Architectural Facade Design Proposal for Water Production via Air Content

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Abstract

The main aim of this article is to analyse current facade techniques, water producing systems and possible profits from the application of adequate facade designs which could produce water with the consideration of the needs of inhabitants. Nowadays for certain countries lacking the financial power to provide adequate water resources, the need of water harvesting becomes more crucial. The proposed water harvesting systems aim to increase the water resources by the application on the building's facade. On the other hand, existing double skin facades have only been used for shading, ventilation or decorative purposes. This investigation focuses specifically on the design of the facade in terms of the production of water. The case study has taken place in North Cyprus, Nicosia. A selected area will be evaluated and the need of the water will be calculated then the proposal of the new facade model will be introduced. Most importantly this proposed facade model will meet the needs of water consumption of the inhabitants. It produces 420 litre water per day by using solar energy. With this system the application uses the sun energy to extract water from the air, also the application has potential to use as multi-functional purposes since it collects water via humidity with turbine systems, it collects up to 396 litres at temperatures between 86 degrees to 104 degrees (30 to 40 degrees Celsius) and between 80% and 90% relative humidity.

Keywords: Facade Design, Sustainability, Water production, Nicosia.

1. Introduction

Cyprus Island in the Mediterranean Sea has a major gap between water demand and water supply in the TRNC (Turkish Republic of Northern Cyprus). The increase in water demand due to the economic growth is expected to result in a further increase in water supply due to climate change (Türkman, 2002).

The economy of the island is mostly agricultural and tourism. In addition to 250,000 citizens there is also huge amount of students coming to the island every year. The city has highly intensive seasonal movement because of 26000 students (Muslu, 2003). The need of the water supply in the TRNC is provided entirely from underground water resources and 41 dams built on existing streams. The Dams purpose is to prevent these streams reaching to the sea and feeding the groundwater (Sıdal, 2006). The total underground water reserve in the T.R.N.C is 74.1 million m^3/year (Alkaravli, 2002). According to the United Nations study for Northern Cyprus and the republic of south Cyprus the following scenario shows there will be a water shortage in 2025 and the country is going to suffer the water shortages (Türkman & Elkıran, 2008). It is clear that in the TRNC 74.1 million m of water provided sustainably by aquifers in 2001 with 126 million m^3 of water consumption, this shows that there is a serious water shortage and negativity. It can be seen that the aquifers water level drops under Sea level and the sea water gets mixed in to the aquifers (Sago, 1999). There are two billion people and 40 Countries that is estimated to suffer from water scarcity in 2030. Moreover, %47 of the world's population will be living in areas with high water stress (WWDT, 2012). Water scarcity may be the most underestimated resource issue facing the world today.

This project's goal is to create a facade design in order to make humidity be absorbed in the air. This system separates the water molecules and store water in a liquid form. This development is for higher quality of life and sustainable development. With this process the facade is not only used to increase the internal comfort or decrease energy consumption but also provides an efficient living condition for the users. The percentage of water consumption for one person is about 3.7 liters for a man and 2.7 liters for a woman a day (Water: How much should you drink every day, 2017). Through this integrated system, the opportunities will be analysed. The case study building is selected in Nicosia, Cyprus, due to the higher population and the life conditions, it will be a residential hostel building. After the analysis of the building, the new facade proposal will be rendered with a simulation program and the result will be seen for further discussions. Water production from the facade has a high influence on economy and also it is environmental friendly and a sustainable resource.

Secondly, the water that would be produced has great taste; no chemical contaminates such as pesticides, pharmaceutical drug residue or industrial or human waste, no bacterial contaminates. The AWG (An atmospheric water generator) eliminates all natural occurring contaminates and pathogens such as; bacteria, viruses, parasites, giardia, e-coli and other dangerous waterborne pathogens that kill 3 to 4 million people. (Air and Water: A Right or Privilege for all Citizens, 2017).The integration of this system has highly positive impact on the majority of human life's and has an alternative solution for facade designs.

2. Literature Review

To expose the importance of sustainability in humans` life can be perceived differently to every individual. As it can be seen with some scholars words, the understanding of sustainability is completely different and a huge topic to discuss (Graber, and Dailey, 2003: 11-12). The main approaches of sustainability are environmental, society focused and economical. Moreover it is important to mention the construction, process etc. (Hoşkara, 2009:3). Sustainability is a kind of environmental, economic and social comfort for the majority which means satisfaction of essential needs in order to have a better quality of life and without future concerns. So in this case the building should be environmental friendly, socially and economically sustainable (Graber and Dailey, 2003: 1-89). Due to the economic developments there are some changes in glass facade systems in terms of technological, energy performance as well as construction methods and materials. They call these facades double skin glass facades (DSGF) and they became very popular (Patterson, et al, 2008: 2-3).

This kind of facades has an air space which mechanically ventilates the air in the cavity. All these devices are designed and integrated in order to improve the indoor climate with active or passive techniques and all of these devices could be controlled via remote control systems (Harrison and Boake, 2003). In general the tectonic of enviromental skins, which called double skin facade systems as esentially a pair of glass 'skins' that are seperated by an air corridor. The double skin facade is higly influencial to the highest temperatures and it has advantages as a wind and sound protector and a sun shading device are all located between the two skins. All elements can be arranged differently into many number of permutations and combinations of both solid and diaphanous membranes (Arons, 2001). We can define double skin facade as a facade that consists of two distinct planar elements which allows interior or exterior air to move through the system.

Although, there are lots of double skin glass facades none of them are used to produce water. Therefore, this research will examine the possibility of producing water on facades. One of the water production systems via air content is a Cooling Condensation type of atmospheric water generator (AWG) shown in figure 1. It has a refrigerant through a condenser and the evaporator coil that cools the air surround it. This causes the water to condense and the fans push the filtered air over the coil, passing through the tank for purification, then to the filtration for reducing the viruses and bacteria which is already collected from the air.

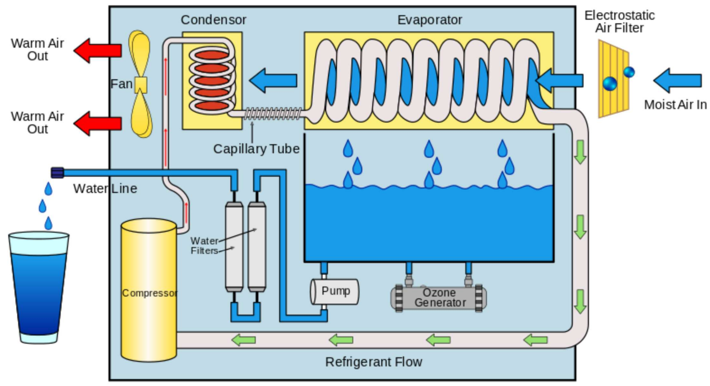

Figure 1. An atmospheric water generator (AWG) **(URL 1)**

The water production depends on relative humidity and ambient air temperature and size of the compressor. The atmospheric water generators become more effective as relative humidity and air temperature increases. As a rule, cooling condensation atmospheric water generators do not work efficiently when the temperature falls below 18.3°C (65°F) or the relative humidity drops below 30% (Wolber, 2017).

Figure 2. Collecting desalinated water through fog **(URL2)**

In figure 2. Researchers have found a system that brings drinking water from the air in Chile. They developed a special mesh that can collect the water from the morning fog channeling it into reservoirs. Using a simple system which has suspended mesh structures. They have used this fog water for agricultural use and had a dramatic impact on the lives of communities.

'This water has been naturally desalinated by the sun, we are trying to build meshes to capture it straight out of the air,' said Gareth McKinley who is leading the project. It is a system that still has a laboratory experiment, variation in the mesh spacing as well as the size

and the wettability of fibers in the mesh all affects the volume of water that can be collected each year (Collecting desalinated water through fog, Design Indaba, 2017). The changing of the fibers improved the system 500% mesh based on fog harvesters are passive, inexpensive to fabricate with close to zero mesh-based fog water in this Chilean cloud this process creates %4 drinking water for an entire year.

Figure 3. (Water Production from the Air Billboard) **(URL 3)**

Figure 3 shows, the Peruvian researchers who are collaborated with an agency to create an unusual billboard that generates drinking water from thin air. Lima University of engineering and technology produced this system to harvest the moisture directly from the air which is then processed through a filtration system. The capable of this system produces 25 gallons (96liters) water a day during the summer. The billboard has produced 9450 liters of clean drinking water for nearby community in the three month since it was first installed. Due to the lack of rain the high humidity makes it possible to harvest water directly from the city's air providing a sustainable alternative source of drinkable water (Peckham & Peckham, 2017).

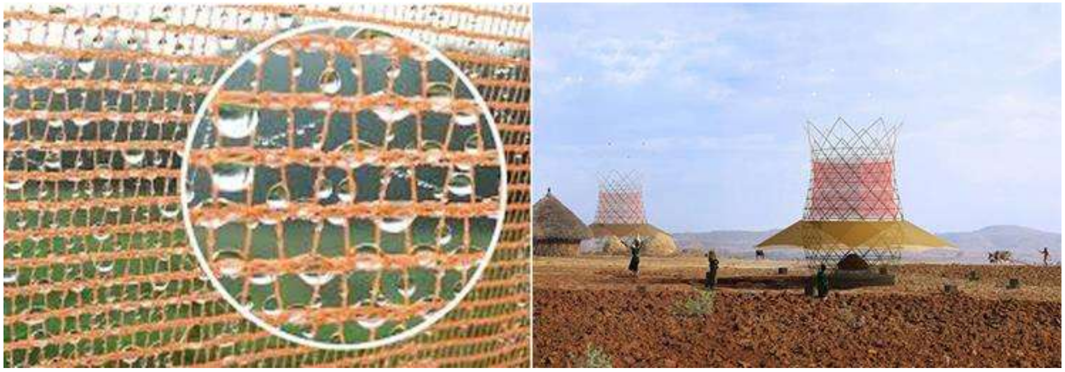

Figure 4. (A Warka water tower Bamboo Tower That Produces Water from Air) **(URL 4)**

The Warka water tower is created by Arturo Vittorio and his team at Architecture and Vision, these towers harvest water from the rain and fog. This design is 30 feet tall and 13 feet wide, it is not half as big as its namesake tree which can loom 75 feet tall, but it is striking nonetheless. The spindly tower, of latticed bamboo lined with orange polyester mesh, the systems brings water out of the air providing a sustainable resource for developing countries (Stinson et al., 2017).

Figure 5. (Fontus Water Producer Bottle) **(URL 5)**

Fontus designed in Vienna by Kristof Retezar. This device can extract humidity from the air which is shown in figure 5, that condense it into drinkable water. It generates water during long distance ride with a bicycle. Fontus has simple basic principle that condenses the humidity contained in the air. Retezár told Live Science, "*You always have a certain percentage of humidity in the air and it doesn't matter where you are— even in the desert. That means you would always potentially be able to extract that humidity from the air".* In additionally, "*Fontus can produce 0.5 quarts (0.5 liters) of water in 1 hour in what is considered "really good" conditions, with temperatures between 30 to 40 degrees Celsius) and between 80% and 90% relative humidity*'' Retezár said. The prototype includes a filter at the top to keep dust and bugs out of the water, but currently it does not include a way to filter out potentially harmful contaminants. The initial Fontus design was shortlisted for the 2014 James Dyson Award (Beach & Beach, 2017).

Figure 6. (Solar Hydro panels Harvest Drinking Water And Energy At The Same Time) **(URL 6)**

In Figure 6, the company source builds a panel which is like a standard photovoltaic but instead of just harvesting solar energy they use the rays of the sun to pull water from the air. Each panel has drawn up 10 liters (2.64) gallons of water per day. This system has standard solar panel that flanked by two hydro panels themselves have two different proprietary materials, one generates the heat, and the other can absorb moisture from the air; together they are able to condense water into an onboard, 30-liter reservoir where it is mineralized with calcium and magnesium. Within this, the water can be siphoned directly to a drinking tap (Pham & Pham, 2017).

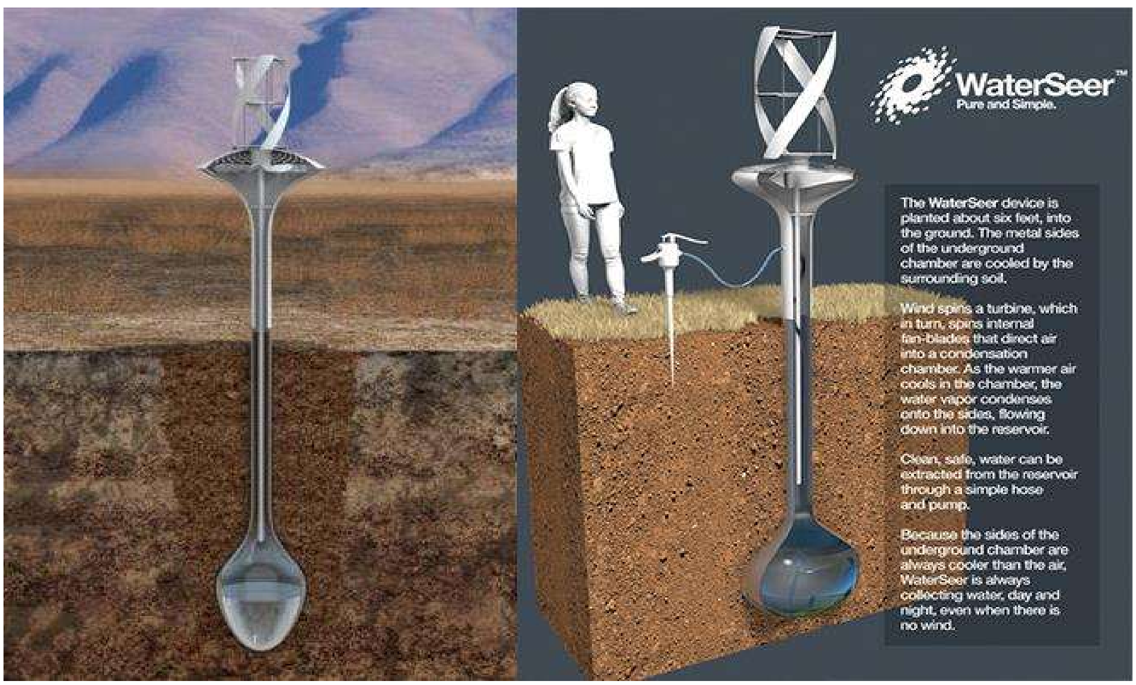

Figure 7. Water Seer **(URL 7)**

Water Seer is a low-tech, low-cost atmospheric water condenser that could help create water self-sufficiency in communities around the world. It is a device that operates without an external power input and without the need of costly chemicals. It pulls the moisture from the air and condenses it into water use. The temperature difference between the above-ground turbine and the collection chamber installed six feet underground. They use simple pump and hose to take the water; this device produces up to 11 gallons per day, even in arid regions. It has been developed by Vice and they have collaborated with UC Berkeley and the national peace curbs association, aims to provide a sustainable source of clean and safe water for the millions without a reliable water supply. This device helps to alleviate some of those that has poverty issues (Froelich, 2017).

3. Methodology

The methodology of this research is mainly analytical and descriptive. For this study a case study has been represented in order to show a possible use for the water harvesting in TRNC, Cyprus. This selected building is in Nicosia, Ortakoy and the function of the building is residential hostel. The further details of the case study is explained further within the reading. In addition to the case study, an interview has been undertaken to provide further information about the stated case study. Moreover, all the data collection of this case study analysis has been made with E.Z.B Architecture studio from the interview with the architect of this residential building. The data has been collected to evaluate the new proposed model of water producer facade. Furthermore, the paper provides a theoretical review on the double skin facade designs, the needed amount of water and the system of water production from the air. With the discussion of cases, the paper then will provide a framework to understand the application profits.

Finally, the listed findings are provided to understand the success of the application of the proposed water harvesting facade design. The simulation of proposed model made in Rhinoceros modelling program (Rhinoceros, 2017) and visualized in KeyShot ("3D Rendering and Animation Software - KeyShot", 2017) rendering program.

3.1. North Cyprus Weather Condition and Opportunities.

According to the Meteorology office of TRNC, North Cyprus has Mediterranean climate with hot and dry in summer seasons and warm and wet in winter (Pakishan, 2011).

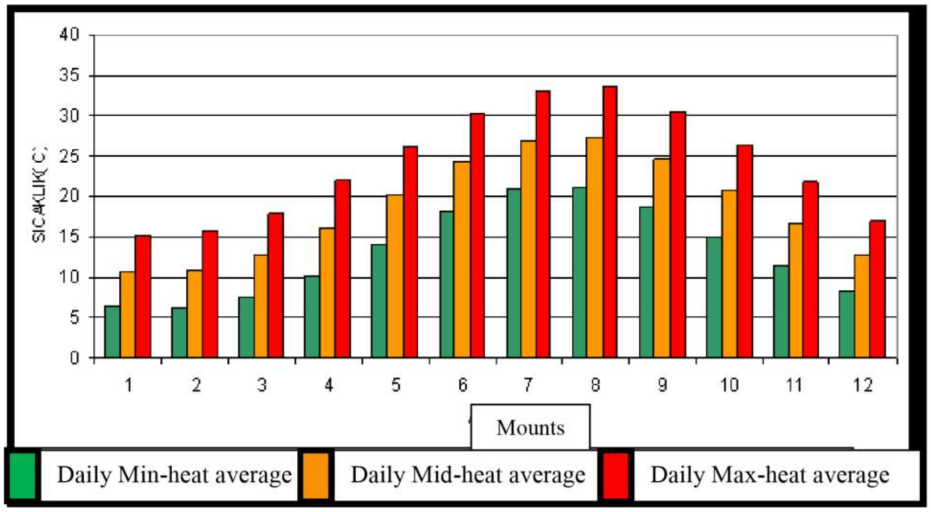

Figure 8, Monthly Amount of Heat during a Year **(URL 8)**

It can be seen in figure 8, that the average temperature is 19.0 °C .In July the air temperature during the day is (in shaded) 37 °C -40 °C. The coldest month is January that the air temperature during the day is 9.0 °C-12°C. The coldest night of the year is in the month of January, these nights freezing happens due to the decrease of the temperature of the earth down to 0.0 °C.

In order to summarize the opportunities and conditions in Nicosia; there is a strong wind in January and December and a strong sun in June, July and August, the concept of water production from the facade could be valid. Furthermore, the sun exposure is much more in seven months of a year and 9 hours a day in average. Solar radiation is at its minimum in December and January with 9MJ/m2, increasing up to 29MJ/m2 in June and July. In additionally, for Nicosia, the lowest amount of solar radiation intensity as 110W/m2 in December increases to 350W/m2 in June and July. Meanwhile the highest air temperature changes from 15.34 ºC and 36.23 ºC in general. On the other hand, the lowest air temperature changes from 5.43 ºC and 21.54 ºC average. Occasionally, during summer time the maximum air temperature can even go up to 44ºC and during the winter time the minimum air temperature can be seen as -6 ºC. Moving the humidity percentages, the highest amount can change from 25% to 86% during summer times and from 41% to 92% in winter times. In spite of the high percentage of humidity levels in winter time, there is few amounts of rain. Especially in the first month of the year, which normally is the month with the highest rain amount, has 60 mm/month and July and August experience no rains (Özdeniz, 2010).

3.2 Wind and Moisture in North Cyprus

The Wind is very important to produce water on facade for this reason it is very important to understand the wind direction of the region in North Cyprus wind blows from many different directions and this is because of the topography. In Figure 9, shows the maximum wind blow that is 22.2% is from west.

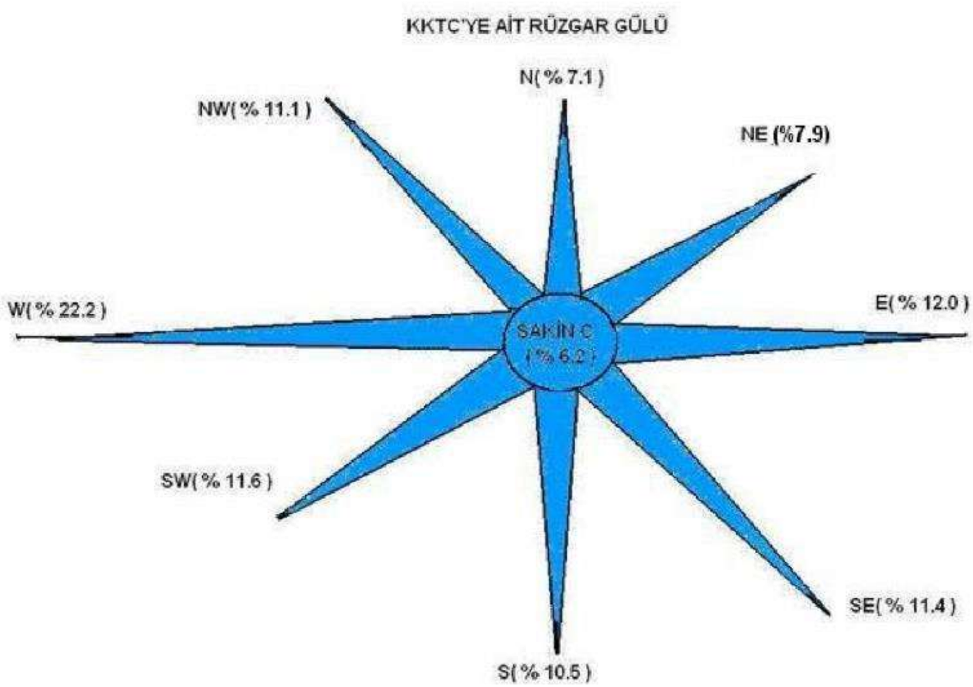

Figure 9, Wind Direction in North Cyprus **(URL 9)**

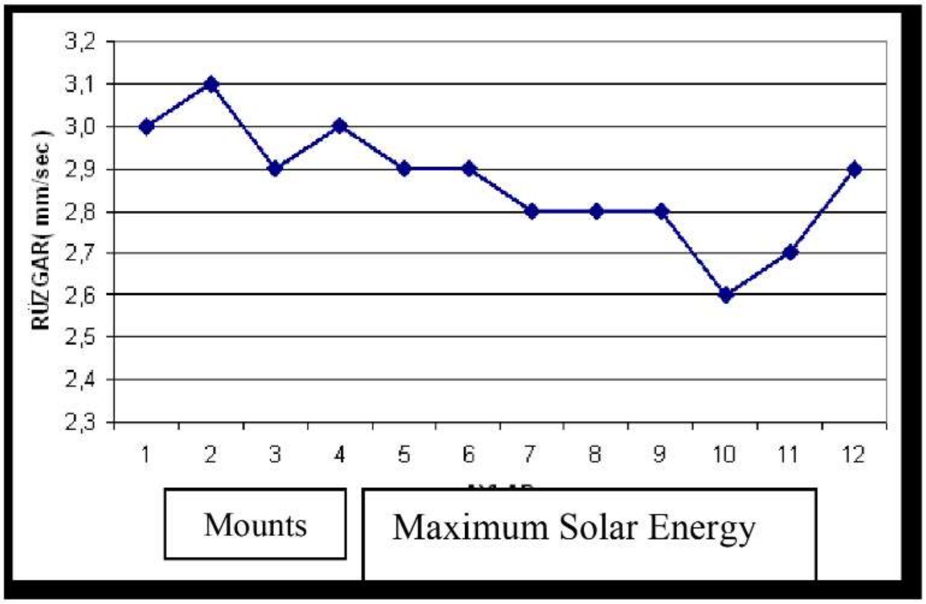

Figure 10, wind Speed in NC **(URL 10).**

As it is shown in Figure 10, average wind speed is 2.8 m/s that is mostly blown in July, August and September.

3.3. Analyses of the Case: Riverside Residential Hostel Building.

Figure 11, (River Side Residential Hostel) **(URL 11)**

The building is made by E.Z.B Mimarlik was started from November 2016 and finished in August 2017 the building is located in Nicosia, Ortakoy and the function of the building is residential hostel.

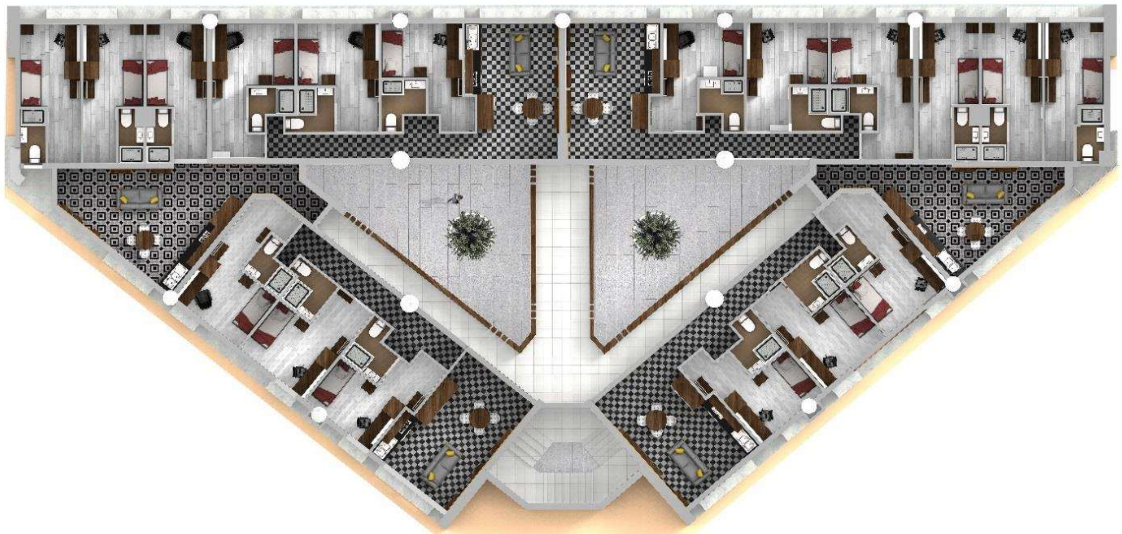

Figure 12, (River Side Residential Hostel Rendered Plan) **(URL 12)**

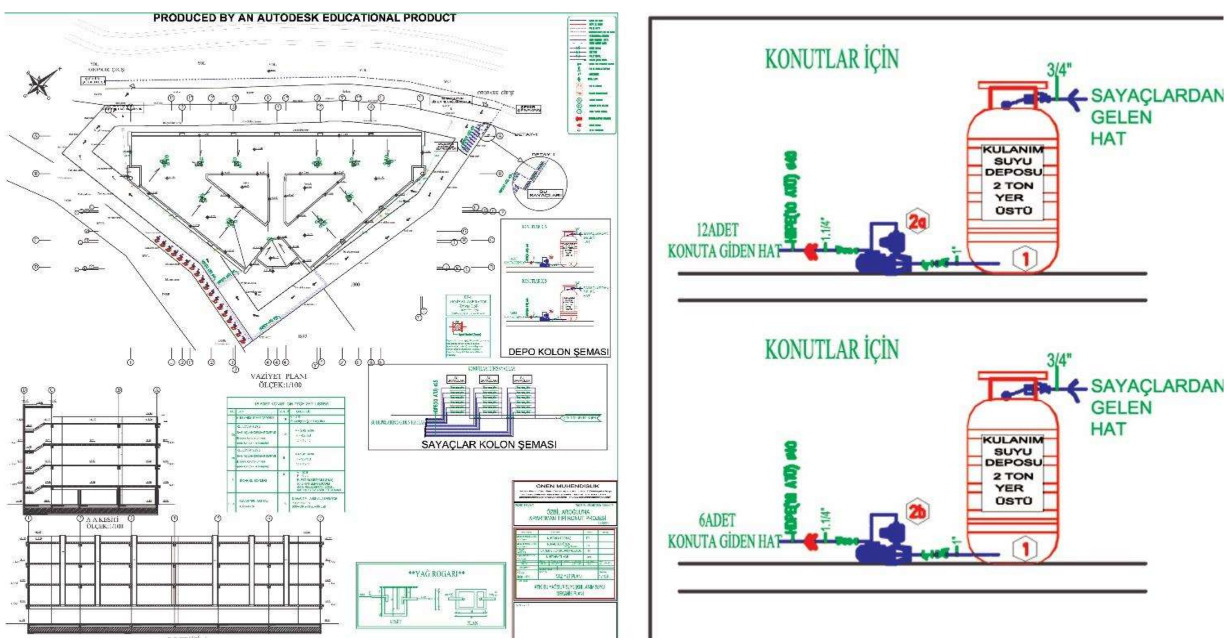

Figure 13, (River Side Residential Hostel Electric and Water Plan) **(URL 13)**

The building has three floors and used as a hostel for students, each floor has totally 18 bedrooms total capacity of the building is 54 persons and all the bedrooms have their own individual toilets. The interior of the building separated from each other and each three bedrooms have their own kitchen.

Figure 14, (River Side Residential Hostel Water Tanks and System) **(URL 14)**

According to the research and the interview with the E.Z.B architectural office the water consumption of each bedroom is approximately 350 litters. As it can be seen above, the waste water is removed from the system that is also visible in Figure 14.

4. Finding and Discussions

According to the research study the new water producer façade design proposal has been analysed in the literature review, finally it has uploaded into the case study the total amount of water has been analysed and the negative and positive parts will be evaluated by recommending design suggestion on hostel building.

4.1 The New Water Producer Façade Design for Riverside Residential hostel Building.

After the interview with E.Z.B architecture studio, the hostel building problems have been analysed, finally the proposal of mesh Micro climatic facade design (SOLTIS FT381) has been uploaded to the facade. This microclimatic facade has solar protection, minimizing lightness, minimizing of secondary structure, aesthetical and short time for installation (''Bioclimatic facade- Serge Ferrari, Serge Ferrari, 2017''). This integration system on the facade has structural differences between existing models. The model has steel structure empty pipes that can transfer water from the air to the filtration and the water tanks.

Figure 15, (Integration to (SOLTIS FT381) **(URL 15)**

Figure 16, (River Side Residential Hostel Integration of the Water Producer Façade design) **(URL 16)**

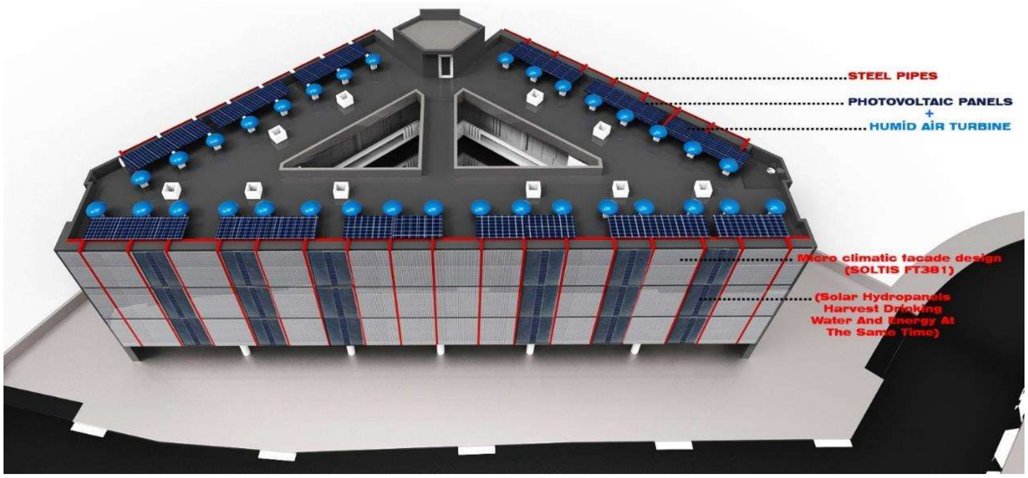

Figure 17, (River Side Residential Hostel Integration of Façade Front and top Vıew)
(URL 17)

Figure 18, (River Side Residential Hostel Integration of the System back side top view)
(URL 18)

In Figures 16, 17 and 18 as it is shown how the Photovoltaic and purification system has been uploaded to the building; the integration of both of the systems have been analysed. The blue circular parts have got an air turbine inside to humid air for the water production that each of them produces 12 litters water per day. In Figure 19, it is shown that the mesh structure pipes translate the water to the catchment basin.

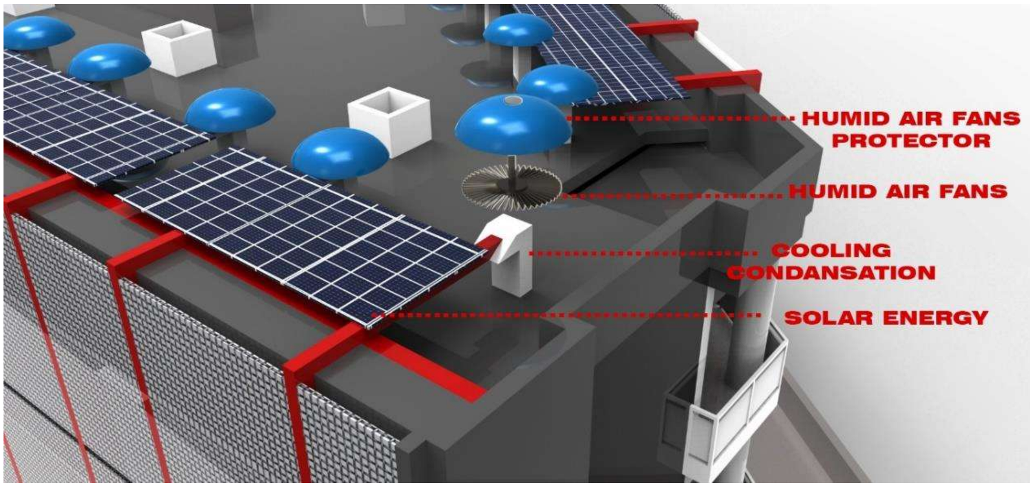

Figure 19, (humidity from the air system detail) **(URL 19)**

The section of the building in Figure 20, shows the process of how the system work has started from air turbines and photovoltaic panels; each photovoltaic panel has produced 10 litre a day there are 42 photovoltaic panels and 33 purification system. After the water production all the water goes through the catchment basin; inside the catchment the water goes through the filtration process and transfer to the cistern.

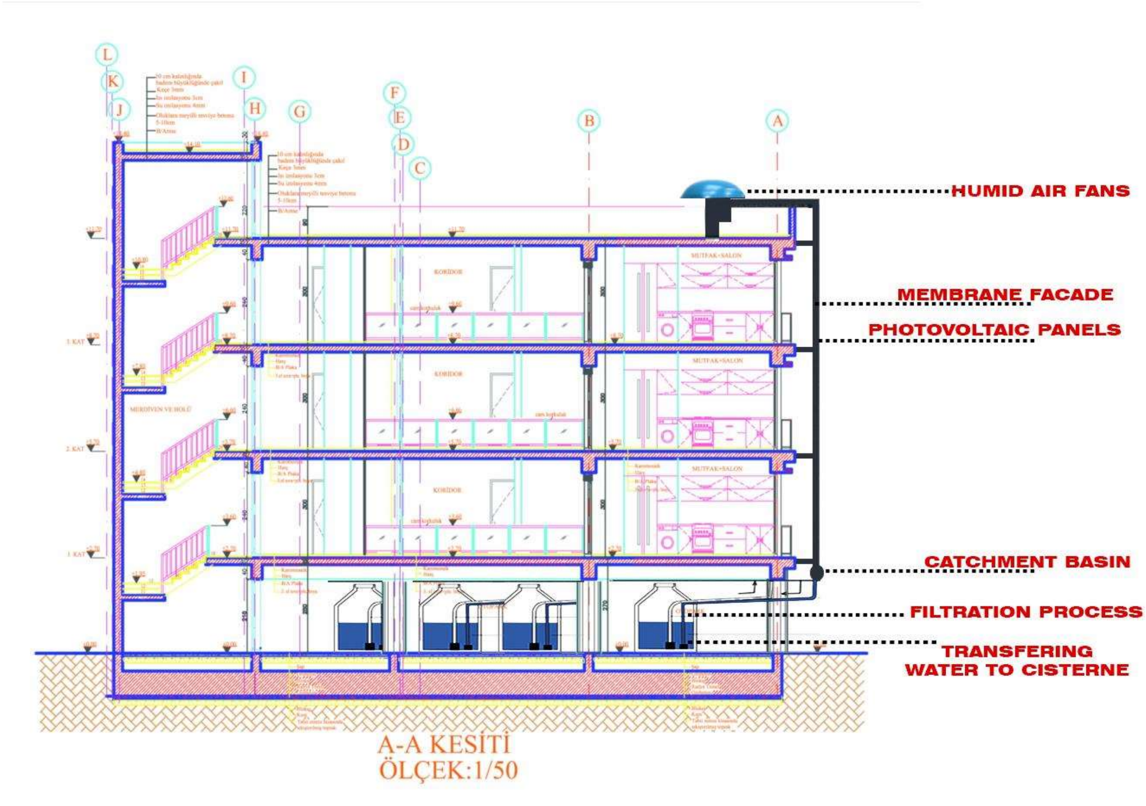

Figure 20, (River Side Residential Hostel Integration of the System) **(URL 20)**

4.2 Discussion

In order to summarize the opportunities and conditions of Nicosia North Cyprus; in January strong winds are seen and in June, July and August sunny days are seen. Therefore, the concept of water production due to the climate of the country and the region is claimed to be available to produce water from the façade. Furthermore, this application of new facade design can be used for only drinkable purposes. According to the research and the findings, this project produces 420 litre water per day by using solar photovoltaic panel's energy; it also collects 396 litre water by via humidity turbine with temperatures between 86 degrees and 104 degrees Fahrenheit (30 to 40 degrees Celsius) and between 80% and 90% humidity. Totally, the whole system produces 816 litter drinkable water per day. The daily fluid intake is about (3.7) litter 15.5 cups for a man and 11.5 cups (2.7) litters for a woman ("Water: How much should you drink every day?" 2017).The case study shows in figure 14 total residents who are living in riverside hostel are 54. If the analysis was made according to men`s water need the total amount of water they would need 199.8 litre per day and for the women it would be 145.8 litre per day. This calculation shows the water producer facade design is valid for producing daily drinkable water. Both systems collect totally 816 litter water per day and it is more than enough for 54 person. The negative effect of the water producer facade is the changing weather condition in Cyprus especially the humidity of the air; the calculation of 816 litter water could decrease due to the climatic factors such as the sun exposure as it is more seen with the seven months of a year and 9 hours a day in average. Solar radiation as it is minimum in December and January with 9MJ/m2, increasing up to 29MJ/m2 in June and July (Özdeniz, 2010: 10-80). Moreover, it is impossible to have less than 199.8 litter water or 145.8 litre water a day. Therefore, the facade application appropriately gives the total amount of water which is desired to be drunk during the day.

5. Conclusion

The importance of wind, daily sunshine period, total solar radiation, intensity, dry bulb temperature, mean-maximum and mean-minimum relative humidity, are all shown in the research by bar charts and figures in methodology then in literature survey it is found that the water production the temperature must be 86 or 104 Fahrenheit (30 to 40 degrees Celsius) and between 80% and 90% humidity for the highest result for the water production. (Beach & Beach, 2017).

Due to the findings and literature survey the total water production from the air 12 litters a day from the each purification system. Moreover, the photovoltaic panel has produced 10 litters a day there are 42 photovoltaic panels and 33 purification systems. The total amount of water produce by photovoltaic are 420 litre per day whereas by using solar energy, the humidity turbines collects 396 litters with temperatures between 86 degrees and 104 degrees Fahrenheit (30 to 40 degrees Celsius) and between 80% and 90% humidity.

The opportunities of the weather conditions in Nicosia is the strong wind in January and December or the strong sun in June, July and August, the concept of water production from the facade could be valid for only producing drinkable water from the air. Furthermore, the sun exposure is more in seven months in a year and 9 hours a day in average. Solar radiation is minimum in December and January with 9MJ/m2, increasing up to 29MJ/m2 in June and July (Özdeniz, 2010: 10-80).

The new water producer facade has been uploaded by simulation techniques and the system process has been evaluated and shown by figures. The main reason behind this research was to investigate the possibility and opportunity of creating architectural water producer facade design that can provide water due to the climate conditions in North Cyprus.

Finally, the importance of water harvesting lies in the process of taking the unused water in the air and preparing it to use by the people in order to increase the quality of life and lifecycle. In this research the existing double skin designs have been analysed and the model of (SOLTIS FT381) structure has been modified to produce water also the humidity turbine has been uploaded to give an extra efficiency for the windy days in Cyprus.

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