

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

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**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 construction that uses the LEED rating system for the last two decades. To do this the researchers have analysed the data of around 61000 LEED-registered buildings 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 trend in the green building progress and provided insight analysis for the reasons behind this progress.*

**Keywords**— **LEED, green buildings, big data, rating system**

### I. 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]. The number of green buildings is growing rapidly all over the world [2]. 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 [3]. Also, green buildings are providing a solution for improving human well-being and reducing waste and resource consumption [4].

Currently, around the world, there are several green building rating systems like LEED, BREEM, ITACA, ESTIDAMA, HQE, CASBEE, SBTool, GSAS and LEED which is considered the most accepted rating system that is used in 167 countries [5-11].

Different researchers have addressed the current research status for green buildings [3, 12, 13], and other researchers have addressed comparative reviews of different green building rating systems [14-17]. The development of green building rating systems and tools was the target of several researches too [18, 19]. Additionally, other researches addressed the sustainability certification for certain regions and the environmental impact of buildings [20-24] 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 [25, 26]. Green building rating systems are mainly used in the design stage and their use in the operation stage is limited [27].

To promote sustainable development, the LEED (leadership in Energy and environmental design) was established in 2000 by the US green building council which was established in 1993 [28]. Later, many rating systems worldwide have been developed and adapted to a very similar LEED rating system [29-31]. LEED has been used as a base for the evaluation and adaptation of new green building rating systems [32, 33]. 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 [34, 35].

The LEED rating system is the rating system that has influenced green design advancement [36]. The LEED green building rating system has the most excellent building energy performance in the market of the green building construction industry [37]. 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 [38]. The LEED rating system is one of the best tools to integrate social, environmental and economic aspects related to the built environment [39].

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 construction industry. This paper aims to underline the current and future progress of LEED green

building projects to 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.

## II. 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 [40]. 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.

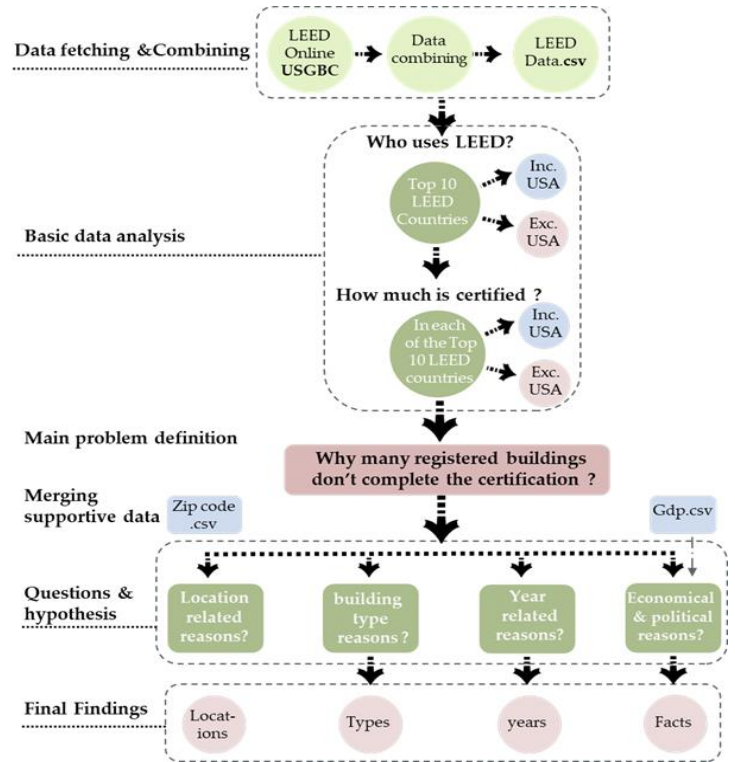


Figure 1. Research Methodology

## III. RESULTS

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.

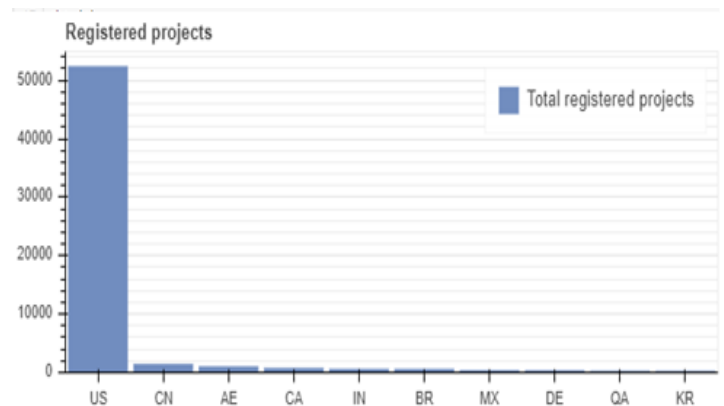


Figure 2: Registered LEED projects around the world.

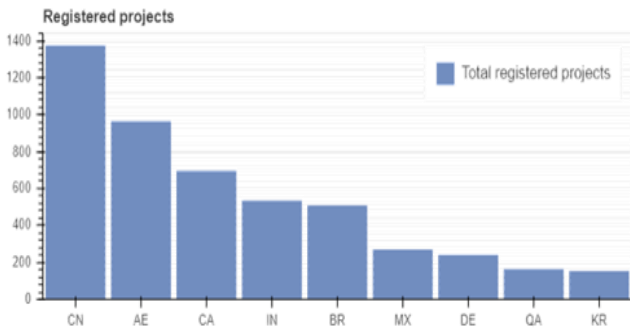
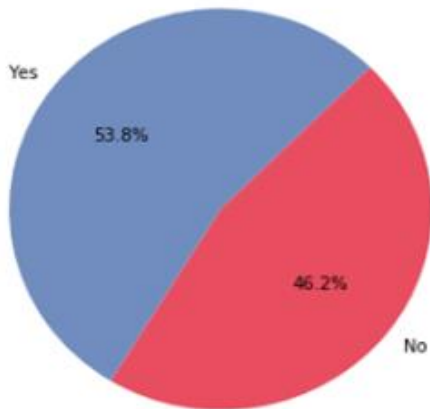


Figure 3: Registered green projects excluding USA

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.

How much of LEED registered projects got certified ?



How much of LEED registered projects got certified in USA?

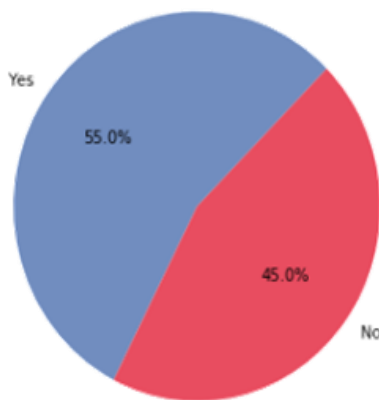


Figure 4: The percentage of registered versus certified LEED projects worldwide and in the USA.

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.

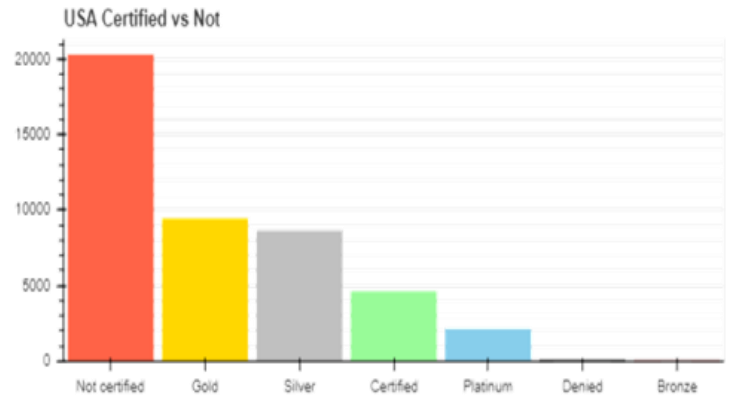


Figure 5: certified (in different levels) versus not certified projects in the USA

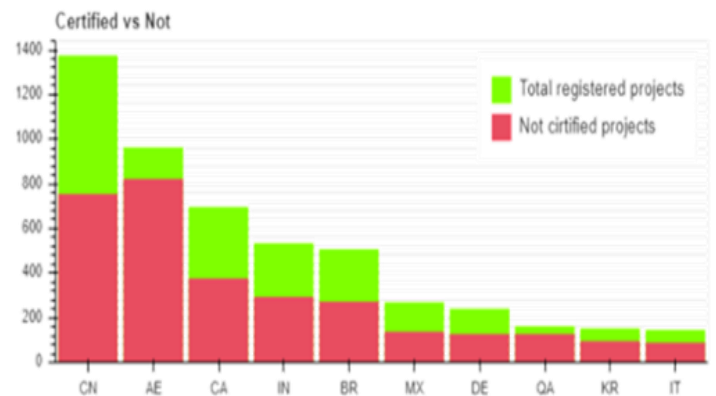


Figure 6: registered versus not certified projects for top 10 countries excluding the USA

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.

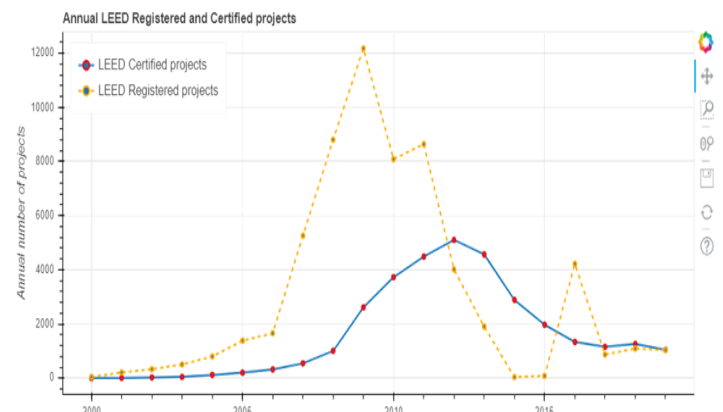


Figure 9: Number of registered and certified green building projects per year



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.



Figure 12: 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”.

#### IV. SUMMARY

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. But the

shrinking difference between registered and certified projects highlights a rise in the 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. But 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. 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.

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