Sustainable Land Use Code

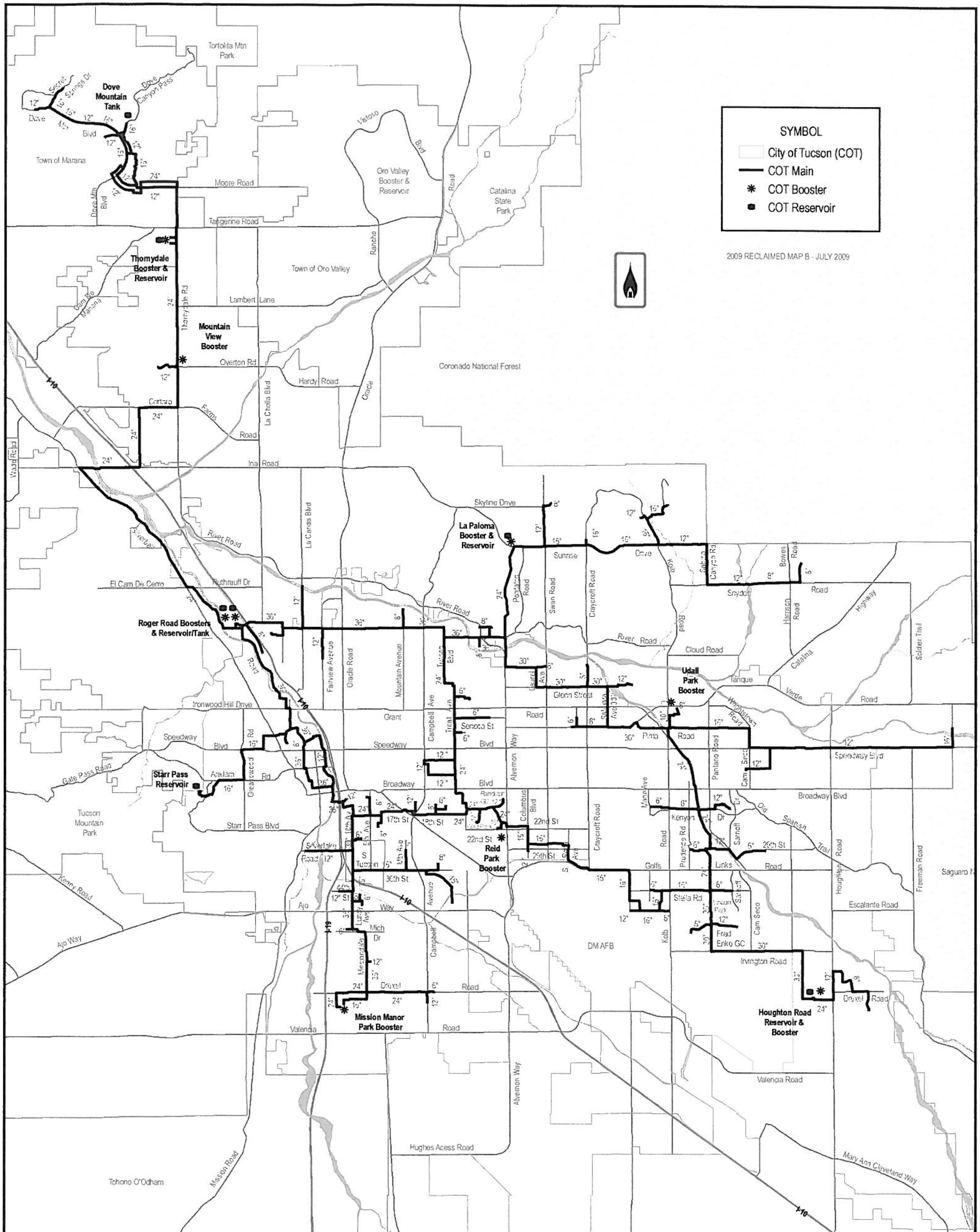
Group: Neighbors
Attendees: Colette Altaffer (CA) and Bill Dupont (BD)
Facilitator: Darcie White
Staff: Adam Smith

<u>Colette Altaffer's Comments</u>

- Diagnostic doesn't solve the problems.
- The diagnostic fails to describe the positive or negative effect each policy's enactment will have on the other policies.
- Diagnostic presumes that density drives everything, but this is an incomplete picture.
- There is a value to older neighborhoods with houses on large lots.
- There is a direct connection between oil production and food production and distribution.
- Diagnostic Report: Page1 – Add the City-County Water Wastewater Study to the list of Citywide Sustainability Initiatives.
- Cost of infrastructure study done for Avra Valley shows that development must pay $30,000/rooftop to pay for itself.
- Diagnostic fails to look outside the box. The policies need to be modeled on our climate. Why not assist with the removal of swimming pools, restrict the installation of swimming pools in the future, and facilitate use of clotheslines? See attached articles.
- Recently approved grey water policies will exacerbate our wastewater system that has a shortage of water in it to flush the system. Trucks are currently injecting water into the system.
- Adaptive re-use of buildings is oversold. Tucson is overbuilt with commercial strip malls.
- Neighborhoods rely on the LUC to be reliable and provide protections for neighborhoods. Any changes to the LUC need to be clear and easily understood.

<u>Bill Dupont's Comments</u>

- Diamond Ventures estimates the cost at closer to $50,000/household.
- Need to protect historic neighborhoods.
- Need to limit impervious cover and require more detention.
- Park and open space at Reid Park is being taken away for commercial interests such as baseball fields that are only activity a few months out of the year and the proposed zoo expansion. The City doesn't have enough places for people to gather. Reid Park is used too intensely. The City needs more parks dispersed throughout the City.
- Where is the money going to come from to pay for mass transit? Construction of light rail lines has led to business closures in Phoenix. Customers are not returning once the construction is completed.
- Police has said that an increase in renter-occupied rates results in an increased workload for TPD.
- Davis-Monthan has a negative impact on older, historic, central city neighborhoods.
- Need to partner with the University to locate more students on-campus. Studies have shown that students that live on campus get better grades. ASU is redeveloping fraternities and sororities with high density residences.
- Cost of attenuating noise from airport noise is estimated at $32,000 for a 1,200 sq. ft. home. There is no funding for retrofit.
- Need to plan comprehensively. Developers are not building to the conditions agreed upon with surrounding neighbors.
- If a developer flips a property once the zoning entitlements are achieved, the new property should have to go back to the City and the neighborhood for approval.
- Before the City proceeds with the SLUC project, the City, neighborhoods, and the developers need to re-establish trust.



CITY OF TUCSON - TUCSON WATER - RECLAIMED WATER SYSTEM - JULY 2009

CLIMAS
Climate Assessment for the Southwest

Climate Change and Water in the Southwest: A summary of a special peer-review article series

Published January 25, 2011
Zack Guido

The Southwest is hot, and it has been getting hotter in recent years. Since around 1970, average temperatures have increased by about 2 degrees Fahrenheit, making warming in the region among the most rapid in the nation.

This has caused more rain to fall instead of snow and large swaths of piñon pine forests to die, the victims of high temperatures and severe drought. To make matters worse, the dry landscape and withered trees have combined to increase the frequency of large wildland fires. These and other changes are expected to continue. But the greatest impact of climate changes likely will be felt in changes to the water supply.

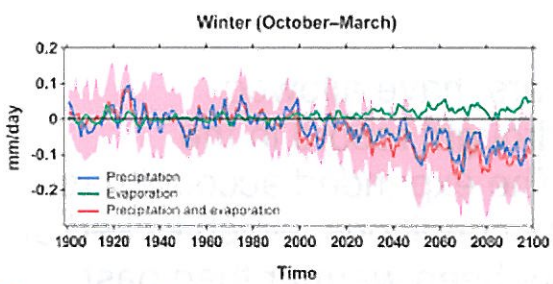


Figure 1. Many climate models project lower precipitation in the Southwest in the future driven predominantly by decreasing winter rain and snow. The combination of decreasing precipitation and increasing evaporation compound each other and make the region drier. The pink shading corresponds to the combined precipitation and evaporation and denotes the range in which half of the 24 models analyzed fall. Source: Seager and Vecchi, 2010, PNAS.

The Southwest has experienced prolonged drought in recent years. In 2002, 2003, 2007, and 2009 the average precipitation across California, Nevada, Utah, Arizona, and New Mexico was less than 25 percent of the 20th century average. Storage in Lakes Powell and Mead, which provide water to more than 30 million people in seven states and Mexico, plunged from nearly full in 1999 to about 49 percent of capacity at the end of December.

Many scientists also believe that the future will become drier at the same time that tens of millions of people flock to the region. The confluence of population growth, recurring droughts, and climate change raises a critical question: Is the increasing aridity in the Southwest capable of posing significant challenges to socioeconomic and environmental sustainability?

To help answer this question, the journal Proceedings of the National Academy of Sciences (PNAS) devoted a special series in December 2010 to water and climate change in the Southwest. The eight articles in the series help answer burning questions for the region, such as how will projected future warming impact water supplies and what strategies can be employed to create sustainable water use. Together, the articles suggest climate changes will likely make water scarcer in the region, accelerating the need for new innovative water use and management strategies.

A worst-case drought scenario

Tree rings, which are wider during wet years, have allowed researchers to extend the observational drought record in the Southwest back more than 1,200 years. The expanded account has helped scientists determine that recent dry conditions, which kicked off during the 1998–1999 La Niña event, have been warmer than past drought episodes.

Because observations from weather stations and models suggest that temperatures will continue to increase in the future, and because the region is naturally plagued by drought, scientists scrutinized the 1,200-year record for a dry period that can serve as a worst-case scenario for future episodes.

They found the most severe and widespread of all past droughts smothered the western U.S. in the mid-12th century. It has been dubbed the megadrought and lasted more than 50 years.

“The drought in the mid-12th century far exceeded the severity, duration, and extent of subsequent droughts. The driest decade of this drought was anomalously warm, though not as warm as the current drought,” Connie Woodhouse and co-authors wrote in their article “A 1,200-year Perspective of 21st Century Drought in Southwestern North America.”

During the driest decade in the mid-12th century, drought covered more than 65.5 percent of the Southwest, more than double the average drought extent during the last 100 years. Colorado River flows were consequently low, averaging an estimated 11.5 million acre-feet per year, which is about 3.3 million acre-feet less than the average during 1900–2006. That decrease is also more than Arizona’s total allocation of Colorado River water.

These numbers beg the question: If a drought comparable to the mid-12th century were to occur today, would there be enough water to go around?

“I believe if we got to that stage, people would be rethinking the way water was allocated, and we might see some very creative approaches to at least making sure domestic and municipal water needs were met,” Woodhouse said in an email. “As far as agriculture goes, I’m sure fields would be fallowed.”

Future warming and its effect on water

Woodhouse and co-authors state that despite the severity and duration of the 12th century episode, the megadrought should be considered a best worst-case scenario for future droughts because it was at least 0.7 degrees F cooler than the current drought and likely cooler than severe future droughts.

Warmer temperatures make the landscape more arid by increasing evapotranspiration, the amount of water consumed by evaporation and vegetation growth. Past events, therefore, likely underestimate warm future droughts, all else being equal.

To assess possible future conditions, researchers also turn to sophisticated computer models. In their paper "Greenhouse Warming and the 21st Century Hydroclimate of Southwestern North America," Richard Seager and Gabriel Vecchi analyze changes in the combined values of precipitation and evaporation in 24 climate models used in the most recent Intergovernmental Panel on Climate Change (IPCC) Assessment.

The researchers focus on the broad region extending from the California–Oregon border to southern Mexico, and slightly east of the Rocky Mountains to the Pacific Ocean. The models were driven by a "middle of the road" greenhouse gas (GHG) emission scenario known as the A1B scenario. (For a comprehensive description of GHG emission scenarios, see the August 2009 Southwest Climate Outlook feature article "Two or 12 degrees warmer? Greenhouse gas emission scenarios that drive future climate outlooks" on the Web at **www.climas.arizona.edu/feature-articles/august-2009**).

The authors report that the models robustly predict drying in the region throughout the current century due to rising greenhouse gases and that the drying is driven by a reduction in winter precipitation (Figure 1). Drier winters, the researchers explain, are caused by a poleward shift in storm tracks that originate in the Pacific Ocean.

However, changes in climate that have occurred in the last 30 years clearly demonstrate that natural climate variability also causes drying. El Niño–Southern Oscillation (ENSO) events and changes in sea surface temperatures in the north Pacific and Atlantic oceans play a role, and it is unclear how these natural oscillations will evolve in a warmer world. In fact, the authors are concerned with the inability of the climate models to accurately simulate Pacific sea surface temperatures, which cause precipitation projections to be less certain.

Modeling tests suggest slight warming or cooling in the tropical Pacific would both cause drying, although the severity of drying changes considerably between the warming and cooling scenarios.

Temperature projections, however, do not suffer the same uncertainty because ENSO events do not influence temperature as strongly as they affect precipitation.

Nonetheless, the authors conclude that "despite ample uncertainties in model projections of hydroclimate change, and the continuation of natural climate variability on all timescales, it seems very probable that the southwest North America will be drier in the current century than in the one just past."

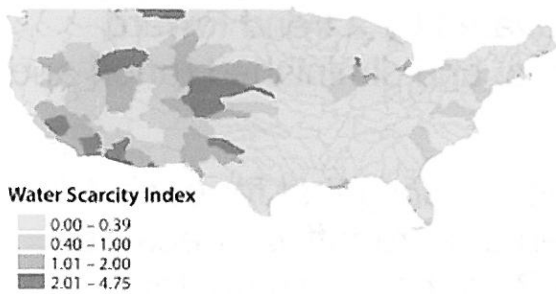


Figure 2. Water stress is commonly defined when the WSI is greater than 0.4, meaning more than 40 percent of the natural river flow is withdrawn. Many river basins in the Southwest are currently stressed; some have more water allocated than naturally flows in the river, requiring the use of groundwater to balance the deficit. Source: Sabo et al., 2010, PNAS.

In a complimentary study, Dan Cayan and co-authors combine future climate projections with a hydrology model to assess how climate changes alter surface water. Their research, presented in the article "Future Dryness in the Southwest US and the Hydrology of the Early 21st Century Drought," relies on climate projections generated from "medium high" and "moderately low" greenhouse gas emissions scenarios, or the A2 and B1 scenarios, providing bookends for future projections.

Results suggest the Southwest would experience decreases in snowpack and soil moisture. This would cause the number of years of extreme drought—defined by the authors as water years (October 1–September 30) in which the averaged soil moisture spanning the entire study area is equal to or below the 5th driest year in the 1951–1999 period—to increase from five events observed during the historical period to between six and thirteen during the second half of the century, depending on the GHG emission scenario. The number of extreme events is higher for the medium-high emission scenario than for the moderately-low scenario.

The authors also point out that there is no change in the number of years of extreme drought in the first half of the 21st century for either scenario. Their results imply future extreme droughts are more likely; those droughts would in turn drive reductions in stream flows.

"Inevitably, there will be precipitation shortages, and during these times the resulting hydrological drought is aggravated by a trend toward much less snowpack, warmer temperatures, and diminished runoff and soil moisture," the authors conclude.

Other research corroborates this conclusion, stating that for each 1.7 degree F (1 degree Celsius) rise in temperature, runoff will decrease between 2 and 8 percent in the Colorado River basin. To put that number in perspective, if the Southwest warmed by 4 degrees F, reductions in the Colorado River could be as much as 2.8 million acre-feet, which equals Arizona's total Colorado River water entitlements.

Rethinking sustainable water use

In several of the articles in the series, including those mentioned above, the authors suggest a need for new water management strategies to deal with likely reductions in future water supply.

"We are entering a new era in water management," Peter Gleick writes in the paper "Roadmap for Sustainable Water Resources in Southwestern North America." Unlimited population growth, irrigation of crops in certain places, and water use habits that mimic areas with bountiful supplies can no longer be sustained in the region.

The ways of the past are no longer prudent in the Colorado River and other southwestern water systems, Gleick writes, because it is nearly impossible to withdraw additional water supplies.

John Sabo and co-authors illustrate this in their paper "Reclaiming Freshwater Sustainability in the Cadillac Desert." They compare the average amount of water withdrawn each year to the amount naturally available and show that on average, more water leaves many river basins in the Southwest than is available; reservoirs and groundwater makes this possible (Figure 2).

Other limitations also curtail future water supplies. Federal funding for traditional water systems such as reservoirs has largely evaporated, Gleick writes, while water withdrawals from every major aquatic ecosystem in the region, including the Colorado River Delta and the Salt, Verde, Gila, Santa Cruz, Rio Grande rivers, cause more ecological harm than benefit.

While the situation may appear bleak, it is not all bad news. Numerous strategies can help attain sustainable water use.

On the supply side, sources of water that were previously ignored or unusable could be tapped, including the desalination of brackish groundwater, reuse of treated wastewater, and rainwater harvesting.

On the demand side, limiting water used for residential landscaping and applying drip irrigation systems can help conserve huge amounts of water. For example, nearly half of the crops in California are grown with flood irrigation, Gleick writes.

Improving water management is also necessary. Institutions could generate and apply up-to-date information on water availability and use, and integrate climate change impacts into management. "These new approaches have been used successfully here and there in the western U.S. and offer a way to effectively move toward water sustainability, but they have yet to be adopted in a comprehensive and widespread manner," Gleick concludes.

Take home messages

- These PNAS highlighted articles and the other three in the series provide an overview of the state-of-the-science on water and climate change in the Southwest and represent the leading edge of research on the impacts of climate on water in the region. Several insights broadcasted from these articles strengthen several previously held beliefs:

- The most severe past drought, which presents a near worst-case scenario for future episodes, reduced Colorado River flows by about 3.3 million acre-feet.
- Many different climate models, each representing the climate dynamics in slightly different ways, predict drying in the Southwest.
- Future drying is principally controlled by reductions in winter precipitation as a result of a shift to the north in storm tracks.
- Water use strategies that will help the region attain sustainable water use include more efficient irrigation, limited residential landscape watering, desalination of brackish groundwater, reuse of treated wastewater, rainwater harvesting, and the use of climate change information in management decisions.

Traditional Cooling Systems in the Third World

by
Allan Cain,
Farroukh Afshar,
John Norton
&
Mohammad-Reza Daraie

Today more than ever the technology of the industrialised world is being exported intact to the developing world. Western industries depend on marketing their wares to the Third World in order to buoy up their own countries' failing economies. For example, in Britain now 50 per cent of the building industry is dependent on foreign contacts.[1] The West's technological development was founded on the cheap raw materials and energies taken from the colonial world. Developing countries today do not have a world of resources to freely exploit and a few are now beginning, out of necessity, to look towards a more self-reliant road to development.

Agricultural technology in the United States now demands 5 calories of energy input to produce 1 calorie of food; on the other hand, in China 1 calorie input of energy produces 20 calories of food – 100 times less.[2]

There exist in the Third World a wealth of indigenous technologies which have largely been ignored, if not actually suppressed, during the era of rapid growth in the industrialised world. However large numbers of people in the rural areas and old quarters of cities and towns in the Third World rely entirely upon indigenous technologies. These technologies are almost always identified as signs of underdevelopment because they are most often employed by the poorer classes of society. Those who have never had access to large amounts of expensive

which are efficient in use of local materials.

Millions of pounds are spent on the research and development of 'Advanced Technologies' – advancing them further and further away from any relevance to the majorities of the world. We believe that we must research and develop those "simpler" and not unadvanced technologies which the majority of the people in the Third World use and live within. Such a scientific reassessment of the indigenous in Third World countries could form the basis of a real development.

This article deals particularly with the indigenous technologies of cooling, using largely natural sources of energy and techniques which have been developed by people locally.

Maziara Cooling Jars

The Maziara is a traditional water cooling and purification system used in rural areas of Upper Egypt. The evaporative cooling properties of large porous ceramic water storage pots are employed. Similar methods have been used in different parts of the world to keep liquids and perishable food cool.

The supply of safe drinking water is a primary factor in the maintenance of public health in developing countries. Consideration must be given not only to the water source and its quality but also to the distribution and storage systems. In an Egyptian village area studied by the authors,[3] there was no modern system of piped water to individual

wells or from the Nile River and its canals. Nile water and water from irrigation channels is unfit for drinking and often carries dangerous pathogens such as 'bilharzia larvae'. Shallow wells are also often polluted and clean water is only guaranteed from deep wells. Women collect water from these sources in the early morning and then carry water jars (bellas) on their heads back to their homes. Once home the water is stored in the Maziara. These large, unglazed ceramic jars hold the day's supply of water for drinking and domestic use.

The porous nature of the unglazed ceramic means that water seeps through the jar's wall, maintaining a wet outside surface. Some of the water evaporates and the rest drips down the sides of the jar and is sometimes collected. Drinking water is usually scooped out of the pot with a dipper, though it was discovered that water collected at the base after it had been filtered through the pot is much cleaner. The water in the Maziara is kept cool all day by the action of evaporation from the jar's outer surface. Evaporation, or the change of water from a liquid to a vapour, absorbs a considerable amount of heat energy (580 calories of energy for every cc. of water evaporated.) Heat is therefore continually drawn out of the water in the storage jars. The dry Egyptian climate means that the outside air can absorb a great deal of water vapour, and in turn a considerable amount of evaporative cooling can take place. The energy have invented technologies ual homes. Water was available from Maziara is usually situated so that

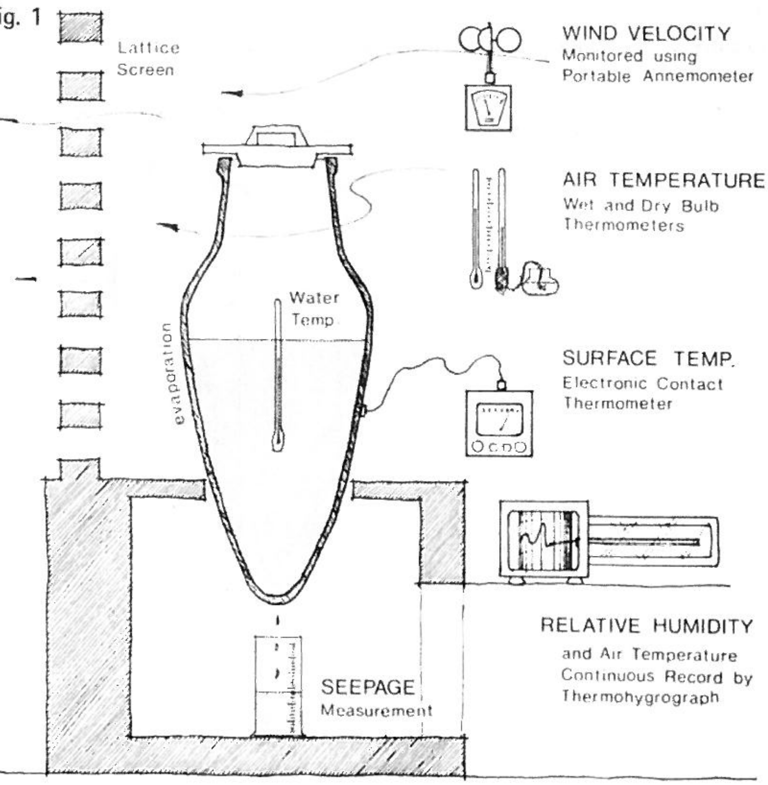
Page text show all print text

Traditional Cooling Systems in the Third World by Allan Cain, Farroukh Afshar, it is in a draft, for air movement aids evaporative cooling.

An experiment was set up using portable meteorological testing equipment in order to evaluate the cooling action of the Maziara (Fig. 1) Water samples were taken at various stages in the system, to be measured later in the laboratory for purity.

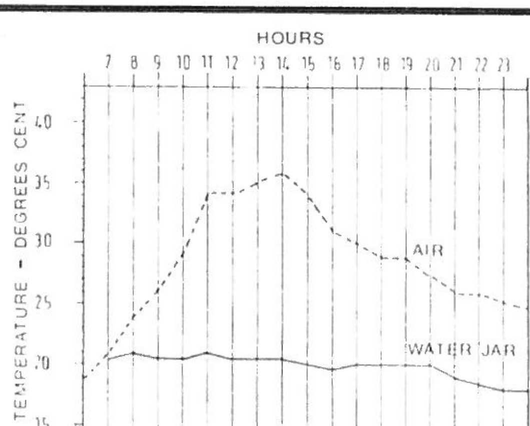
Results of the climatic tests showed that even though the outside air temperature ranged from 19°C. to 36°C. over the day, the temperature of the Maziara water remained relatively constant at 20°C. Since one feels comfortable in Egypt only between the narrow range of 21°C. to 26°C. the water feels refreshingly cool all day. The constant Maziara temperature (Fig. 2) may seem surprising with such a large air temperature range, i.e. 17°C. This can be explained by the fact that as the day progresses and the air temperature rises, the relative humidity (the amount of water vapour in the air) decreases (Fig. 3). As the air becomes drier more water evaporates from the water jar's surface and the cooling rate increases (Fig. 4).

Fig. 1



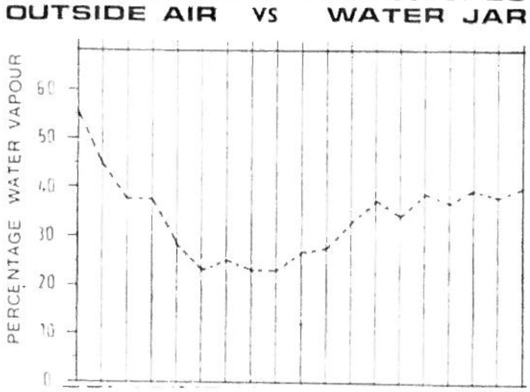
MAZIARA WATER JAR TESTING METHOD

Fig. 2



COMPARATIVE TEMPERATURES OUTSIDE AIR VS WATER JAR

Fig. 3



The Maziara though mechanically simple proves to be a very sophisticated system; its temperature self-regulation is a response to local climatic changes.

Over a 16 hour test period a single jar produced 1700 k. cal. of cooling. At the hottest time of the day the jar's cooling rate was 165 k. cal./hr. or about 192 watts (Fig. 5).

In order to test the Maziara's water purification action a series of laboratory tests were made on water samples. Into the Maziara was placed water collected from the nearby Nile River. Samples were taken from the river source and from the effluent runoff after water had been allowed to filter through the Maziara system. Other samples were taken from inside the jar. Samples were tested in the Government laboratories in the Luxor hospital and it was found that the filtered outflow water was pure to the Government's drinking water standards, even though the original Nile water that was put into the jar was contaminated.

Pollutants can either be suspended

RELATIVE HUMIDITY OF AIR

in the water or chemicals dissolved in the water. The filtering action of

Page text show all print text

i t is in a draft, for air movement aids evaporative cooling.

Fig. 4

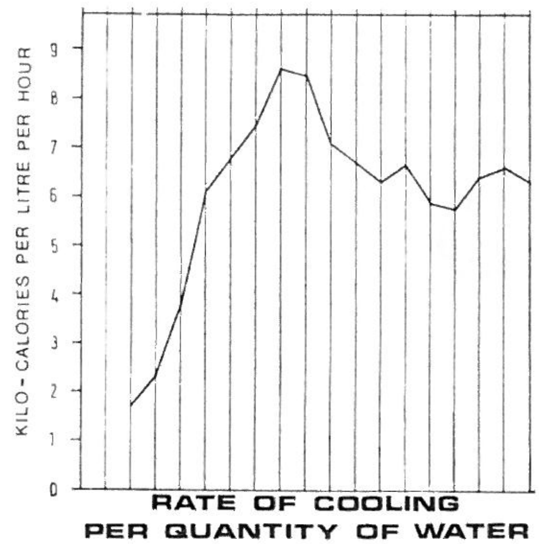
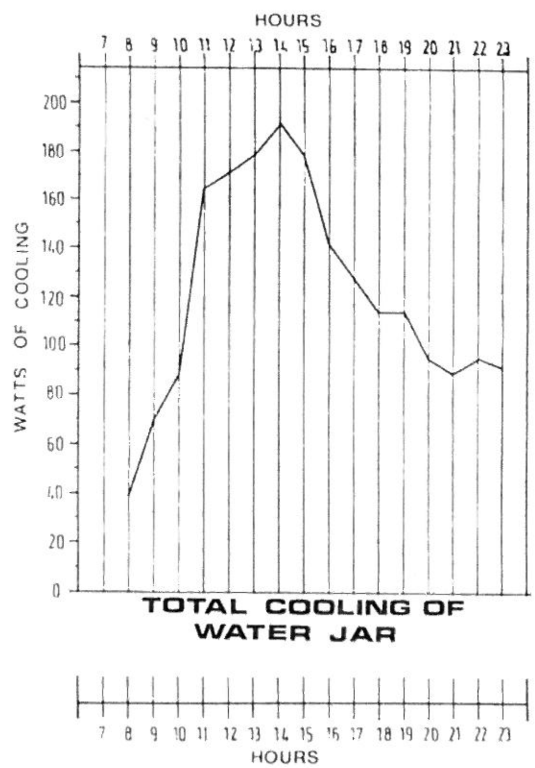


Fig. 5



the Maziara removed some of the suspended pollutants, but filtering alone cannot remove harmful chemicals or all microscopic organisms. It is therefore assumed that there were no such elements in the original samples taken. If the cleaning action of the jars is to be maintained they would have to be rinsed periodically and sterilised with boiling water.

The results of the purification

drinking water contamination can be reduced if the Maziara's filtering action is used.

Western Technology versus the Indigenous

It is interesting now to compare the indigenous Maziara cooling jar method to its Western counterpart, the mechanical cooler.

Technological sophistication is usually measured in terms of the parts. On this count the mechanical air conditioner could be called a piece of advanced equipment. If we evaluate sophistication in terms of efficiency we find the opposite. An air conditioner producing 12,000 BTU's of cooling will in turn consume 2400 watts of electrical energy.[4] This means that an equivalent of about 70 per cent of the total cooling output is required in electrical energy to run the unit. The Maziara cooling jar method, on the other hand, requires no other energy than that required to fill the jar with water in the morning. It is, as well, totally self regulatory and responsive to climatic changes without the aid of a complicated thermostat. The inefficiency of these mechanical systems is compounded and in global terms: "200 million Americans use more electricity for air conditioning than 800 million Chinese use for everything."[5]

The hazards of modern air conditioning systems are rarely advertised in the glossy brochures distributed by companies' dealers in the Third World. Mild shock sometimes occurs at the entry of an excessively cooled building, if the temperature differences between inside and outside are too great. Mechanical air conditioners often produce pools of very dense cold air in the lower parts of rooms. Such stratification of temperature over long periods affects blood circulation, respiration and other bodily functions particularly in children and old people.[6] Indigenous cooling systems by the very fact that they are usually naturally regulated, avoid these dangers.

Most of the vast rural areas of the Third World do not have access to electricity in order to power a mechanical unit, and must therefore rely on some other non-energy consuming method. The average per capital income of people in many countries, if accumulated over several years, would hardly be enough to purchase the cheapest mechanical air conditioner. On the other hand, a large unglazed jar suitable for cooling, costs less than a pound, and can be made in a village kiln, and could if developed form the basis of a small industry.

Comparitive experiments are currently

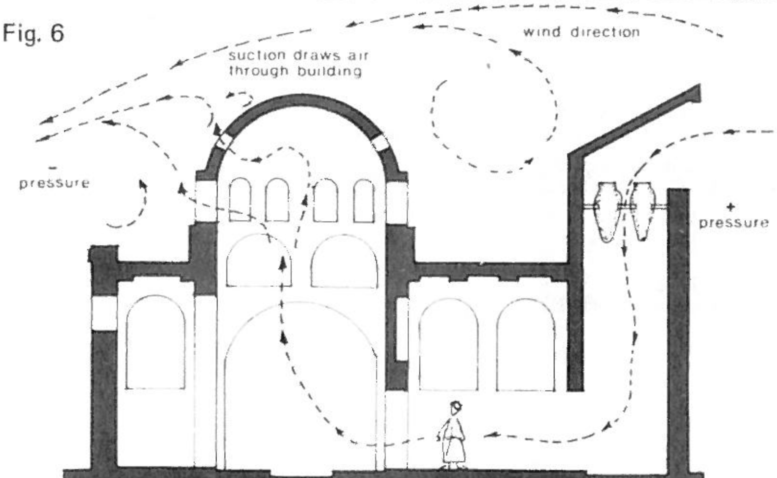
The result of the purification tests illustrates that chances of usually measured in terms of the number of transistors or moving Comparative experiments are currently being planned by the authors

62

Page text show all print text

Fig. 4

Fig. 6



WIND-CATCHER WITH COOLING JARS

Air is cooled as it passes over evaporative cooling jars

in Iran, in the use of water jars for air cooling within buildings as against mechanical cooling. In theoretical terms, five or six water jars, each producing up to 200 watts of cooling, would be equivalent to a small window-mounted mechanical cooling unit of 1000 to 1200 watts.

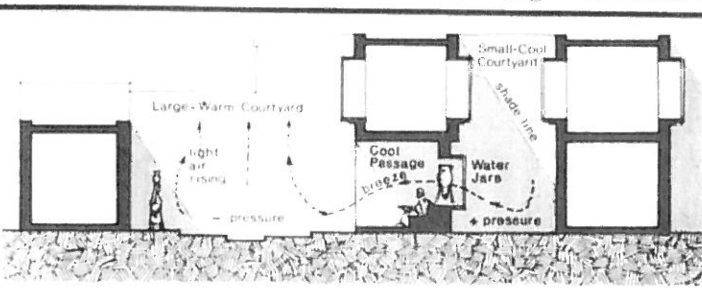
Development of Local Technologies

A wide variety of cooling solutions based on the principles illustrated above have been developed indigenously in Third World countries, and there is still much scope for their improvement and wider use. Porous water jugs and even simple dampened reed matting have been used in conjunction with wind catching towers, which funnel air down into rooms of houses after it has been conditioned by evaporatively cooled surfaces (Fig. 6). Professor Hassan Fathy, in a design for a wind catcher for a school in Upper Egypt, used beds of wet charcoal for air to pass over before entering rooms, and he reports a drop of 10°C. in air temperature.[7] In Iran, wind shafts often lead to basement water cisterns. Both the air and water is cooled by the effects of evaporation. The water being stored underground retains its coolness, and the air after being cooled is directed up into the rooms of the house. (More information on the wind catcher as an air cooling device can be found in *Architectural Design Magazine*, April 1975, pp 217-218, by the authors.)

The courtyard of the Middle Eastern or Mediterranean house has long been known for its cooling properties.[8] The court acts as a well to trap cool night-time air and retain it throughout most of the day. An interesting adaptation of the typical case is the two courtyard house. One court is small and deep and therefore generally shaded and cool; the other is wide and open to the heating of the sun's radiation. Air in the small courtyard, being cool and dense, has a higher pressure than the warm air of the large courtyard, which tends to be lighter and therefore rises. If an opening or passageway connecting the two courtyards is well positioned, there will be air movement induced by convection from the cool courtyard through the passage to the warm courtyard. The air's velocity is controlled by the size and nature of the passageway as well as the temperature and pressure differences between the two courtyards. Water cooling storage jars if placed in this passage will add to the cooling effect of the breeze (Fig. 7). In houses where this feature is employed, the inhabitants spend the hottest hours of the summer days in this cooled space between the courtyards.

In Muscat Oman, water jars have been mounted in specially designed window openings, not only for the provision of cooled water but to reduce the temperatures of the air passing over them and entering the room (Fig. 8). Similarly in India simple coarse woven mats over window openings when wetted cool the air passing over them into the room. Such matting usually needs rewetting by hand every 20 minutes. A recent development in India based on research into the indigenous method is an air conditioning unit (Fig. 9) using matting of khus-khus grass, which is widely available in Northern India and gives off a pleasant aroma when wet, in conjunction with a water reservoir and a small mechanical fan. The water reservoir maintains a controlled drip which is just enough to keep the matting wet. A low voltage fan, which could even be battery powered, is the only energy consuming part of the unit.[9] A development upon this could use a roof-mounted wind trap to provide air

Fig. 7



TWO COURTYARD HOUSE - AIR MOVEMENT INDUCED

Convection system between courtyards. Breeze is drawn across cooling jars

Page text show all print text

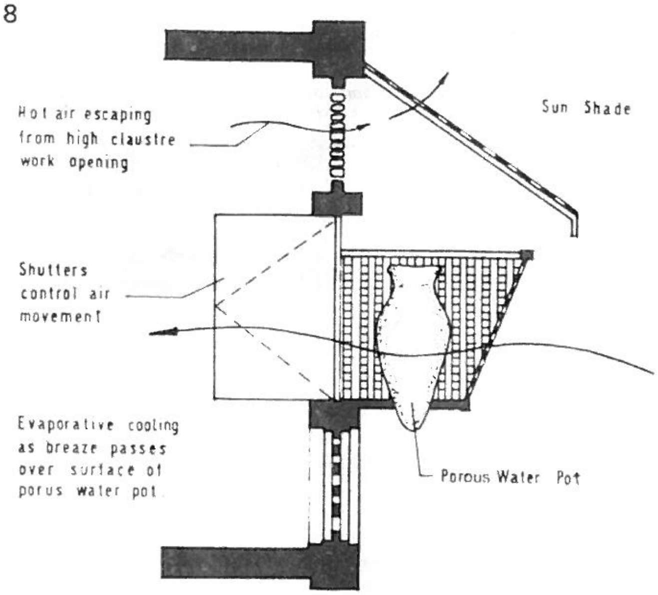
Fig. 6

movement and the fan as only a back-up system.

Perhaps more important than air cooling is the cooling and storage of perishable foods. A large percentage of the total food produced in Third World Countries rots and is lost before it is eaten because of the lack of any cooling storage facilities. Again in India evaporative coolers have been used indigenously which could help alleviate this problem. A domestic cooler was developed using a porous outer water jar and a glazed inner jar as a dry compartment to hold the food (fig.10). The space between the two jars acts as a reservoir for water, which keeps the exterior porous jar wet. Evaporation of water from the surface of the outer jar keeps the whole system, including food stored within it, cool.

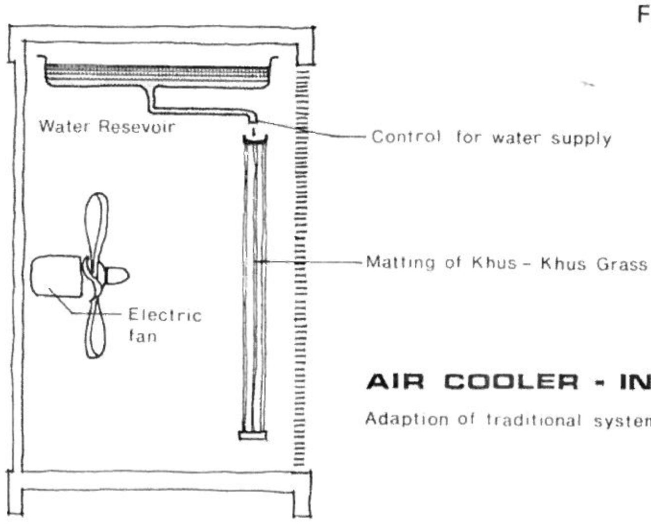
This article has dealt with some of the technological innovations that have grown out of an indigenous scientific approach to a basic problem – cooling – in many Third World countries. It should be seen as one example out of many such neglected systems which could be developed upon. Technologies adopted, as well as the approach taken to the improvement of indigenous methods of solving problems have a strong impact upon the direction of the road any society chooses towards development.

Fig. 8



WINDOW MOUNTED COOLING UNIT - MUSCAT

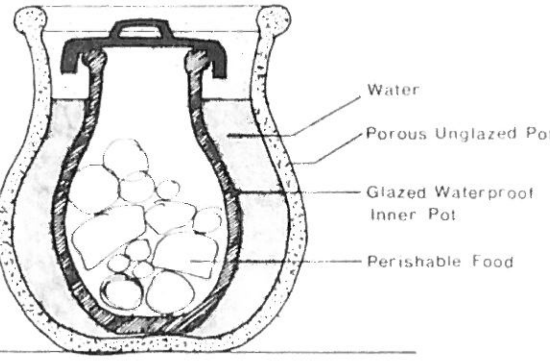
Fig. 9



AIR COOLER - INDIA

Adaption of traditional system

Fig. 10



FOOD STORAGE COOLING UNIT - INDIA

Evaporative cooling from moist exterior surface

References:

1. *Financial Times:* Overseas Construction. March 10, 1975. London.
2. E. Flatten & J. Stansby. It Takes Energy to Produce Energy: The Net's the Thing. *Washington Monthly,* March 1974.
3. *Gourna Village Near Luxor Egypt.* Part of a larger study with O. Farouk, J. Levaux, W. Etchels, W. Aldous, J. Olsen. Special assistance from Hassan Fathy and Architectural Association 1973.
4. Air Conditioning Manufacturer – London.
5. Amory B. Lovins. *World Energy Statistics.* London 1975.
6. M. S. Goromosov. *Physiological Basis of Health Standards for Dwellings.* World Health Organisation, Geneva 1968.
7. H. Fathy. *A Tale of Two Villages.* Cairo 1969.
8. D. Dunham. The Courtyard as a Temperature Regulator. *New Scientist,* September 1960.
9. *Gulmarg.* Courtesy of India High Commission, London.

Note:
All photos, drawings and charts by the Develop-

(5)

Evaporative cooling from moist exterior surface

ment Workshop.

movement and the fan as only a back-up system.

Analysis on Iranian Wind Catcher and Its Effect on Natural Ventilation as a Solution towards Sustainable Architecture (Case Study: Yazd)

Mahnaz Mahmoudi Zarandi (Qazvin Islamic Azad University)

Abstract**—**wind catchers have been served as a cooling system, used to provide acceptable ventilation by means of renewable energy of wind. In the present study, the city of Yazd in arid climate is selected as case study.

From the architecture point of view, learning about wind catchers in this study is done by means of field surveys. Research method for selection of the case is based on random form, and analytical method. Wind catcher typology and knowledge of relationship governing the wind catcher's architecture were those measures that are taken for the first time. 53 wind catchers were analyzed. The typology of the wind-catchers is done by the physical analyzing, patterns and common concepts as incorporated in them.

How the architecture of wind catcher can influence their operations by analyzing thermal behavior are the archetypes of selected wind catchers. Calculating fluids dynamics science, fluent software and numerical analysis are used in this study as the most accurate analytical approach. The results obtained from these analyses show the formal specifications of wind catchers with optimum operation in Yazd. The knowledge obtained from the optimum model could be used for design and construction of wind catchers with more improved operation

Keywords**—**Fluent Software, Iranian architecture, wind catcher

I. Introduction

A WIND CATCHER, as its name denotes, is considered a part of a building form as is customarily constructed in any hot and dry or humid area of Iran. It plays an effective role in modifying heat and adjusting a temperature of interior living spaces in regard to thermal comfort as it uses the convection created by a wind flow and natural pure energy as exists in nature.

This paper is created to understand and identify, on the whole, how a form of these characteristics can influence the operations or functions of wind catchers by investigating them and recognizing their forms. The city of Yazd, as one unique hot and dry city of Iran with the most number of wind catchers and known as wind catcher city, has been selected for study in this enterprise.

Author is an assistant professor in Qazvin Islamic Azad University (corresponding author to provide phone: +982813670058; fax: +982813670058; e-mail: m_mahmoudi59@yahoo.com).

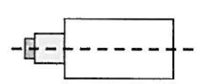
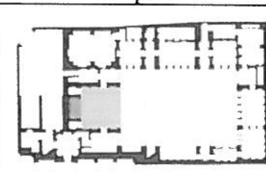
Understanding a typological study of different wind catchers as incorporated in a plan and categorizing them according to their particularities and features serve as a first step in identifying them. Then, fluent software has been used as CFD[1] to analyze the thermal property and behavior of each of them. This would allow finding a plan provided the best results of a decreased temperature of air.

II. Typology of Yazd Wind Catchers Based on What Set up in a Plan

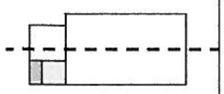
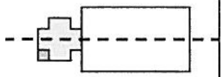
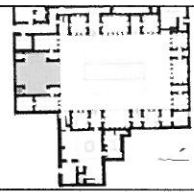
The ways in which wind catchers were set up on top of a house differed from different plans from one plan to another. However, it probably contributes to the cooling operation of a wind catcher. The main sections of an Iranian house, as concern our discussion in this paper, is yard or courtyard, hall or saloon and wind catcher.

A hall is directly and closely connected with a wind catcher but from time to time this link is provided through a medium of an alternative space. Based on their positions on sites on top of roofs in different houses and their interactions with original spaces of aestivation ward and courtyard, the wind catchers can be divided in to three types [1]:

TABLE I
THREE KINDS OF TYPOLOGY OF TYPE A

type	model	plan
1		

[1] computational fluid dynamic

2		
3		

1) A wind catcher positioned behind the hall its axis of symmetry. In this type of wind catcher, the axis of symmetry, hall and courtyard extend together.
2) A wind catcher positioned on a corner of a yard: this type requires that wind catcher connected to the hall through the medium of an aquarium space but not directly related to it.
3) A wind catcher positioned on one of northern corner of a hall (Table I).

III. Typologies of Wind Catchers in Plan

Varied plans of wind catchers in Yazd are nowhere to seen at least throughout the middle cast area. This indicates how much genius and creativity the architects in the city of Yazd have.

Generally speaking, in Iran wind catchers have been recognized in varied forms and plans such as circle, Octagon, polygon, square and oblong. No triangular form of it has been yet recognized or located nowhere in the Middle East area. Wind catcher with a circular plan or form is the very rare. Such type of wind catcher doesn't exist in Yazd. There is only one sample of it Yazd suburb.

Not in view of their internally- arranged blades form. Such blades as are commonly used in wind catchers are elements that are made up of adobe and brick which decompose a wind catcher's duct in to some smaller ducts. These partitions form a plane grid of vents ending to a heavy masonry roof on top of the tower [2].

These blades can be divided in to two categories: Main blades and side blades. Main blades take their rise from a floor at ground reaching 1.5m -2.2m high, continue to the ceiling of a wind catcher and contribute to development of smaller ducts.

Main blades play operational roles more often and influence operation of wind catcher. In contrast, side blades are inserted within the input gap of a wind catcher and play lesser roles. They resemble exactly the blades of modern cooler. These blades add more aesthetic feature to wind catchers rather than anything else. Main blades can not be in sight on the external view but those of secondary; that is to say side blades substantially affect the outside views of a wind catcher and urban landscape altogether.

Given the geometrical form of plan and the manner in which the blades are arranged in their positions, the wind catchers can be etymologized. This paper deals with typologies of wind catchers with oblong plans as a final purpose of studying how the architecture of wind catchers plans affects thermal or heat treatment the most commonly applied type of which already exists in the city of Yazd and encompasses 88/6% as reported [3].

Typology of wind catchers with oblong plan

This is the most commonly applied type of wind catcher and the only one out of 53 types of wind catchers under consideration that has an oblong plan. The varied main blades that make up a wind catcher provide a plan with an oblong shape in different types.

A. Wind catcher with X-form blades

This type of wind catcher exists rarely or in a small number in Yazd. The length of wind catcher of this species is fairly 1/5 times as many as its width. There were only two out of 53 houses under study in Yazd had wind catchers with oblong blade and blade X (fig1).

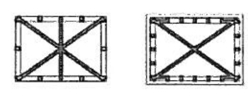


Fig. 1. Wind catchers with X-form blades

B. Wind catchers with + shaped blades

Wind catchers with blades perpendicular to each other and with a + shape is the most dominant shape of a wind catcher in Yazd [4]. The different types of them with their varied symmetries have been seen there. The depth of its canal in linear front is 1/2 of its latitudinal depth. In this latitudinal front the depth of its canal depends largely on its length and number as well as forms of its separating blades. This specie of wind catcher can be separated in to two more subsets (fig2).

Fig. 2. Wind catchers with +-form blades

Wind catchers with equal canals

In these types of wind catchers, the blades are equally spaced and as a result of it some tiny canals are created with equal sizes and spaces (fig3). this type of wind catcher is the most prevalent one in Yazd in view of plan. Plan symmetries (length-width) vary from 1 – 1.4 to 1 - 2.25 (fig4).

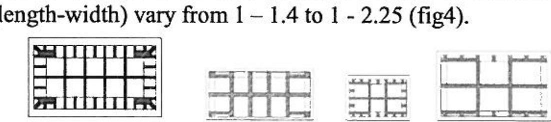


Fig. 3. Wind catchers with +-form blades and equal canals

Wind catchers with different canals

Plan extension is more oriented in these species of wind catcher and the symmetries of plan vary from 1-1.58 to 1-2.92 according to field study (fig 5). In species where the canals on the latitudinal form are larger, the width of oblong plan faces the dominant winds. In these patterns, the architect could not lay the wind catcher exposed to northern dominant wind from longitudinal form because of the plan form the house had and as a consequence, having changed the plan form, the architect was able to provide more wind to flow from the latitudinal to that of longitudinal (fig 6).

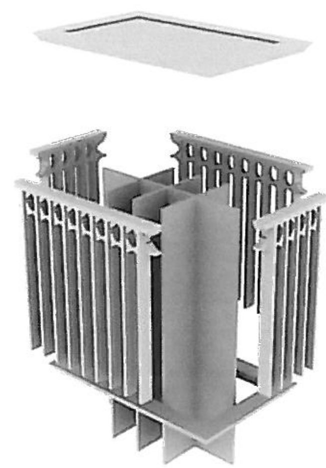


Fig. 4. 3D model of a Wind catcher with equal canals

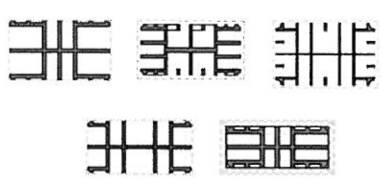


Fig. 5. Wind catchers with +form blades and different canals

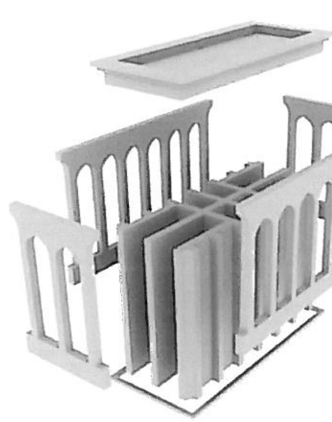


Fig. 6. 3D model of a Wind catcher with different canals

C. Wind catcher with H-form blades

For these types of wind catchers, the plan is designed that the main blade of a wind catcher that isolates the duct of it is inserted in to the centre of canal and does not extend to the latitudinal walls of wind catcher. The symmetries of plan approach the square (quadrant) and plan is not extended with an oblong. The symmetries of a plan is 1-1.3 or less.

This type of a wind catcher is seldom seen in Yazd. Four of them under study are adapted to this plan configuration. This specie reveals that the cross- section of canal in the latitudinal front is larger than canals that receive wind from the longitudinal from (fig7)

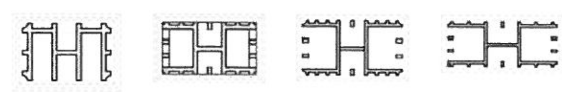


Fig. 7. Wind catchers with H form blades

D. Wind catcher with a K-shaped blade

This species of plan design is, indeed, combination of a plan and X blade and + shape. This had been rarely seen in living houses architecture (fig8).

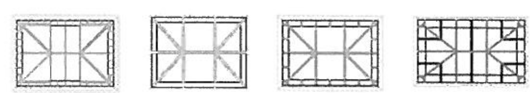


Fig. 8. Wind catcher with K form blades

E. Wind catcher with I-shape blades

The main blade is hidden in the latitudinal front of the wind catcher. One closed opening exists on the opposite side of an opened hole to let wind escape, for the wind would have escaped through a hole or gap on the opposite direction. This is the most extended oblong. Shape plan in Yazd the proportional plan of which is 1- 3.75. Only one model out of 53 has been configured and drawn as below (fig9).

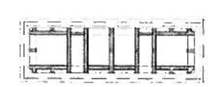


Fig. 9. Wind catcher with I form blades

IV. Function

A Wind tower is used to convey the wind current to interior spaces of buildings in order to provide living comfort for occupiers. In Iranian architecture a wind tower is a combination of inlet and outlet openings (fig10).

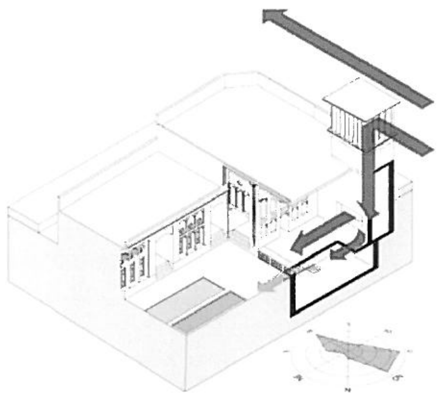


Fig. 10. Function of wind tower with high wind speed (www.cyberarchi.com)

The purpose of using wind catcher is reaching reasonable temperature and relative humidity. Therefore, considering below parameters will improve wind catchers operation:

1. Wet decks; which is used as water basin or jug that is placed below wind catcher canal. Hence, leaving air temperature from wind catcher is reduced as the air flows over this humid system.
2. Geometry; cross section and wind catcher height.

Evaporation efficiency is proportional to air volume in constant speed [5]. Namely, the more cross section of wind catcher, the more air will flow through building with suitable speed and evaporation efficiency will improve. The most important item to achieve this goal is wind catcher geometry.

The more wind catcher height (distance from air entrance to discharge point), the more pressure difference will be and efficiency will improve. On the other hand, according to Bernouli Effect, as the air flows through smaller cross section, the airflow speed will increase [6]. Therefore, increasing height proportional to total area of canal will cause the wind flow speed increase.

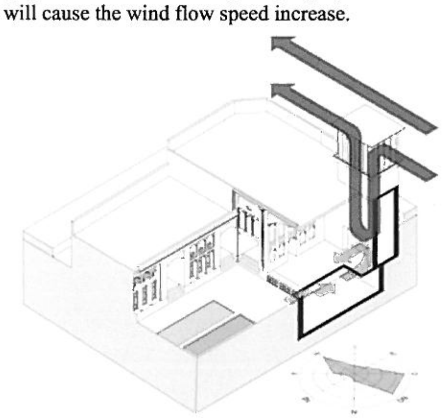


Fig. 11. Function of tower with low wind speed (www.cyberarchi.com)

The tunnel therefore provides cool air for the building while serving as a conduit through which the stuffiness within the building is conveyed through its shaft.

Wind tower is divided by partitions to make disparate shafts. One of the shafts operates all the time to receive the breeze and the other three shafts work as outlet air passages. They convey the stuffiness out of the living space based on the chimney effect. The chimney effect is based on the principle that air density increases with temperature increase. The difference in temperature between the interior and exterior parts of a building and between different regions creates different pressures and result in air currents.

V. Bases to Select Samples of Wind Catchers for an Analysis of Heat Treatment

given the way in which a wind catcher has been most importantly set in a plan, the house of type 1 which was the only specie fitted under a wind catcher of a pool where an evaporating cooling was occurring was selected and the house belonging to a man called Rasoulian was nominated as a model house that is a valuable historical- architectural house. The wind catcher of this house was investigated in field study during the research.

Given the different types of configurations that the internal blades of wind catchers with oblong plan form, three dominant models of plan with uniformed dimensions but with only differed internal blades were made as computerized models and their heat conduct property was reviewed.

To known how a passing air current behaves in the wind catcher the geometry of a wind catcher's structure was modulated by using available maps in Gambit software. Considering the fact that the existing buildings are dispersed or distributed and a used UBC[2] as well as data concerning the climatic conditions in Yazd area such as temperature, relative humidity and wind speed, a suitable borderline (marginal) conditions were used. Similarly input and output borders were delimited in sufficient number a way from building so that the uniform effects of flow would be maintained.

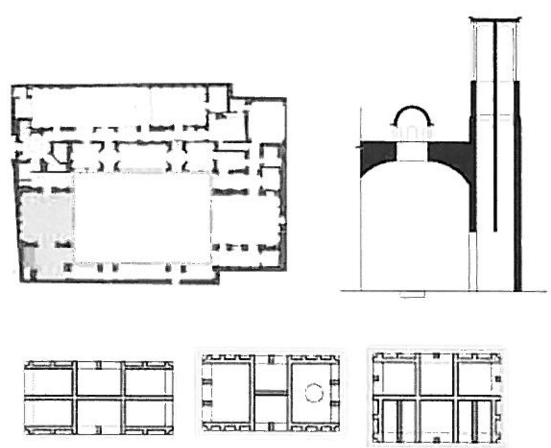


Fig. 12. Samples for analysis

[2] uniform building code

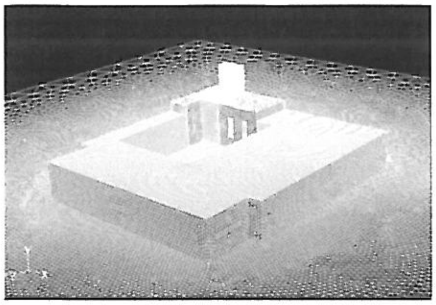


Fig. 13. model of Rasolian house geometry in fluent soft ware

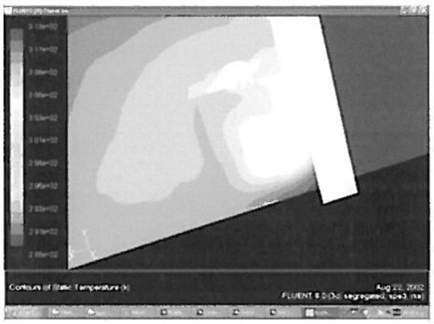


Fig. 14. counter of temperature, model 1

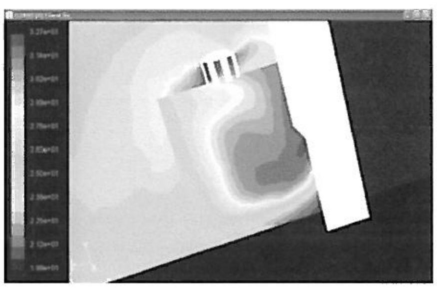


Fig. 15. Counter of relative humidity, model 1

Fig. 16. Counter of temperature, model 2

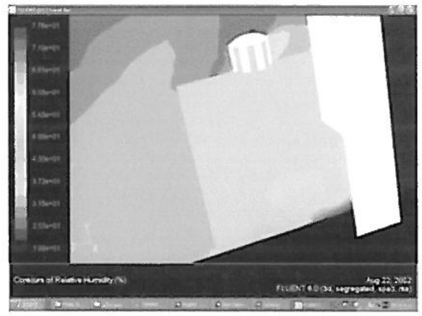


Fig. 17. Counter of relative humidity, model 2

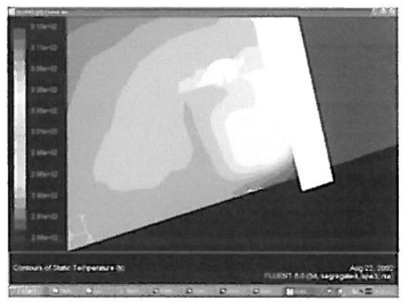


Fig. 18. Counter of temperature, model 3

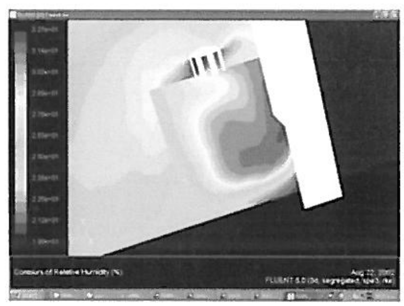


Fig. 19. Counter of relative humidity, model 3

TABLE II
CONCLUSION OF FLUENT ANALYSIS OF MODELS

Effective parameters for comfort	**Model 1**	**2**	**3**
Fall of temperature from 40 $^{\circ}$C	29.3	30.8	32.2
Rise of humidity from 17%	36.7%	34.15 %	32.9%

VI. Conclusion

Three different wind catchers in 3 models as exist in resultant's house were studied and different results were obtained although the plans of houses, the way in which they were set up in houses, uniformed cross section height and inter-faces, it therefore follows that architecture and forms of wind catcher's blades play role in thermal behavior. A wind catcher with + shape will respond the best from among other models.

References

[1] M. Mahmoudi, "wind catcher symbol of the image city in Yazd", Baghe Nazar journal, vol.5, 2007, p 97.

[2] Mahyari, Ali, "wind catchers", Ph.D thesis, Sydney University, 1997, p 62.

[3] M.Mahmoudi. S.M. Mofidi, "Analysis on typology and architecture of wind catcher and finding the best type", honarhaye ziba journal, vol 36, p 29, 2008.

[4] M. Mahmoudi, "wind tower as a natural cooling system in Iranian architecture", proceeding of passive and low energy cooling in buildings conference, Greece, 2005.

[5] Bahadori, M.N, "An Improved Design of Wind Towers for Natural Ventilation and Passive Cooling", Solar Energy; vol 35, No.2, 1985.

[6] Battle McCarthy Consulting Engineers, Ahmadinezhad (translator), "wind towers", 2002, page 24