ABSTRACT

The Outside-In House is a residential design concept for living comfortably and conveniently in securely-defined spaces that provide outside-air thermal comfort conditions within the traditional interior residential setting. The house allows for human thermal comfort to be maintained in a hot-arid climate through the implementation of natural environmental thermal control principles.

Ultimately, by constructing hot-arid climate homes to achieve human thermal comfort without the need for air-conditioning, a substantial reduction in the amount of non-renewable energy will result. The reduced consumption of underground, fossil fuel resources will ultimately make the world a better place.

Creative use of traditional passive climatic architectural responses such as wind scoops, natural ventilation, deep shading, and thermal mass, are reintroduced as architectural concepts for the Outside-In House. Newly developed architectural design strategies as well as lesser known traditional design strategies are presented as passive ways to thermally condition the Outside-In House.

1. SUPPORTING EMPIRICAL DATA

The Outside-In House project began from the need to rethink what is really necessary to stay comfortable during the summertime in the desert southwest. People have been living and working in southern Arizona for centuries — long before air conditioning was even conceived. How did they manage to keep comfortable? Quite likely they were not always perfectly comfortable. The Outside-In House takes advantage of current technology, and knowledge gained through empirical experience and research, to assess and effectively design for outdoor comfort conditions.

Present-day resources include analyzing homes and buildings in which people are still living without air-conditioning in hot-arid climates, and analyzing people who work outdoors all day in hot-arid climates. Many experiential resources also exist within the built environment of modern cities in hot-arid climates, from which information can be collected via personal experience and analysis. Restated, cool spaces and cool places can be experienced in the summer and by translational and inferential application, similar conditions can be implemented into the Outside-In House design.

From the empirical investigations and analysis, there are six fundamental physical cooling effects used for keeping cool in seasons of extreme heat: air movement, shading, evaporation, reflectance, conduction, and radiation. Each passive strategy that is used as part of the Outside-In House for staying cool involves at least one of these cooling effects.

1.1 Cooling Principles Borrowed from Traditional Homes

Traditional (before air-conditioning) homes in southern Arizona involved the use of many cooling effects. Take for example a courtyard house or especially a Zaguán house from southern Arizona and Mexico. These homes were built of thick adobe walls which allowed the rooms to be flushed-out and cooled at night. Heat from the adobe walls would be lost to the cool air as the cool night air
observing how outdoor workers get cool on lunch breaks to stay comfortable while working in the summer sun.

1.2 Cooling Principles Borrowed from Outdoor Workers

Outdoor workers in the desert southwest have learned to stay comfortable while working in the summer sun. Observing how outdoor workers get cool on lunch breaks is especially revealing. Learning from the lifestyles of desert animals is an important part of developing concepts for the Outside-In House, but learning from the human animal is just as important. The following are examples of cooling effects that can be translated into strategies for the Outside-In House.

Desert workers learn immediately that being in the shade makes everything cooler – both people and lunches. One of the first things observed by the desert worker is where the shade is, and particularly where the shade will be at various times of the day. The shade is where lunches will be placed and where workers will go to eat at lunchtime in order to stay cool.

Within a typical lunch bucket is the principle of the thermos bottle. A thermos is designed to keep hot things hot and cold things cold. Insulation of the thermos is provided by a vacuum space within the outside walls of the container. Most modern lunch boxes are also insulated on the outside – to keep hot things hot and to keep cold things cold. Herein is an extremely important principle to be translated to homes and home insulation strategies: Homes are also insulated to keep the hot things inside hot and the cold things cold. The problem with a well-insulated home for a hot-arid climate is that things in the house are already hot and generating heat (people, appliances, lights, windows, etc.). Thus the insulation will serve to keep the house warm, which is counterproductive for summertime comfort. Instead, and referring to the Zaguán house discussion, thick massive walls are needed in the Outside-In House so that body heat and heat from appliances can be radiated to (absorbed by) the cool high-mass walls. For the sake of clarity, a poorly designed home that needs to constantly be cooled by extensive mechanical air conditioning does require insulation to keep the cold air cold.

Lunchtime is also when the outside desert worker has a better opportunity to choose preferred methods of staying cool. In order of priority, the worker will seek shade, air movement, and cool surfaces. One ideal spot is the north face of a tall masonry parapet wall on the roof of a building. Most people think roofs are hot. Well, they are, but only if you are in the sun on a roof. The shaded part of a roof offers what other parts of the building do not: plenty of air movement. Areas higher above ground generally allow free-flowing air movement and thus higher velocity of air movement. The north face of a masonry parapet wall is cool, having been in the shade all morning long, and because of its thermal mass is generally still cool at lunchtime. Sitting against a cool surface feels cool because the heat is transferred from the human body to the skin will create a cooling effect from evaporation of the perspiration.

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cool wall by conduction.

Other places workers can be found in the summer during lunch break include: in corridors of buildings where air movement is intensified, under trees, in the shade, where evapotranspiration has cooled the surrounding areas, and in shaded arroyos where the shaded sand may still be cool and where the air currents naturally follow the slope of the arroyo.

Workers stay cool while working outside in the summer heat by self-shading, which includes wearing long-sleeved shirts and wearing wide-brimmed hats, or wearing hats that incorporate draped cloth around the sides and back to keep the neck and lower parts of the head in shade. Whenever possible they will work with their backs to the sun so that their heat-sensitive faces will stay in the shade.

Workers also stay cool by drinking a lot of water, which facilitates perspiration, which in turn promotes cooling evaporation from their bodies. Air movement is needed to effect the evaporation. The workers generally locate themselves in areas of air movement and wear loose fitting clothes to allow air to pass over as much of their skin as possible.

Clothes and hats are traditionally white in color so the sunlight and radiated heat reflects away from their clothes instead of being absorbed by their clothes. The cooler the clothes, the cooler the people inside their clothes become.

In the desert southwest one can almost always find a breeze (air movement) and overhead cover (shade). Learning from the desert worker, these two effects alone offer a huge cooling relief from the hot-arid summer environment.

1.3 Cooling Principles Borrowed from Migration

For centuries human populations have migrated seasonally back and forth between warm climates and cool climates in order to be thermally comfortable. The Outside-In House borrows from this principle by providing a variety of spaces and variety in levels of thermal comfort such that occupants of the house are free to migrate from one part of the house to another, both diurnally and seasonally, in order to find a thermally comfortable place in which to have an activity. Considering we are a fairly mobile society, including having notebook computers and wireless networks, we are free to relocate within the house or to the outside of the house as required to find a comfortable place to work, play, or sleep. The multi-level design concept for the Outside-In House creates the required variety of spaces with varying temperatures.

1.4 Cooling Principles Borrowed from Iran

Desert regions in other parts of the world respond to harsh hot-arid climates in different ways, yet provide strategies that result in benefits from the typical cooling effects; namely air movement, shading, thermal mass and evaporation. One such strategy found in vernacular Iranian homes is the Badgir, a wind tower that funnels and forces wind down through a home and then out the other side of the home [2]. As the wind-powered air circulates through the home, the cooling effects of air movement are felt by occupants of the home. In some cases the base of the wind scoop has a water pond that further cools the air from the evaporation of the water as the air moves across the water. Refer to figure 1 for a modern interpretation of a wind scoop tower for the Outside-In House.

1.5 Cooling Principles Borrowed from Eskimos

Consider an igloo in which the Eskimo crawls down into a cold-pocket entryway tunnel and back up into the warm thermal pocket of the main room [3]. The understood purpose for the cold-pocket is to trap cold air at a lower level than the main room of the igloo. The cold air pocket then serves somewhat as an insulating thermal barrier and somewhat as a wind barrier. Understand that oftentimes methods used to stay cold are fairly opposite of means for staying hot. Draw a section through the igloo just

Fig. 1: Section through a wind scoop tower

Fig. 1: Section through a wind scoop tower
described, and then turn the drawing of the igloo upside-down. You will discover that the new inverted igloo configuration makes sense for a hot climate. That is, a person would crawl up into a warm-pocket and back down into a below-grade cool-pocket where the cool air drops and settles at the bottom of the space. Refer to figure 2.

Fig. 2: Section through a desert igloo

2. OUTSIDE-IN HOUSE AS A CONCEPT

The Outside-In House includes the above principles about staying cool in hot-arid climates that were learned empirically from observation and experience.

In the southern Arizona desert, summers are very hot and winters are pretty chilly. One important precept for designing the Outside-In House is that finding and making warm spots in a desert house, even in the winter is generally not a problem, therefore, designing for summertime is the main thrust of the project. Besides, occupants can always put on a sweater, or even a coat, to stay warm. Because designing a space to stay cool in the summertime is the big challenge, the Outside-In House program is primarily about creating spaces to stay cool.

Another very important aspect of the Outside-In House design is to understand that despite harshly warm summers, most of the time during most of the seasons, the weather and outdoor air temperatures are quite pleasant. This condition creates a strong concept for letting the outside in and to develop sheltered spaces that are essentially outside living spaces.

Again, to borrow from the notion of migration, a very important concept of the Outside-In House is to provide many options for experiencing the various levels of the physical effects of cooling. Provide multiple spaces on different sides of the house with some spaces high and some spaces low, allowing for heat stratification. Also, providing many options for controlling and encouraging air movement is very important. In this way occupants are very likely to find a location in at least one area of the house that has the right balance of temperature coolness and air movement. Refer to figure 3

2.1 The Camping Concept

Camping is fun, or people would not go camping. The irony of camping is that people have fun even though the weather is not always perfect – nights can be cool and days can be warm – yet people still enjoy camping, enjoy being outside, and enjoy adapting to the changes in weather.

One thing in particular is different about camping compared to home living; that one big difference is attitude. For example when people are at home, by convenience, and by learned social behavior, adjusting the thermostat to a level of thermal comfort is both expected and encouraged. Conversely, in the camping environment, there is no thermostat to instantly change the air temperature – and that is okay with campers. Consequently, campers naturally move to warmer spots when they are cold and move to colder spots when they are warm or they add or remove clothes based on what is necessary to stay comfortable. Nobody minds because that is the camping experience which people love.

Also, like living in the Outside-In House, campers must anticipate the weather and be able to respond in advance. Doing things like tying down a tent before a wind storm, putting up rain coverings before a rain storm and pitching the tent in shady spots or sunny spots depending on anticipated weather conditions are all anticipatory events required of campers.

Likewise, a particular requirement of occupants in the Outside-In House is that the occupants must anticipate changes in weather and know when hot days are coming so that the cool night air can be brought into the home for several evenings prior to the hot days. In this manner, the thermal mass in the house can be primed and energized with cool air. The house must be pre-cooled, or “charged-up” with coolness in the walls like a battery and the longer the thermal mass walls are kept cool, the longer the house will stay cool when the outside weather is hot.

Reasonable time is required to get the heat evacuated from the thermal mass so that the walls, floors, and roofs will then be able to absorb heat from the occupants and keep everyone cool during a series of hot days. This idea of anticipating hot weather and building up coolness in the thermal mass walls of the Outside-In House is similar to the squirrel anticipating winter and gathering nuts to store food during the cold season.

The Outside-In House must be fun and refreshing yet challenging – but in a natural and relaxing manner, like camping, or people will not want to live in the Outside-In
House. Refer to figure 3 to get an idea of the variety of spaces in the Outside-In House and the large proportion of outdoor living areas (only the shaded area can be fully enclosed when needed).

Fig. 3: Outside-In House concept section

3. OUTSIDE-IN HOUSE FEATURES

The Outside-In House is more of a concept for a house than an actual house; however, the design of one interpretation of the Outside-In House does exist as a computerized digital model. The digital model allows for a descriptive and visual opportunity to communicate the strategies and ideas for keeping an Outside-In House cool in the summertime. Some of the images in this document are from the computer model. Refer to figure 4 as an example.

Fig. 4: Aerial view of an Outside-In House project

3.1 Cleared and Cooled Induced Air Movement

During the daytime in the desert there is typically a breeze, at least to some extent. There are times, however, especially at night when there is no outside air movement, in which case air movement must be induced within the Outside-In House.

Induced air movement results from controlled differential buoyancies of warm and cool air (convection currents). Interconnected spaces between the floors of a multi-level building will experience induced convection currents (thermosiphoning or stack effect) because the upper story will be warmer than the basement space, causing cool air from the basement to be drawn into the attic space. The Outside-In-House requires a basement and at least one space above grade to assist in the thermosiphoning process that is required to induce air movement. Air in the attic must be vented out the top and air must be able to enter the building in the lower part of the basement in order for the air to flow. Refer to figure 3.

Fig. 5: Thermal chimney section view

In addition to the multi-level concept, the Outside-In House has a thermal chimney to induce air movement through the house. The basic principle of the Outside-In House thermal chimney is that air travels up through a chimney shaft that is surrounded by hot water. The hot water heats the air, causing the air in the chimney to become lighter and rise out the top of the chimney. Then by atmospheric pressure, air is forced into the house through a cool area outside of the house which then cools the house. The water in the solar chimney is heated during
the daytime by solar collectors. Refer to figures 5 and 6 for two different examples of thermal chimneys.

![Fig. 6: Outside-In House longitudinal section](image)

Air pushed into the house via the induced pressure differential of the thermal chimney is cooled and filtered by drawing the air through a vegetated area of the house. The moving air is then cooled by evaporation of moisture within the vegetation – operating somewhat like a giant evaporative cooler. The vegetation also filters the air because dust particles stick to the moist leaves, eventually washing off to the ground level. Refer to figures 7 and 8.

![Fig. 7: Section view of tree row cooling and filtering](image)

The Summer Wing floor plan (figure 9) illustrates how the induced air movement flows during nighttime when there is otherwise no wind. Air enters by the force of atmospheric pressure through the open Temperate Living Space (right hand side of figure 9) and flows down through the secondary vegetative air treatment to the basement level (figures 8 and 9). The cooled air then circulates through the basement areas before rising up into the garage area (figures 6 and 9). The air, now becoming warmer is then drawn up through the thermal chimney from the thermosiphoning effect (figure 6).

![Fig. 8: Outside-In House Transverse Section](image)

![Fig. 9: Summer wing floor plan](image)

3.2 Amplified Natural Air Movement

During times when there is at least some natural wind, which will be most of the daytime, a mild breeze gets amplified by the shape of the building and/or the shape of the rooms. The prevailing wind direction in Tucson, Arizona, which is a probable site for the first Outside-In House prototype, is generally easterly or westerly, depending on the time of day. The bridge level of the Outside-In House (figure 10) illustrates how the wedge-shaped forms of the rooms funnel air from either direction, accelerating the wind velocity through each space. Wind generators at the smaller end of the rooms make electricity for the house.

The building form also funnels winds from any direction...
to under the bridge level and through the shaded patio breezeway (figure 11) where regular outdoor living is expected to take place in the summer season.

Fig. 10: Bridge level floor plan

Fig. 11: Patio breezeway under the shade of the bridge

3.3 Plenty of Shading

Essential to all that survive a desert summer is shading. Desert animals, even desert plants with self-shading, are able to survive the heat by using shading to keep cool.

The Outside-In House has a ramada-style roof over the occupiable roof of the north wing. The occupiable roof over the south wing has provisions for an operable sail roof, which shades the roof as needed to keep the roof surface comfortable. Because the south wing is the winter season wing, the roof sails double as a means to retain the heat from the roof on a cool night. The bridge area is covered by photovoltaic panels set above the roof surface and also serves as roof shading.

Much of the outdoor yard space is designed for outdoor living. In fact there is an entire open-air casita surrounded by wall, for privacy, and only covered by an overhead louvered shading system (figure 13). Much of the site is covered by the same overhead louvered shading system to keep the outdoor spaces cool (figure 12).

Fig. 12: Site plan indicating shaded outside living

Fig. 13: Shaded, open-air casita floor plan

3.4 Plenty of Thermal Mass

The walls of an Outside-In House are thick and massive as were the traditional desert homes prior to air-conditioning. The high-mass walls are cooled from the cool nighttime temperatures. In turn, the walls then cool the occupants during the day by accepting (absorbing) the heat radiating...
from their bodies.

3.5 Plenty of Variety

Having a lot of thermally varying spaces is another key concept of the Outside-In House. The temperature of the spaces is often dependent on the location in and around the building. Having many areas for sitting, sleeping, working and eating around the entire house will help to assure the occupant that there is a comfortable place for their activity somewhere in a north, south, east, west, roof, interior, exterior or basement area.

3.6 Outdoor Living and Sleeping

Places for hammocks and hooks for hammocks are abundant in the Outside-In House. Hammocks are generally comfortable and allow the cooling effect of air movement to envelop the body.

Most every space will accommodate sleeping. The roof spaces are especially designed for open-air sleeping at night so body heat can radiate to the night sky while keeping the sleepers safe, secure, and comfortable

4. OUTSIDE-IN HOUSE RETRACED

The Outside-In House is a concept for living in a sheltered variation of the outside; bringing the outside in by employing basic principles of outdoor human thermal comfort. The analogy of camping is a basis for the concept of living in the Outside-In House, yet this is a house that comes with all the modern conveniences. Most importantly, the Outside-In House has effective means to passively condition and control the air quality and temperature.

Two major physical effects required for comfort in the desert – shading and air movement – are the driving concepts for the Outside-In House. Air movement in the desert southwest will generally take care of itself provided there are ample openings throughout the house to allow natural air movement to freely flow through the house. Shading is imperative and future visions of the Outside-In House will manifest even more shading than described or illustrated herein. Other than for areas designated as open-sky, outdoor, nighttime, living or sleeping, the entire remainder of the home should be shaded, including walls as well as roofs. Refer to figure 14 for a section concept of whole-house shading.

Living comfortably within a sheltered outdoor setting provides plenty of opportunity for proactive planning, creative thinking, integrated exercise, and flat-out enjoyment of life. May the Outside-In House find you and bring you happiness!

Fig. 14: Section view of whole-house shading

5. ACKNOWLEDGEMENTS

Gratitude is extended to Professor Nader Chalfoun and Director Rob Miller at the University of Arizona for knowledge, support, and encouragement.

6. REFERENCES

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