Healing Village: Implementing Biomimicry and Natural Architecture to Promote Sustainability in Healthcare

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Abstract
Sustainability in healthcare is essential to have many beneficial outcomes. Healing Village is a healthcare project in Tehran, Iran which is designed not only for the patients to have better healing experience, but also for all people living in the surrounding community. Healing Village aims to spread long-term health and well-being through biomimicry and sustainable natural architecture. In this redesign process, the researchers present a new healthcare center completely adaptive with its surrounding environment. This center would produce and consume based on its resources and needs. Analyses of the surrounding neighborhoods and the climate reveal challenging issues like air pollution, as well as other characteristics the project such as its limitations, weaknesses, and strengths. The function of the hospital in the Healing Village is considered as a prospective example of biomimetic architecture operating similar to natural organisms that create a living structure which is transforming, breathable, and self-cleaning to protect the indoor building and help users reach better outcomes. The biomimicry and natural architecture methods make Healing Village a good example of well-being for the city of Tehran and could be used as a model for other polluted cities in the world.

Keywords: Sustainability, natural architecture, biomimicry, healthcare architecture, well-being

Introduction

Healing Village is a sustainable design project in healthcare that seeks to provide long-term health and well-being among neighbors, reduce the surrounding neighborhood carbon footprint, and provide people with opportunities to be healthier. Healing Village is designed as a green space inside a busy city to create a feeling of being in nature to improve occupants' health and well-being. Thus, Healing Village is a concept that obtains to proactively encourage a healthy lifestyle before people become sick. Sustainability is a lens to analyze neighborhood issues and climate change. To achieve Healing Village's goals, this research is divided into three categories: well-being neighborhood, building a hospital with sustainability and efficiency design strategies, and produce energy.

Research Significance

This project will be beneficial for the people and have four levels of impact with different scales including city, district, neighborhood, and site. In the largest level of impact, Healing Village would be connected to agriculture schools of the city to share research and educational aspects of planting on the site. In the scale of city, this project would encourage other hospital owners to implement sustainable strategies such as using renewable energies. On the district scale, it would encourage people to use electric cars as well as bicycles. Incorporating a charging station on the site can encourage people to use electric cars and decrease the level of air pollution. Since electric cars need a considerable time to recharge, people can spend their time on the site or even in the surrounding areas while their vehicles are charged. Turning to neighborhood, the project's goals are purifying air, generating electricity, minimizing the possibility of power outage during the high usage season (summer), and attracting people for social and healthy activities. Finally, on the fourth level, site, Healing Village aims to improve staff satisfaction and efficiency, decrease the length of hospitalization, and encourage people to walk and have better lifestyles and fresh food.

Research Question

What design solutions could be incorporated to make Healing Village sustainable? To answer this question, this research looks at the project site and climate issues to identify the site's strengths, weaknesses, and limitations to provide better natural architecture and biomimicry solutions that fit this particular site.

Term

Biomimicry is learning from and then emulating nature's forms, processes, and ecosystems to create more sustainable designs (biomimicry.net). Biomimicry offers a deep understanding of how living things work and learn strategies to react to surrounding problems. These strategies can be used to solve design challenges in sustainability (biomimicry.org).

Analyses

Climate and Precipitation

The weather in Tehran is extremely different between summer and winter. The summer is hot and arid, while the winter is cold and dry. The summer lasts for 3.6 months (average high of 97°F and low of 77°F). The winter lasts for 3.5 months (average low of 34°F and high of 47°F) ("Average Weather in Tehran", 2019).

The wind comes from three directions: west, south, and north. It comes from the west for four months with a peak percentage of 37% on April 18. It comes from the south for 4.8 months with a peak percentage of 49% on July 23. It comes from the north for 2.2 months, with a peak percentage of 32% on January 1 (Average Weather in Tehran, 2019).

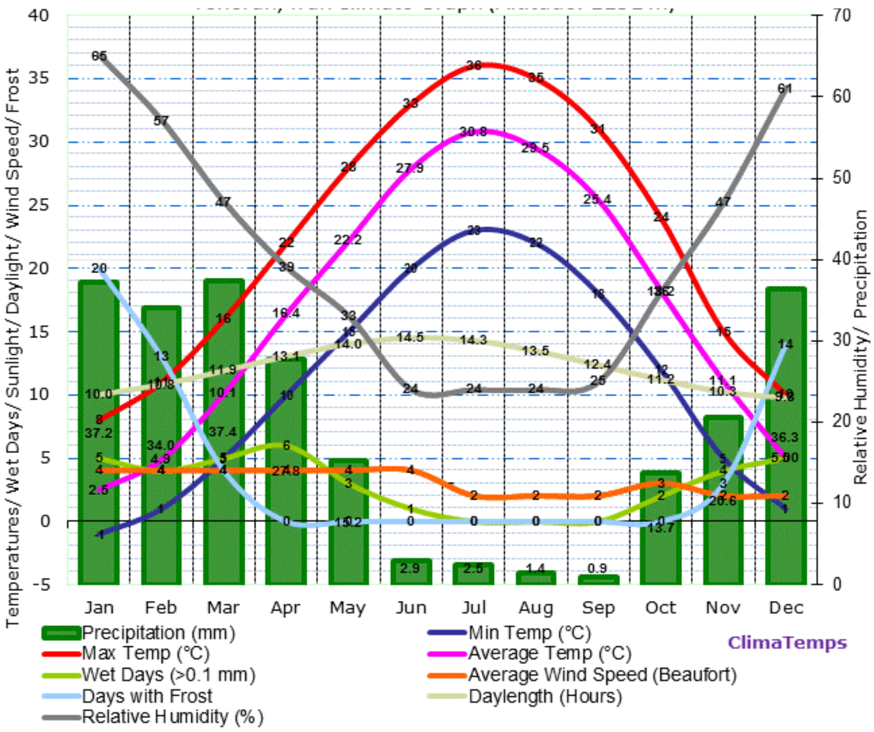

Figure 1. Climate in Tehran, Iran in 2019 (Average Weather in Tehran, 2019)

The city of Tehran is exposed to the sun for a long time. On the longest day, the sun lasts for 14.5 hours, while on the shortest day, for 9.5 hours ("Relative Humidity in Tehran, Iran", 2019). "The average annual relative humidity is 40.2% and average monthly relative humidity ranges from 24% in June to 65% in January" ("Relative Humidity in Tehran, Iran", 2019).

Figure 2. The site analysis shows the different wind directions, different sun altitudes between summer and winter, and the directions of the most noise and polluted streets.

Site Issues

The project is located in Tehran, Iran. Tehran is the capital of Iran which is the most populated city of the country with over nine million people. The site of the project has strengths, weaknesses, and limitations, all of which were considered throughout the project. Site area, underground water, wind, and sunlight (as lighting and energy source) were considered as the main strengths of the site and were implemented to enhance the environmental quality and sustainability. Tehran faces many problems due to overcrowding; consequently, the main weaknesses of the site are air pollution, noise pollution, and traffic. Also, there are not enough fresh food markets for the people living in the neighborhood. It is important to consider some strategies in this project to address these problems. There are also some natural limitations that need to be considered including limited water sources, dry weather, changing temperature (hot and cold), and sunlight (as heating source during summer). Design strategies that were implemented for this project directly and indirectly address these issues.

Table 1: Research finding

Strength	Weakness	Limitation
- site area - wind - sunlight (as lighting and energy source)	- air pollution - noise pollution - visual pollution - traffic	- water source - dry weather - changing temperature (hot & cold) - sunlight (as heating source in summer)

Well-being Neighborhood

The overall design of Healing Village was inspired by Persian culture and Persian garden elements such as water fountain, dome, and sunken courtyard. The Healing Village design addresses the neighborhood's problems since the site would produce and consume based on finding resources and demands. It would include space for gardening on site (5) and indoor center with the hydroponic system (4) to use in the hospital and for community needs. It also would consider neighbors' activities as a part of the content of the project (2, 3, 12). Neighbors could learn a healthy lifestyle and participate in the Healing Village actives such as gardening (5), exercising (12), and cooking in healthy ways (2). The design of the site has areas for participants to walk and gather for social events and activities (3, 12) as well as walking paths for Healing Village workers (8). Healing Village encourages users to use bicycles (6) or use electric cars and provides a charging station in the parking lot. The site's contoured topography helps to design a hidden parking lot (7). The energy generators, solar panels and cells (11,12), wind turbines (10), and carbon engineering system (9), would be visible to show neighbors Healing Village's ways to generate its energy and educate them about alternative ways to consume available natural resources.

1. Water from Persian Garden
2. Community Center
3. Stair and elevator
4. Planting (Hydroponic System)
5. Planting for Hospital and community Needs
6. Bike Station
7. Access to Parking
8. Walking Paths
9. Air Purifying System
10. Wind Turbine
11. Solar Energy
12. Pergolas for Seating
13. Car Entrance
14. Main Entrance
15. Sunken Courtyard

Figure 3. Redesigned site plan

Efficient Hospital Building

Hospitals are not sustainable; large amounts of energy are consumed 24 hours a day, seven days a week (CBECS, 2012). According to CBECS, hospitals use the most energy on heating the building, air conditioning (HVAC) systems, lighting as well as many other energy-intensive activities that occur. Through the design of Healing Village project, natural architecture and biomimicry were considered to find solutions to reduce the usage of the energy in these systems and make the building more efficient. Efficient design considerations are divided into natural ventilation approaches and daylight solutions.

Natural Ventilation Approach

Healing Village looks at the natural ventilation strategies that work well in the site. Findings reveal that using wind tower, sunken yard, and debulking façade will help to maximize the natural airflow indoors and reduce the use of HVAC systems during certain times of the year (see Figure 6). However, because the site suffers from pollution, these strategies need to be supported by filtration systems, and other strategies, which were inspired by biomimicry.

The First Approach: Green Façade

One of the design solutions for this project to address some of the weaknesses and limitations is the Green façade system. In this system, polluted air passes the green surface while being purified and cooled and is then diverted into the building via a fan. While this system could be efficient in warm seasons, by closing the vents in cold seasons, energy waste could be prevented. The water needed for this system is circulated, which makes the system more efficient and uses less water. Finally, this element on the façade will prevent direct sunlight from penetrating into the building during summer.

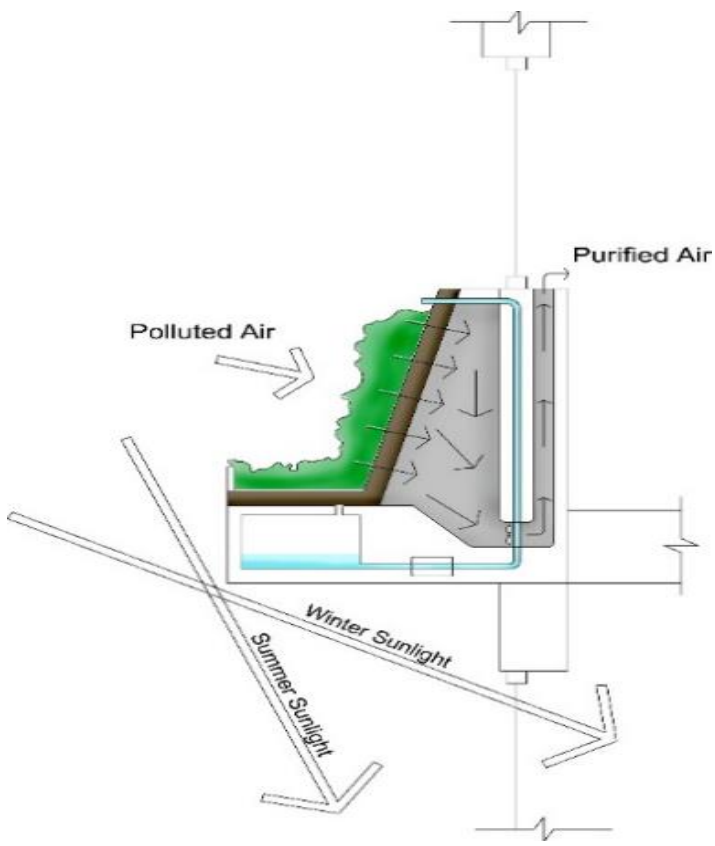

Figure 4. Green façade

The Second Approach: Biosystem (Breathing)

An evaporative cooling system, Biosystem, would be located between the double skin façade and the original façade in the south and west sides of the building. This system works in hot and dry climates, and it is inspired by four natural systems (biomimicry): stoma of plants, pinecones, hair around eyes in the desert, and human skin (Minsolmaz Yeler & Yeler, 2017). The Biosystem would use the stoma of plants concept to address osmotic pressure changes and control openings for evaporation and use pinecone concept to address relative humidity changes. The hair around eyes (eyelashes) concept would apply to protect against small particles (dust and sand). Finally, the human skin concept would apply to latent heat transfer– cooling through evaporation.

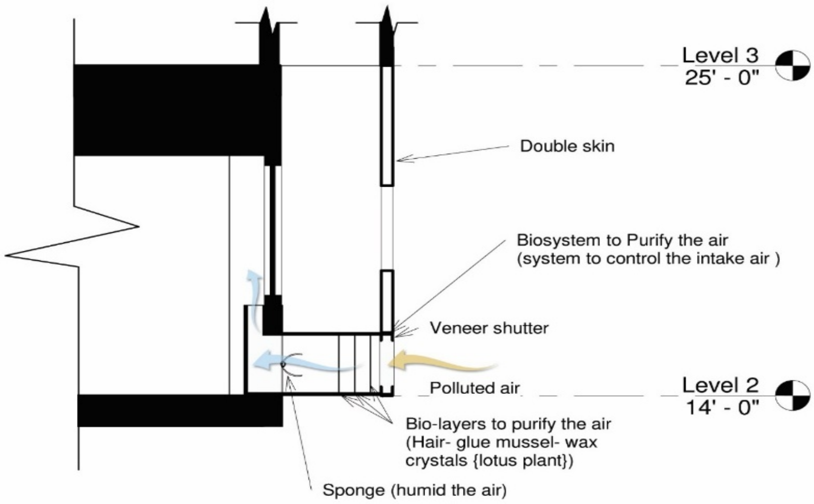

Figure 5. The section shows the Biosystem layers and functions

This system would allow fresh air to penetrate patient rooms and exam rooms. The system would have a veneer shutter to control internal airflow. In addition, it has three different layers to catch dust and small germs. Finally, after purifying the air, the system has a sponge to make the air humid to become cooler. This system would have the ability to control opening and closing, depending on individuals' needs.

The Third Approach: Decrease Pollution and Self-Cleaning

This strategy is used in the design to purify the air before it comes into the interior spaces using two biomimicry strategies (decrease pollution and self-cleaning) to catch dust and pollution. The first layer in this system would have the potential to catch small germs and infection. Mussels have strong water-based glue that cleans their surfaces (biomimicrybe.org). Inspired by this sanitary bond, the first layer would have

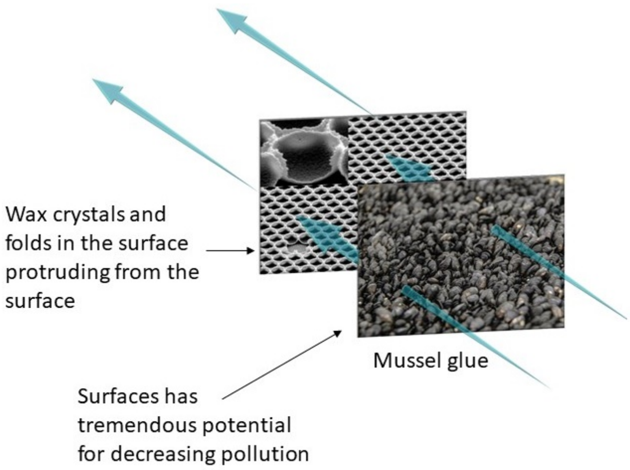

Figure 6. The drawing shows the two layers: decrease pollution and

mussel glue to decrease pollution at Healing Village. The second layer would contain wax crystals folded in to the surface to catch dirt, like in a lotus plant (a dirt-free plant) (AskNature Team, 2002).

The Fourth Approach: Transformer

The building would have the capability to change its color, adjusting to the surrounding temperature. The concept of this approach is inspired by changing colors in chameleons; chameleons have the ability to reflect different wavelengths of light and change their color to protect themselves (lauranadineolivier, 2016). In the building design, this strategy would be applied in the façade using Thermochromic, a "heat-sensitive paint contain[ing] pigments" (Ashish, 2018). These pigments change the color of the applied surface according to changes in the surrounding temperature: the color of the building façade turns white during hot temperatures to reflect the sunlight (protect the indoors from heat), while the color turns darker (dark brown) during the cold temperatures to absorb the heat from the sun. As the main goal, this strategy would help the building reduce energy usage.

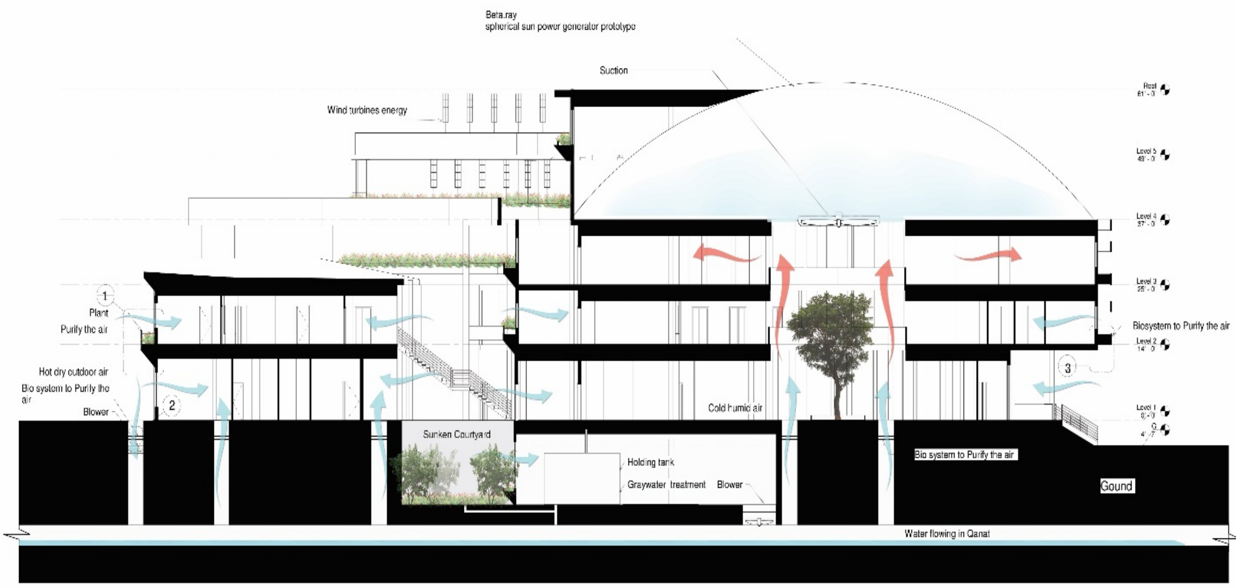

Figure 7. This section shows the natural ventilation strategies to purify and cool the air (2) to bring it to the indoor spaces. All patient rooms are located on the side of the building to access purified and cool air either purifying the air via Green Façade in north and east (1) or purifying the air via Biosystem in the west and south (3).

Daylight Solutions

The nature of healthcare facilities' layout and physical space requirements causes many limitations to provide indoor spaces with natural lighting. Due to the huge area needed for every healthcare facility and other limitations of building shape, it is almost impossible to provide natural lighting for all indoor spaces. On the other hand, natural lighting has many benefits for the users and the building. To overcome this problem, some natural strategies were implemented on this project to maximize natural lighting in indoor spaces.

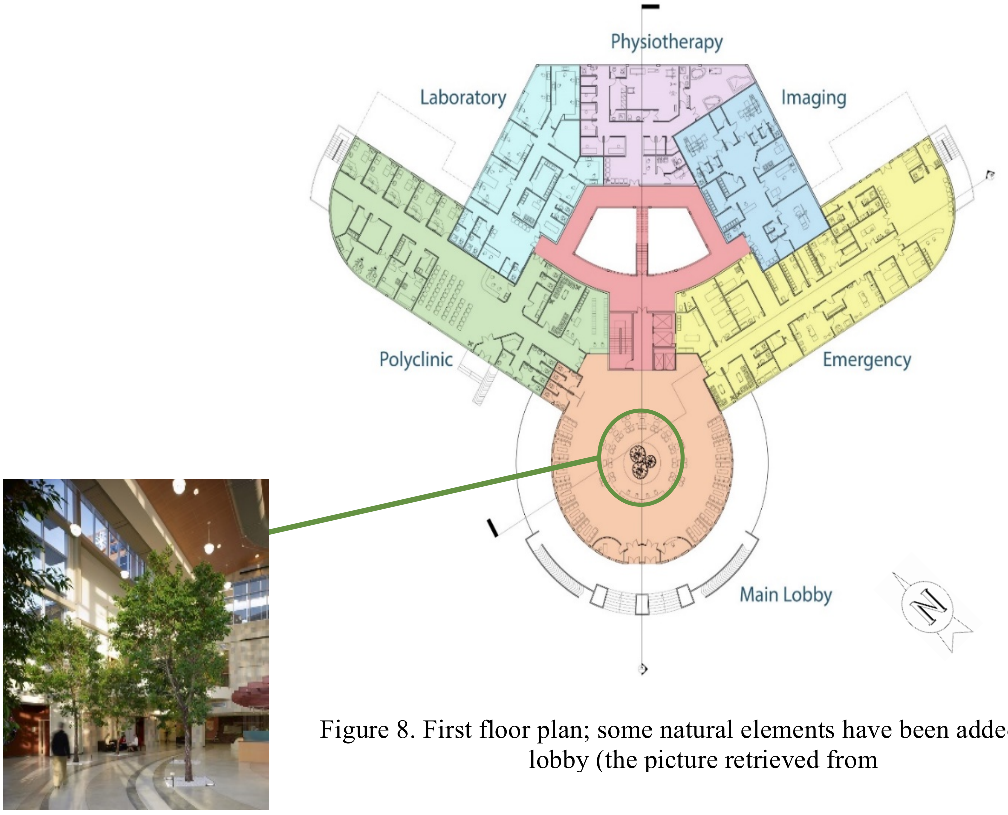

Figure 8. First floor plan; some natural elements have been added to the lobby (the picture retrieved from

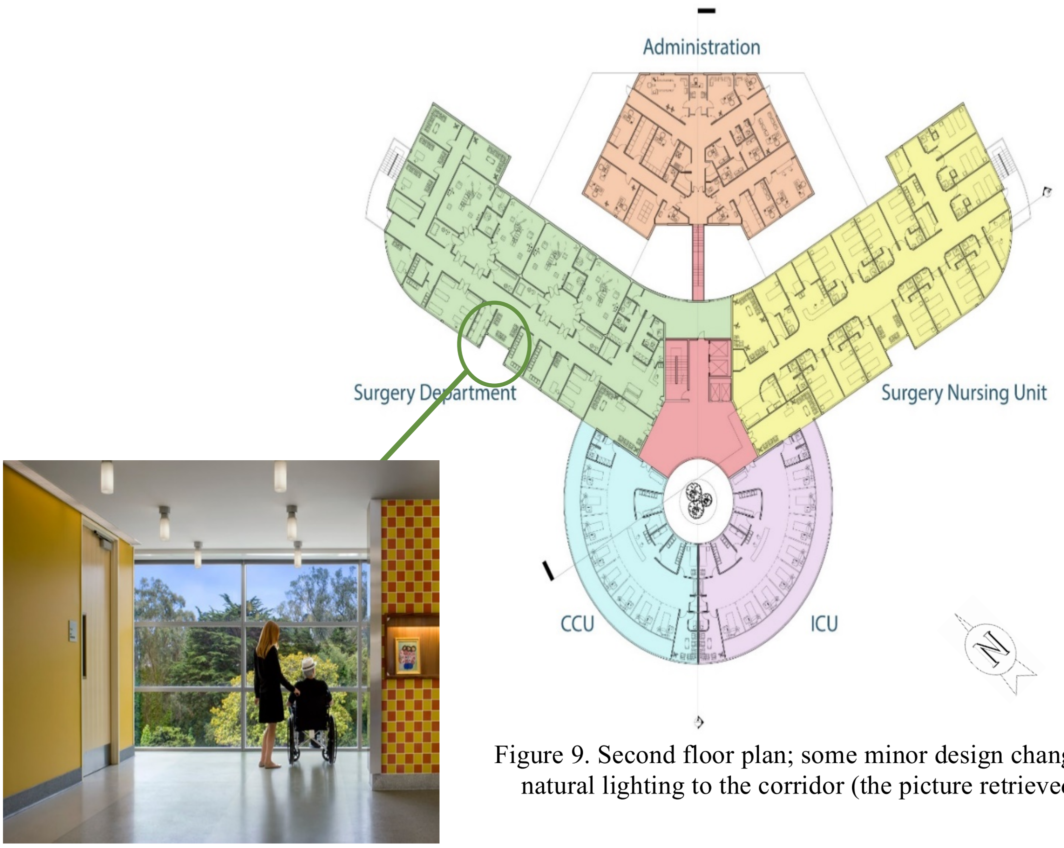

Figure 9. Second floor plan; some minor design changes bring natural lighting to the corridor (the picture retrieved from

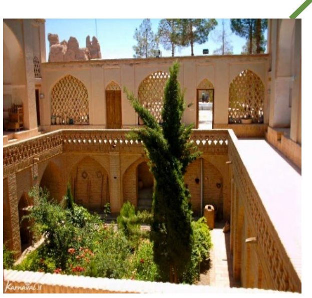

Figure 10. Basement floor plan; some change on the floorplan design and considering sunken courtyard bring natural lighting and natural ventilation for support departments (the picture retrieved from https://irandoostan.com/fr/Iran-tour/tours-to-iran-civilizacion-persa-

Produce Energy

The aforementioned solutions would allow Healing Village to be more efficient and reduce energy usage. However, the site needs energy to function; therefore, the design takes advantage of the site's strengths to produce solar and wind energy for Healing Village's use. Another potential source of energy would be the pollution from the site vehicles, known as Carbon Engineering.

Solar Energy

Spherical Sun Power Generator Prototype (Beta.ray)

Spherical sun power generator prototype (Beta.ray) was establish by German Architect Andre Broessel. This technology has a spherical geometric shape to take advantage of its principles; it provides twice the output of a traditional solar panel in a smaller area ("The Spherical", 2015). Healing Village would have a dome in the hospital building (inspired from the surrounding culture) using the Beta.ray method to produce a significant amount of energy to cover the building demands.

Solar Panel (Inspired by Lotus Plant)

The site would have numerous solar panels with a special coating (inspired from the Lotus Plant) developed by the Oak Ridge National Laboratory. The panel has "new water-repelling, anti-reflective glass coating that could increase the efficiency of solar panels by up to 6%" (Dana, 2015) and helps the panel last longer. This coating resists high temperatures and benefits the panel through self-cleaning, similar to the Lotus

Plant. These solar panels would be located in various locations: pergolas, parking lot, and walking path.

Wind Energy (Wind Turbine Parks - Biomimicry)

Wind Turbine Parks is a wind energy generator inspired by the concept of fish swimming in shoals, using small water vortexes that allow them to swim faster using less energy (Rovalo, Dwyer, & Dorfman, 2017). This method increases the turbine productivity because each turbine catches more wind. These turbines would be located on top of the building and have less noise, are safe for birds, and fit better in the natural landscape compared to traditional turbines.

Carbon Engineering (Air to fuel & Air purifying)

Due to many reasons such as population density, traffic, industrial factories, poor quality of gasoline, and inadequate transportation systems, Tehran is among the most polluted cities of the world. Therefore, air pollution is one of the main challenges of designing Healing Village. Carbon Engineering Ltd is a Canadian-based clean energy company that works on practical ways of reducing carbon dioxide from the air or even converting it to other forms of energy. By using this system on the site, the polluted air will be absorbed using gigantic fans and purified by advanced systems and filters; these systems can absorb existing carbon dioxide in the air and convert it to solid and clean fuels to be used in transportation systems. Having this technology on the project site not only provides people living on surrounding area with clean or at least less-polluted air, but it can also produce clean and environmentally-friendly fuel for transportation systems.

Conclusion

This paper presents a research project that considers the neighborhood and climate issues to reduce neighborhood problems and enhance well-being through designing a sustainable hospital. Healing Village is designed to produce strategies and systems from natural architecture and biomimicry to address air quality, lighting, gardening, and energy. In designing this type of hospital, the researches consider the social and environmental impacts of the building on people in the surrounding neighborhood with aims to reduce harmful practices on the environment and improve neighbors' well-being and health. The considered design strategies could be valuable to other dry climate and polluted cities. This paper presented some product strategies on the market as well as the authors' efforts to bring suggested solutions to the site design. Many aspects may need to be considered for future research; one potential experiment may be the use of transformer strategy and how it can help reduce energy usage. Moreover, the research could examine Biosystem strategies to find solutions to bring fresh air indoors in polluted climates. Future research might look at sustainability in healthcare climate to decrease carbon and pollution footprint, increase hospital's building efficiency, and improve well-being. Research should expand people's understanding of living things' functions to obtain better biomimicry solutions to develop new strategies to help designer and architecture practices.

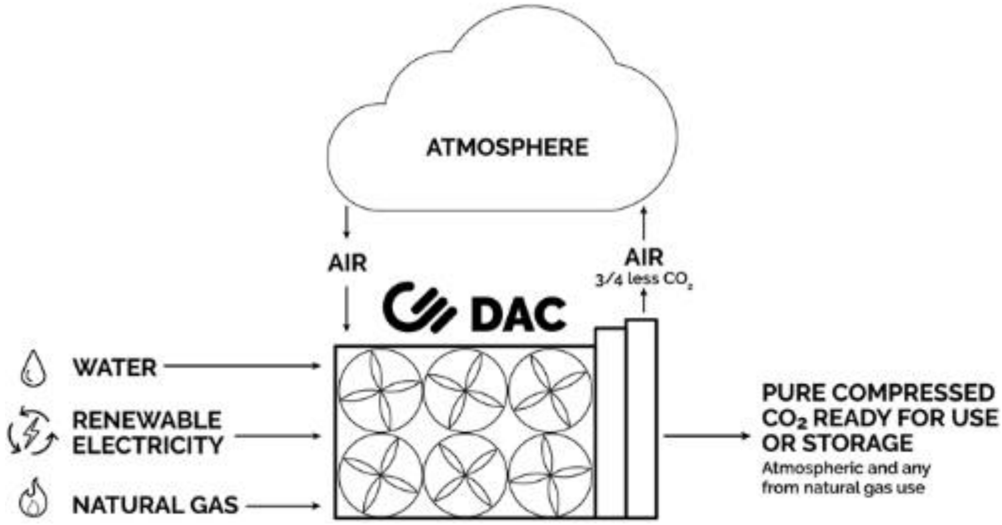

Figure 11. How Carbon Engineering system can purify the air and convert carbon dioxide to other forms of energy (retrieved from https://carbonengineering.com/our-technology/)

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