# 2022 年臺灣國際科學展覽會
# 優勝作品專輯

作品編號 **200016**

參展科別 **環境工程**

作品名稱 **Generating Conditioned Air in an Open Space in Accordance with Sustainable Architecture Criteria (Based on Wind-Catchers)**

得獎獎項


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關鍵詞 **sustainable architecture、renewable energies、fossil fuels**

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# Abstract

Nowadays, cooling open spaces in hot seasons without using fossil fuels has gained a lot of attention. In this regard, natural air conditioning is a great method for conserving energy that can be used for reducing energy consumption and environmental pollution. Structures like windcatchers are used for natural air conditioning as a building component in warm climates since they are placed in the path of the wind and direct the wind to play a significant role in reducing the temperature. The main objective of the current study is to explore air conditioning in open spaces based on sustainable architecture. The current study reviews the relevant literature from credible journals, and it includes studies with relevant subjects published from 1851 to 2021. The findings show that implementing this design project can result in significant advances in terms of reducing humidity, removing dust and insects from the air, conserving energy, reducing the global temperature, using renewable energies, and producing conditioned air for the area.


## Introduction

The increasing growth in energy consumption and fossil fuel usage in the modern world has created the need for using renewable energies. In this regard, ancient architecture and its principles can be utilized to create the desired conditions in a way that is compatible with the needs of modern architecture [5]. One of the available solutions is to construct building units that require the least amount of energy for warming and cooling. In this regard, the structure of ancient living residences can be considered since such structures would often use renewable energies [5]. Windcatchers are an example of such structures that would provide air conditioning as a cooling unit using renewable wind energy. By guiding the flow of the air and making use of clean natural energy, windcatchers played an effective role in mitigating hot temperatures and lowering them to the level of human comfort [3].

Moreover, as a tool that creates airflow without the need for a mechanical device, a windcatcher provides cooling in hot seasons by harnessing the wind flowing outside and bringing it inside the house. Windcatchers use renewable wind energy, and these structures act similarly to modern evaporative coolers. Windcatchers can significantly reduce the temperature by catching the airflow and directing it into the house. Therefore, the current study tries to provide effective insights and ideas based on the working mechanisms of windcatchers in producing air conditioning in open spaces according to the principles of sustainable architecture.

## Literature Review

Using windcatchers has always been common in the traditional architecture of arid regions in Iran and implementing such structures goes back to 4000 BC [1]. Various types of windcatchers have been constructed in cities in central and southern Iran, each of which has been designed and implemented based on the height and direction of the wind. Despite the fact that these windcatchers have different structures, they all serve the same function, i.e., guiding the airflow and using natural clean energy to mitigate the heat and reduce the temperature of the residential space to the level comfortable for human beings [1]. In general, windcatchers were usually built above a part of desert houses called the 'pool room' (Hoazkhane), and through their holes, the air would be directed over the water in the pool to circulate the conditioned air inside the building [8]. Before the invention of coolers and air conditioners, windcatchers were widely used in various buildings, including residential, religious, and service buildings. While nowadays using air conditioners is common in many cities of Iran, windcatchers are still used in the hot and dry climate of cities in central Iran, including Yazd, Kashan, Kerman, Tabas, Semnan, and Isfahan, and in the hot and humid climate of cities in southern Iran, including Bushehr, Bandar Abbas, Bandar Lengeh, and Qeshm [4].

Iranian windcatchers are divided into three main groups, i.e., Yazdi (from Yazd), Ardakani (From Ardakan), and Kermani (from Kerman). Yazdi windcatchers are usually four-sided

and are built at high altitudes to better capture the airflow; hence, they transfer a higher volume of conditioned air into the building [3].

Moreover, windcatchers are now used all around the Middle East in various countries, including Egypt, Pakistan, Afghanistan, Iraq, and UAE [1].

## The Working Mechanism of a Modern Windcatcher

The structure of a windcatcher includes a high turret which is built on the ceiling of the building on a part of the house called the ‘pool room’ (Hoazkhane). These structures are usually used in windy areas and their turrets are often perpendicular to the vertical direction of the wind [5].

Windcatchers are usually one-sided, four-sided, or eight-sided depending on the climatic. and geographical conditions of the area. Due to high wind speeds in areas with high elevation, it is recommended to build these windcatchers out of concrete.

Windcatchers usually have two basic mechanisms; however, since this project is going to be implemented in a hot and humid area, i.e., Bandar Abbas, the first mechanism must be used:.

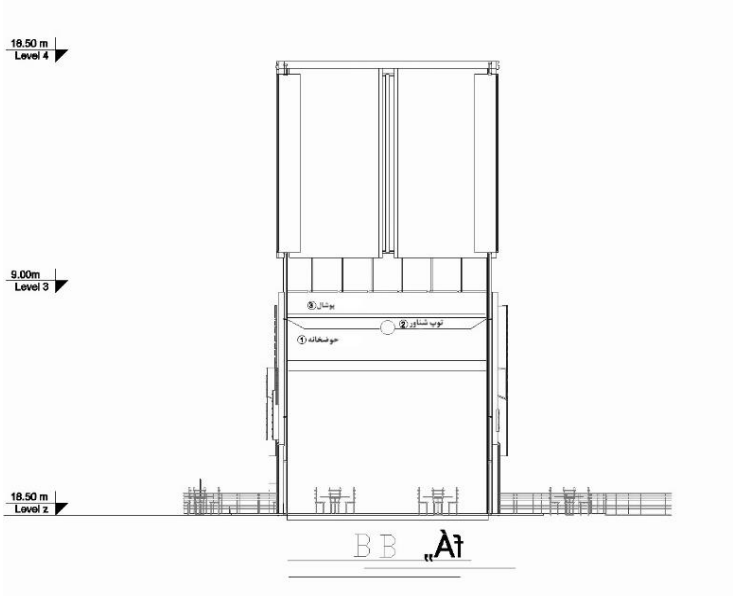
1. Based on the traction of the windward side and the suction of the lee side.
2. Based on temperature gradients.

This mechanism of the windcatcher is obtained as the airflow between the sides of the windcatcher creates a pressure drop that establishes an airflow into the windcatcher, which will hit the internal septa or blades and continue toward the ‘pool room’ [3].

## The Components of a Modern Windcatcher

The structure of windcatchers usually has four main sections as well as some secondary parts as follows:

1. The body,
2. The openings,
3. The ventilator,
4. The blades (main and secondary),
5. The pool room (Hoazkhane),
6. Excelsior (wood wool) or felt,
7. Channels, and
8. The roof.




## Converting Renewable Wind Energy into Conditioned Air

The working mechanism of the windcatcher is as follows: the air is collected by the windcatcher while pipes from the sea will fill the small pool at the bottom of the .

windcatcher with cold water. The small pool is completely covered by felt or excelsior, which becomes wet through contact with the water in the pool. Moreover, the pool is equipped with a float valve to prevent overflowing. When the wind passes over the excelsior through different pipes installed over the pool, it is directed to the open spaces through the specific channels built over the same pool. It is worth mentioning that the colder the water, the cooler the wind that we can transfer outside. Inside the windcatcher, there is an air filter that prevents insects and dust from entering the windcatcher and the building. In addition, the environment is built like a small town where the buildings are constructed in a circular manner to cover the perimeter. The buildings that transfer conditioned air outside will have commercial shops at lower levels so that tourism can be developed as well.

## Numerous factors play a role in optimizing this plan including the following:

***The number of openings***: by creating four inlets in a four-sided windcatcher, one inlet will be the main entrance for the air, while the adjacent inlets can also catch some of the wind around the windcatcher.

***The size of the openings***: the larger the size of the outlets compared to the inlets, the higher the speed of the wind in the channels.

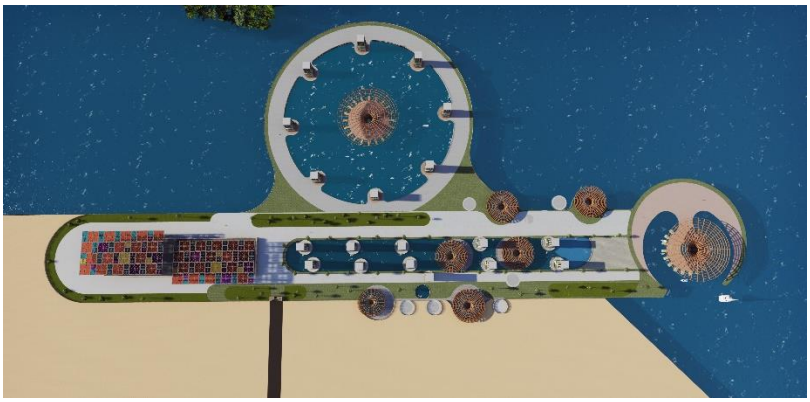
***The type of the internal blades***: in this project, the blades that divide the windcatcher's column into a number of smaller columns as well as the internal blades of the windcatcher that divide it into various channels are built out of concrete. In general, using a higher number of blades in the structure of the windcatcher will increase the velocity of the airflow.

***The height of the windcatcher***: windcatchers are usually made out of adobes and bricks. Therefore, due to the high elevation of the windcatcher, their stability decreases over time. As a result, using materials such as concrete in constructing windcatchers can increase their stability in the long run.

Other important factors may include the location of the windcatcher, the angle of the incoming wind, and the type of the windcatcher's roof, which is usually flat [7].

## This general plan can result in significant progress in eight areas:

1. Producing conditioned air in the area,
2. Reducing the humidity of the air,
3. Using renewable energies,
4. Compatibility with the environment (sustainable architecture),
5. Conserving energy,
6. Developing tourism,
7. Reducing the global temperature, and
8. Removing dust and insects.



## Methodology

The current study utilized a survey method, i.e., by evaluating papers published in credible scientific databases from 1851 to 2021 related to the keywords of this study, the relevant papers were selected and analyzed. Moreover, to obtain satisfactory results and appropriate answers for the research questions, various library sources, including media, papers, and websites, were reviewed as well. Finally, by visiting the available field facilities and collecting samples, the gathered data were analyzed and completed to reach a final conclusion. .

## Analysis

In the modern world, buildings are characterized based on climate and environmental conditions. Geographical and climatic conditions, including sunlight, wind, humidity, cold, and heat, have a direct impact on architecture while increasing the use of

renewable energies according to the principles of modern sustainable architecture. As an example, in the ‘Cool Abu Dhabi’ challenge, by designing a modular structural system in the heart of the city in the form of a palm tree capable of artificial breathing, Mask Architects were able to spread a thin fog in the surrounding areas while solar energy could be absorbed by the solar panels installed at the top of the palm trees. In essence, these two processes work together to cool the area surrounding these trees [9]. The design presented in this study uses cool air instead of fog to provide air conditioning and reduce humidity. Moreover, by placing palm trees and plant coverage around the structures, their efficiency will be improved. The next item is a humidifier (a fog machine) that can provide cool air for people in a yard, a restaurant, a pool, and so on by spraying small water droplets or particles through a number of nozzles [11]. Compared to this system, using windcatchers to cool open spaces will require lower costs for installation and implementation and laying pipes and power lines while it does not increase the humidity of the air. Humidity can have a number of adverse effects on human health. For instance, the level of humidity directly influences the density of allergens, and it can disrupt the balanced level of fluids in the body. Moreover, there is a direct relationship between the humidity of the environment and dehydration, i.e., the higher the humidity, the higher the dehydration [10]. Furthermore, there is a reverse relationship between wind and humidity, i.e., the higher the speed of the wind, the lower the humidity, and vice versa. Therefore, the windcatcher project will reduce the humidity of the area by producing cool wind.

## Suggestions

In this general project, the water from air-conditioning units in commercial spaces near the windcatcher can be collected and transferred to the pool room at the bottom of the windcatcher to be used again. Moreover, solar panels can be used for providing the power needed for the air-conditioning units of the shops. Nonetheless, it should be noted that dry climates do not need air-conditioning units, and the cool wind inside the windcatcher can be transferred to the closed space under the building through specific channels. .

## Results and Findings

The study shows that by transferring cool air to open spaces without using fossil fuels, environmental impacts can be mitigated. Moreover, due to its wide coverage area because of using a number of buildings with windcatchers that can create cool wind, this project will significantly cool the environment and make it comfortable for humans. In addition, with the presence of commercial shops in the lower levels of the buildings and the ability of the visitors to enjoy cool open spaces, the applicability of the project is increased. Therefore, considering the available knowledge and the ability to resolve limitations, modern windcatchers can be used as a highly efficient element for air conditioning and cooling. As a result, it can be said that windcatchers have the potential to become practical elements for the air conditioning and cooling of modern buildings as well as open spaces using renewable energies. .

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The topic looks interesting. However, more experimental or simulation data are needed to prove the concept and evaluate the efficiency.