**Introduction** (Group)

The research question this paper addresses is how residential buildings in North Texas can be designed to consume less energy. We have found that passive solar design elements such as orientation, thermal mass, windcatchers, solar water heating, and daylighting can be combined synergistically to reduce energy consumption beyond the capacity of the individual components. We therefore propose an original model of *synergistic passive-solar design* (SPD) for homes in North Texas.

Our proposal is important because passive solar designs the ecological benefits associated with reduced energy consumption such as reduced CO2 emissions. These benefits are achieved by reducing the amount of energy used to light, heat, cool, and supply the building with hot water. They also offer a sound investment for home owners. Passive solar homes are a financially attractive option because they have lower energy cost and a high resale value (Charles Eley Associates, 2013).

Passive solar design has a history of proven effectiveness that spans thousands of years and virtually every climate (Crosbie). This concept has only recently been pushed to the background in home design with the advent of climate control systems such as HVAC (standing for heating, ventilation, and air-conditioning). However buildings account for a 41% of energy consumed in the U.S. and the corresponding greenhouse gas emissions and are a major contributor to global warming (Energy.gov, 2012)

At this time, comprehensive passive-solar construction is virtually nonexistent in North Texas, even though the region is an ideal location for such an endeavor. The climate and socioeconomics of North Texas are well suited to the introduction of a SPD approach in home construction. Climate wise, Texas has mild winters, allowing designers to focus primarily on the issue of cooling the structure in the hot months. Additionally, passive solar techniques do not conflict with existing building codes in the region because they can utilize the same building materials that have already been vetted. Economically, Texas has a demonstrated market for products that integrate environmental consciousness as part of their brand (Eley).

In this paper we describe each component of SPD (orientation, thermal mass, windcatchers, solar water heating, and daylighting) individually. We demonstrate the efficacy of these concepts through historical and climatic antecedents. We address their applicability to North Texas, including adaptation to the region's climate. We discuss how the components of SPD can be combined for synergistic affect. Finally, we offer evidence for the marketability of such a model.

**Orientation** (Zack Houser)

Orientation in home design is the process of intentionally placing certain features of the structure in particular locations that take into account the relative position of the sun throughout the year. The choices made while deciding how to orient a house will take into account how the house aligns with the cardinal directions and which rooms will be located where in the design. Orientation seeks to utilize the sun for warmth during cold months and create shade for cooling during warm months. In this way it reduces energy consumption and offers the associated ecological benefits of lower carbon emissions.

The alignment of the house with the cardinal directions affects how much surface area of the house is exposed to direct sunlight at any given time. This in turn impacts how much a given part of the house heats up due to absorption of solar energy throughout the day. In the northern hemisphere the sun travels in the southern part of the sky. Therefore, if one wants to maximize the amount of direct sunlight available to heat the home in the winter months, the broadest side of the house should face south (Energy.gov 2010).

Placement of certain rooms on certain sides of the house will affect the temperature of those rooms during a given part of the day or year. For example, a room on the east side of the house will receive a lot of morning sunlight but little during the evening. This may be ideal for bedrooms, for example. Light and warmth enter in the morning and the room is shaded in the evening when, coolness and dark are desired. Rooms that face south will receive copious light all day and may become hot in warm climates. As a result, spaces in which maintaining a comfortable temperature is less important maybe used. An example of this would be a garage or laundry room.

The consideration of solar orientation in the construction of buildings is ancient and was widespread until the invention of HVAC systems (Crosbie). In North Texas, orientation is sometimes ignored even though orientation confers benefits to home temperature control regardless of other strategies used. Orientation has a disproportionate effect on the effectiveness of other passive-solar tactics and proper orientation is crucial to our concept of Synergistic Passive-solar Design.

**Thermal Mass and Insulation** (Benoit Thiercelin)

The purpose of this section is to look at how passive temperature control features can be used in Texas to reduce energy consumption in housing. Two important principles for maintaining temperature using SPD in a residential building are insulation and thermal mass. These principles are often paired with an ability to modify temperatures actively, such as a source of heat or ventilation to cool.

Insulation is the property of a material to resist thermal conductivity (Al-homoud, 2005). The most effective agent of insulation is static air. The issue with insulation and the ideal of zero loss is the problem of thermal bridging. For example, if a building is completely insulated except for the windows, then the insulation is irrelevant. The windows will act as a thermal bridge and negate the effects of the insulation. To correctly insulate, insulation must be designed holistically for the project and thermal bridges must be reduced and eliminated. There are several ways to insulate: exteriorly, as a wrap around the building or internally. The LEED certificate argues for exterior insulation as the best method but the reality is much more situational. For example, insulating an underground room is much easier from the inside than from the outside as we would not want the insulation to be the barrier between soil and structure.

Thermal mass is the property of a material to resist a change of rate in thermal conductivity. The most effective agent of thermal inertia is water. The resistance to a change of rate in thermal conductivity results in a slow variance of temperatures and can be seen as a delay in reaction to change of temperatures. As the extreme differences in temperature happen, the structure maintains an average temperature. Earthships, homes developed by architect Michael Reynolds, combine thermal mass using soil, ventilation systems, temperature buffer zones, orientation according to natural inputs of energy, and controlling sunlight penetration according to season through the angle of the roof ("Earthship Biotecture"). All this helps to control and maintain a temperature around 70 degrees Fahrenheit.

Buildings that have not been designed by an architect and respond to local climate, local materials and local culture are defined as vernacular architecture (crosbie). Vernacular buildings often make use of passive systems to control temperature as they rely on limited local resources. Insulation in vernacular architecture is typically found in very cold areas. The Eskimo's igloo is a poignant example. Body heat from occupants creates a thin layer of ice which traps air between the inside of the igloo and the ice block structure that creates a highly insulated zone. Body heat from occupants is enough to maintain favorable temperatures even with a freezing exterior because there is no loss of temperature to the outside environment. Thermal mass in vernacular architecture is typically found in areas where there is a great difference of temperature between day and night or between seasons. Examples of these are the sunken cities and troglodyte houses of Turkey. In Southern France, a technique is used for vernacular architecture combining ventilation and thermal inertia (Bi, 2002). The input of air comes from an underground shaft, effectively cooling the hot outside air before it enters the house using the thermal inertia of the soil. This technique is also used in Canada but for opposite effects (Bi, 2002). The cold air is warmed using the thermal inertia of the soil before entering a house. The applications of all principles are varied.

Vernacular architecture in Texas has had different forms. Before colonization, the Caddo Indians used two forms of housing, one for summer and one for winter (Swanton). The summer house consisted in elevated flooring combined with a roof, effectively creating a cooler area in the hot and humid weather. The winter house consisted of a thatched hut devoid of windows creating a highly insulated zone as air is trapped in the thatch. After colonization, a form of the shotgun house, the dog-trot was often used by settlers (White, 2013). The dog-trot shotgun house can be described as an elongated house, one room in width, with an open covered area in the middle. This middle area provides a cool workspace for the summers while the enclosing rooms provides an insulated zone for winters. The middle also provides ventilation for the house. One could make a connection with the dog-trot form of the shotgun house with the Caddo Indian strategy.

In Texas, the conventional house is a timber frame with insulation between the structure. As wood contains many bubbles of air, it is a very effective insulator and will not act as a thermal bridge. Therefore, a conventional house in North Texas relies on insulation rather than thermal mass. The issue with conventional U.S. housing comes from the joinery between structure and fenestration which drastically reduces the effectiveness of the insulation (Al-homoud, 2005). Temperature control is often maintained by HVAC systems which lose their efficiency if the building is not properly sealed as more energy is needed to compensate for the thermal bridges with the exterior environment.

If we consider that thermal mass is more appropriate for areas with high variance in temperatures then the conventional U.S. house does not score highly in Texas, but if we look at vernacular architecture in the area, thermal mass has not traditionally found its place in Texas. This is surely due to availability of certain resources over others. Using thermal mass is not common in contemporary architecture because it relies on abundance of matter. Earthships show that thermal mass has a place in the southwest, basing itself on the availability of used tires as the main material ("Earthship Biotecture"). Michael Reynolds, with his Earthships, show that there is a place for thermal mass for contemporary housing and this can be applied to Texas to greatly decrease the use of exterior energy (Al-homoud, 2005).

**Windcatchers** (Mitchell Dodd)

A windcatcher (also known as a windtower) is an architectural feature which cools a building by harnessing the wind (see appendix A). This feature is relevant to North Texas because indoor climate control is a major consumer of energy in the region and a substantial expense to home owners (Pe´rez-Lombard et al). By using this passive form of cooling, the building consumes less energy to maintain a desirable temperature.

Traditional windcatchers take the form of a tower attached to the structure with one or more openings at the top and bottom. Windcatchers may be used in a variety of configurations. These configurations include the single tower design, multiple tower design, and either design with the incorporation of a qanat (a subterranean horizontal shaft containing water) (A'zami, 2005).

In the single tower design the opening at the top of the tower is facing the prevailing wind (typically, adjustable ports at the top of the tower allow for the opening to face the wind regardless of direction). The wind is directed downward and into the tower. At this point, the air is constricted and, following Bernoulli's principle, moves faster and compresses (Elmualim). As this fast moving air is released into the structure it expands and cools (in accordance with the Joule–Thomson effect) (Elmualim).

To achieve further cooling, a qanat can be incorporated into the design. The air moving through the tower is redirected horizontally through the qanat and over a pool of water. The shaft, being subterranean, has a lower temperature than the surface and cools the air current through conduction as well as through evaporative cooling as it passes over the surface of the water. At this point, the air is channeled into the building. As the cool air entering the structure warms and raises it is vented through openings in the upper portions of the building (A'zami 2005).

The convection current created by this rising warm air can be further potentiated by the inclusion of another tower at the opposite end of the building (the multiple tower design). This tower acts to expel exhaust (hot air) from the house. This tower's port is opened to face counter the prevailing wind. This creates a pressure differential that increases the flow of air through the building, providing additional ventilation (Roaf).

Windcatchers have been used for thousands of years in hot climates and are particularly common in Egypt and Iran. However, they have also been employed more recently in western architecture (El-Shorbagy). For example, Zion National Park Visitor Center in Utah and the

Kensington Cricket Ground in Australia utilize the windcatcher concept in a modern interpretation. These iterations of the windcatcher demonstrate the concept's adaptability to modern architecture (National Renewable Energy Laboratory, Saadatian et al).

In contrast to windcatchers, the most common way of cooling a residential building in North Texas is the use of an HVAC system. HVAC systems consume 50% of the energy used by buildings and 20% of total energy usage in the United States (Pe´rez-Lombard et al). The incorporation of windcatchers into residential buildings represents a serious opportunity to cut energy usage and consequently greenhouse gas emissions. Further, because windcatchers reduce energy consumption, they lower the homeowner's energy bill. In hot climates, such as North Texas, where energy cost associated with air conditioning can be quite high, the windcatcher presents a financially attractive option.

**Daylighting** (Briana Amelio)

Daylighting is a design concept that seeks to provide a home with ample daylight while simultaneously regulating heat gain and loss. It accomplishes this through the use of number of methods including glazing, devices that redirect sunlight, and thoughtful placement of windows, shading and other exterior components of the house. By incorporating this concept into home design, buildings can achieve greater energy efficiency through a reduction in the necessity of daytime electric lighting and undesired fluctuations in temperature.

High-performance glazing uses a double pane glass unit with a high insulation rating that will admit more light and less heat than a typical window (Ander, 2012). Devices that redirect light such as light tubes, reflectors, and light shelves bring light into parts of a build that would otherwise be too interior or obscured from sunlight by interior walls. The careful placement of windows and shading allows in more light when it is desirable and less when it is not. For example, if a house is designed with a large number of windows facing south those windows will let the low winter sun into the home to warm it. Awnings can be utilized to shade these same windows from letting in excess sun during the summer when the additional heat is not desired. Because the sun is higher in the sky in the summer months the awnings prevent the rays coming from a steeper angle from reaching the windows. The placement of deciduous trees around the house can provide shade during the summer but allow light to reach the house in winter once the leaves have fallen (Planning Services Special Project Unit, 2010).

Currently, the need for the use of artificial lighting indoors during the day is pervasive in residential buildings in North Texas. This is unnecessary even in existing homes with the availability of sunlight redirection devices. Moreover, Texas has a great deal of sun throughout the year, approximately 61%, and this can dramatically affect the temperature of a building (NCDC, 2004). This means that, to control indoor temperature, special attention must be paid to the concept of daylighting.

**Solar Water Heaters** (Alexander Johnson)

Solar water heaters utilize the radiation from the sun to warm water for use in the residence. Since solar water heaters are powered by the sun there is no power required from utilities and a very low cost of operation past the initial installation. They provide an energy and financially efficient way to heat water. These water heaters can operate in any climate but can be especially effective in the climate of North Texas.

There are two types of solar water heaters; passive and active. Both have pros and cons in different climates and locations. Active solar water heaters have pumps for circulation and controls and a passive system does not. Passive systems have less issues with maintenance however are less effective. Active circulation systems work in two ways; direct and indirect. Direct systems utilize the suns radiation to directly warm the water being used. In an indirect system the suns radiation is used to warm a special nonfreezing liquid similar to a car's engine coolant which is used to warm water for use in the residence (energy.gov, 2012).

Active solar heating has been incorporated into home designs for years now and is widely used in parts of China. The most common form of the apparatus has been in use for over fifty years. The idea is not a new one however recent breakthroughs in solar technology has given way for more advance and less expensive hardware making the technology more available for the general population.

In North Texas, since there is a relatively low number of freezing days an active circulation system that features direct circulation would be most efficient. Adding a solar heating system to a house is only slightly more difficult than adding a conventional system, so implementing one in the initial design of the residence can offset any extra installation cost. Efficiency can also be increased when the solar water heating system is designed into the residence by taking maximum advantage with the angles of sunlight.

Cost has been one of the main concerns with solar water heaters. In the North Texas climate where more days are sunny than not, the energy efficiency can outweigh that of a conventional system. A solar water heater will have a higher up front cost but lower cost of ownership than that of a conventional water heating system (energy.gov, 2012).

**Synergistic Passive-solar Design** (Mitchell Dodd)

The heart of our proposal is the idea that the individual passive-solar concepts described above can be combined in such a way that they feed off each other and provide additional effectiveness. The model we propose is largely theoretical in its synergistic qualities. It therefore advocates some as-yet untested combinations of architectural techniques. However, these combinations follow a logical congruence with our research findings. Since the main concern of indoor climate control for North Texas is that of cooling, that is our design focus.

This Synergistic Passive-solar Design begins with orientation. The house is oriented with the broad sides facing south and north. A buffer, comprised of rooms that are not living spaces, is on the east and south-east side of the house. To this we add some daylighting techniques. Deciduous trees are planted around the house. These trees build upon the concept of orientation by being planted in a way that takes into account the rooms in the house that most need shade as well as the need for particular amounts of light at any given time of day / year. Additionally, awnings are used on the south side of the house to block the high summer sun by allow in the lower winter sun's light. High-performance glazing is used where natural light is desired but additional heat unwanted. The walls and ceiling of the house use high grade insulation that helps keep heat out. Temperature control within the residence is further enhanced through the strategic placement of thick walls that act as thermal masses. These masses absorb surplus latent heat by day and release it at night. Further cooling is provided by a multiple-tower-qanat windcatcher system. We also take orientation and daylighting into account in the implementation of our solar water heater system; being sure to allow the solar water heater batch collector uninterrupted direct sunlight. We also position the opening of our exhaust tower in our windcatcher system so that it releases the hot air on or near the batch collector, increasing its temperature. It is through a series of thermal energy of transfers like this that we seek to move heat away from where it is not desired to places where it is.

**Marketability** (Estefania Rodriguez)

We understand that regardless of how innovative and efficient our proposal is, in order for it to get traction there needs to be a financial return on investment. Two factors support the marketability of our proposal and its commercial success. The first factors are the identification and growth of the potential market. The second factor is the direct financial gain from implementing our proposal in North Texas.

The first factors addressed to support the marketability of our proposal are the identification and growth of the potential market. We use the background information corresponding to Earthships Biotecture, the company of pioneer Michael Reynolds (Schirber), in order to model the market for our proposal. We will use the data associated with Earthships because our proposal has similar ecological goals and the nature of our proposal is a design innovation of residential housing just like the earthships. The most fundamental ecological goal our proposal shares with Earthships is the reduction of energy consumption. Earthships' commitment to the reduction of energy consumption is obvious, however to cite an example we will reference their current development of earthships in Santa Fe, New Mexico called

Oshara Village (Schirber). New Village Institute ran a study and found that residents of Oshara Village could lower their total energy bill — for car and home — by about 50 percent, as well as reduce their carbon footprint by 26,000 pounds of carbon dioxide per year (Schirber).

Earthships Biotecture Information:

The consumer base sustaining the earthships design is as diverse as their motives are for acquiring an earthship home. According to John Kejr, a real estate agent who specializes in selling earthships homes in Taos, "The mixture of people is much more diverse than I expected -- they range from very young people to retirees, large families to single people," (Alcantara). This first-hand account of the consumer base helps counter the myth that the market of people interested in alternative residential design is limited. Kejr continues to explain that the motives of people looking to buy an earthship are also varied. He explains, "Some are looking to lessen their environmental footprint; others just don't want to pay an electric bill," (Alcantara). Since our proposal fulfills similar ecological goals as the earthships, we are confident that the market that sustains the earthship model would support our proposal as well.

The growth of Michael Reynold's company Earthship Biotecture will serve as evidence to establish the success of a product that aims to reduce energy consumption through an innovation in architectural design, and consequently the success of Earthship Biotecture supports the future success of our proposal. The first earthship home was built in 1988 in Taos, New Mexico (Schirber). Since then 3,000 earthship homes worldwide and 500 of those have been built by Earthship Biotecture (Schirber). Although our proposal for synergistic passive solar design is focused for North Texas, in order to exhibit the growth and popularity of earthships we will mention the various places they are found worldwide. Earthship communities are found in Africa, Haiti, Australia, Canada, Europe, Guatemala, New Zealand, South America, and, of course, the United States ("Earthship Biotecture"). Clearly, there is a growing market for earthship homes worldwide. The success of an alternative design for residential homes has proven to be a commodity for many of the world's citizens, and with this promising precedent we are confident our proposal for synergistic passive solar design will be a sought after commodity, here, in North Texas.

The second factor addressed is the direct financial gain from implementing our proposal in North Texas. The financial gain is evident through the following benefits of passive solar implementations in North Texas (as demonstrated by the government publication *Passive Solar Design Strategies for Home Building in North Texas)*: energy performance, low maintenance, value, and investment (Eley). Passive solar provides energy performance by reducing energy bills all-year round (Eley). It has a low maintenance because its upkeep includes durable reduced operation and repairs (Eley). The value of passive solar heating is reflected in a higher owner satisfaction ate and a higher resale value (Eley). Finally, passive solar heating is a return on investment because it will retain independence from a rise in future fuel costs and it will continue to save money long after any initial costs have been recovered (Eley).

Marketing Conclusion

Ultimately, our proposal for synergistic passive solar design will smoothly integrate itself into the market that presently sustains the growth of earthships. Our proposal incorporates the use of several atypical passive solar design techniques in order to achieve  the ecological goal of the reduction of energy consumption. We use Earthship Biotecture's consumer background information and the overall growth of earthships, as well the growth of Earthship Biotecture, to model the market success of our own proposal for synergistic passive solar design.

**Conclusion** (group)

In this paper we address the use of a Synergistic Passive-solar Design model to reduce energy consumption in North Texas.  The components of this model are orientation, thermal mass, insulation, windcatchers, daylighting, and solar water heaters.  We have explained the viability of these components in the setting of North Texas.  We put forth a model for how these features can be combined to confer greater benefits than implied by the sum of their parts.  We believe the resultant reduction in energy consumption and accompanying greenhouse gas emissions that would be achieved by such a model would be substantial. Further, this model offers financial benefits to home owners in the form of reduced utility bills and high resale value.  We have also provided evidence of the market for such a model. Beyond these benefits we believe that this concept can be compared to the resilience of a system. The more variance there is in ways to control temperature and lighting in housing design, the more resilience the system embodies.

# Bibliography


Austin Business Journal, . N.p.. Web. 19 Apr 2013. <http://www.bizjournals.com/austin/stories/2010/06/07/daily54.html>.

"The Green Market Oracle." The Green Market Oracle. The Green Market Oracle. Web. 17 Apr 2013. <http://www.thegreenmarketoracle.com/>.

United States . U.S. Department of Energy . Passive Solar Design Strategies: Guideline for Home Building. Web. n.d. n. page. <http://money.cnn.com/magazines/fortune/fortune500/2012/snapshots/10572.html>.

Stevens-Garmon, J., C. Huang, and B. Lin. n.d. n. page. <http://www.choicesmagazine.org/2007-2/grabbag/2007-2-05.htm>.

"Traditional Islamic-Arab House: Vocabulary And Syntax | Abdel-moniem El-Shorbagy - Academia.edu." *Traditional Islamic-Arab House: Vocabulary And Syntax | Abdel-moniem El-Shorbagy - Academia.edu*. N.p., n.d. Web. 19 Apr. 2013.

"National Renewable Energy Laboratory (NREL) | Alliance for Sustainable Colorado." *National Renewable Energy Laboratory (NREL) | Alliance for Sustainable Colorado*. N.p., n.d. Web. 19 Apr. 2013.

"Guide 3 Shading out the Heat." Townsville City Council. Planning Services Special Project Unit, 2010. Web. 19 Apr. 2013. <http://www.townsville.qld.gov.au/>.

Eley/ Associates, Charles. "Passive Solar Design Strategies: Guidelines for Home Building." Passive Solar Industries Council, n.d. Web. 12 Apr. 2013. <http://www.nrel.gov>.

Saadatian, Omidreza, Lim Haw, K. Sopian, and M.Y. Sulaiman. "Review of Windcatcher Technologies." *ScienceDirect.com*. Solar Energy Research Institute, n.d. Web. 19 Apr. 2013. <http://www.sciencedirect.com/science/article/pii/S1364032111005843>.

Perez-Lombard, Luis. "A Review on Buildings Energy Consumption Information." *Energy and Buildings*. Elsevier, 12 Mar. 2007. Web. 2 Apr. 2013. <http://wenku.baidu.com/view/647f5d69561252d380eb6e9f>.

Elmualim, Abbas Ali. "Dynamic Modelling of a Wind Catcher/tower Turret for Natural Ventilation." *Dynamic Modelling of a Wind Catcher/tower Turret for Natural Ventilation*. Innovative Construction Research Centre, School of Construction Management & Engineering, The University of Reading, UK, n.d. Web. 19 Apr. 2013. <http://bse.sagepub.com/content/27/3/165.abstract>.

A'zami, A. "Badgir in Traditional Iranian Architecture." Islamic Azad University of Tabriz, Department of Architecture, May 2005. Web. 23 Mar. 2013. <http://www.inive.org/members_area/medias/pdf/Inive/palenc/2005/Azami2.pdf>.

Roaf, S. "Air-conditioning Avoidance: Lessons from the Windcatchers of Iran." Department of Architecture, Oxford Brookes University, Oxford, May 2005. Web. 23 Mar. 2013. <http://www.inive.org/members_area/medias/pdf/inive/palenc/2005/roaf.pdf>.

Ander, Gregg D. "Daylighting." WBDG. U.S. Department of Energy, 24 Aug. 2012. Web. 19 Apr. 2013. <http://www.wbdg.org/resources/daylighting.php>.

"Solar Water Heaters." Energy.gov. N.p., 7 May 2012. Web. 19 Apr. 2013. <http://energy.gov/energysaver/articles/solar-water-heaters>.

Crosbie, Michael J. “Sustainability by ‘Amateurs’.” American Institute of Architects. Web. 29 Apr. 2013. <http://info.aia.org/aiarchitect/thisweek08/0404/0404rc_face.cfm>.

Energy.gov. “Guide to Passive Solar Home Design.” U.S. Department of Energy. 2010. Web. 27 Apr. 2013 < http://energy.gov/sites/prod/files/guide_to_passive_solar_home_design.pdf>

"Earthship Biotecture." Earthship Biotecture. Earthship Biotecture, n.d. Web. 30 Apr 2013. <http://earthship.com/network>.

Schirber, Michael. "Making Earthships mainstream." NBCNews.com. NBCNews, 12 Nov 2007. Web. 29 Apr 2013. <http://www.nbcnews.com/id/21755230/ns/business-going_green/t/making-earthships-mainstream/

Alcantara, Kristine. "New Mexico's Earthship Homes Are a World Away From Traditional Living (Off the Grid) ." Aol Real Estate. Aol Real Estate, 18 Sep 2012. Web. 29 Apr 2013.

Eley, Charles. United States. U.S. Department of Energy. Passive Solar Design Strategies:Guidelines for Home Building. North Central Texas: National Renewable Energy Laboratory, Web. <http://www.nrel.gov/docs/legosti/old/17252.pdf>.k[p;-]=[pouyjhvcx>

White, W. W. "DOG-RUN HOUSES," Handbook of Texas Online. Texas State Historical Association. Web. April 29, 2013. <http://www.tshaonline.org/handbook/online/articles/cfd01>

Al-Homoud, Mohammad. "Performance characteristics and practical applications of common building thermal insulation materials." Building and Environment. 40.3 (2005): 353-366. Web. Apr 29, 2013 <http://www.sciencedirect.com/science/article/pii/S0360132304001878>.

Bi, Yuehong. "Ground heat exchanger temperature distribution analysis and experimental verification." Applied Thermal Engineering. 22.2 (2002): 183-189.

Swanton, John Reed . Source Material on the History and Ethnology of the Caddo Indians. Print.

"Ranking of Cities Based on % Annual Possible Sunshine in Descending Order from Most to Least Average Possible Sunshine." *National Oceanic and Atmospheric Administration*. National Climatic Data Center, 2004. Web. 01 May 2013. <http://www.ncdc.noaa.gov/oa/climate/online/ccd/pctposrank.txt>.

**Appendix A**

Windcatchers in the city of Yazd, Iran (2007)

Photo by golisnow http://www.flickr.com/photos/33449025@N00/3371011219/