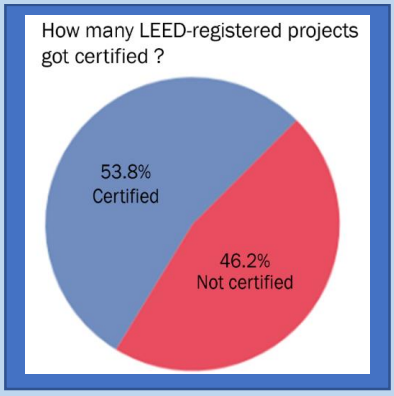
An-Najah University Journal for Research – A
Natural Sciences

Green building progress assessment: analysis of registered and certified buildings for LEED rating system

Iyad Ghazal [1], Sameh Monna[1,*]

Received 8th Sep. 2023, Accepted: 14th Feb, 2023, Published 1st Aug. 2024. https://doi.org/10.35552/anujr.a.38.2.2212

Abstract: Green buildings are of great importance to overcome climate change effects and the depletion of natural resources. This paper aims to provide a review of the progress in green building constructions that have used the LEED (Leadership in Energy and Environmental Design) rating system for the last two decades. To do this the researchers have analyzed the data of around 61000 LEED-registered buildings (from the U.S. Green Building Council (USGBC) website) Using Google data analysis module studying different factors affecting green building growth and trying to spot any possible correlation between LEED and each factor. The review will provide the researchers and the construction industry with the necessary information about the analysis of green building development. The results showed the trends in the green building progress and provided insight analysis for the reasons behind this progress which can help rating system developers, green building designers, and governmental decision-makers, to promote green building worldwide.



Keywords: LEED, green buildings, big data, green building rating system, Google data analysis module

Introduction

Green building design and construction are playing an important role in the efforts to overcome the 21-century challenges including global warming, climate change, resource depletion and achieving the sustainable development goals for 2030 [1, 2]. The number of green buildings is growing rapidly all over the world [3]. There is also growing interest in the green economy, green materials and products and saving in natural resources, especially energy and water. Worldwide the growing demand for energy being consumed in buildings, which represent around 40% of the total energy consumption and more than two-thirds of the total electricity consumption, has encouraged investment in green buildings [4]. Also, green buildings are providing a solution for improving human well-being and reducing waste and resource consumption [5].

Currently, around the world, there are several green building rating systems like BREEM, ITACA, ESTIDAMA, HQE, CASBEE, SBTool, GSAS and LEED (leadership in Energy and Environmental Design) which is considered the most accepted rating system that is used in 167 countries [6-12].

Different researchers have addressed the current research status for green buildings [4, 13, 14], and other researchers have addressed comparative reviews of different green building rating systems [15-18]. The development of green building rating systems and tools was the target of several researches too [19, 29]. Additionally, other research addressed the sustainability certification for certain regions and the environmental impact of buildings [21-25] however, the progress and the challenges for the certification of green projects have been barely addressed. North American and European green building rating systems are used as a benchmark for developing rating systems in developing and developed countries [26, 27]. Green building rating systems are mainly used in the design stage and their use in the operation stage is limited [28].

To promote sustainable development, the LEED rating system was established in 2000 by the US Green Building Council which was established in 1993 [29]. Later, many rating systems worldwide were developed and adapted to a very similar LEED rating system [30-32]. LEED has been used as a base for the evaluation and adaptation of new green building rating systems [33, 34]. The LEED green building rating system has been moving towards involving automation tools to facilitate the implementation of the rating system mainly during the design stages [35, 36].

The LEED rating system is the rating system that has influenced green design advancement [37]. The LEED green building rating system has the most excellent building energy performance in the market of the green building construction industry [38]. Moreover, the LEED rating system is one of the first rating systems that offer certification not only to new constructions but also to existing buildings [39]. The LEED rating system is one of the best tools to integrate social, environmental and economic aspects related to the built environment [40].

As the LEED green building rating system is considered the most used and the most widely accepted green building rating system, it has been adapted by this study to evaluate the progress made and the future trends in the green building

1 Architectural Engineering Department, Faculty of Engineering and Information Technology, An-Najah National University P. O. Box 7, Nablus, Palestine
*Corresponding author: samehmona@najah.edu

construction industry. This paper aims to underline the current and future progress of LEED green building projects to help predict the future trends and challenges for this important building construction. This paper also aims at studying different factors affecting green building growth and trying to spot any possible correlation between LEED and each factor.

METHODOLOGY

Among many green building rating systems available LEED green buildings rating system was chosen because it represents the most used and most widely spread green building rating system. Data analysis for more than 61000 registered and certified projects by the LEED rating system during the period (2000-2020) was done. The objective is to quantitatively measure the trends, and progress, and predict the future growth of green buildings.

The study applied the Google data analysis module (ask, prepare, process, analyse, share, and act) using Python language to conduct the analysis. This data analysis was used to find and analyse some hidden facts about the LEED system and try to find the reasons behind those facts using the methodology detailed in Figure 1. In the first step, the main source of data in this study is derived from the U.S. Green Building Council (USGBC) website in CSV format [41]. Then, the data combining; even though the data is accessible, the problem was that the website allows you to download a maximum of 10000 records each time, to tackle that issue the data was fetched in stacks then combined and grouped in one CSV that contains 61139 registered green buildings. Finally, the CSV file was constructed to contain every LEED registered project's basic details such as; project name, type, country, and points achieved. Many projects were confidential or had some missing data, but the available details of those projects can still be sufficient. To minimize data loss, instead of dropping these projects, different special data filtering was used.

To explore, analyse and learn from the green building progress in the last two decades, different questions were addressed: What are the top 10 LEED countries? How often LEED registered projects get certified? What are the top 10 LEED project Types? What are the certification levels for the top 10 LEED project types? How many LEED registered and certified projects per year? How many LEED registered and certified projects per year in the USA versus the rest of the world? Are the annual LEED-registered projects affected by GDP? Are there any political or economic reasons behind the registration peak? Where are most of the LEED projects in the USA?

Figure 1 explains the methodology workflow that consists of six stages, the first stage is to find data fetching and combining. The second stage is the data analysis about in which countries LEED is most used and the number of certified buildings inside and outside the United States. Then the next stage is defining the problems facing the green building certification process, especially for buildings being registered and not going until the end of the certification process. Then combining supportive data and questions and hypotheses to be able to explain the green building progress for LEED certification progress. Finally, the findings from the five steps above are introduced and discussed in the next section.

.

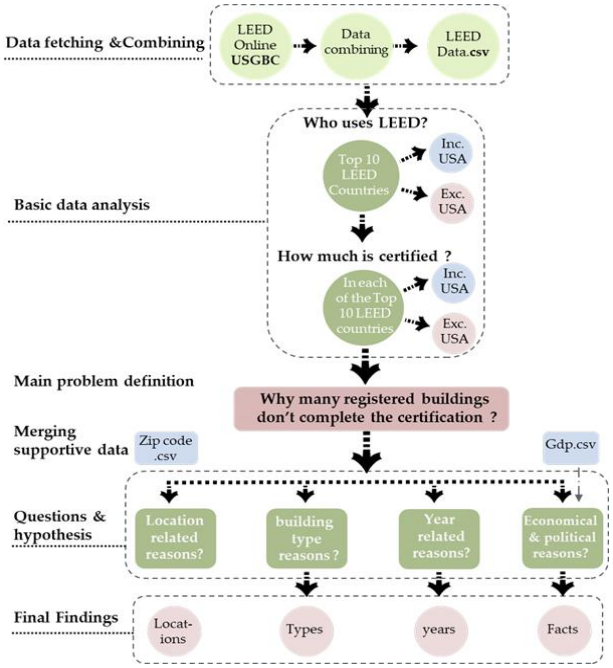


Figure (1): Research Methodology.

Results and Discussion

The results from the green building survey and the data analysis are summarized as follows. Regarding the number of registered projects by country, the US is on the top of the list with more than 90% of the LEED projects in the world as shown in Figure 2. Even though it is expected that the United States should be on the top of the list, this brings back the question: How far can a system that is 90% adopted by one country be considered international? Furthermore, to reasonably read the other countries' data the USA were excluded from the list as shown in Figure 3.

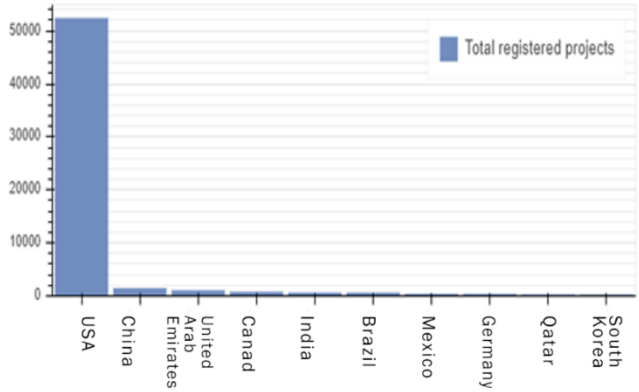


Figure (2): Registered LEED projects around the world.

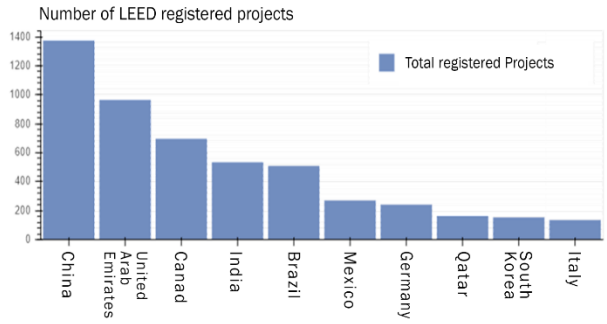


Figure (3): Top 10 Registered green projects excluding USA.

Regarding how many of those registered projects have completed the certification process and got certified, the results show that almost 45% of the registered projects did not get the certificate which means that they cannot be called green buildings. Those results were almost the same in both the USA and worldwide.

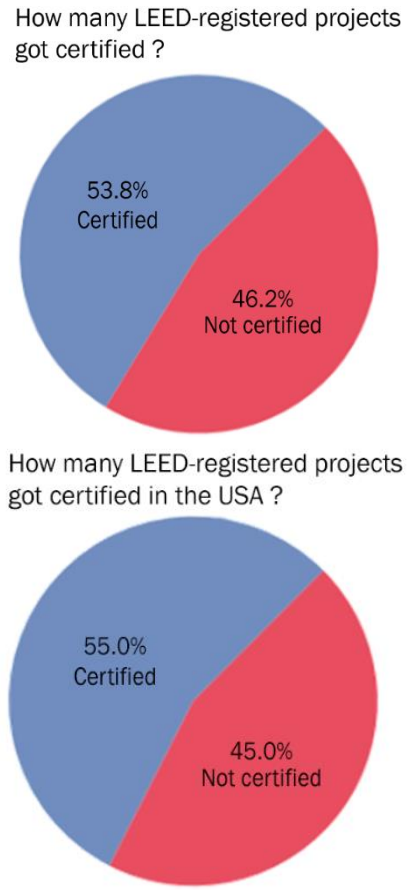


Figure (4): The percentage of registered versus certified LEED projects worldwide and in the USA.

Regarding the building certification level, there are more than 20000 not-certified projects in the US making them a majority followed by gold-certified, and silver-certified buildings as seen in figure 5. Figure 6 shows that in all of the other top 10 countries (excluding the USA) the number of the not certified projects is more than half and in some countries like Qatar and UAE the majority of the projects are not certified.

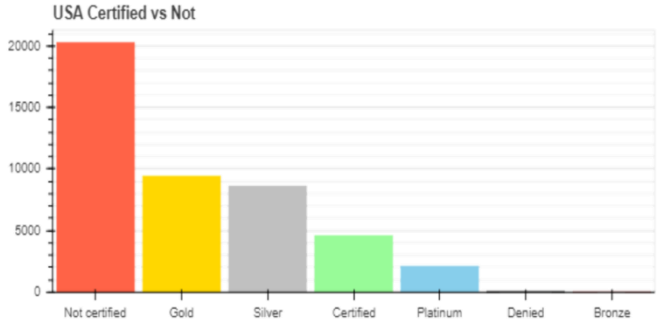


Figure (5): certified (in different levels) versus not certified projects in the USA .

Figure (6): registered versus not certified projects for top 10 countries excluding the USA.

Regarding the project types, the results show that most LEED-certified green buildings are commercial offices and they also have the highest number of not certified projects. Banks have the highest ratio of not certified projects, while the homes and professional offices have the lowest. It is concluded that fast-changing activities like banks and commercial offices are most likely not to get certified as can be seen in Figure 7

Regarding the certification level for each building type, the results show that not certified projects are at the highest followed by Gold, Silver, certified and Platinum as it can be seen in Figure 8.

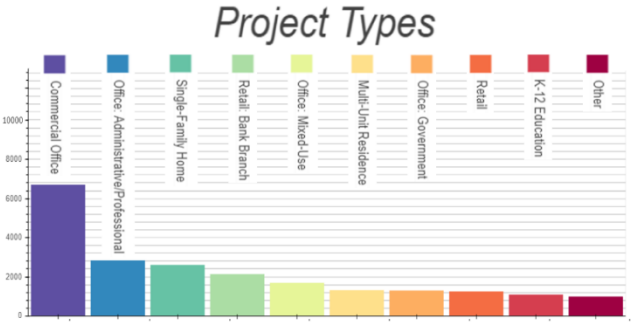


Figure (7): Types of the Certified green building projects.

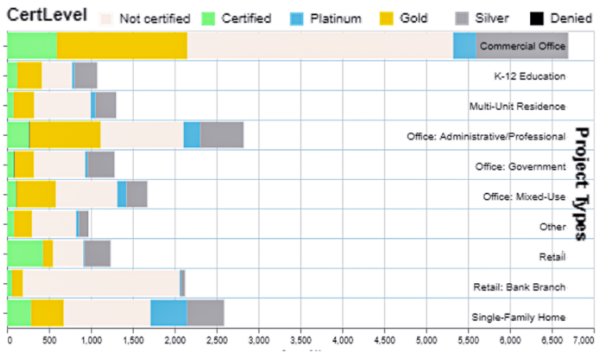


Figure (8): Green building certification level for each building type

The number of registered green building projects per year shows that there has been a rapid growth in the number of LEED registered projects until the peak in 2008 and 2009 and this growth happened in both the USA and Worldwide. After that, the number of LEED registered and certified projects per year decreased as seen in Figures 9 and 10.

Figure (9): Number of registered and certified green building projects per year

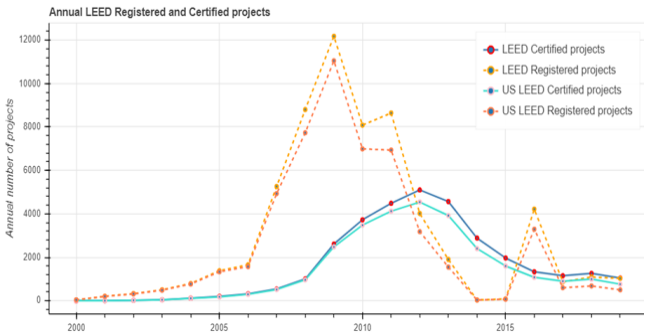


Figure (10): number of registered and certified green building projects per year for the world versus the USA

The comparison between the progress in the registered and certified green building projects and the GDP in the last 2 decades shows that the world GDP per capita has been almost steadily increasing since 2000 while the number of registered projects has been fluctuating which means that there is no direct relation between the GDP and the annual amount of LEED projects as it can be seen in figure 11.

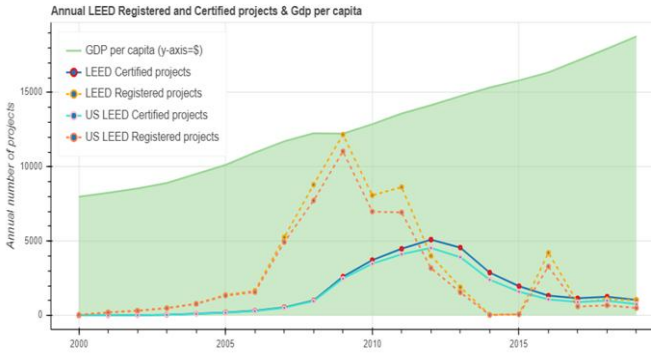


Figure (11): The GDP per capita and the registered and certified green projects

Regarding the potential effects of policies and regulations around 2008 there have been many regulations forcing to have LEED buildings at the governmental scale, especially in the US as shown by “LEED Initiatives in Governments and Schools U.S. Green Building Council May 2010”.

Conclusion

Based on the analysis of previous questions and answers, this research reveals important new information on the LEED (Leadership in Energy and Environmental Design) rating system based on the analysis of around 61000 building data. At first, it showed that 90% of the system's applicability is restricted to the United States, where its deployment is mostly centred. Furthermore, about 45% of the projects that have been registered failed to obtain certification, indicating that a sizable fraction of projects still need to meet their green goals. Recent patterns reflect a drop in the annual number of registered projects, which means that fewer projects are joining LEED. However, the shrinking difference between registered and certified projects highlights a rise in success rates, potentially due to the USGBC's (U.S. Green Building Council) initiatives. Notably, 2008 saw a significant upsurge in LEED projects, which can be partly linked to legislative rules. However as seen by the decline in LEED projects after laws were passed, this data shows that regulations may not be enough to promote the expansion of green buildings, thus further research behind the drop reasons is needed.

Finally, it is concluded that Almost half of the LEED-registered projects are not certified at the end, which means that some problems or challenges prevent them from reaching their goal of being certified as green buildings. Outside the USA it is concluded that more than half of the registered projects are not certified. As a result, further research into this data is recommended to discover all the expected reasons behind this phenomenon.

Recommendations

This data-driven research serves as a guidepost for USGBC's professionals and directs their attention towards critical areas that require further attention and refinement during the development of the rating system. By spotlighting the predominant challenges—such as the substantial percentage of LEED-registered projects failing to secure certification—.

Understanding the concentration of LEED projects in the United States prompts a reevaluation of the international applicability of the system. This awareness is crucial for professionals operating outside the U.S., guiding them to adapt

strategies that resonate with regional contexts, thereby enhancing the chances of successful certification, and highlights the importance of promoting LEED outside the USA more.

Moreover, the revelation that commercial offices dominate certified green buildings, while banks exhibit challenges in certification, equips professionals with sector-specific insights. Such knowledge is instrumental in tailoring strategies for different building types, ensuring that green goals are not only set but effectively met across diverse projects.

The observed peak in LEED projects around 2008, potentially associated with governmental regulations, underscores the impact of policy frameworks. Professionals can leverage this understanding to advocate for supportive policies that catalyze green building initiatives. However, further research into this data is recommended to discover all the expected reasons behind this phenomenon.

In conclusion, this basic research is one step to help the LEED rating system developers, green building designers, and governmental decision-makers, to help promote green building worldwide and further research is recommended to get more insightful results.

Ethics approval and consent to participate

Otherwise, add Not applicable

Consent for publication

Not applicable

Availability of data and materials

The raw data required to reproduce these findings are available in the body and illustrations of this manuscript.

Author's contribution

Author's contribution should be added, for example.

The authors confirm contribution to the paper as follows: study conception and design: S Monna, I Ghazal theoretical calculations and modeling: S Monna, I Ghazal; data analysis and validation, S Monna, I Ghazal. draft manuscript preparation: S Monna, I Ghazal. All authors reviewed the results and approved the final version of the manuscript.

Funding

This research received no funding

Conflicts of interest

The authors declare that there is no conflict of interest regarding the publication of this article

References

1) Hamid, Zuhairi Abd, Maria Zura Mohd Zain, Foo Chee Hung, Mohd Syarizal Mohd Noor, Ahmad Farhan Roslan, Nurulhuda Mat Kilau, and Mukhtar Che Ali. 2014. Towards a National Green Building Rating System for Malaysia. Malaysian Construction Research Journal 14: 1–16.

2) Okasha, Aly, et al. "Effect of Khoms Power Station Stack Emission Impact on the Ancient City of Leptis Magna, Libya." An-Najah University Journal for Research - A (Natural Sciences), vol. 36, no. 1, Feb. 2022, pp. 109–32. Crossref, https://doi.org/10.35552/anujr.a.36.1.2006.

3) Kibert, Charles. (2003). Green buildings: An overview of progress. Journal of Land Use & Environmental Law. 19. pp. 491-502, Florida State University College of Law.

4) Li, Y., Rong, Y., Ahmad, U.M. et al. A comprehensive review on green buildings research: bibliometric analysis during 1998–2018. Environ Sci Pollut Res 28, 46196–46214 (2021). https://doi.org/10.1007/s11356-021-12739-7

5) Awadh, Omair. 2017. Sustainability and Green Building Rating Systems: LEED, BREEAM, GSAS and Estidama Critical Analysis. Journal of Building Engineering 11: 25–29.

6) Assefa, S.; Lee, H.-Y.; Shiue, F.-J. Sustainability Performance of Green Building Rating Systems (GBRSs) in an Integration Model. Buildings 2022, 12, 208. https://doi.org/10.3390/buildings12020208

7) BRE Global. BREEAM International New Construction 2016; BRE Global: Watford, UK, 2017; Available online: https://hbreavis.com/wp-content/uploads/2017/06/BREEAM-International-New-Construction-2016.pdf (accessed on 18 October 2022).

8) U.S. Green Building Council. LEED v4.1|USGBC. 2019. Available online: https://new.usgbc.org/leed-v41 (accessed on 12 September 2022)

9) Cerway. HQE Certification. 2019. Available online: https://www.behqe.com/cerway/specificities (accessed on 18 October 2022)

10) CASBEE Certification System; Japan Sustainable Building Consortium: Tokyo, Japan, 2022

11) Building Research Establishment Group. BREEAM Worldwide. 2019. Available online: https://www.breeam.com/worldwide/ (accessed on 18 October 2022)

12) Italia, I. ITACA. 2019. Available online: http://www.iisbeitalia.org/ (accessed on 18 October 2022)

13) Frank Victor Mushi, Huba Nguluma & Jacob Kihila (2022) A critical review of African green building research, Building Research & Information, https://doi.org/10.1080/09613218.2021.2015276

14) Jian Zuo, Zhen-Yu Zhao, Green building research–current status and future agenda: A review, Renewable and Sustainable Energy Reviews, Volume 30, 2014, Pages 271-281, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2013.10.021

15) Binh K. Nguyen, Hasim Altan, Comparative Review of Five Sustainable Rating Systems, Procedia Engineering, Volume 21, 2011, Pages 376-386, https://doi.org/10.1016/j.proeng.2011.11.2029

16) Laura Florez, Sustainability and Green Building Rating Systems: A Critical Analysis to Advance Sustainable Performance, Editor(s): Saleem Hashmi, Imtiaz Ahmed Choudhury, Encyclopedia of Renewable and Sustainable Materials, Elsevier, 2020, Pages 211-220, https://doi.org/10.1016/B978-0-12-803581-8.11411-0

17) B. Mattoni, C. Guattari, L. Evangelisti, F. Bisegna, P. Gori, F. Asdrubali,

18) Critical review and methodological approach to evaluate the differences among international green building rating tools, Renewable and Sustainable Energy Reviews, Volume 82, Part 1, 2018, Pages 950-960, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2017.09.105

19) Dat Tien Doan, Ali Ghaffarianhoseini, Nicola Naismith, Tongrui Zhang, Amirhosein Ghaffarianhoseini, John Tookey, A critical comparison of green building rating systems, Building and Environment, Volume 123, 2017,

Pages 243-260, ISSN 0360-1323, https://doi.org/10.1016/j.buildenv.2017.07.007

20) Ricardo Mateus, Luís Bragança, Sustainability assessment and rating of buildings: Developing the methodology SBToolPT–H, Building and Environment, Volume 46, Issue 10, 2011, Pages 1962-1971, https://doi.org/10.1016/j.buildenv.2011.04.023

21) Ferreira, J.; Pinheiro, M.D.; de Brito, J. Portuguese sustainable construction assessment tools benchmarked with BREEAM and LEED: An energy analysis. Energy Build 2014, 69, 451–463.

22) Sánchez Cordero, A.; Gómez Melgar, S.; Andújar Márquez, J.M. Green Building Rating Systems and the New Framework Level(s): A Critical Review of Sustainability Certification within Europe. Energies 2020, 13, 66. https://doi.org/10.3390/en13010066

23) Bernardi, E.; Carlucci, S.; Cornaro, C.; Bohne, R.A. An Analysis of the Most Adopted Rating Systems for Assessing the Environmental Impact of Buildings. Sustainability 2017, 9, 1226.

24) Mattoni, B.; Guattari, C.; Evangelisti, L.; Bisegna, F.; Gori, P.; Asdrubali, F. Critical review and methodological approach to evaluate the differences among international green building rating tools. Renew. Sustain. Energy Rev. 2018, 82, 950–960.

25) De Klijn-Chevalerias, M.; Javed, S. The Dutch approach for assessing and reducing environmental impacts of building materials. Build. Environ. 2017, 111, 147–159.

26) Doan, D.T.; Ghaffarianhoseini, A.; Naismith, N.; Zhang, T.; Ghaffarianhoseini, A.; Tookey, J. A critical comparison of green building rating systems. Build. Environ. 2017, 123, 243–260.

27) Varma, C.R.S.; Palaniappan, S. Comparison of green building rating schemes used in North America, Europe and Asia. Habitat Int. 2019, 89, 101989.

28) Ali, H.H.; Al Nsairat, S.F. Developing a green building assessment tool for developing countries—Case of Jordan. Build. Environ. 2009, 44, 1053–1064.

29) Ding, Z.; Fan, Z.; Tam, V.W.; Bian, Y.; Li, S.; Illankoon IC, S.; Moon, S. Green building evaluation system implementation. Build. Environ. 2018, 133, 32–40.

30) Cassandra L. Champagne, Can B. Aktas,Assessing the Resilience of LEED Certified Green Buildings, Procedia Engineering, Volume 145, 2016, Pages 380-387, https://doi.org/10.1016/j.proeng.2016.04.095

31) Asdrubali, F.; Baldinelli, G.; Bianchi, F.; Sambuco, S. A comparison between environmental sustainability rating systems LEED and ITACA for residential buildings. Build. Environ. 2015, 86, 98–108.

32) Macias, M.; Garcia Navarro, J. VERDE, a methodology and tool for a sustainable building assessment. Inf. LA Constr. 2010, 62, 87–100.

33) Reader, L. Guide to Green Building Rating Systems: Understandung LEED, Green Globes, Energy Star, the National Green Building Standard, and More. Residential Rating Systems: A Comparison; John Wiley & Sons: Hoboken, NJ, USA, 2011; pp. 1–25.

34) Alyami, S.H.; Rezgui, Y. Sustainable building assessment tool development approach. Sustain. Cities Soc. 2012, 5, 52–62.

35) Zarghami, E.; Azemati, H.; Fatourehchi, D.; Karamloo, M. Customizing well-known sustainability assessment tools for Iranian residential buildings using Fuzzy Analytic Hierarchy Process. Build. Environ. 2018, 128, 107–128.

36) Nguyen, T.H.; Toroghi, S.H.; Jacobs, F. Automated Green Building Rating System for Building Designs. J. Archit. Eng. 2016, 22, 4.

37) Choi, J.O.; Bhatla, A.; Stoppel, C.M.; Shane, J.S. LEED credit review system and optimization model for pursuing LEED certification. Sustainability 2015, 7, 13351–13377.

38) He, Y.; Kvan, T.; Liu, M.; Li, B. How green building rating systems affect designing green. Build. Environ. 2018, 133, 19–31

39) [37] Lee, W.L.; Burnett, J. Benchmarking energy use assessment of HK-BEAM, BREEAM and LEED. Build. Environ. 2008, 43, 1882–1891.

40) Mahmoud, S.; Zayed, T.; Fahmy, M. Development of sustainability assessment tool for existing buildings. Sustain. Cities Soc. 2019, 44, 99–119.

41) Castellano, J.; Ribera, A.; Ciurana, J. Integrated system approach to evaluate social, environmental and economic impacts of buildings for users of housings. Energy Build. 2016, 123, 106–118.