

## Research Article

## Wind Towers "Wind Catchers" A Perfect Example of Sustainable Architecture in Egypt

M.M.Tolba<sup>^\*</sup><sup>^</sup>Department of Architecture, Higher Institute of Engineering -ELShorouk Academy, Egypt

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### Abstract

*This research seeks to examine how to use renewable natural resources to preserve the environment for future human generations. The use of such renewable natural resources is always the best option. In addition, searching for innovative architectural solutions for our energy-consuming buildings for ventilation, air conditioning and heating, poses a challenge for designers, who need to take up responsibility in finding different solutions. Older generations used available technologies to design buildings that imitate the benefits provided by natural resources, while present generations continue to drain energy. Older generations worked on finding treatments for different environmental architectural buildings. Amongst the best examples are: the wind towers (wind catchers), domes and cupolas, courtyards, water fountains, oriels, takhtbosh, ewan, salsabeel, shokhshikha, sistrum, kamarhya, omarhya, etc., which are widely used in the Middle East, especially in Cairo, Egypt. This research aims to describe the elements used in Islamic energy-saving architecture with the help of natural resources. This paper will also explain how to use these simple and smart energy-saving solutions to design buildings to save our energy-depleted resources.*

**Keywords:** *renewable, natural resources, energy-saving, environmental design, wind towers (wind catchers), courtyards, domes, modern design.*

### 1. Introduction

Environmental design is a type of design that helps fulfill our basic needs of an architectural space while being environmentally friendly and stable all year round. It is attained by using natural renewable energy resources, such as the sun, water, and wind. Geographically, Egypt is a site that can apply these environment friendly, sustainable and renewable options over time, as it contains various climate zones, and each zone has its own advantages. Most lands in Egypt are desert land, falling between latitudes 18-30 north of the equator ( Edwards, B )This area is characterized by a dry climate with scarce and irregular rain fall with large differences in temperature between day and night in both summer and winter. The northern part of the desert is located in the Mediterranean region (moderate climate territory) which is located between latitudes 30-40 north of the equator and is characterized by high temperature and low humidity (dry) summer, and by mild temperatures and rain in winter (Egyptian Meteorological Authority (EMA)).

Therefore, in the history of architecture in Egypt, which dates back many centuries, we find the use of wind towers (wind catchers) as a design for buildings in different regions with varying climates. Wind towers had appeared as an architectural element in Pharonic architecture in the house of "Neb Amon"(Ministers of

Islamic architecture). They appeared later in old churches in Christian architecture in Egypt, and in Islamic architecture, particularly during the Abbasid period, hospitals and most houses were designed with air towers (wind catchers). Islamic architecture took into account the climatic conditions and sought to meet the needs of the buildings in the environment. The wind tower of El-Saleh Talaea Mosque is considered one of the oldest wind towers to remain intact. Following that are the wind towers found in El-Camilia School, Baibars House and El-Senary House (1209AJ/1794 AD). The wind tower in El-Senary House is located on the right side of the house with the aim of cooling the interior of the house in the morning when temperatures are high. All of these examples of wind catchers and other similar solutions created Egypt's many architectural theories in the history of architectural buildings.

In this research we want to know if it were possible to implement the theory of the wind catchers in modern times, and thus introduce it as an architectural concept with existing modern air-conditioning to keep up with the current needs. Also, we consider the use of mono-draught technology with a new approach, in addition to taking into account other factors such as the economic factor (represented in high energy prices) and environmental impacts (global warming) to study the suitability of these technologies using wind towers as a good and energy-saving alternative in the future if they could be used on a larger scale.

\*Corresponding author: M.M.Tolba

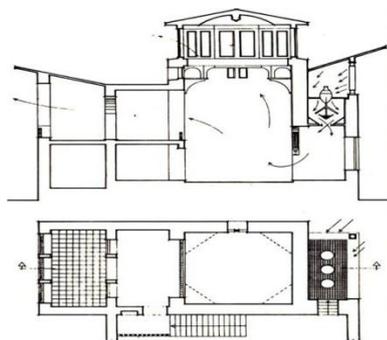
## 2. Wind Towers

Wind towers (wind catchers) are around 5-8 meters in height at the top deck of the building; they have a slot corresponding to the direction of the prevailing winds.

The advantages of wind towers are:

- They provide natural ventilation and passive cooling for the interior spaces of buildings.
- They seize the air passing over the building that is clean and free of dust from the upper layers in the outside space, which is usually cooler. They push it into the building and make it flow through the interior spaces, causing air circulation and making the interior spaces cooler with constant air flow and proper ventilation. The increase in air speed inside the building provides coolness and comfort to the people living inside.
- They reduce the level of noise coming from outside the building, which usually accompanies the ventilation coming from windows.
- They ventilate buildings that do not have external windows.
- They capture fresh air in any direction of the building, even if the room is not facing the prevailing wind.
- They provide proper ventilation for many floors inside the building with no need for artificial methods of ventilation.
- They minimize dust pollution carried with warm air drafts in desert climate zones.
- They transfer heat by convection and evaporation from inside the building to the outside. Figure 1 shows sector and cross section of a building with a wind tower (wind catcher) (Montazeri, H.R).

Wind towers can work with or without wind flow due to differences in air temperature and pressure inside and outside the building, which works by sucking air in.



**Figure1:** Sector and cross section of a building with a Wind Tower (Wind Catcher).

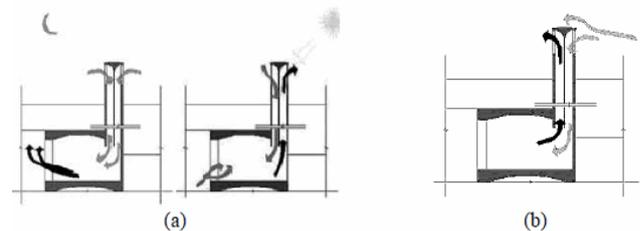
### 2.1 The Impact of climate on designing wind towers (wind Catchers) in terms of size and type

Wind towers used in dry atmospheres differ from those used in the humid climates. The size of the wind tower depends on the temperature of the external air. If the temperature is low at the entrance to the wind tower then the horizontal cross section must be large, but if the temperature is high at entrance of the wind tower then the

horizontal cross section must be small, so that it can moisturize and cool the air passing through it.

In Egypt, pottery (with micro-pores) is filled with water that is put in the course of air passing through like the wind tower. Wet hay and wet charcoal plates are placed between metal sheets for the same purpose. Air flow can also be directed through a water fountain or "Salsabeel" for extra cooling. Also, air flow can be directed to a specific room or to a cool room to preserve food (refrigeration). In order for Wind towers to absorb humidity, they should be placed on the interior walls and should not be facing the sun directly. This shows that climate plays an important role in the use of wind towers. The most common types of wind catchers according to their forms and aspects are:

- **One-way Wind Towers:** These are towers placed on top of a building with air outlets that direct prevailing air currents. It captures cold air and passes it through to the interior spaces of the building. This type of wind tower is usually built within the thickness of the wall itself and usually does not exceed 50 cm x 20 cm in diameter. In the lower end opening it does not rise more than one meter above the ground. This type of one-way wind catcher is covered at its opening by a rectangular slope or a semi-circular lid which leads to a cylindrical cellar. It is usually used in desert areas, like the sirocco in Egypt, which abound with wind-provoking dust. It is used to prevent this dust from entering the house; the tower can also be treated by placing a filter. (Lecoq,1978).
- **Two-way Wind Towers:** In this type of towers, each opening has a specific function. The first is placed in the direction of the prevailing wind (to absorb the wind and leave it inside the house), while the second is placed in the opposite direction to absorb hot air from the rooms and release it to the outside. The hot air is therefore replaced by moist air coming from the first opening (Montazeri, H.R ). as shown in Fig 2.



**Figure 2:** The hot air is replaced by moist air coming from the first opening

- Wind tower openings can be controlled day and night, and can vary in function from one to the other Figure2a. Due to varying temperatures, during the day one is used to absorb the air and the other is used to discharge it, while at night when the weather is cool both openings absorb the air.
- **Multi-direction Wind Towers (Albadjir):** These are considered a development of the one-way wind tower. However, it opens in four directions to absorb the air from every direction. Although, there are multiple forms of the Albadjir design, the square shape is the

most common. There is also a rectangular shape which has the longer side in the direction of the prevailing wind. Some hexagonal and octagonal wind towers were found in some Gulf countries and Iran. These can be controlled through the opening and closing of some slots, during the different seasons in the year, or during day and night.

- **Wall Wind Towers:** These towers are based on the idea of the impact of wind pressure on the surfaces of walls in large rooms. On the outside, they appear as horizontal hollow niches, located at the top-center of the outer wall, at the bottom of the niche there is a key to control the opening or closing from the inside. High-pressure air flowing on the surface of the outer wall facing the prevailing wind is collected in the niche and pushed through the opening causing the inside air current.
- **Ventilation Tower:** It is a square tower, from the inside, divided into four longitudinal wells by two perpendicular walls which parallel the external walls. Air enters from outside through two wells facing the wind, and at the same time the hot air leaves through the other two wells. In complex ventilation systems, groups of wind catchers are joined together to create a tower for combined ventilation to serve a number of rooms and is commonly used in tropical areas. Some systems place containers of cold water in several places to increase cooling, or hot coal in others for heating (Montazeri, H. R).

2.2 Impact of wind towers on ventilation rates

When there is a difference between internal and external temperature, the difference in air pressure generated as a result of expansion of air may be used in creating ventilation by way of wind towers. The rate of ventilation (V) depends on the difference between internal and external temperature. The difference in height between the entrance and exit of air is measured from the center of the holes (h) and air inlet area (A), ventilation rate per unit (aperture area) is explained in the Figure 3,4 and in the equation :  $V = 0.117 A \Pi h. dt m^3 / sec / m^2$

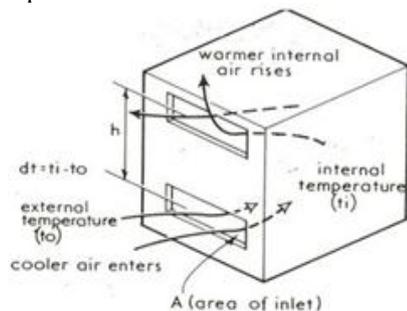


Figure 3: ventilation rate per unit (aperture area)

When the different air inlet area varies considerably from the exit area, a correction factor is used to increase or decrease the value of (V) or the rate of ventilation. The previous equation is used to calculate the speed of air flowing through the entrance and exit as a function of difference between internal and external temperature.

Table 1: using a correction factor

Correction factor	Area of outlet ÷ Area of inlet
1.38	5
1.37	4
1.32	3
1.26	2
1:0	1
0.85	0.75
0.63	0.5
0.34	0.25

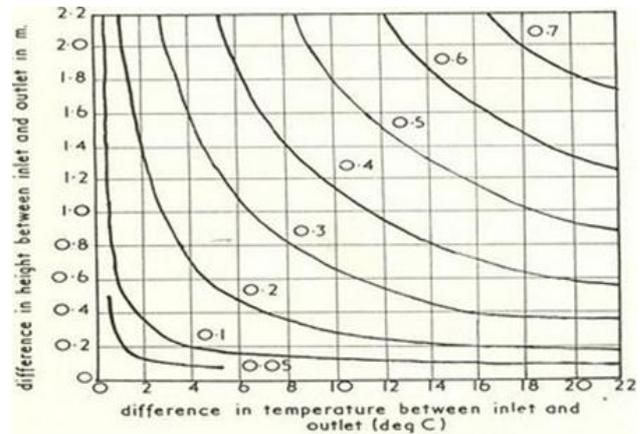


Figure 4: shows the difference in height, value and this speed in current can be regulated using a correction factor

The same graph can be used to show the difference in height and value. This speed in air current can be regulated using a correction factor given earlier if there is a difference in size of the entrance and exit, this same graph can be used to find a ventilation rate when the size of the opening is known. The graph in Figure 4 also illustrates several points including:

- In the presence of a slight difference in temperature and a slight difference in height, there is little movement of air due to the impact of the wind towers
- Wind speed at the entrance is stronger when there is a difference between internal and external temperature. This is due to heating in winter.
- Under conditions of warm weather with open windows, the difference between internal and external air temperatures does not exceed five degrees and the highest difference in height between the entrance and exit is one floor with large openings that do not exceed 1.5 meters.
- In hot, dry weather, the building is heavy and exposed to daily difference in temperatures ranging from 5 to 10 degrees and at night when the temperature drops outside, the impact of the buildings mass contributes to cooling the building.

2.3 Building materials of wind towers

Proper thermo-sensitive insulating materials must be used properly when building wind towers (wind catchers). Such materials should have the characteristic of discharging heat from the building during night time (because air

temperature outside the building is less than temperature inside, and so heat is discharged to the outside; the exact opposite of this happens during winter). Therefore, materials that can be used include: hollow cement blocks which help in thermal insulation, refractory bricks and heat reflectors such as aluminum plates which are fixed to the wall or modern insulating materials such as plant cork foam, polyurethane foam, felt granules that fill hollow blocks used in building walls and insulation slabs (structural perlite). Wind towers can be protected with bay wood to purify the air from dust used; this method is used in Egypt as shown in Fig 5

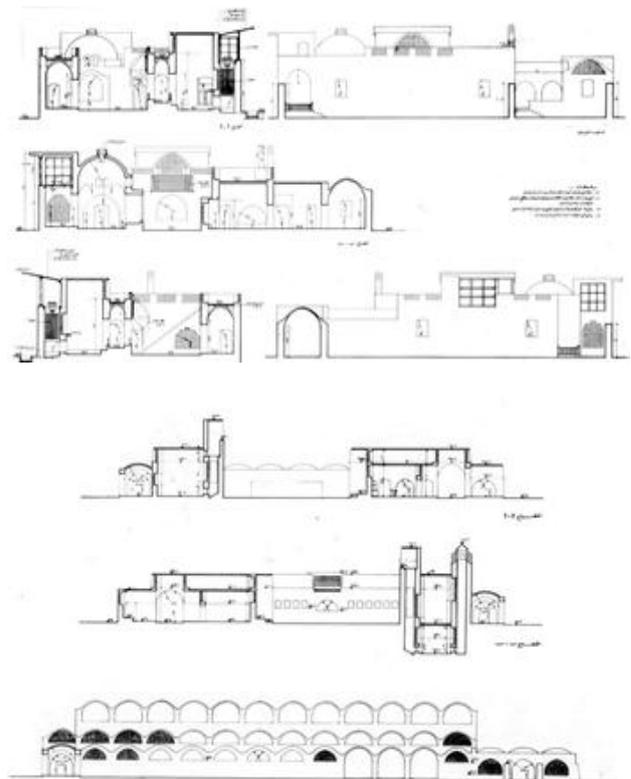


**Figure 5.** Wind Towers (Wind Catchers) protected with bay wood to purify the air from dust used, in Egypt.

*2.4 Wind towers in contemporary Islamic architecture*

Architects use wind towers to reflect their interest in reviving traditional and Islamic architecture, which reflects regional characteristics, whether in construction materials or methods of set-up. But this trend has changed in the designs of Egyptian architect Hassan Fathy, who opened up with his philosophy and ideas opportunities for some architects to rethink the elements they use in traditional architecture. Hassan Fathy used primitive materials and simple technology that has minimal environmental and climatic effects on buildings. When designing buildings in the village of Paris Oasis in Egypt, he bore in mind the study of temperature that sometimes reaches 50 degrees Celsius in summer as well as the need to store food without the use of any refrigeration. So, he resorted to natural air-cooling systems and was able to lower the temperature inside the house by about 15 degrees Celsius, using wind towers as well as air barriers and towers to improve air circulation and coolness. The underground level is used for storage (Fathy, H ). Figure 6 shows buildings in Paris Oasis in the Western Desert of Egypt. The Facades and the private sectors of the design of

architect Hassan Fathy explain the use of wind towers in architecture.



**Figure 6:** shows Buildings in Paris Oasis Western Desert of Egypt

*2.5 Wind Towers in Global Architecture*

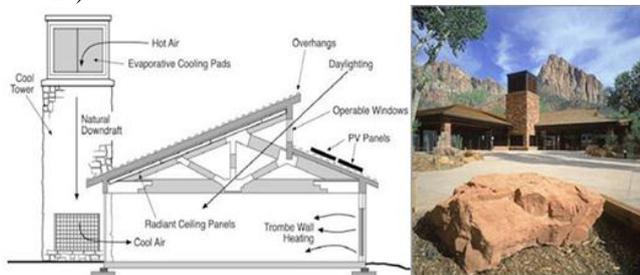
During the global architectural development, Western architects had a different approach to Islamic Architecture than Arab architects. In the early sixties, the interest in traditional architecture was growing away from the ideas promoted by modernist architects. This period witnessed a rejection of the "International Style Architects" because of their designs and materials that were not ecofriendly, added to their lack of creativity. Traditional architects objected to modernism in regards to the latter's use of huge glass windows in large concrete structures. They saw that this was not logical as it increased the trapped heat in open spaces, thus requiring use of huge amounts of energy to maintain a comfortable indoor environment. All of this led to raising awareness of how western architects can combine principles of modern technology and the use of wind towers (wind catchers) (Fathy, H ) for the following reasons:

- To improve the quality and circulation of air
- The use of natural cooling and ventilation instead of modern air conditioners. Extensive studies were conducted to verify the feasibility and performance of wind towers. Results proved that natural air circulation inside the building has improved air quality and reduced internal temperatures. The wind catcher idea



**Figure 7.** Wind Catchers) in contemporary Islamic architecture

- attracted the attention of western architects, who executed this traditional Arabic form in the modern wood buildings without adding any modern air conditioning devices as shown in the Visitor Center in Zion National Park in the United States, which represents a successful model for the adoption of energy-saving technologies, such as wind catchers as shown in Figure 8 (Mito, A.S., Fathy, H., and Doshi, B).



**Figure 8:** Successful model for the adoption of energy-saving technologies



**Figure 9:** A removable door added to close the top of the tower

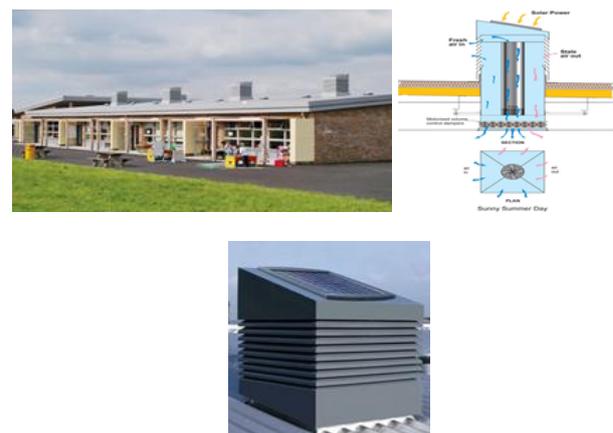
A cooling tower was designed using combined traditional wind towers and modern devices made of light-weight aluminum provided with a fan in order to create a large flow of air, with the addition of a water tank and a small pump to spray and circulate the water to cool the air. A

removable door may be added to close the top of the tower in case of a wind storm (Sharm el-mill ).

Western universities, like the University of Arizona, began developing research on wind towers. Cooling towers of different sizes and heights were developed using wind catchers made of clay and other materials to suit areas or spaces that need to be cooled. Such wind towers have top openings on all four directions covered with a layer of hay or cellulose that is kept constantly wet using a small pump, excess water is channeled down to the tank. The cold air in the tower goes down to the bottom and enters the building to replace dry hot air.

### 3. Models for using Wind Tower using Mono-Draught Technology

In the coastal city of Lansing in West Sussex, England, sun pipes and wind catchers are known as mono-draught technology. They are used to activate the systems of natural ventilation in an elementary school which accommodates 420 students on an area of 1200 square meters. This is carried out through the use of sensors in classrooms. If these levels exceed the maximum standard rates specified, automatic response activates the natural ventilation system. Mono-draught technology provides central control for different spaces together with local manual control in each space. All of this is designed according to the school's building codes as shown in Figure 10 (Foudazi, F., Rithaa, M).



**Figure 10:** The systems of natural ventilation in the elementary school in the coastal city of West Sussex-England using mono-draught sun pipes and wind catchers

In the 2006 Inter-build fair, mono-draught technology was used for residential air ventilation utilizing solar-power to provide cooling during summer without the use of heavy powered air-conditioning. Combining mono-draught technology and natural ventilation by using a solar-powered fan reduces energy costs at home as well as carbon dioxide emission as shown in Figure 11, which shows some of the shapes used in natural ventilation systems for homes. Warm air rises below the ceiling and through the solar-powered fan, so that warm air is pushed outside the building. In summer, solar panels generate constant energy making fans work efficiently expelling

warm air outside and cooling buildings and improving ventilation. At night cooling is achieved by leaving air expulsion openings open to allow cool air to flow in from outside. In winter, the system can be closed totally or can be open by only 5% to provide enough ventilation. During winter with wind speed ranging between 2-3 meters per second (m/s), the system provides 110 liters/s of air inside the house and in summer, solar energy provides an estimated additional amount of 35 liters/s. This system has multiple forms that can be placed on rooftops or above doors and does not require any additional work (Sharm el-mill).



**Figure11:** shows some of the shapes used in natural ventilation systems for homes

### 3.1 Zero-Energy Natural Ventilation and Daylight Systems

This technology utilizes systems of natural ventilation without energy-consuming air-conditioning. This is done through air channels that control the amount of fresh air passing to the space under the ceiling regardless of direction of air-flow and without any mechanical assistance. The wind-catcher system is divided into four parts so that one or more parts are always in the direction of the wind and under the influence of positive and negative wind pressure, resulting in constant air circulation. This technology works on minimizing noise generated by air passing through pipes and works according to the rates of ventilation required for each project, the need for night ventilation and the need to maintain security for the project (Monodraught, Ltd ).

### 3.2 Natural Daylight Systems

This technology relies on the distribution of natural daylight in different spaces. It is achieved by the use of the dome of the diamond (sun-pipe) and silverside aluminum pipe containing a mirror and a light distributor to distribute the light evenly around the room along with the use of a daylight florescent bulb. The dome prevents the entry of rain, dust and insects; it works in various degrees of sun brightness, does not require high maintenance and can be designed for compatibility with most structures. In case of high rises, light penetration will be reduced, especially in the winter, but it is useful as it minimizes heat loss. In

summer it is useful to get rid of the strong light glow (Naghman, K., Yuehong, Su., -, Saffa, B. R )

### 3.3 Natural Daylight and Ventilation System

Sun-catcher mono-draught systems provide natural ventilation and daylight through a combination of a wind-catcher and a natural daylight sun-pipe put together in a single system. Therefore, the sun-catcher is able to provide fresh air and natural daylight as well as extract the warm high carbon in the air. This group of sun-catcher and wind-catcher systems can be available in various sizes to suit the sun-pipe sizes as 2 (Monodraught, Ltd ).



**Figure12:** Wind-catcher

### 3.4 Passive cooling and heat recovery systems

Passive cooling and heat recovery technology was developed in collaboration with the University of Nottingham to develop a mechanical air-conditioning system utilizing storage and release of dormant thermal energy resulting from molecular change of phase change materials (PCM) (where they can store nearly 4 kilowatt/h of thermal energy, and supply about one kilowatt of cooling. This is done by using the passing of air through a series of exchanges precisely-engineered, through which PCM is pumped). A big difference in air temperature can be achieved before and after heat exchange using a fraction of the energy required to run conventional air conditioning systems (Naghman, K., Yuehong, Su., -, Saffa, B. R )

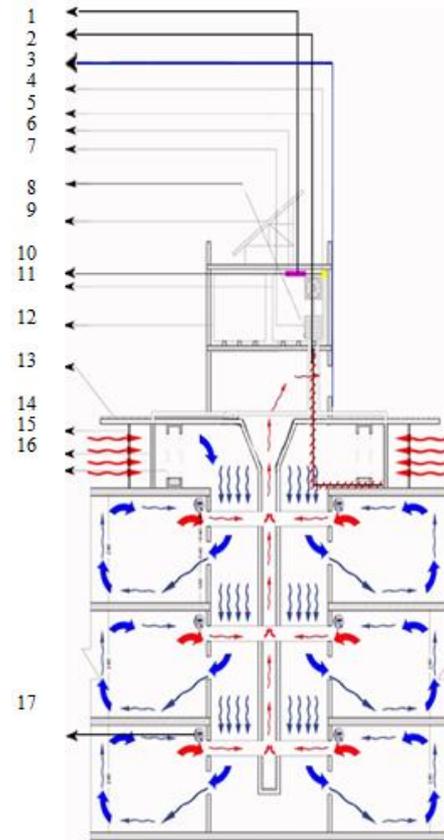
### 3.5 Solar-powered natural ventilation systems



**Figure 13:** Oval Cricket Stadium

These systems reduce costs and energy consumption; they are used to address the economic concerns of high energy prices and the fear of global warming. They also address the environmental impacts of high carbon dioxide gas and Freon gas Cricket, K., Booth, R., ARP Associates)

1. Ammonia gas inside pipe Low Temperature Low Pressure Liquid State.
2. Ammonia gas inside pipe Low Temperature Low Pressure Vapor State.
3. Ammonia gas inside pipe Low Temperature High Pressure Liquid State
4. VAPOR make ammonia gas inside pipe High Temperature High Pressure
5. FAN To make ammonia Low Temperature High pressure liquid State
6. Compressor
7. Expansion Valve – To make ammonia gas inside pipe Low Temperature Low Pressure Liquid State
8. pipe cool
9. Solar cells to run water spray and treatment systems such as the refrigerator or water heating
10. Expansion Valve
11. Refrigerant ( Industry Standard )
12. water tank can heat water in it through heat exchange tubes
13. umbrella to protect equipment from the sun
14. Air Falter
15. pipe heat exchanger to cool the air inside
16. water fitted with a machine gun for the continuation of the water cycle
17. each sensor to detect room temperature and humidity for the operation of the system automatically



**Figure14:** The use of Wind Towers (Wind Catchers) in refrigeration "designed by researcher"  
Design made by researcher

#### 4. The use of wind towers in refrigeration

Wind towers (wind catchers) can be used in operating the cooling system used in environment-friendly refrigerators by utilizing solar energy.

The hot air that returns from the building and the hot air resulting from refrigeration can be used to heat water for the building, thus minimizing energy consumption.

#### Conclusion

Technical development especially in the field of architecture in the twentieth century cannot be denied as we have achieved much in building appropriate structures using simple, feasible and inexpensive methods and materials, including environment friendly methods, though what is known as environment friendly in architecture is still limited. The techniques developed by our ancestors and that include innovative and simple solutions using available resources, particularly in the field of natural ventilation, can be adopted and applied in modern times. Huge insulated, air-conditioned structures are not always functional or economically feasible, not to mention their negative environmental impact on the community. Modern communities suffer from energy drainage and destruction of the environment because of the use of advanced technologies. Developing communities suffer the environmental impacts of trying to keep up with advancing communities and their technologies, alongside

their own economic difficulties. Consider, for example, concrete buildings in high-temperature desert environments are rejected by the population of these areas because they do not provide a comfortable living environment due to poor ventilation. Therefore, we need to develop natural ventilation techniques that were used in the past to accommodate modern living needs, as well as working to create a certain perception of an architectural style that fits the needs of the community by avoiding building or creating designs of geometric shapes which have zero ventilation whether natural or mechanical. Therefore, we ought to take into account, the cultural heritage of Islamic architecture and its influence on local architecture with the important contribution of contemporary architecture and technology solutions to the problems of engineering.

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