Journal of
Design Studio
v:2 n:1 July 2020

Do Green Building Standards Meet the Biophilic Design Strategies?

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Received: April 28th 2020, Revised: May 19th 2020, Accepted: May 31th 2020
Refer: Sat, Gungor, B., (2020), Do Green Building Standards Meet the Biophilic Design Strategies?, Journal of Design Studio, V.2, N.1, pp 5-23,

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DOI: 10.46474/jds.739849. https://doi.org/10.46474/jds.739849

Abstract. Energy efficiency in buildings, comprises many things as mitigation effect of global warming and climate change, decreasing heat island effect in the built environment and also conservation of natural resources. Besides as a new phenomenon we should add biophilic design criteria to the green building tools to increase human productivity by considering human wellbeing. Biophilic design, which inspired by nature, is a new juvenile design concept that gains importance day by day because of its positive effects on human wellbeing mood and relatedly human productivity. Here some conflicts can be occurred between energy saving and human wellbeing; as natural ventilation and energy saving.

Biophilic design comprises inherent human inclination to affiliate with nature. All sensations which help to be in contact with natural components as daylight, plants or some animal species like birds; plants occupy an important place in its definition. Biophilic design seeks to create good habitat for people as a biological organism in the modern built environment that promotes people's health, fitness and wellbeing. Scientific studies reveal that contact with nature has significant effects on people's physical and mental health, performance and wellbeing. This phenomenon has, an increasing importance more than ever before, especially in daily life. The need for beneficial contact with nature continues in today's built environment. This paper aims to determine whether the biophilic design strategies are match with green building tools that mostly targeting energy saving in built environment. Also paper handling whether the 14 biophilic design patterns are match with 3 main mind-body systems that are; stress reduction, cognitive performance and emotion mood preference.

Keywords: Biophilic design, natural systems, energy saving, green building tools, mind-body systems

The Term biophilia and biophilic design?

The term 'biophilia' was first used by social psychologist Eric Fromm (1964) at "The Heart of Man" and later popularized by biologist Edward Wilson (Fromm, 1964; Browing et al., 2014). The American biologist and entomologist, Edward O. Wilson, was the first to clarify the importance of contact with nature for the psychological development of people. Edward O. Wilson introduced and popularized the hypothesis in his book, "Biophilia". He defines biophilia as "the urge to affiliate with other forms of life". The term biophilia means interact with other living systems and he describes the connections that human beings subconsciously seek with the other forms of life (International Well Building Institude, 2019); for millions of years our species was related to its wild environment, created a kind of dependency, an overwhelming emotional need to be in contact with other living beings. This inherent need was called Biophilia (Wilson 1984, 1993; Sanchez et. Al. 2018). The scientists Roger S. Ulrich and Stephen Kellert gave the final approach to the term Biophilia by defining it as "the innate human affinity for nature" (Sanchez, 2018).

Although the term biophilia, named by Fromm, has been proposed and defined over many times (Browing et al. 2014), it is also defined by

Kellert (2008) as an inherent human inclination to natural systems and processes and it urges us to affiliate with other forms of life (Kellert, 2008; Xue et al., 2019a). The concept of biophilia is the idea of human contact with nature. This connection has been thought beneficial for human physical and mental well-being. A study reveals the benefits of nature as healing effect (Reeve et al., 2017). As pointed out by Beatley (2016), nature is not optional, but an absolutely essential quality of modern urban life. The essential benefits of biophilia urges us not only to conserve and restore the natural elements that already exist but, insert new forms of nature for the twenty first century (Xue et al. 2019a; Beatley, 2016).

Biophilic design came in sight after the term biophilia. Alexander (2002) defines biophilic design as "integration" or sometimes "manipulation" of natural elements or systems to create sense of "life" in the built environment (Alexander, 2002). Biophilic design, defined as a response to the inherent need of human beings to be in contact with nature, improves productivity in the workplaces (Sanchez, 2018). Recently, the concept of biophilic design has received attention among practitioners and environmental psychologists (Lee, 2019). Kellert et al. (2011) explained that biophilic design inspires firms to use natural systems and processes in the design of the built environment. Biophilic design fulfills the human need for exposure to nature and several studies have shown benefits of natural features and systems into the built environment on people. Studies revealed that adding natural light and windows significantly improve participants' mood (Kellert et al., 2011; Zadeh et al., 2014). This effect of biophilic design considered since it is related with human productivity. People's concentration increases after they spend time in nature or even view scenes of nature; reduces stress, improves cognitive functions and creativity (Lee, 2019). As the world population continues to urbanize these qualities will be ever more important (Browing et al., 2014). The United Nations predicts that by 2030, 60% of the world's population will live in urban environments (UN-HABITAT, 2019).

When the biophilic design considered to increase human productivity, the studies' direction changes to follow those related subjects; Sutermeister (1976) defines performance as a quality considered output per employee hour. Accuracy and speed are the two distinct aspects to measure of human performance. Accuracy is defined as a measure of the quality of behaviour (Sanchez et al., 2018). Biophilic design modifies and apply the natural systems in the built environment for human wellbeing in many aspects and indirectly effects human performance. Biophilic spaces have been defined as spaces that strengthen life and support the sociological and psychological components (International Well Building Institute, 2019).

Key strategies of biophilic design

According to the biophilic design concept, 25 biophilic design strategies are identified by considering the related references. The key strategies of the Biophilic Design have been analysed and summarized as below table (Xue et al., 2019a).

Table 1. *Key strategies of Biophilic Design (Xue et al., 2019a).*

Biophilic Design Aspects	**Indicators**	**Strategies**	**References**
Biophilic Infrastructure	Biophilia ratio	Increase green space coverage ratio;	Barton and Pretty (2010)
		Promotes plant canopy configuration for shading and sheltering;	Xue et al. (2017b)
		Enhance native species ratio;	Oldfield et al. (2015)
		Enhance biodiversity level;	Maes et al. (2016)

		Enlarge water area;	White et al. (2010)
		Diverse water configuration and appearance;	(Hunter et al. 2010; Ulrich et al. 1991)
	Biophilia management	Natural landscape promotion and with minimal management;	Hwang and Yue (2015)
		Permeable surfaces for stormwater management;	(Beatley 2011; Stovin 2009)
		Enhance natural ventilation and airflow design;	Ignatius et al. (2015)
		Enhance daylight and shadow design;	(Aries et al. 2015; Hraska et al. 2015)
Sensorial Design	Visual connection with nature	Optimize window view of the natural landscape, i.e. forest, seascape etc.;	(Ambrey and Fleming 2014, Schweitzer 2004)
		Optimize window view of weather changes i.e. sunshine, rain, snow;	Kellert et al. (2008)
		Provide indoor potting plants;	Chang and Chen (2005)
		Provide indoor green walls;	(Beatley 2000, 2012)
		Provide observable art works i.e. painting, sculpture etc.;	Zbaśnik-Senegaènik and Kuzman (2014)
	Non visual connection	Natural sound design i.e. wind, song of birds and insects etc.;	Browing et al. (2014)
		Aromatic plant design;	Mlnar and Vodvarka (2004)
		Urban farming, plants touching and tasting activities;	Gonzales and Kirkevold (2014)
	Thermal comfort and airflow	Openable window for natural ventilation;	Gou et al. (2014)
		Thermal comfort controls as air temperature, humidity;	USGBC (2013)
Biophilic Setting and Performance	Biomorphic forms and patterns	Biophormic building form and façade for energy cost reduction;	(Senosiain Aguilar 2003, Zevi 1959)
		Biophormic ornament design;	Pawlyn (2011)
		Surface pattern design from natural environment;	Pawlyn (2011)
	Natural material and color design	Natural material selection as wood, bamboo, rock etc.;	(Tsunetsugu et al. 2007, WGBC 2014)
		Color selection to enhance creative environments	Lichtenfeld et al. (2012)

Briefly the included biophilic design strategies according to the biophilic design aspects are explained below;

Biophilic infrastructure aspect includes biophilia ratio and biophilia management; biophilia ratio is the percentage or quantity of natural elements available to users, green area cover ratio, plants canopy configuration, native species ratio, biodiversity level, and water area and appearance. Biophilia management measures the quality of the elements such as how natural landscapes require minimal management: the availability of permeable surfaces for stormwater management, the use of natural ventilation and airflow as well as the presence of daylight and shadow design. Biophilic infrastructure is more related on quality than quantity.

Sensorial design aspect, includes visual connection, non-visual connection, thermal comfort and airflow. Visual connections with nature are the most obvious methods of biophilic design and can be achieved through having window views of natural landscapes. Non-visual connections with nature engage the other senses such as through natural sound design, aromatic plant design natural elements related art works. Natural ventilation is another factor allows people to feel in-touch with nature.

Biophilic setting and performance aspect includes biomorphic forms and patterns and natural materials and colors. This creates a visual connection with nature with other benefits such as enhancing creativity (Xue et al., 2019a).

The visual connection with nature is an important strategy in the field of art, since implementation is relatively easier to create. Especially art works inspired by natural systems are in demand recently. This form of art combines natural daylight with natural inspired artwork. Stained glass designed by inspiration of natural cells structure, is used as the contemporary artwork in a public space, as shown in the example provided in Figure 1 and visual connection with water element that reflects light and weather conditions from above and invites by-passers to touch it, as in the example of the Luxembourg Gardens in Paris in Figure 2. Children or adults spend time by floating their wooden model sailboats and enjoy the pool's climatic effect.

Figure 1: *contemporary stained glass art work inspired from cells by Ayşe G. Süter . Photo By: Pere Virgill (Süter, 2015).*

Figure 2: *Water use in Luxembourg garden in Paris Photo Jiel Beaumadier CC BY-SA (Beaumadier, 2006).*

Biophilic design strategies and Green Building Ratio Tools (GBRTs)

Green Building Ratios are an indicator to measure green architecture. They are more focused on energy efficiency. How can we measure the biophilic designed space meets human wellbeing and improve productivity? This question's answer is a challenge. Actually there are many indoor stressors effective on human wellbeing and productivity, such as excessive thermal factors, lighting aspects, moisture, noise and vibration, radiation, chemical compounds, and particle fluctuations. In a place, a whole range of effects has been associated with these stressors that known as Sick Building Syndrome (SBS) (Sanchez et al., 2018). A research implemented in Keio University – which focused on the element that is most valued at the work environment - shows that in top five natural light was the most valued element, followed by indoor plants and vivid colours. Use of daylight is most effective on reducing the fatigue feeling.

Biophilic design strategies are added to the principles of Green architecture. In fact, biophilic design includes some of the green building standards but it targets not only energy saving but also human wellbeing, good mood and productivity. Biophilic strategies and their sub-relevant categories are matched with updated Green Building Rating Tools (GBRTs) as LEED (Leadership in Energy and Environmental Design), BREEAM (Building Research Establishment Environmental Assessment) GM NRB (Green Mark Non-Residential Building), GBL (Green Building Label), WBS (Well Building Standard) and LBC (Living Building Challenge). The framework is used in a recent study to emphasize the shifting of GBRTs from the energy-oriented approach to a human-oriented approach through biophilic strategies (Xue et al., 2019b).

Table 2: Selected GBRTs

Selected GBRTs	Classification
LEED	Internationally most widespread, industry standard for sustainability (Shan and Hwang, 2018; Xie and Gou, 2017).
BREEAM	
GBL	Developed and employed in the local situations and are tailored to native climates and contexts: respectively China and Singapore (Hwang et al., 2016; Shan and Hwang, 2018; Ye et al., 2015; Zou et al., 2017).
GM	
WBS	Innovative green building regulations which focus on human health and wellbeing. First protocol to address human wellness into the built environment (Morton, 2015).
LBC	

Each GBRT credit has been assessed in terms of its intent to improve human health and wellbeing. Some credits such as thermal comfort and air quality are dedicated to improving human health; these credits are easily identified as human-oriented credits. Some credits such as public transport and cycling have multi-purposes including reducing greenhouse gas emissions while improving health and wellbeing. These credits are also human-oriented credits. Other credits that are dedicated to energy efficiency and greenhouse gas emission reduction are excluded. Prominently, WBS and LBC have more credits on human health and wellbeing. The GBRT credits are generally grouped in 8 categories: Place, Transport, Energy, IEQ (Indoor Environmental Quality), Water, Material, Health and Management. The relationship between the 8 categories of GBRT credits and the 6 different GBRT's are analysed in a cross-table by considering biophilic design strategies (Xue et al., 2019b).

As seen in Table 3.1 the biophilic infrastructure deals with essential comfortable conditions for human wellbeing as natural ventilation and day light.

Table 3.1: GBRTs matching with "biophilic infrastructure" design category and strategies (Xue et al., 2019b).

Strategies	**LEED**	**BREEAM**	**GM**	**GBL**	**WBS**	**LBC**
Increase green space coverage ratio;	Place		Place	Place	Place	
Promote plants canopy configuration for shading and sheltering;	Place	Place	Place	Place	Place	
Enhance native species ratio;	Place	Water	Place	Place		Place
Enhance biodiversity level;	Place	Place	Place	Place		Place
Enlarge water area;						
Diverse water configuration and appearance;			Place	Water		

Natural landscape promotion with minimal management;	Water	Place	Place	Place		Place
Permeable surfaces for storm water management;	Place	Water	Place	Place		Water
Enhance natural ventilation and airflow design;	IEQ	IEQ	IEQ	IEQ	IEQ	IEQ
Enhance daylight and shadow design;	IEQ	IEQ	IEQ	IEQ	IEQ	IEQ

"Enlarge water area" biophlic infrastructure design category does not match any of the GBRTs and "Diverse water configuration and appearance" category just match with two of the GBRTs. In this table we can summarize just three of the credits as water, place and IEQ related with biophilic infrastructure design category.

Table 3.2 presents the sensorial design category of biophilic design strategies that match with GBRT credits like Place, IEQ (Indoor Environmental Quality) and Health.

Table 3.2: GBRTs matching with "sensorial design" design category and strategies (Xue et al., 2019b).

Strategies	**LEED**	**BREEAM**	**GM**	**GBL**	**WBS**	**LBC**
Optimize window view of the natural landscape. i.e. forest, seascape, water motif, etc.;	IEQ	IEQ		IEQ	IEQ	IEQ
Optimize window view of weather changes (i.e. the sunshine, rain, snow);	IEQ	IEQ			IEQ	
Provide indoor potting plants;			Health		Health	
Provide indoor green walls;			Health	IEQ	Health	
Provide observable artworks (i.e. painting, sculpture);			Health		Health	Health

Natural sound design (i.e. the wind, song of birds and insects);					Health	
Aromatic plant design (i.e. certain trees and flowers);						
Urban farming (i.e. plants-touching and tasting activities);	Place				Health	Place
Openable window for natural ventilation;	IEQ	IEQ	IEQ	IEQ	IEQ	IEQ
Individual/group thermal comfort controls (i.e. air temperature, air speed, and	IEQ	IEQ	IEQ	IEQ	IEQ	IEQ

"Sensorial design" category includes only three credits as IEQ, health and place. Place has seen just at LBC tool. Health and IEQ seen as more related with sensorial design category in biophilic design strategies.

Table 3.3. presents the relation to the built environment, through materials, textures, forms and structures. It is at this level where energy efficiency provided by the thermal insulation and ventilation is tackled.

Table 3.3: GBRTs matching with "Biophilic setting and performance" design category and strategies (Xue et al., 2019b).

Strategies	**LEED**	**BREEAM**	**GM**	**GBL**	**WBS**	**LBC**
Biomorphic building form and façade for energy cost reduction;			Health			Health
Biomorphic ornament design (i.e. Golden mean and Fibonacci series);			Health			Health
Surface pattern design from natural environment (i.e. pattern of animal skin);			Health			Health
Natural material selection, i.e. wood, bamboo, rock, etc.;	Material	Material	Material	Material	Material	Material

Color selection to enhance creative environments.	Health				Health	

"Biophilic setting and performance" category includes mainly health and material credits in biophilic design strategies. Mainly GM and LBC matches.

Table 3.4 emphasized the fact that Place, Health and IEQ (Indoor Environmental Quality) credits are dominant in the transportation connectivity category of biophilic design strategies.

Table 3.4: GBRTs matching with "transportation connectivity" design category and strategies (Xue et al., 2019b).

Strategies	**LEED**	**BREEAM**	**GM**	**GBL**	**WBS**	**LBC**
Locate public bus/MRT station within 300m walking distance;	Transport	Transport		Transport	Transport	Transport
Provide a fully connected pedestrian network;	Transport	Transport			Transport	
Provide shaded corridors/bridges between buildings and districts;						
Provide fully accessible and dedicated cycling lanes;	Transport	Transport	Transport	Transport	Place	
Configure with bike parking facilities;	Transport	Transport	Transport	Transport	Place	Place
Configure with change room and shower facilities;	Transport	Transport	Transport		Place	Place
Provide landmark in public open space for attraction and gathering;						
Effective visual information system design for wayfinding and collaboration;	Place	Transport			Place	
Locate public bus/MRT station within 300m walking distance;	Transport	Transport		Transport	Transport	Transport

"Transportation connectivity" category includes just transport and place credits in biophilic design strategies match. GM and LBC seen weaker in this category match.

Table 3.5 indicates "place" and "management" credits that meet with the work-live-play integration category of the biophilic design strategy.

Table 3.5: GBRTs matching with "work-live-play integration" design category and strategies (Xue et al., 2019b).

Strategies	**LEED**	**BREEAM**	**GM**	**GBL**	**WBS**	**LBC**
Share public green spaces, open plaza and community spaces;	Place	Management	Management	Place	Management	Place
Share food & beverage, food court facilities;	Place	Management			Management	
Share learning and collaboration facilities;	Place	Management		Place		
Security management (i.e. patrol, CCTV);		Management				
Enhance facility and site maintenance;	Management	Management	Management	Management	Management	Management

"Work-live-play" integration category includes just management and place credits in biophilic design strategies match again GM and LBC seen weak in this category match. "Green space place making" *category mostly matches with* WBS and includes just place and management credits.

Most of the biophilic strategies (%85) are matching with GBRTs. 5 biophilic strategies that are presented below does not match any of the GBRTs;
- enlarge water area,
- aromatic plant design,
- shaded corridors/bridges between buildings and districts,
- landmark in public open space for attraction and gathering
- shaded outdoor seats for café and restaurants.

Table 3.6: GBRTs matching with "green space place making" design category and strategies (Xue et al., 2019b).

Strategies	LEED	BREEAM	GM	GBL	WBS	LBC
Provide shaded outdoor seats for café and restaurants;						
Volunteer-engagement for urban farming;					Place	Place
Provide Friday/holiday market (vegetable, food, and other commercial sales);	Place				Place	
Provide outdoor performance/exhibition of art events during lunch breaks (i.e. live		Management	Management	Management	Management	Management

Biophilic patterns and mind-body systems

Mind-body systems that relate directly with people's health and well-being are impacted by the environment. Table 4 clarifies the relationships between 14 biophilic design patterns and mind-body systems with related references. Biophilic design addresses to people as a biological organism, respecting the mind-body systems as indicators of health and well-being. There are three factors identified in mind-body systems. Those considered main mind-body systems are; stress reduction, cognitive performance and emotion mood preference.

Table 4: *14 Biophilic Design Patterns matching with Mind-Body Systems (Browing et al., 2014).*

		No*	Mind-body systems		
14 patterns		3	Stress reduction	Cognitive performance	Emotion, mood preference
Nature in the Space	Visual connection with nature	2	Lowered blood pressure and heart rate (Brown, Barton & Gladwell, 2013; van den Berg, Hartig, & Staats, 2007; Tsunetsugu & Miyazaki, 2005)	Improved mental engagement/ attentiveness (Biederman & Vessel, 2006)	Positively impacted attitude and overall happiness (Barton & Pretty, 2010)
	Non-visual connection with nature	2	Reduced systolic blood pressure and stress hormones (Park, Tsunetsugu, Kasetani et al., 2009; Hartig, Evans, Jamner et al., 2003)	Positively impacted on cognitive performance	Perceived improvements in mental health and tranquility (Li, Kobayashi, Inagaki et al., 2012; Jahncke, et al., 2011; Kim, Ren, & Fielding, 2007; Stigsdotter & Grahn, 2003)
	Non-rhythmic sensory with stimuli	2	Positively impacted on heart rate, systolic blood pressure and sympathetic nervous system activity	Observed and quantified behavioral measures of attention and exploration (Windhager et al., 2011)	

			(Kahn et al., 2008; Beauchamp, et al., 2003)		
	Thermal & Airflow with variability	2	Positively impacted comfort, well-being and productivity (Heerwagen, 2006; Tham & Willem, 2005; Wigö, 2005)	Positively impacted concentration (Hartig et al., 2003; Hartig et al., 1991; R. Kaplan & Kaplan, 1989)	Improved perception of temporal and spatial pleasure (alliesthesia) (Parkinson, de Dear & Candido, 2012; Zhang, Arens, Huizenga & Han, 2010; Arens, Zhang & Huizenga, 2006; Zhang, 2003; de Dear & Brager, 2002; Heschong, 1979)
	Presence of Water	2	Reduced stress, increased feelings of tranquility, lower heart rate and blood pressure (Alvarsson, Wiens, & Nilsson, 2010; Biederman & Vessel, 2006)	Improved concentration and memory restoration (Alvarsson et al., 2010; Biederman & Vessel, 2006) Enhanced perception and psychological responsiveness (Alvarsson et al., 2010; Hunter et al., 2010)	Observed preferences and positive emotional responses (Windhager, 2011; Barton & Pretty, 2010; White, Smith, Humphryes et al., 2010; Karmanov & Hamel, 2008; Biederman & Vessel, 2006; Heerwagen & Orians, 1993; Ruso & Atzwanger, 2003; Ulrich, 1983)
	Dynamic & Diffuse light	2	Positively impacted circadian system functioning (Figueiro, Brons, Plitnick et al., 2011; Beckett & Roden, 2009) Increased visual comfort (Elyezadi, 2012; Kim & Kim, 2007)		
	Connection with natural systems				Enhanced positive health responses; Shifted perception of environment (Kellert et al., 2008
Natural Analogues	Biophormic Forms & Patterns	1			Observed view preference (Vessel, 2012; Joye, 2007)
	Material Connection with Nature			Decreased diastolic blood pressure (Tsunetsugu, Miyazaki & Sato, 2007) Improved creative performance (Lichtenfeld et al., 2012)	Improved comfort (Tsunetsugu, Miyazaki & Sato 2007)
	Complexity & Order	2	Positively impacted perceptual and physiological stress responses		Observed view preference (Salingaros, 2012; Hägerhäll, Laike,

			(Salingaros, 2012; Joye, 2007; Taylor, 2006; S. Kaplan, 1988)		Taylor et al., 2008; Hägerhäll, Purcella, & Taylor, 2004; Taylor, 2006)
Nature of the Space	Prospect	3	Reduced stress (Grahn & Stigsdotter, 2010)	Reduced boredom, irritation, fatigue (Clearwater & Coss, 1991)	Improved comfort and perceived safety (Herzog & Bryce, 2007; Wang & Taylor, 2006; Petherick, 2000)
	Refuge	3		Improved concentration, attention and perception of safety (Grahn & Stigsdotter, 2010; Wang & Taylor, 2006; Wang & Taylor, 2006; Petherick, 2000)	
	Mystery	2			Induced strong pleasure response (Biederman, 2011; Salimpoor, Benovoy, Larcher et al., 2011; Ikemi, 2005; Blood & Zatorre, 2001)
	Risk/Peril	1			Resulted in strong dopamine or pleasure responses (Kohno et al., 2013; Wang & Tsien, 2011; Zald et al., 2008)

*** numbers are giving the patterns which are supported more empirical data**

Discussion and Conclusion

When we examine the GBRT's with biophilic design strategies; it is obvious that the GBRT's are insufficient to meet the needs of biophilic design. New approaches and additions should be provided to meet those strategies in the concept of human wellbeing, good mood and productivity. In the other hand it is obvious that biophilic patterns are effective on mind-body systems positively. However, it needs more empirical data on that. Some nature interactions can even induce stress or fear responses. Fortunately, an emerging number of studies teach us which specific interactions with nature are restorative and which are stressful. Understanding how people viscerally respond to nature and how such beneficial experiences can be supported in urban settings is essential to shaping a healthy and vibrant society. Biophilic design must be implemented correctly to optimize health benefits (Ryan, 2014).

The therapeutic influence of the natural environment on human is being lost, touch of nature into our daily lives can raise this again. The scientific results that supporting biophilic design is still emerging. Deep down, we know that the connection to nature is important. While empirical evidence is accumulating, we ought to go about restoring the human-nature connection in the built environment. In coming decades, it is projected that 70 percent of the world's population will live in cities. It makes human more be in search of nature to feel fresh. This is estimated that biophilic design will get more important day by day. Biophilic Design helps shed light on the importance of the human connections with nature in our built environment and encourages people to challenge convention by bringing biophilic design patterns into a vision for healthy homes, workplaces and cities.

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