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SUSTAINABLE ENERGIES IN DESERT CLIMATE BUILDINGS

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Abstract- Lack of fossil energy resources on the earth is a vast problem which human is facing with. Maybe, human beings continue and expand for the future if they can correctly use the natural resources. This fact is threatened by population explosion and other items. In this circumstance, the rule of architects and designers are more important than ever. They should use sustainable energy in buildings and avoid consume unsustainable energy. One of the climates on the earth is desert climate. Someone who lives in this area not only doesn't know how much great sustainable energy has around them but also wastes a lot of fossil energy. In this paper, the first aim is exploring the desert climate and the second one is explaining sustainable energies that exist in these regions. The main objectives of this paper are as follows: Firstly, the way of using sustainable desert energy in buildings and how to use solar energy and the way of decreasing infiltration inflow weather from outdoor and absorption of the heat of solar energy; Secondly, how to use air condition and make cold weather with using solar power to have comfortable place in desert buildings.
Finally, using traditional wind catcher illustrated and suggested similar system for new tall tower and buildings that can be used in other hot climates.

Keywords: Sustainable Architecture, Desert Climate, Natural Resources, Wind Catcher, Solar Energy.

I. INTRODUCTION

When we debate about sustainable architecture, new manufacturing methods are remembered. It is assumed that sustainable architecture is a new topic, but it should be memorised that ancient humans without having acknowledgment and only with their experience help, lived in unsuitable climate condition. If we could remember these experiences and use them, we will know many methods of sustainable architecture.

One third (33 percent) of world's land is located in desert region. [10] This fact and population explosion force scientists and architects to solve living problems in desert climate. In this way, scientists could use ancient people experience. In Iranian traditional architecture, there are some items that help people to live in desert regions without any important problems. Central courtyard, wind catcher, summer side and winter side, Narenjestan yard and Cistern are some of these items [2]. By investigating traditional methods, architects are able to update ancient architect's experiences, and succeed in design and creation.

Desert is a hot or cold area where annual precipitation is less than 1 inch (25 mm). In fact, we haven't enough water in desert climate, because of this fact; there are not adequate plant and humidity. But there are a lot of appropriate energies such as wind energy or solar energy and some underground energy such as underground water energy or underground thermal energy. Due to lake of humidity in the air, it is possible to achieve more appropriate solar energy in desert. Sun heat cause to engender wind and wind energy. Underground water and thermal energy is the best resource for cooling during days and heating during night. By changing in the path of underground water, it is possible to create rage water and electricity energy. All of these items need to investigate and probe in desert concealed abilities.

II. DESERT CLIMATE

Arid and semiarid climates cover about a quarter of Earth's land surface, mostly between 50° N and 50° S, but they are mainly found in the 15-30° latitude belt in both hemispheres. Desert climates are formed by high-pressure zones in which cold air descends. Then the descending air becomes warm but, instead of releasing rain, the heat from the ground evaporates the water before it can come down as rain. The ground is very hot because the sun's rays beat down on it directly overhead. We don't need much atmosphere to protect from radiant energy. Here, maximum temperatures of 40 to 45°C are common, although during colder periods of the year, night-time temperatures can drop to freezing or below due to the exceptional radiation loss under the clear skies at night. This change is because deserts are bare. There is little protection to keep them from heating up in the sun and cooling off when the sun disappears at night. Such areas include the Sahara, Saudi Arabia, large parts of Iran and Iraq, northwest India, California, South Africa and much of Australia. [9]

Not all deserts are hot. Some like the Gobi Desert in central Asia do have hot summers, but can experience very cold winters as well, with temperatures falling to -30°C. Cold deserts also occur in the polar regions of the

Arctic and Antarctic, because the air is so cold and dry, so there is very little moisture to form snowfall. By the way, approximately 1 inch (25 mm) of rain falls in dry deserts per year. [4] Plants of the Dry Desert have adapted to the lack of water by using dew for moisture and taking in water through their leaves and stems. 33% of world land is in desert climate (Figure 1) [10].

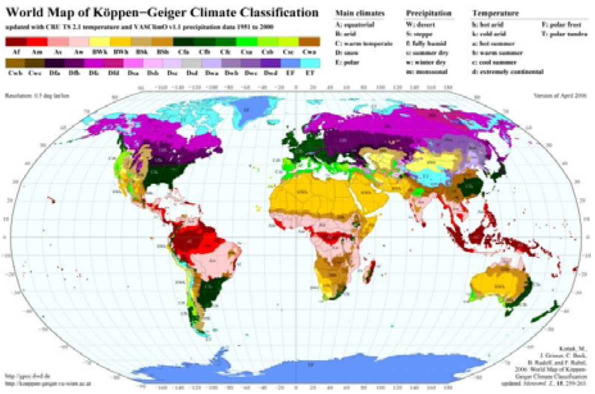

Figure 1. World Map of Koppen-Geiger Climate Classification [4]

III. EXISTING ENERGIES IN DESERT

Sandy wastes, brutal sun, forbidding emptiness those are the stark images of a desert. But these vast, sunburn areas are also home to a powerful renewable energy resources: the sun, water and wind. The desert regions are some of the most magnificent ecosystems of this world: unique natural habitats boasting incredible diverse fauna and which have been home to some of the world's oldest civilizations. To capture and exploit this fragile beautiful landscape from renewable resources deserts represent large lands with cruel surfaces, underground wealth, sunny and windy climate conditions, severe inhabitants living conditions.

Wind energy is renewable and sustainable because as long as the sun shines, wind will blow. Wind is created when warm air over land rises. The land heats up more quickly than the water the cooler air over the water moves into the space created by warm air rising over land. Wind energy is used mainly to generate electricity. Usually, in desert wind exist, because during the day sun energy heat the ground and ground heat under part of air, heated air rise and cause to circulate air frequently and wind be existed.

Ancient architects in desert climate used wind for ventilation. In Iran, Egypt and other countries wind catchers lead the wind to circulate in home and decrease weather heat and increase humidity by usage pools under wind catchers or usage wet straw at top of wind catchers.
Another renewable energy in desert is water energy. In first view, we think that there isn't sufficient water to have enough water energy, but because of desert ground, there are very abundant underground water resources in desert (Figure 2).

IV. SUSTAINABLE ENERGY

Until about twenty years ago energy sustainability was thought of simply in terms of availability relative to the rate of use. Today, in the context of the ethical framework of sustainable development, including particularly concerns about global warming, other aspects are equally important.

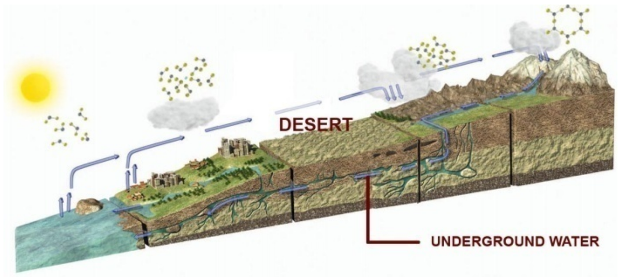

Figure 2. Underground water resource in desert.

The concept of energy sustainability encompasses not only the imperative of securing adequate energy to meet future needs, but doing so in a way that (1) is compatible with preserving the underlying integrity of essential natural systems, including averting dangerous climate change; (2) extends basic energy services to the more than 2 billion people worldwide who currently lack access to modern forms of energy; and (3) reduces the security risks and potential for geopolitical conflict that could otherwise arise from an escalating competition for unevenly distributed energy resources. Sustainable energy sources are most often regarded as including all renewable sources, such as bio fuels, solar power, wind power, geothermal power, wave power and tidal power.

According to Lechner, characteristics of the 'Ideal Energy Source' are as follows:
1. Sustainable (renewable). 2. Non-polluting. 3. Not dangerous to people or the planet. 4. High-grade energy useful for any purpose. 5. Silent. 6. Supplies power where it is needed (no need to transport energy). 7. Most available at peak demand time, this is frequently a hot, sunny summer day. 8. Has additional benefit of creating the building envelope (displaces conventional building materials). 9. High reliability. 10. No moving parts. 11. No maintenance required. 12. Modular (can come in any size required). 13. Low operating cost. 14. Low initial cost. 15. Supplies energy all the time [5].

V. SOLAR ENERGY

Brutal sun is a characteristic of desert. Due to the fact that there isn't any evaporation in desert air, sun heats soil without any disturbance and causes to raise temperature (Figure 3). In hot deserts the temperature in the daytime can reach 45°C or higher in the summer, and dip to 0°C or lower in the winter. Incoming solar radiation is 174 petawatts (PW) at the upper atmosphere. After atmosphere absorption and reflection, about 124 PW received to land in desert, but in the other place only 89 PW received to land and about 35 PW is reflected by clouds and moisture. Because of this fact, desert is the best place to store solar power (Figure 4).

Solar energy is the radiant light and heat from the sun that has been harnessed by humans since ancient times using a range of ever-evolving technologies. By using small case special device, it's possible to save this energy and use it at home or some factories (Figure 5).

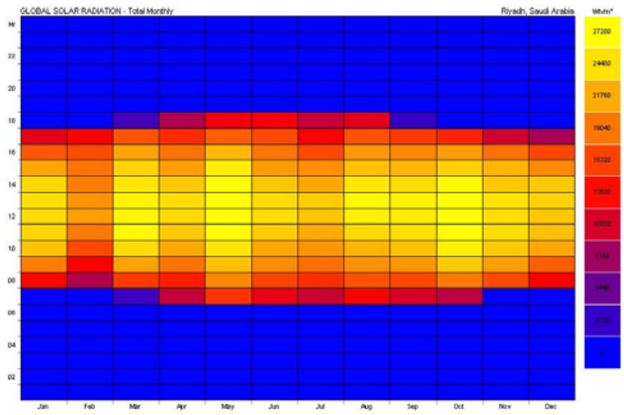

Figure 3. Global solar radiation in Saudi Arabia desert

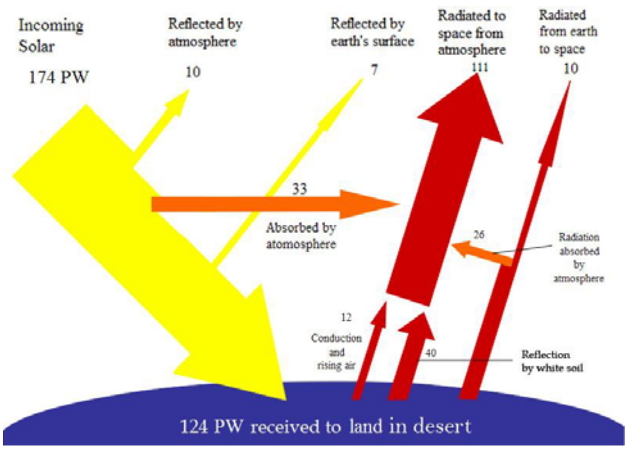

Figure 4. Solar absorption and reflection in desert. [12]

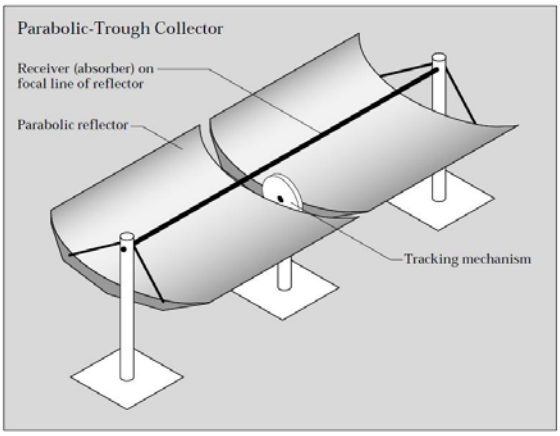

Figure 5. A device that can save and shift sun heat

Solar energy is likely to become an important resource as the world looks ever more urgently for alternatives to fossil fuels. A recent renewed interest in alternative energy technologies has also revitalized interest in solar thermal technology, a type of solar power that uses the sun's heat rather than its light to produce electricity. Although the technology for solar thermal has existed for more than two decades, projects have languished while fossil fuels remained cheap. But solar thermal's time may now have come and mirrored arrays of solar thermal power plants may soon bloom in many of the world's deserts (Figure 6) [8].

Figure 6. A Department of Energy-sponsored pilot solar thermal project built in California's Mojave Desert in 1981, shown here, was a 10-megawatt power tower surrounded by more than 1,800 sun-tracking mirrors [12]

VI. WIND ENERGY

Wind is the flow of air or other gases that compose an atmosphere. The differences in temperature induce circulation of air from one zone to another. Wind has been recognized as a force of nature, ever since the planet came into existence. Human civilization has been harnessing the force of wind from time immemorial. However, the harnessing of wind energy for power generation commercially started only in the early 1970s and has continued to grow since then. Before this date only traditional methods exist. Wind energy is now recognized as one of the low investment high yield sources of power generation.

Traditional methods only used wind power in the same place and couldn't transmit this power. Conversion of this power isn't possible in traditional methods. Nowadays, wind power is able to transmit and converse to electricity. Desert area has most powerful winds. Desert winds are two kinds: Prevailing wind and local wind. Prevailing wind depends on geographical situation. It is varied and maybe so powerful than local wind (Figure 7). Local wind exists when sun heats desert ground and closer air to ground; this heated air mount and cold air descend. This circulation causes to engender local wind in desert (Figure 8).

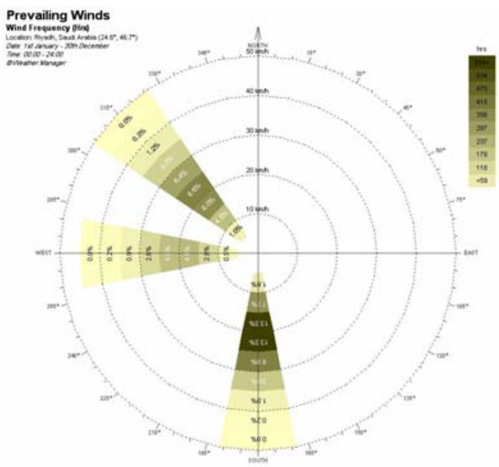

Figure 7. Prevailing wind frequency in Saudi Arabia desert

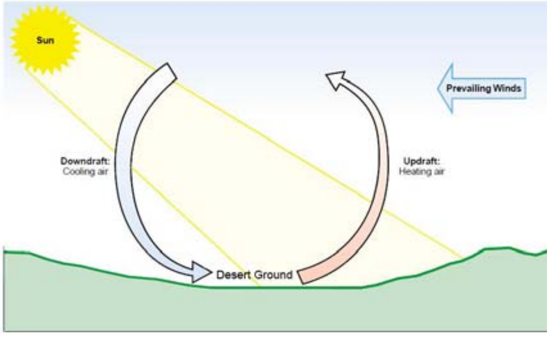

Figure 8. Engender local wind in desert

Natural ventilation has been a fundamental approach to the design of low energy buildings in desert and it is well known that in low rise buildings this is mainly achieved by wind-driven air flow through windows and openings. Purposefully designed and positioned openings are able to draw in and draw out air. A wind catcher or wind tower is a single device to facilitate the supply and extract of air. They have been used in the desert area of Middle East countries for centuries to generate natural ventilation and passive cooling and sufficient humidity in buildings. These buildings have external openings at the upper, internal openings at the lower, partitioned interior airflow passages and a pool under wind catcher. The outdoor fresh airflow may be directed into the building via external openings facing wind, while the indoor stale air may be extracted through other external openings at the leeward due to negative wind pressure (Figure 9) [7].

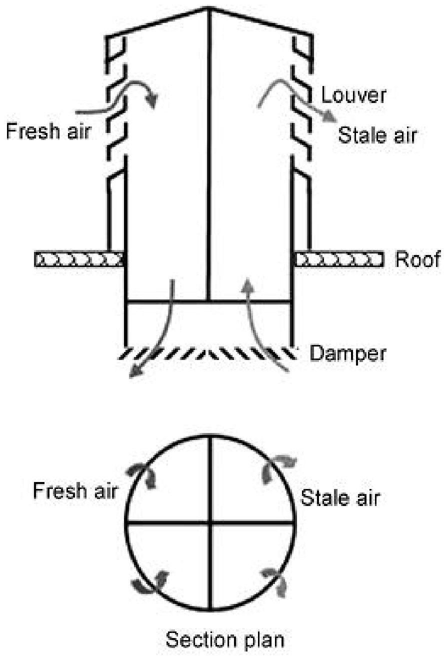

Figure 9. Schematic view of new wind catchers [7].

In Iran's traditional architecture in arid climate, wind catchers are exactly located on top of "Houz-khane", (a filter between yard and summer rooms with a shallow pool) and air flow is conducted on the surface of water of the pool. This act causes to engender soft and humid air in buildings interior (Figure 10).

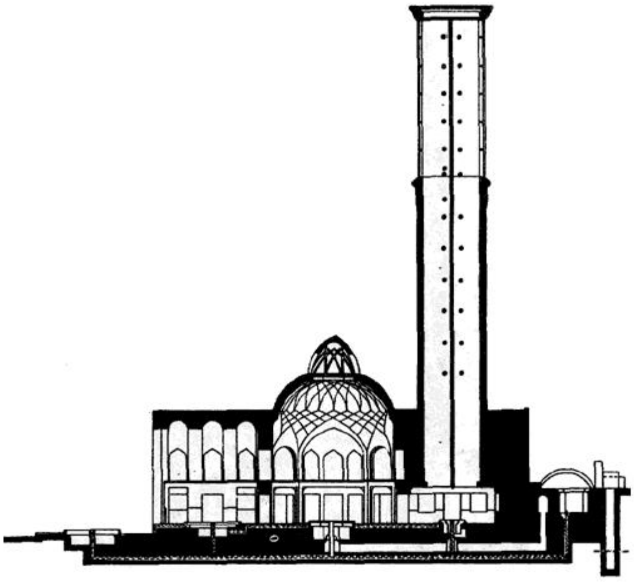

Figure 10. Schematic view of Dolat Abad wind catcher

VII. UNDERGROUND WATER ENERGY

Water is the important matter in desert, because it's rare. In some desert such as Sahara desert in Africa, Turpan desert in china and Kavir desert in Iran, water is concealed underground. Desert soil could absorb water and conceal it. In these deserts, it's possible to use water energy and create hydroelectricity. In the past, ancient people used wind pressure to raise underground water to cistern (Figure 11).

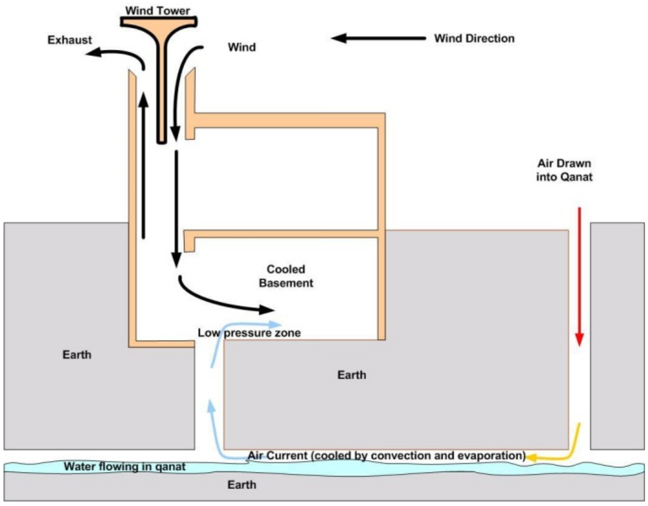

Figure 11. Schematic view of ancient cistern and the way of water shift [12]

Under ground water network was called Qanat or kariz in Middle East countries. Qanat was a water management system used to provide a reliable supply of water to human settlements in arid climate. Qanats are constructed as a series of well-like vertical shafts, connected by gently sloping tunnels (Figure 12).

Underground has suitable and stable temperature to living in desert climate by usage underground water indoor and underground temperature will be balanced.

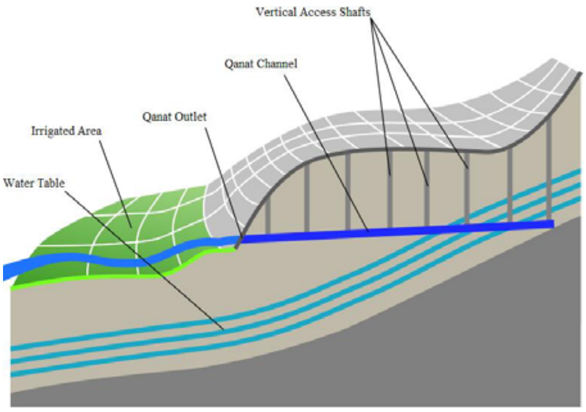

Figure 12. Schematic diagram of Qanat construction [12]

VIII. SUSTAINABLE ARCHITECTURE

The World Congress of Architects in Chicago, June, 1993, indicated:

Sustainability means meeting the needs of the current generation without compromising the ability of future generations to meet their own needs. A sustainable society restores, preserves, and enhances nature and culture for the benefit of all life present and future; a diverse and healthy environment is intrinsically valuable and essential to a healthy society; today's society is seriously degrading the environment and not sustainable [3].

Prof. Norbert Lechner said: "Many ways exist to describe sustainable design. One approach urges using the four Rs: Reduce, Reuse, Recycle, and Regenerate" [5]. According this paragraph, in desert climate, desert energy usage is essential item to sustainable architecture.

IX. THERMAL COMFORT IN DESERT CLIMATE

Thermal comfort is seen as a state of mind where occupants desire neither a warmer nor a cooler environment to perform their activity. Since it varies physiologically and psychologically between occupants, neither perfect conditions nor well defined comfort boundary settings exist. To optimize hybrid ventilation operation and energy savings it is necessary to determine at which times passive operation is appropriate without comfort being compromised. In the simplest terms one would like to know the maximum internal air and surface temperatures that could be tolerated before having to provide supplementary cooling.

X. PASSIVE COOLING METHODS

Since heat avoidance is usually not sufficient by traditional buildings to keep temperatures low enough all summer, the second tier of response, called passive cooling, is used. With some passive cooling systems, temperatures are actually lowered and not just minimized as is the case with heat avoidance. Passive cooling also includes the use of ventilation to shift the comfort zone to higher temperatures.

According to Lechner, the methods of passive cooling are as follows:

1. Cooling with ventilation
2. Radiant cooling
3. Evaporative cooling
4. Earth cooling
5. Dehumidification with a desiccant: Removal of latent heat [5].

XI. SHADING

Shading design for the exclusion of solar input is a geometrical task. External shading devices are the most effective tools to control sun penetration. According to Steven V. Szokolay three basic categories of shading design devices can be distinguished:

1. Vertical devices, e.g. vertical louvers or projecting fins. These are characterized by horizontal shadow angles (HSA) and their shading mask will be of a sectored shape.
2. Horizontal devices, e.g. projecting eaves, a horizontal canopy or awning, or horizontal louvers and slats. These are characterized by a vertical shadow angle (VSA).
3. Egg-crate devices, e.g. concrete grille-blocks, metal grilles. These produce complex shading masks, combinations of the above two and cannot be characterised by a single angle [6].

XII. MATERIALS

Materials used in desert buildings should be vernacular materials that are mostly comprised of the soil obtained from excavations. High thermal mass of the bricks cause a lag in thermal transmit which has an important role in slow absorption of heat. Eventually, this phenomenon results in high thermal efficiency of the structure. In the other hand, material colour is necessary item in architectural design for desert climate. If the exterior surface of the walls is smooth stucco painted white, so that 70-80% of incident solar radiation is reflected, compared with about 50% for most commonly used finishes, such as limestone or textured stucco. However, thermal lag in buildings body contacting the surrounding soil isn't so effective in long period and after a definite time from the construction the materials used in the structure keep a balance with surrounding soil.

In 1964, six small experimental buildings were built on the grounds of the Cairo Building Research Centre, using different materials. They were used to evaluate cost, local availability, and thermal comfort. Two modes of these six are represented extremes. One was built entirely of mud brick with the 50-cm (20-inch) thick walls and roof in the shape of a combined dome and vault. The other was built of 10-cm (4-inch) thick prefabricated concrete panels for both the walls and the roof.

These models were examined on a day in March when external air temperature varied from 12 °C (53.6 °F) at 6 A.M. to 28 °C (82.4 °F) at 2 P.M. and back to 12 °C (53.6 °F) at 4 A.M. The air temperature fluctuation inside the mud-brick model did not exceed 2 C° (3.6 F°) during the 24-hour period, varying from 21-23 °C (69.8-73.4 °F), which is within the comfort zone. However, the maximum air temperature inside the prefabricated model reached 36 °C (97 °F), or 13 C° (23 F°) higher than in the mud-brick model and 9 C° (16 F°) higher than the outdoor air temperature. It fell within the comfort zone for only one hour in the morning (9-10 A.M.) and between 8:40 P.M. and 12:20 A.M., as recorded in figure 8. The contrast can be explained by the fact that concrete has a thermal conductivity of 0.9, while that of mud brick is 0.34, and that the mud-brick wall is five times thicker than the prefabricated panels. Thus, the mud-brick wall has a thermal resistance more than 13 times greater than the prefabricated concrete wall. Unfortunately, these models were not evaluated for the salient dates of the equinoxes and solstices, which would have provided complete information, especially about the lag effect and heat storage (Table 1) [1].

Table 1. Thicknesses of walls of different material that give coefficients of thermal transmittance of approximately 1.1 kcal/hm²C° (0.225 Btu/htt²F°) [1]

Wall Material	Wall Thickness		Thermal Transmittance	
	(in m)	(in in)	(in kcal/ hm²C°)	(m Btu/ hft²F°)
Hollow brick block	0.30	12	1.10	0.225
Double-wall brick with holes and 8-cm cavity	2 x 0.12	2 x 4.7	1.12	0.229
Brick wall with holes	0.38	15	1.03	0.211
Sand-lime brick	0.51	20	1.25	0.256
Hollow block sand-lime brick	0.51	20	1.16	0.238
Lime	0.51	20	1.10-1.35	0.225-0.277
Concrete	1.00	39	1.20	0.246

XIII. RECOMMENDED METHOD

In desert climate, by using photovoltaic modules, solar energy catches and transforms to electricity. Wind turbine changes wind energy to electricity. Basement floor could transmit ground temperature to building. Shading could exclude sun heat. Thick wall with high thermal mass cause to delay exterior temperature inter. But how is it possible to use underground water energy? Underground water circulates in Qanats. By jagged qanat path, water power will be increased and it's possible to restore left water to circulation. If wind pressure used to help water circulation, increase water force and water be able to propel small turbine blades, besides wind pressure could raise underground water along building wall consequently interior temperature decrease. If wind enter some wicket and evaporate this water, interior air can be fresh (Figure 13).

XIV. CONCLUSIONS

According to this paper, summery specifications of sustainable architecture in desert climate are as follows:
1. Renewable energy such as: solar energy, wind energy and underground water energy.
2. Passive cooling methods.
3. Species Shading.
4. Suitable materials.

In addition, the following methods are recommended:
1. Design and implementation appropriate proportion of windows to solid parts in buildings.
2. Combination use of ventilation and simple mechanical systems utilizing solar energy.
3. Transfer of stored heat from inside to outside of the building.
4. Installation of opening in the direction of the wind and installation of canal for transferring warm air in the direct of the sun.
5. Usage of underground cooling and heating.
6. Usage of high thermal mass for exterior wall and low thermal mass in floor.
7. Installation of photovoltaic system in top of building and store necessary electricity.

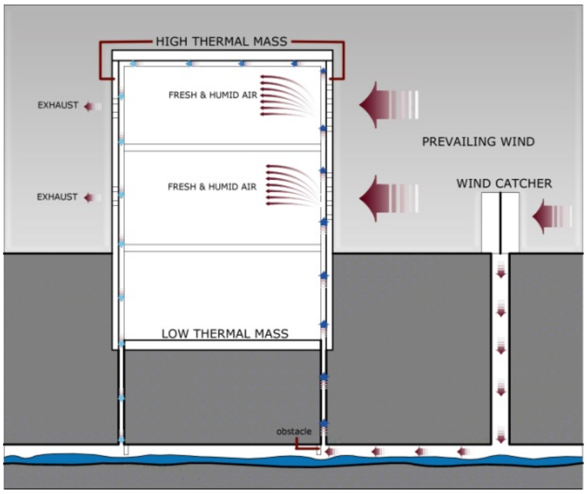

Figure 13. Suggested model for water usage and underground cooling system in desert buildings

REFERENCES

[1] H. Fathy, "Natural Energy and Vernacular Architecture", Chicago/London, USA/Great Britain, 1986.
[2] V. Ghobadian, "Climatic Analysis of the Traditional Iranian Building, 1998.
[3] Inter Academy Council, "Lighting The Way: Toward A Sustainable Energy Future", 2007.
[4] M. Kottek et al, "World Map of the Koppen-Geiger Climate Classification Updated", Meteorologische Zeitschrift, Vol. 15, No. 3, 2006.
[5] N. Lechner, "Heating, Cooling, and Lighting: Design Methods for Architects", 2001.
[6] S. Szokolay, "Introduction to Architectural Science the Basis of Sustainable Design", 2004.
[7] Su.Y. et al, "Experimental and CFD Study of Ventilation Flow Rate of a Monodraught TM Wind Catcher", 2004.
[8] U.S. Department of Energy, "Assessing Climate to Improve Solar Design", Aug. 2001, Mar. 1996.
[9] T. Warner, "Desert Meteorology", 2004.
[10] http://www.geotimes.org
[11] http://www.desertrockenergy.com
[12] http://en.wikipedia.org

BIOGRAPHIES

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