

IJEAST

INTERNATIONAL JOURNAL
OF ENGINEERING APPLIED SCIENCE
AND TECHNOLOGY

VOLUME : 5 ISSUE : 10 Print / Issue Publication Date: 25-Apr-2021

ISSN : 2455-2143

DOI : 10.33564/IJEAST.2021.v05i10.016

Indexed In

Google SCHOLAR OPEN ACCESS doi Crossref

WWW.IJEAST.COM

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International Journal of Engineering Applied Sciences and Technology, 2021
Vol. 5, Issue 10, ISSN No. 2455-2143, Pages 104-111
Published Online February 2021 in IJEAST (http://www.ijeast.com)



QUALITATIVE AND QUANTITATIVE ANALYSIS OF LEED PLATINUM RATED SKYSCRAPERS

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***Abstract*— Green skyscrapers and their design have now become a crucial point, for that, many architects, engineers and designers are being involved in green buildings and skyscraper practices. This research paper is based upon the importance of rating systems especially LEED as worldwide and why it is compulsory now to have LEED rating systems for skyscrapers along with the sustainable development goals achieved by them. It mainly covers the points needed for clarifying LEED rating with its criteria for selection depending upon its credit categories and its impact in the built environment. The case studies mainly covers detailed study of LEED Platinum rated skyscrapers and techniques used to make it a green high rise building. All the 3 high rise buildings have different typologies and timeline through which we can study each building depending upon techniques used during each time. Through this study we can analyse gaps and strengths of LEED rated high-rise buildings with some recommendations. The statistical comparative study shows varying credit categories and study of different energy efficiencies of each building. We also come to know about how much energy efficient is each building in our case studies and what techniques are used to make it more energy efficient.**

Keywords— **LEED rating systems, Skyscrapers, Credit categories, Energy Efficiency, Built environment**

I. INTRODUCTION

Skyscrapers[1] being the ultimate icon act as a symbol for technical progress and also act as a landmark that signifies built environment of a city. The process of urbanisation is rapidly increasing resulting in limited land and increase in high massive inhuman skyscrapers and buildings. The architectural profession should be more concerned for developing new design principles that are appropriate for reinventing the skyscraper as something green and environment-user friendly. Thus, sustainable is a unique initiative that will bring innovation, relevance and high performance to an architectural project in skyscrapers [1]. Green solutions have now become a main agenda to overcome or reduce the inhuman buildings and suffocating environment, creating ecological integration and harmony between built environment and nature with balance in ecosystem.

Green building rating system turned out to be necessary in raising awareness and popularising the green solutions for increasing performance of building and skyscrapers with its adverse affect in the environment. In rating systems – different categories, levels, criteria and scoring chart is provided showing ecological performance of a building[2].

Arresting visuals are provided by skyscrapers with great skyline, but nowadays sustainability is the key factor that comes to our mind while designing them. Green skyscrapers act as a critical component of sustainable urban development. According to the studies, In United States more than 45% of energy goes to buildings and nearly 25% of landfill volume is directly related to construction waste [3].

Green building[2] technologies and its parameters have replaced the Conventional architectural style because it's now a norm to have green high rise structures. In many developed countries like Italy LEED certification is mandatory for the construction of new buildings, this show us how rating systems play an important role and corrective measures are being taken for the same.

The green building rating systems have been in practise around the world for improving efficiency and performance of building. Specialising in green rating systems with its solutions can automatically reduce negative environmental impacts and incorporate into sustainable practices in the field of architecture, in terms of aesthetics, comfort and efficiency of a high rise building [4]. Studying green rating systems can be helpful for the unification of a building, creating comfortable spaces and spreading the importance of green construction or sustainability around the world.

[1]*SKYSCRAPERS - According to this research skyscrapers can be defined as high rise buildings above 100 m that not only helps in creating identity and power of a particular place but it should also be ecologically integrated and create harmony among the natural and built environment.*

[2]*GREEN BUILDINGS –Green buildings are mainly high performance structures that fulfill the standards consumption of natural resources and are environmental friendly.*

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Published Online February 2021 in IJEAST (http://www.ijeast.com)

II. RESEARCH METHODOLOGY

It mainly consists of the steps followed during own research study and case studies. The main aim of our research is to identify the gaps and effective parameters in existing LEED rated skyscrapers with its statistical comparative analysis. In which, we'll be covering all the 3 platinum rated high rise buildings with different typologies and timeline to understand techniques applied on them.

The study will mainly focus on energy efficient LEED rating systems along with its parameters and levels. Parameters will be analyzed depending upon their performance in high rise buildings and our understanding for LEED rating systems.

From this we can conclude that LEED rating systems can make skyscrapers energy efficient with better performance and thus, it's compulsory to have LEED rating criteria for such buildings.

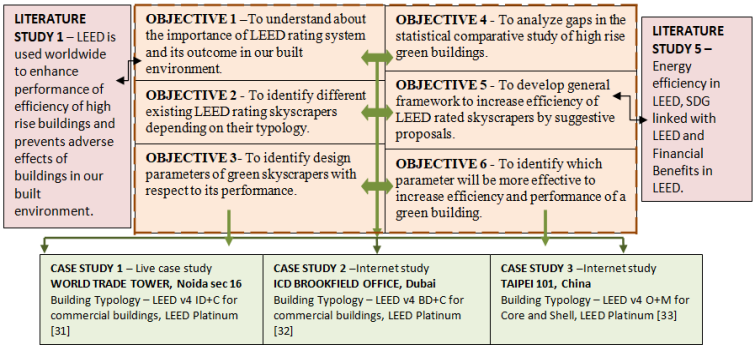


CHART 1 Objectives link with case studies

The study will only be restricted to LEED rating building systems for which we have also asked several research questions from the expert engineer of World Trade Tower and analyzed accordingly.

As per Chart2.1 7 Objectives are explained below and shown its link with our case

The main reasons for the selection of our case studies is that all the 3 skyscrapers are LEED platinum rated having different typologies.

For example – World Trade Tower is LEED ID+C[3], ICD Brookfield Tower being LEED BD+C[4] while Taipei 101 with LEED O+M[5] shown in methodology flowchart having varying credit categories, different techniques and timeline for making themselves LEED Platinum Rated Skyscrapers.

III. BACKGROUND STUDY

The green building rating systems have been in practise around the world for improving efficiency and performance of building. Specialising in green rating systems with its solutions can automatically reduce negative environmental impacts and incorporate into sustainable practices in the field of architecture, in terms of aesthetics, comfort and efficiency of a high rise building [5].

All the developing countries have its own rating systems and it has to be considered in buildings and skyscrapers to qualify as a green or sustainable building. Some of the most used rating systems.

Around the globe is BREEAM[6] (UK), LEED (USGBC/IGBC), GRIHA[7] (India), GREEN STAR (Australia), GREEN GLOBES (Canada)[2].

a) Importance of LEED in comparison to other rating systems

- LEED ACT AS A TRUE LEADER FOR OTHER RATING SYSTEMS

LEED rating systems is one of the most popular green building certification systems in the US; it's a way of knowing how "green" a building is and provide its own identity. LEED has undoubtedly auctioned the green building industry in a way that can't be imagined and the popularity of LEED ratings have result in encouraging competition as well as criticism[6].

-ONE OF THE MOST USED RATING SYSTEMS USED WORLDWIDE

LEED system uses benchmarking scheme and credit rating for certification award. LEED green rating system acts as the base system for the developing rating tool systems of other countries like Green Globes, GRIHA and BREEAM.

It is also said that if the success of LEED have never arisen, efforts such as Architecture 2030 aiming for carbon-neutral new construction by 2030 would have never taken place. Along with this the existence of LEED rating systems has encouraged all green building standards to raise competition and bar [7].

As per Fig. 3.1 the graph shows the increase in popularity of using LEED rating systems annually.

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[3] *LEED v4 ID+C – LEED Ratings for Interiors Design and Construction*

[4] *LEED v4 BD+C – LEED Ratings for Buildings Design and Construction*

[5] *LEED v4 O +M – LEED Ratings for Operation and Management*

[6] *BREEAM-BREEAM (Building Research Establishment Environmental Assessment Method) launched in 1990 which is a green building rating system developed by United Kingdom Building Research Establishment* [35].

[7] *GRIHA - GRIHA (Green Rating for Integrated Habitat Assessment) is a national green building rating system endorsed by the Government of India, Ministry of New & Renewable Energy (MNRE) and The Energy and Resources Institute (TERI)* [36]

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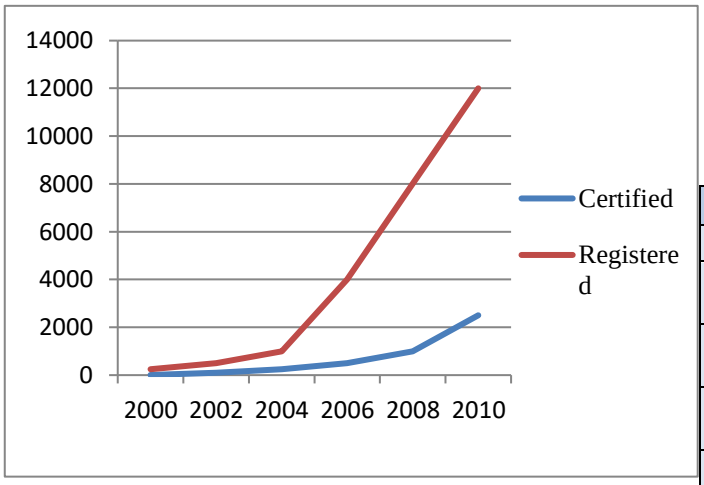


Fig 1: LEED projects certified and registered each year.
Source: Self Analyzed

-RATING APPROACH

In case of rating approach, LEED rating systems adds all the credit category points that sum up to achieve final grade and scoring of a building while other rating systems have different rating that covers most of the parameters of LEED. Along with this it also fulfills 13 of the Sustainable development goals (SDG'S) out of 17 unlike other rating systems [8].

b) Credit Categories and Evaluation Criteria in LEED

United States Green Building Council (USGBC) developed LEED[8] (Leadership in Energy & Environment Design) program which is green building rating system officially launched in 2000 with first rating system for construction and has large influence around the globe[9].

LEED rating systems is an important factor as they play an important role in augmenting awareness and publicizing green design resulting in better production of buildings [10] and skyscrapers in our society and having its adverse impact in the environment.

LEED rating level	Score (in points)
PLATINUM	80 – 110
GOLD	60 – 79
SILVER	50 – 59
CERTIFIED	40 – 49

TABLE 1 LEED RATING SYSTEMS (Referred from USGBC)

[8] *LEED RATING SYSTEMS - LEED rating systems is an important factor as they play a major role in augmenting awareness and publicizing green design resulting in better production of buildings and skyscrapers in our society and having its adverse impact in the environment.*

As per Table 3.1 and 3.2 we can observe that Point score is achieved by the total 110 point score collected over all 8-9 credit categories mentioned below, based on these points skyscrapers can obtain one of the four LEED rating levels that is Certified, Silver, Gold and Platinum[11].

S.NO.	CATEGORIES	POINTS
1.	INTEGRATIVE PROCESS	1
2.	ENERGY AND ATMOSPHERE	33
3.	INDOOR ENVIRONMENTAL QUALITY	16
4.	LOCATION AND TRANSPORTATION	15
5.	MATERIALS OR RESOURCES	14
6.	WATER EFFICIENCY	11
7.	SUSTAINABLE SITES	10
8.	INNOVATION	6
9.	REGIONAL PRIORITY	4
	TOTAL	110

Table 2. Credit Categories in LEED (Referred from USGBC 2016)

From the fig shown above we can analyze that for LEED Evaluation there are different categories and different percentages given to each category depending upon their influence in the high performance of skyscrapers.

More focus should be given to the energy, atmosphere and indoor environmental quality as they play a major role in making a skyscraper green rated in terms of LEED rating systems. Because of following these evaluation criteria LEED rated buildings bring more comfort and efficiency as compared to non rated buildings [12].

LEED comprises of 5 rating systems out of which LEED v4 BD+C, LEED v4 ID+C and LEED v4 O+M played an important role for estimating the ecological execution of skyscrapers [13].

***c)* Energy Use and Financial Benefits in LEED**

This chapter consists of topics like Energy-use and financial benefits of LEED rating systems that makes it as the most popularly used green rating systems and the reason for selecting it in our research.

1) ENERGY-EFFICIENCY IN LEED

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As per Table 2.3we can observe the National Building Stock according to LEED building typology and EUI (**Energy Use Intensity)**[9][14]**.**

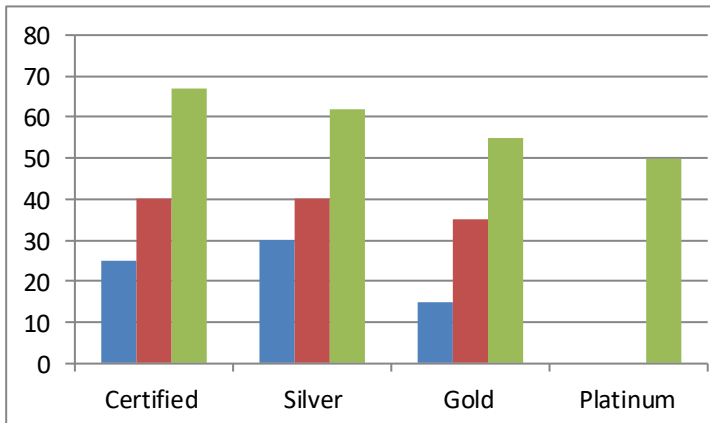


Fig. 2 -ENERGY USE BY LEED CERTIFICATION – Self analyzed

Description of fig – Figure shown above are the results by LEED certification level including certified, silver, gold and Platinum which displays the EUI (KBtu/ft2/yr) for all the 100 LEED-New Construction Commercial Buildings. For the most common type: office spaces, LEED averaged a EUI of 33%. Additionally, gold and platinum buildings show a 55% and 50% energy saving. This graph omits the 21 buildings from the study [15].

d) FINANCIAL BENEFITS IN LEED

LEED certification can be defined as a facility which is not only just an eco-friendly and sustainable but it also helps limiting the costs and enhancing the efficiency of high rise buildings.

The financial benefits of LEED Rating Systems are:

1) Increasing energy efficiency with lower utility bills
2) Tax Benefits
3) Low Operation Costs

All these points are mentioned above with explanation

1) Helps by increasing Energy Efficiency leading to Lower Utility Bills

Significant reduction in Energy costs can be achieved by using LED lights and energy efficient heating and cooling compounds. According to the latest USGBC by LEED they've concluded that LEED certified building consume 25% less energy and 11% less water as compared to a non LEED building [16]. LEED buildings also have 20% less maintenance cost than a typical commercial building, resulting in decrease in operational cost up to 10% in a year.

2) HIGHER REST AND TAX BENEFITS

According to USGBC, LEED certified buildings retain higher property values and qualify for incentives and benefits are given to them in tax from states across the country which leads to reduction in fees, tax credits and expedites building permits.

3) COMPETITIVE EDGE

LEED certifies buildings with better indoor environmental quality and lower operating costs are more attractive than a non rated LEED building to growing groups of architects, corporate, buyers and individual buyers.

For example, USGBC issues a report in which, a study of PNC Bank which is LEED-certified found that the LEED-certified branches brought in 3 million dollars more in customer deposits and originated 25.5 more in consumer loans annually [1].

E) Comparative study with Quantitative ratings of LEED Platinum rated High rise building

As per table below we've done statistical comparative study of all the 3 LEED platinum Rated skyscrapers from different areas having varying credit categories and scores.

The summary of these buildings with attractions explained along with LEED ratings and their detailed typology.

From the table below we can observe that all the 3 skyscrapers are LEED platinum rated having different typologies.

For example – World Trade Tower is LEED ID+C[10], ICD Brookfield Tower being LEED BD+C[11] while Taipei 101 with LEED O+M[12] shown in methodology flowchart having varying credit categories, different techniques and timeline for making themselves LEED Platinum Rated Skyscrapers.

[9] *EUI (Energy Use Intensity) - It is the ratio of annual total energy consumed by the building to the total gross floor area of the building.*

[10] *LEED v4 ID+C – LEED Ratings for Interiors Design and Construction*

[11] *LEED v4 BD+C – LEED Ratings for Buildings Design and Construction*

[12] *LEED v4 O +M – LEED Ratings for Operation and Management*

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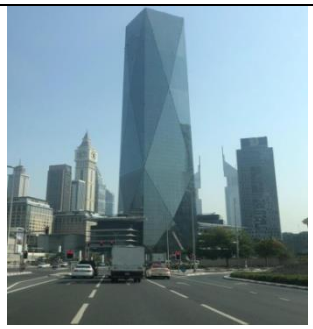
FACTORS	1.WORLD TRADE TOWER	2.ICD BROOKFIELD OFFICE	3.TAIPEI 101
TIMELINE	2012	2020	2004
LEED RATING	LEED Platinum/LEED Gold (ISGBC)- LEED v4 ID+C	LEED Platinum/ LEED v3 BD+C: Core and Shell	LEED Platinum v2009 O+M : Core and Shell
SELF CLICKED CERTIFICATE OF WORLD TRADE TOWER BY IGBC WHILE HAVING QUESTIONAIRE WITH EXPERT	 Indian Green Building Council (IGBC) hereby certifies that World Trade Tower C-01 Sector-16, Noida has achieved precertification under the LEED India for Core & Shell Rating System. Documentation has been submitted for this project, which demonstrates an intent to design and build a high performance building in accordance with LEED India Green Building Rating System. LEED India for Core & Shell Pre-certified Gold July 2013 C N Raghavendran Chairman, LEED India Dr Prem C Jain Chairman, IGBC S Raghupathy Executive Director, CII-Godrej GBC		
Building type	COMMERCIAL BUILDING	COMMERCIAL BUILDING	COMMERCIAL BUILDING
PLACE	Noida Sec 16 , Delhi NCR	Dubai	Xinyi District , China
DESIGNER	Nostri Architects	Foster + Partners	C.Y. Lee
LEED SCORE	90/110	82/110	82/110
Certified Year	2018	2020	2011
HEIGHT	130m	282m	509m
No. of credit categories	8 Credit Categories	7 Credit Categories	6 Credit Categories
Description	Energy: 35 / 38 Location &Materials : 17 / 18 In. Env.: 10/17 Material: 5/13 Water : 12/12 Innovation : 5/6 Regional Priority Credits Integrative Process Credits : 2 / 2 [17]	Energy: 24 / 37 Sites: 20 /28 In. Env. Quality : 11/12 Material: 7/13 Water : 10/10 Innovation : 6/6 Regional Priority Credits : 4/4[18]	Energy: 25/35 Sites: 19/26 In. Env.: 12/15 Water : 15/14 Material: 5/10 Innovation :6/6 [19]
MAIN ATTRACTIONS	-FIRE SAFETY SYSTEMS[13] -BUILDING MANAGEMENT SYSTEMS -EXTERIOR CANOPY	-SKYLIGHT SUITES[14] -HIGH ATRIUM SPACE -MIXED USE HIGH RISE BUILDING	-EARTHQUAKE RESISTANT -1,010 METERS PER MINUTE WORLD'S ULTA HIGH SPEED ELEVATOR
Energy consumption	Total energy consumption of WTT is 9.5 MW and they are planning to insert solar panels to minimize this consumption.- (Self Analyzed)	ICD Brookfield tower in Dubai has reduced 28% of its energy consumption above standards of the industries.[20]	Taipei 101's energy consumption is 30% lower in comparison to that of anon LEED building, leading to annual energy cost savings of $700,000 US.[21]

Table 3 Quantitative Analysis with Comparative study of all the 3 case studies

[13]*They have provided refuge area open to sky in 4th floor so that in case of fire the building occupants can rush where fire fighting team can rescue them.*

[14]*SKY VIEW SUITES -The top three floors of the building feature* ***"Sky View suites*** *"providing views of the surrounding buildings with internal gardens and 6-meter high ceilings.*

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f) FINDINGS AND DISCUSSIONS

CASE STUDY	***a. Strengths analysed***	***b. Gaps Analysed***	***c. Recommendations after analysing***
WORLD TRADE TOWER, Noida sec 16 	-LEED v4 USGBC Platinum / IGBC Gold rated high rise building. -Fire and Life safety plan systems (Self analyzed). - Exterior canopy for shading and natural light - Building Management Systems	-Inadequate walking space for pedestrians. -No Use of Renewable Energies. -No recycle of construction materials -No bicycle facilities - Less Focal Points	- Defined Separate Edges for Pedestrians and vehicular circulations. - Install Programmable Thermostat - Proper Landscaping in Site - Use of renewable sources of energy to minimise power consumption [22].
ICD BROOKFIELD OFFICE, Dubai 	-LEED v4 USGBC Platinum rated high rise building. - Sky View suites[23] -Mixed Use High Rise Building - 87% of waste was recycled in ICD[24] - High atrium space is provided for natural light	-No open spaces and green area on the exterior of the building. - No Use of Renewable Energies in building structures. - No materials were reused. -No plan for storm water management - No system for light pollution reduction	-Instalment of green and open spaces inside and outside the building. - Storm Water Management Plan[25] - Renewable energies like Wind Energy, Solar and Geothermal energy can be used.
TAIPEI 101, China  Source - https://simple.wikipedia.org/wiki/Taipei_10	-LEED v4 USGBC Platinum rated high rise building - Ultra High Speed Elevator was introduced[26] - Taipei being world's tallest green building [27]. - Earthquake Resistant High rise building situated in earthquake prone area.	-Taipei 101 acts as an obstacle to the aircrafts[28] - There was limited space for landscaping on site of Taipei 101, it become important to implement sustainable landscaping practices inside or outside the building. - Taipei is more expensive than lower structures.	- Providing internal gardens with better views of skyline. - Improvements in occupant's comfort : **a)Creating a productive and visual space** **b)** Noise Reduction c) Warm and cool air stratification

Table 4 - QUALITATIVE ANALYSIS of all 3 case studies

Above is the table in which we've done the analysis about the gaps and strengths of case studies along with the recommendations which can lead to increasing efficiency of these high rise buildings.

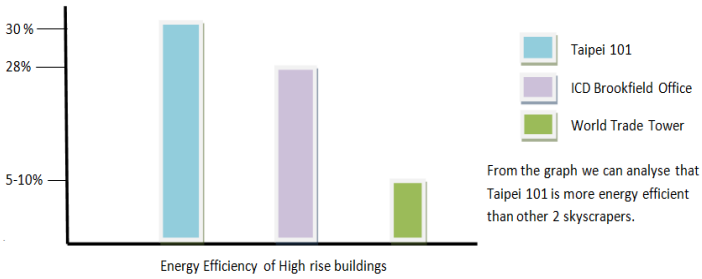
In the Table shown above is the comparative analysis of the 3 case studies of different typologies having different characteristics used to make it LEED platinum through this we came to know how a building has its own identity and can differ in terms of strengths and attractions.

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d)Energy efficiency of all the 3 high rise buildings

As from the graph below we can conclude that TAIPEI 101 is more energy efficient as compared to the other 2 towers. So, we can follow the techniques used in TAIPEI 101 for energy efficiency.

Fig. 3 – As per figure 3.3 graph below shows the percentage of energy efficiency of high rise buildings of our case studies out of which Taipei 101 is the most energy efficient.- Self Analyzed



IV. CONCLUSION

This chapter has covered and summarized rating systems National / International mainly focussing on LEED rating Systems and its Platinum rated case studies of high rise buildings with different building typologies which can be used for evaluating the ecological and environmental performance of skyscrapers, and showing the sustainability degree of these tall buildings.

The USGBC and its LEED rating system acts as two step systems leading to the right direction towards minimizing the effects of high-rise buildings on natural environment and have made it compulsory to achieve green building ratings for skyscrapers. However, with increase in popularity and use of LEED stronger arguments exist for justifying the inclusion and alterations in modern construction projects. Because of the alterations in credit categories and following latest need of today's society LEED itself remains more of a checklist of a green building guidelines than a comprehensive set of guidelines[29].

For example – Energy and Atmosphere is one of the most important factor considered in all the 3 case studies but later in case of ICD Brookfield Place and Taipei 101 more emphasis is given to sustainable sites while in case of World Trade Tower they have considered Location and Transportation as the second most important factor which results in creating different identity and features of each green skyscrapers. Not only this, each building has different credit categories depending upon their building typology, For World Trade Tower which is a ID+C (Interior Design and Construction) type has 8 credit categories while for other 2 case studies like ICD Brookfield tower has 7 credit categories which is BD+C (Building design and Construction) type skyscraper and Taipei 101 has 6 credit categories which is O+M (Operation and Management system) type of skyscraper.

Finally, it is necessary to mention that green buildings rating systems are very important to play a major role in raising awareness and in popularizing green design to improve the performance of skyscrapers, and to make these tall buildings to have an excellent impact on the environment.

According to the results shown in the Comparative case study analysis of LEED rating skyscrapers along with its gaps and strengths, it can be concluded that green building rating systems like LEED give important credits for evaluating the energy performance of skyscrapers. From the table and pie charts shown we can say that each LEED rated high rise building has its own typology and varying credit categories.

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INTERNATIONAL JOURNAL
OF ENGINEERING APPLIED SCIENCE AND TECHNOLOGY

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