Volume 10, Issue 1, January – 2025 *International Journal of Innovative Science and Research Technology (IJISRT)*
ISSN No:-2456-2165 *https://doi.org/10.5281/zenodo.14730659*
IJISRT25JAN266 *www.ijisrt.com*

The Impact of Biophilic Design into High Rise Building: Towards Sustainable Urban Environment

Marim M A Baka[1]; Demet Irkli Eryildiz [2]

Istanbul Okan Unıversıty
Instıtute of Graduate Studıes, Istanbul, Turkey

Publication Date: 2025/01/24

Abstract

This study claify how to improve sustainable credits in high-rise structures by investigating the integration of biophilic design principles into ecological footprint measures. This study demonstrates how comparative techniques can efficiently handle the issues connected with urban high-rise development while boosting sustainability. The study focuses on the impact of biophilic design in decreasing energy consumption material use and waste , Water Management, Air Quality Improvement on environmentally, Thermal Design and Comfort, to increases the overall environmental effects of high-rise structures. By adding natural components into the built environment, the study demonstrates how biophilic design may contribute to more sustainable, energy-efficient, and health-conscious architectural practices in the context of vertical urbanization. The findings highlight the necessity of incorporating natural solutions to promote sustainable building practices that are consistent with larger environmental aims by assessesment using framework analysis of five case studies from best sustainble highrise building: The Oasia Hotel Downtown (Singapore), Bosco Verticale (Milan), The Edge (Amsterdam), Commerzbank (Frankfurt), and Parkroyal Collection Pickering (Singapore).

Keywords: *Biophlic Desgin, Highrise Buildings, Sustainble Credits, Ecological Footprint, Urban Environment.*

I. INTRODUCTİON

Nowadays, the use of energy resource in high rise building is one of the most widely discussed issues, and several research are being undertaken around the World (Doraj et al., 2021). In the modern period, energy plays an important part in the socioeconomic growth of countries. As a result, energy regulators place a high value on managing and optimizing energy consumption as one method of ensuring energy security (Moreira et al., Rodrigues, 2022). The building sector has a significant environmental impact, accounting for one-third of greenhouse gas emissions and 40% of energy consumption globally high-rise buildings (Bartlett & Howard, 2000). In high-density cities can account for 60% of carbon emissions and 90% of total electricity consumption (Rahmani et al., 2023). As the residential building sector consumes around 30% of the total energy consumed worldwide, buildings account for approximately 36% of carbon dioxide (CO2) emissions, which are the principal cause of global warming (Saleki & Bahramani , 2018)(Ascione et al., 2021). This percentage is likely to rise in the future as population and urban development grow at an exponential rate. As a result, cities spread vertically due to limited land area to accommodate the growing population (Lima et al., 2019). Furthermore, urban expansion will result in changes in energy use patterns, where governments, particularly in developing countries, are concerned about further high demand in the building construction industry. The availability of more modern high rise building in urban areas has contributed significantly to meeting the growing demand for urban buildings from the large number of people who move to fast-growing cities. Furthermore, urbanization will cause changes in energy consumption patterns, which will be worsened by changing climate conditions (Riahi et al., 2014), emphasizing the importance of urban sustainability. High-rise buildings are indeed a symbol of urban progress and growth. However, this urban growth goes hand in hand with formidable environmental challenges that require innovative solutions in order to achieve sustainability principles and careful design to meet the growing environmental, economic, and social needs. Probably, one promising solution is biophilic design, which has recently gained more interest in architecture, and especially in high-rise buildings. Biophilic design aims to combine natural elements with the built environment to enhance sustainability and reduce the environmental impact of high-rise buildings (Gong et al., 2023). Biophilia connects humans with nature by incorporating natural elements such as plants, water, natural ventilation, and natural lighting into buildings, which improves thermal and environmental comfort (Radha, 2022). Recent studies focus on the presence of biophilic design, which has proven effective in reducing carbon emissions and renewable energy (Kellert 2018). There are several studies that investigate how to develop strategies for biophilic design and its applications to improve energy management, environmental conservation, and sustainability (Hong et al., 2019; Kadai et al., 2023). Based on recent researches , practices have been developed to maintain the ecological footprint and sustainability, some of them have been identified having an impact on reducing the ecological footprint of buildings such as : solar energy harnessing, preferences for structure and materials, green facade, rainwater harvesting system, and natural ventilation. Hence, the idea of developing the features of the biophilic design and using them in sustainable architectural straitgies to enhance urban environmental (Hong et al., 2019; Kadai et al., 2023) (Qian et al., 2019).

II. METHODOLOGY

The study is based on the analysis of five high-rise buildings using biophilic design patterns, and some sustainability points that have an impact on the environmental footprint. Data were collected from academic publications, building performance reports, and architectural studies.The aim of this study is to enhance sustainable credits in high-rise buildings, demonstrating how these comparative approaches can address challenges and use biophilic design strategies within ecological foot print methods to investigate the role of biophilic design in boosting sustainability in high-rise buildings, emphasizing on the potential to reduce energy consumption, minimize reliance on unfreindly materials, and improve environmental health through following framework scheme:

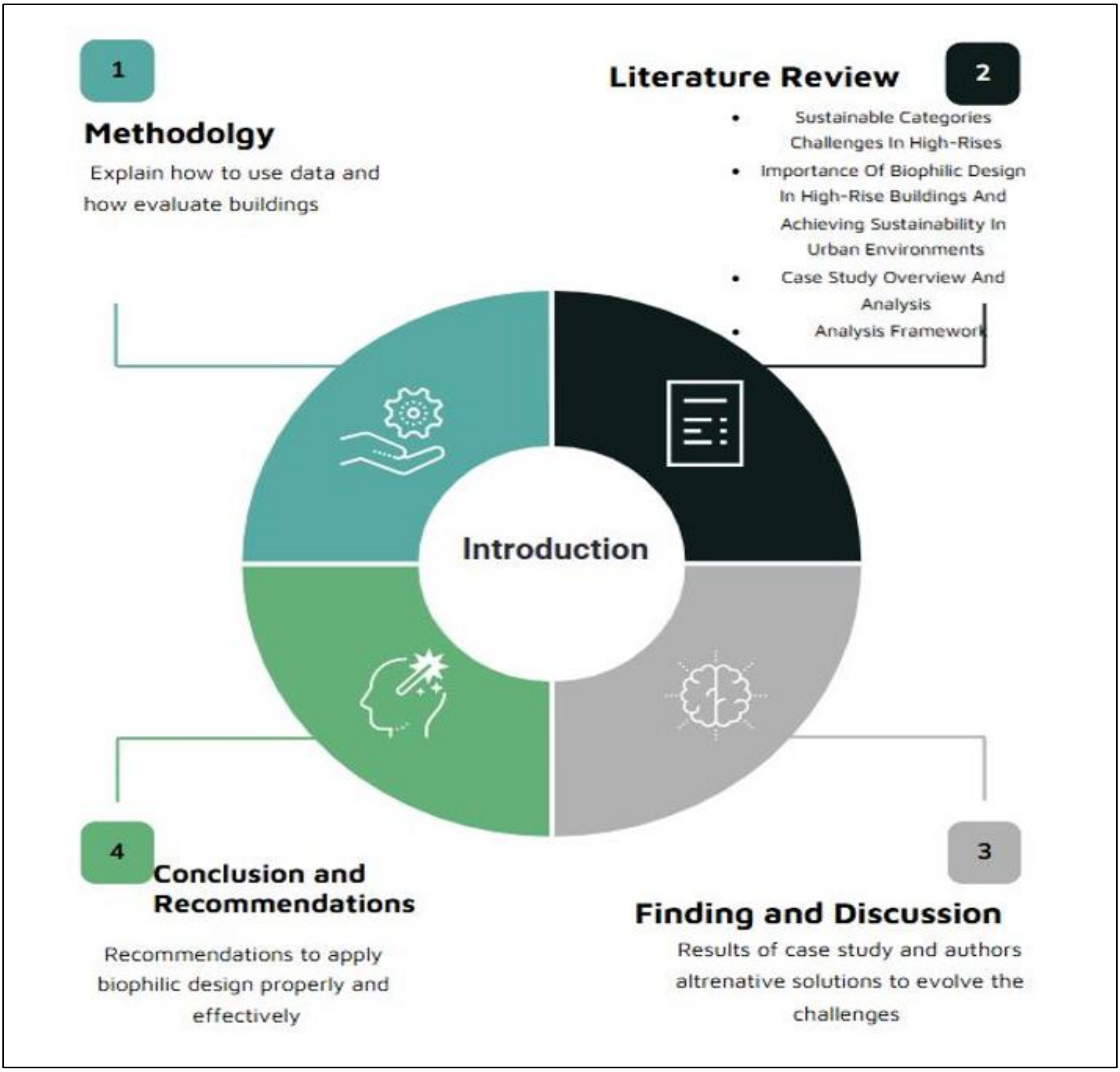

Fig 1 Framework Scheme (Author)

III. LİTERATURE REVİEW

Erich Fromm, a social psychologist, first used the word "biophilia" in the 1980s. The word, which has Greek origins, implies "love of nature." the phrase refers to "the links that humans intuitively seek with the rest of existence." The term "biophilic architecture" or "biophilic design" describes how a building is adapted to its surroundings. It is a method of planning and architecture that incorporates natural elements into constructed spaces to improve productivity, well-being, and human-nature relationships. Based on Edward O. Wilson's "biophilia" hypothesis, which postulates an innate affinity between humans and nature, biophilic design principles for interior design will incorporate both direct and indirect interactions: direct interactions, with plants, water features, and daylight; indirect interactions, with natural materials, patterns, and colors. Studies show that adding biophilic features can lower stress, boost cognitive function, and improve an individual's mental health (Kellert et al., 2008). Another study has found that employees had a 15% decrease in absenteeism and a 6% increase in productivity when workplaces were designed with biophilia in mind. However, Terrapin Bright Green's "14 Design Styles" and "Biophilic Design" provide a systematic approach to applying these concepts in a variety of settings. It does this by demonstrating the importance of the sense interaction with nature for human well-being (Browning, Ryan, & Clancy, 2014). Previous studies demonstrate the importance of biophilic design in improving sustainable buildings and linking them to the urban environment through the interaction of occupants with the environment and surroundings. The presence of biophilic design in sustainable buildings, especially tall buildings, has become a priority in urban design. One of the biophilic design strategies is the participation of plants in building occupancy, which leads to improving air quality and reducing energy (Smith, 2023). Green roofs contribute to urban sustainability by improving air quality and regulating temperatures. biophilic suggests , biodiversity and its impact on improving mental health in the region (Brown, 2022). The vegetation that covers high-rise buildings reduces temperatures, increases cooling, and reduces environmental impacts, which was concluded by modern architectural research (Green, 2021). When the applications of biophilic design are improved in high-rise buildings, architects can comprehend the factors of the the project success and its challenges, it might facilitate the process of translating biophilic design strategies and transforming them into ideas that enhance sustainability in buildings, it can helps influence future methods and decision-making. (Ardiani et al., 2020).

➢ *Sustainable Design Categories And Challenges ın High-Rises*

Sustainable tall buildings face some challenges in maintaining the environmental footprint and these challenges can be comprehend through the leadership credits in energy and environmental design, such as consumption, water management, material selection, indoor environmental quality, and sustainable site design (Cabeza et al., 2022).

- *Energy Consumption*

Despite the multiplicity of energy saving methods, it is still a burden on tall buildings. Due to their complexity and efficiency, tall buildings often consume a lot of energy for heating, cooling and lighting (Tzempelikos and Athienitis, 2023). Recent research indicates the difficulty of achieving the goal of zero energy despite relying on natural elements such as ventilation and natural light in relatively hot areas. Also, trying to reduce the burdens by using air conditioning systems for ventilation and thermal comfort increases energy consumption, moreover reducing the sustainability of buildings, hens the tall buildings contain complex energy systems as well to the burden of loads in vertical areas, which poses a challenge for sustainability researchers. (Chong et al., 2020).

- *Water Management*

Water scarcity is another major issue in high-rise buildings, especially in urban areas. Although modern techniques such as rainwater harvesting, water recycling and water-managing can help reduce water consumption, but their slow implementation due to technical and financial challenges is another obstacle. Green energy and stormwater management applications can reduce water runoff, but they require poor quality and difficult maintenance, making them an impractical application in urban areas. Building constraints and complexity are another challenge to their implementation (Berndtsson et al., 2022).

- *Indoor Air Quality*

Air quality is one of the most important issues necessary for the health of the building and the productivity of its occupants and is one of the most important considerations in sustainable construction. The building balance between achieving optimal ventilation, natural lighting and circulation is one of the most important sustainability problems that are difficult to achieve, leading to poor ventilation and light, as well the problems of low-emitting materials and air control management who lack proper management (Kellert et al., 2021).

- *Material Selection*

The materials used in sustainable construction increase the difficulties of achieving sustainability because high-rise buildings rely on concrete, and if a more efficient material is found, it poses a material challenge to its use in construction, which excludes its application (Cabeza et al., 2022). Recent studies have found the use of materials who require high energy eliminates the reliance on natural energy, which poses a new challenge. The development of materials science, such as the development of self-healing concrete, is a logical solution, but its application is an obstacle due to its high cost. It also discussed how tall buildings often fail to manage natural light and ventilation within the limits of urban requirements, and it causes air circulation problems within poor light. Sustainability methods may conflict with materials used in construction, such as low-emitting materials, with the need for high-performance air tightness, may possibly requires more consideration (Huang et al., 2021).

- *Sustainable Site Design*

It is difficult to implement sustainability solutions in urban areas with limited biodiversity (Beatley, 2023). Such as green spaces, water bodies and parks, including stormwater management. Moreover, the lack of renewable resources leads to look for innovative methods for applying the biophilic design in high-rise buildings. It also requires choosing sites that do not have the threats of natural factors and wet environments, flood plains, including easy access to public transportation to reduce the use of private vehicles that cause harmful environmental emissions, in addition to unfavorable environmental laws in the urban environment. Heat island and harmful air emissions to the environment also affect the effectiveness of sustainability site measures to mitigate environmental impacts (Benedict et al., 2021).

Table 1 Sustainable Credits Challenges (Author)

Challenges	**Impact**	**Impact**	
Energy Consumption	40% of global building energy consumption	Increases urban heat islands and greenhouse gas emissions	Santamouris, 2020
Water Management	30% of water wasted	Exacerbates water scarcity in urban areas	Wong et al., 2021
Sustainable site	UHI can lead to up to a 15-20% increase in energy consumption for cooling in cities	Buildings in large urban cities absorb harmful radiation and reflect it back to the environment, leading to higher air and surface temperatures.	(Liu et al., 2023).
Air Quality Improvement	60% of buildings with poor indoor air	Reduces occupant health and productivity	Kaushik, et al., 2020
Thermal Design and Comfort	25-30% higher cooling costs	Reduces occupant health and productivity	Cheung et al., 2021
Material Use and Waste	50% of urban solid waste	Depletes resources and increases landfill challenges	Ghaffar et al., 2020

- *The Importance of Biophilic Design in High-Rise Buildings for Sustainability Urban Environments*

The concept of biophilic design should take into account natural environments and their interaction with humans. Human experiences with nature can increase mental processes and environmental adaptation conditions that humans have used since long times ago, which makes us always wants to explore healthy environments that support productivity and well-being. Biophilic design can help increase our awareness of the importance of the environment and its preservation. The ultimate goal of design is not the physical structure, but its impact as a lived experience. Biophilic design is mainly based on three types of natural experience patterns. (Aouadi et al., 2023). Figure 2:

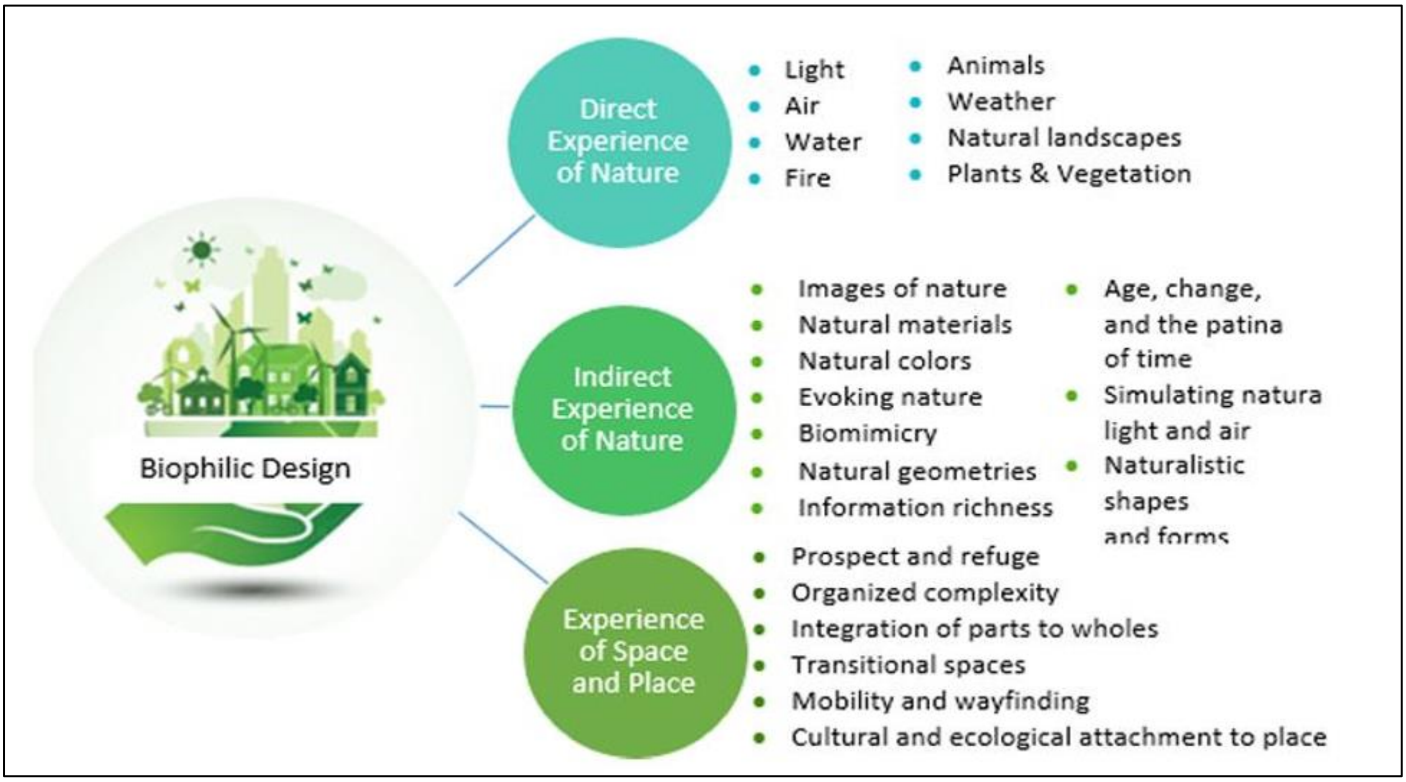

Fig 2 Biophilic Design Pattern and Experiences (Aouadiet al., 2023)

Many studies have explored the necessity of applying biophilic design in high-rise buildings and its role in enhancing and raising productivity, reducing stress, increasing biodiversity, and its impact on air purification and sustainability. Another study indicated the application of biophilic design strategies in buildings and their role in reducing energy consumption, improving air quality, enhancing biodiversity, and promoting environmental sustainability while providing healthier living environments for building occupants (Aouadi et al., 2023). The importance of applying biophilic design has been proven by several results in the urban environment, as following:

Improving well-being: Biophilic design reduces stress and increases mental capacity. Thus the exposure to green spaces and natural light leads to a relaxing sensory experience, and the light and sensory effect seems to be particularly important in buildings with limited access to natural light (Nieuwenhuis et al., 2014).

Energy efficiency: Biophilic elements such as biodiversity, green walls and open spaces with natural surroundings can reduce the use of artificial air cooling structures and thus reduce energy consumption (Tzempelikos and Athienitis, 2023). Another study found that heat island effects can be reduced by integrating green roofs with solar panels (Hong et al., 2020).

The sustainability of high-rise buildings is focused on the application of green roofs and vertical gardens, as green roofs contribute to reducing consumption, which leads to controlling the temperature of the area (Saadatian et al., 2013).

Environmental quality: The application of windows and ventilation openings in a correct manner similar to natural open environments, such as the use of sky gardens, increases cooling and reduces dependence on artificial light (Glicksman et al., 2018).

Water management: Simulating nature by applying water bodies such as ponds and fountains enhances the sustainability of a building, which leads to solving the problem of rainwater and preventing flooding (Berndtsson, 2010).

Application of materials: The use of raw materials such as wood, stone and clay in high-rise buildings enhances the sustainability of the building and reduces environmental emissions, which leads to reduced energy consumption (Cabeza et al., 2014).

In summary, although sustainable high-rise structures offer various environmental and social advantages, challenges like energy use, water management, choice of materials, indoor environmental quality, and sustainable site planning need to addressed for them to fully achieve their potential as environmental urban spaces.

➢ *Case Study Overview And Analysis*

These case studies clarify how biophilic design can be applied in various vertical structures, transforming conventional high-rise buildings into vibrant, environmentally sustainable, and nature-inspired environments. These illustrations may act as motivation for upcoming enhancements and advancements in the sector as we explore the existing influence of biophilic components on the ecological footprint of tall structures and their role in promoting sustainability in contemporary vertical living.

- *Case Study Limitations*

The study proposed on buildings istablished between 1997 and 2016.geographical coverage is limited to urban centers in Asia, Europe and data availability on building performance varies.

- *Oasis Hotel Downtown (Singapore)*

✓ Established Year: 2016
✓ Area: 25,000 sqm

Fig 3 Flora Green Facade ,Oasis Hotel Downtown Singapore
(CTBUH,2018)

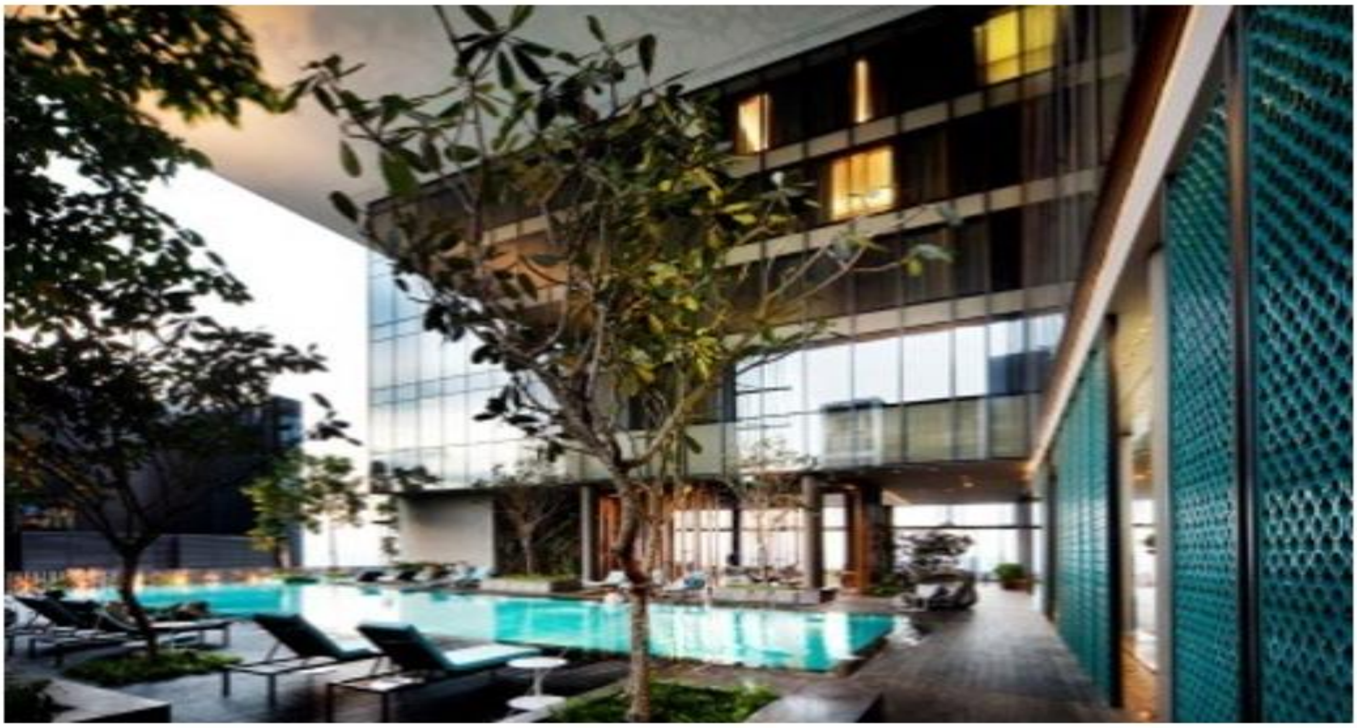

Fig 4 Water Featuer, Oasis Hotel Downtown, Singapore
(CTBUH,2018)

The Oasia Hotel Downtown in Singapore, is a stunning example of a vertical refuge in the midst of a bustling metropolitan environment. The building's façade is covered with lush flora, which serves both aesthetic and utilitarian purposes It introduces a green plot ratio GPR standards as a measure of the density of greenery inside a property. The green façade using aluminium mesh shading serves as a natural thermal buffer, reducing the building's reliance on artificial cooling systems while also providing a visual break for both tenants and viewers. Furthermore, the building's vegetation has an environmental benefit by helps regulate stormwater runoff and contributes to local biodiversity. The incorporation of flora with 33 kind of trees and shurbs into the building's design is a novel method to creating sustainable structures that benefit the urban environment provides with automatic irrigation system which reduce water waste. The Site closed to public transportation, decrease the demand for private car use and the carbon emissions (CTBUH,2018).

Biophilic Features: Green façade ,Vertical gardens, rooftop green spaces, water features, optimized natural lighting, mesh shading.

Sustainable Strategies In Building: automatic irrigation energy-efficient cooling systems, solar panels.

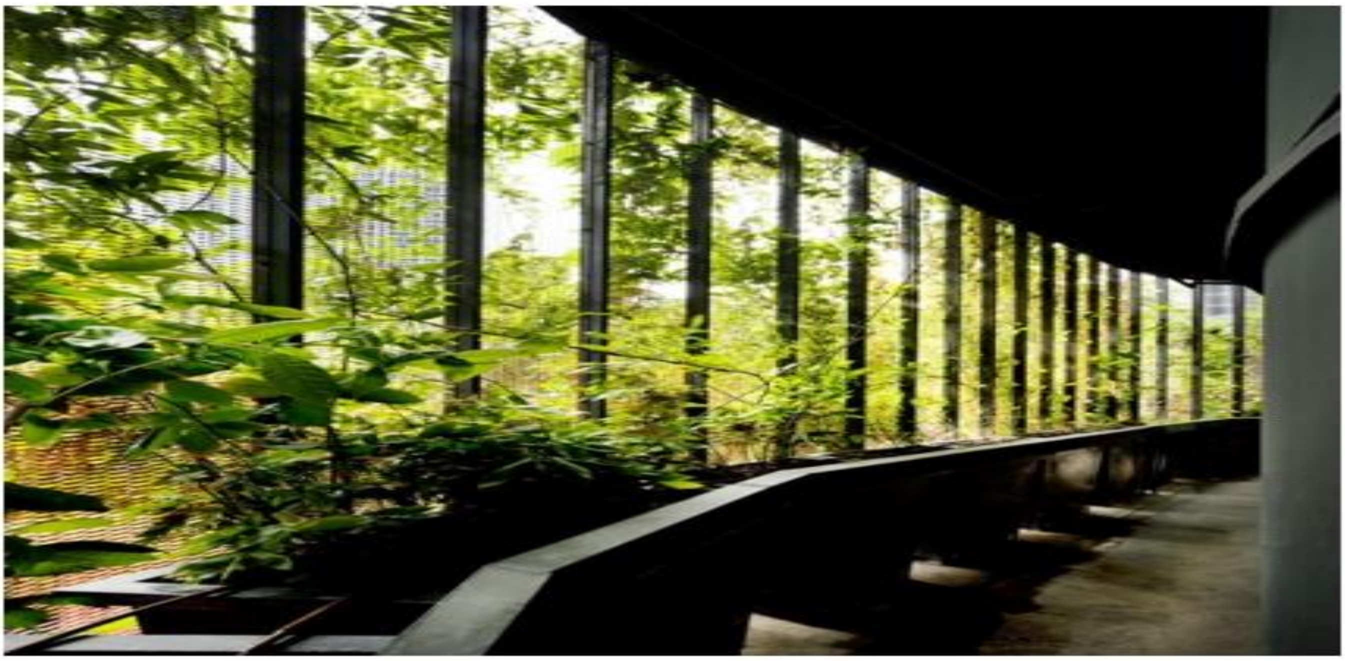

Fig 5 Vertical Garden, Oasis Hotel Downtown, Singapore
(CTBUH,2018)

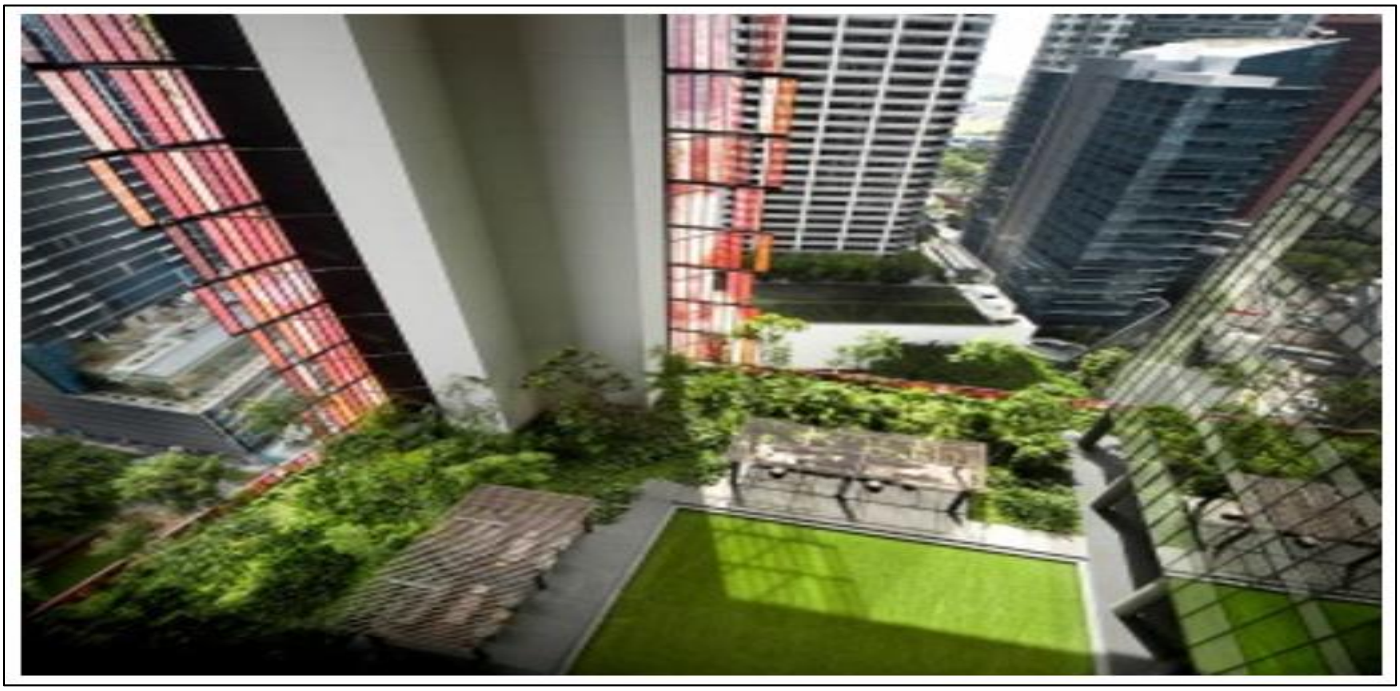

Fig 6 Green RoofTop ,Oasis Hotel Downtown, Singapore
(CTBUH,2018)

- *Bosco Verticale (Milan, Italy)*

✓ Established Year**:** 2014
✓ Area**:** 40,000 sqm

The Bosco Verticale in Milan exemplifies biophilic design's role in enhancing urban sustainability. By integrating over 20,000 plants, including 700 trees, into its two residential towers, the project improves air quality, reduces noise pollution, fosters biodiversity within the urban environment. The vegetation of dark foliage serves as a natural insulator, mitigating the urban heat island effect and lowering energy consumption for heating and cooling. Additionally, the building employs a sustainable storm water irrigation system that recycles excess water from occupants and the building for plant nourishment. This integration of nature within the built environment not only enhances residents' quality of life but also sets a precedent for sustainable urban development. Ventilated façade with translucent grey composite material such as stonware panel can reduce heat .The complex serves as a landmark in the city, providing a changing landscape that varies in form and color depending on the plant species (CTBUH,2015).

Biophilic Features: Vertical forests with over 700 trees, use of native plant species.

Sustainable Strategies In Building**:** Green dark foliage design using green wall reduces urban heat island effects and storm water, natural insulation lower energy consumption and solar radtiation, irrigation system.

Fig 7 Site contains a variety of green landscape , Bosco Verticale,Milan
(Giacomello et al,. 2015)

Fig 8 Green Façade , Bosco Verticale,Milan
(Giacomello et al,. 2015)

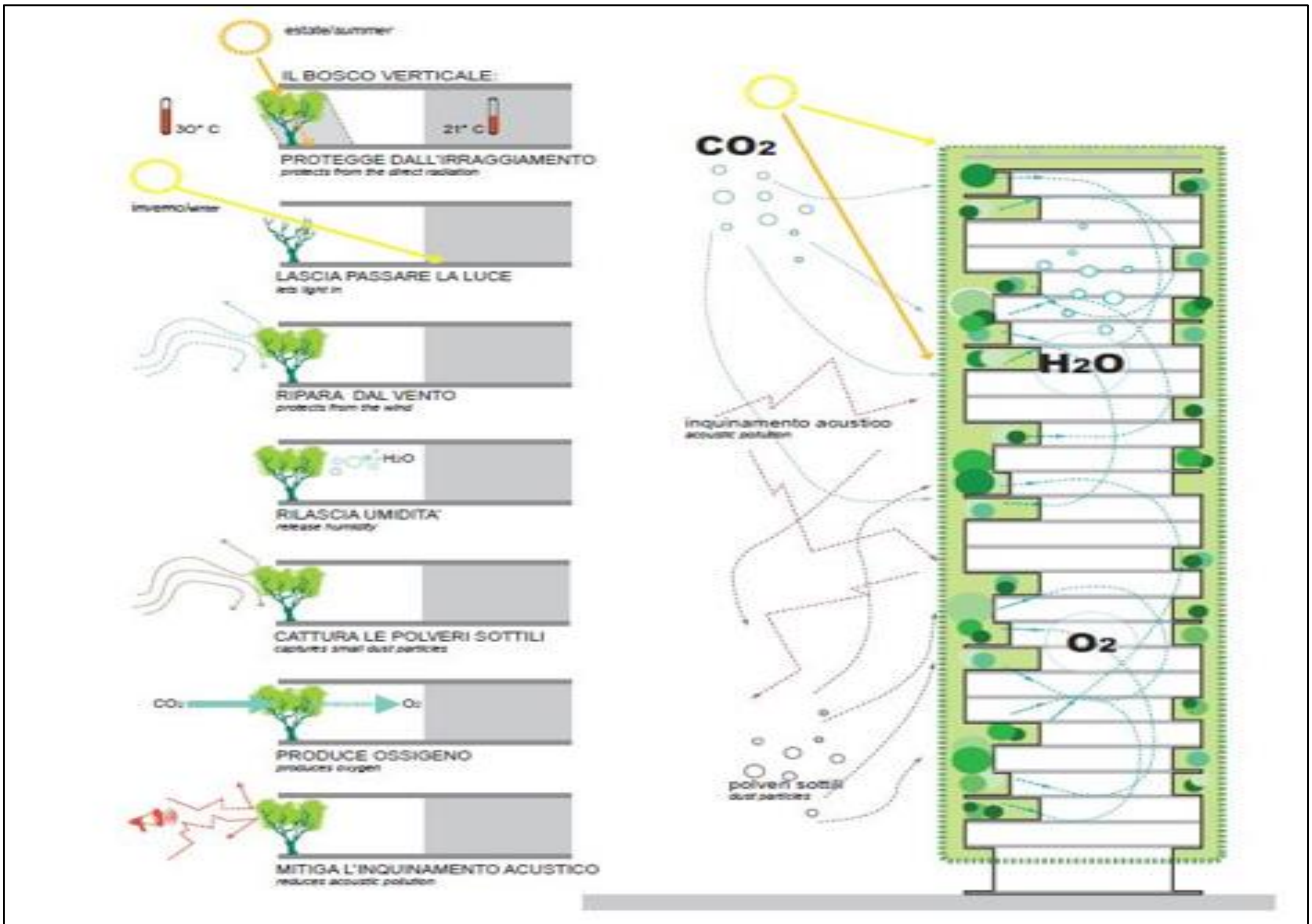

Fig 9 Green Wall conditions Bosco Verticale,Milan
(Giacomello et al,. 2015)

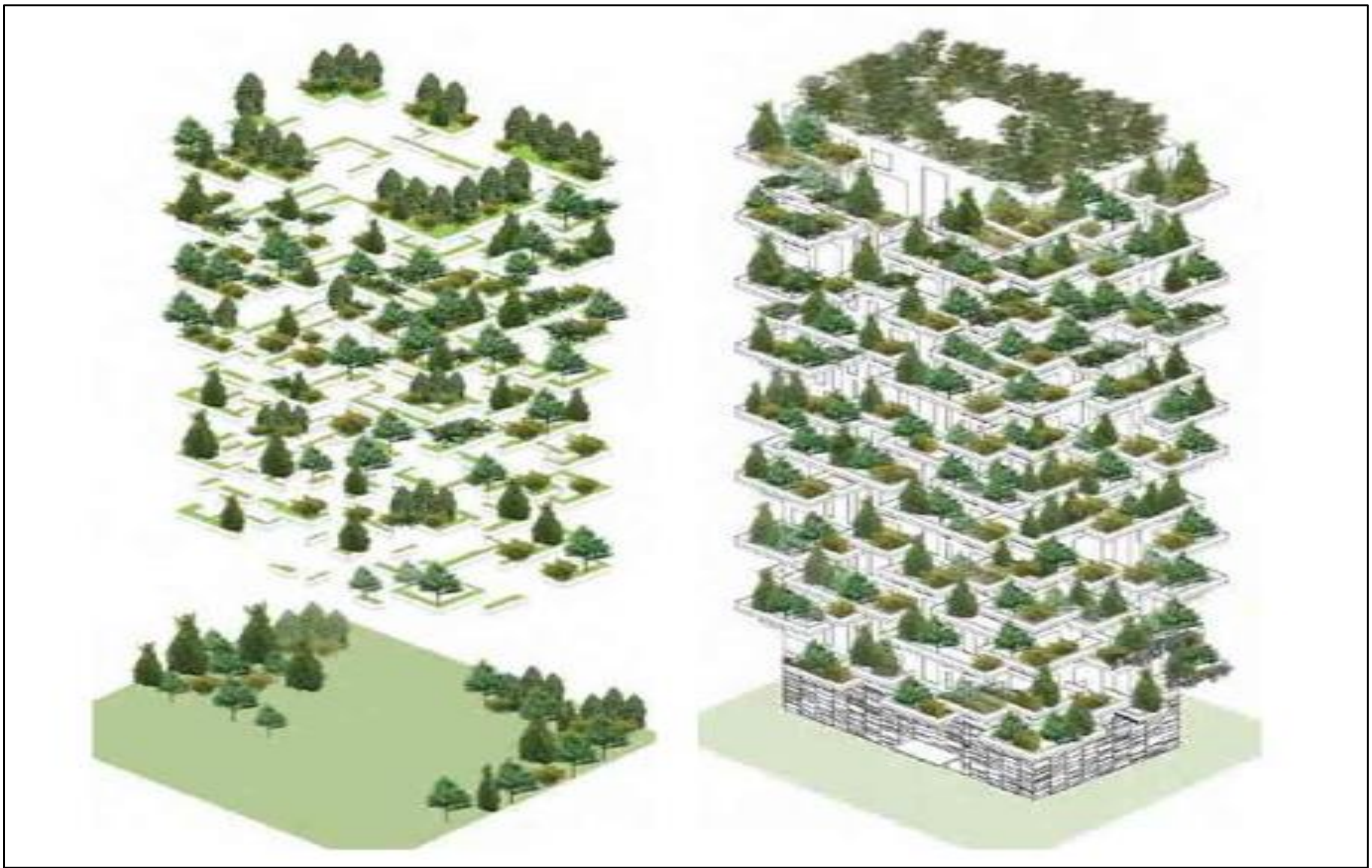

Fig 10 Vertical garden Bosco Verticale,Milan
(Giacomello et al,. 2015)

- *Commerzbank (Frankfurt)*

- ✓ Established Year**:** 1997
- ✓ Area: 121,000sqm

Fig 11 Site , Commerzbank Frankfurt
(Powell, 2006)

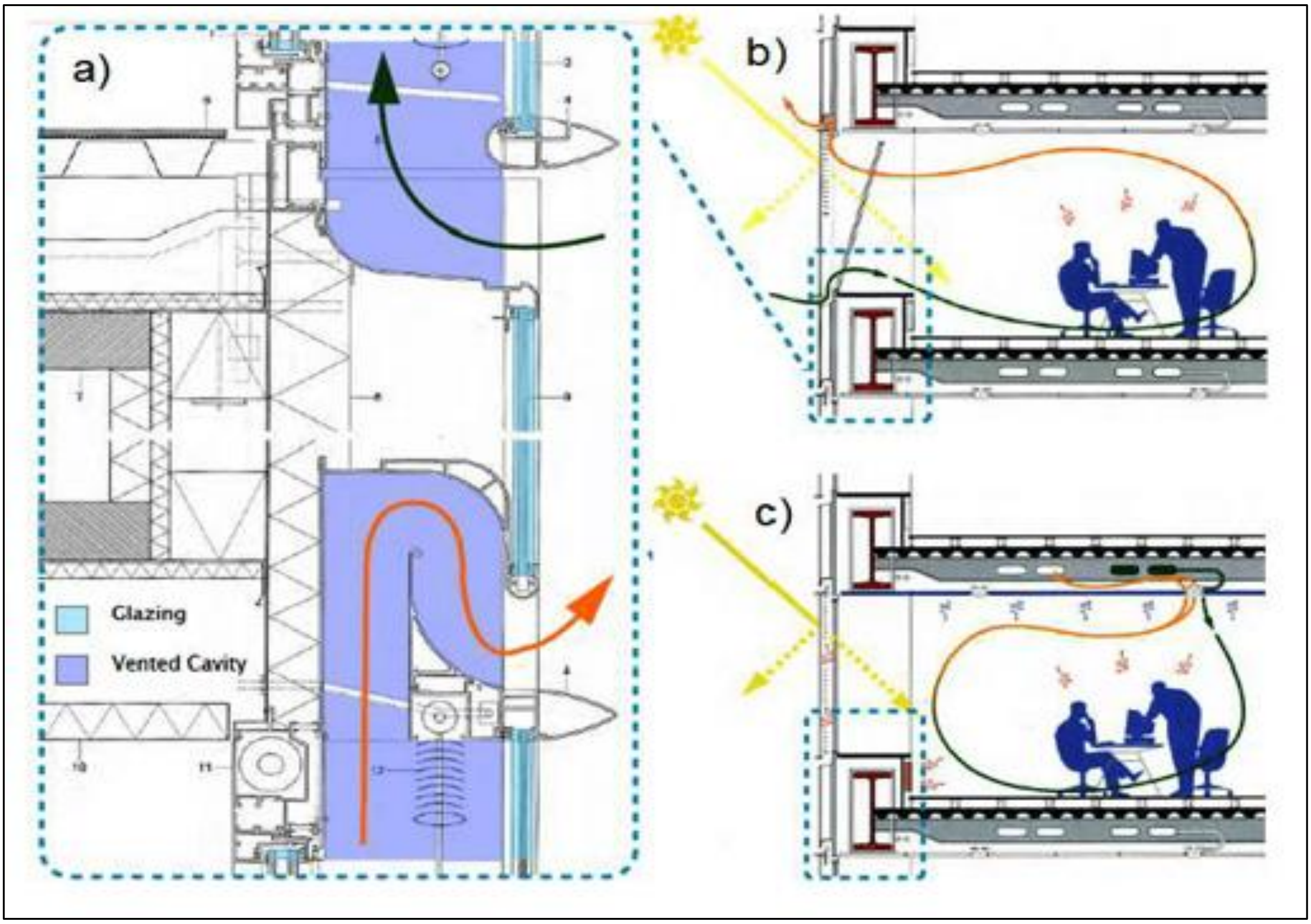

Fig 12 High-performance glazing , Commerzbank Frankfurt
(Powell, 2006)

This tower, which serves as the headquarters of Commerzbank and is located on Neuheimer Strasse in Frankfurt, Germany, is a renowned example of ecological and life-loving design. It was designed by Foster + Partners, helmed by renowned architect Norman Foster, and constructed between 1994 and 1997. It is 259 meters tall, with 56 storeys, and a 300-meter antenna, making it the tallest structure in Europe at the time. It was renowned as the world's first environmentally friendly skyscraper and is still the tallest building in Germany. Commerzbank makes a social, economic, and ecological message through architecture. The tower's design strives to integrate natural elements into the constructed environment in order to promote users' wellbeing and health; it also contributes to a reduction in energy consumption, making it a pioneering model in environmentally friendly structures. One of the most notable and creative aspects of the Commerzbank Tower is its biophilic design (Author, et al., 2015). The adopted biophilic elements are as follows:

Cloud gardens are a key biophilic component in landscape design. The fact that these gardens are distributed across multiple floors allows for the creation of indoor green zones that reduce interior temperatures and improve air quality. Additionally, the gardens act as biological thermal insulators, reducing the need for artificial cooling systems (Gissen, 2003). These gardens also provide biological diversity through the variety of plants used. Asian flora are used from the east; North American vegetation from the west; and Mediterranean plants from the south. This design also follows geographic tendencies. The design centers on an internal courtyard running the length of the building, with a glass roof that allows sunshine to permeate all floors. Employees also utilize it as a place to sit and observe the sky gardens. The Commerzbank Tower's architecture makes extensive use of natural illumination. The building facades are constructed with double-glazed windows that allow plenty of natural light in. Glass walls separate offices and corridors to allow natural light into all interior spaces and maximize brightness (Scribd, n.d.). This strategy decreases reliance on artificial lighting during daylight hours, which helps to save energy. Furthermore, natural lighting promotes employee well-being by lowering eye strain and increasing productivity (Powell, 2006). Commerzbank Tower's architecture is based on an innovative natural ventilation system that involves enveloping the tower in two-layered facades. The corridors allow fresh air to flow from outside to inside, improving interior air quality while reducing the demand for artificial cooling and heating systems.

Biophilic Features: Nine sky gardens , provide natural light and ventilation, cloud gardens in landscape design.

Sustainable Strategies In Building: high-performance glazing and rainwater harvesting systems, low energy consumption and environmental impact, achieving net-zero carbon status, ventilated reducing reliance on artificial cooling systems.

Fig 13 Cloud gardens, Commerzbank, Frankfurt
(Powell, 2006)

Fig 14 Site, Commerzbank, Frankfurt
(Powell,2006)

- *The Edge (Amsterdam, Netherlands)*

✓ *Established Year: 2020*
✓ *Area: 28,000 sqm*

Fig 15 The Edge Site Surrounding, Ecological Corridor
(https://archinspires.com/2024/08/12/case-study-sustainable-features-of-the-edge-in-amsterdam/)

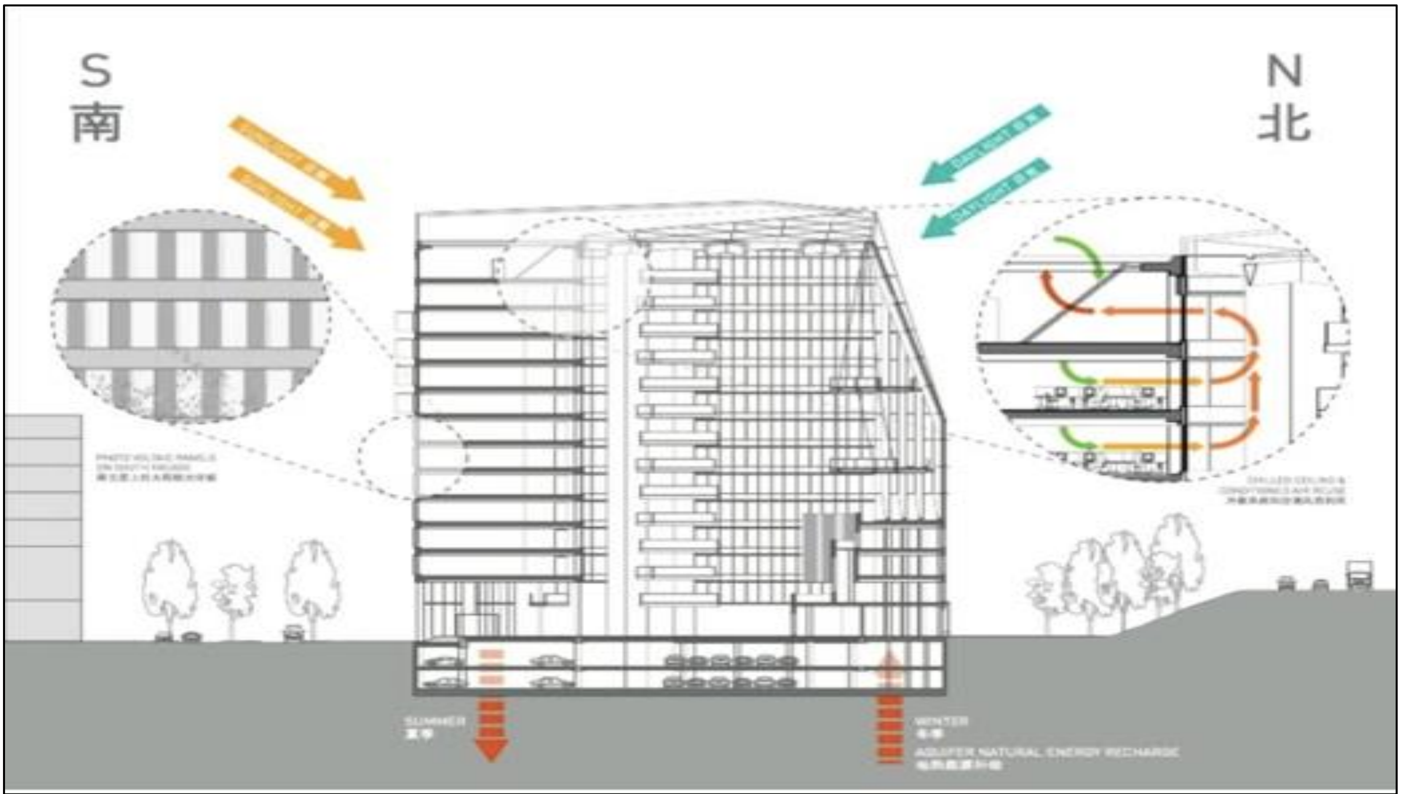

Fig 16 Water Storage
(https://archinspires.com/2024/08/12/case-study-sustainable-features-of-the-edge-in-amsterdam/)

The Edge in Amsterdam is another high-rise that follows biophilic design concepts. Known for its emphasis on sustainability and employee well-being, The Edge has a big atrium with plenty of natural light, generating a sense of connection with nature while being an office building. The building also incorporates smart technologies to improve environmental control and energy efficiency, ensuring sustainability. the building's smart lighting system is tuned for daylight levels and automatically changes to cut energy use when there is adequate natural light. The building's smart lighting system is tuned for daylight levels, and it automatically adapts to cut energy use when there is enough natural light. The site include ecological corridor contain green landscape it separate the buildıng from transportation way and helping animals to cross way safely (CDDB,2017). The Edge has green roofs, which give numerous environmental benefits such as, Stormwater Control: Green roofs absorb rainwater, thereby minimizing runoff and reducing the risk of flooding nearby, temperature Control: Green roofs provide insulation for the building, maintaining a cool environment in the summer and warmth during winter, which lowers the demand for heating and cooling.

Biodiversity: Green spaces also attract local flora and wildlife, which contributes to urban biodiversity. The building's energy management system uses sensors to monitor and optimize energy consumption, ensuring that the facility runs at peak efficiency.Solar panels built into the building's facade and roof generate renewable energy, helping the building achieve its aim of near-zero energy consumption. The use of sustainable materials throughout the construction process reduces the building's environmental impact. The materials are carefully chosen to reduce embodied energy, with a preference for low-carbon, recycled, and locally sourced alternatives such as timber which is sourced from forests that are managed in a way that protects biodiversity and promotes sustainable forest practices. One of the materials used in the construction is smart glass that automatically dims sunlight, reducing the need for air cooling (CDDB,2017).

Biophilic Features: natural lighting, green terraces, use of timber wood, ecological corridor.

Sustainable Strategies In Building**:** water managment and recycling, smart glass , green roof.

Fig 17 Atrium Surrounding
(https://archinspires.com/2024/08/12/case-study-sustainable-features-of-the-edge-in-amsterdam/)

Fig 18 The Edge Facade
(https://archinspires.com/2024/08/12/case-study-sustainable-features-of-the-edge-in-amsterdam/)

- *Parkroyal Collection Pickering (Singapore)*

✓ Established Year: 2015
✓ Area: 29,000 sqm

Fig 19 Facade Appears Sky Gardens Parkroyal Collection Pickering ,Singapore
(Terrapin Bright Green,2015)

The building features a green façade and undulating sky gardens containing green plants, which reduces the effect of heat islands and improves air quality through the application of 15 thousand square meters of green spaces. This demonstrates the impact of the biophilic application on sustainability factors by utilizing rainwater, reducing energy consumption, and using integrated solar panels. The application of vertical gardens has proven its effect in reducing heat, purifying the air, and rationalizing energy consumption. It is one of the smart and innovative methods suitable for the geographical area (Terrapin Bright Green, 2015).

The building is outfitted with solar panels that provide renewable energy. By incorporating these systems into the building's design, the hotel lessens its dependency on fossil fuels and hence its carbon footprint. Using sustainable materials in building reduces the environmental impact of resource extraction and transportation. Many of these materials are sourced locally, which decreases the carbon footprint of the building's construction. The hotel bar and main lobby desk are both made of curved wood layers.These constructions appear to arise naturally from the wood bands covering the surrounding walls and ceiling.The bar and lobby desk stand on textured carpet islands that blend into the floor. These elements defy crisp angles, creating formations that resemble the gradual erosion of land by wind or water. The sky-gardens feature regional species such as Frangipani trees, Euterpe palms, floral Heliconias, Alpinias, largeleafed bushes, ferns, and hanging creepers(Terrapin Bright Green,2015).

Biophilic Features: Sky gardens, integration of natural materials such as curvy timber wood shape , 15,000 m2 of green space , regional species such as frangipani trees, euterpe palms, floral Heliconias, alpinias, largeleafed bushes, ferns, and hanging creepers.

Sustainable Strategies in building**:** Rainwater harvesting, reduction of carbon footprint with solar panels, sky garden lowering the urban heat island effect and increasing air quality,

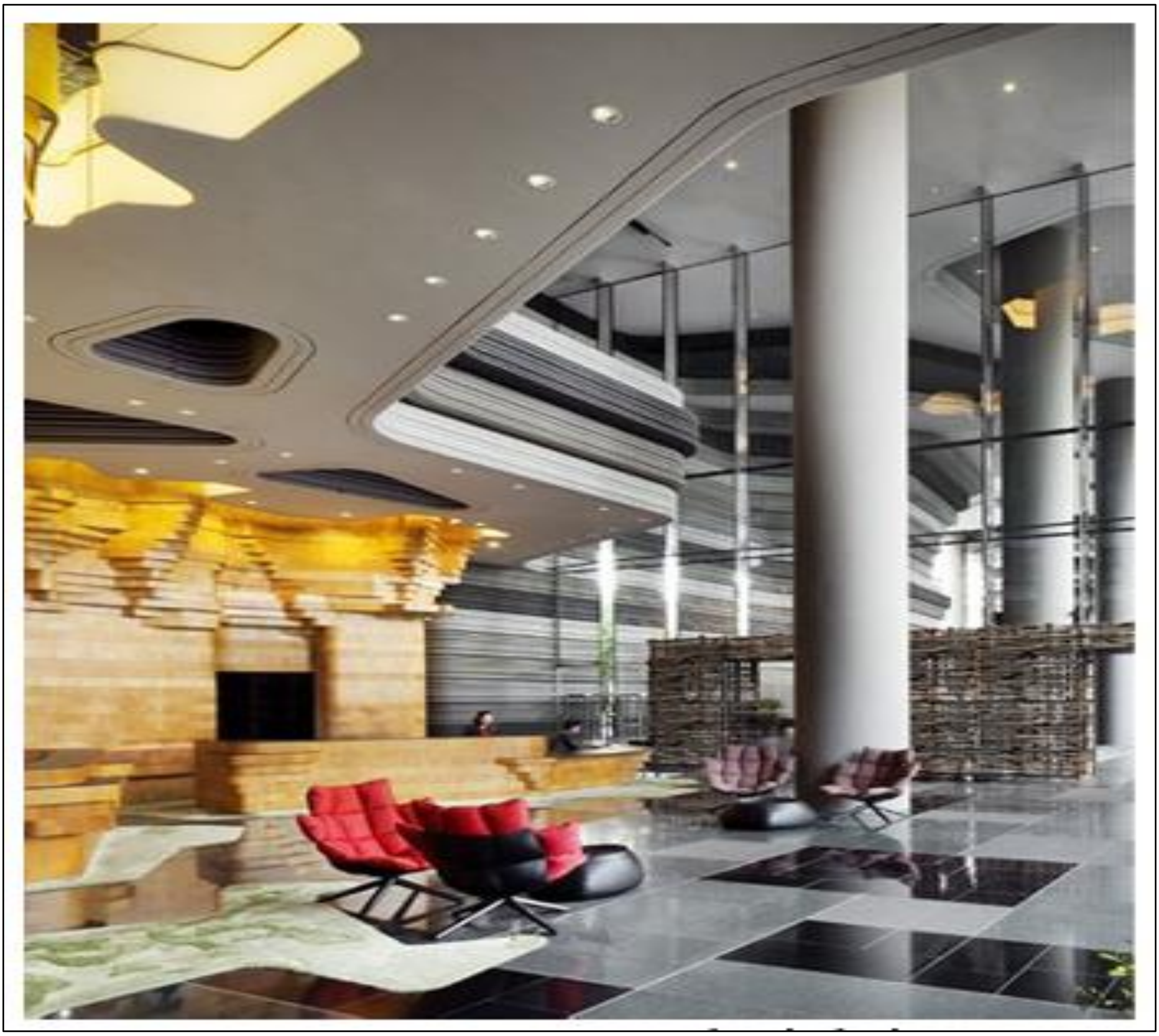

Fig 20 Natural Lighting Pickering ,Singapore
(Terrapin Bright Green,2015)

Fig 21 Open Space Interact with Animals and Birds Pickering ,Singapore
(Terrapin Bright Green,2015)

Fig 22 Using Timber wood into Interior Space Pickering ,Singapore
(Terrapin Bright Green,2015)

➢ *Analysis Framework*

Based on the previous data, a brief table was design to describe the role of biophilic in improving sustainability strategies in the five high-rise buildings, the table shows the best building in applying the most credits of sustainability. The table can be taken as a reference to measure sustainability and reduce ecological footprint challenges Table 2:

Table 2 Biophilic Impact on Sustainable High Rise Buildings (Author)

Credits Of Sustainable Uses	***Oasia Hotel Downtown (Singapore)***	***Bosco Verticale (Milan)***	***Commerzbank (Frankfurt)***	***The Edge (Amsterdam)***	***Parkroyal Collection Pickering (Singapore)***
	Biophilic Design Impact On Sustainability And Ecological Foot Print				
Energy Consumption	Green façade and natural ventilation reduce cooling loads.	Dark foliage of green wall helps to reduce solar radiation	Use of passive cooling and natural ventilation.	High-performance systems ensure minimal energy use.	Passive cooling through vertical greenery and energy-efficient systems.
Water Management	Water Feature recycling for irrigation.	On-site water systems to irrigate vegetation.	Water-efficient technologies for landscaping and waste.	Rainwater harvesting and smart water fixtures integrated.	Advanced rainwater harvesting and drip irrigation systems.
Site Sustainability	Extensive greenery serves to moderate ambient temperatures, so minimizing the UHI effect.	Green spaces absorb precipitation and assist manage stormwater, relieving pressure on the city's drainage systems.	Greenery and green interior spaces improve the local microclimate, which is especially significant in densely populated cities such as Frankfurt.	Green roofs and landscaping enhance local biodiversity and reduce the UHI effect.	The utilization of natural ventilation and passive cooling reduces overall energy demand and helps to cut carbon emissions.
Air Quality Improvement	Green façade acts as a thermal buffer, reducing heat gain.	Green vegetation helps reduce fine particulate matter in urban air by cooling .	Plant integration reduces CO_2 and improves air quality inside the building	Advanced air filtration systems improve air quality.	Extensive greenery purifies surrounding air.
Thermal Design	Natural ventilation and aluminum shading	Dense vegetation using green dark foliage provides shading and insulation.	Use of passive solar energy, double-glazed windows.	Smart glazing and insulation ensure optimal thermal performance.	Vertical greenery ,curvey floors simulate nature
Thermal Comfort	Green façade lowering temperature provide thermal comfort	Vegetation moderates indoor temperatures and improves comfort.	Natural ventilation combined with energy-efficient.	Personalized climate control features optimize comfort.	Integrated shading and ventilation ensure thermal comfort.
Insulating Material	Used natural source such as flora trees. there's no mention for natural materials	Natural vegetation acts as insulation, supplemented by modern materials. such as grey composite materials stoneware	Not mentioned any natural material but the use of double-glazed and insulated glass used for energy efficiency.	Smart glass helps to reduce energy by optimizing the amount of solar heat gain. Using lumber as a renewable material can help store carbon dioxide.	Use of timber wood, regional species such as frangipani trees, euterpe palms, floral Heliconias, alpinias, largeleafed bushes, ferns, and hanging creepers.

IV. FINDINGS AND DİSCUSSİON

Depends on analysis data from the biophilic impact on sustainble credits and ecological foot print we admit the study was competitive among high-rise buildings which applied most of the requirements, within the features of biophilic. The use of materials inspired by nature was not applied except in two buildings, such as the Oasis Hotel and Parkroyal Collection Pickering. The author also found the Comerzbank building did not meet the credit of sustainable site.

The author remark the usage of green façades, open sky gardens, flora, natural vegetations, and dark foliage shading might be the finest alternatives to manage energy consumption in addition to reducing the UHI effects on the ecological footprint. In terms of water management, most buildings use water harvesting systems for automatic irrigation, but water recycling system application in building would be more sustainable solution for building, such as oasis hotel water management, site sustainable applying is varies and fair for both sustainable ecolocical footprint challenges of the areas by using green roof within energy management system including stormwater system, and this appears more into the edge.Air quality Improvment considered to be the most essential concern in the highrise building Credits, along with thermal design and comfort. It discovers that the structure of buildings necessitates smart green applications that can take advantage of natural resources through the usage of green vegetation.The discussion ends with material use, which demonstrates the vulnerability of most buildings; applying greeny to structures can reduce environmental impact; the author recognise grey composite materials and the use of timber into the Bosco vertical and Parkroyal Collections Pickering can be decent and more advanced in terms of environmental needs than Commerzbank, which appears to be the weakest building of all in applying sustainbility by biophilic featuers from the exterior.

V. CONCLUSİON AND RECOMMENDATİONS

This study has identified that biophilic design can actually play an influential role in trying to solve the various issues of sustainability related to high-rise buildings. The integration of natural elements and strategies in design enhances ecological sustainability, hence improving the living standard of people residing or working within those buildings. The study, through five high-rise case studies of biophilic design in buildings around the world-Oasia Hotel Downtown, Singapore; Bosco Verticale, Milan; The Edge, Amsterdam; Commerzbank, Frankfurt; and Parkroyal Collection Pickering, Singapore-showcases real and quantifiable benefits related to energy efficiency, water management, air quality improvement, thermal comfort, and material use.

Results indicated that the best-performing high-rise buildings are those designed with biophilic features such as green façades, vertical gardens, systems for water management, and the use of natural materials. Moreover, integrating renewable energy systems, green roofs, and smart technologies contributes not only to cost reductions but also to enhancing environmental resilience. While most case studies present astonishing strategies of sustainability, some areas of concern still remain: challenges in the application of natural materials, water recycling, and site-specific adaptability.

Its seems the use of natural source isn’t only way to obtain sustainability, the author finds high-rise buildings materials calls to more studies on installation materials, biophilic design can offer using natural materials or simulation which can helps sustainable challenges in addition to improves future buildings. Using of glass as main shape isn’t favorable to recent biophilic high-rise buildings, although natural material could be new approach to observe for future researches .The research findings show that biophilic design not only reduces ecological footprints, but also improves the overall sustainability of high-rise buildings by promoting energy efficiency, better air quality, and biodiversity protection. By integrating urban spaces to nature, these designs contribute significantly to environmental protection while also improving residents' living situations. there is still a need to refer to some recommendations can be consider to next step while planning to integrate biophilic features into sustainable high-rise buildings:

- Use green facades and vertical vegetation to reduce cooling loads, to reduce energy usage in tropical and temperate regions.
- Apply modern rainwater collection and greater recycling systems for irrigation and landscaping.
- Use substantial greenery to reduce urban heat islands (UHIs) and manage storm water.
- Green roofs and ecological corridors can improve biodiversity and reduce environmental impact.
- Apply green façade, dense vegetation, and indoor plants to minimize CO_2 and filter fine particulate matter.
- Advanced air filtration technologies, together with natural plants, help improve indoor air quality and occupant health.
- Use natural ventilation, shade from plants, and high-performance glazing to improve thermal comfort .
- Vertical vegetation and curving floor designs can mimic nature and help indoor temperature regulation.
- Consider obtained renewable materials like timber and grey composites materials such as stoneware.

REFERENCES

[1]. Doraj, P., Aluclu, I., & Hossein Eskandani, O. (2021). The impact of architectural structures from past to present on developing tourism (example of the city of paris). International Journal of Scientific and Technological Research (JSTR), 7(9), 8-19. https://doi.org/10.7176/JSTR/7-09-02 .

[2]. Moreira, A. C., Ribau, C. P., & Rodrigues, C. D. S. F. (2022). Green supply chain practices in the plastics industry in Portugal. The moderating effects of traceability, ecocentricity, environmental culture, environmental uncertainty, competitive pressure, and social responsibility. Cleaner Logistics and Supply Chain, 5, 100088. https://doi.org/10.1016/j.clscn.2022.100088

[3]. Bartlett, E., & Howard, N. (2000). Informing the decision makers on the cost and value of green building. Building Research & Information, 28(5-6), 315-324. https://doi.org/10.1080/096132100418474

[4]. Rahmani, A., Mashayekh, J., Aboojafari, R., & Naeini, A. B. (2023). Determinants of households' intention for investment in renewable energy projects. Renewable Energy, 205, 823-837. https://doi.org/10.1016/j.renene.2023.01.096

[5]. Saleki, S., & Bahramani, S. K. (2018). Designing a Low-Carbon Building via LCB Method 3.0, Case Study: An Educational Building in Tehran. Journal of Construction in Developing Countries, 23(2), 129-150. https://doi.org/10.21315/jcdc2018.23.2.8

[6]. Ascione, F., Bianco, N., Mauro, G. M., & Napolitano, D. F. (2021). Knowledge and energy retrofitting of neighborhoods and districts. A comprehensive approach coupling geographical

information systems, building simulations and optimization engines. Energy Conversion and Management, 230, 113786. https://doi.org/10.1016/j.enconman.2020.113786
[7]. Lima, I., Scalco, V., & Lamberts, R. (2019). Estimating the impact of urban densification on high-rise office building cooling loads in a hot and humid climate. Energy and Buildings, 182, 30-44. https://doi.org/10.1016/j.enbuild.2018.10.019
[8]. Riahi, P., Mehrabani, SR., Safari Moradabadi, M. (2014). Investigating the effects of climate on the structure and body of architecture in cold and mountainous regions (case example: Palangan village), The first national conference on sustainable development in the sciences of geography and planning, architecture and urban planning, https://civilica.com/doc/336720
[9]. Gong, Y., Zoltán, E. S., & Jánoš, G. (2023). Healthy Dwelling: The Perspective of Biophilic Design in the Design of the Living Space. Buildings, 13(8), 2020. [Available at: https://www.mdpi.com/2075-5309/13/8/2020]
[10]. Radha, C. H. (2022). Biophilic Design Approach for Improving Human Health in the Built Environment. Journal of Urban Research, 13(1), 65-78. [Available at: https://www.researchgate.net/publication/364051002_Biophilic_Design_Approach_for_Improving_Human_Health_in_the_Built_Environment]
[11]. Kellert, S. R. (2018). Nature by Design: The Practice of Biophilic Design. Yale University Press. [Available at: https://yalebooks.yale.edu/book/9780300246282/nature-design
[12]. Hong, Y., Deng, W., & Ezeh, C. I. (2019, May). Low-rise office retrofit: prerequisite for sustainable and green buildings in Shanghai. In IOP Conference Series: Earth and Environmental Science (Vol. 281, No. 1, p. 012025). IOP Publishing. https://doi.org/10.1088/1755-1315/281/1/012025
[13]. Kadaei, S., Nezam, Z., González-Lezcano, R. A., Shokrpour, S., Mohammadtaheri, A., Doraj, P., & Akar, U. (2023). A new approach to determine the reverse logistics-related issues of smart buildings focusing on sustainable architecture. Frontiers in Environmental Science, 10, 2510. https://doi.org/10.3389/fenvs.2022.1079522
[14]. Qian, D., Li, Y., Niu, F., & O'Neill, Z. (2019). Nationwide savings analysis of energy conservation measures in buildings. Energy Conversion and Management, 188, 1-18. https://doi.org/10.1016/j.enconman.2019.03.035
[15]. Capellán-Pérez, I., Campos-Celador, Á., & Terés-Zubiaga, J. (2018). Renewable Energy Cooperatives as an instrument towards the energy transition in Spain. Energy Policy, 123, 215-229. https://doi.org/10.1016/j.enpol.2018.08.064
[16]. Kellert, S. R., Heerwagen, J., & Mador, M. (2008). Biophilic Design: The Theory, Science, and Practice of Bringing Buildings to Life. Wiley Scribd. (n.d.). Commerzbank Tower facts. Retrieved December 8, 2024.
[17]. Browning, W. D., Ryan, C. O., & Clancy, J. O. (2014). 14 Patterns of Biophilic Design: Improving Health & Well-Being in the Built Environment. Terrapin Bright Green. Retrieved from https://www.terrapinbrightgreen.com
[18]. Smith, J. (2023). "The Role of Green Roofs in Urban Sustainability." Journal of Environmental Science, 45(2), 123-135.
[19]. Brown, L. (2022). "Biophilic Design and Its Impact on Urban Environments." Urban Planning Review, 38(4), 201-215.
[20]. Green, A. (2021). "Sustainable Building Practices in Modern Architecture." Sustainable Development Journal, 12(3), 89-102
[21]. Ardiani, A., Soemanto, S., & Murti, B. (2020). Meta-analysis: The association between social support and postpartum depression. Journal of Maternal and Child Health, 5(6), 641–650. https://doi.org/10.26911/thejmch.2020.05.06.04
[22]. Athienitis, A. (2007). The impact of shading design and control on building cooling and lighting demand. Solar Energy, 81(3), 369–382. https://doi.org/10.1016/j.solener.2006.06.015
[23]. Chong, W. T., et al. (2020). "Challenges and opportunities for achieving net-zero energy buildings in high-rise construction." Energy Reports, 6, 1245-1253.
[24]. Berndtsson, J. C., et al. (2022). "Green roofs for urban sustainability: A systematic review of performance and challenges." Environmental Science & Technology, 56(3), 2118-2129.
[25]. Cabeza, L. F., et al. (2022). "Sustainable building materials: Challenges and opportunities." Sustainable Materials and Technologies, 27, 100340.
[26]. Huang, X., et al. (2021). "Self-healing concrete: State-of-the-art review." Construction and Building Materials, 267, 121282.
[27]. Beatley, T. (2023). Biophilic Cities: Integrating Nature into Urban Design and Planning. Island Press.
[28]. Benedict, M. A., et al. (2021). Green Infrastructure: Smart Conservation for the 21st Century. Island Press.
[29]. Santamouris, M. (2020). Recent progress on urban overheating and heat island research: Integrated assessment of the energy, environmental, vulnerability and health impact, synergies with global climate change. Energy and Buildings, 207, Article 109482. https://doi.org/10.1016/j.enbuild.2019.109482
[30]. Wong, T., Brown, R., & Deletic, A. (2008). Water management in a water sensitive city. Water, 35(11), 52–62.
[31]. Liu, D.; Liang, J.; Xu, S.; Ye,M. Correction: Liu et al. Analysis of Carbon Emissions Embodied in theProvincial Trade of China Based on an Input–Output Model and k-Means Algorithm. Sustainability 2023, 15, 9196. Sustainability 2023, 15, 15912. https://doi.org/10.3390/ su152215912
[32]. Kaushik, A., Mohammed, P., Tumula, D., & Ebohon, P. (2020). Effect of thermal comfort on occupant productivity in office buildings: Response surface analysis. Building and Environment, 180, Article 107021. https://doi.org/10.1016/j.buildenv.2020.107021
[33]. Ghaffar, S., Burman, M., & Braimah, N. (2019). Pathways to circular construction: An integrated management of construction and demolition waste for resource recovery. Journal of Cleaner Production,

244, 118710. https://doi.org/10.1016/j.jclepro.2019.118710
[34]. Kellert, S. R., et al. (2021). Biophilic Design: The Theory, Science, and Practice of Bringing Buildings to Life. Wiley.
[35]. Nieuwenhuis, M., Knight, C., Postmes, T., & Haslam, S. (2014). The relative benefits of green versus lean office space: Three field experiments. Journal of Experimental Psychology: Applied, 20, 199–214. https://doi.org/10.1037/xap0000024
[36]. Hong et al. City and Built Environment (2023) 1:2 https://doi.org/10.1007/s44213-022-00002-9
[37]. Saadatian, O., Sopian, K., Salleh, E., Lim, C. H., Riffat, S., Saadatian, E., Toudeshki, A., & Sulaiman, M. Y. (2013). A review of energy aspects of green roofs. Renewable and Sustainable Energy Reviews, 23, 155–168. https://doi.org/10.1016/j.rser.2013.02.022
[38]. Glicksman, R. (2004). Environmental Law and Policy. Ecological Economics.
[39]. Council on Tall Buildings and Urban Habitat (CTBUH). (2018). Oasia Hotel Downtown Singapore: A tall prototype for the tropics. Retrieved from https://global.ctbuh.org/resources/papers/download/3790-oasia-hotel-downtown-singapore-a-tall-prototype-for-the-tropics.pdf
[40]. Council on Tall Buildings and Urban Habitat (CTBUH). (n.d.). A new urban forest rises in Milan. Retrieved from https://global.ctbuh.org/resources/papers/download/2099-a-new-urban-forest-rises-in-milan.pdf
[41]. Author, N., & Čamprag, N. (2015). Frankfurt and Rotterdam: Skylines as embodiment of a global city. CTBUH Journal, 2015, 26–32.
[42]. Scribd. (n.d.). Commerzbank Tower facts. Retrieved December 8, 2024, from Gissen, D. (2003). Big and Green: Toward Sustainable Architecture in the 21st Century. Princeton Architectural Press. [Available at: https://www.papress.com/big-and-green]
[43]. Powell, K. (2006). Architecture Reborn: Converting Old Buildings for New Uses. Laurence King Publishing. [Available at: https://www.laurenceking.com/product/architecture-reborn/]
[44]. Centre for Digital Built Britain (CDBB). The Edge: A Case Study on the Integration of Smart Technology and Sustainability. Cambridge University, n.d., https://www.cdbb.cam.ac.uk/system/files/documents/TheEdge_Paper_LOW1.pdf.
[45]. Terrapin Bright Green. (2015). Parkroyal case study. Retrieved from https://www.terrapinbrightgreen.com/wp-content/uploads/2015/11/Parkroyal_Case-Study.pdf
[46]. Tilleman, R. (n.d.). The Edge / PLP Architecture [Photograph]. ArchDaily. https://archinspires.com/2024/08/12/case-study-sustainable-features-of-the-edge-in-amsterdam/