Translate to Transform

Sustainable Strategies in Phoenix, AZ

Shalaleh Kasebi

University of Detroit Mercy

Winter 2019

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Introduction:

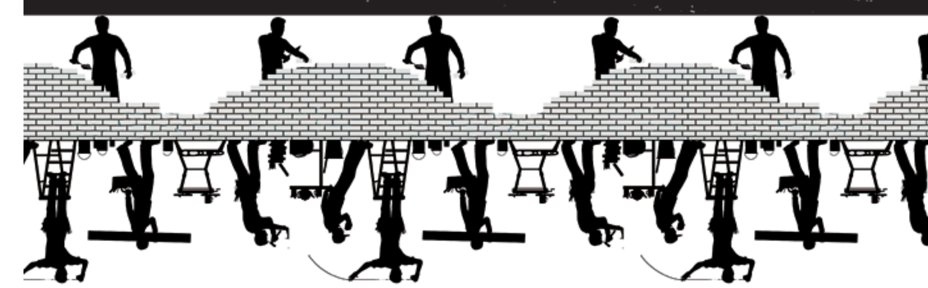
There is a history and reason behind every design, no matter what you are designing for. The very early built environments happened based on the needs of society. These built environments were very simple only meeting the basic needs of the people who were using them. As time passed, the builders and the craftsmen became more professional, and they tried to solve the issues of these designs. What makes something perfect is the imperfection. The errors and flaws in a specific design can be the key to improve it by solving those problems. However, not every single builder, architect or designer takes this path. In modern and more developed societies the designer might design a specific built environment only once, and it can be done in a way which no one else would repeat it to discover the design flaws. But if we pay attention, we can see how repetition can bring up the issues regarding the specific designs and methods of building. However, this is not limited to architecture. Repetition can solve issues in almost every single practice.

Stone edge backs to 3.4 million years ago. It was the time when men started to use the materials available in nature to make a shelter for himself. Throughout centuries, he learned how to create different tools to improve his shelter. Vernacular architecture goes back to the stone age, and the era when men started to use local materials to build the environment. Different climates demanded different methods to solve the problems resulting from the climate type. The climate type and the availability of the materials were the dominant factors to direct the builders to where to start. That's why different materials appear to be prominent in different architectural methods of different regions.

Vernacular architecture talks about how the old and the traditional building ways work together to shape the local building methods to meet the needs of the societies. But what do we mean by the vernacular architecture? Architecture means the science of building, and vernacular means native. Putting them together, the vernacular architecture means the native science of building. However, in usage current vernacular refers to the language or dialect of the local architecture. And why vernacular architecture? Because we can use the local materials and the local architectural methods to solve the problems resulting from a specific climate type, and it can be the cheapest and the wisest way to solve these problems.

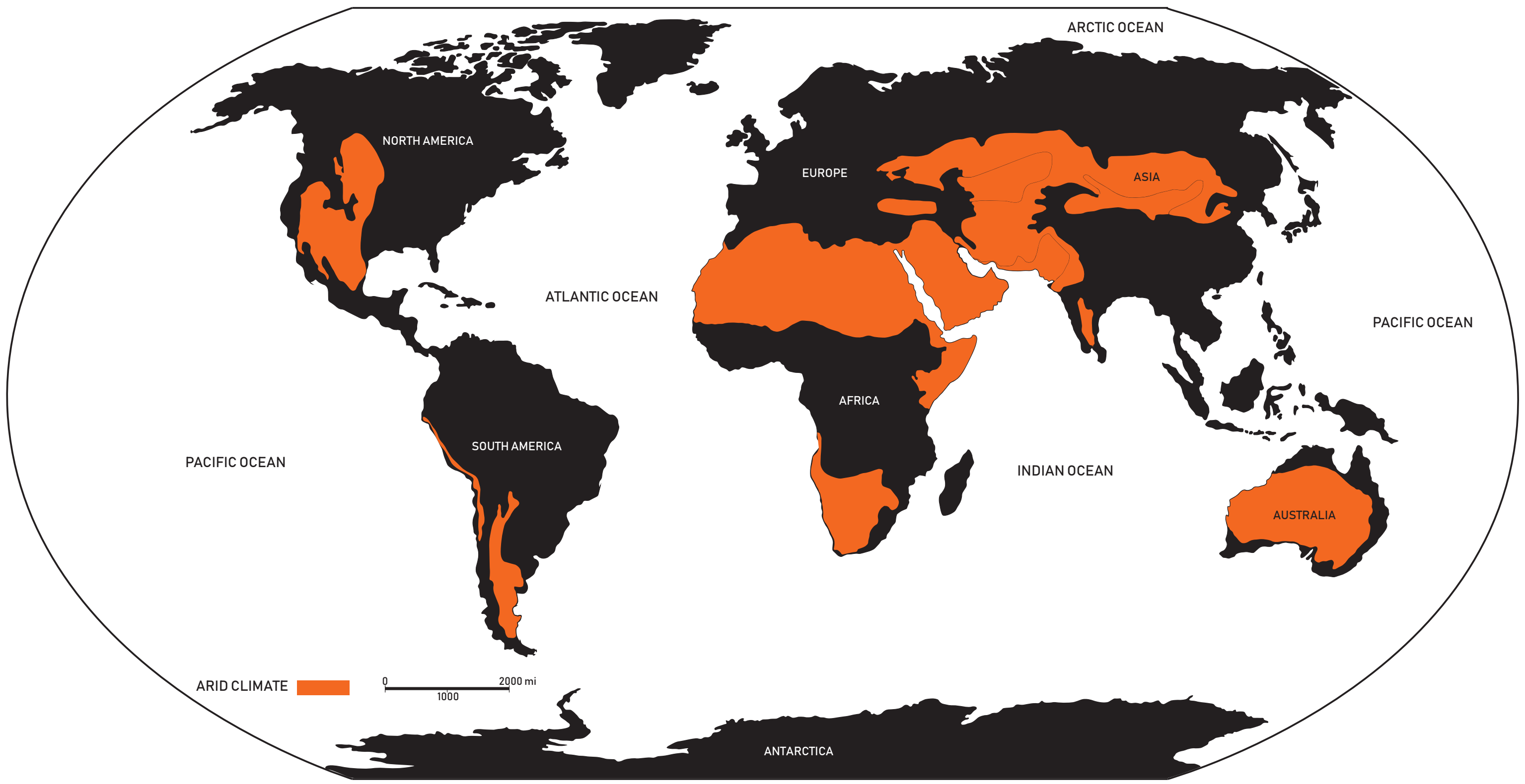
As we know, Mesopotamians have the oldest civilization history in the world, and the Middle East and parts of Africa belong to this civilization. Since the civilization of these regions is the oldest in the world, they took more way towards solving the problems arising from the harsh climate condition. Mentioned earlier, the more steps you take, the more experienced you get. On the other hand, since North America has the youngest civilization history, it would be interesting to try new ways to translate the oldest vernacular architectural methods into a young and more modern country and society to create cheaper and more sustainable built environments. This thesis investigates different types of passive cooling systems in conjunction with the traditional windcatchers to solve the extreme heat issue specifically in low-income neighborhoods of Phoenix, AZ.

To start looking for the appropriate and passive ways to solve the extreme heat issue in Phoenix, a closer look took at the climate type of the Phoenix, in addition to the factors related to this environmental issue. The investigation begins with studying the climate type and diving more into different passive approaches towards cooling down the interior spaces all over the world in different countries and different regions.



Arid Climate:

Arid climate or desert climate zones fall into two categories. Hot-dry and mixed-dry climate. A hot-dry climate is generally defined as a region that receives less than 20 in. (50 cm) of annual precipitation and where the monthly average outdoor temperature remains above 45°F (7°C) throughout the year, while A mixed-dry climate is generally defined as a region that receives less than 20 in. (50 cm) of annual precipitation with approximately 5,400 heating degree days (65°F basis) or less, and where the average monthly outdoor temperature drops below 45°F (7°C) during the winter months.



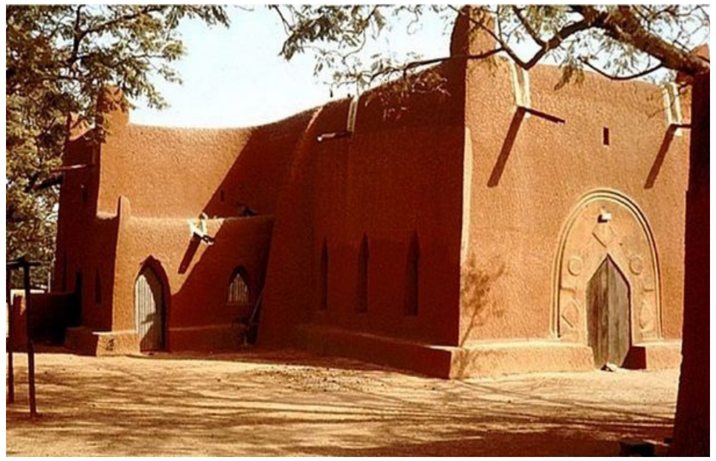
Different Passive Cooling Systems used in the Vernacular Architecture:

There are different approaches to control the extreme heat to get into the interior spaces and make more comfortable to live all over the world in arid climate zones. In Middle Eastern countries, like Iran and Pakistan, the use of courtyards, fountains, thick masonry walls along with the windcatchers has been the solution for more than 1000 years now. In North Africa in countries like Morocco, Senegal, Sudan, Niger, and Nigeria the use of reeds, grasses, and mud buildings resulted in having cooler interior spaces. However, in Egypt and the United Arab Emirates, the approach is closer to the Middle East by using windcatchers as passive cooling elements in buildings. In North America, in regions like New Mexico and Arizona, the use of Adobe buildings along with

Courtyards and water feature is very popular while in South America like Argentina the use of thick masonry walls with light exterior colors results in a lower temperature in interior spaces comparing to the outside air temperature.

Thermal mass is a universal way in arid climate zones to avoid the flow of hot exterior air into the interior spaces. Different names for it are used such as mud buildings, earth buildings, or adobe buildings. But in fact, the concept is the same, using thick masonry walls to minimize the passage of exterior hot air into the interior spaces and minimizing the heat gain by applying the light colors for façades.

This brings up the idea of using windcatchers, which are commonly used in the Middle East and some parts of Africa, as a passive cooling system in regions with the same climate type of Arizona.



Senegal
Photo Credit: www.Flickr.com

Niger
Photo Credit: www.Flickr.com

Nigeria
Photo Credit: www.Flickr.com

Iran
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Sudan
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Egypt
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Dubai
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Iran
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Qatar
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Argentina
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Pakistan
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Santa Fe
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Windcatcher:

Windcatchers are built elements that employ natural ventilation and passive cooling in traditional architecture. They project vertically from the roof, bringing the outside air into the building through open space or cavity. They are vertical shafts that channel the exterior air to the interior. The air movement is based on the different air pressure between the outside and the inside. The outlets are usually at the floor level where people sit. The exterior portion of the windcatcher has one or more openings facing the prevailing winds. It is usually made of brick or mud with blades to direct the wind current down throughout the shaft. The outside cool air moves through the interior spaces absorbs the excess heat, gets warmer, and leaves the space through the windcatcher shaft. By using thermal mass in windcatchers, the wind which passes through the shaft gets cooler before entering the interior. In addition, this thermal mass absorbs the direct heat gain from the sun which hits the body of the windcatcher during the day, and it radiates back out during the night.

The way the windcatcher works is like stack ventilation in a passive cooling system. However, being wrapped by a thermal mass adds to its proficiency compared to the stack ventilation. The overall shape of the windcatcher is different from one country to the other. Moreover, in each region, there are different shapes of the windcatcher. For example, in Iran, windcatchers are rectangular, square or hexagonal in plan section. Moreover, each category has sub-categories based on the form of the blades. For instance, the square shape is divided into H-Blade, X-Blade, and +-Blade. What is interesting about the windcatchers is their social aspect. Windcatchers of wealthy neighborhoods are higher in height and more detailed while the low-income residents have shorter and simpler windcatchers.

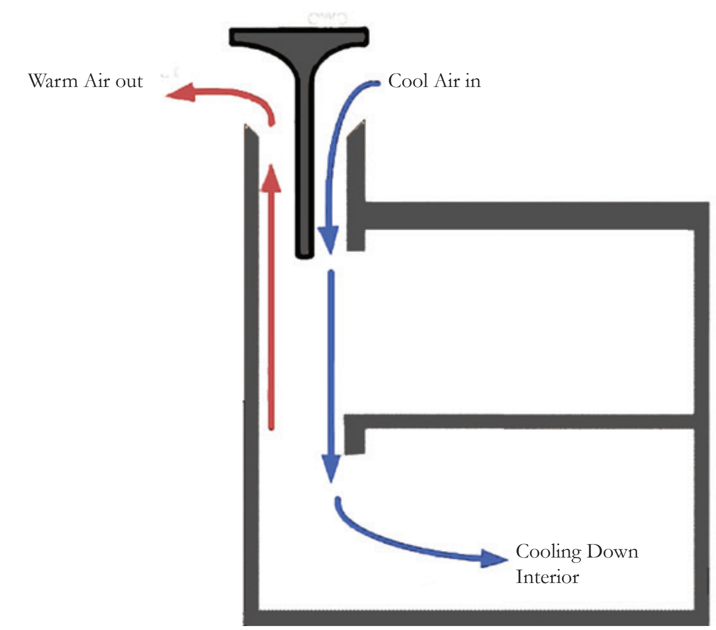



Photo Credit: www.Flickr.com

Sketch Problem 1:

Phoenix is located in hot dry climate zone of North America with long extremely hot summers and short mild to warm winters. As a result, it can be the potential city to be considered as a place to apply the windcatchers. However, mentioned before, vernacular is the specific language of the local architecture. Given that, it is not possible to take a vernacular element from a totally different region with different culture and needs and just place it in another region with only the same climate type. To be acceptable, the new embedded element should speak the same dialect with the architecture and the culture of the destination. In sketch problem 1, we can see how two cities with the same climate type, but in different regions have dissimilar archetype and the language of architecture. Therefore, to be able to employ the windcatchers in the city of Phoenix, we need to find the right translation of the traditional windcatchers. This is including the materiality, the shape, and the overall look in addition to the social, environmental and cultural aspects.

Case Studies:

To dig deeper into the idea of using windcatcher as a passive cooling system in Phoenix, I am going to take a closer look into five different precedents from different countries and continents. These case studies are either in a residential or urban scale. Moreover, two of them are traditional while three of them are modern examples. So, I tried to cover different categories to reach a reasonable level of understanding of how they work on different scales. After studying them, we are going to compare them regarding their relationship to the building, the path of the wind through the windcatcher, the prevailing wind direction of the location, the city skyline resulting from applying them, and the skin and the materiality of the windcatcher.

Bajoghli Residence, Isfahan, Iran:

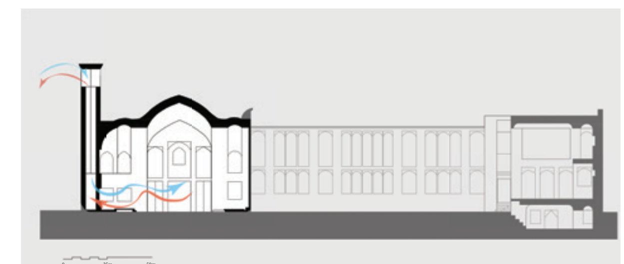
The first example is a traditional residential building located in the city of Isfahan, Iran. In Isfahan, the wind blows from almost all directions, but the prevailing one blows from the south-west. The building has one windcatcher which is rectangular in shape, and its location is central in relation to the other spaces. Moreover, it has a large central courtyard, which divides the residence into two distinct parts, north-east, and south-west. The windcatcher is located at the south-west portion of the building which is facing the strongest winds.

Because the main sitting area of this residence is located on the first floor, the windcatcher outlets are located on the first floor as well. The second floor is mainly balconies around the building perimeter. Once the cool air gets into the first floor through the vertical shaft of the windcatcher, it cools off the first floor. Because the first floor is a double height space, the cool air gets warmer and lighter when it moves vertically towards the ceiling.

The exterior skin of this windcatcher is made of bricks with the vertical openings to direct the wind towards the shaft. When it comes to the urban scale, this building is located in a highly dense residential and historical neighborhood. All buildings in the neighborhood are either one or two-story which makes the windcatcher more capable of catching the winds. These buildings mostly have courtyards and windcatchers as other passive cooling strategies. Moreover, the ceiling of this building is a dome shape in the main sitting area, which adds on the proficiency of the windcatcher to make the inside air cooler. Thus, windcatcher works better in combination with the other passive strategies like central courtyards, water features, and domes.

Bajoghli Residence
Photo Credit: www.Flickr.com

Second Floor Plan

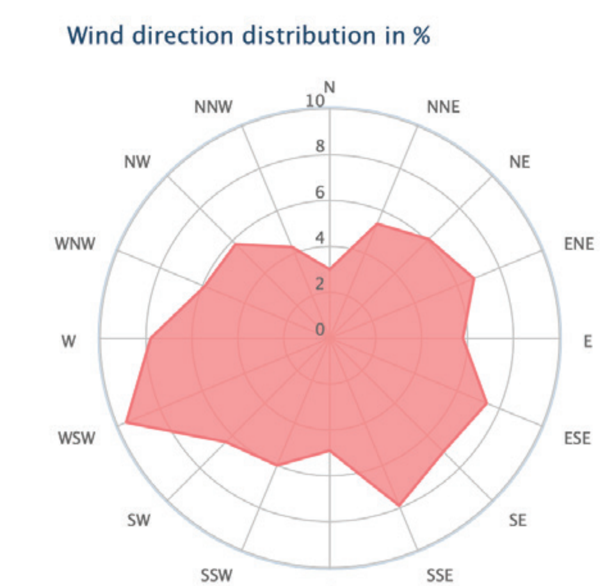


North-South Section

South Elevation

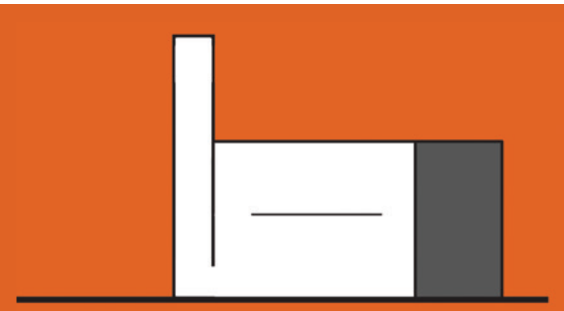
Iran

Photo Credit: www.windfinder.com

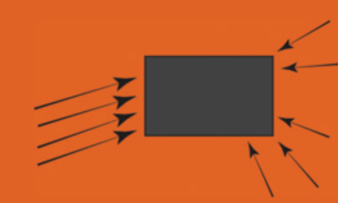


Relationship to the Building

Path through the Building



Wind Direction



Urban Skyline

Skin

Bajoghli Residance, Iran

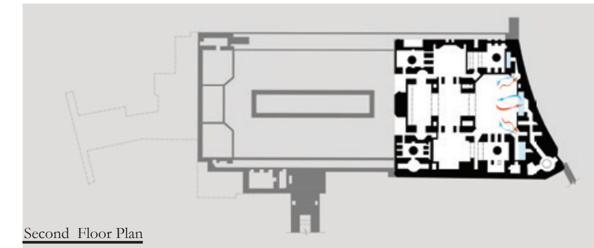
Boroujerdi Residence:

The second example is another residential building in Iran, but in a different city, Kashan. In Kashan wind blows from different directions of the north side, but the prevailing one blows from the north-west. However, there are two strong winds blowing from the north-east as well. The orientation of the case study located in Kashan is north-east—south-west. This building has three different windcatchers, two of them on the north-east side, and one on the south-west side with the circular shapes. This building has a central courtyard as well as the previous example. Moreover, this residence has several balconies which create shadows and help to cool down the interior areas even more. Use of dome, clay as thermal mass, and shading works well with the existing windcatchers to create a comfortable interior temperature.

The windcatchers of this precedent are more complicated than the first case study since they work in conjunction with different openings and a dome to cool off the interior spaces. The outlets of one windcatcher are located in the basement. The second windcatcher cools off the first floor while the third one cools off the second floor. Moreover, the wind gets into the building through several openings located around the dome.

The windcatchers are located on the sides of the building. The exterior skin of the windcatchers is all brick. However, the dome and the openings are made of clay. This building is located in a highly dense historical residential neighborhood similar to the previous example, and the surrounding buildings are either one or two-story. The windcatchers are attached to the residence and cool off the interior directly and are capable of sucking the warm air out when it gets warmer and lighter.

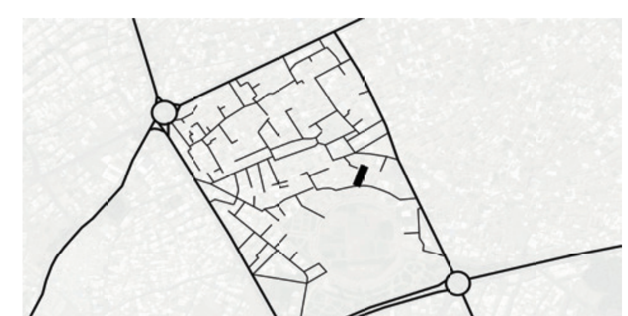
Boroujerdi Residence
Photo Credit: www.Flickr.com



Second Floor Plan

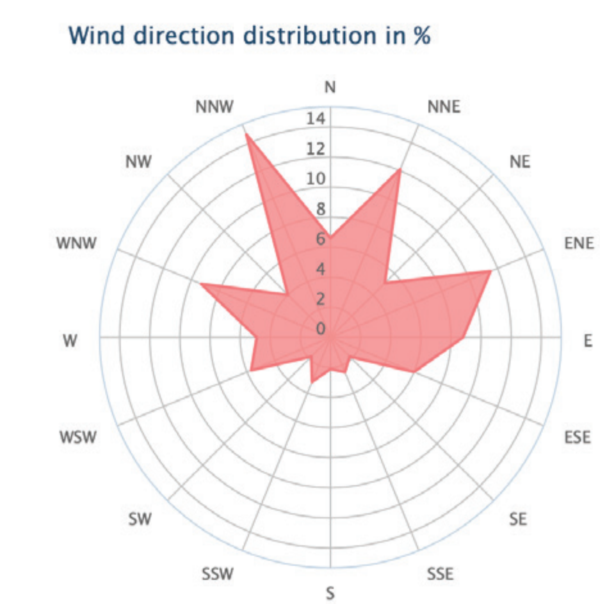
North-South Section

South Elevation



Iran

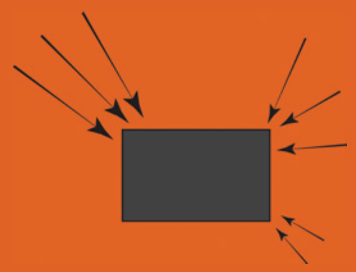
Photo Credit: www.windfinder.com



Relationship to the Building

Path through the Building

Wind Direction



Urban Skyline

Skin

Boroujerdi Residance, Iran

Masdar Windcatcher:

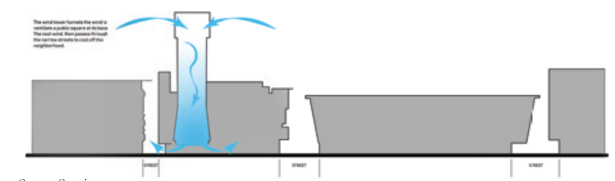
The third example is the Masdar City Windcatcher which is located in the city of Masdar in the United Arab Emirates. The prevailing wind blows from the north-west in Masdar, and it is almost the only direction the wind blows throughout the year. The Masdar city windcatcher is standing by itself on an urban scale. It cools off a neighborhood and makes the exterior air cooler in conjunction with the shadows resulting from the buildings surrounding the area. This windcatcher is taller than all the buildings around it, and it has a circular shape.

The windcatcher of Masdar is a great example of an urban element which works with other buildings or built environments to achieve a certain goal. The streets of the Masdar are so narrow, and the buildings are not higher than four-story. This results in shadows which cover the narrow streets while the windcatcher directs the cool air into them. Moreover, the windcatcher makes the air even cooler by using mist joists located horizontally in the windcatcher to humidify the incoming air before releasing it into the neighborhood.

The outlets of this windcatcher are located at the street level where people sit or walk. It is a circular windcatcher in shape made of steel mesh. There are steel louvers on the section plan of the windcatcher at the top which direct the wind into the windcatcher shaft. The incoming air then gets humid by passing through the mist joists. When it comes to the role of the windcatcher in the city skyline, as we mentioned before, the neighborhood is dense with three to four story buildings and this windcatcher works as a tall landmark which can even be an iconic structure of Masdar city.

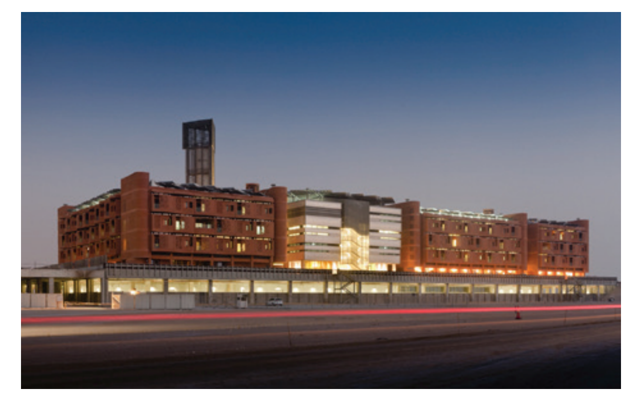
Masdar Windcatcher
Photo Credit: www.Flickr.com

Masdar City
Individual Photo Credit: www.Flickr.com



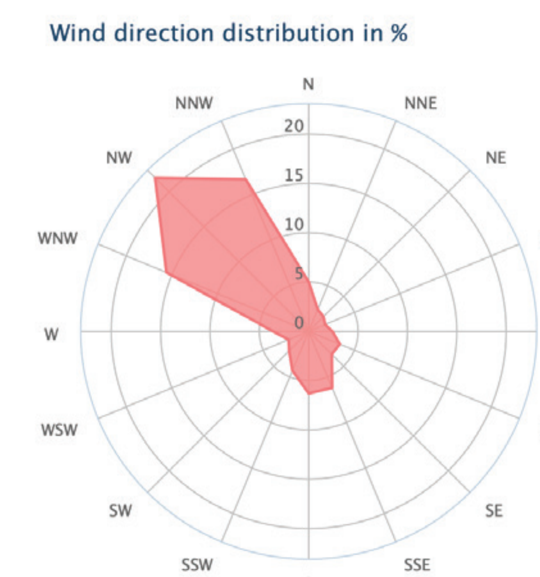
Street Section

United of Arab Emirates



Masdar City
Photo Credit: www.Flickr.com

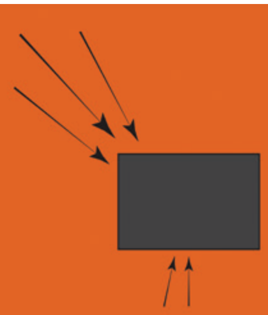
Photo Credit: www.windfinder.com



Relationship to the Building

Path through the Building

Wind Direction



Urban Skyline

Skin

Masdar Windcatcher, UAE

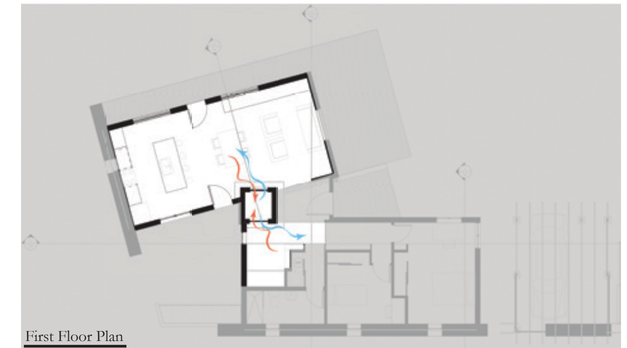
Windcatcher House:

The next case study is the Windcatcher House located in North America, Utah. The windcatcher is for a two-story residential building which was built in 2008. The wind direction of the site is from the north-west and the south-east, with the dominant south-west one. However, since there are only three residential buildings in the neighborhood, even the weakest winds can be caught by the windcatcher to reduce the interior temperature. This building has only one windcatcher, which is located in the center of the house.

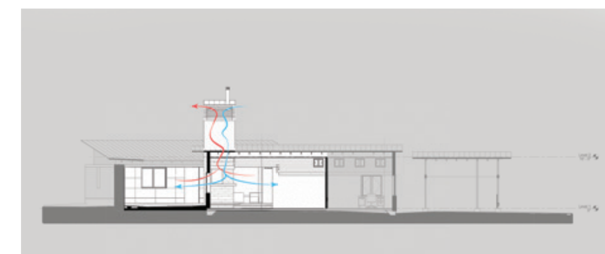
Since Utah is cold during the winter months, this windcatcher works as both a passive cooling element during summer and a chimney during the cold winter time. The main sitting area is on the first floor, and that is why the outlet of this windcatcher opens to the first floor. In summer the fireplace damper needs to be closed and the wind gets into the building through the outlet of the windcatcher. On the other hand, during winter, the outlet needs to be closed and by opening the fireplace damper the shaft works like a chimney.

The skin of the windcatcher is clay with steel louvers on the exterior. The louvers help in directing the prevailing wind into the windcatcher shaft while the clay part of the shaft works as a thermal mass during the summer months. As mentioned before, the site where this windcatcher is located is mostly flat land. As a result, it doesn't have any urban role in the neighborhood. Moreover, the other neighbors are far away from this building. This results in a fact that they don't even need a tall windcatcher to catch the wind. This case study apparently shows that how a chimney can work as a windcatcher and help with cooling down the interiors.

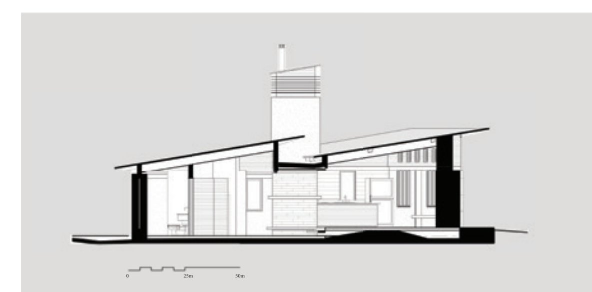
Windcatcher House
Photo Credit: www.Flickr.com



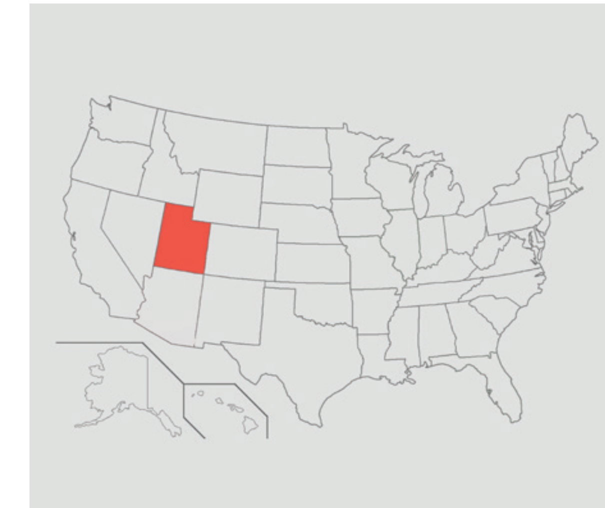
First Floor Plan



East-West Section

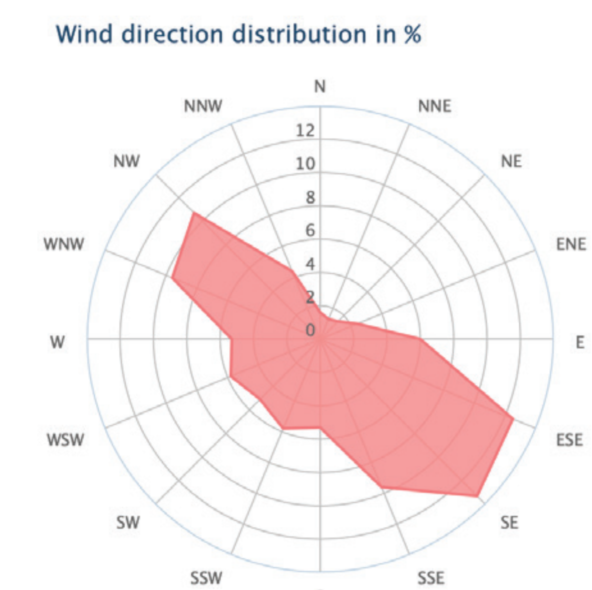


East Elevation

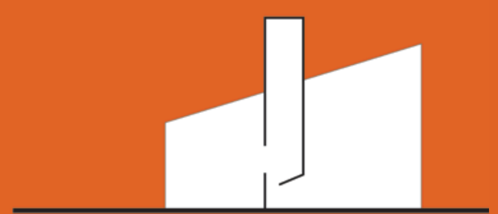


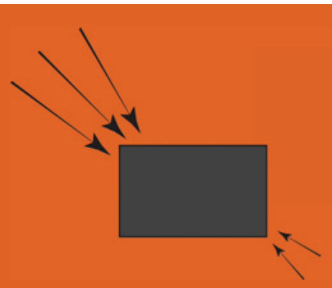
United States, Utah

Photo Credit: www.windfinder.com



Relationship to the Building | Path through the Building | Wind Direction | Urban Skyline | Skin





Windcatcher House, USA

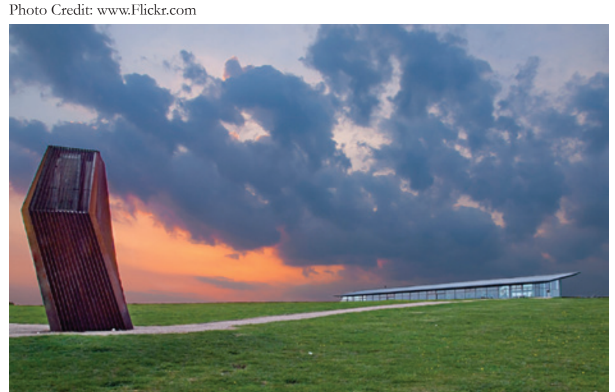
Chiltren's Gateway Centre:

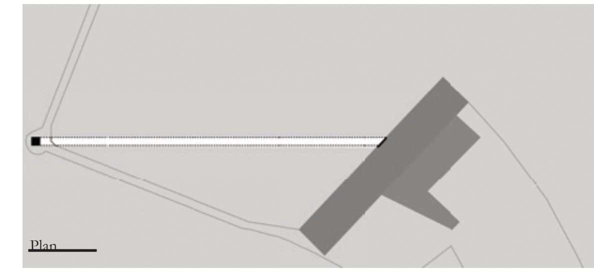
The last case study is the Chiltren's Gateway Visiting Centre in Dunstable, England. This windcatcher is on an urban scale, and it is located in a park on top of a hill. The prevailing winds of the site blow from the west and the south-west. In fact, this windcatcher is an element to capture the wind and direct it to the main building of the visitors' center which is located far away from the actual windcatcher. It helps to cool down the building passively. Therefore, this precedent is standing by itself like the Masdar Windcatcher, and it is not attached to the building.

A concrete underground tunnel connects the windcatcher to the main building. This tunnel is located 2 meters under the ground surface because the temperature stays at 12 °C constantly throughout a year. When the wind gets into the windcatcher shaft, it passes through this tunnel to get into the visitors' center, and by passing through it, it gets cool. The earth surrounding the tunnel work as a thermal mass to keep the air cool while passing the tunnel. The outlets of this windcatcher are in the main building far away from it.

The skin of this windcatcher is made of wood strips and steel louvers to direct the wind into the shaft. Then the wind leaves the windcatcher through the outlets located on the ground surface and gets into the concrete tunnel. By passing through the tunnel, the wind gets cooler and then it enters the main building through the other outlets located inside the visitors' center. This windcatcher works on an urban scale. However, it is located in an outdoor park which makes it stand alone from the cityscape.

Children's Gateway Centre
Photo Credit: www.Flickr.com

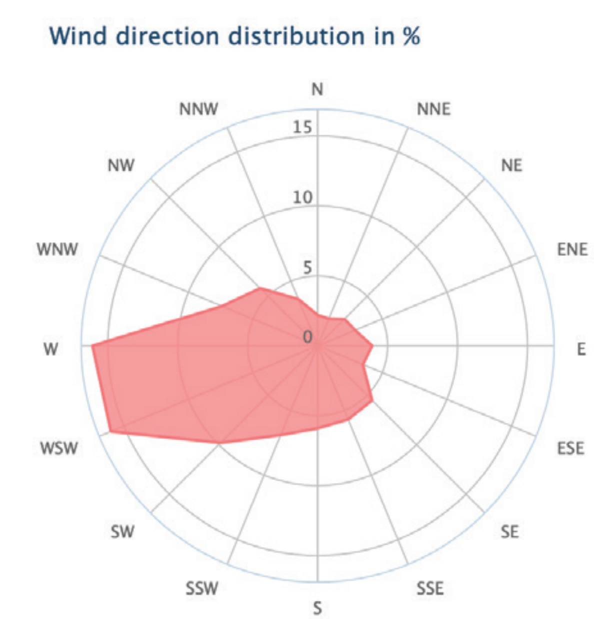




Children's Gateway Centre
Photo Credit: www.Flickr.com

England, Dunstable

Photo Credit: www.windfinder.com



Relationship to the Building

Path through the Building

Wind Direction

Urban Skyline

Skin

Windcatcher House, USA

Phoenix:

After studying various vernacular methods and passive strategies in arid climate zones of different regions and countries, I started to take a closer look to different cities of North America to find a city located in the arid climate region and examine the idea of applying windcatchers to the residential and urban scale. This could be a solution towards controlling the extreme heat issue and making the interior spaces more livable.

Phoenix is the capital and most populous city of Arizona, with 1,626,078 residents, and the fifth most populous city in the United States. Moreover, it is the most populous American state capital, and the only state capital with a population of more than one million people.

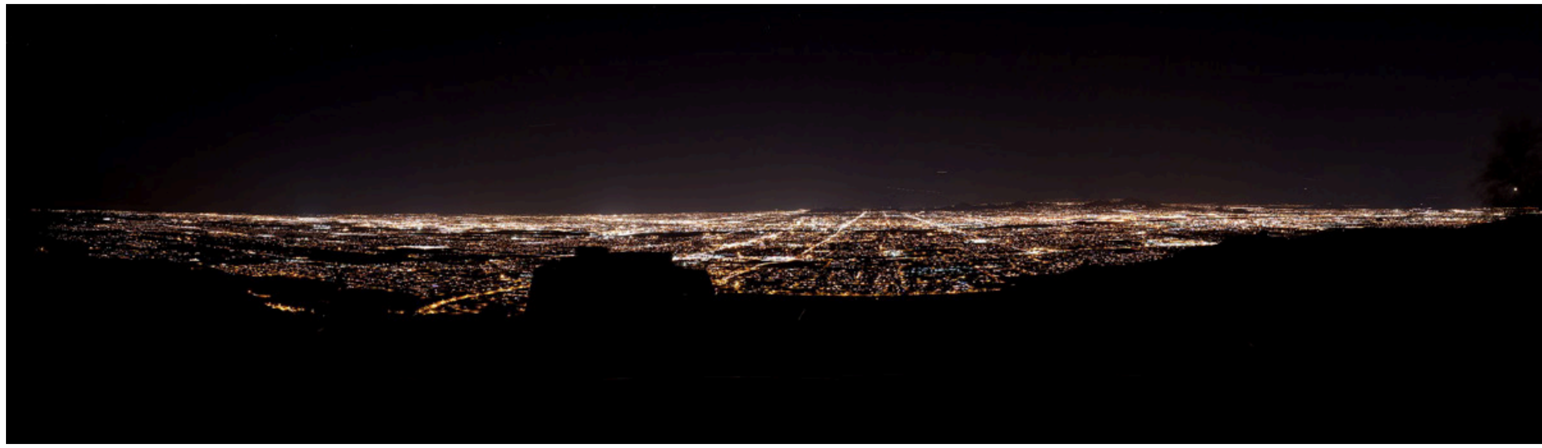
Other than the mountains, the topography of Phoenix is generally flat, allowing the city's main streets to run on a clear-cut grid with wide, open-spaced roads. The Salt River runs westward through the city of Phoenix, but the river bed is frequently dry or contains little water due to large irrigation changes. According to the United States Census Bureau, the city has a total area of 517.9 square miles (1,341 km2). 516.7 square miles (1,338 km2) of it is land, and 1.2 square miles (0.6 km2, or 0.2%) of it is water.

As with most of Arizona, Phoenix does not use daylight savings time. In 1973, Governor Jack Williams claimed that due to air conditioning units not being used as often in the morning on standard time, energy use would increase in the evening. He went on to say that energy use would also rise early in the day since there would be more lights on during the early morning. Additionally, he said that daylight savings time would cause children to go to school in the dark. Sunrise happens at around 7:29 am on December 21 and 5:19 am on June 21. Sunset hits at around 5:25 pm on December 21st and 7:41 pm on June 21st. As a result, Phoenix doesn't observe daylight savings time since they see no need for it.

Phoenix has a hot desert climate with hot summers and mild winters. It is located in the sunniest region of the world, with 3,872 hours of bright sunshine annually. Moreover, it receives the most sunshine of any other city in the world. Annually, there are 107 days with a high of at least 100 °F (38 °C). These hot days start from late May until early October. Most desert locations undergo drastic fluctuations between the day and the nighttime temperatures, but Phoenix's diurnal temperature variation is limited by the urban heat island effect which makes even the nights warm. As the city has grown, average summer low temperatures have been regularly rising. The heat of the sun during the day is stored in pavement, sidewalks, and buildings, and it is radiated back out at night. As a result, the daily normal low remains at or above 80 °F (27 °C) for an average of 67 days per summer. The prevailing wind direction throughout the year is from the east side with some angle changes towards the south east during July.

Arizona

Photo Credit: www.en.wikipedia.org



Extreme Heat and UHI in Phoenix:

Exposure to extreme heat is a potentially serious issue in the desert location, particularly during the summer months when the daytime temperature regularly exceeds 43 °C (110 °F). Extreme heat is impaired by the growth of the city's strong near-surface urban heat island (UHI), which can raise the nighttime temperature even by more than 6 °C (10.8 °F).

Persistent exposure to high temperature has been shown to be hazardous to human health. Severe temperature also has effects on human morbidity and mortality, as seen in July 1995 Chicago heat wave that killed 700 (Semenza et al.1996, Klinenberg 1999) and in the July and August 2003 Western European event which killed 35,000 (Stott, Stone, and Allen 2004). More than 250 deaths in Arizona were recognized to extreme heat between 1993 and 2002. The level of age-adjusted deaths from heat exposure was the highest in the nation (Centers for Disease Control and Prevention [CDC] 2005).

UHI is the most apparent, yet unintended, impact of urbanization on local-scale weather and climate. It is usually strongest at night when excess heat stored in urban surfaces during the daytime is freed to the atmosphere. The large-scale urbanization of Phoenix has been complemented by a UHI of growing intensity and expanse (HSU 1984, Sun et al. 2009).

A parallel set of studies tackled the human consequences of UHI development in Phoenix, including increased distress hours per day when apparent temperatures exceed 37° C (100° F) and there are more degree hours per day. (Balcer et al. 2002). The UHI has also been shown to add to residential water use (Guhathakurta and Gober 2007), costs of cooling buildings during the peak energy use summer months (Golden et al. 2008), and the increased potential for heat anxiety, especially among vulnerable divisions of the urban population (Haelah et al. 2006).

The Vulnerability of Human Populations to Extreme Heat:

The vulnerability of human populations to severe temperatures and other environmental threats is usually defined as the degree to which they are likely to experience harm due to exposure (Turner et al. 2003). Such harm depends on physical exposure to extreme heat, and a population's adaptive capability (The ability to diminish risk through mechanisms such as air-conditioning or irrigated landscaping to cool areas neighboring the home and proximate neighborhood or through adjustments in behavior, such as staying indoors during excessive heat notices or finding help in case of an emergency instead of staying socially isolated.)

The capacity to react to risks has been linked to racial and ethnic status, income level, gender, age (young children and elderly), migration status and housing incumbency (Ngo 2001, Heinz Center 2002, Winser et al. 2004, Mayborn 2005, and National Research Council 2006). Populations missing the economic resources and access to the public support system, with diminished physical or mental abilities to respond to warnings and missing strong and permanent social support systems are least able to adapt and thus the most vulnerable to a hazardous event.

There have been numerous efforts to measure vulnerability to hazards in Phoenix from the environmental equity and social justice viewpoints. Harlen et al. (2006) recorded temperatures in eight cities of Phoenix neighborhoods having different socioeconomic types, and researchers developed a human thermal comfort index based on the energy balance of a person exposed to the surrounding micro-climate and thermal radiative atmosphere.

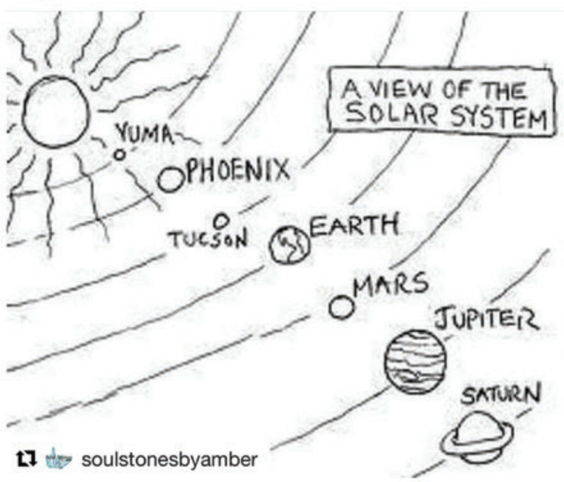
High heat stress exposure was expressively and positively linked with high population densities, heavily Hispanic populations, age and negatively coupled with access to open spaces, irrigated vegetation, and income. Homes in areas with higher-than-average physical exposure to heat were, generally, less well adapted to accommodate heat stress as well as a less well-developed social network.

Many poor neighborhoods exposed to severe heat accommodated residents who spoke only Spanish and who were newcomers to the city. Thus, high physical exposure was parallel with high social vulnerability, rendering low-income residents highly vulnerable to harm from extreme heat.

Given the importance of irrigated vegetation in UHI modification, Jenerette et al. (2007) used a path model to examine social factors of surface temperature and vegetation patterns. They claim that social vulnerability to heat works through the ability to alter land cover by vegetation, and live at lower urban densities.
Wealthy Phoenicians used superior social and economic status to keep low-density housing units with much-irrigated vegetation to lower heat stress.

Golden et al. (2008) documented harmful health results of heat exposure using information about 2001 through 2006 heat-related emergency dispatches (HRD) for most of Phoenix. Annual, monthly and day-of-week distribution of HRD were associated with some climate variables, including a human comfort index based on various climate data from several Phoenix stations. Heat-related health emergencies were strongly connected to extreme temperature, prominent human comfort and heat indexes, and temporal exposure to extremely high solar irradiance, especially during summer.

customcarnerd

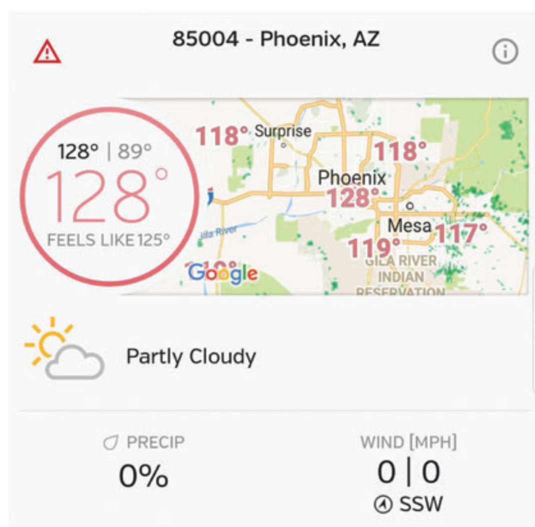


customcarnerd #Repost @soulstonesbyamber with @repostapp
• • •
Oh, is it hot outside? 🔥 😲Phoenix summertime life. #phoenixheat

customcarnerd @shakabanza1 The single highest land skin temperature recorded in any year of the study was found in the Lut Desert, Iran in 2005 and measured a stunning 159.3 F (70.7 C). Lut had the highest surface temperature in 2004, 2006, 2007 and 2009 as well [...]

Photo Credit: www.instagram.com

blair.bunting



blair.bunting When " FEELS LIKE 125° " is the mantra you use to convince yourself that the winters in AZ are worth it... #PhoenixHeat

heididoeshair •
Phoenix, Arizona

heididoeshair When it's so hot in Phoenix, even the cactus are passing out... 🌵
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miriam_vngs

miriam_vngs Only in Arizona you can do this LMAO! #arizona#phoenix#phoenixheat#cookies#hotcar#bakingtime#cookiemonster#onlyinaz#az#hotashell.

jjoperez_602

jjoperez_602 This looks about accurate! We're expecting to hit 120 degrees on Tuesday!!!! #itshotoutside #phoenixheat #azheat #therealheatiscoming

Four Measures of Social Vulnerability:

Individual characteristics:

Elderly and children under the age of 18 have been shown to be more affected by heat stress than other population. (Smoyer, Rainharn, and Hewko 2006).

Household Income:

House income as a substitute for a household's ability to use refrigeration or irrigated landscaping to control heat stress. Jenerette et al. (2007) showed that greater prosperity enables Phoenix households to moderate heat stress.

The social structure:

It is the capability to lessen risk when individuals are physically exposed.

The size of a census tracts foreign-born, non-citizen population is a proxy for populations with difficulty in observing warnings and looking for help in case of medical emergencies. Harlan et al. (2006) showed that immigrant status prevents incorporation within a minority neighborhood. A notable number of Phoenix's non-citizen immigrants are illegal migrants from Mexico. As a result, they often lack health insurance and access to the public health care system.

The recentness of residence and population mobility:

Lastly, people who changed residences in the past five years before the census period, such as short-term renters, were more expected to lack social support in their neighborhoods, hampering personal access to help during heat-weave events (EPA 2006).

In conclusion, the high social vulnerability in a census tract stems from large numbers of elderly, children under the age of 18, foreign-born non-citizens, and low-income residents.

Programs to Help with Overcoming the Extreme Heat Issue in Phoenix:

Desert House Idea:

Different studies, research, and programs are going on in Phoenix to control the extreme heat issue. One of these studies is the Desert Home idea which uses all of the ancient techniques including south-facing windows and doors, thick walls, thermal mass materials and insulation combined with modern technology to make the house livable. Passive solar heating and cooling strategies and the orientation of the building are very important in this idea. These technologies are maintenance free and can save the average homeowner thousands of dollars in heating and cooling costs.

Passive heating and cooling in modern building construction attempts to create living spaces where the active heating and cooling systems, such as heat pumps or gas furnaces, do not have to supply all of the heating and cooling. Phoenix houses which use heat pump technology but not incorporate the passive technologies typically use 45% of all electric energy for heating and cooling.

The orientation of the house is critical attention. During summer the sun shines approximately directly overhead, while in winter the sun follows a path that is rather low in the southern sky. Windows on south walls in winter gather as much heat as possible. In summer, the windows are shaded from the sun by a parapet wall, overhang, awning, tree, and patio to reduce the direct solar heating. Clerestory windows can be opened to let rising warm air to leave the house, much the same way chimney or windcatcher does. East and north walls have only two windows. In addition, the west wall has only one window which is hindered from direct sunlight by a wall or another element. Windows are mainly 16 inches into the wall to create shading. Trees which are placed near the house provide shadow and minimize the heat gain during the summer. Deciduous trees placed in front of the south facing windows allow the sun's heat to get into the house during winter when there are no leaves. On the other hand, they shade the windows from direct solar exposure during the summer. Moreover, the garage is located on the west end of the house. This offers a good-sized buffer against the sun's heat for the living areas of the house.

The critical time to increase the temperature a house interior is in the evening where outside temperatures are relatively low. Conversely, the critical time to cool down the interior is during the day. Thermal mass materials like concrete, stone, and Adobe have the capability to absorb and release heat depending on conditions. Desert house thermal mass is created by an insulated six-inch thick concrete floor and an Integra concrete block wall system. Wall-to-wall carpet and vinyl floor coverings are not used in the house, because the insulation delivered by

these products restrains the effectiveness of the concrete floor thermal mass.

Arizona Department of Housing Programs:

ADOH offers monies to programs managed by local government and nonprofit organizations in rural Arizona for the rehabilitation of certain property types owned and occupied as primary residences by low-income homeowners. Housing rehabilitation may involve roof replacement, painting, major plumbing repairs, and replacement of doors and windows.

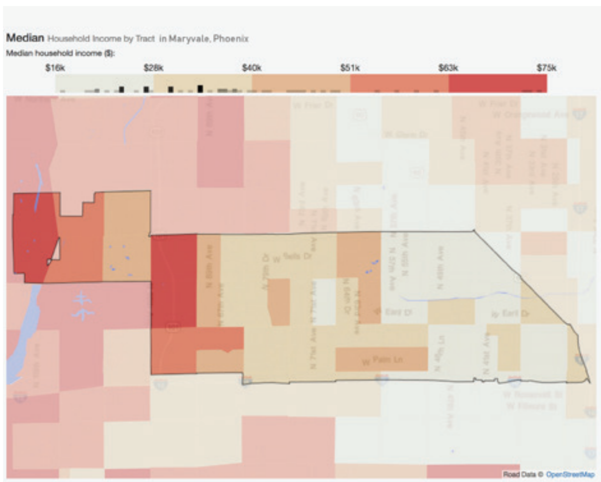
Homes approved for rehabilitation must meet Arizona's home rehabilitation criteria upon completion of work. The rehabilitation standards are planned for use in the examination and evaluation of conditions of residential properties considered for rehabilitation, to determine whether rehabilitation is achievable for individual properties and to serve as a minimum standard for improvement when rehabilitation will take place.

The Target Neighborhood:

By studying different passive cooling strategies in arid climate zones and diving deeper into windcatchers, the results show that passive cooling systems work better in conjunction with each other. It means that to be able to reach the maximum level of saving energy and comfortable indoor temperature, it is a better idea to apply different vernacular methods to work with each other to get the best results.

By studying the extreme heat issue in Phoenix and the social factors related to it, different layers of choosing a neighborhood were considered. As completely explained before, neighborhoods with high density, low-income Hispanic residents and the majority of the population under the age of 18 or above 60 are suffering from the excess heat issue more. Layering these social factors led us to choose Maryvale which is located on the west side of the Phoenix for this study.

The infographics of this neighborhood reveal the following facts. The poverty level of Maryvale is 22% comparing to the 14% USA, 15% Arizona, and 21% Phoenix. Moreover, 75% of its population is Hispanic with an income of less than $40,000 in a year. 38% of its population are children under the age of 18, and 10% are elderly above 60. In addition, it is consisting of 45% of families living with kids comparing to 32% in Phoenix. The average number of people living in a household is 4 plus the fact that it is a dense neighborhood by having almost 6,000 people per square mile compared to 3,000 in Phoenix. The following charts show the demographic information of Maryvale comparing to USA, Arizona, and Phoenix. Data is collocated from census 2018 records.



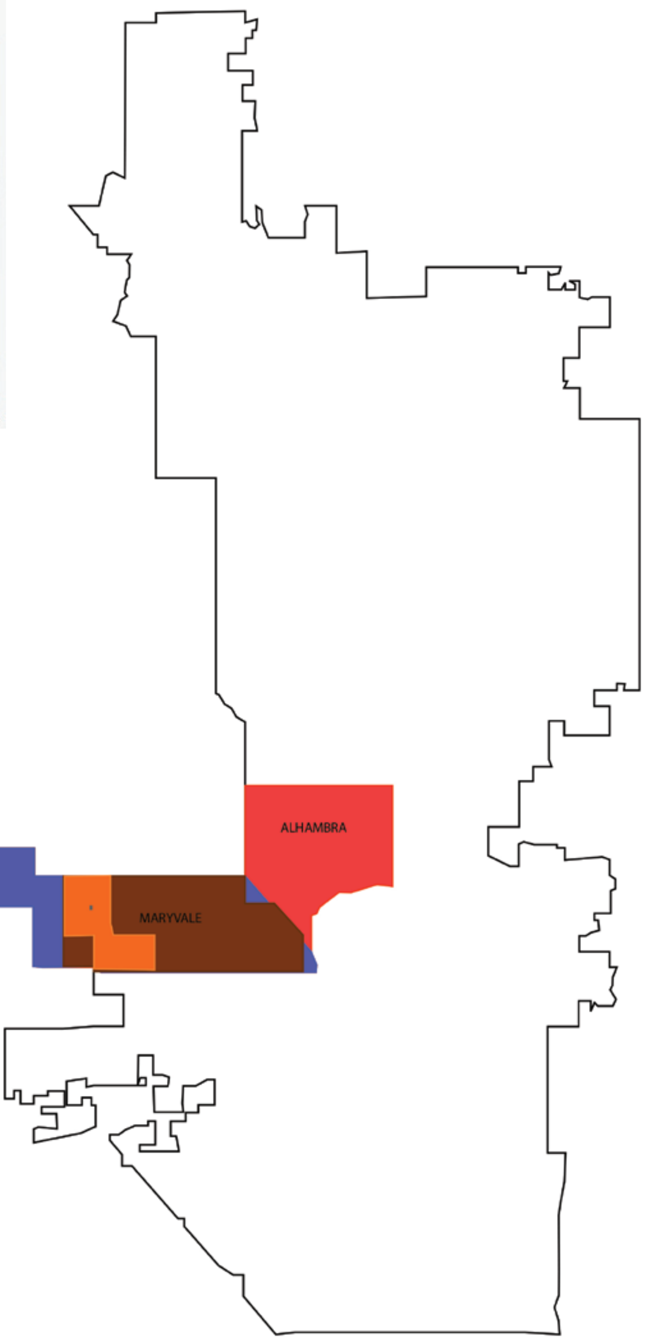
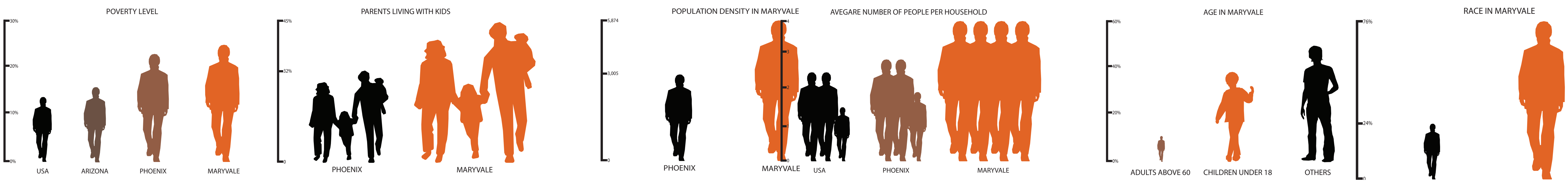
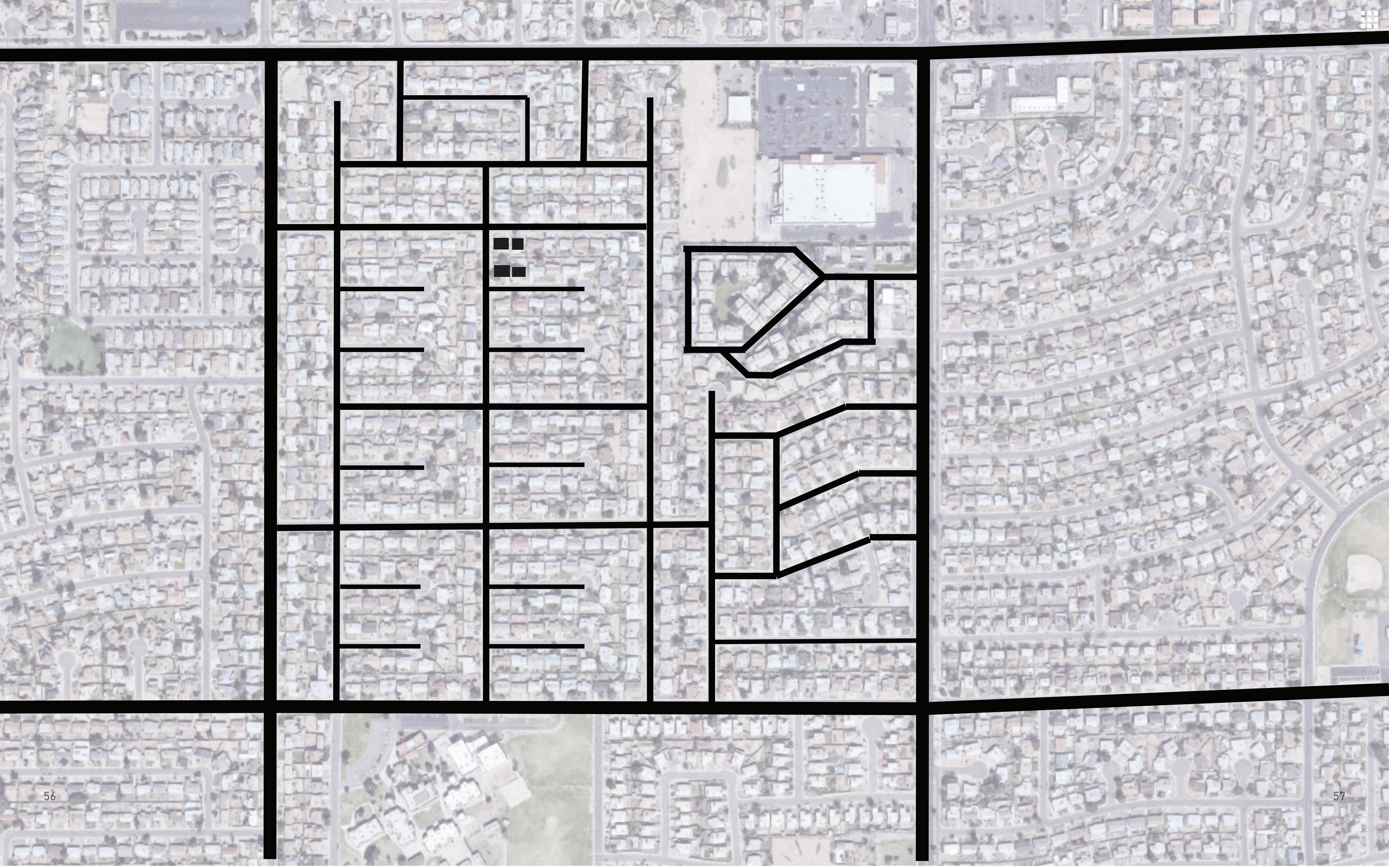


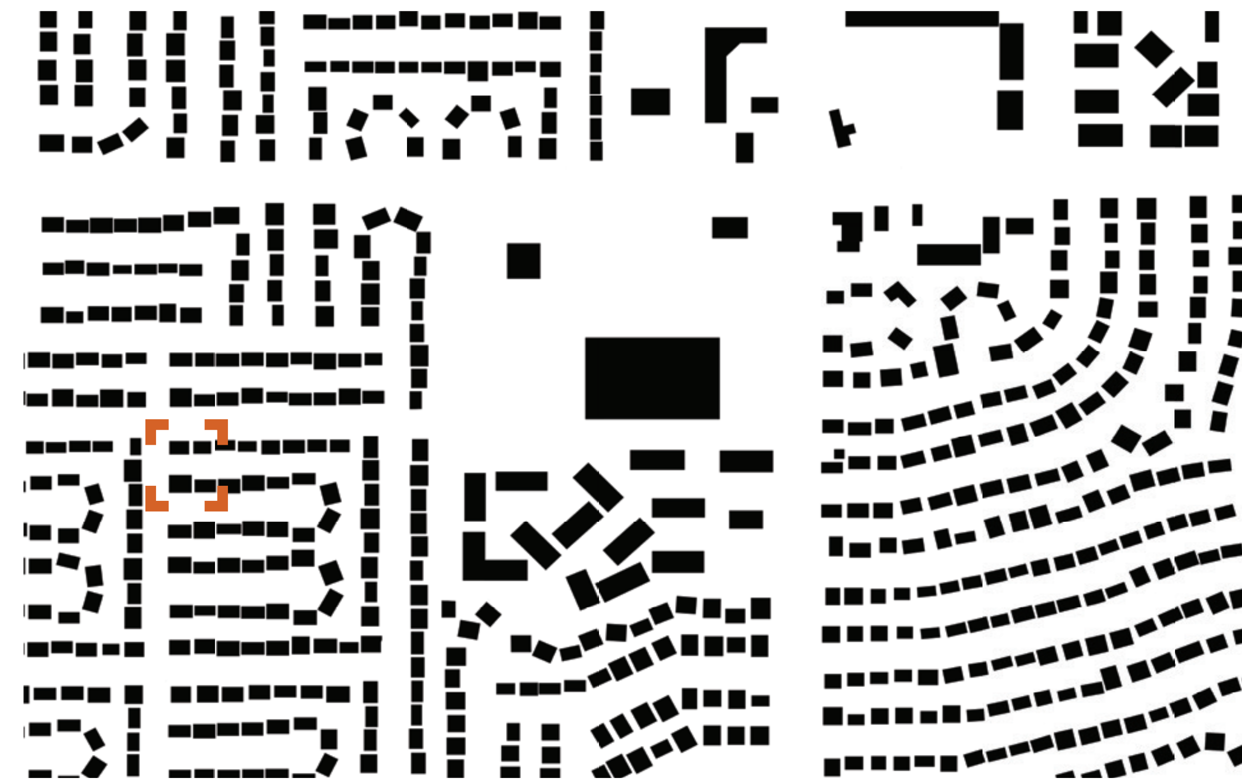
Photo Credit: www.en.wikipedia.org


POVERTY LEVEL
30%
20%
10%
0%
USA
ARIZONA
PHOENIX
MARYVALE
PARENTS LIVING WITH KIDS
45%
32%
0
PHOENIX
MARYVALE
POPULATION DENSITY IN MARYVALE
5,874
3,005
0
PHOENIX
MARYVALE
AVEGARE NUMBER OF PEOPLE PER HOUSEHOLD
USA
PHOENIX
MARYVALE
AGE IN MARYVALE
60%
40%
20%
0%
ADULTS ABOVE 60
CHILDREN UNDER 18
OTHERS
RACE IN MARYVALE
76%
24%
0



Commercial Residential High-Density Condos

Density Map



Empty Lots
Photo Credit : www.maps.google.com

High-Density Condos
Photo Credit : www.maps.google.com

Commercial
Photo Credit : www.maps.google.com

Residential
Photo Credit : www.maps.google.com

2 to 3.5 acre- Traditional Lot

5 to 10 acre - Traditional Lot

10 to 15 acre - Higher density attached townhouses, condos, or apartments

15+ acre - Higher density attached townhouses, condos, or apartments

Parks/Open Space - Publicly Owned

Commercial

Industrial

Commerce / Business Park

Public / Quasi - Public

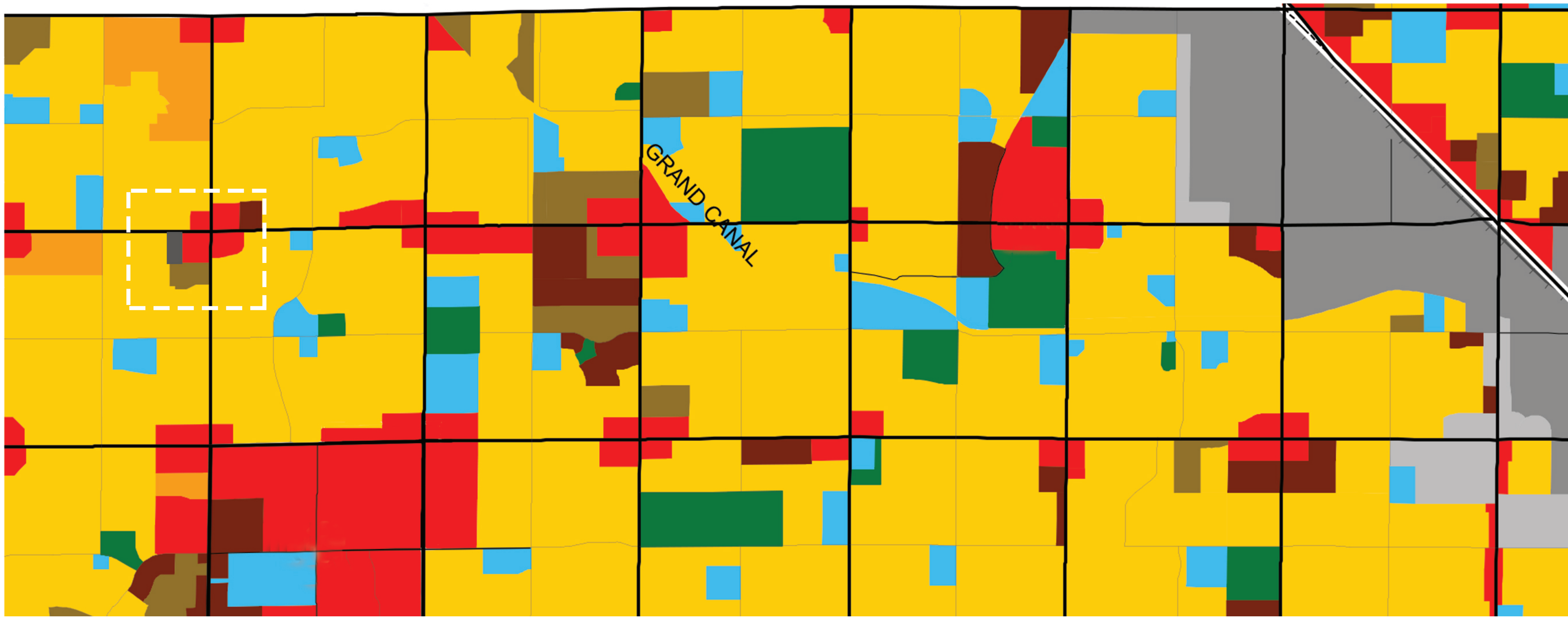
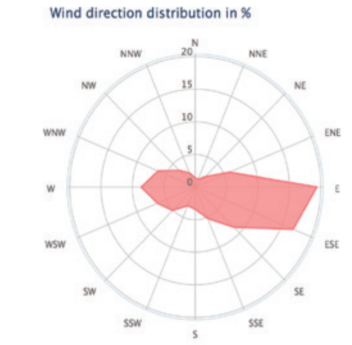


Photo Credit:www.phoenix.gov

Month of Year	Jan 01	Feb 02	Mar 03	Apr 04	May 05	Jun 06	Jul 07	Aug 08	Sep 09	Oct 10	Nov 11	Dec 12	Year 1-12
Dominant Wind Direction													
Wind Probability >= 4 Beaufort (%)	7	9	11	16	16	12	13	9	9	8	9	7	**10**
Average Wind Speed (mph)	7	8	8	8	9	8	8	8	8	8	8	7	**7**
Average Air Temp. (F)	57	61	68	75	82	95	95	93	90	79	66	57	**75**

Photo Credit:www.windfinder.com



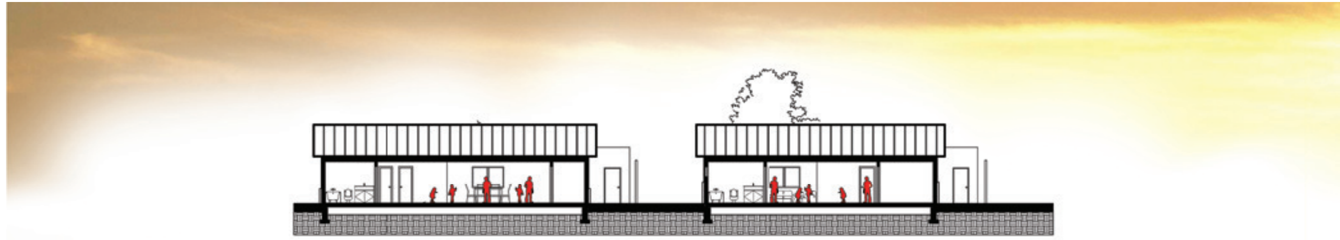
After studying the overall condition of the neighborhood regarding the land use, demographic facts, density condition, and the archetype, four adjacent houses were chosen, and a closer look took at the architecture type, landscape condition, the space between the houses, and the materials used in them. Then, the floor plans were guesstimated. They are mainly three to four-bedroom residentials. Developing the floor plans helped us to create the existing sections. Moving forward, we started to find out the existing design flaws of these houses. The architecture type of this neighborhood is generally one-story ranch buildings. Since it is a very dense neighborhood the spaces between the houses are relatively narrow.

In general, there are no garage spaces provided for these residential. The lots are not clean and well maintained. There are lots of junk and garbage left on them, mostly car junks, which are made of metal parts that result in absorbing the direct sun heat gain and radiate it back to the environment. The roofs are mostly dark shingle roofs which absorb the direct solar heat gain and transfer it to the interior spaces. Moreover, the cladding of these houses is not suitable for the climate type. It is either siding, brick or stone with dark colors which again absorb the heat instead of radiating it. When it comes to the shading, one house out of four has window shutters and awnings. The amount of vegetation is at its lowest level. There is a minimum number of trees planted to create shadow, and the soil in almost totally exposed without covering. Even if there is any lawn planted in any areas, it is totally damaged and doesn't cover the ground surface.

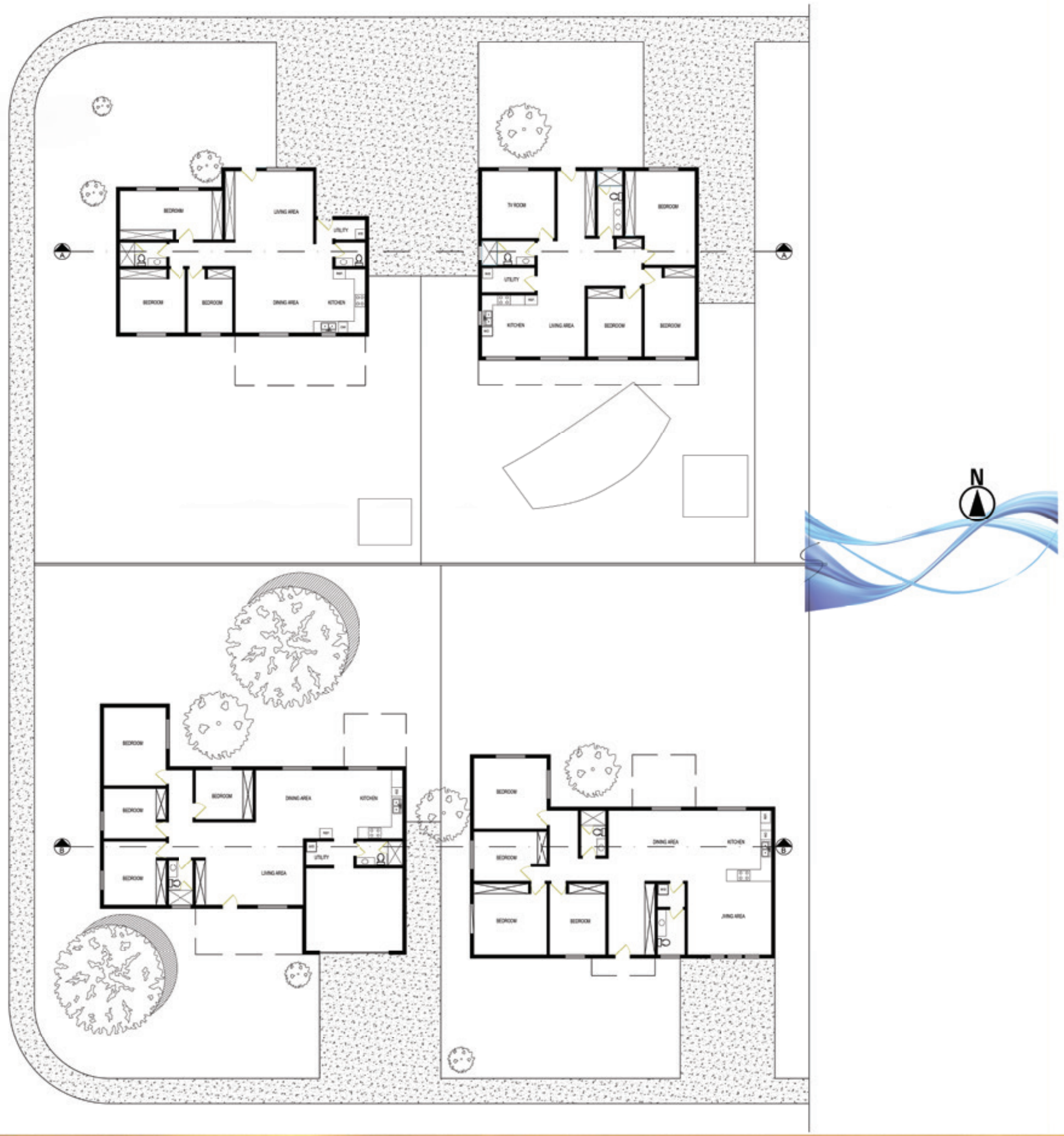
The following pictures show the existing condition of the neighborhood regarding the lot condition, the neighborhood cleanness condition, the archetype, the residential houses which have been studied, and their in-between spaces.

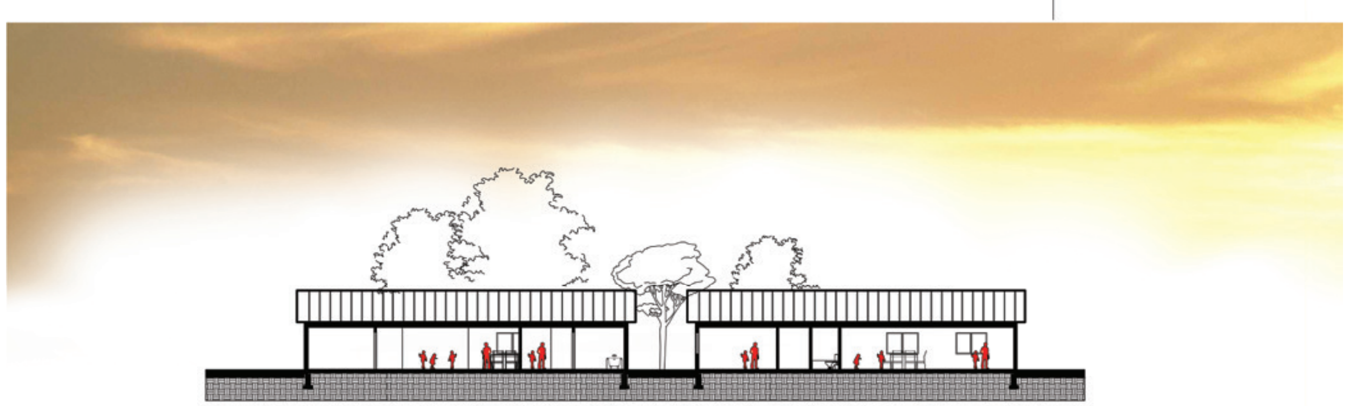
Observing the existing condition of these residentials helped us to start thinking about the very basic solutions before purposing any major changes to the buildings since these residents are low-income and they can't afford big costs of applying major changes to the existing buildings. So, we began with purposing applying the passive strategies as much as possible first. Then, we can go further and use the empty lot areas to apply windcatchers to act like clerestory windows or stack ventilation to bring the cool outside air in during the day and cool down the interior.

The land use of the neighborhood shows the commercial corner of the neighborhood as well as some high-density condos existing in the neighborhood. By providing the density map, we can easily observe how dense the area is.



SECTION A-A





SECTION B-B

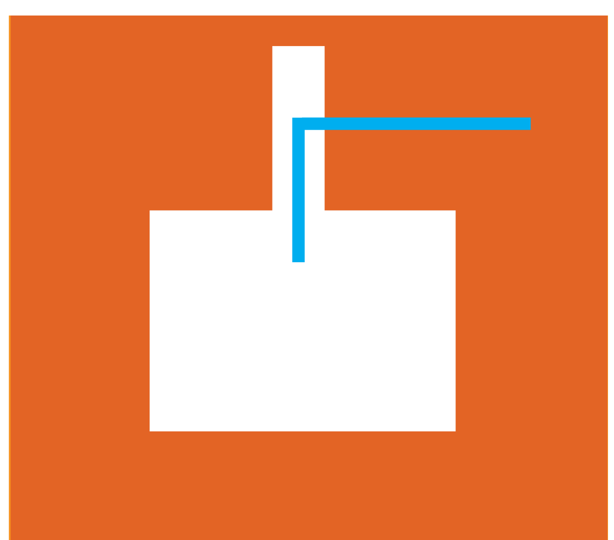
Proposed Solutions:

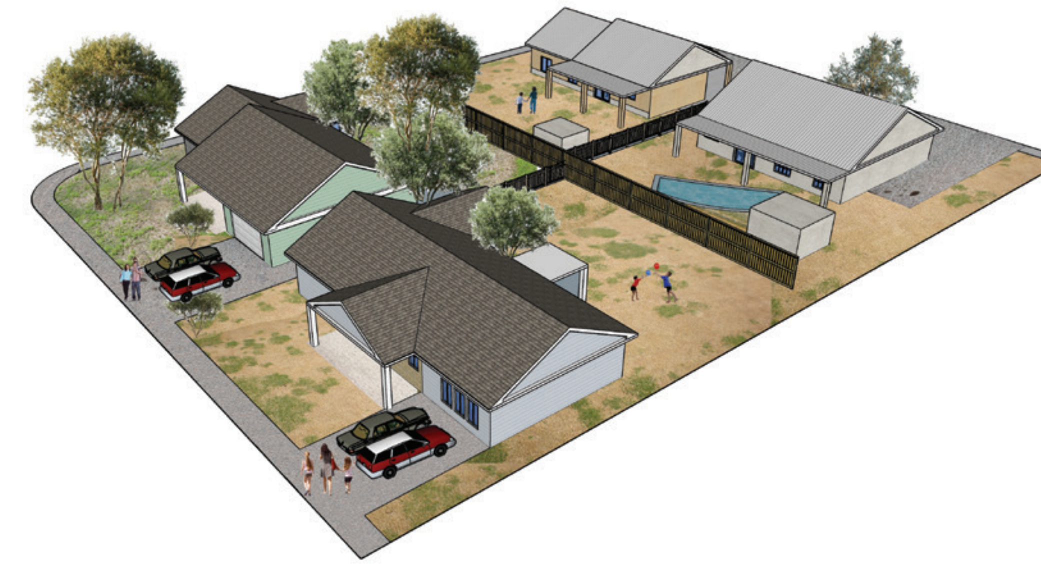
Cleaning up the Lots and Utilizing a Windcatcher:

The first step is cleaning up the lots out of junk and unwanted materials. This process can be done easily, and it is going to help a lot to minimize the extreme heat of the surrounding environment. The main change is employing a windcatcher to these houses. The proposed windcatcher is located in the intersection of four lots, and it is going to serve all four residential. The reason to have one windcatcher for four houses instead of having one for each individual house is first to split the costs of constructing it to 4 since these people are low-income and the intention is saving money, and secondly, to break the social boundary between the residents of these houses. By taking a closer look at these houses, we can see the fences they use to separate their lots from the neighbors. If one element serves all four homes, the residents need to interact and communicate more often, and this brings social sustainability to the neighborhood.

The critical point is the way this windcatcher gets connected to the houses. Underground tunnels are going to be used for this purpose. This tunnel needs to be 2 meters under the ground surface to have a constant temperature of 12 °C throughout the year. So, as the wind passes through this tunnel to get into the building, it gets cooler. The outlets are located in the main seating areas of the buildings.

Proposed windcatcher works as a stack ventilation which connects to the residential houses through under ground tunnels which are located 6 feet under the ground surface to maintain the temperature.





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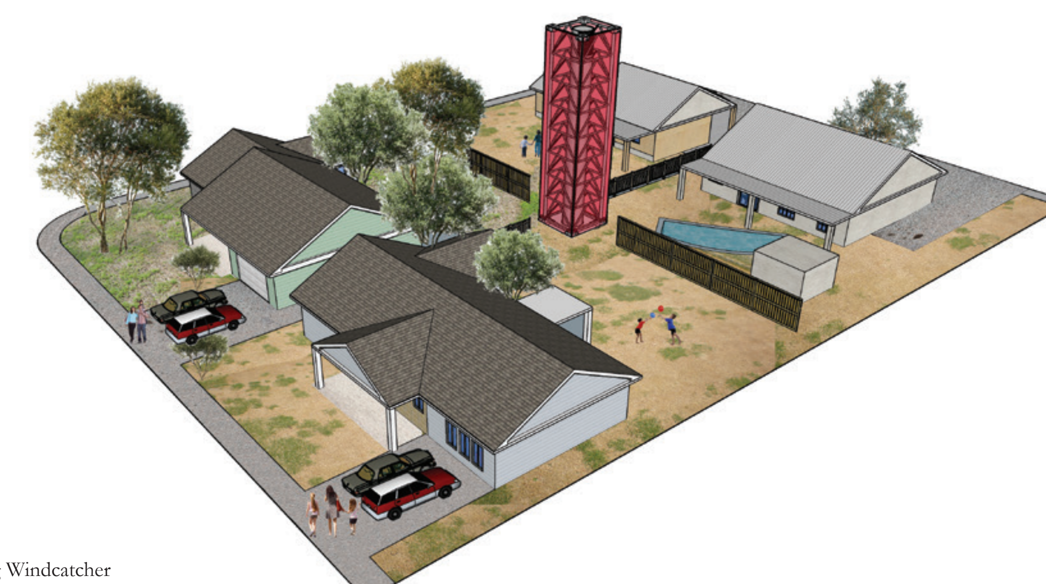
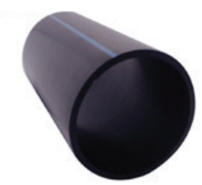


After Applying Windcatcher

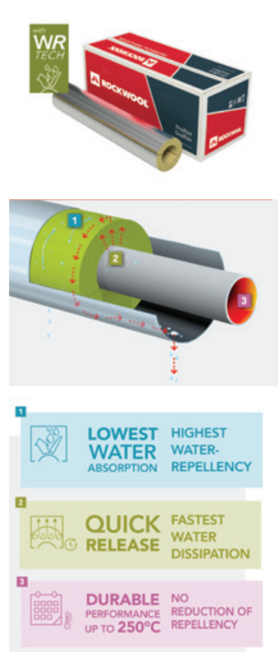
When it comes to the windcatcher itself, the main structure is a prefabricated radio mast which can be bought from Alibaba.com. A PVC pipe is going to act as the windcatcher shaft. There are going to be intakes at the top of its surfaces on the east side to catch the wind even more and direct it towards the shaft. A layer of 3-1/4 inches insulation is going to wrap around the pipe. This insulation is made of fiberglass aluminum-coated sheet, and it is going to keep the pipe cool as well as keeping the insulation dry with the provided aluminum coat. The cladding is going to be the permeable plastic window blinds which are available in different colors. Since they are permeable, they allow the wind to pass through them, while they create a shadow over the windcatcher shaft. This helps with cooling down the wind which passes through the pipe in addition to the air barrier which the insulation layer provides.

Foundation of these windcatchers are going to be the individual footings which extend 5 feet under the ground surface and the four main corner plates are going to be bolted to these footings. The soil surrounding the underground tunnel acts like a thermal mass which builds an additional layer of insulation to it. It absorbs the heat slowly during the hot summer days and radiates it back to the environment when the temperature drops at night without letting it make the tunnel warmer in the day. On the other side, during winter, it absorbs the heat during the day, and if the outside temperature gets cooler than the underground tunnel at night, it keeps the tunnel's warmth.

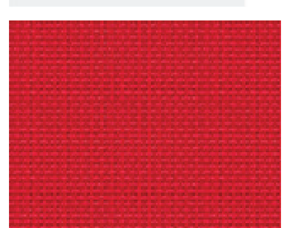
Each windcatcher in the same neighborhood can be a specific color by using different blind colors, or each neighborhood can have a particular color. Because the archetype of Phoenix is very flat, and there is no specific way to separate the neighborhoods visually, these windcatchers can bring social identity to the city and to the neighborhoods. Furthermore, these windcatchers will work as landmarks in the flat beige color Phoenix.



PVC Pipes as the Windcatcher Shaft

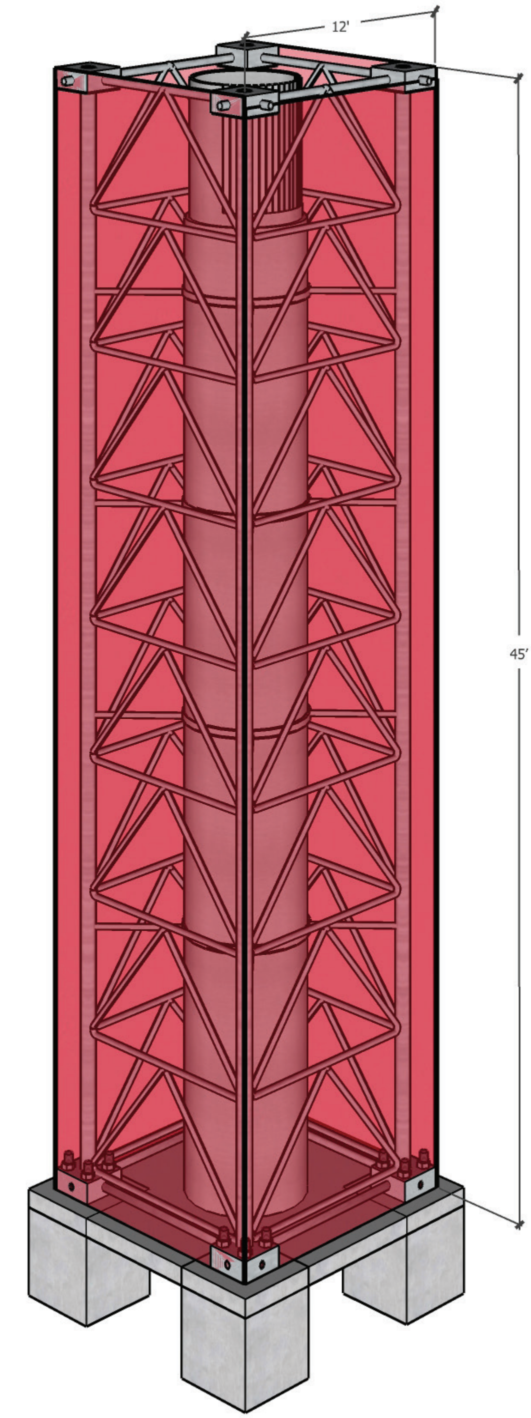


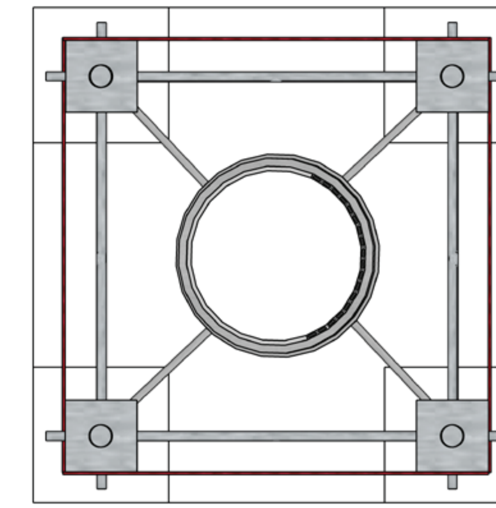
3-1/2 inches Fiberglass Aluminum Coated Insulation Wrapping the PVC pipe to add a layer of air barrier to ir

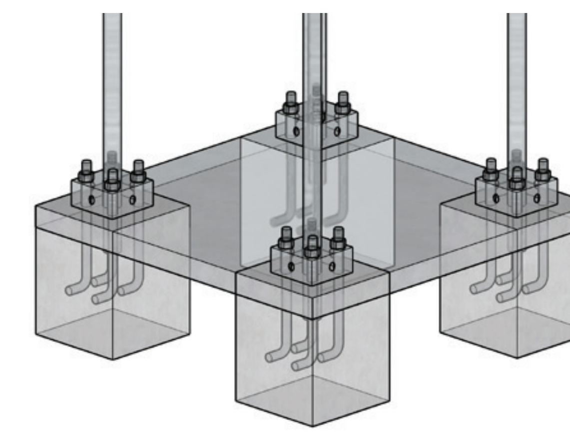


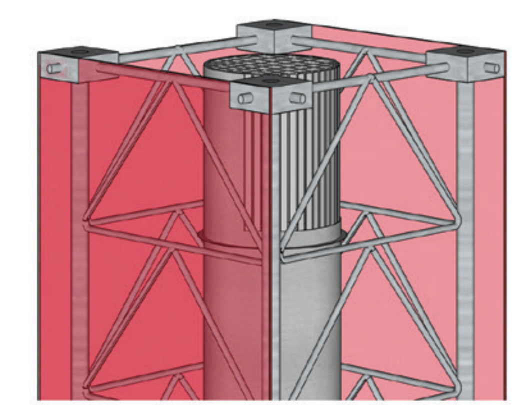
Colorful Permeable Plastic Window Blinds as Cladding

Overall Cost of Windcatcher:
Radio Mast = $900
PVC Pipe = $94
Plastic Blinds = $960
Insulation = $168
Total = $2,122.00





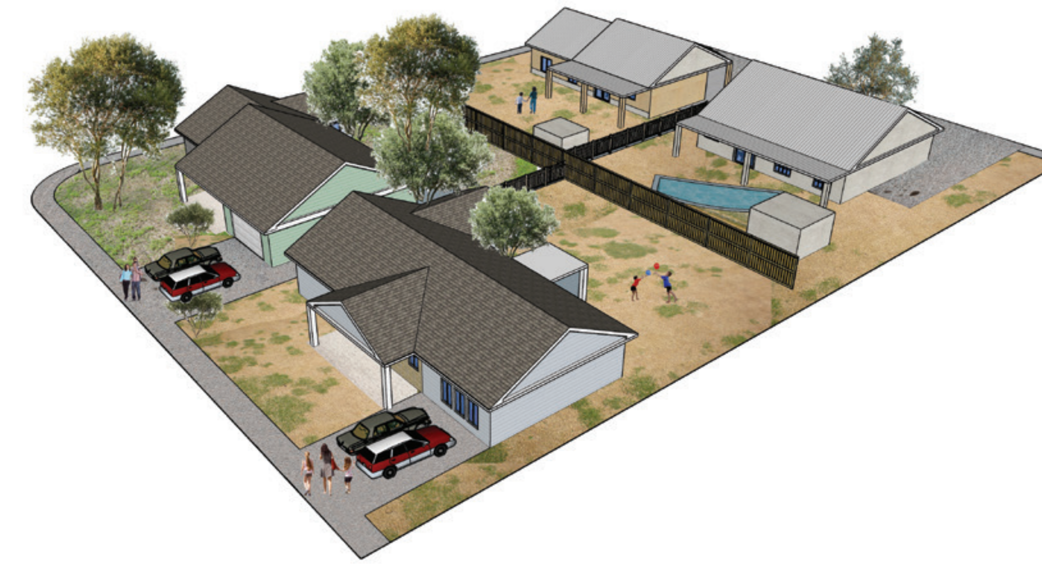




Applying Cool Roofs and Ventilated Roofs:

After applying windcatcher, the next step is changing the roofs to ventilated roofs which are double-layered, and there is a cavity between two layers. When the sun hits the exterior layer, the heat which gets into the cavity between the layers through conduction gets directed to the outside through the provided vents. The interior layer acts as a barrier while the vents work to transfer the heat to the outside and keep the air circulation active. In addition, coloring the roof to light colors like white helps more with keeping the roof and as a result, the ceiling cool. Cool roofs with light colors radiate 85% of the direct solar heat back to the environment, while dark colors direct this 85% to the interior spaces. As mentioned before the Arizona Department of Housing provides monies to change the roofs. Some residents might be eligible for this program and get help from ADOH. Even if they are not eligible or they can't afford the costs of changing the roof, by coloring the roof to the light colors they can diminish the excess heat which gets into the building significantly.

Cool roof and double roofing systems are proposed to transfer the minimum amount of the heat to the interior spaces through the roof. Light color roofs radiate 80% of the solar heat while the dark color roofs absorb 80% of the direct solar heat.



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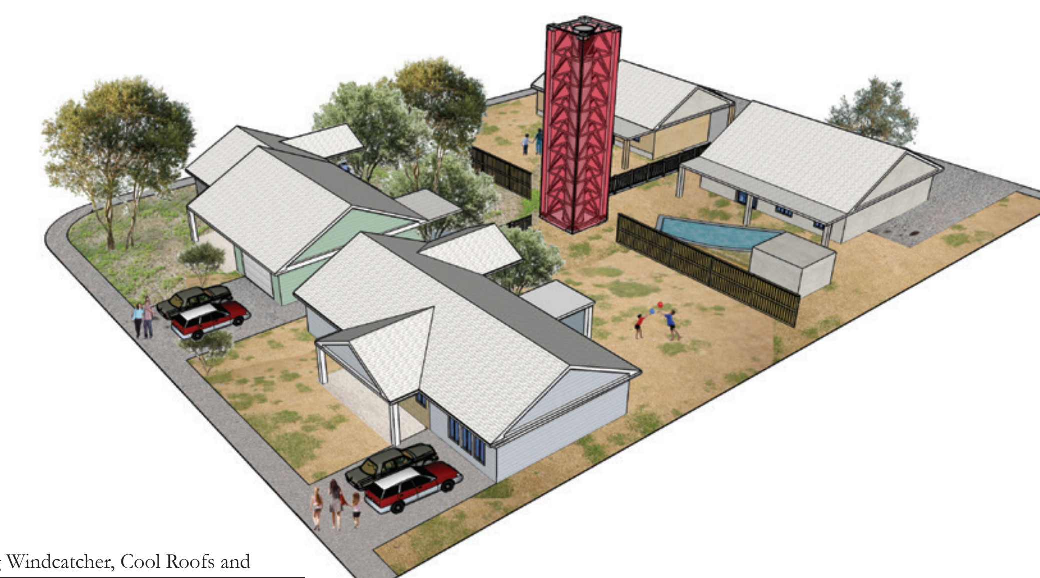


After Applying Windcatcher, Cool Roofs and Ventilated Roofs

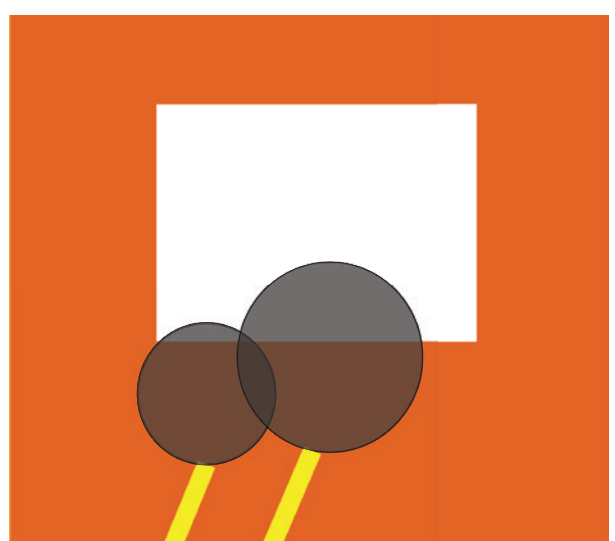
Employing Xeriscaping Landscape and Native Vegetation:

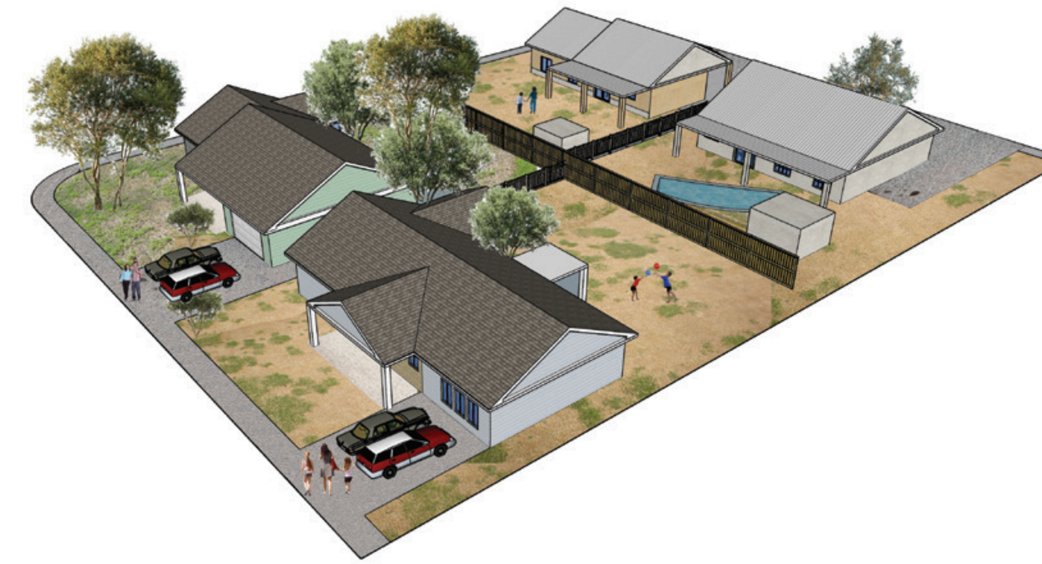
Planting trees and applying xeriscaping landscape is the next step. SRP which provides electricity to the neighborhood offers 2 free trees per house. The first step is getting the advantage of this program. There are three different ways to treat the ground surface in Arizona: real grass, synthetic lawn, and crushed stone or gravel. Since irrigation is expensive, the best solution is going with either the synthetic lawn or the gravel as the ground cover. However, there are some types of lawns which are native to Arizona. These lawns don't need every day watering, and they can be watered once or twice a week. Buffalo grass is one of them with thicker and rougher texture compared to the regular lawns.

Applying native lawns can be an alternative way for the ones who do not like the look and the texture of the synthetic grass, nor they want to go by the regular lawn and irrigate it every day. In fact, planting native grass is a better idea if we want to increase the proficiency of the windcatcher. If we have real grass covering the ground surface above the underground tunnel, by watering the grass when the exterior temperature is too high, the soil covering the tunnel gets wet resulting in a cooler tunnel thus, a cooler wind passing through it.

Planting native flowers and cactuses are adding another layer of vegetation to the landscape. This creates humidity in addition to helping to cool down the atmosphere. Some flowers which can be used in xeriscaping landscape are Pineapple Guava, Salvia Farinacea, Rain Lily, and different types of cactus. Native tree examples can be Palo Brea, Desert Willow, Desert Museum Palo Verde, and Ironwood. Native vegetation is adaptive to the climate type, and with the minimum level of irrigation, it can last for years and help with environmental sustainability.

Planting trees on the south side of the building creates shadow during the hot summer times. With applying native vegetation and xeriscaping landscape we can provide the desired amount of vegetation to the landscape. Synthetic lawns or gravel can be used to cover the ground.





Before

After Applying Windcatcher, Cool Roofs, Ventilated Roofs, and Vegetation


Palo Brea


Desert Willow

Pineapple Guava


Salvia farinacea


Desert Museum Palo Verde


Ironwood

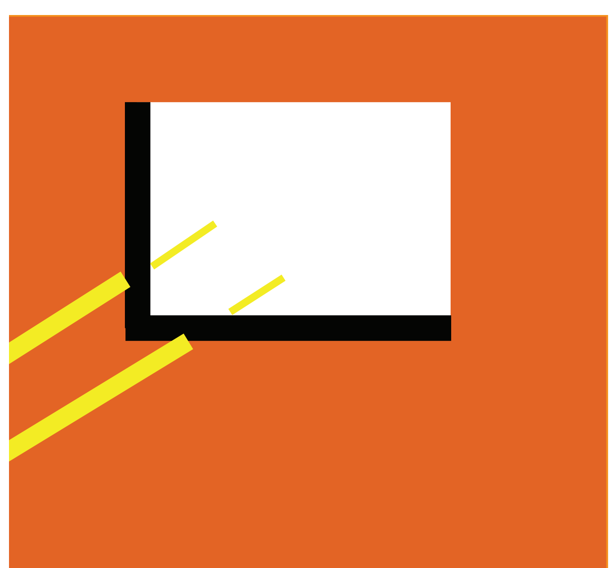
Rain Lily

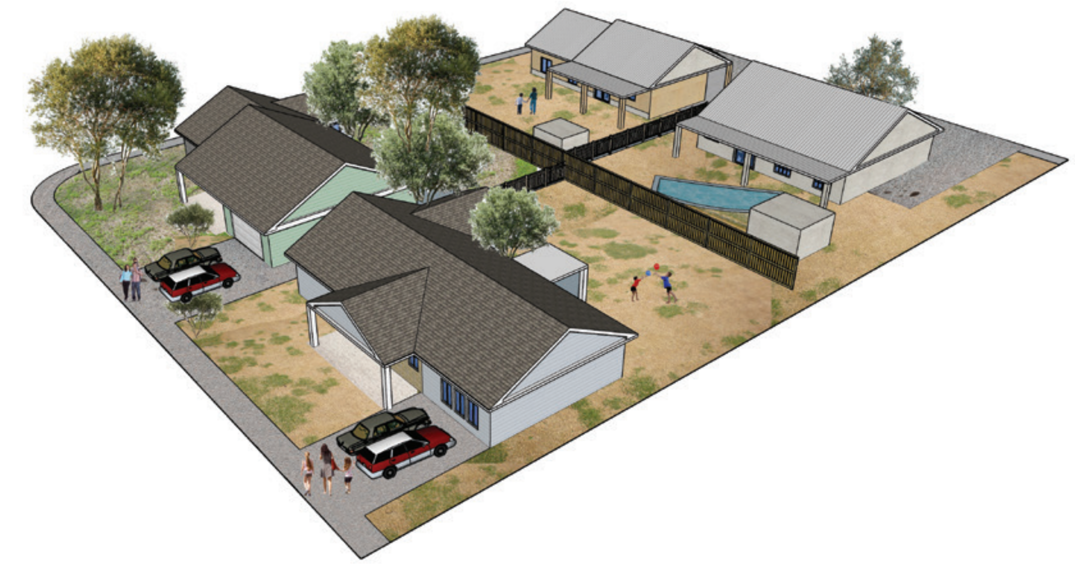

Cactus


Adding a Thermal Mass:

The next passive strategy is to add a thermal mass layer to the exterior walls. The minimum can be applying a layer of stucco or mud and color it in light colors like white on the south and the west walls. The south is the face which receives the maximum amount of direct solar heat gain during summer. On the other hand, the west is the side which gets the afternoon sunshine and it is the warmest time of the day in any climate. So, protecting the south and the west from the direct sunshine is the priority. However, if the residents can go further and apply the thermal mass to all exterior walls, it would be more helpful with controlling the heat to get into the interior spaces.

Applying a layer of stucco or mud over the walls creates an additional level of insulation to the existing walls. The south and the west side of the building are mostly exposed to the direct solar radiation. So, providing a layer of mud on these two surfaces is proposed.





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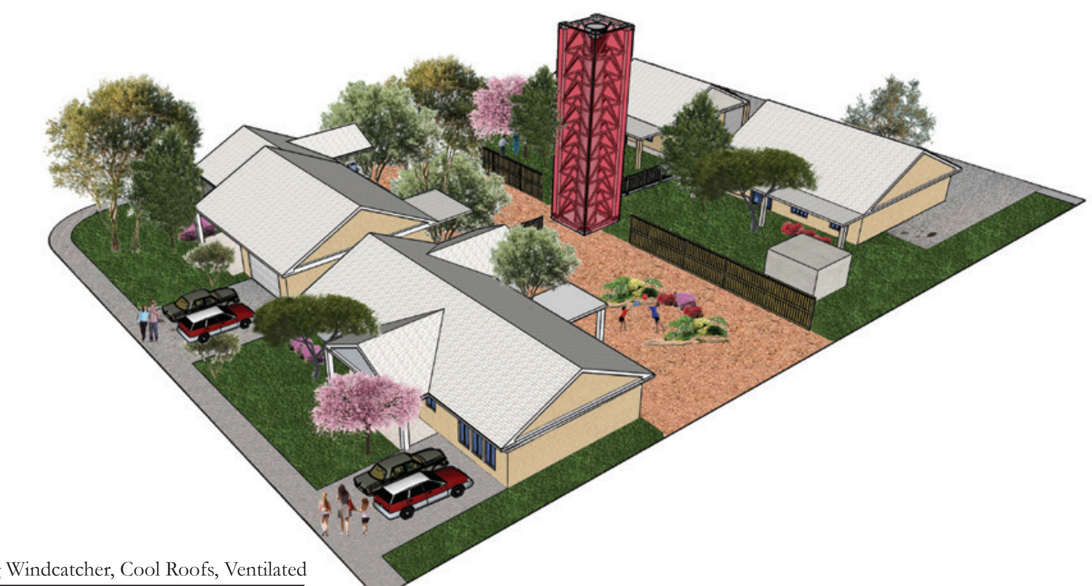
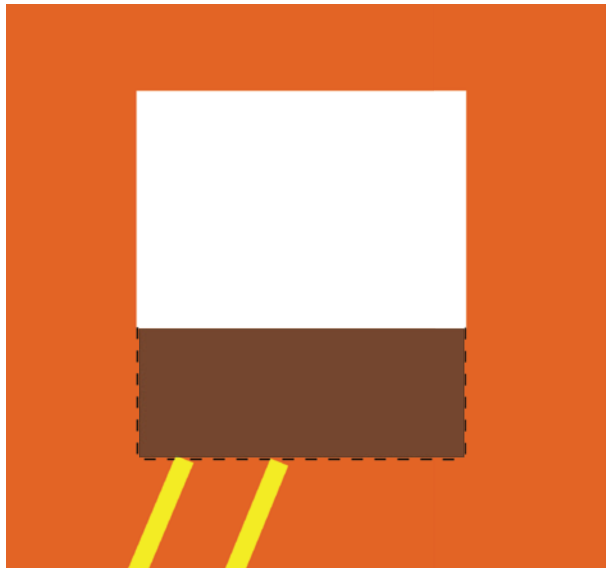


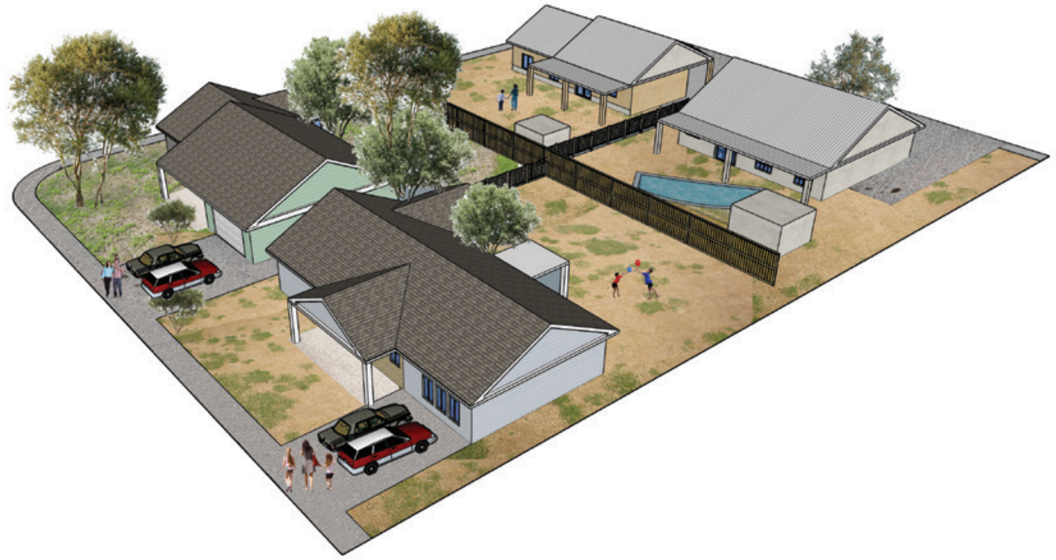
After Applying Windcatcher, Cool Roofs, Ventilated Roofs, Vegetation, and Thermal Mass

Using Shading Devices:

Finally, adding overhangs, shading, awnings, shutters, and parapet walls to create shadows over the windows where it is necessary particularly on the south and west sides is another way which can prevent the solar heat gain to get into the building directly. Window shutters are the best, easiest and cheapest way to achieve this goal, and they have been used in buildings for hundreds of years in traditional architecture before inventing any types of active cooling systems. But unfortunately, relying on fossil fuels and modernization took us so far away from applying the very basic methods to the buildings and just get help from what is available and affordable in nature.

Creating shadow on the south facing windows is critical. Shutters, parapet walls, and overhangs can provide shadow where it is necessary as well as trees. Extending the exsiting overhangs where it is necessary over the south facing windows is proposed.





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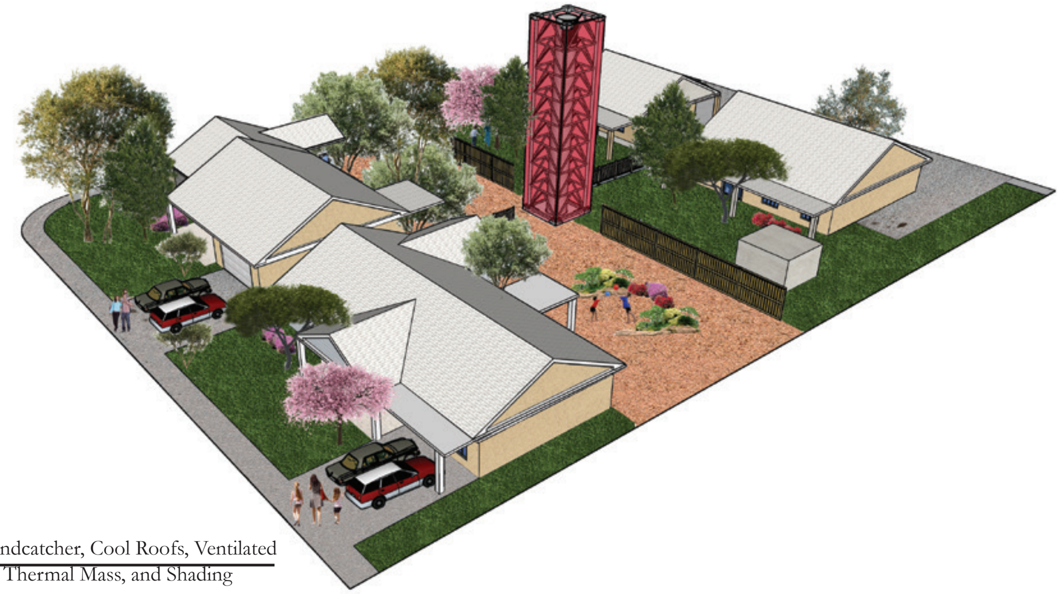
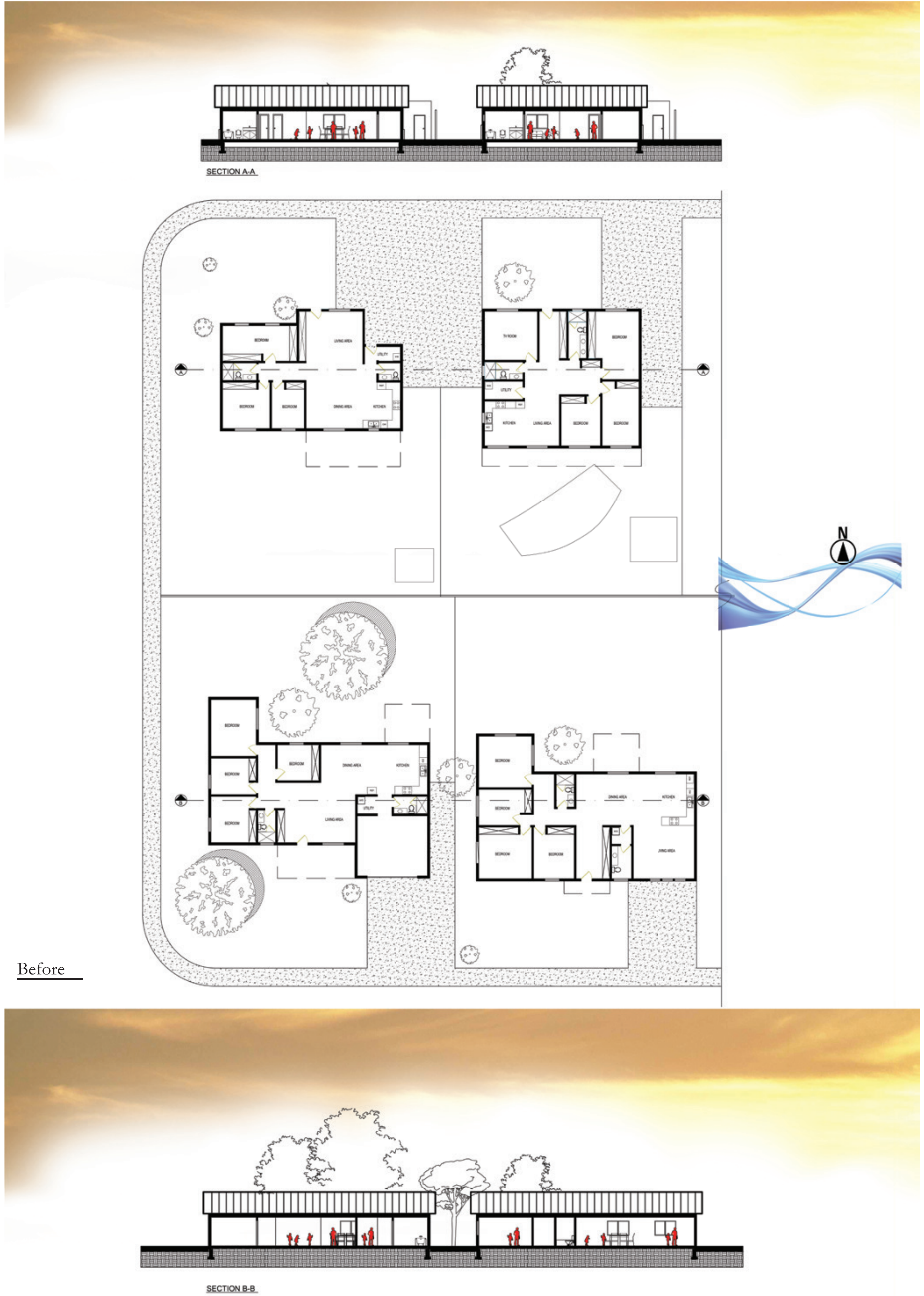


After Applying Windcatcher, Cool Roofs, Ventilated Roofs, Vegetation, Thermal Mass, and Shading

Conclusion:

In conclusion, the median price of homes lists in Maryvale is $186,850, and the median rent price is $1,175. Based on the Census data, 57% of the occupied units are renter-occupied. The average cooling costs of a 3-bedroom house are $240 monthly when they set the temperature on 78 during summer months and 75 during winter months. 45% of the all electricity used in a house is for cooling purposes. By applying proposed changes, the residents can save 26% on active cooling costs which means that each household can save up to $744 in a year. Four residential houses can save up to $2,976 in a year when the costs of building a windcatcher supplying all the four buildings are $2,122.
By using the programs provided by SRP and ADOH, in addition, to save monies in cooling costs each year, the low-income residents can have a better life one year after the other, and spend the monies they saved on the other necessary things like education, healthcare, and applying more layers of the passive cooling systems for the environmental sustainability. 38% of the Maryvale population is children under the age of 18. These children are the future's designers, builders, and engineers. They can learn how to save and how to get help from nature to build a better future.
Applying windcatchers in combination with the other passive cooling systems can bring social identity and sustainability in addition to the environmental sustainability to the neighborhoods and therefore to the city. Every single step taking towards finding the passive and traditional solutions for the environmental and social issues counts for a better future.



Before

After

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