develop, and the big impact is to support prevent global warming.

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REFERENCES

[1] H. Noprisson, N. Husin, N. Zulkarnaim, P. Rahayu, A. Ramadhan, and D. I. Sensuse, "Antecedent factors of consumer attitudes toward SMS, E-mail and social media for advertising," *2016 International Conference on Advanced Computer Science and Information Systems (ICACSIS)*, 2016, pp. 165–170, doi: 10.1109/ICACSIS.2016.7872742.

[2] A. I. Suroso and A. Ramadhan, "Structural Path analysis of the influences from smallholder oil palm plantation toward household income: one aspect of e-government initative," *Advanced Science Letters*, vol. 20, no. 1, pp. 352–356, 2014, doi: 10.1166/asl.2014.5317.

[3] J. Kleissl and Y. Agarwal, "Cyber-physical energy systems," *Proceedings of the 47th Design Automation Conference on - DAC '10*, 2010, p. 749, doi: 10.1145/1837274.1837464.

[4] M. B. Hoy, "Smart buildings: an introduction to the library of the future," *Medical Reference Services Quarterly*, vol. 35, no. 3, pp. 326–331, 2016, doi: 10.1080/02763869.2016.1189787.

[5] A. H. Buckman, M. Mayfield, and S. B.M. Beck, "What is a smart building?," *Smart and Sustainable Built Environment*, vol. 3, no. 2, pp. 92–109, 2014, doi: 10.1108/SASBE-01-2014-0003.

[6] "Smart buildings." https://advisory.kpmg.us/articles/2021/smart-buildings.html (accessed Jan. 28, 2022).

[7] W. Zhang and M. Yue, "The application of building energy management system based on IoT technology in smart city," *International Journal of System Assurance Engineering and Management*, vol. 12, no. 4, pp. 617–628, 2021, doi: 10.1007/s13198-021-01054-6.

[8] M. Dryjanski, M. Buczkowski, Y. Ould-Cheikh-Mouhamedou, and A. Kliks, "Adoption of Smart cities with a practical smart building implementation," I*EEE Internet of Things Magazine*, vol. 3, no. 1, pp. 58–63, 2020, doi: 10.1109/IOTM.0001.1900050.

[9] R. Apanaviciene, R. Urbonas, and P. A. Fokaides, "Smart building integration into a smart city: comparative study of real estate development," *Sustainability*, vol. 12, no. 22, p. 9376, 2020, doi: 10.3390/su12229376.

[10] L. Yang, N. Elisa, and N. Eliot, "Privacy and security aspects of e-government in smart cities," in *Smart Cities Cybersecurity and Privacy*, Elsevier, 2019, pp. 89–102.

[11] R. Yuliastri and H. Amani, "Indicators to measure a smart building: an indonesian perspective," *International Journal of Computer Theory and Engineering*, vol. 9, no. 6, pp. 406–411, 2017, doi: 10.7763/IJCTE.2017.V9.1176.

[12] B. Qolomany *et al*., "Leveraging machine learning and big data for smart buildings: a comprehensive survey," *IEEE Access*, vol. 7, pp. 90316–90356, 2019, doi: 10.1109/ACCESS.2019.2926642.

[13] M. Himanen, "The significance of user involvement in smart buildings within smart cities," in *Designing, Developing, and Facilitating Smart Cities*, Cham: Springer International Publishing, 2017, pp. 265–314.

[14] E. Laurini, M. Rotilio, M. Lucarelli, and P. De Berardinis, "Technology 4.0 for buildings management: from building site to the interactive building book," *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, vol. XLII-2/W11, pp. 707–714, 2019, doi: 10.5194/isprs-archives-XLII-2-W11-707-2019.

[15] A. H. Buckman, M. Mayfield, R. Meijer, and S. B. M. Beck, "Progressing from intelligent to smart buildings," *Proceedings of the 13th International Conference for Enhanced Building Operations*, 2013.

[16] D. Minoli, K. Sohraby, and B. Occhiogrosso, "IoT considerations, requirements, and architectures for smart buildings—energy optimization and next-generation building management systems," *IEEE Internet of Things Journal*, vol. 4, no. 1, pp. 269–283, 2017, doi: 10.1109/JIOT.2017.2647881.

[17] B. Kitchenham, "Procedures for performing systematic reviews," 2004. [Online]. Available: https://www.inf.ufsc.br/~aldo.vw/kitchenham.pdf.

[18] S. T. Matarneh, M. Danso-Amoako, S. Al-Bizri, M. Gaterell, and R. Matarneh, "Building information modeling for facilities management: A literature review and future research directions," *Journal of Building Engineering*, vol. 24, p. 100755, 2019, doi: 10.1016/j.jobe.2019.100755.

[19] D. Moher, A. Liberati, J. Tetzlaff, and D. G. Altman, "Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement," *BMJ*, vol. 339, no. jul21 1, pp. b2535–b2535, 2009, doi: 10.1136/bmj.b2535.

[20] N. J. van Eck and L. Waltman, "Software survey: VOSviewer, a computer program for bibliometric mapping," *Scientometrics*, vol. 84, no. 2, pp. 523–538, 2010, doi: 10.1007/s11192-009-0146-3.

[21] Q. Ha and M. D. Phung, "IoT-enabled dependable control for solar energy harvesting in smart buildings," *IET Smart Cities*, vol. 1, no. 2, pp. 61–70, Dec. 2019, doi: 10.1049/iet-smc.2019.0052.

[22] P. M. McGuirk, R. Dowling, and C. Carr, "The material politics of smart building energy management: A view from Sydney's commercial office space," *Political Geography*, vol. 74, p. 102034, 2019, doi: 10.1016/j.polgeo.2019.102034.

[23] Y. Liu *et al*., "Coordinating the operations of smart buildings in smart grids," *Applied Energy*, vol. 228, pp. 2510–2525, 2018, doi: 10.1016/j.apenergy.2018.07.089.

[24] Z. Li *et al*., "Energy management strategy of active distribution network with integrated distributed wind power and smart buildings," *IET Renewable Power Generation*, vol. 14, no. 12, pp. 2255–2267, Sep. 2020, doi: 10.1049/iet-rpg.2020.0049.

[25] K. Zhang, K. Yang, S. Li, D. Jing, and H.-B. Chen, "ANN-based outlier detection for wireless sensor networks in smart buildings," *IEEE Access*, vol. 7, pp. 95987–95997, 2019, doi: 10.1109/ACCESS.2019.2929550.

[26] J. Pašek and V. Sojková, "Facility management of smart buildings," *International Review of Applied Sciences and Engineering*, vol. 9, no. 2, pp. 181–187, 2018, doi: 10.1556/1848.2018.9.2.15.

[27] C. K. Metallidou, K. E. Psannis, and E. A. Egyptiadou, "Energy efficiency in smart buildings: IoT approaches," *IEEE Access*, vol. 8, pp. 63679–63699, 2020, doi: 10.1109/ACCESS.2020.2984461.

[28] N. A. Efkarpidis, G. C. Christoforidis, and G. K. Papagiannis, "Modeling of heating and cooling energy needs in different types of smart buildings," *IEEE Access*, vol. 8, pp. 29711–29728, 2020, doi: 10.1109/ACCESS.2020.2972965.

[29] E. Janhunen, N. Leskinen, and S. Junnila, "The economic viability of a progressive smart building system with power storage," *Sustainability*, vol. 12, no. 15, p. 5998, Jul. 2020, doi: 10.3390/su12155998.

[30] Y. Xu, P. Ahokangas, M. Turunen, M. Mäntymäki, and J. Heikkilä, "Platform-based business models: insights from an emerging ai-enabled smart building ecosystem," *Electronics (Switzerland)*, vol. 8, no. 10, p. 1150, Oct. 2019, doi: 10.3390/electronics8101150.

[31] W. Li, C. Koo, S. H. Cha, J. H. K. Lai, and J. Lee, "A conceptual framework for the real-time monitoring and diagnostic system for the optimal operation of smart building: a case study in Hotel ICON of Hong Kong," *Energy Procedia*, vol. 158, pp. 3107–3112, Feb. 2019, doi: 10.1016/j.egypro.2019.01.1005.

[32] B. Pardamean, H. H. Muljo, T. W. Cenggoro, B. J. Chandra, and R. Rahutomo, "Using transfer learning for smart building management system," *Journal of Big Data*, vol. 6, no. 1, p. 110, Dec. 2019, doi: 10.1186/s40537-019-0272-6.

[33] A. Pellegrino, V. R. M. Lo Verso, L. Blaso, A. Acquaviva, E. Patti, and A. Osello, "Lighting control and monitoring for energy efficiency: a case study focused on the interoperability of building management systems," *2015 IEEE 15th International Conference on Environment and Electrical Engineering (EEEIC)*, 2015, pp. 748–753, doi: 10.1109/EEEIC.2015.7165258.

[34] R. Carli, G. Cavone, S. Ben Othman, and M. Dotoli, "IoT based architecture for model predictive control of HVAC Systems in smart buildings," *Sensors*, vol. 20, no. 3, p. 781, Jan. 2020, doi: 10.3390/s20030781.

[35] F. Liberati, A. Di Giorgio, A. Giuseppi, A. Pietrabissa, E. Habib, and L. Martirano, "Joint model predictive control of electric and heating resources in a smart building," *IEEE Transactions on Industry Applications*, vol. 55, no. 6, pp. 7015–7027, Nov. 2019, doi: 10.1109/TIA.2019.2932954.

[36] H. Park and S.-B. Rhee, "IoT-based smart building environment service for occupants' thermal comfort," *Journal of Sensors*, vol. 2018, pp. 1–10, 2018, doi: 10.1155/2018/1757409.

[37] M. K. M. Shapi, N. A. Ramli, and L. J. Awalin, "Energy consumption prediction by using machine learning for smart building: case study in Malaysia," *Developments in the Built Environment*, vol. 5, p. 100037, Mar. 2021, doi: 10.1016/j.dibe.2020.100037.

[38] R. A. Shahad, M. H. Md Saad, and A. Hussain, "Activity recognition for smart building application using complex event processing approach," *International Journal on Advanced Science, Engineering and Information Technology*, vol. 8, no. 2, p. 315, 2018, doi: 10.18517/ijaseit.8.2.2575.
[39] K. Irshad, A. Almalawi, A. I. Khan, M. M. Alam, M. H. Zahir, and A. Ali, "An IoT-based thermoelectric air management framework for smart building applications: a case study for tropical climate," *Sustainability*, vol. 12, no. 4, p. 1564, 2020, doi: 10.3390/su12041564.
[40] G. Stamatescu, I. Stamatescu, N. Arghira, and I. Fagarasan, "Data-driven modelling of smart building ventilation subsystem," *Journal of Sensors*, vol. 2019, pp. 1–14, 2019, doi: 10.1155/2019/3572019.
[41] W. Zhang, W. Hu, and Y. Wen, "Thermal comfort modeling for smart buildings: a fine-grained deep learning approach," *IEEE Internet of Things Journal*, vol. 6, no. 2, pp. 2540–2549, 2019, doi: 10.1109/JIOT.2018.2871461.
[42] K. Weekly *et al*., "Building-in-briefcase: a rapidly-deployable environmental sensor suite for the smart building," *Sensors*, vol. 18, no. 5, p. 1381, Apr. 2018, doi: 10.3390/s18051381.
[43] M. Y. L. Chew, E. A. L. Teo, K. W. Shah, V. Kumar, and G. F. Hussein, "Evaluating the roadmap of 5G technology implementation for smart building and facilities management in Singapore," *Sustainability*, vol. 12, no. 24, p. 10259, 2020, doi: 10.3390/su122410259.
[44] P. Minarčík, H. Procházka, and M. Gulan, "Advanced supervision of smart buildings using a novel open-source control platform," *Sensors*, vol. 21, no. 1, p. 160, 2020, doi: 10.3390/s21010160.
[45] F. Divina, M. García Torres, F. A. Goméz Vela, and J. L. Vázquez Noguera, "A comparative study of time series forecasting methods for short term electric energy consumption prediction in smart buildings," *Energies*, vol. 12, no. 10, p. 1934, 2019, doi: 10.3390/en12101934.
[46] C. Benavente-Peces, "On the energy efficiency in the next generation of smart buildings—supporting technologies and techniques," *Energies*, vol. 12, no. 22, p. 4399, 2019, doi: 10.3390/en12224399.
[47] F. Moya, J. Torres-Moreno, and J. Álvarez, "Optimal Model for energy management strategy in smart building with energy storage systems and electric vehicles," *Energies*, vol. 13, no. 14, p. 3605, 2020, doi: 10.3390/en13143605.
[48] M. Dey, S. P. Rana, and S. Dudley, "Smart building creation in large scale HVAC environments through automated fault detection and diagnosis," *Future Generation Computer Systems*, vol. 108, pp. 950–966, 2020, doi: 10.1016/j.future.2018.02.019.
[49] S. A. Nabavi, N. H. Motlagh, M. A. Zaidan, A. Aslani, and B. Zakeri, "Deep learning in energy modeling: application in smart buildings with distributed energy generation," *IEEE Access*, vol. 9, pp. 125439–125461, 2021, doi: 10.1109/ACCESS.2021.3110960.
[50] S. Fernandes, J. Granderson, R. Singla, and S. Touzani, "Corporate Delivery of a global smart buildings program," *Energy Engineering*, vol. 115, no. 1, pp. 7–25, 2018, doi: 10.1080/01998595.2018.11950815.
[51] Q. Lin *et al*., "Design and experiment of a sun-powered smart building envelope with automatic control," *Energy and Buildings*, vol. 223, p. 110173, 2020, doi: 10.1016/j.enbuild.2020.110173.
[52] F.-J. Ferrández-Pastor, H. Mora, A. Jimeno-Morenilla, and B. Volckaert, "Deployment of IoT Edge and fog computing technologies to develop smart building services," *Sustainability*, vol. 10, no. 11, p. 3832, 2018, doi: 10.3390/su10113832.
[53] A. Daissaoui, A. Boulmakoul, L. Karim, and A. Lbath, "IoT and big data analytics for smart buildings: a survey," *Procedia Computer Science*, vol. 170, pp. 161–168, 2020, doi: 10.1016/j.procs.2020.03.021.
[54] M. Elsisi, M.-Q. Tran, K. Mahmoud, M. Lehtonen, and M. M. F. Darwish, "Deep Learning-based industry 4.0 and internet of things towards effective energy management for smart buildings," *Sensors*, vol. 21, no. 4, p. 1038, 2021, doi: 10.3390/s21041038.
[55] D. Sembroiz, D. Careglio, S. Ricciardi, and U. Fiore, "Planning and operational energy optimization solutions for smart buildings," *Information Sciences*, vol. 476, pp. 439–452, Feb. 2019, doi: 10.1016/j.ins.2018.06.003.
[56] R. Jia *et al*., "Design automation for smart building systems," *Proceedings of the IEEE*, vol. 106, no. 9, pp. 1680–1699, 2018, doi: 10.1109/JPROC.2018.2856932.
[57] H. Elkhoukhi, Y. NaitMalek, A. Berouine, M. Bakhouya, D. Elouadghiri, and M. Essaaidi, "Towards a real-time occupancy detection approach for smart buildings," *Procedia Computer Science*, vol. 134, pp. 114–120, 2018, doi: 10.1016/j.procs.2018.07.151.
[58] M. H. Rahim, A. Khalid, N. Javaid, M. Alhussein, K. Aurangzeb, and Z. A. Khan, "Energy efficient smart buildings using coordination among appliances generating large data," *IEEE Access*, vol. 6, pp. 34670–34690, 2018, doi: 10.1109/ACCESS.2018.2805849.
[59] R. Casado-Vara, Z. Vale, J. Prieto, and J. Corchado, "Fault-tolerant temperature control algorithm for IoT Networks in smart buildings," *Energies*, vol. 11, no. 12, p. 3430, 2018, doi: 10.3390/en11123430.
[60] R. Apanaviciene, A. Vanagas, and P. A. Fokaides, "Smart building integration into a smart city (SBISC): development of a new evaluation framework," *Energies*, vol. 13, no. 9, p. 2190, 2020, doi: 10.3390/en13092190.
[61] X. Jin *et al*., "Scheduling distributed energy resources and smart buildings of a microgrid via multi-time scale and model predictive control method," *IET Renewable Power Generation*, vol. 13, no. 6, pp. 816–833, 2019, doi: 10.1049/iet-rpg.2018.5567.
[62] S. Hadri, Y. Naitmalek, M. Najib, M. Bakhouya, Y. Fakhri, and M. Elaroussi, "A comparative study of predictive approaches for load forecasting in smart buildings," *Procedia Computer Science*, vol. 160, pp. 173–180, 2019, doi: 10.1016/j.procs.2019.09.458.
[63] M. Froufe, C. Chinelli, A. Guedes, A. Haddad, A. Hammad, and C. Soares, "Smart buildings: systems and drivers," *Buildings*, vol. 10, no. 9, p. 153, 2020, doi: 10.3390/buildings10090153.
[64] S. Bourhnane, M. R. Abid, R. Lghoul, K. Zine-Dine, N. Elkamoun, and D. Benhaddou, "Machine learning for energy consumption prediction and scheduling in smart buildings," *SN Applied Sciences*, vol. 2, no. 2, p. 297, 2020, doi: 10.1007/s42452-020-2024-9.
[65] M. Ostadijafari, A. Dubey, Y. Liu, J. Shi, and N. Yu, "Smart building energy management using nonlinear economic model predictive control," *2019 IEEE Power & Energy Society General Meeting (PESGM)*, 2019, pp. 1–5, doi: 10.1109/PESGM40551.2019.8973669.
[66] Y. Bapin and V. Zarikas, "Smart building's elevator with intelligent control algorithm based on bayesian networks," *International Journal of Advanced Computer Science and Applications*, vol. 10, no. 2, 2019, doi: 10.14569/IJACSA.2019.0100203.
[67] Z. Foroozandeh, S. Ramos, J. Soares, and Z. Vale, "Energy management in smart building by a multi-objective optimization model and pascoletti-serafini scalarization approach," *Processes*, vol. 9, no. 2, p. 257, 2021, doi: 10.3390/pr9020257.
[68] X. Wang, M. Umehira, H. Otsu, T. Kawatani, and S. Takeda, "Energy efficient learning-based indoor multi-band WLAN for smart buildings," *IEEE Access*, vol. 6, pp. 34324–34333, 2018, doi: 10.1109/ACCESS.2018.2849094.
[69] Z. Jiang and Y. M. Lee, "Deep transfer learning for thermal dynamics modeling in smart buildings," *2019 IEEE International Conference on Big Data (Big Data)*, 2019, pp. 2033–2037, doi: 10.1109/BigData47090.2019.9006306.
[70] F. Almaguer-Angeles, J. Murphy, L. Murphy, and A. O. Portillo-Dominguez, "Choosing machine learning algorithms for anomaly detection in smart building IoT scenarios," *2019 IEEE 5th World Forum on Internet of Things (WF-IoT)*, 2019, pp. 491–495, doi:

10.1109/WF-IoT.2019.8767357.
[71] A. Mokhireva, P. Loginova, E. Glebova, and V. Bespalov, "Hardware base and experimental potential of a smart building prototype," *MATEC Web of Conferences*, vol. 245, p. 16001, 2018, doi: 10.1051/matecconf/201824516001.
[72] Y. Dagdougui, A. Ouammi, and R. Benchrifa, "High Level controller-based energy management for a smart building integrated microgrid with electric vehicle," *Frontiers in Energy Research*, vol. 8, 2020, doi: 10.3389/fenrg.2020.535535.
[73] K. Afsari, L. Florez, E. Maneke, and M. Afkhamiaghda, "An experimental investigation of the integration of smart building components with building information model (BIM)," *Proceedings of the 36th International Symposium on Automation and Robotics in Construction, ISARC 2019*, 2019, pp. 578–585, doi: 10.22260/ISARC2019/0077.
[74] L. Linder, D. Vionnet, J.-P. Bacher, and J. Hennebert, "Big building data - a big data platform for smart buildings," *Energy* Procedia, vol. 122, pp. 589–594, 2017, doi: 10.1016/j.egypro.2017.07.354.
[75] P. M. Papadopoulos, V. Reppa, M. M. Polycarpou, and C. G. Panayiotou, "Scalable distributed sensor fault diagnosis for smart buildings," *IEEE/CAA Journal of Automatica Sinica*, vol. 7, no. 3, pp. 638–655, 2020, doi: 10.1109/JAS.2020.1003123.
[76] "The world by income and region." https://datatopics.worldbank.org/world-development-indicators/the-world-by-income-and-region.html (accessed Jan. 30, 2022).
[77] K. Lawal and H. N. Rafzanjani, "Trends, benefits, risks, and challenges of IoT Implementation in residential and commercial buildings", *Energy and Build Environment*, vol. 3, no. 3, pp. 251–266, Jul. 2022, doi: 10.1016/j.enbenv.2021.01.009.
[78] N. Attoue, I. Shahrour, and R. Younes, "Smart building: use of the artificial neural network approach for indoor temperature forecasting," *Energies*, vol. 11, no. 2, p. 395, 2018, doi: 10.3390/en11020395.
[79] F. M. Bhutta, "Application of smart energy technologies in building sector — future prospects," *2017 International Conference on Energy Conservation and Efficiency (ICECE)*, 2017, pp. 7–10, doi: 10.1109/ECE.2017.8248820.
[80] A. Corna, L. Fontanab, A. A. Nacci, and D. Sciuto, "Occupancy detection via iBeacon on Android devices for smart building management," *Design, Automation & Test in Europe Conference & Exhibition (DATE)*, 2015, 2015, pp. 629–632, doi: 10.7873/DATE.2015.0753.
[81] M. A. Alduailij, I. Petri, O. Rana, M. A. Alduailij, and A. S. Aldawood, "Forecasting peak energy demand for smart buildings," *The Journal of Supercomputing*, vol. 77, no. 6, pp. 6356–6380, 2021, doi: 10.1007/s11227-020-03540-3.

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