BIOPHILIC SOLUTIONS THAT CAN BE USED IN AMC BUILDING TO MAXIMIZE ENERGY EFFICIENCY

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ABSTRACT

This paper acts as a guideline for Academic Medical Center(AMC) in Amsterdam on how to implement biophilic design solution into their buildings. The paper will mainly focus on biophilic design solutions in the facade and interior. The expected outcome will be to maximize the energy efficiency of the nursery area of AMC(Block F, G &H).

The paper will first explore the biophilic design principles, then to examine the criteria through different case studies. The same will be examined for energy saving principles and examples. Then we will try to find out the relationship between biophilic design and energy efficiency. Together with the research on AMC building we will find out the most feasible biophilic design solutions to be implemented in the nursery area of AMC building.

KEYWORDS: *Biophilic design , AMC, façade, interior, energy efficiency, nursery area*

I. INTRODUCTION

1.1. General Background

According to the Netherlands Bureau for Economic Policy Analysis, the healthcare expenditure will soon grow faster than the GDP. The growth has been more significant than the other EU country. The cause of the growth can be mainly traced to the longer life expectancy. In 2011 Netherlands male and female has an average life expectancy of 80 and 83. However , there is an increase of people having chronic illness earlier in their life. The increased burden of the chronic illness include mental disorder, cardiovascular diseases and cancer. (The European Observatory on Health Systems and Policies, 2016).

In result the average length of stay of patients in hospital get increased. The amount of day-patient and inpatient also increased significantly. According to the study done by the Institute of Health Policy and Management of Erasmus University , in 2014 there are 32.5 % of expenditure spent on Hospital Care, which have an increase of 3% when compared to 1998. There is a need to reduce the cost of both patient care and staffing while improving medical outcomes. (The European Observatory on Health Systems and Policies, 2016).

On the other hand, the EU has implemented a national target for improved energy performance of existing building under renovation. In 2020, they are aiming to achieve 45-80% energy saving in the built environment. Therefore, the Netherland government has proposed new requirement for energy performance for new renovated building, which is the deliverance of zero-energy building, including 50% of use in renewable energy. (European Commission,2012)

1.2 Biophilia

Edward O. Wilson, an American biologist, described a concept of Biophilia in 1980s, in which he described “biophilia is the innately emotional affiliation of human beings to other living organism”. The concept of biophilia implies that humans hold a biological need for connection with nature on physical, mental and social levels, and that this connection affects our personal well-being, productivity and societal relationship. (Wilson, 1984)

In 2008 Stephen Kellert has translated the concept of Biophilia into the built environment and published a book called Biophilic design, in which he outlined three classification of user experience: Nature in the Space, Natural Analogues and Nature of the Space. A good biophilic design is the designing for people as a biological organism, respecting the mind-body systems as indicators of health and well-being in the context of what is locally appropriate and responsive. (Kellert, Heerwagen, & Mador, 2008)

Biophilic design has been proved by many research, showing the evidence that biophilia can be linked to three overarching mind-body systems, cognitive, psychological and physiological. Number of studies have shown how people’s health and well-being are impacted by the environment. In 1984, Roger Ulrich, a professor of Architecture at the Center for Healthcare Building Research in Chalmers University of Technology in Sweden, found out the positive influence of nature and urban sceneries on patient faster recovery rate after surgery. Therefore, it is proven that biophilic design should be implemented into hospitals to help create a healing environment for patients. (Ulrich, 1997)

1.3 Academic Medical Center (AMC)

The Academic Medical Center(AMC) is one of the largest and leading hospital in Netherlands. It is located in the Bijmer neighborhood in Amsterdam. It was taken into use in early 1980s and now it is in need of a complete renovation.

Figure 1. Site map of AMC+ Side Entrance of AMC(Source: https://en.wikipedia.org/wiki/Academic_Medical_Center#/)

According to a study done by dGMR, the hospital (block A) is having 50% of the energy use in lighting, and 25% of energy use in heating.(Figure 2). This percentage is much higher than the normal energy distribution in a hospital. Furthermore, the building have zero reliance on renewable energy. There is a need to reduce the overall energy consumption of the building, at the same time to maximize the energy efficiency of the building. (DGMR BOUW, 2016)

Therefore the paper will research on biophilic design solutions that can be used in the façade and interior of the nursery area of AMC building to maximize energy efficiency.

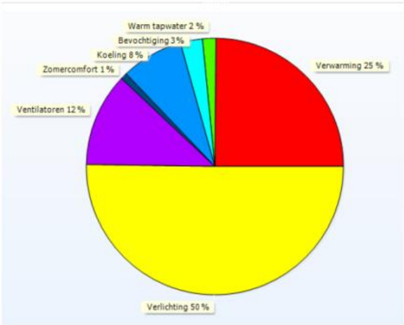


Figure 2. Energy distribution of Building block A © DGMR

II. HYPOTHESIS , RESEARCH QUESTIONS AND METHODOLOGY

2.1. Hypothesis

Applying biophilic design into AMC can achieve the followings:

- Healthier Patients: Patients will have shorter stay in hospital, fewer negative observational comments from nurses, and fewer strong post-surgical analgesics
- Healthier Profits: Reduction of national average expense per diem of a hospital stay after surgery
- Better Performance of staff: Biophilic design can increase working motivation of staffs
- Reduce Energy Consumption: Reduce energy usage in terms of heating, cooling, lighting, ventilation and water saving

2.2. Research Questions

The research question for this paper is :

What are biophilic design solutions that can be used in interior and facade of the nursery area of AMC hospitals to maximize energy efficiency of the building?

In order to answer the main question, the following sub-questions will also be explored:

1. What are the criteria in different type of biophilic design? How is biophilic design applied into interior and façade of hospitals ,and what are the effects and principals behind?
2. What are the main sources of energy consumption in AMC hospitals, and how to achieve higher energy efficiency in AMC hospitals in combination with biophilic design principles?
3. What and how the programs in AMC in related to the circulation and usage by staffs and patients? And what are the historic values of AMC and the old building regulation?

2.3. Biophilic design studies

Biophilic design study will base on knowledge gained from the workshop held by Amanda Sturgeon, the CEO of the international Living Future Institute(ILFI). She has organized the biophilic design elements into six different attributes based on Stephen Kellert's book 'Biophilic Design'. Through studying different case studies, we will find out how biophilic design are implemented in different ways in building projects.

2.4. Energy Reduction Techniques in relation to biophilic elements

First we will examine what are the climatic requirements for a general hospital , then we will examine case studies which involve reduction in energy consumption technology together with biophilic features, the result will combine with the biophilic design principles , in order to develop a biophilic technique which can maximize energy efficiency in AMC.

2.5. Site Research of AMC hospital

Site Research of AMC will be done by site visit, interviewing with the facility manager of AMC, and study of site and building drawings. The old regulation and building development will also be studied.

III. RESULT

3.1 . Biophilic Design

The principles of biophilic design is based on the fact that every human being has an innately emotional affiliation to other living organisms. Therefore biophilic design must respect the mind-body systems as indicators of health and well-being in the context of what is locally appropriate and responsive. In short, biophilic design must nurture a love of place.(Terrapin Bright Green LLC, 2014)

Biophilic elements can be divided into 6 different attributes. It involved direct and indirect experience of nature, and the experience of space and place. The six attributes are namely Environmental Features, Natural Shapes & Forms, Natural Patterns & Processes, Light & Space, Place-Based relationships , and Evolved Human-nature Relationships. (Table 1)(Sturgeon & Grable, 2017)

When we observe how are these biophilic elements applied into different projects(Table 3), we can find out one thing in common-which is the strong connection of the building to the land, the people and the history. It cannot be built in any other places. Besides, the example shows that biophilic design does not only show up in one way, but it is multifaceted, to facilitate repeated and variable experiences that allow people to connect with nature in many different ways. Some of the elements are found to be more frequently appeared, such as Light and Shadow, Central Focal point, and Ecological Connection to Place, which are the key elements to the building to its place and community. Therefore these three elements will be used as the fundamental criteria to be applied into the renovation of AMC.

Categories such as the Environmental Features, Natural Shapes & Forms, and Light & Space are the most frequently used in the project examples. They are the more direct way which you can see it appeared in many other design project nowadays. These criteria can be easily combined with energy measures to maximize energy efficiency .

On the other hand attention do needed to give to Natural Patterns & Processes, and Evolved Human-Nature Relationships. These two categories are more difficult to be implemented, because they are based on the psychological connection between human and nature, and how people react and respond to spaces. However these abstract elements do proved significantly effective in supporting stress reduction, cognitive performance , emotion and mood enhancement and the human body. (Table 2)(Terrapin Bright Green LLC, 2014). Therefore these elements should be further analyzed on how it can be combined with the fundamental elements to achieve energy efficiency and healing effect at the same time.

BIOPHILIC DESIGN ELEMENTS AND THEIR CORRESPONDING ATTRIBUTES

Environmental features	Natural shapes and forms	Natural patterns and processes
• Color • Water • Air • Sunlight • Plants • Animals • Natural materials • Views and vistas • Façade greening • Geology and landscape • Habitats and ecosystems	• Botanical motifs • Tree and columnar supports • Animal (mainly vertebrate) motifs • Shells and spirals • Egg, oval, and tubular forms • Arches, vaults, domes • Shapes resisting straight lines and right angles • Simulation of natural features • Biomorphy • Geomorphology • Biomimicry	• Sensory variability • Information richness • Age, change, and the patina of time • Growth and efflorescence • Central focal point • Patterned wholes • Bounded spaces • Transitional spaces • Linked series and chains • Integration of parts to wholes • Complementary contrasts • Dynamic balance and tension • Fractals • Hierarchically organized ratios and scales
Light and space	**Place-based relationships**	**Evolved human-nature relationships**
• Natural light • Filtered and diffused light • Light and shadow • Reflected light • Light pools • Warm light • Light as shape and form • Spaciousness • Spatial variability • Space as shape and form • Spatial harmony • Inside-outside spaces	• Geographic connection to place • Historic connection to place • Ecological connection to place • Cultural connection to place • Indigenous materials • Landscape orientation • Landscape features that define building form • Landscape ecology • Integration of culture and ecology • Spirit of place • Avoiding placelessness	• Prospect and refuge • Order and complexity • Curiosity and enticement • Change and metamorphosis • Security and protection • Mastery and control • Affection and attachment • Attraction and beauty • Exploration and discovery • Information and cognition • Fear and awe • Reverence and spirituality

Table 1. Biophilic design Elements and their corresponding attributes © International Living Future Institute

	14 PATTERNS	•	STRESS REDUCTION	COGNITIVE PERFORMANCE	EMOTION, MOOD & PREFERENCE
NATURE IN THE SPACE	Visual Connection with Nature	• • •	**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	• •	**Reduced systolic blood pressure and stress hormones** (Park, Tsunetsugu, Kasetani et al., 2009; Hartig, Evans, Jamner et al., 2003; Orsega-Smith, Mowen, Payne et al., 2004; Ulrich, Simons, Losito et al., 1991)	**Positively impacted on cognitive performance** (Mehta, Zhu & Cheema, 2012; Ljungberg, Neely, & Lundström, 2004)	**Perceived improvements in mental health and tranquility** (Li, Kobayashi, Inagaki et al., 2012; Jahncke, et al., 2011; Tsunetsugu, Park, & Miyazaki, 2010; Kim, Ren, & Fielding, 2007; Stigsdotter & Grahn, 2003)
	Non-Rhythmic Sensory Stimuli	• •	**Positively impacted on heart rate, systolic blood pressure and sympathetic nervous system activity** (Li, 2009; Park et al, 2008; Kahn et al., 2008; Beauchamp, et al., 2003; Ulrich et al., 1991)	**Observed and quantified behavioral measures of attention and exploration** (Windhager et al., 2011)	
	Thermal & Airflow Variability	• •	**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	• •	**Reduced stress, increased feelings of tranquility, lower heart rate and blood pressure** (Alvarsson, Wiens, & Nilsson, 2010; Pheasant, Fisher, Watts et al., 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	• •	**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	Biomorphic Forms & Patterns	•			**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	• •	**Positively impacted perceptual and physiological stress responses** (Salingaros, 2012; Joye, 2007; Taylor, 2006; S. Kaplan, 1988)		**Observed view preference** (Salingaros, 2012; Hägerhäll, Laike, Taylor et al., 2008; Hägerhäll, Purcella, & Taylor, 2004; Taylor, 2006)
NATURE OF THE SPACE	Prospect	• • •	**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	• • •		**Improved concentration, attention and perception of safety** (Grahn & Stigsdotter, 2010; Wang & Taylor, 2006; Wang & Taylor, 2006; Petherick, 2000; Ulrich et al., 1993)	
	Mystery	• •			**Induced strong pleasure response** (Biederman, 2011; Salimpoor, Benovoy, Larcher et al., 2011; Ikemi, 2005; Blood & Zatorre, 2001)
	Risk/Peril	•			**Resulted in strong dopamine or pleasure responses** (Kohno et al., 2013; Wang & Tsien, 2011; Zald et al., 2008)

Table 2. Biophilic Design Patterns & Biological Responses © 2014 Terrapin Bright Green/14 Patterns of Biophilic Design

Table 3. Table mapping the biophilic elements through different case studies

3.2 Energy Reduction Techniques in relation to biophilic elements

3.2.1 Indoor climate requirement for hospital

Thermal insulation and Temperature

A normal hospital has a requirement for indoor temperature to be minimum of 21 to 22 degree. AMC has a new requirement of increasing the indoor temperature of nursery rooms to 23 degree due to the limited movement of the patients . The maximum temperature is around 26 degree around the warmer seasons. The entire building envelope, windows, roof , wall and foundations need to achieve a certain level of thermal transmittance . (Caddet Energy Efficiency, 1997)

Ventilation and Hygiene

Indoor ventilation need to be renewed from time to time to remove odors and pollutants due to the contamination from occupants inside the hospital. The ventilation rate normally ranging from 35 to 140 m^3 per person/hour. For operation room the ventilation rate will be higher , ranging from 30-55 m^3 per square/hour. The room temperature needed to be higher than the new supplied air, so that the new supplied air will move down due to the thermal effect. This can ensure high hygienic safety.(Siemens, Retrieved May 2018)

Lighting

Natural daylight should be maximized in hospital by having large enough window opening(Figure 3), which can help patient's connection to the outside environment. However, excessive entry of sunlight do give the uncomfortable effect of glaze and overheating. In result artificial cooling will need to be employed which will use up even more energy. Therefore adaptable sun shade and blind should be employed , and they can be automatically adjusted to suit with different orientation of sun and wind. It should also be able to adjusted based on individual need of patient. (Caddet Energy Efficiency, 1996)

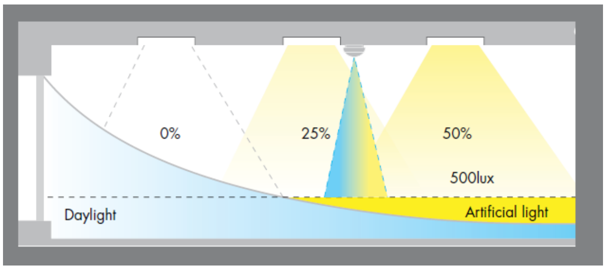


Figure 3. Daylight to Artificial light ratio © THORN

Indoor humidity

The comfort range of humidity is around 35-70%. Operating theaters and intensive care will have a more strict requirement for humidity. (Caddet Energy Efficiency, 1997)

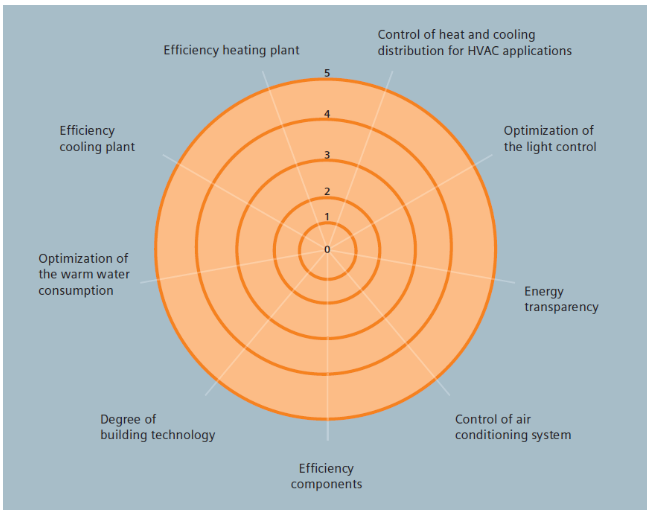


Figure 4. Criteria for optimization of building management system of Hospitals © Siemens Switzerland Ltd

Hospital Climate Requirement for Patients Room

	Min	Max
Temperature	23 degree	26 degree
Ventilation Rate	35 m3 per person/hour	140 m3 per person/hour
Humidity	35%	70%
Lighting	250 lux	500 lux

Table 4. Hospital Climate Requirement for Patient Rooms

3.2.2 Case studies regarding biophilic design in relation to energy saving

Case 1: NTFGH and Jurong Community Hospital

The innovative fan-shaped design is one of the biggest breakthrough for the hospital. Because of the fan shape every patient get to have their own window, which improve ventilation and maximize natural light. This respond to the biophilic elements 'Natural Ventilation', 'Views and vistas', 'Shapes resisting straight lines and right angles' , 'Natural Light' and ' Inside-Outside Space'. Because of the biophilic design it helps to give greater comfort to the patients, and so help to accelerate their rate of recovery.

Biophilic Healing Feature

The first feature of the design is that the patient can choose to sleep to face the window side without facing the other patients. There are adjustable curtains for privacy control. There are greenery planted in front of every patients' window, therefore provide each patient with a view of nature and good ventilation.(Figure 5 & 6) (Source: https://www.ntfgh.com.sg/)

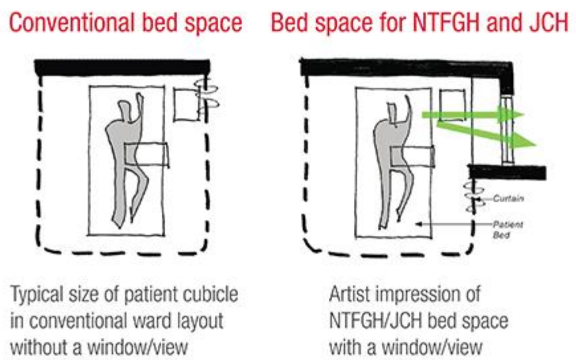


Figure 5. Conventional bed space against bed space for NTFGH and JCH, Source: https://www.ntfgh.com.sg/Our_Facilities_and_Amenities/Wards.aspx

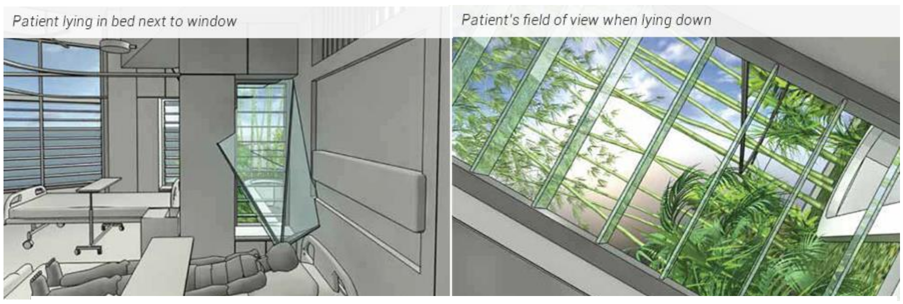


Figure 6. Patient lying in bed next to window, and Patient's field of view when lying down, Source: https://www.ntfgh.com.sg/Our_Facilities_and_Amenities/Wards.aspx

Figure 7&8. 6- bedded ward and 4-bedded ward with fan-ventilated, showing the individual window for each patient Source: http://www.db-a.co/work/ng-teng-fong-general-hospital/

Energy Measures

The second feature is the building optimization to sunlight through its shape and orientation. The angle of the sun throughout the whole year is studied in order to achieve optimized sunlight while reducing glaze. Together with the sliding sunscreen and the light shelves , it greatly reduce the energy cost for air-conditioning and lighting. (Figure 7 &8)

The design of the floor has imitated like the wings of a bird, so that the outside walls of the splayed floor plan catch the wind and channel it toward the windows. As the floor plan getting more narrow, air flows through the tightening spaces in a Venturi effect, which increases air velocity without mechanical intervention. Single-loaded corridors reduce the building depth, and help to promote more effective cross ventilation and reduce the chance of transmission of diseases through different patients. (Logan, 2017)(Figure 9, 10 & 11)

According to the report done by the American Institute of Architects, The energy use intensity(EUI) of the building is 72 kBtu/sf/year , which is a 38 percent reduction compared to the typical Singaporean hospital and a 69 percent reduction compared to U.S. hospitals. The mechanical system also uses efficient plant-side and air-side equipment which is able to create a efficiency of lower than 0.625 kW/ton.

Others energy measure also includes heat recovery in operating rooms using heat pumps and heat exchangers. For mechanically cooled spaces, a dual mode switch automatically switches off air conditioning when a window opens. All of the hot water demand is heated by solar thermal collectors. The hospital also employs daylight and occupancy sensors so that the lighting will be switched off when there is enough amount of sunlight and no one is using the room
(Source: http://www.hok.com/thought-leadership/aia-cote-2017-top-ten-project-winner-ng-teng-fong-general-hospital/)

Figure 9. Typical ward layout
Source: http://www.db-a.co/work/ng-teng-fong-general-hospital/

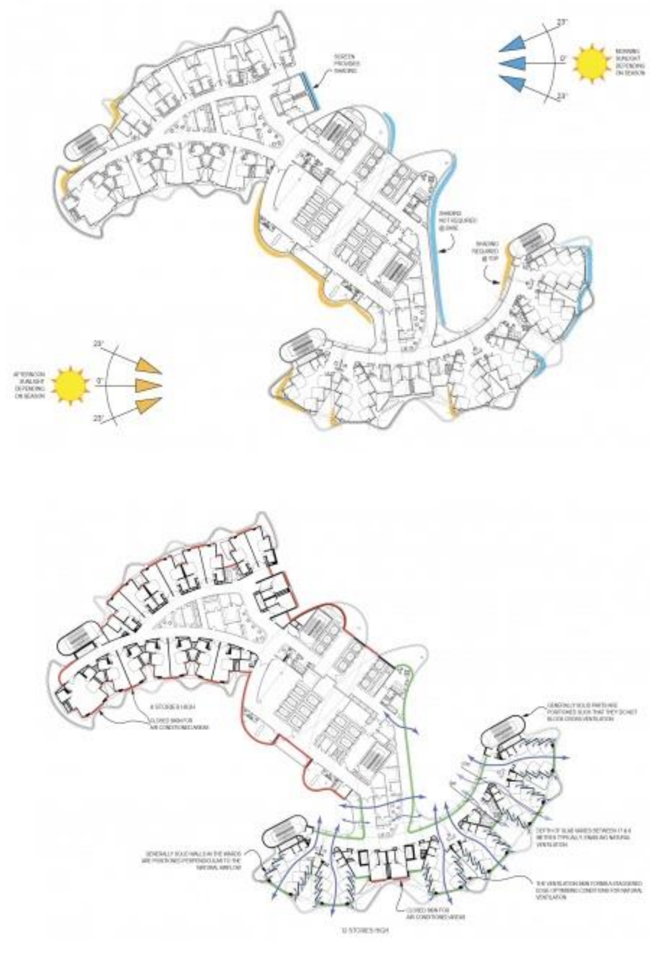


Figure 10 &11. Sun shading elements and natural ventilation
Source: http://www.studio505.com.au/work/project/ng-teng-fong-general-hospital/62

Case 2: Sidwell Friends Middle School

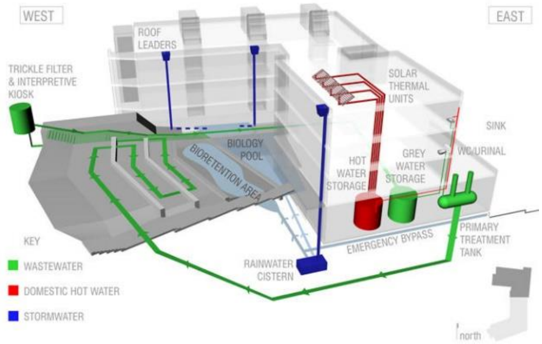


Figure 12 & 13. Diagram showing the water saving strategy, and the existing landscape
Source: http://www.aiatopten.org/node/140

Water Saving strategy

The biophilic energy approach is the retention of rainwater on the green roof, with the over-flow directed down partially open leaders into a sloped spillway where it makes its way into a pond and rain garden at the building entry (Figure 12). In the handling of wastewater, a living machine is used to process sewage. The machine is a constructed wetland (Figure 13), an integral landscape that can process wastewater but give biophilic element of the landscape aesthetic in the same time. The constructed wetland also helps to reduce storm water runoff, improve the quality of infiltrated runoff and reduce municipal water use. The green roof also slows the flow of rainwater and divert it through a series of scuppers and downspouts to biological pond. The naturally treated water is eventually reused in the toilet and cooling towers, reducing the school use of potable water.

Energy Saving Strategy (Light & Air)

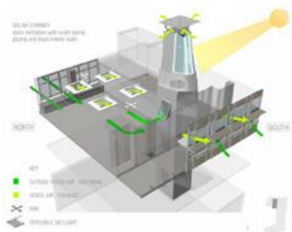


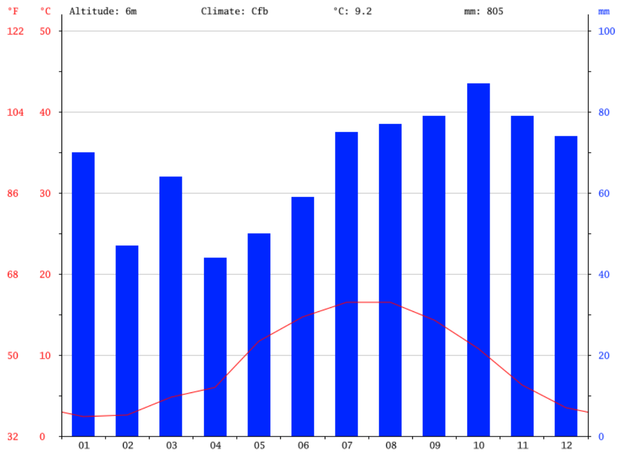
Figure 14 & 15. Diagram showing the light entry, solar chimney and existing rooftop garden. © KieranTimberlake Associates © Barry Halkin

The building employ exterior sunscreen to optimize thermal performance and maximize daylight. On the north side there is no sunscreen, with high window to obtain diffuse light. On the south side screens were placed horizontally above the window. On the east and west sides, the shades were arrayed vertically for minimal heat gain and maximum penetration of daylight. A lightshelf incorporated in the rooftop transmit daylight deep into the building while shading the corridor from direct sun (Figure 14). The green roof provide shading and enhance the roof insulation value. (Figure 15)
There is adaptability of the lighting design corresponding to the amount of daylight enter, by having an automatically controlled light with photosensors to make sure lighting is used when no daylight enters. There is also occupancy sensor to ensure the lighting is turned off when no one is occupying the room. High performance operable windows, skylight and ceiling fan minimize the use of mechanical cooling. Solar Chimney helps to create a flow of air current to draw cold air into the building through the open windows.

3.3 Site Research

3.3.1 Site Climate Condition

Amsterdam has an oceanic climate mostly influenced by its closeness to the North Sea to the west, with normally a strong westerly wind. Amsterdam's average monthly precipitation range from 44-87 mm, with the most in October and least in April. The average temperature ranges from 6-16.5 °C, with the highest in August and lowest in January.(Figure 16&17) In winter Amsterdam is mostly cloudy and damp and quite cold, in summer it has a longer daylight time and can get quite warm occasionally.



	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature (°C)	2.4	2.6	4.8	6	11.7	14.7	16.5	16.5	14.3	10.8	6.3	3.5
Min. Temperature (°C)	-0.1	-0.1	1.6	4	7.7	10.6	12.6	12.5	10.4	7.5	3.7	1.1
Max. Temperature (°C)	4.9	5.4	8	8.1	15.8	18.8	20.5	20.6	18.3	14.2	9	6
Avg. Temperature (°F)	36.3	36.7	40.6	42.8	53.1	58.5	61.7	61.7	57.7	51.4	43.3	38.3
Min. Temperature (°F)	31.8	31.8	34.9	39.2	45.9	51.1	54.7	54.5	50.7	45.5	38.7	34.0
Max. Temperature (°F)	40.8	41.7	46.4	46.6	60.4	65.8	68.9	69.1	64.9	57.6	48.2	42.8
Precipitation / Rainfall (mm)	70	47	64	44	50	59	75	77	79	87	79	74

Figure 16 & 17. Data showing Amsterdam's climate
Source: https://en.climate-data.org/location/3330/

3.3.2 Historic value and regulation of AMC

AMC hospital is a teaching hospital intend to combine education, research and treatment. The organization of the different disciplines is to promote the collective cooperation of cross-disciplines. When the building is constructed they have set up the following several requirements for the layout of the building:

- the building with the greatest usage should be situated near the public transport
- the density and height decreases in southwest
- construction density to be set at 25 %
- at least 50% of the land should be used as park
- maximum overall height is 45 meters, with an average building height of 20 meters

(Source: WELSTANDSVISIE AMC | 2016)

The site need to be retained due to its historic value and regulation. The new building needed to build on the same parcel while existing hospital has to remain fully operational. The challenge is to find a reasonable way to retain part of the historic old facility and to modify and add on to it .

3.3.3 Program and Usage

The building block F, G & H starting from floor 4^{th} to 9^{th} contains the nursery areas, of which they have all the patients' rooms situated on the periphery of the building in order to receive more sunlight, while the office space, storage and technical space are situated in the middle of the building(Figure 18). But also because of this arrangement the corridors are all closed space without connection to the outside environment. These long corridors will cause a problem in wayfinding, in which there is always limited choice of route from Point A to B, and there is no significant identifier to locate yourself which part of the building you are in.

In the future the hospital wants to focus more on tertiary care, in which more operation and research rooms will be required. The hospital also would like to have more flexibility in workplaces so that staff can easily be deployed without a fix departmentalization.

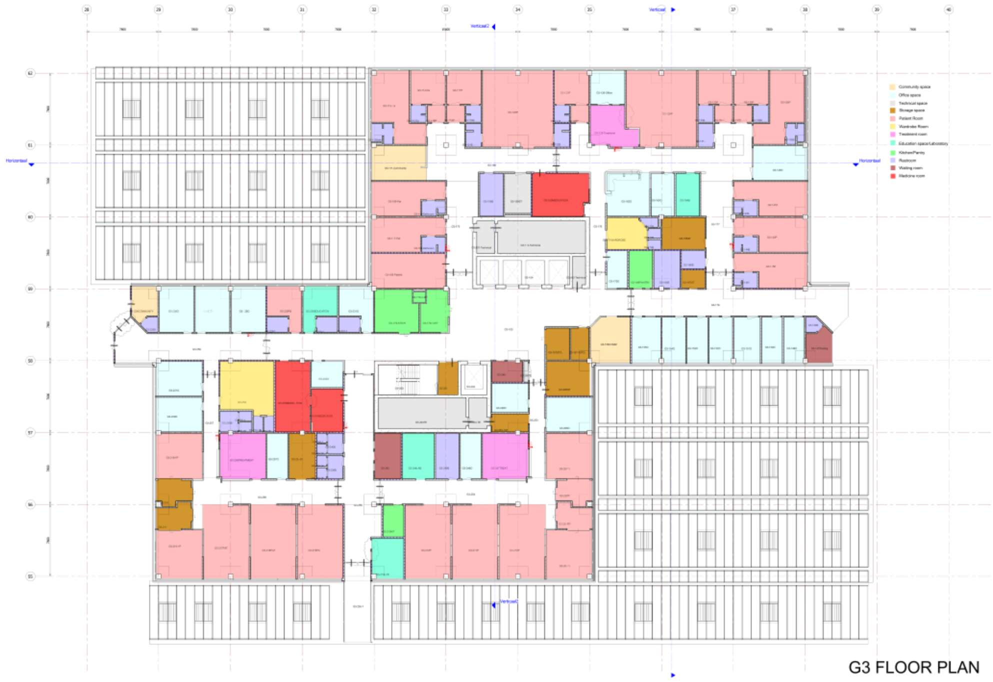


Figure 18. 3rd floor plan of building block G, showing the program and circulation

Because of the small window openings, as well as the shape and depth of the building, light can hardly penetrate into the building. In result the corridor and the core space requires the usage of a lot of artificial light to maintain the long working hours in hospital. This can explain why the hospital has a high energy consumption in lighting.

According to a lighting analysis done on the 3rd floor of the building G(Figure 19), in the morning there are around 65% of the floor area with a daylighting intensity lower than the threshold value. It is important to bring light into the interior of the building to simultaneously engage the patients in natural environment as part of the healing experience, and to reduce energy consumption.

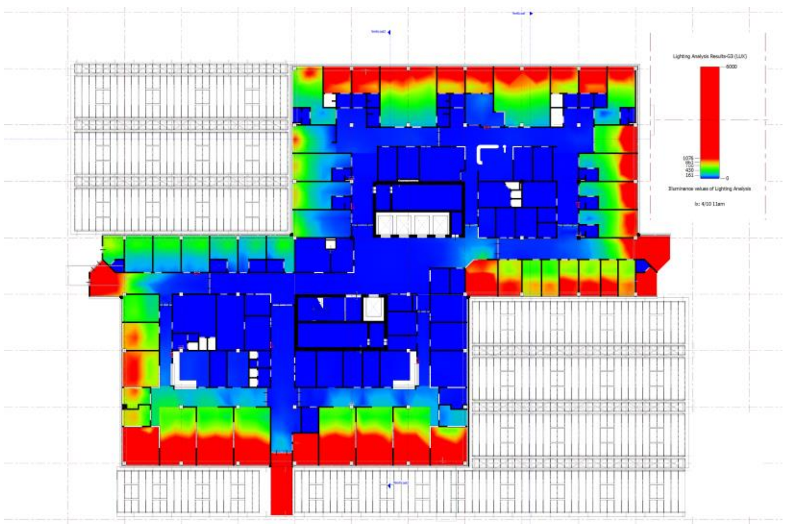


Figure 19. 3rd floor plan of building block G, showing the daylight intensity

IV. CONCLUSIONS

The purpose of this research paper is to answer the question: What are biophilic design solutions that can be used in interior and facade of the nursery area of AMC hospitals to maximize energy efficiency of the building?

The conclusion is: There are six biophilic design solutions that is applicable in interior and facade of the nursery area of AMC to increase the energy efficiency of the building. The six biophilic solutions are: biowall system, light vent, rain veil, vegetative roof, constructed wetland landscape, & fan shaped design. Their relationship with biophilic elements, temperature, water, light and air are listed below. (Table 5) In application into AMC building, building block G is used as a scenario to test out the feasibility and their effectiveness. The result is being evaluated using nine parameters, namely cost efficiency, energy efficiency, maintenance efficiency, sustainability, expansion potential, comfort performance, biophilic values, psychological values, and adaptability in ongoing hospital operation. The design solutions are evaluated based on these nine parameters with 0-5 marks, 5 marks indicated very good and 0 mark indicated very poor. From the evaluation graph, we can compare the strength and weakness of every design solutions, in order to find out the best combination of biophilic intervention into nursery area of AMC.

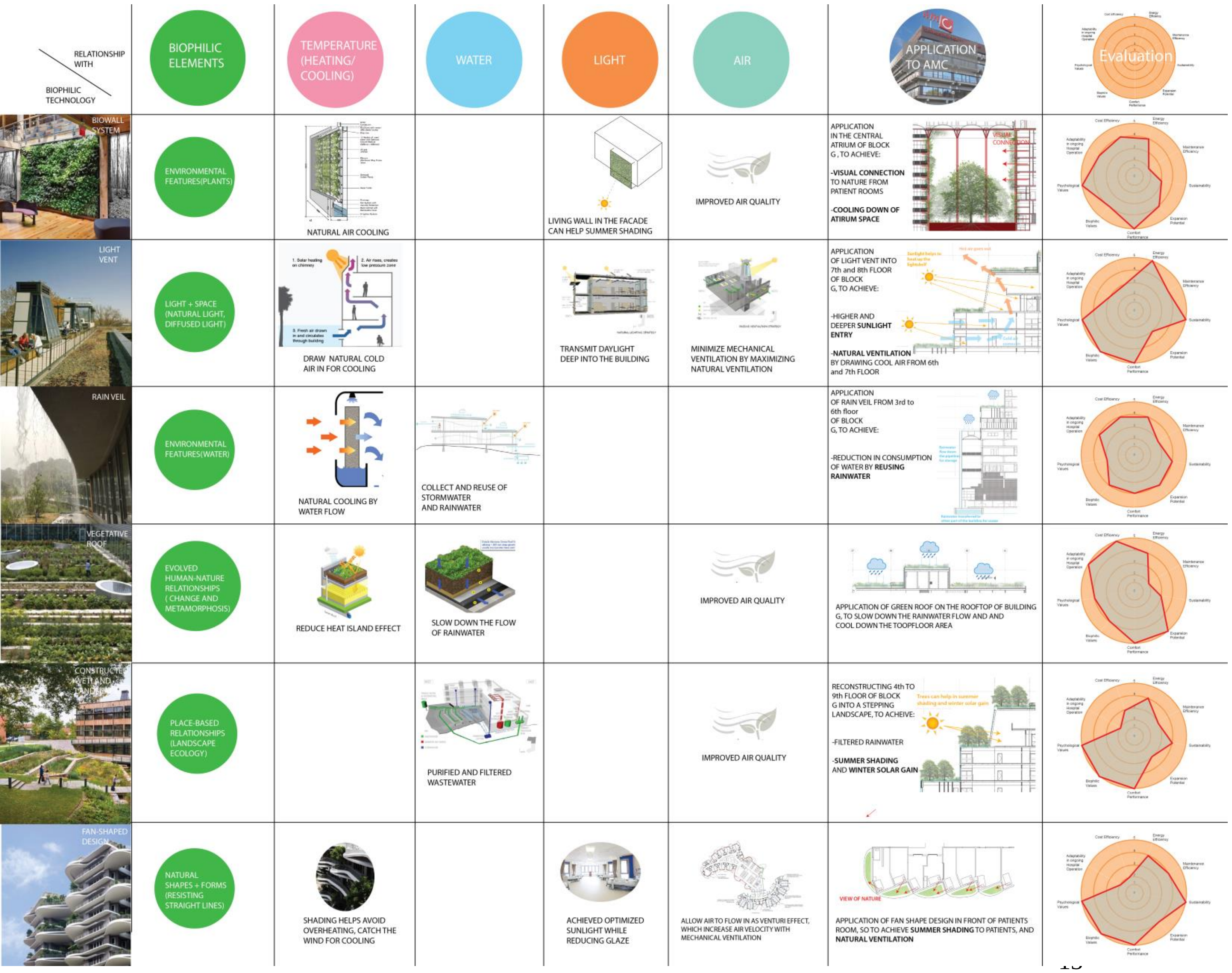


Table 5. Table showing the relationship between biophilic elements and energy through the different biophilic technology, their application into to AMC and corresponding evaluation

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APPENDIX

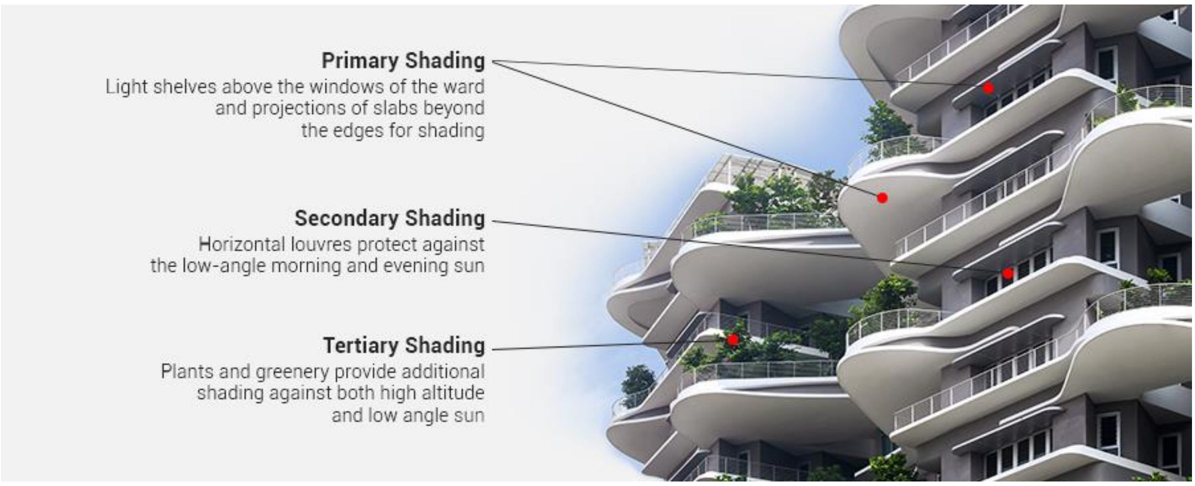

Figure 20. Shading device of NTFGH and Jurong Community Hospital to optimize daylight without glaze
Source: https://www.ntfgh.com.sg/Our_Facilities_and_Amenities/Wards.aspx

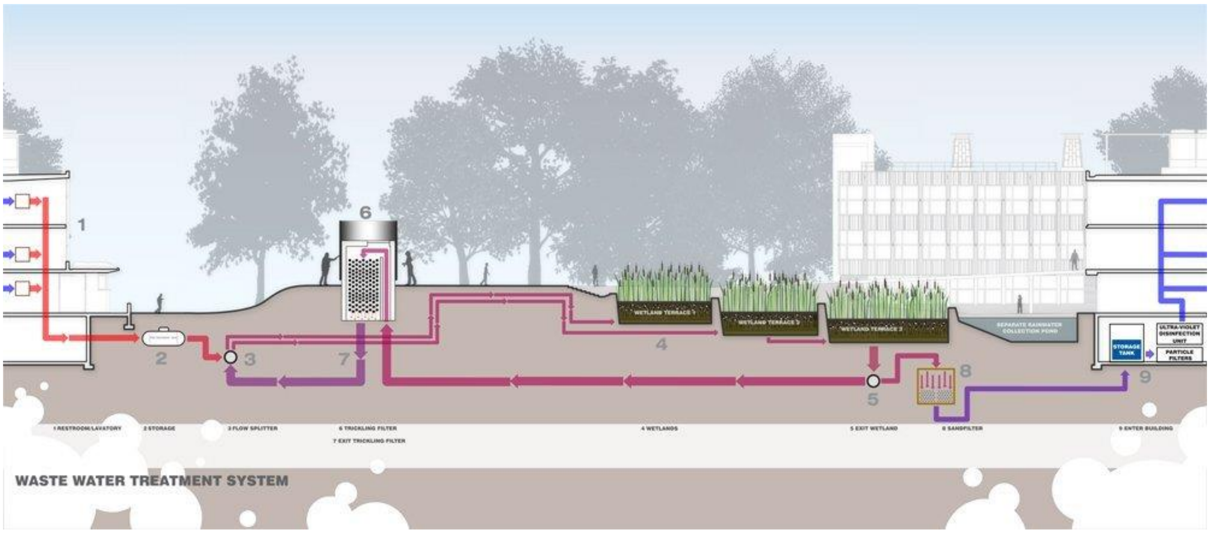

Figure 21. Diagram showing the purification of wastewater through the constructed wetland of Sidwell Friends Middle School

Source: https://www.archdaily.com/32490/ad-interviews-kieran-timberlake/1250614433-694-519-centered-text

Proposal of Combination of Biophilic Design solutions into AMC Block G

The intervention is to modify the shape and depth of the building, and also to increase the size of the windows openings with adjustable features, to achieve maximize daylight entry on the southeastern facing side, so that the patients will be able to receive morning sun for better healing, and to reduce the energy consumption in artificial lighting.

The biophilic elements that is related to energy efficiency not only contribute to the natural light, but also to plant, water and air. By converting the shape of the building with stepping(Figure 23), not only allow more sunlight to reach deeper into the building, but also provide more surface area for vegetative planting. By creating the green roof it can help to reduce heat island effect, and also give the patient a view to the nature. The green roof can also helps to slow down the rainwater runoff, in result the rainwater flows down in a moderate rate through the stepping roof and finally reach the bottom of the building to be stored underground for other functions in the building. This can also reduce the energy needed in harvesting and purifying water.

In terms of ventilation and cooling (especially in summer), the light vent helps to heat up the double-height chimney space at the top and create a suction force to draw cool air in from the lower floors. In result the patient rooms can have fresh natural cool air in, to reduce the use of mechanical cooling. The use of the natural air ventilation also helps provide fresh clean air for faster healing of the patients. In winter and bad weather condition, the windows will be closed and it can be substituted with mechanical ventilation, and the warm air trapped can circulate, together with air cleansing device, to supply warm and clean air in the nursery area.

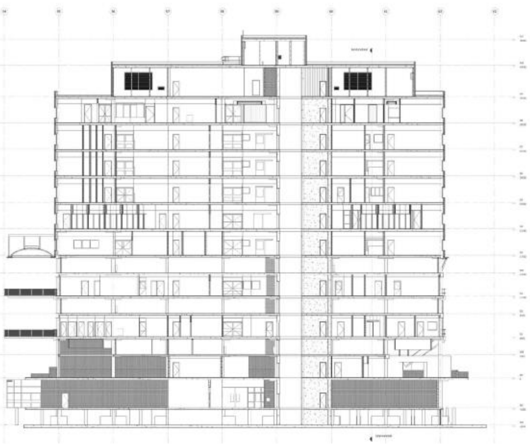

Figure 22. Section of existing building block G

After
Modification

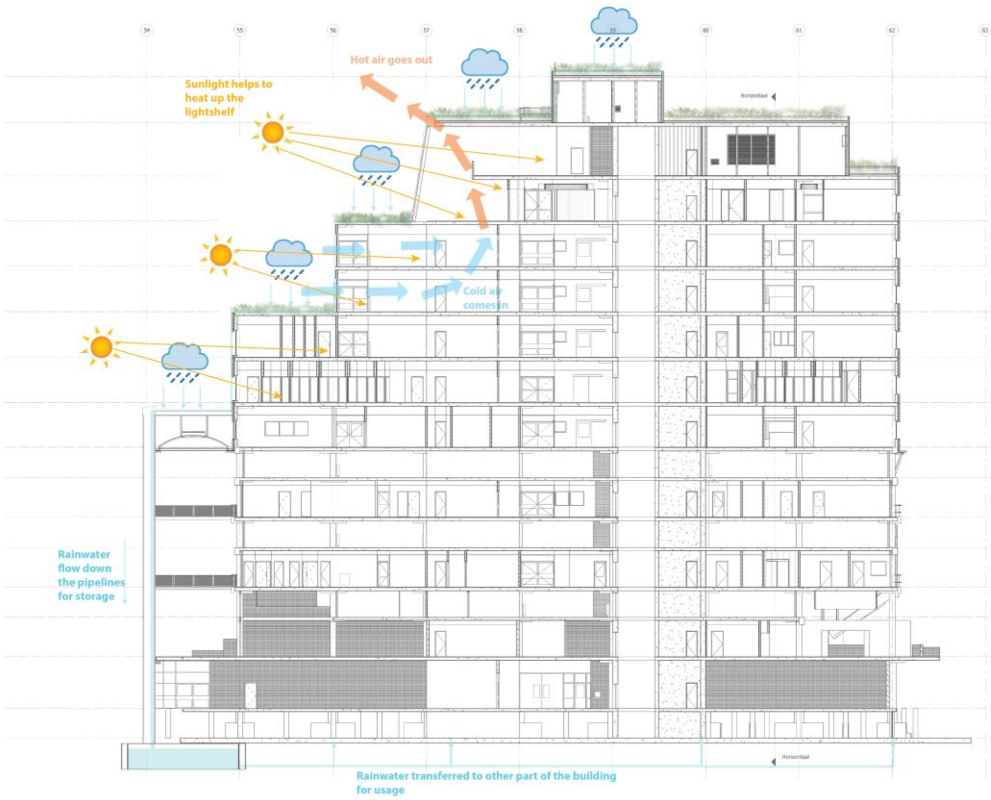

Figure 23. Section of modified building block G, with biophilic intervention