Bioclimatic Architecture: Housing and Sustainability

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Abstract

This paper aims to define several natural conditions that influence the architecture and sustainability of several buildings selected from various climatic zones around the world. The case studies in this paper vary from traditional to modern buildings, with a focus on the natural conditions that influence the architectural decisions of sustainable housing. This research paper encourages analyzing and taking advantage of environmental conditions around buildings to maintain ideal living conditions within the buildings through minimal consumption of energy, and to achieve sustainability that has become a philosophy of the modern architecture. The paper also includes climate studies of two cities in Syria, with differing environmental conditions that result in certain architectural decisions.

Keywords: Sustainability, Bioclimatic, Housing.

1. Bioclimatic Architectural Engineering – definitions of Housing, Sustainability, and Bioclimatic Architecture

The term Housing in Architectural refers to the architectural design of structures that serve as dwellings or shelters for individuals. The House should be designed in a way that provides people with pleasant conditions and affective space for daily life, hence designing houses is very critical as it not only influences individuals' activities and routines, but also directly determines their moods. As Figure 1 illustrates, traditional housing has always correlated to the natural conditions of the surrounding area.

Sustainability refers to the concept of coexistent of man and nature in harmony. Sustainable Architecture has become a philosophy for many generations, as the survival and well-being of mankind depends on nature, its elements, and resources. Without Sustainable Architecture, man would continue exploiting the natural resources to produce means of living such as electricity and potable water, which may lead to scarcity of such natural resources for the coming generations.

The term "Bioclimatic Architecture" summarizes a number of differing general terms as the single planning definition-that is a group of design decisions that offer appropriate living conditions within buildings by the minimal use of technical units "the group of machinery" that require energy consumption of non-renewable resources (Grondin, 1959). In other words, such relations should be formed between a building and its surroundings that allow the possibility of the desired change in the habitation interior, which depends on the habitation's physical and morphological "formative" characteristics, as well as its dimensions and measurements. Considering conditions change according to the building location, and knowing that these conditions also change through time and building position, an ideal "bioclimatic habitation" should have the potential to adapt in a way that allows it to absorb the maximum amount of heat in cold days. Additionally, it should be able to absorb and retain solar energy throughout daytime during winter in order to use it when in need ,and reflect solar radiation in hot climate zones. Hence, creating appropriate living conditions and maintaining the architectural spaces within the scope and limits of comfort "22-24 degree Celsius." (Fersonov , 1982).We can achieve such building behavior, which is known as the "ideal or model behavior" by making use of certain schemes and specific building patterns. And I hereby by would like to mention that this paper will only address the residential scene of the matter; however, proposed results can be applied on other architectural structures.

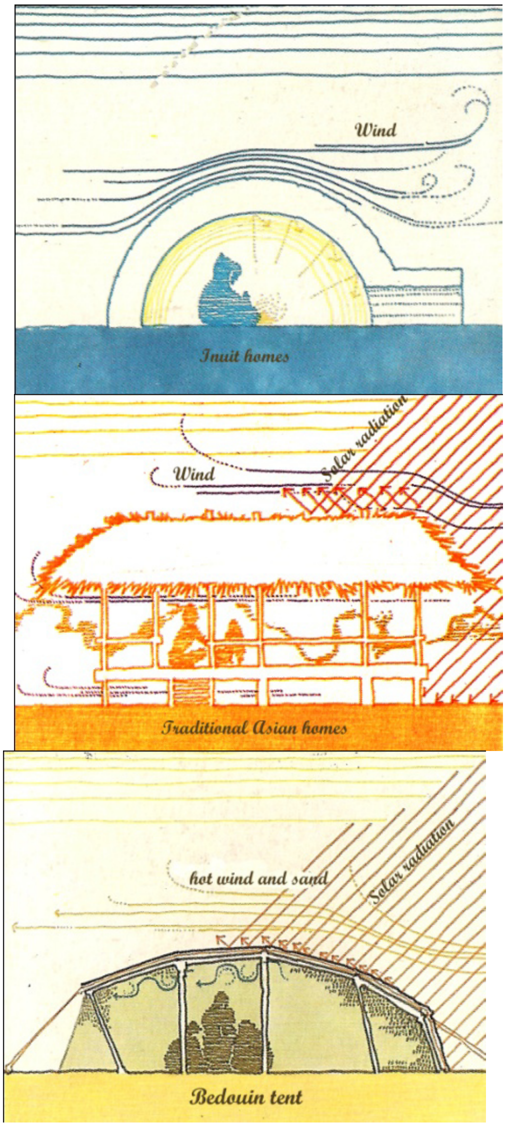

Figure 7. Traditional housing indifferent environmental conditions.

2. Climatic aspects affecting the architectural composition and how to put them to good use

To begin with, we should take into account the shape of the building and its direction; we should direct its architectural spaces in relation to the function of each space separately, and address the time spans in which the space is used during a one-day climatic cycle. For instance, in the case of very closely set buildings, we witness a drop of heat dispersion, a significant impact of solar radiation and heat, and a disparity between temperature ratings inside and outside, while open buildings allow more of a temperature exchange as a result of continuous ventilation that flows between multiple architectural spaces. Buildings' directions and surfaces' area that is exposed to direct sunlight differently, as these surfaces collect solar radiation, wind direction in accordance to building's position and direction compared to adjacent buildings, and natural topography, waterways and forests are all factors that have an immediate impact on the thermal exchange from the exterior of the building to its interior and vise versa as shown in Figure 2. As for alleviating heat loss, we must thermally isolate the building by placing several layers of non-visible isolation on the walls, roofs and attics "or spaces under the gable." (Fersonov, 1982). In general, glassed area should be kept within their acceptable boundaries "in hot, dry climate zones", corresponding to the function of each architectural space, as these glass openings allow for solar radiation leakage to the building's interior. Therefore, we should use double-glazing window frames and operating louvers "sun breakers" to reduce heat dissipation to the minimum during evening time. While in regions that are subjected to extreme, prolonged solar radiation, especially those that face south, windows should allow for solar radiation absorption in winter by the use of large glass facades. It is worthwhile mentioning that the dimensions of these facades correspond to the climate conditions; blinds and operating louvers should be available to shield the openings during nighttime. Accumulated energy through the method mentioned above piles up within architectural volumes, spaces, and walls, otherwise this phenomenon would lead to a rise in temperature within interior spaces, which would have a negative impact on the comfort of the building and increase heat dissipation; the ideal spatial design results in an exemplary interrelationship with the layout of the building's external enclosure (Hatkness, 1984).

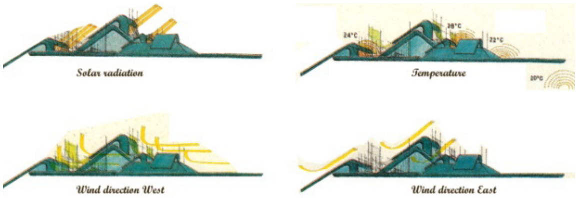

Figure 8. Impact of solar radiation and wind speed and direction on the temperature

The urban planning of the old cities illustrates how architects, in hot climate zones, maintained the correlated effect between architectural and urban spaces, the direction of circulation axes and their distribution, and created an environmental equilibrium and positive effectiveness on the overall living conditions within old cities as shown in figure 3.

Figure 9. Site plan of Aleppo city 1880

While in extreme cold climate zones, large glass facades should be placed towards south as shown in Figure 4 – small openings has been a characteristic of architecture in hot climate zones throughout history- a model space design would attempt to allocate spaces used in daytime towards south, while staircase and other facilities would be face other directions. As regards to summer time conditions, the perforation of direct solar radiation through glass facades should be avoided; however, these facades should have the ability to open and be protected from direct sunlight by the use of both fixed and operating louvers, which perform as shadow in times of high temperature and solar radiation. The design of open spaces "their forms, dimensions and position" should allow for ventilation and cooling all rooms during nighttime, while the building's elevation that faces north should be partially inserted in soil, and the foundations should go to a certain depth according to available conditions, as shown in figure 4. By applying this system, living conditions will improve in both winter and summer according to the well-balanced temperature of the soil, and will protect the building from the cold, harsh winter wind.

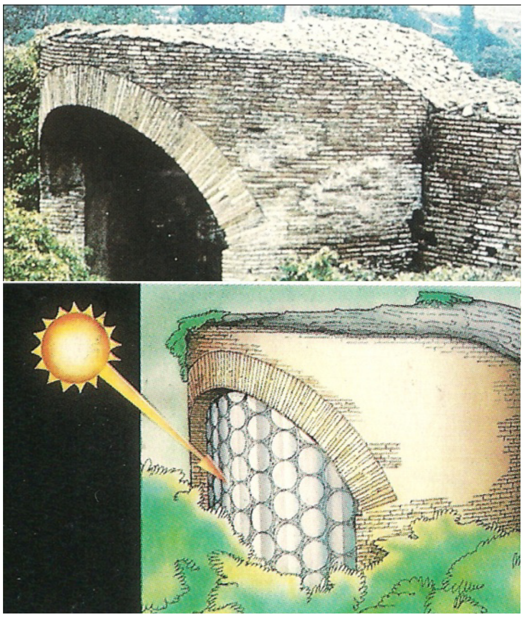

Figure 10. Example of large opening and façade insertion within soil

Energy problems develop from the difference in temperature between the architectural spaces, and it is the architect's responsibility to overcome these problems to create a state of comfort between individuals and their surroundings; the more the difference between spaces is, the harder the architect's job is. An architect's decision to use technical units, in other words neglect the studies of climate conditions and relationship between the building and the surrounding will result in more consumption of energy. Hence, the climate aspects of the building location must be identified accurately for an ideal town planning, which should correlate to the surrounding environment. Generally, the monthly average rate of the various temperature values in a specific region can set out the value of the temperature. The variables of temperature rates are taken as highest and lowest points monthly, and are used periodically to determine thermal absorption and dispersion, hence decide on architectural solutions for insulation such as Trombe walls.

Furthermore, indicating the value of humidity is very important as it directly affects the temperature of residential and public buildings, as well as indicating the possibility of thermal exchange, as shown in Figure 5.

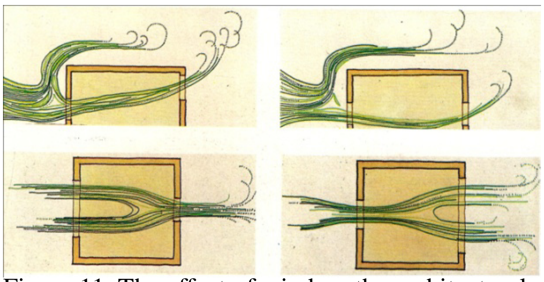

Figure 11. The effect of wind on the architectural spaces

Recently, many modern architects have been neglecting wind data, whether or not intentionally, despite the fact that the speed of airflow around the building results in the value of thermal exchange in winter and summer. For a successful design, we should take into account all data related to the direction and speed of wind throughout several time intervals and establish a seasonal or monthly map that clearly illustrates the figures of wind speed and direction, which will lead to helpful guidelines for ideal building position, relationship to the surroundings, and maximum use of the environmental elements such as natural breakers, water features, and areas of vegetation, their form and density (Fersonov , 1982).

Finally, we should consider the amount of solar radiation, that is the value of solar energy absorbed by the multiple exterior surfaces of the building. Solar radiation is considered a critical issue during hot months "summer", but a part of a solution during cold winter months (Gosiev, 1985) (Hatkness, 1984), as shown in Figure 6.

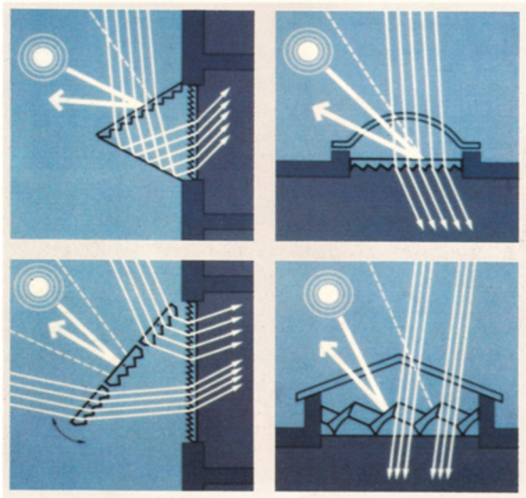
Figure 12. Control the amount of solar radiation

The information gathered from climate aspects as discussed earlier primarily assist in developing site analysis and creating schematic designs such as directions, measurements and the glazing versus shade areas caused by the outside environment or the structure of the building itself. In many countries, all the data related to climate is collected under the supervision of special national councils, thus we have all the information needed on a great number of occupied areas (Bonin, 1981). Furthermore, conducting climate studies and gathering necessary related data help to create a comprehensive climate map of all surrounding areas and set up urban and architectural guidelines, which can be used by the architect at any time. Such studies were developed throughout the years and are used vastly nowadays; however, they are still not available in the Middle East.

3. Examples of the ideal utilization of climate aspects and their impact on the architectural decision-making by experience and climate analysis technology

3.1 Mesa Verde National Park, Colorado, United States.

Mesa Verde, Spanish for “green table” was founded in 1200 AD to protect some cliff dwellings, and considered as the ideal example of utilizing nature for survival and exemplary living conditions. Since it is located in a horizontal slit, and towards the south, it is fully protected from direct sunlight during summer, and subjected to the maximum amount of solar radiation in winter. Additionally, the surrounding rock may have its own inertia considering its major mass, which results in creating excellent, consistent living conditions throughout the year. The harmony between the structures and the surrounding rocks “the cave” collects solar energy “56% more energy in winter than summer”. During sunset, the location is covered by sunlight, and solar energy is retained in both rocks and building bricks, which then spread steadily throughout the inhabited inside are after sunset. As a result, a model confined climate state is established which provides sustained and comfortable living conditions, instead of the harsh nature of the weather in such areas, where winter is extremely frosty while summer is sweltering. Figure 7.

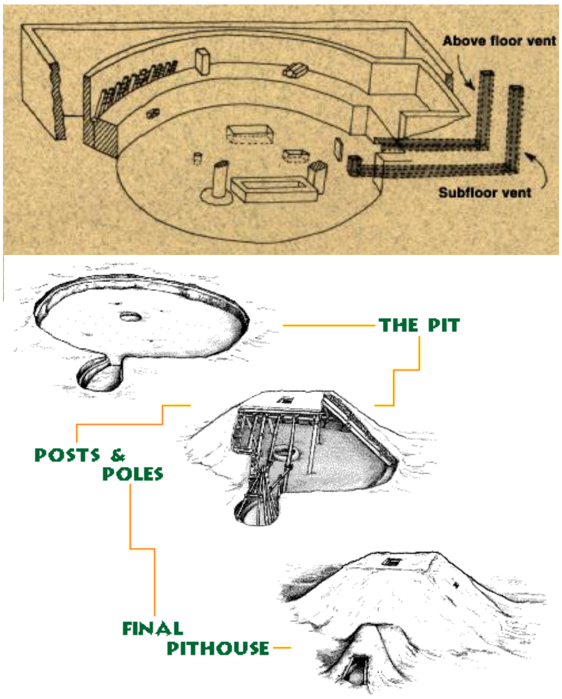

Figure 13. Bioclimatic architecture of Mesa Verde

During daytime, social life of the Anasazi Indians takes place inside the pit traditional house dwellings, known as Kivas "world below", which were built at least partially underground, and heated by a central fireplace. The natural ventilation system operates as the shown in Figure 8: the air flows in through the vents positioned at the lower part of the Kiva, and at the same time hot air moves upwards from the fireplace and goes out through the roof vent. This continuous process ensures natural ventilation throughout the day (Putsavage, 2001) (Prakhin, 1979).

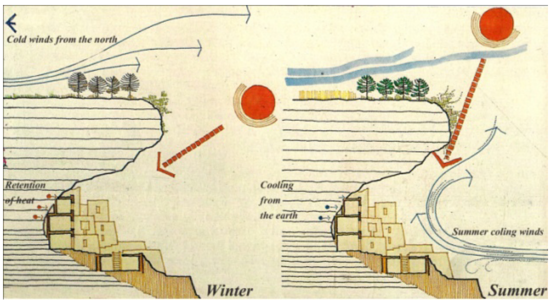

Figure14. Different elements and ventilation of Kivas

3.2. Tower of Shadows, Chandigarh, India.

A pavilion built in 1960, on the edge of Capitol Hill by Le Corbusier. It consists of a number of platforms oriented towards Cardinal points in an extremely precise way. The north elevation is completely open, while the other three elevations are equipped with sun breakers to control the amount of sunlight entering the building. Although Tower of Shadows is not particularly a residential case study, but the exhaustive environmental studies that Le Corbusier carried out can be applied on housing units to minimize the consumption of energy. Using a scale model of the building, Le Corbusier observed and recorded the movement of the sun in details throughout the year to determine the ideal direction of sunbreakers, as shown in Figure 9.

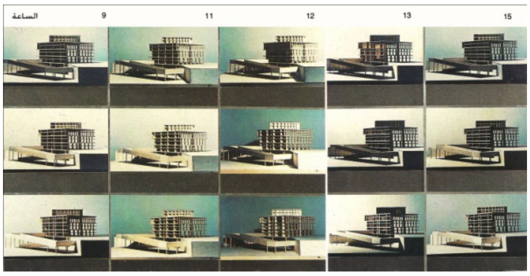

Figure 15. A scale model of the pavilion

From observing the changes of the sunlight impact on the building, he concluded the following: the south elevation that is provided by vertical breakers allows for a minimal amount of sunlight during summer when the sun is vertical, while in winter, was the sun is at an angle, sunlight is allowed in to light up the interior architectural spaces. Also, shadows on the model were recorded through still images and calculated mathematically and geometrically (Girsberger, 1986).

The open architecture space creates a feeling of coolness during the blistering hot days in India. Furthermore, due to the ideal living conditions of the building, it has become a place for social meetings and spiritual recreation. The Tower of Shadows is considered as a model reference for architecture for its ideal use of sunlight and shadow, especially for residential building design (Vytorin, 1984).

3.3 Wind catchers.

The Wind catcher is a traditional Persian element that is used to create comfortable living conditions through natural ventilation in the building. Wind catchers have multiple designs, structure and function according to the location and direction of the building. The most common designs are theuni-directional and the multi-directional, and they consist of one, four or eight openings. There are various ways in which a wind catcher functions: steering airflow at the top of the building, which is often colder downward, steering airflow upward through wind-assisted temperature slope, or steering airflow upward through solar-assisted temperature slope, as shown in Figure 10. The wind catcher is usually directed towards prevailing wind. The airflow outside the building creates a difference in pressure between the inside and outside which results in directing the airflow downward to the building. Some wind catchers are provided by a net that purifies the air from dust, pollutant and insects. Others are supplied with burnt coal that absorbs bad odors entering the building from outside (Edkin, 1976).

The thermal exchange between the building and their surroundings depends on the airflow rate, which means that great airflow results in more thermal exchange. Hence, if we desire to reduce the temperature of the building using natural ventilation, wind should be directed towards the building, even if forced, while to minimize thermal dispersion, we should protect the building from undesired wind. Windbreakers are used on the building to eliminate undesired wind effect by directing it towards different directions (AlSuliman, 2009). The size and depth of windbreakers determine the surface area that is protected. Airflow causes the temperature to drop on the building's elevations; as well as thermal exchange resulted from continuous ventilation. The air pressure often rises at the building's elevations that are exposed to direct wind, while it drops at those that are on the facing sides, resulting in airflow inside the building through openings and sometime cracks.

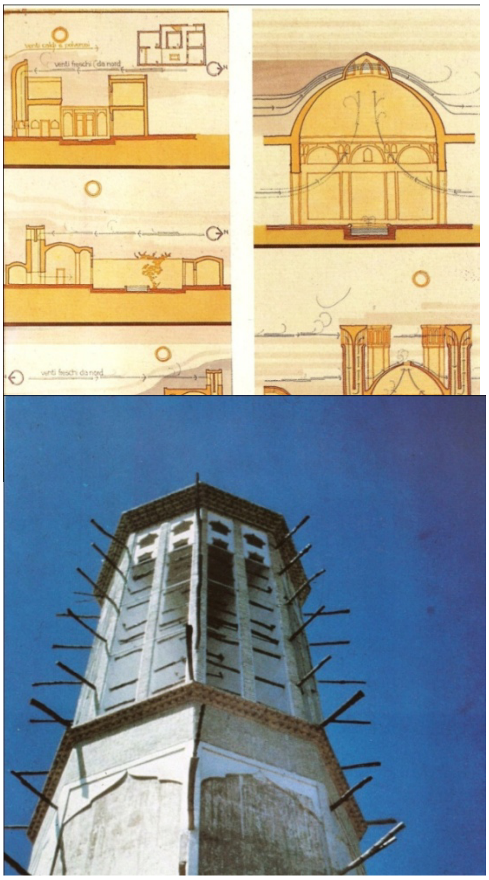

Figure 16. Different examples of windcatchers and how they operate

3.4 Z6 House, California, USA.

A modern case study is this two-story residence, which was completed in 2006 and chosen as an AIA committee Top Ten Green Projects for 2007. The name is taken from the main design concept "Six Zeros", which refers to: zero emissions, zero waste, zero energy, zero carbon, zero water, and zero ignorance. The section of the house is illustrated in Figure 11.

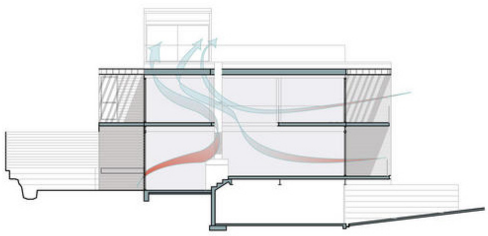

Figure 17. Sections through Z6 House

The main issue of designing a building at this particular location -where climate is dry and humidity control is not a concern- was to take advantage of the constant, foreseen breezes from the coast, from the Southwest and Northwest to create natural ventilation in the house. The house is oriented 45 degrees from the North-South axis. The Southwest, Southeast, and Northeast facades are all provided with operating windows and exterior sliding doors that allow for natural ventilation. Also, the open plan design of the two-story house contributes to the continuous air movement throughout the house. Moreover, a chimney effect is noticeable in the design as the whole-house fan that is located at the top of the stairs takes hot air out of the house, as shown in figure 12.

Figure 18. Natural ventilation in the house

Another issue was to provide mild heating in winter. Although air-conditioning was not required, good passive solar orientation and shading was a major design aspect. The Southwest, Southeast, and Northeast facades are all equipped with large overhangs to protect from the summer solar heat, as shown in Figure 13. While the Northwest façade has a clear insulation panel to transmit daylight. During winter, direct sunlight is admitted through the Southeast glazing, which warms up the concrete floors and heats the entire house, as shown in Figure 13. The floor heating system runs on a heat exchanger that use an evacuated-tube solar hot water collector (The American Institute of Architects, 2007).

Figure 19. Large overhangs on facades and concrete floor

4. Proposed table to address the climatic difficulties and recommendations for a sustainable residential architecture

Using climate charts and tables when to make urban and architecture decisions.

Climate tables and charts are considered an intelligible, solid tool to collect, calculate and analyze climate data of a location and provide architectural and urban design solution to achieve ideal living conditions that suit people's lifestyle (AlSuliman, 2009).The main table structure.

The table, Figure 14, consists of three horizontal sections that have information relating to specified time intervals throughout the year, while the vertical sections include the following:

1) Information about the conditions of the surrounding outside environment, illustrated through four elements: the average temperature, relative humidity rate, wind direction and speed, and solar radiation. This information is clear and can be used for each horizontal section separately.

2) Suggestions to overcome the various environmental difficulties and create ideal living conditions. These suggestions lead to more valuable architectural designs.

3) Propose urban and architectural solutions.

The following are two proposed tables that demonstrate all the information mentioned above for two Syrian cities: Lattakia and Aleppo, which have different and distinct environmental conditions.

Case Study 1 I **Lattakia, Syria**

	Problem	Suggestions to Overcome Problems	Urban and Architecture Solutions
Winter	Extreme low temprature. Strong air currents.	Heat the living room directly. Heat bedrooms through Trombe walls. Provide opennings to allow for continuous airflow.	Provide glass south openings. Provide buildings' proximity. Provide Tromb walls for solar control. Provide opening on the middle floors to guarantee a continuous airflow.
Spring and Autumn	Moderate temprature.	Solar radiation protection. Provide ventilation through shaded areas.	Use sunbreakers on the south elevations to protect from solar radiation. Provide large openings for ventilation through elevations, and use building's mass design for natural ventilation.
Summer	High humidity. Harsh solar radiation.	Provide a continuous ventilation. Solar radiation protection. Provide shading devices.	provide vertical sunbreakers on the south elevations to allow protection from direct sunlight. Provide large openings to allow for high humidity disposal from the architectural spaces.

Case Study 2 I **Aleppo, Syria**

	Problem	Suggestions to Overcome Problems	Urban and Architecture Solutions
Winter	Extreme low temprature. Strong air currents.	Heat the living room and bedrooms directly through direct solar radiation from the south elevation.	Provide solar radiation to the interiors through internal courtyards. Reduce humidity through increasing temprature in the interiors and provide heat insulation. Provide windbreakers to steer cold north-east wind.
Spring and Autumn	Moderate temprature.	direct solar radiation protection. Maintain the internal climate conditions witin the building. Circulate moderate airflow within the range of each rooms' bioclimate separately.	Position the most used rooms towards south-west. Provide open and shaded area on the esterior and artificial operating water bodies. Provide seasonal vegetation in the inetrnal courtyards.
Summer	High temprature. Moderate humidity.	increase humidity. Solar radiation protection. Provide ventilation.	Use windcatchers and internal courtyards for best use of west air currents. Use sunbreakers. Use thermal reservoirs such as Trombe walls. Increase the thickness of external walls for heat insulation. Use pale colors for walls.

Figure 20. Table that shows the architectural solutions to environmental conditions in two cities in Syria

Recommendations for a sustainable residential architecture:

1) Encouraging direct contact between Buildings and natural land “soil”, and placing them at least one meter below ground level for best use of air currents of the appropriate direction of wind. Also, providing buildings with artificial water bodies at the hot climate zones, so that we can control the rate of relative humidity and wind flow according to the desired results.

2) Installing sun breakers on east and south elevations to protect from solar radiation in summer. Also, developing sun breakers to act as an energy source by installing solar cells on the external parameter “east, south east, and west”.

3) Making use of the wind catchers by installing electric units “turbines” to generate electricity within buildings’ interiors, which provides the building with the power needed to operate electric devices.

4) Providing buildings’ wind catchers with solar-operating heaters for best use of the airflow that is transmitted into the interiors, hence heating buildings without the need for electric units and achieving ideal living conditions, which saves power and energy.

Other recommendations that have been discussed within other research papers, and have proven to work in favor of Sustainability and Green Architecture:

1) Installing Trombe walls on parts of the south elevation to allow direct thermal exchange between the interior spaces and the exterior surroundings and control it through different seasons, as shown in Figure 15

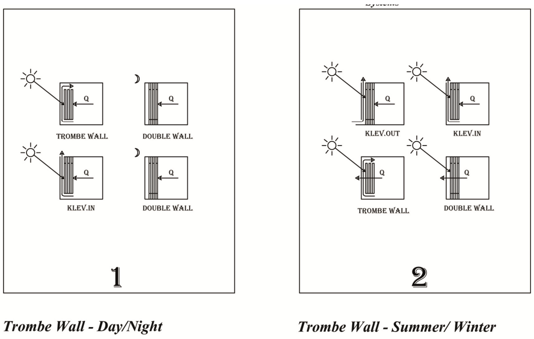

Figure 21. The use of Trombe Walls

2) Installing solar-cell units to support the building's consumption of power and transmit the excess to the public network which helps reduce environmental damages through fossil energy, as shown in Figure 16.

Figure 22. Ceramic roof tiles with solar energy units

3) Using automated lighting that operates in correspondence to people's activities within spaces, which save power.

4) Providing rainwater tanks in buildings' basement. The collected water can be used in summer to provide appropriate humidity within the interiors as shown in the diagrams.

Figure 17 illustrates a section through a building where several architectural decisions are made to achieve sustainability.

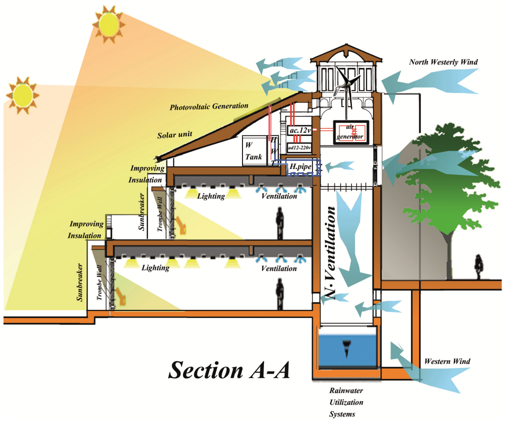

Figure 23. The ideal use of natural conditions to reduce energy consumption

5. Conclusion

Good use of natural and environmental materials and architectural heritage for each region separately has a dramatic influence on the comfort level of living conditions in modern buildings. Modern architects should advocate sustainable architecture through environmental awareness and the ideal use of available natural resources to reduce the consumption of power, which leads to the reduction of carbon dioxide in the occupied architectural spaces. The implementation of sustainability in architectural and urban design through the use of climate and surrounding environment conditions without compromising the building's functions leads to increase in energy conservation. The building then becomes self-sustained, and it can also act as an additional energy source in the city public energy network (Kantlis, 1971).

The use of sustainability both in theory and practice has proved that such systems achieve ideal building design hence ideal living conditions. The cost spent on power and energy consumption in a building through technical units can be spent on a sustainable design instead, which eventually saves a lot in the long run. Architects of the modern world should be encouraged and provided by the sufficient education to focus on sustainable design for better environment, hence better living conditions. Architects design buildings, and buildings design people's lifestyle, therefore it is the architect responsibility to put sustainability in a good use.

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