

nZEB buildings, analysis of the research trend

Edificios nZEB, análisis de la tendencia de investigación

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Abstract— In this paper, the research trend in relation to the NZEB buildings is explored, through the analysis of selected scientific articles published in 11 journals collected in chronological order from 2014 to 2020. The analysis is carried out on the basis and terms of annual investigative publications of the documents in relation to the NZEB, such as contributions made by countries, institutions, authors, and research topics covered. The study carried out uses a document review methodology. The analysis reveals a growing interest in energy efficiency research in recent times, implying that the importance that the construction industry attaches to NZEB in consequences of global warming and accelerating environmental problems. The findings also indicate that, during the period studied, researchers in developed economy areas such as the US and Italy contributed higher rates to promoting research on NZEB. Developing countries like China also went to great lengths to promote research. Research topics covered tend to focus on studies completed with NZEB project delivery and development, building rehabilitation, energy performance, and advanced technologies applied for energy improvement in buildings. This research provides a valuable platform for industry professionals and researchers to understand NZEB construction research trends and developments, including their applicability and their future research and contributions to the topic.

Index Terms— Energy efficiency, nZEB buildings, Research trends, Sustainable development, Sustainable architectures.

Resumen— En el presente trabajo se exploran la tendencia de investigación con relación a los edificios NZEB, mediante el análisis de artículos científicos seleccionados publicados en 11 revistas recopilados en orden cronológico desde el año 2014 hasta el 2020. El análisis se realiza en base y términos de publicaciones investigativas anuales de los documentos con relación a los NZEB, como contribuciones realizadas por países, instituciones, autores, y temas de investigación cubiertos. El estudio realizado utiliza una metodología de revisión documental. El análisis revela un creciente interés de investigación de rendimiento energético en los últimos tiempos, lo que implica la importancia que la industria de la construcción atribuye a NZEB en consecuencias al calentamiento global y problemática ambiental se está acelerando.

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Los hallazgos también indican que, durante el período estudiado, los investigadores de las zonas con economías desarrolladas como los EE. UU., e Italia contribuye-ron con índices más altos a promover la investigación sobre NZEB. Los países en desarrollo como China también hicieron grandes esfuerzos para promover la investigación. Los temas de investigación cubiertos tienden a centrarse en los estudios finalizados con la entrega y el desarrollo de proyectos de NZEB, rehabilitación de edificios, rendimiento energético y tecnologías avanzadas que se aplican para el mejoramiento energético en las edificaciones. Esta investigación proporciona una plataforma valiosa para que los profesionales e investigadores de la industria comprendan las tendencias y los desarrollos de investigación de la construcción NZEB, incluida su aplicabilidad, sus futuras investigaciones y contribuciones al tema.

Palabras claves— Arquitecturas sostenibles, Desarrollo sostenible, Eficiencia energética, Edificios nZEB, Tendencias de la investigación.

I. INTRODUCTION

ESPECIALLY the construction sector is one of the main causes of pollution, since the processes of the heating and cooling system in the building release excessive emissions to the environment [1]–[3]. Therefore, it is necessary to change the direction requiring the design of new buildings to reduce the annual energy demand and support it by incorporating systems powered by renewable energy (RES) [4], [5]. However, the challenge is not conditional on the new buildings [6], [7].

Likewise, the efficiency of the construction sector is considered an important point to achieve the purpose of sustainable development [8], [9], and reduce greenhouse gas emissions [10], [11], where the energy performance of buildings can be improved through various measures, both characteristics of the built environment as well as local conditions [12], [13].

Considering the thermal characteristics of the building [14], it is important to distinguish between the old and the new

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structure[15], [16]. In new buildings, the design phase allows the use of a complete set of information generally derived from technical tables of products and materials[17]. On the other hand, for contemporary buildings, the technical data of the materials used may not be queried[18], because files may have been lost or the structural intervention may change the internal composition of the walls [19].

Therefore, in the general field of focusing on planning energy efficiency tactics, the construction of Net Zero Energy Buildings (Net Zero Energy Buildings NZEB) is a fast growing method due to superior environmental performance [20], compared to ordinary buildings of the same scale and occupancy rate [21][22].

Generally speaking, NZEB refers to buildings whose actual energy required for operation and maintenance is less than or less than the amount of electricity generated by means of renewable energy at the point or outside the residence. This is achieved through the installation of energy efficiency measures (EEM) to reduce the energy demand of the building, while complementing the remaining energy demand with renewable energy measures (REM), namely photovoltaic cells, factories of wind power, geothermal power, and various other hybrids [23], [24].

The United States The National Institute of Standards and Technology (NIST) estimates that, by making full use of existing energy saving measures and technologies, energy can be reduced by 40-50%, while the rest it is generally provided through REM on-site or off-site [25]. In summary, if these two practices (energy efficiency measures and renewable energy measures) are combined, it would be possible to overcome the need to connect to the electricity grid for buildings [26].

Today, the NZEBs are the center of attention for the European Union, since they are taking care of giving an effective response to the problems caused to the environment such as pollution, global warming, among others. The currently perceived result of climate change is nothing more than the result of poor political, technical and economic decisions, which do not meet current needs [27].

Considering the above situation, this work involves an analysis of the global construction trends of NZEB, exploring the latest research from other countries, institutions, and authors in order to provide promising contractual methods for the construction of the industry and contribute to the development sustainable.

II. METHODOLOGIC

For researchers and scientists to acquire knowledge about the current state and future trends of a given topic, Tsai and Wen [28], affirm that a methodical analysis of articles published in scientific and academic journals is essential for a research society [29]. Therefore, the review method is used, where research studies on NZEB published in scientific journals from 2015 to 2020 are collected systematically analyzing to provide a state of the art on research trends on NZEB and identify key research areas. This review method is based on two steps: (1) selection of journals, (2) selection of relevant articles.

A. NZEB definition

Concerns about the impact of the construction industry on human health, excessive energy use [27], and global climate change make NZEB an effective alternative [30]. According to directive 2010/31 / EU [31], [32], nZEB is a building with almost zero energy consumption and a very high energy efficiency level. The energy demand in it is very low or almost zero, so it must supplement most of its energy on many occasions with energy from renewable sources.

However, the NZEB concept has different definitions, and they depend on the climatic, political and / or economic conditions of the country in which the building is located [33], however the objective is common: to reduce the environmental impact of the houses. The four suggestions suggested by the NREL, and DOE are presented below:

- Zero Net Site Energy: ZEB generates at least as much energy as it consumes in one year.
- Net Zero Source Energy - When it comes to energy, zero energy generates at least the same amount of energy that you use in a year, which refers to the primary energy that is used to produce and deliver energy for the site.
- Net zero energy cost: In the ZEB cost, the amount that the grid operator pays the building owner for the energy it provides to the grid is equal to the amount of electricity and consumption paid by the owner to the operator during an anus.
- Net Zero Energy Emissions - This is a net zero emissions building that produces at least as much clean energy as it uses non-clean energy.

The selection of the definition is decided according to the needs and requirements of both each project and the user or designer.

B. Selection of magazines

First, to identify the academic journals that published articles related to NZEB between 2015 and 2020, databases such as Mendeley, Scopus and mainly ScienceDirect were used. Also, using moderate language with appropriate keywords such as "NZEB", "NZEB constructions", "trends in NZEB buildings". Once the search keywords were selected, these pages were used to perform a systematic desktop search identifying and selecting the building construction journals or energy journals (renewable energy, thermal energy, etc.) related to the study.

From the search carried out, 250 documents were found with more than 40 journals (both construction and other topics not related to the study). Therefore, a more detailed filter was made in the database, that is, finally, 11 construction and energy journals were selected for this study, finding: Developments in the built environment, Applied Thermal Engineering, Energy, Renewable Energy, Summary Data, Construction Engineering Magazine, Energy Procedure, Energy and Building, Building and Environment, Renewable and Sustainable Energy Reviews and Sustainable Cities and Society.

It should be noted that the purpose of the research at this stage is to review research articles on NZEB trends. These articles that only mention any keyword in their title or abstract or keywords, but do not focus on the NZEB topic are excluded from the compilation. According to this selection criterion, a total of 30 articles are considered valid and can be analyzed in more detail. Summarizes the results of the initial search and the number of related articles from each of the 11 selected journals.

C. Selection of relevant articles

As mentioned above, 30 documents were considered. However, since the general search used undefined keywords, there was a possibility that inconsequential articles would still be submitted. Thus, the most relevant studies were selected with the help of defined selection criteria [34]. If the document meets each of the criteria, the article will be selected for the development of the research.

III. RESULTS

The purpose of this study is to provide information on NZEB

TABLE I

UNITS SUMMARY OF SEARCH RESULTS AND NUMBER OF SELECTED ITEMS

Selected magazines	No. Jobs Wanted	No. From jobs collected for this study
Developments in the built environment	3	2
Applied Thermal Engineering	2	1
energy	10	5
renewable energy	3	1
Summary Data	2	1
Construction engineering magazine	1	1
It came from energy	12	6
Energy and Building	11	6
Building and Environment	3	1
Renewable and sustainable energy reviews	8	3
Sustainable cities and society	5	3
TOTAL	60	30

architectural research trends by reviewing research articles selected according to scientific criteria. Therefore, it should be considered that the results presented here are based entirely on the analysis of the research articles obtained in the selection criteria matrix.

Results are presented in terms of annual publication trends, research contributions from different countries, institutions, and authors, and research topics covered over time.

D. Annual publication trend

Fig. 1 highlights the annual distribution of NZEB-related analytical articles. It is observed that, among the 30 articles analyzed, only one was published between 2013 and 2016. This can be easily explained as the first NZEB EU directive was introduced in 2010 [35], so there are few publications as it was made during that period. Furthermore, the remaining 29 articles were published between 2017 and 2020, demonstrating that NZEB has received increasing attention from researchers in recent years. This is because, as of December 31, 2018, the

application of the NZEB model in Europe has become a mandatory requirement for new public buildings, all new buildings before December 31, 2020, must be the same. This is not surprising, because the NZEB architecture has become one of the most frequently mentioned topics in current research.

It should be noted that many academic institutions have included elements focused on these buildings in the study plans, increasing the awareness of researchers on the subject. In addition, these buildings have also been the focus of attention for global sustainability agencies due to environmental problems and climate change.

In summary, these discoveries show that NZEB research has experienced a growing trend of interest in recent years, this means that it is becoming a key point for the global construction society. In short, this is because there are currently a large number of NZEB initiatives from both state and non-state groups, where the admission of these constructions at the international level is catalyzed. Such is the case with most of the current governments that direct or plan to direct market activities by means of legislative decrees and governmental public policies of NZEB (as mandatory minimum energy of energy in efficiency standards).

E. Contributions from countries, institutions and researchers to NZEB research

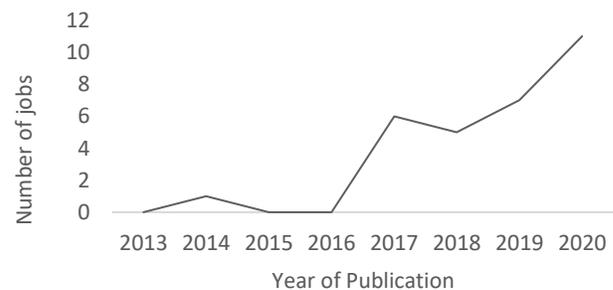


Fig. 1. Annual trend of research publications

Table II shows the country of origin of publication of the selected studies, together with the total sum of researchers and institutions included. From the table it can be inferred that, in the stage studied, research was carried out in both advanced and developing countries, denoting that NZEB is of global interest. However, among the articles reviewed are countries that contributed, such as Italy, Hong Kong, USA, Spain. In summary, these countries have produced more contributions to NZEB research compared to others.

When analyzing the level of focus on sustainable construction in these countries, they can be understood as significant and congruent. The great interest in green building

TABLE II
UNITS FOR MAGNETIC PROPERTIES

Country/City	Institutions	Authors	Documents
EE. UU.	3	9	4
Brazil	1	5	1
China	1	5	1
Cuba	1	4	1
Spain	2	6	2
Estonia	1	4	1
Finland	1	4	1
Greece	1	7	1
Hong Kong	3	7	4
India	1	3	1
Ireland	1	3	1
Italy	8	45	11
Rome	1	6	1
Total	25	108	30

industrial activities advanced NZEB research in these countries. The low participation of research in developing countries is due to various factors such as the lack of culture in publication, the zero priority in the construction activities of these buildings and the lack of awareness regarding the potential of the NZEB, which may contribute to the low participation of research in developing countries.

The results show that various researchers from all over the world and institutions gave time and effort to develop these NZEB studies during the study period.

F. Research topics covered.

In this study, research interests / topics have been identified in NZEB-related articles published during the research period and have been identified and divided into three different groups for summary and differentiation.

The three categories of NZEB research interests identified are:

- Rehabilitation of buildings
- Energy efficiency
- Advanced technologies

This rating is for comparative purposes only. Therefore, the list of NZEB articles provided in this document is considered valuable based on your research interests and is only suitable for reference within a limited scope. Each article is assigned only to one of the three main research interests. So, if an article seems to cover multiple research interests, put it in the most appropriate category.

From the review performed on selected NZEB articles, it was found that the studies of buildings constructed as NZEB, mainly focus on energy efficiency cost optimization and energy efficiency as [23], [36]–[39]; [17]–[21]; life cycle analysis of a building as [44], [45]. Table 3 summarizes the three main research topics and their subtopics, as well as the percentage of articles contained in each research topic. It shows that more attention has been paid to Energy performance with 53% of the

articles included in this area, followed by Rehabilitation of buildings, with 40%, and advanced technologies (3%).

G. Current state of NZEB's research interests

Due to the negative impact of daily construction activities on the environment and the growing global awareness of global climate change, NZEB has become increasingly popular in recent years, with most of the existing research focused on the "Energy efficiency". The literature related to this topic covers a variety of subtopics, focusing on topics related to life cycle analysis, energy consumption, photovoltaic power generation strategies, energy, and economic analysis of NZEB applications. Buildings account for 40% of the world's total energy use. Therefore, the need to reduce energy use and introduce renewable energy into buildings has always been a long-standing and significant problem in the construction industry.

For example, in the European Union, the Energy Performance of Buildings Recast Directive (EPBD) stipulates that by 2020, the energy level of all new buildings should be close to zero [46], which means that it is expected that all new buildings become new buildings. The energy savings were achieved in less than ten years.

In other words, most of the previous studies have focused on exploring the factors that contribute to the energy efficiency of buildings and the resulting cost optimization, which can affect or improve the results of construction projects.

NZEB, barriers to adoption and benefits. If stakeholders continue to understand that NZEB can have a positive impact in solving various environmental problems, more projects are expected to pursue green certification in the future. In other words, the demand for green buildings will continue to increase. Therefore, the "Energy performance" subtopics will continue to arouse the interest of future researchers.

The second popular topic is "building restoration". This topic solves the problems of achieving NZEB building renovation goals, economic and energy payback time, and building repairs to achieve NZEB certification. The results in Table 3 show that a lot of research has been done on these topics, and it is not surprising to find this, because it is essential to solve the high energy consumption in existing buildings, which is characterized by an average age of approximately 55 years. In particular, the transformation of existing buildings in NZEB requires an appropriate combination of technologies, systems, renewable energy and high-efficiency envelope solutions based on location, legislation and market conditions [47].

Regarding the third topic "advanced technology". The literature on energy efficiency technologies and their implementation is a well-developed field, and the general methods used to implement zero-grid modernization have almost no restrictions and therefore need to be reviewed. The general method used in existing research is to analyze the current state of the building and develop a strategy to renovate the building within that time frame, such as NZEB. The current method of using energy simulation software programs.

TABLE III
PERCENTAGE OF ARTICLES BELONGING TO THE THREE MAIN RESEARCH TOPICS / INTERESTS

Research topics	Subtopics	Percentage of documents (%)
Building rehabilitations	Thermal characterization of existing buildings [16]; Achieving NZEB targets for renovated buildings [39], [48]; Energy recovery time for NZEB modernization[40]; renewal through renewable energy sources[49].	40
Energy efficiency	Indoor comfort in the Mediterranean climate [50]; Data on energy consumption [47], [51]; life cycle analysis, photovoltaic generation strategies[37], [52]; construction design using algorithms[42]; cost optimization and energy efficiency [53]; energy and economic analysis for NZEB applications [54].	57
Advanced technologies	Simulation systems for construction [55]–[59]; NZEB buildings integrated with electric vehicles[60].	3

is also limited to using modified building performance parameters to perform energy simulations and obtain changes in energy use during a specific modernization period. This clearly shows the need to solve this problem and create advanced information and communication technologies.

IV. CONCLUSIONS

The increasing global focus on sustainability and climate change has made NZEBs one of the biggest issues in the construction sector. As a result, research on NZEB has increased in recent years. Therefore, the purpose of this research is to systematically analyse NZEB research articles published in 11 selected journals, namely, built environment development, applied thermal engineering, energy and renewable energy, to provide information on NZEB research trends and development in the construction industry. Energy, Data Summary, Construction Engineering Magazine, Energy Programs, Energy and Building, Building and Environment, Renewable and Sustainable Energy Review and Sustainable Cities and Society from 2014 to 2020.

A total of 30 NZEB-related articles were analysed in this study. An analysis of the number of articles published each year shows that NZEB research publications have been increasing in recent years. Developed countries such as the United States, Hong Kong and Italy have made the largest contribution to NZEB research by publishing the most relevant articles. Although developing countries such as China have made great efforts to promote research, in view of the rapid pace of urbanisation in developing countries, they are expected to increase their efforts. Three categories: (1) Energy performance; (2) Building retrofitting; and (3) Advanced technology are identified as the main research interests of NZEB publications. Among them, "energy efficiency" has always been the main theme and will remain a key focus for future research. Finally, it should be noted that this review is not exhaustive because it is limited to the construction industry, which limits the promotion of the

findings to other industries. Future revision may be required to increase the sample size, and focus on NZEB in other industries to provide useful findings for the future research reported in this article. Moreover, public authorities are required to develop open access nZEB implementation databases and methods to improve the implementation trend of these buildings.

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