Dragonfly
Øyenstikker

FINAL REPORT

AREA OF DESIGN:

HOUSING AND INFRASTRUCTURE

VENTILATION

JOHN MAI

REBECCA TAN

WARREN DANG

SAMMY CHEUNG

CHANTELLE THISTLETON

GORDON YAO HENG LIANG

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ABSTRACT

Background

The district of An Minh is located on the east coast of the Mekong Delta. Its location is subject to humid air and the local temperature highs range from 29 to 34°C throughout the whole year. The economic ability of this area limits the means of temperature regulation in homes causing affecting body temperature and health. This unbearable weather is not directly dealt with in existing house design.

Result

For this reason, our team has decided to create a system that provides comfort through natural ventilation and decreasing the humidity in each home. A thorough research of technologies shows that the basic principle underlying air movement is pressure imbalance caused by difference in air temperature. Movement of hotter, less dense air upwards causes colder air to move as it replaces the hot air. Stack ventilation, cross ventilation and solar chimneys rely on this technology. However, an effective opening plays a role in promoting air movement; this is where casement windows, canopy entrance and louvres are able to direct the wind where desired.

In addition, the impact of humidity on the human body greatly affects the temperature the body feels, regardless of the actual ambient temperature. Research of several dehumidifying solutions concluded that bamboo charcoal is the most reasonable choice. Optimally, when the dehumidifier is combined with the solar chimney and adjustable louvres, the residents of An Minh can significantly improve their thermal comfort.

Conclusion

To improve the comfort levels of homes in An Minh our design will be implemented in three stages to respect the local culture. First, the louvres, then the dehumidifier and finally the installation of the solar chimney. The combination of these three technologies will improve not just the comfort of homes in An Minh but the health and well-being.

INTRODUCTION

The EWB challenge organised by Engineers Without Borders seeks to help Vietnam, particularly to improve the current lives of those in the province of An Minh of the Mekong Delta. From information drawn upon the EWB website, we gathered that the people live under very uncomfortable conditions, such as hot weather averaging 30ºC and very high relative humidity. Due to their economic status, they may not realise the difference it would make to have proper ventilation in a house where three generations of families live together. Since air-conditioning cannot be utilised in their homes, it is our aim to introduce a system that will not only provide natural ventilation and improve thermal comfort but also improve their health with minimum effort, time, cost and impact on the environment.

PROBLEM STATEMENT

Due to its **hot climate**, the general temperature in Vietnam ranges from about 21- 34°C[1], and is especially hot during the first half of the year. The effect heat has on a human being's health is significant. The body uses the method of evaporative cooling, also known as perspiration to maintain its internal body temperature. However, there is a limit to how much the human body is able to perspire and beyond that limit; the body will suffer dehydration and loss of chemicals from blood[2].

Humidity is the amount of water vapour found in the atmosphere. Relative humidity levels of 25-60%[3] are ideal for thermal comfort and at any level greater than that, the human body temperature rises, causing a 'sticky' feeling. In this circumstance the body will stop perspiring and the heat within the body will not be dissipated easily. As a result, the human body finds other means to remove excess heat like blood vasodilation, where the blood goes to the surface of the body to dissipate heat through the skin. This causes less blood to flow through other organs like the brain and thereby results in loss of concentration and fatigue[4].

Windows and openings are a fundamental part of the house and often can be placed in the wrong location. Although their placement may have improved natural lighting it can result in the destruction of the roof when there is an imbalance in pressure[5] caused by strong **winds**. Therefore, it is important to design the best position for openings, not only to protect the house and provide privacy but also to allow good ventilation throughout the house that guides the wind properly.

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1 Haivenu. 2012. *Vietnam, The South.* [ONLINE] Available at: http://www.haivenu-vietnam.com/weather-south.htm. [Accessed 10 September 12].

2 AchooAllergy. 2012. *The Effects of Humidity on the Human Body.* [ONLINE] Available at: http://www.achooallergy.com/effects-of-humidity.asp. [Accessed 13 September 2012].

3 The Engineering Toolbox. 2012. *Recommended Relative Humidity.* [ONLINE] Available at: http://www.engineeringtoolbox.com/relative-humidity-d_895.html. [Accessed 13 September 2012].

4 Ibid

5 Rats to You, Daniel Bernoulli! - Understanding Air Pressure . 2012. *Rats to You, Daniel Bernoulli! - Understanding Air Pressure.* [ONLINE] Available at: http://www.energyvanguard.com/blog-building-science -HERS-BPI/bid/29996/Rats-to-You-Daniel-Bernoulli-Understanding-Air-Pressure. [Accessed 13 September 2012].

Overheating in extreme conditions may lead to heat exhaustion, resulting in chemical imbalances in the body and dehydration, having a detrimental impact on **health**. Moreover, older people with weaker bodies and those suffering from cardiovascular diseases are more susceptible to illnesses in a hot and humid climate. Waste gases from cooking and unpleasant air in the house, especially carbon dioxide, do not provide a healthy environment within the household for residents. The use of natural ventilation however, will mean that these air pollutants will not linger within the household and thereby, provide healthier living conditions. Alongside good ventilation, reducing humidity levels will improve comfort and prevent moss, mould and insects from growing and residing within the household and furthermore avert poor health.

With many of the residents living off a low income due to having basic jobs (such as farming), the district of An Minh has a **limited economy and skills basis**. Close to the Mekong Delta river, An Minh is a rural region that does not receive many visitors. The residents therefore have to rely on their own community and the result of this is a limited economy. The rate of poverty within the region is also an issue and leaves many of the residents with limited money to spend. Many of the jobs within the community are agricultural and thus their skills are restricted to farming. However, as the residents have to conduct their own labour work, they do possess a basic level of skills in house construction and maintenance. The level of education within An Minh is limited, with many of the residents having only received a basic level of schooling.

DESIGN CRITERIA

1. Improve the comfort levels in houses with better air ventilation, controlled wind movement and decreased humidity levels.

Thermal comfort refers to a level of satisfaction that a human being has with their surrounding environment. Maintaining an acceptable level of thermal comfort is a necessary goal however, it is often prevented by various barriers. Such barriers within the region of An Minh include stagnant air, uncontrollable wind and high levels of humidity. In order for these barriers to be overcome, creating a system that will improve air ventilation, control wind and decrease humidity levels needs to be designed and implemented.

2. Improve the health of the residents, especially senior citizens and younger ones.

A human being's health can be significantly affected by indoor room temperature and humidity levels if they are not within a tolerable level for the human body. High room temperatures will generally result in overheating and heat exhaustion, which has a detrimental impact on a person's health, particularly those who are elderly or young. Therefore temperature and the level of humidity within a room need to be regulated to not just prevent life threatening conditions but to promote comfortable living.

3. Improve air ventilation of the house using natural methods.

It is desired to have a minimal footprint on the environment and to maximise natural resources in achieving good ventilation. For a new system to be implemented it must be within the economic capability of the residents and so a powered system would not be widely accepted since electricity costs are relatively high in the An Minh district.

4. Use of natural, local or recycled materials.

The residents within the region of An Minh are of a low socioeconomic background, thus minimal cost of the design must be achieved through the use of natural, local and recycled materials. As these materials require little to no cost, the residents will be more acceptable in using such a design. If high expenses were necessary, it is likely that the residents would not be willing to sacrifice other expenses to create a ventilation system that is foreign to them.

5. The design must be easy enough to build by hand and require relatively low skills.

Requiring hired labour is not a favourable option to the residents of An Minh as it would require money. Instead, the residents of An Minh would prefer to do their own labour work and as such, the system must be simple to build. Residents in this area are concerned with agricultural practice and so their construction skills are limited to those techniques used to fix their houses.

6. Ensure openings are designed to prevent animals, insects and rain from entering. Device must be resistant to tearing.

Animals, insects and rain entering will become a nuisance to the household occupants and therefore, should be prevented. The proposed design should address these issues with adequate sealing or covering of holes. Likewise, the device must be durable by being resistant to tearing so that it is able to withstand damage from strong winds and invasive insects.

7. Reduce interference with the existing Vietnamese architecture.
Respecting the community's culture is imperative, in order to have the residents accept the design and keep it as a long-term solution. Alongside this, it is in our best interest to not interfere with their existing architecture, as too much of a change, no matter how effective it is, will not be interpreted as a good thing by the community.

8. Keep the houses and their orientation unchanged, to prevent introducing too much change to their lifestyle.
The design should not be obtrusive by regarding the community's existing houses and their orientation. If the orientation of their houses was to be changed, it would require too much work to be carried out by the residents. If this was the case, the residents could question the effectiveness and need for the ventilation system and hold an opinion of doubt.

9. Educate the importance of good ventilation and decreasing humidity levels.
Before a new system can be implemented, the residents need to be informed as to why good ventilation and humidity control is important and how an effective ventilation system will benefit their household. There will be a need to educate them in the operation of the systems, which will require the support of the community to organise this program.

Design Criteria Development

The design criteria was developed by identifying the key aspects of good ventilation. Such aspects included a satisfactory level of thermal comfort, a decrease in levels of humidity and indoor temperature. The needs of the community were also considered, by first considering what their current living conditions are and how implementing a ventilation system can be adapted to their current lifestyle. Issues as cost, materials and construction were identified from researching the residents' current living conditions.

These factors were then considered as necessary foundation to the design criteria. The research of the resident's living conditions also revealed the type of environment they lived in, raising the concern of how the environment could interfere with the overall design. Therefore, animals (including insects) and the weather affected the overall outcome for the design as well. Alongside this came cultural, social and ethical implications. The consideration of these implications highlighted the aspect of change, which became the final element that was adapted into the design criteria.

Needs of the community

The needs of the community are addressed through this design criteria by focusing on a number of community concerns. One concern is the level of comfort, as residents spend a lot of time within their household (indoors) and therefore require comfortable living. The consideration of health is a necessity in a community whose current living conditions have caused a number of health issues. Another issue is cost and due to the community's low income the implemented system must be cheap and efficient. It also must use natural means as electricity is high cost within the region. Moreover, it must be easy to build so that the residents are capable of building the system themselves, without additional (hired) labour.

Improvement of community life

If implemented appropriately, the lives of the community will be improved significantly. The level of health of and comfort for the residents will be improved, as the indoor temperature and humidity levels will become more tolerant. Moreover, as air circulation will also be improved, stale air will be removed and reduce the growth of mould and thereby further preventing illnesses. As the indoor environment is a place where residents spend a great amount of their time, improvement of indoor conditions will greatly benefit the community.

Response to the design

The community is likely to respond well to such a design criteria because existing ventilation systems within the An Minh region are insufficient. As a community, Vietnamese people seek advancement and to expand their knowledge. The introduction of an efficient and inexpensive ventilation system is likely to be viewed as a foreign concept, however, its applicability will be an interest of change within the community.

Being likely to welcome the idea of the ventilation system, it is assumed that the community will respond to the design criteria by questioning how each principle is relevant to their family and household. Through necessary discussion and demonstrations, the community is then likely to acknowledge that implementing the ventilation system is an acceptable change for their households.

DESIGN PROCESS

The design process can be summarised as the following flow chart:

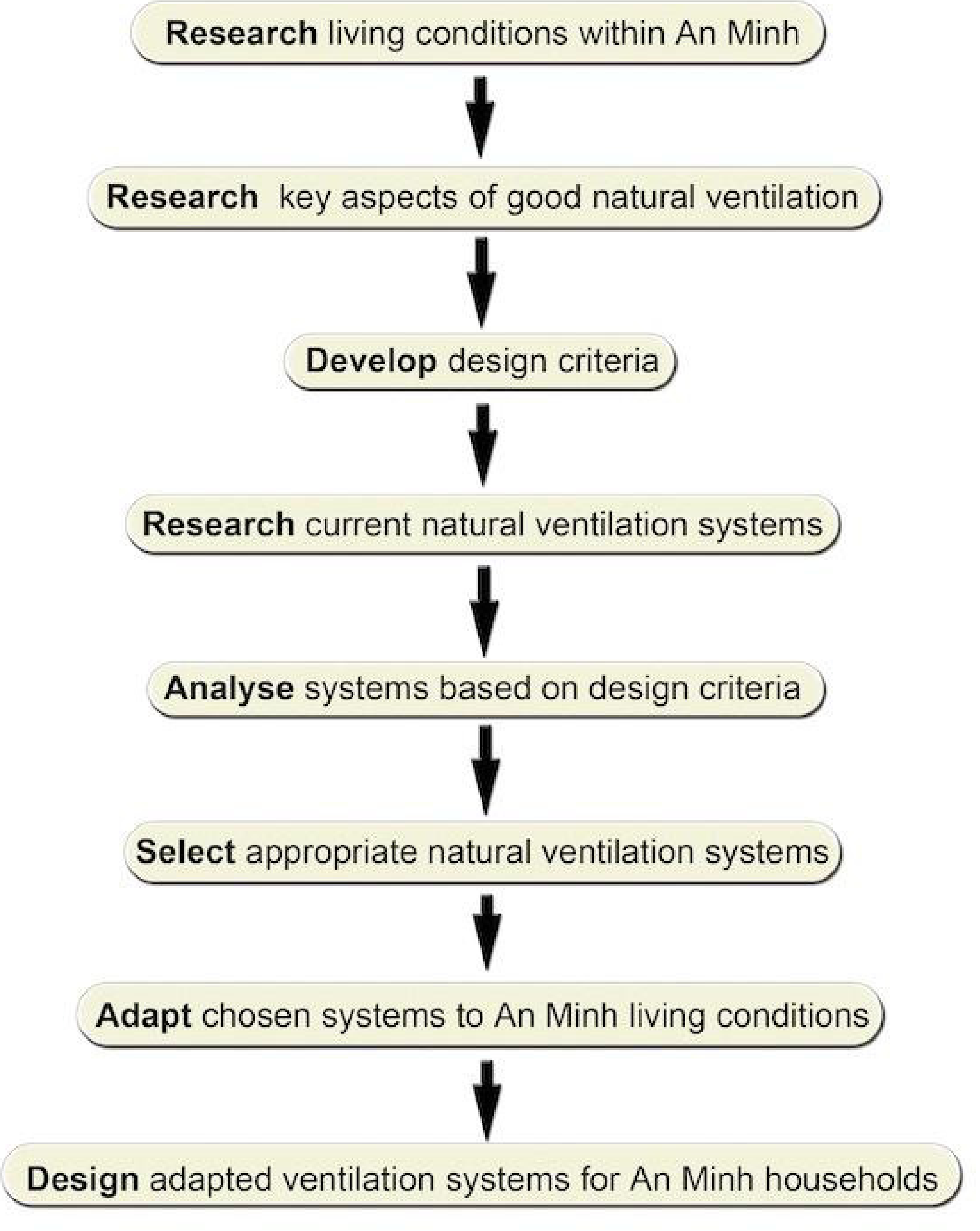

Figure 1 Flow chart of design process

Refer to Appendix A for preliminary design sketches of ventilation system.

BACKGROUND INFORMATION

The An Minh district belongs to the province of Kien Giang and is located on the western coast of the Mekong Delta which itself is located at the southern tip of Vietnam. It is a low lying and flat region that is utilised for farming. It has a total population of about 112,215 with a poverty rate being one of the highest in the Kien Giang Province. In developing a better perspective of the community in which we will make a change, we will be considering factors such as climate, current ventilation systems, societal and cultural issues, ethical, environmental and economic issues.

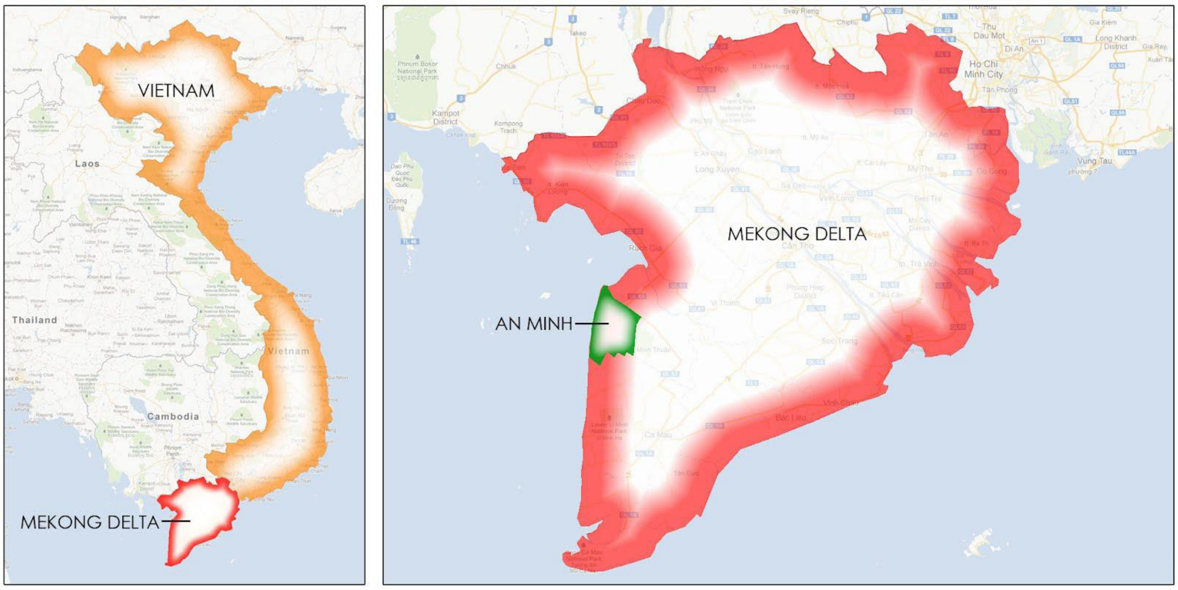

Figure 2 Courtesy of Google Maps

CURRENT VENTILATION

Current ventilation in the An Minh district is simply achieved through the permanent presence of windows and doors that allow prevailing winds to cause circulation of the air within the house. Due to their construction techniques, the majority of the houses are effectively shelters. It is feasible that over the many years that the community has lived in An Minh, and the broader Mekong Delta, the design of houses in the region has been refined to most effectively cool its occupants. The presence of houses built on stilts and the widespread use of thick coconut leaf roofs suggests a knowledge of ways for improving the comfort level inside a house, namely by passive cooling and introducing more thermal mass.

Effective ventilation however is compromised by the properties of the materials used and the construction methods. These properties include a lack of solid walls and unnecessary gaps between adjoining components of the house. The nature of houses being shelters without any specific orientation and seemingly only having openings for functional use serves to heighten the sense of no dedicated ventilation system. This is further stressed in the use of electric fans used as a ‘brute force’ method to cool the occupants of the house.

The possible cooling and ventilation techniques used seem to be at odds with the lack of solid walls that possess better insulation properties, and the presence of unnecessary gaps in components of the house. Thus it can be assumed that the there is little to no ventilation system that currently exists for most of the residents in the An Minh district.

CLIMATE AND WEATHER

The An Minh district, being located near the southern perimeter of Vietnam experiences a more pronounced difference in precipitation between the dry and wet season than the rest of Vietnam. The rainfall can range from around *5.8 to 50.8 millimetres of rainfall per month in the prime of the dry season, while in the middle of the wet season; the rainfall is approximately within the range of 254 to 304 millimetres*[6] when the Mekong delta experiences annual flooding. However, despite this large difference in rainfall the climate of southern Vietnam is fairly constant all year round, with *temperatures of 30˚C - 35˚C during the day and 20˚C - 25˚C at night*[7]. The *humidity in the south ranges from 60 to 80 % in the year, with the lower range in the dry season.*[8] (See Appendix B) In general it is constantly warm and humid throughout the year. There have been reports that there has been more flooding than usual to low lying houses due to climate change and there has also been reports that the dry seasons have begun to last longer.

Due to the topography and prevailing winds of the central and southern areas, this region of Vietnam is not troubled much by the more extreme weather conditions such as tropical storms. However, larger ocean winds have been causing damage to the roofing of houses. Off the southern coast of Vietnam where An Minh is located, the *wind speed is mostly light to moderate with wind speeds of less than 15 knots or 30 km/h. However, the wind speed increases during the wet season, reaching 11- 21 knots or 20-40 km/h for significant portions of time, and with surges of wind speed reaching 25- 35 knots or 45-65 km/h*[9]. The wind direction changes throughout the year, with particular winds being more prevalent at certain times of the year. There are generally northerly and easterly winds from November to January; North-Easterly to South-Easterly winds from February to April; North-Easterly and Westerly winds during May to September; and October has variable and unpredictable winds, as seen in Figure 2.

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6 Haivenu. 2012. *Vietnam, The South.* [ONLINE] Available at: http://www.haivenu-vietnam.com/weather-south.htm. [Accessed 10 September 12].
7 Ibid
8 Opcit
9 Chang, R. 2009. *Offshore Vietnam and Thailand* [ONLINE] Available at: http://www.terra-weather.com/summ_thv.html [Accessed 15 September 12]

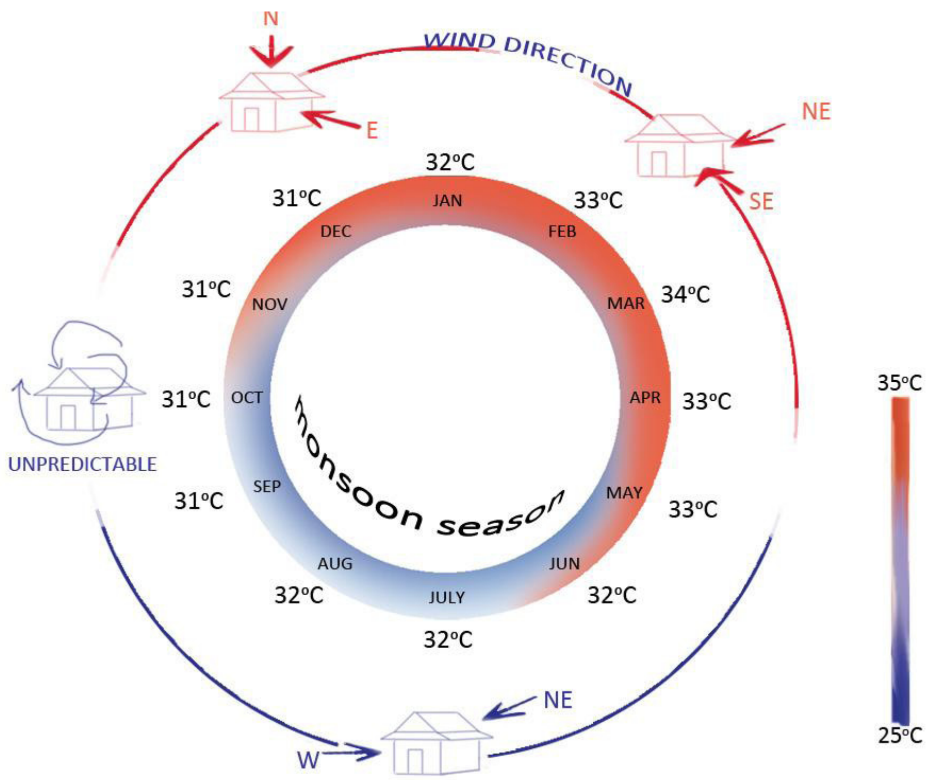

Figure 3 Graphical representation of monthly temperatures and wind direction in An Minh

SOCIETAL AND CULTURAL ISSUES

In general, the people of An Minh, like the general population of Vietnam, are united in friendship and would care for each other like one would care for their family. They are considerate of each others' feelings and reputation. Moreover, not only do they value respect for and from one another, they pay great respect to people with high positions in the village, which is a common value throughout the country.[10] Most importantly, they are very afraid of losing face thus are very careful of their delivery of speech, *for embarrassment will linger amongst the society, that can also be brought to the whole family.*[11]

Greatly influenced by Confucian principles ever since the invasion of the Chinese, the Vietnamese are left with a traditional and valuable sense of duty to their family and their society.[12] This value is seen in families as children grow up to work and earn income for the family. The strong relationship between family members is apparent as it is normal to have at least three generations, that is, the immediate and extended family, living together under the same roof.[13] It is also of the Vietnamese culture to have constant contact wherever they are and this carries throughout generations.

10 Vietnamese Culture and Tradition. 2006. *Vietnamese culture: Vietnamese Value System* . [ONLINE] Available at: http://www.vietnam-culture.com/articles-18-6/The- Vietnamese-Value-System.aspx. [Accessed 05 September 2012].

11 Ibid

12 Vietnamese Culture and Tradition. 2006. *Vietnamese Culture: Vietnamese traditional family values.* [ONLINE] Available at: http://www.vietnam-culture.com/articles-53-6/Vietnamese-traditional- family-values.aspx. [Accessed 05 September 2012].

13 Ibid

The Vietnamese culture is parent dominant. The elders of the family, including the ancestors are greatly respected, regardless of their economic and social status. The grandparents and parents are the ones to make decisions for the household. This attitude is expected of any Vietnamese, thus no form of condescending is to be tolerated. *In addition, discipline for both the wife and the children is highly stressed and beatings will not be considered abuse but love and care and for the good of the family*.[14]

Language is an important aspect to be aware about as certain language is reserved to a particular person *depending on their relative age, status in society, their gender and relationship* in order to be considerate of the reputation of others, and if negative comments were to be said, it will be said very indirectly. Even the names of people cannot be addressed in speech unless relatively younger, otherwise it shows disrespect.[15]

ETHICAL ISSUES

Ethical principles in Vietnam are generally set from Confucianism (the basic virtue of filial piety) and Buddhism (the eightfold path - there are eight "right" ways to live virtuously). With Vietnamese culture having many Eastern values, it is greatly different to values within Western culture. Vietnamese life primarily revolves around the family, with the father being considered the head of the family. From this, it is therefore the father's responsibility to make important decisions.

Moreover, in Vietnam, *there are many vague and loose regulations and in the past, many foreign companies have used this to their advantage by cutting costs and being inconsiderate to the local residents and their surroundings*[16]. In the interest of the local residents and their surroundings though, it is preferable to respect their values and make decisions for their benefit.

One primary concern however, is that there is a high percentage of people living in Vietnam that *do not grasp the true meaning of ethics, such as maintaining the belief that stealing is acceptable*[17]. With such circumstances, the best means to resolve any possible issue is to outline what the ethical implications may be. If any of their values, morals and beliefs is violated, it could lead to signs of disrespect and cause obstructions to progress.

14 Opcit

15 Vietnamese Culture and Tradition. 2006. *Vietnamese Culture: Social Relationships*. [ONLINE] Available at: http://www.vietnam-culture.com/articles-57-6/Social-relationships.aspx [Accessed 05 September 12]

16 kwintessential. 2012. *kwintessential*. [ONLINE] Available at: http://www.kwintessential.co.uk/resources/global-etiquette/vietnam.html. [Accessed 05 September 2012].

17 Ibid

ECONOMIC ISSUES

In general, since Vietnam has launched the “doi moi” policy in 1968, socio-economic conditions of the country have improved for a majority of the population. However, Mekong Delta still remains as a less developed economic region. *Mekong Delta’s GPD (gross domestic product) is equivalent to two thirds of the country’s average, with the quality of living standards compared to other regions being poor*[18]. The rate of people living in short-lived houses is the highest in the country and this is due to the economic issues many of the residents face.

According to statistics, *around 50% of households have daily earnings of US$1 or less per person, with some even earning as little as US$0.30 a day. Some earn 2.4 millionVND (US$100) a person each year, or even less at around 200,000VND (US$2) a person each month*[19]. Accordingly, *poor households account for 18-20% of the region*[20]. Nam Sang, a local resident complains that “the prices for everything, including school fees and spending for books, rise, except for income”[21], exemplifying why many families struggle with financially supporting their families. With the *rate of poverty being accounted for as 28.9% in 2002*[22], Mekong Delta experiences great economic difficulties. Therefore, to many of the residents, how money is spent is greatly restricted. Where possible, residents will implement other means, such as growing their own crops to avoid spending money.

18 Vietnam Net Bridge, Special Reports, 2011, *Lying on a field of gold, the Mekong Delta still poor.* [ONLINE] Available at: http://english.vietnamnet.vn/en/special-report/10741/lying-on-a-field-of-gold--the-mekong-delta-still-poor.html. [Accessed 05 September 2012]
19 Ibid
20 Opcit
21 L. Robert; Mai Van Nam, Economic Development of the Mekong Delta in Vietnam, *CDS Research Paper No. 27 December 2008.* [ONLINE] Available at: http://www.rug.nl/gsg/Publications/ResearchReports/Reports/Vietnam3.pdf [Accessed 05 September 2012]
22 Ibid

ENVIRONMENTAL ISSUES

During flood season, Mekong Delta is affected by overbank flooding which can exceed 1 metre in depth. Within Mekong Delta, floods have a great capability to constrain human habitation and economic development. The severity of the floods results in great damage within the region, particularly due to the low elevation and relief of the delta plain.

1.6 million hectares within the Mekong Delta region is acid sulphate soils (ASS)[23] and there have been many recent issues that have occurred from it, particularly due to large-scale water-control projects such as the construction of canals. However, the main issue that has arisen from the impact of ASS is the acidification of soils and waterways. The heavy seasonal rainfall ameliorates the accumulation of soil acidity and as such, it hinders the crop cultivation over a large area of the Mekong Delta region. Therefore in certain areas, only acid tolerant crops such as pineapple, cashew and yam can be grown. Rice, one of the main crops that are grown within the region does not grow well under these conditions and has therefore suffered low yields or total failure. Likewise, waterways are also affected due to the mass flushing of acid into them at the commencement of the wet season. Such an incident results in "extreme fluctuations in water quality and chemistry."[24]

"Because most of the region is on average only a few metres above sea level and because any increase of sea level will change the complex relationship between tides and down-river water flow, the Mekong Delta is one of the areas in the world most vulnerable to the effects of climate change."[25] As a result, changes in the flow of the Mekong Delta river will affect the ecology of fauna and flora within the region, which can have flow on effects for the community and economy.

23 Hashimoto, T. ,WORKING PAPER SERIES Working Paper No. 4.June 2001, *Environmental Issues and Recent Infrastructure Development in the Mekong Delta: Review, Analysis and Recommendations with Particular Reference to Large-scale Water Control Projects and the Development of Coastal Areas*. [ONLINE] Available at: http://sydney.edu.au/mekong/documents/wp4.pdf. [Accessed 05 September]

24 Ibid

25 Stewart Mart A.; Coclains, Peter A., *Environmental Changes and Agricultural Sustainability in the Mekong Delta*, Series: Advances in Global Change Research, Vol 45, 1st edition 2011. [ONLINE] Available at: http://www.springer.com/environment/book/978-94-007-0933-1. [Accessed on 05 September 2012]

HOUSE PLAN

Due to the lack of literature related to the housing in the An Minh District we have made the assumption that the houses in this area can be represented by the general housing seen in the Mekong Delta within the same demographic class. From the images presented by the EWB challenge we can gauge that the typical houses in the An Minh district are similar to the "Bát dần" or "Ba gian" typology[26]. They seem to present themselves as one large space under a gable roof that spans the whole house, sometimes with partitions to separate particular spaces. Under the single roof are the living/family, kitchen, dining, bedroom and storage spaces. The majority of houses are built on stilts or higher ground to reduce the chance of flood damage, whilst the simple typology of the house makes it easier for repairs to be made in the event of flooding.

To facilitate the design process we made the assumption that the houses in the An Minh district were similar to the "Ba gian" typology simply because of its more open plan layout which is comparable to the photos present on the EWB website.

Typical house size varies due to the economic capabilities of the owner, however we will assume a house size of 6m x 8m including the verandah. With a typical house height of 4m measured from the ground to the crest of the roof.

Houses in the An Minh district do not have a preferred orientation in terms of true bearing, however from maps of the region we found that houses tend to be orientated to be in line or close to in line with the river or canal that they are built along.

26 Van, N.K 2012, Adaptation of Land Use and Houses in the Upper Mekong Delta's Deep Flooding Area, Dept. of Architecture, National University of Singapore, Singapore

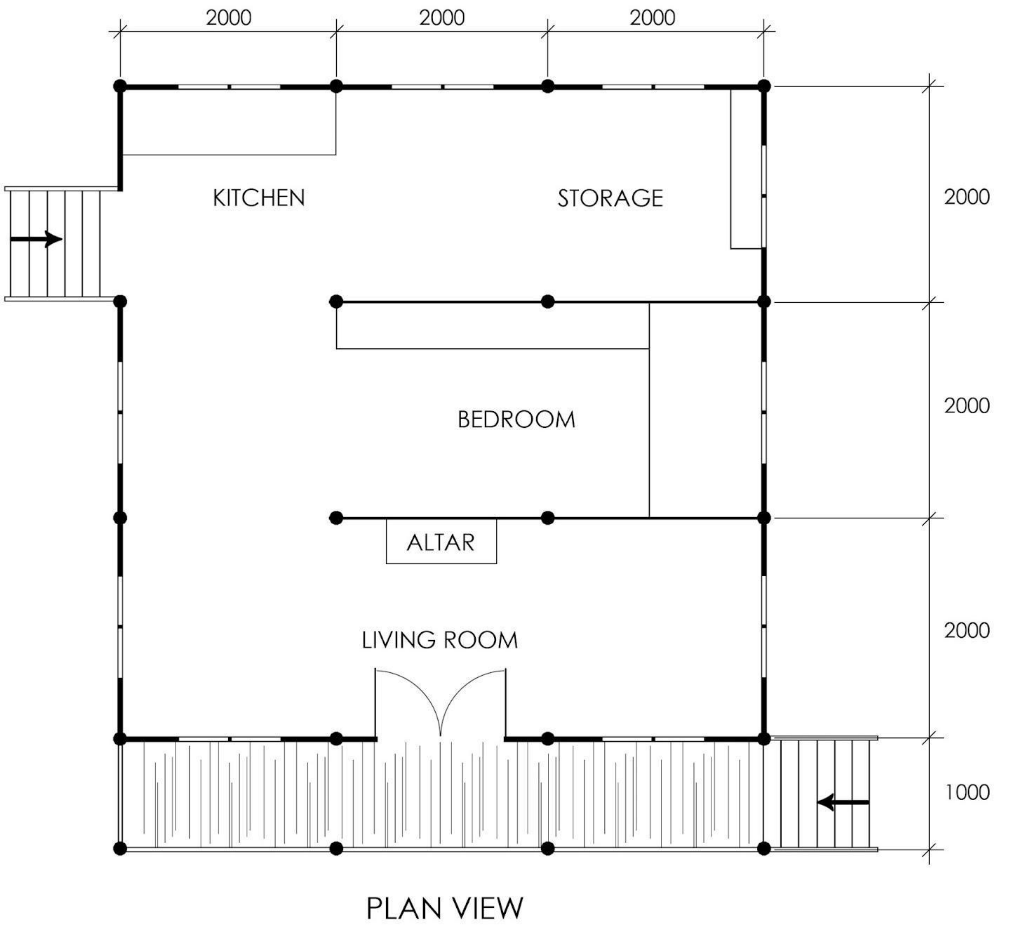

Figure 4 Plan view of typical An Minh House, adapted from Van, N.K 2012

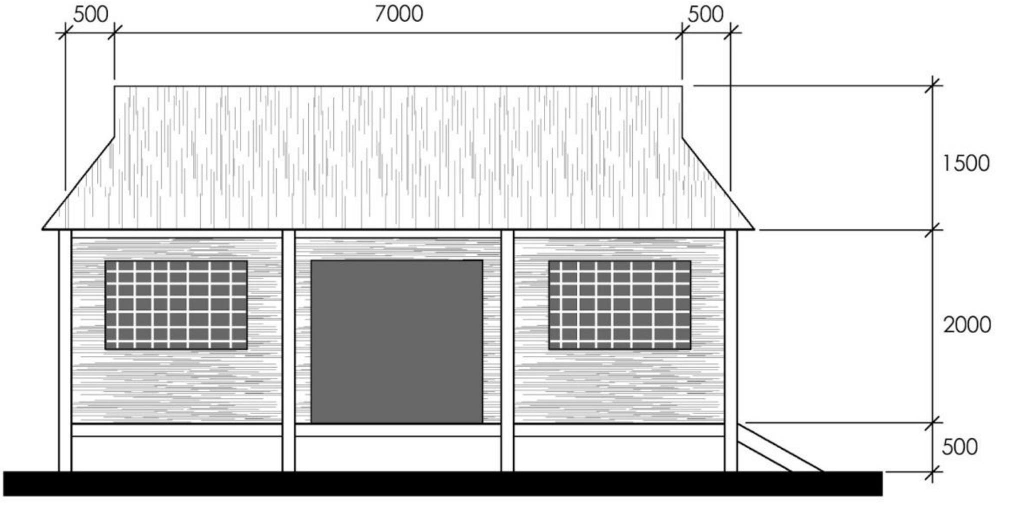

Figure 5 Front elevation of typical An Minh house, adapted from Van, N.K 2012

IDEAS AND TECHNOLOGIES

SOLAR CHIMNEY

A solar or thermal chimney is a form of natural ventilation that utilises natural convection to cool down a building and keep the air from becoming stagnant. *A solar chimney is basically a narrow configuration or a chimney, with an interior lined with heat absorbing material, glazed front and a vent above roof level that allows hot air to escape*[27]. The chimney is commonly coloured black to maximise heat absorbance. Air is heated within the solar chimney with sunlight to a heat greater than that of the atmosphere. This is done with the metal conductor inside the chimney. The heated air will naturally rise out to the atmosphere from the chimney, and the air within the other regions of the house will naturally flow towards the chimney to replace the lost air, therefore allowing a constant movement of air from an opening (such as a window) to the chimney and cooling the house through natural convection currents.

Disadvantages of using a solar chimney however, is that it is mainly effective during the day and will not operate at night. Also, the heat generated inside the chimney would not create a large difference between the air inside the chimney and the rest of the house, therefore the pace of the airflow is much slower than a breeze, resulting in less ventilation. Additionally, *in cold weather, the thermal chimney would continue to reduce the temperature of the house unless the vent can be closed*[28]. In more modern designs, the vents can be closed if the temperature is cool and the air that is heated can be forced back into the house with a fan or turbine, however, this detracts from the solar chimney's initial appeal being a form of ventilation that requires no energy to operate.

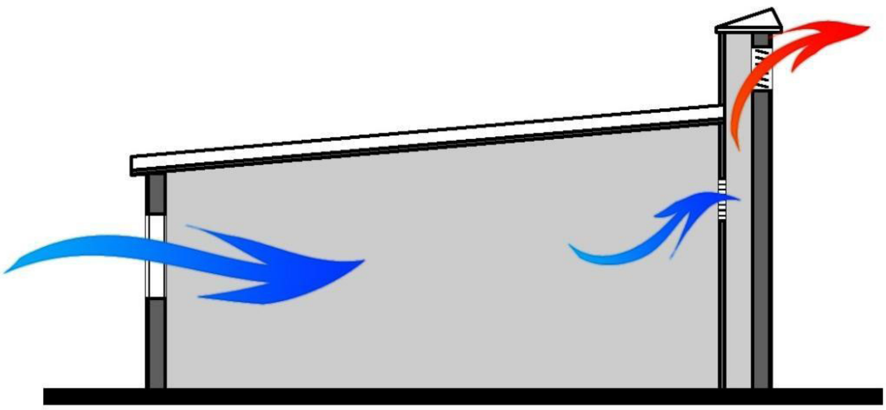

Figure 6 Section of house showing solar chimney facilitating cross ventilation, the solar chimney exhausts warm air and takes in cooler air from inside the room

27 ResourceSmart, *Ventilation system: Solar Chimney*, 2012. [ONLINE] Available at: http://www.resourcesmart.vic.gov.au/documents/solar_chimney.pdf [Accessed 15 September 2012]

28 Y. Kaneko, K. Sagara, T. Yamanaka, and H. Kotani, 2005, *Ventilation performance of solar chimney with built - in latent heat storage* [ONLINE] Available at: http://intraweb.stockton.edu/eyos/energy_studies/content/docs/FINAL_ PAPERS/4B-7.pdf [Accessed 15 September 2012]

Design Criteria	
Improve comfort levels	✓
Improve health	✓
Improve air ventilation	✓
Can be made from natural, local or recycled materials	✓
Easy to build design	
Animal, insect and weather proof	✓
Does not interfere with Vietnamese architecture	✓
Does not introduce too much change	

STACK VENTILATION

Stack ventilation is a method used for centuries to create natural ventilation and prevent air from being stagnant. Air moves vertically through the building driven by the pressure imbalance caused by the escape of hot air from the building. Hot air is less dense than cold air and rises up to the top of the building. The openings at the top of the building allow hot air to escape and the openings at the bottom of the building allow the cold air to enter. However, the air entering the building must be continuously heated for air movement to be continuous. This technology depends not only on the temperature difference between the outer surroundings and within the building, but also the height of the building and the area of the openings. The benefit of this technology is that it does not rely on wind and operates on a still day.

Unless the houses in An Minh are tall buildings with a temperature difference within the building significantly greater than the outside temperature, this technology would not be efficient. However, we can learn from this technology that creating a pressure difference leads to movement of air, which may be incorporated into any ventilation technology to increase its effectiveness.[29]

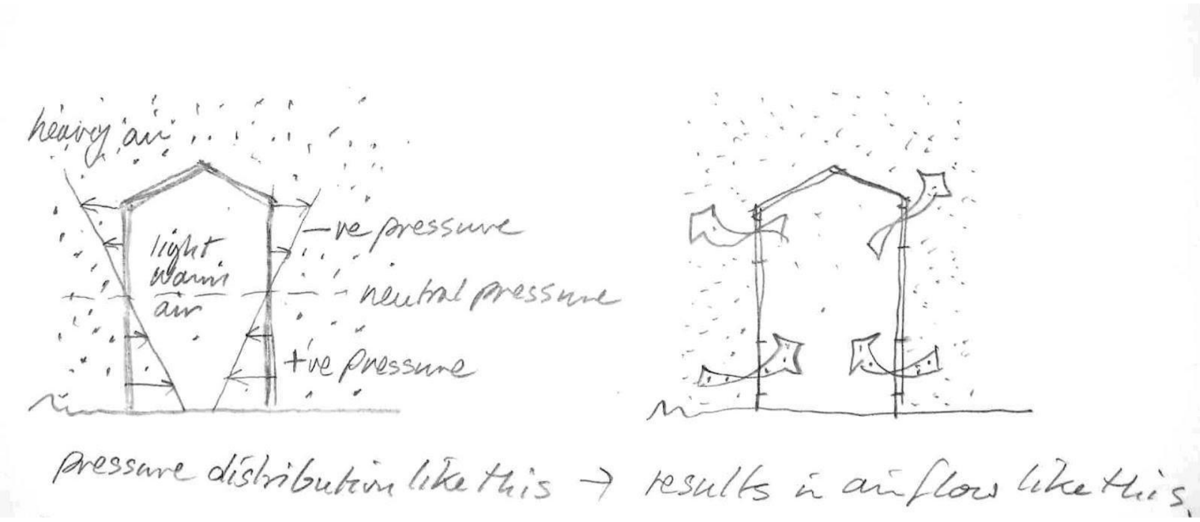

Figure 7 Illustration of stack ventilation (Image URL: http://www.architecture.com/SustainabilityHub/ Designstrategies/ Air/1-2-1-2-Naturalventilation-stackventilation.aspx.)

29 Nick, B, Royal Institute of British Architects, *Natural Ventilation: Stack Ventilation*, 2011. [ONLINE] Available at: http://www.architecture.com/SustainabilityHub/Designstrategies/Air/1-2-1-2-Naturalventilation-stackventilation.aspx [Accessed 05 September 2012]

Design Criteria	
Improve comfort levels	✓
Improve health	✓
Improve air ventilation	✓
Can be made from natural, local or recycled materials	✓
Easy to build design	
Animal, insect and weather proof	
Does not interfere with Vietnamese architecture	
Does not introduce too much change	

LOUVRES

Traditionally, windows are used as a simple solution to providing natural ventilation. As most houses have windows, it is possible to modify them to provide an even more efficient solution to natural ventilation. Typical windows, such as the single-hung sash window (Figure 8.a) are limited as only half the window can be utilised for ventilation.

Louvres (Figure 8.b) are a type of window that has horizontal slats which can be adjusted at angles. Unlike the single-hung sash window, the window style has a 100% open area, allowing the entire window space to be utilised, to let air enter the house. Louvres can be precisely angled to control how much air/wind will enter the home such as having them opened fully on hotter days and opened partially on cooler days. Another advantage is the ability to direct airflow upward or downward.

With the use of louvres, windows placed on opposite sides of the house will allow fresh air to enter from one side of the home and stale air exit from the other, implementing cross flow ventilation. By implementing cross flow ventilation it will naturally cool the house and also remove stale air and therefore, stop mould from forming which would therefore prevent any potential health problems.

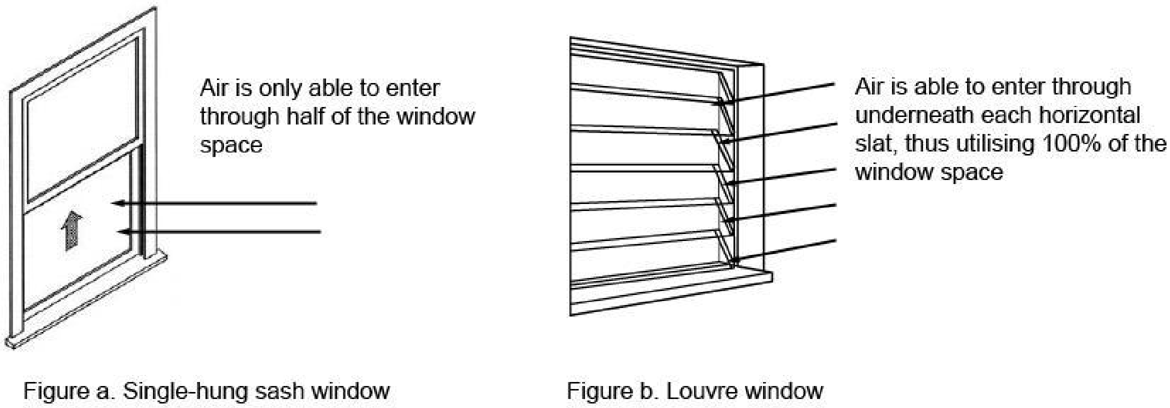

Figure 8 Comparison of single-hung sash window and louvre window

Design Criteria	
Improve comfort levels	✓
Improve health	✓
Improve air ventilation	✓
Can be made from natural, local or recycled materials	✓
Easy to build design	
Animal, insect and weather proof	✓
Does not interfere with Vietnamese architecture	✓
Does not introduce too much change	✓

CROSS VENTILATION

Cross or natural ventilation is a strategy where air circulates the house through infiltration pathways such as windows, and doors. It is a natural way for which cool air displaces warm air out of the house due to pressure differentials. Its success depends on two continuously changing, and often uncontrollable, factors: wind availability and wind direction. The positions of inlets and outlets of airflow are critical to harness this natural process.

To maximise the effectiveness of openings, narrow buildings with open plans and well placed openings work best; that is, the longest faces of the building are perpendicular to the typical wind direction. Furthermore, single-loaded corridors (rooms only on one side of a corridor) will provide better airflow than double-loaded ones as it provides openings on opposite walls. The amount of air moved will be directly proportional to the size of the inlet and outlet openings. As a rule-of-thumb, an inlet is useful for cross ventilation if the direction of wind flow is in the range of -45 degrees to 45 degrees to the surface normal of the window.[30]

Driven by natural means, it is effective only when the outside temperature is lower than the inside temperature of the house. When a natural breeze is not possible, reflecting the major downside of cross-ventilation, it still works in conjunction with a solar chimney or an electric fan.[31]

In addition, privacy concerns need to be considered when employing cross ventilation. Inlet and outlet openings may be positioned throughout the house to harness the optimal amount of natural ventilation, but areas like the bathroom must not be overexposed. Hence, there is a need for prioritisation on privacy and the amount of air that infiltrates various sections of the house to achieve the best ventilation outcome.

30 Tomoko Sekiguchi. 2012. *Cross Ventilation.* [ONLINE] Available at: http://pages.uoregon.edu/esbl/es_site/student_option/explanations_folder/cross_ventilation.htm. [Accessed 12 September 12].

31 Technical Manual, Design for lifestyle and the future, 4.6 *Passive cooling, Climate specific design principles.* [ONLINE] Available at: http://www.yourhome.gov.au/technical/fs46.html. [Accessed 12 September 12].

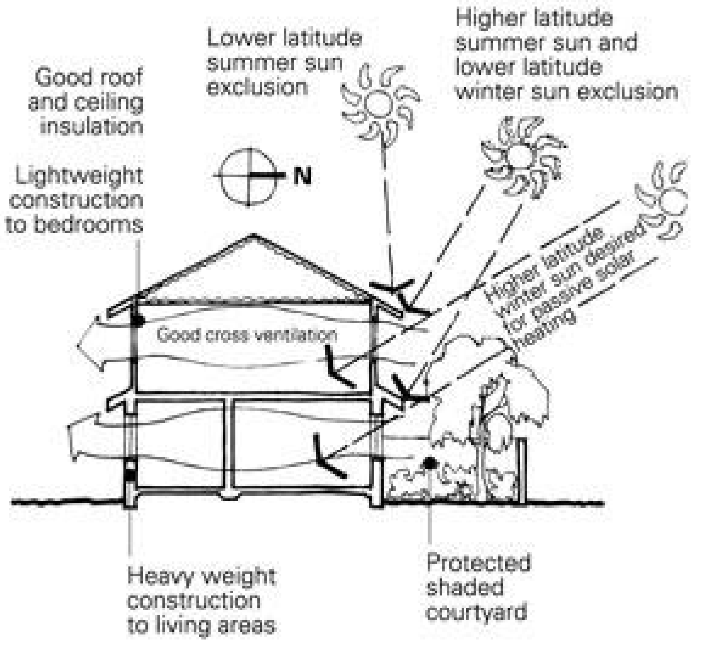

Figure 9 An example of good cross ventilation (Image URL: http://www.yourhome.gov.au/technical/fs46.html)

Design Criteria	
Improve comfort levels	✓
Improve health	✓
Improve air ventilation	✓
Can be made from natural, local or recycled materials	✓
Easy to build design	
Animal, insect and weather proof	
Does not interfere with Vietnamese architecture	
Does not introduce too much change	

CANOPY ENTRANCE VENTILATION

Canopy entrance ventilation is a form of cross ventilation which allows a breeze to be brought through an entrance opening, while displacing the warmer air through an exit opening. While wind can still pass through an opening in the wall, a canopy directs the air through the opening without too much turbulence. It is possible that by placing the entrance opening lower on the wall and the exit opening at a higher point, warm air rises in the process of convective ventilation which will occur during periods of no wind.

A canopy before the entrance of an opening will allow a breeze to be funnelled through the opening. This generally causes the air to be directed upwards and across the room[32]. The living space is at the bottom of the room, so the opening needs to be placed at the bottom of the wall to be effective in displacing the warmer air at the bottom of the room.

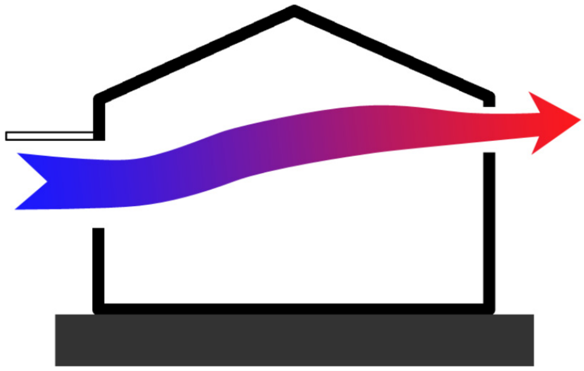

Figure 10 Canopy before entrance opening directs airflow upwards

However, if a gap is introduced between the canopy and the wall, higher pressure created at the top will force the air to flow downwards, which is ideal to cool down the living area. This may still leave the top of the room warm.

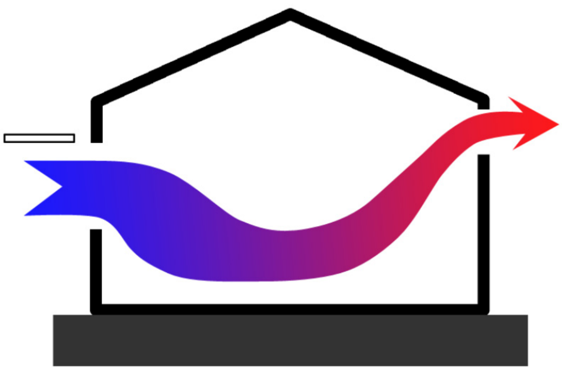

Figure 11 A gap between the canopy and wall directs airflow downwards

32 EJCR, 2012, Natural Ventilation, Cooling and Home Design, *Types of natural ventilation: cross, stack and induced.* [ONLINE] Available at: http://www.house-energy.com/Cooling/Ventilation-Cross-Design.html [Accessed 03 September 2012]

A canopy with several gaps will create alternating pressures which will direct airflow upwards and downwards across the room. This creates a more uniform flow of air through the room, and keeping a consistent room temperature without an uncomfortable draft.

Figure 12 Multiple gaps directs airflow up and down

It is also possible that by having water below the entrance opening, the warmer air passing over it will cool down before entering the house, as the air absorbs the cooler water. However, this may not work well due to the humidity of the air in the An Minh district.

Design Criteria	
Improve comfort levels	✓
Improve health	✓
Improve air ventilation	✓
Can be made from natural, local or recycled materials	✓
Easy to build design	
Animal, insect and weather proof	
Does not interfere with Vietnamese architecture	✓
Does not introduce too much change	✓

ROOF AND WALL INSULATION

The hot and humid region of South-East Asia brings about the need for adequate ventilation and insulation from the heat. For this reason, the people of An Minh should not be excluded from having a comfortable home in such conditions. Research in Japan shows that the technique of double roofing controls the amount of heat that can enter the house. This technique reflects 74% of combined radiation and convection; 24.8% is lost by convection into the layer of air between the two roofs and only 0.7% of heat is transferred by conduction, as opposed to 6% through the usual single roof as shown in Figure 13 below. [33]

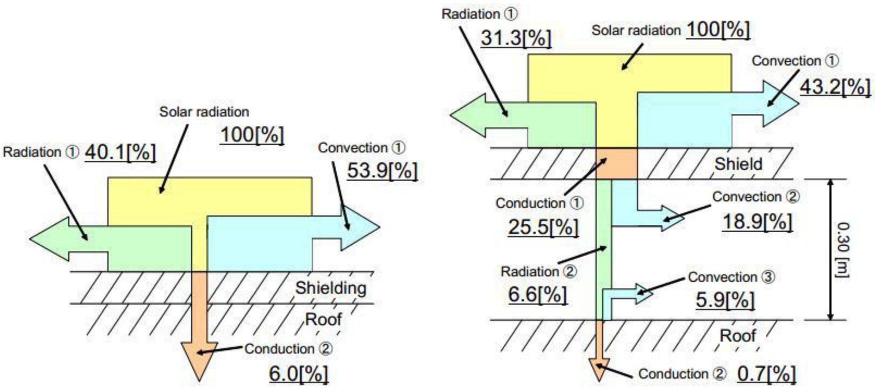

Figure 13 Heat distribution in double roof Note 6% conduction of solar radiation into the room with a single roof and 0.7% with a double roof (Image URL:http://alexandria.tue.nl/openaccess/635611/p0648final.pdf)

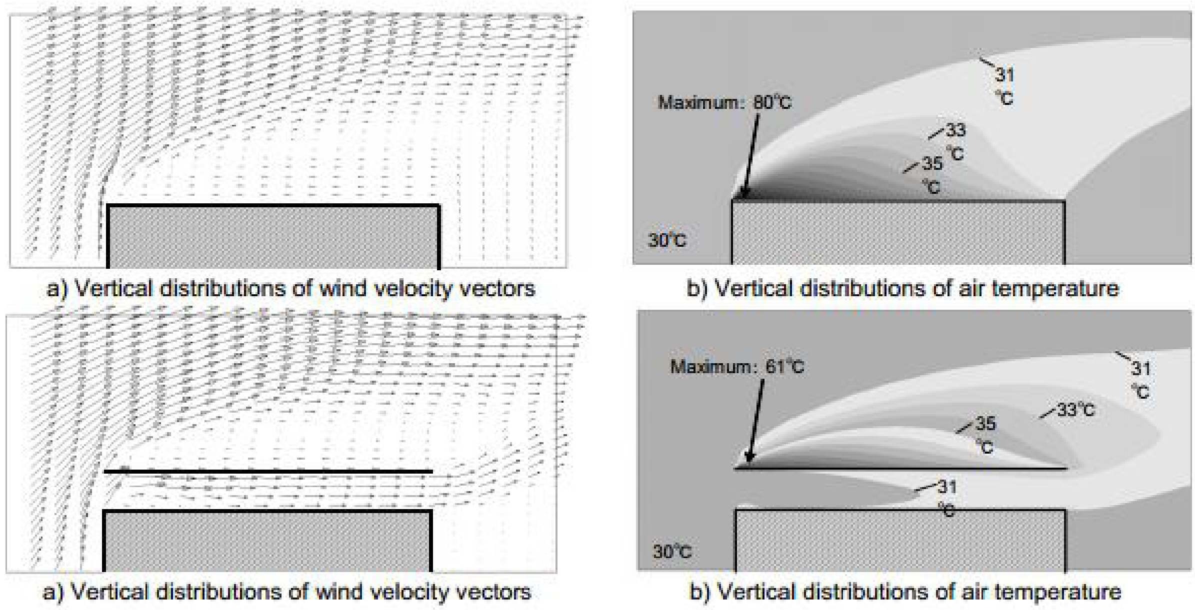

Figure 14 Distribution of wind velocity and air temperature with and without a double roof (Image URL:http://alexandria.tue.nl/openaccess/635611/p0648final.pdf)

33 Yasuyuki, S et al., 2004. *"Study on thermal shielding effect of double roofing with air passage by coupled simulation of convection and radiation"* Eindhoven, The Netherlands [ONLINE] Available at:http://alexandria.tue.nl/openaccess/635611/p0648final.pdf [Accessed 04 September 2012]

Otherwise, the temperature that can increase in a certain region of the roof can reach up to 61°C as depicted in Figure 14. [34]

Below is a formula to calculate the rate of airflow:

$$V_H = \frac{\left(\sum_{i=1}^{n} U_i \times \Delta X_{2,i}\right)}{H}$$

V_H[m/s] = air flow rate per unit sectional area of the air passage. [35]

This system works best when wind velocity is greater than 1.0m/s but also works under conditions with no wind. When the ratio of the height of the separation to length of the roof is more than 0.1, temperature rise does not increase past 3°C. This technology limits temperature rise of the house, however it does not lower the temperature within the building.

Below are cross sections of the double roofing on a double sided roof and a single sided roof.

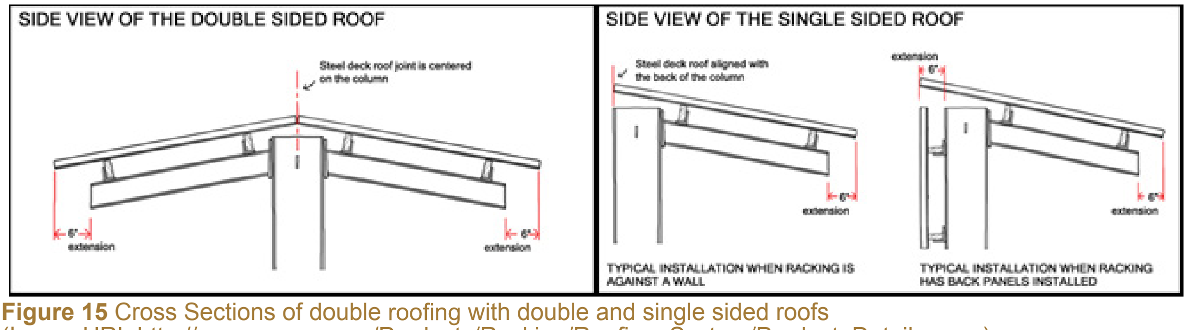

Figure 15 Cross Sections of double roofing with double and single sided roofs
(Image URL:http://www.cogan.com/Products/Racking/Roofing_System/Product_Details.aspx)

Design Criteria	
Improve comfort levels	✓
Improve health	✓
Improve air ventilation	✓
Can be made from natural, local or recycled materials	✓
Easy to build design	
Animal, insect and weather proof	✓
Does not interfere with Vietnamese architecture	
Does not introduce too much change	

34 Yasuyuki, S et al., 2004. *"Study on thermal shielding effect of double roofing with air passage by coupled simulation of convection and radiation"* Eindhoven, The Netherlands [ONLINE] Available at:http://alexandria.tue.nl/openaccess/635611/p0648final.pdf [Accessed 04 September 2012]

35 Ibid

CASEMENT WINDOWS

Ventilation is directly related to the amount of open area there is for air to pass through and into the building. Casement windows have an effective open area of 90%[36] allowing for a large amount of airflow per window area. Casement windows operate best with consistent wind flow, the strategic opening of windows to a particular wind direction can maximise the amount of wind that can be 'caught'. Opening casement windows on the same side of a house but having one hinged on the left and the other on the right acts well to direct wind into a room and out again particularly if cross ventilation cannot be achieved[37].

Figure 16 Casement Window
(Image URL: http://timbawindows.com.au/content/wp-content/uploads/2011/08/casement-window.jpg)

Design Criteria	
Improve comfort levels	✓
Improve health	✓
Improve air ventilation	✓
Can be made from natural, local or recycled materials	
Easy to build design	
Animal, insect and weather proof	
Does not interfere with Vietnamese architecture	✓
Does not introduce too much change	✓

36 U.S. Department of Energy, 1997, Selecting Windows for Energy Efficiency, U.S Department of Energy, USA
37 Walker, A 2010, *Natural Ventilation*, WBDG. [ONLINE] Available at: http://www.wbdg.org/resources/naturalventilation.php. [Accessed 03 September 2012]

WHOLE-HOUSE VENTILATION

Whole-House Ventilation involves the use of one or more fans and duct systems to exhaust stale air, and supply fresh air to the house. It is able to supply air in a controllable manner, and reduces infiltration of pollutants, thereby maintaining adequate indoor air quality at all times. Unlike natural ventilation, air exchanges are not subject to wind availability and directions.

It is categorised into three functions:

1. exhaust ventilation if the mechanical system forces inside air out of the home
2. supply ventilation if the mechanical system forces outside air into the home
3. balanced ventilation if the mechanical system forces equal quantities of air into and out of the home

Design Criteria	
Improve comfort levels	✓
Improve health	✓
Improve air ventilation	✓
Can be made from natural, local or recycled materials	
Easy to build design	
Animal, insect and weather proof	
Does not interfere with Vietnamese architecture	
Does not introduce too much change	

EVAPORATIVE COOLING

Evaporative cooling is a method of natural ventilation that utilises water to provide cooler air. This result is achieved through the evaporation of water, with the temperature of air decreasing *due to large amounts of heat being consumed by the water as it evaporates*[38]. It is most commonly used in climates with medium to low humidity as evaporative cooling requires a water source and must continually consume water to operate. Greater air movement will improve the rates of evaporation and therefore, provide a greater source of cooler air to enter the household. Design solutions for evaporative cooling include *the use of ponds, water features and pools that are placed directly in front of windows, to pre-cool the air before it enters the house*[39]. Figure 17 shows a pool within the courtyard of the house design, to cool the air by evaporation before it enters the household through the surrounding windows. Despite that evaporative cooling is a suitable method to cool any existing hot air before it enters a household, it is less possible to implement in climates with high humidity, such as Vietnam.

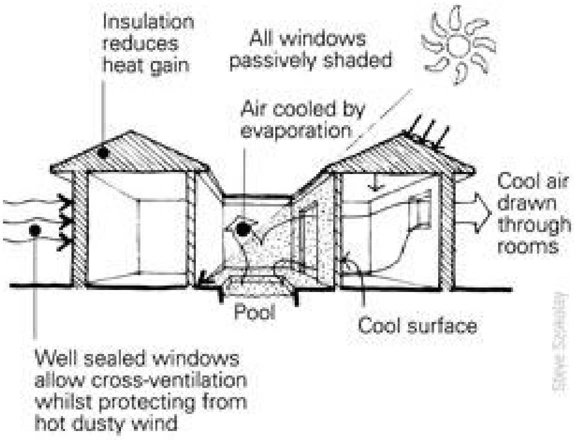

Figure 17 Passive cooling by a pool situated in a courtyard (Image URL: http://www.yourhome.gov.au/technical/fs46.html)

Design Criteria	
Improve comfort levels	✓
Improve health	✓
Improve air ventilation	✓
Can be made from natural, local or recycled materials	✓
Easy to build design	
Animal, insect and weather proof	
Does not interfere with Vietnamese architecture	
Does not introduce too much change	

38 Technical Manual, Design for lifestyle and the future, 4.6 *Passive cooling, Climate specific design principles* .[ONLINE] Available at: http://www.yourhome.gov.au/technical/fs46.html. [Accessed 12 September 12].
39 Ibid

DEHUMIDIFICATION

Improving air circulation will help to lower levels of humidity. The basic approach for this is to open windows to increase air circulation, including when showering and cooking, to avoid the build-up of steam and smoke. Residents should be informed of this and practise it when necessary. The house should also be examined, to see if there are any small cracks or openings that may allow for water to leak through. If any small openings are found, necessary corrective measures should be implemented, in order to prevent any excess moisture from around the home.

To naturally dehumidify the house, charcoal can be used to absorb moisture from the air. Because of its porous nature, charcoal will be able to readily absorb excess moisture from the air, especially if it is humid. *One gram of charcoal is believed to have an effective surface area of 250 m^2* [40] and while this large surface area is what makes it so effective in absorbing moisture, charcoal also has the ability to absorb air pollutants that may be present within the house.

Bamboo charcoal is an even more effective product to remove moisture from the air. It has four times the effective surface area of traditional charcoal.[41] Its appeal also comes from the fact that the Moso bamboo which the charcoal is made from is one of the fastest growing plants, taking only five years to grow from a seedling to maturity.[42] Its abundance within Vietnam and the speed at which it grows makes it an ideal source that is environmentally sustainable.

The production of the bamboo charcoal requires a heat treatment process which takes about two weeks. For the charcoal to work effectively it requires exposure to sunlight every two to four weeks to dry the charcoal, and will last one year.[43] This makes it a very attractive option for reducing the humidity within a house.

Design Criteria	
Improve comfort levels	✓
Improve health	✓
Improve air ventilation	✓
Can be made from natural, local or recycled materials	✓
Easy to build design	✓
Animal, insect and weather proof	
Does not interfere with Vietnamese architecture	✓
Does not introduce too much change	✓

40 Health & Eco, 2011, *Purify the Air with Bamboo Charcoal.* [ONLINE] Available at: http://www.healthandeco.com/2011/08/purify-air-with-bamboo-charcoal.html. [Accessed 12 September 2012]
41 Ibid
42 Hinzi Media, 2008, Dehumidifiers made from bamboo: Bamboo Charcoal Dehumidifiers.[ONLINE] Available at: http://www.infobarrel.com/Dehumidifiers_made_from_bamboo. [Accessed 12 September 2012]
43 Ibid

SUMMARY OF DESIGN CRITERIA

Design Criteria
1. Improve comfort levels
2. Improve health
3. Improve air ventilation
4. Can be made from natural, local or recycled materials
5. Easy to build design
6. Animal, insect and weather proof
7. Does not interfere with Vietnamese architecture
8. Does not introduce too much change

Ventilation Option	1	2	3	4	5	6	7	8	Score
Solar Chimney	✓	✓	✓	✓		✓	✓		6/8
Stack Ventilation	✓	✓	✓	✓					4/8
Louvres	✓	✓	✓	✓		✓	✓	✓	7/8
Cross Ventilation	✓	✓	✓	✓					4/8
Whole-House Ventilation	✓	✓	✓						3/8
Canopy Entrance Ventilation	✓	✓	✓	✓			✓	✓	6/8
Roof and Wall Insulation	✓	✓	✓	✓		✓			5/8
Casement Windows	✓	✓	✓				✓	✓	5/8
Evaporative Cooling	✓	✓	✓	✓					4/8
Dehumidification	✓	✓	✓	✓	✓		✓	✓	7/8

Ventilation Option	Benefits	Constraints
Solar Chimney	Form of natural ventilation Removes hot air Works without wind	Only effective during day, will not operate at night Will continue to cool the house even in cold weather
Stack Ventilation	Form of natural ventilation Prevents air from being stagnant Removes hot air Works without wind	Depends on the height of the building Depends on the area of the openings
Louvres	Form of natural ventilation Uses existing window space Allows 100% open area Can control how much air/wind will enter the home Have the ability to direct airflow upward or downward	Can be difficult to build
Cross Ventilation	Form of natural ventilation Allows air to circulate the house	Depends on wind availability and wind direction, which are uncontrollable Depends on the plan of the house Effective only when outside temperature is cooler than interior temperature Can have privacy concerns
Whole-House Ventilation	Removes stale air and supplies fresh air to the house	Not a form of natural ventilation Uses one or more fans and duct systems
Canopy Entrance Ventilation	Form of natural ventilation Effective in displacing air throughout the room Can keep a room at a consistent temperature	Whilst cooling the room, it can still leave some areas warm
Roof and Wall Insulation	Controls the amount of heat that can enter the house Works without wind	Does not lower the temperature within the building Expensive and difficult to implement
Casement Windows	Form of natural ventilation Allows 90% open area Directs wind well	Only operates best with consistent wind flow
Evaporative Cooling	Form of natural ventilation Utilises water to provide cooler air Allows only cool air to enter the household	Only works effectively in climates with medium to low humidity Greater air movement is required for it work efficiently
Dehumidification	Can be utilised by natural means Lowers humidity levels	Charcoal needs to be dried at regular intervals

Considering the above ventilation methods for their benefits, constraints and relevance to the design criteria, it was found that louvres, solar chimney and dehumidification were most applicable to An Minh households. As most households within An Minh already have windows, modifying the windows into the louvre design would allow for 100% open area yet allow for control of wind flow most effectively (as opposed to casement windows and canopy entrance openings).

The solar chimney was also viewed as a desirable option. On still days the louvres would be hardly effective in providing natural ventilation as they rely on incoming wind. The solar chimney can then operate to provide ventilation through the house on these hot days when the sun is visible but there is no wind.

Dehumidification was the final option that was chosen, and is viewed as a necessity due to the high levels of humidity within An Minh. Whilst the louvres and solar chimney both provide a good means of natural ventilation they are limited as they cannot control air humidity. Therefore, dehumidification is required to lower humidity levels, in order to provide an overall satisfactory level of thermal comfort.

Implementing the three ventilation methods would allow for indoor air temperature to be reduced, alongside humidity levels. Such means would provide an indoor environment that is sufficiently cooler and thereby, more desirable for the residents to occupy.

ISSUES

MATERIALS

Residents currently repair their households once every two years and thus, a continual supply of materials is required. The current materials that are used include bamboo, *Melaleuca* wood and coconut leaves which are locally sourced and can be easily acquired. Other materials which last longer and are more robust but expensive include mortar, bricks, concrete and corrugated iron sheeting. Due to their high cost, they are less commonly used by the residents and should be avoided if possible. It is of the best interest for the residents to use materials that they commonly use, as they will be most familiar with such materials and therefore have fewer issues when it comes to other factors such as labour. The below outlines the social, environmental and economic issues that may arise as a result of the use of materials for our project.

MOSO BAMBOO

1. Social:

Bamboo charcoal is dusty and dirty, it is therefore unhygienic to place it where it may be reached easily by children. Since it must be kept at least 2m off the ground where it is most effective, this has the added benefit of having the charcoal kept away from children. The proposed solution would be to hang the charcoal from the ceiling so that the maximum surface area of the charcoal is exposed to moisture in the air. In the long run, the charcoal may be clogged or saturated with water. It must be placed outside to dry under the hot sun before being used again, which requires an element of labour to move the charcoal.

2. Environmental:

- Natural charcoal absorbs moisture just fine, but since the residents use it for cooking, it is very unlikely for them to use around 3kg of it to absorb water and provide comfort for the house. Since bamboo charcoal will be used, the charcoal produced from scarcer resources will not be used for dehumidification purposes. This will mean there is no net effect on the sustainability of other resources.
- Bamboo's fast growing property may cause an over population of supply, however this means that it can be used extensively without the concern of exhaustion of supply. Due to its fast growing rate, bamboo can be used for construction or many other purposes, replacing the use of wood. Bamboo is a sustainable resource, because *it reaches its maximum hardness at maturity in around 4-5 years, reaching amazing heights.*[44]
- The production of bamboo charcoal produces bamboo vinegar as a by-product. The vinegar comes from vapour emissions, which are distilled and collected. It can be used as an insect repellent as well as a natural disinfectant.

44 Jiang S., Bamboo Engineering Research Centre, Nanjing Forestry University, Dehumidifiers made from bamboo - InfoBarrel. 2008. *Bamboo Charcoal Dehumidifiers [Sustainable +Reusable +Recyclable] Purify by nature!* [ONLINE] Available at: http://www.infobarrel.com/Dehumidifiers_made_from_bamboo. [Accessed 04 October 2012].

- Parts of the bamboo that cannot be used in construction or any other applications are usually thrown away. These are the upper and lower cuts of the bamboo culm and the thicker branches. Instead of creating more waste, these can be turned into charcoal. However, waste matter from sliver units that consist of a large amount of particulate matter cannot be used to make charcoal.[45]
- 35.2 metres of Moso bamboo is required for the solar chimney and 18kg of raw bamboo is required to produce 3 kg of bamboo charcoal , provided it has the ability to absorb a moisture content of 10-12% of its own weight.[46]

3. Economic:

- It costs 4000VND per metre of bamboo. The solar chimney requires 32.5 metres of bamboo, therefore the total cost is 140,800VND. In addition, the cost to produce a kilogram of bamboo charcoal is 12,000VND, which brings the cost to 36,000VND.
- The total cost of bamboo culm used per house for both the solar chimney and the charcoal is 176,800VND. This is almost one person's average income per month (200,000VND). However, the cost can be offset by not using for fans and other electrical cooling devices as well as reducing the frequency of repairing wood that rots more quickly under humid conditions.

CORRUGATED IRON

1. Social:

- A corrugated iron roof is a common material used on houses and built 'toilets' over the rivers and canals. Some houses have walls made of patches of corrugated iron. Rather than buying a brand new piece of iron, older corrugated iron can be used for the solar chimney as it will conduct and radiate heat just as well.

2. Environmental:

- Seeing that thrown away metal can be put to good use, the environment has one less type of rubbish to fill its land. Putting metal to good use, in our case for the solar chimney, will influence the people to find other uses for metal, because they will see that using rubbish will reduce rubbish. This may introduce the idea of sorting their rubbish, recycling it or reusing it.

3. Economic:

- To buy a 2m^2 brand new piece of galvanized corrugated iron will cost the residents 240,000VND, which is about 12 USD. Even though it may be a one off expense, it is still considered expensive as unforeseen maintenance must be accounted for. However, scrap or recycled metal could still be used.

45 National Mission on Bamboo Applications(NMBA), *2012 Bamboo-based Charcoal Production* [ONLINE] Available at: http://www.bambootech.org/files/Charcoal.pdf [Accessed 06 October 2012].
46 Ibid

MELALEUCA WOOD

1. Social:

- Better positioning of the windows prevent the roof from blowing off the house, so this results in less use of resources for repair.
- Research of Buddhism beliefs does not suggest that repositioning of the windows, doors or a mystical object offends their belief, nor do they present as an invasion of space.
- The louvres which use the *Melaleuca* wood are easy to build and assemble, therefore maintenance requires low skill.

2. Environmental:

- The louvres requires the use of wood which they are already using for the construction of their house. This type of wood used is tough, *fire tolerant and does not rot under salty winds, however it is susceptible to saline conditions*[47]*.* It does not develop as fast as bamboo, as it only starts to bud after planting for 13-14 months, however, it grows very fast once budded, total nursery period is 3-6 months. The *Melaleuca* tree grows 2.3m in height and 70mm in diameter per year.[48]
- A louvre for each window requires 29 metres of timber, and a house with nine windows requires 261 metres. To promote sustainability of the environment, the timber should be sourced from plantations rather than natural forest.

3. Economic:

- The total cost of *Melaleuca* for the louvres is 195,750VND. However, the upfront costs will be offset by the lower maintenance required for the house as a result of the ability to control the air flow into the house, which reduces damage caused by monsoonal winds.

COST

As the residents generally have a low source of income, their expenses are restricted. The average income of a rural resident per annum is 5,210,000 VND, which is the equivalent of 260.50 USD. If a ventilation system that was highly-priced was introduced to the residents, it is foreseeable that they will reject the design. Therefore, it is in the best interest of the residents to implement a design that will use minimal cost. By spreading the implementation of the ventilation into stages, there will be a perceived decrease in the upfront costs for the households that choose to adopt the design.

47 AgroForestryTree Database, World Agroforestry centre, *A tree species reference and selection guide*, [ONLINE] Available at: http://www.worldagroforestrycentre.org/sea/products/afdbases/af/asp/SpeciesInfo.asp?SpID=18108. [Accessed 07 October 2012].

48 Doran, J.C., 1999. Melaleuca cajuputi Powell. In Oyen, L.P.A. & Nguyen Xuan Dung (Eds.): Plant Resources of South-East Asia. No. 19: Essential-oils plants. Prosea Foundation, Bogor, Indonesia. pp. 126-131.

TIME

Many households in the area rely on agriculture such as rice farming, raising fish and shrimp farms to support themselves[49] and provide for the greater needs of the region by supplying rice and fish stocks. The time consuming nature of these activities mean that the locals often lack the time required to manage their own homes. Because of the location of many of the houses along the canals, it is quite difficult to have visitors access the area, so the home-owners are left to deal with their own homes.

It is ideal as a design requirement to make it quick to install and have low maintenance so the locals do not see the addition of a ventilation system as a burden to their lives. If local labour is required to install the system, it is still ideal to have rapid installation so more of the systems can be implemented across the region.

SKILLS

The local community in the An Minh district would prefer to utilise their own skills in the construction and maintenance of their homes, which includes the utilisation of skilled local labour.[50] Since the people in the local area are often not equipped with the necessary skills, this effectively means that complex and advanced techniques often used in modern society may not be applicable to the locals in the area. Otherwise, the local builders will require formal education to build their skills, which, requires time and effort for training.

The alternative would be to implement a design that allows the homeowner to do it themselves. Many of the homes in the local district rely on agricultural skills to earn their living. However, as many of the homes within the region are maintained every two years, the residents are familiar with the process and skills required for maintaining their homes. As many houses do not have a proper ventilation system, introducing such a new concept may confuse some residents. Hence there needs to be an emphasis on the simplicity of the design to install, operate and maintain the ventilation system.

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49 Sumernet, 2012, *Livelihoods and Resource Use Strategies of Farmers in the Mekong Delta*. Challenges to Sustainable Development in the Mekong Delta: Regional and National Policy Issues and Research Needs. pp 78. [ONLINE] Available at: http://www.sumernet.org/MekongDeltaMonograph/6Chapter2.pdf [Accessed 05 September 2012]

50 EWB, 2012, *Housing Design and Construction.* [ONLINE] Available at: http://www.ewb.org.au/explore/initiatives/ewbchallenge/hfhewbchallenge/hfhhousing [Accessed 05 September 2012]

HEALTH

The health and general well-being of the district is generally poor, as many have to work for long periods of the day just to support their families. Diarrhoea and dengue outbreaks are the main health problems in the area,[51] possibly as a result of poor water quality. Since the housing in the district have several openings, mosquitoes and rats around the area may enter the dwellings and increase health concerns, with the possibility of diseases such as malaria being transferred.

In kitchens, open fires fuelled by charcoal and wood presents a health risk if the smoke and ash released is not cleared adequately by proper ventilation. This is further compounded by the fact that most people in the village area simply burn all their rubbish in a pile. Since the rivers and canals are the primary way of disposal of rubbish and human waste, the products that have been farmed from the waters such as fish and shrimp pose a risk to the well-being of the locals.

ETHICS

In reference to our project, the guidelines to professional conduct by Engineers Australia are a helpful tool in recognising the ethical issues regarding our design. Knowing that the information that our judgement relies on is limited, we know that there are inherent flaws in our design which may not become prevalent until we engage with the community of An Minh, and so we adhere to the relativistic approach. It helps our design to be adaptable and flexible to the situation of physical constraints or community requests.

Invariably, engineers will be confronted with ethical dilemmas in their projects. These may arise from pressure to falsify results and overlook safety margins as a result of cost and time constraints, or ignoring technical faults to protect reputation. Ethical responsibilities must be taken into account, where engineers have a duty of care for their work, and for the health and safety of others as a whole. In the course of our project, we are aware of the following issues and mindful to avoid them if they should arise:

1. Often, incentivised by money or reputation, engineers overreach projects beyond their competencies. Therefore, part of the ethical responsibilities of engineers is to recognise their personal limitations and stay within their professional competencies, as well as owning up to any design failures or mistakes. This exemplifies Code 1 of Engineers Australia's Code of Ethics: demonstrate integrity. Focusing on section 1.1 - act on a basis of a well formed conscience, by acting impartially and objectively it will ensure that the community of An Minh will gain more benefit than what the benefit an engineer would receive from a 'successful community project'.

51 EWB, 2012, *Field Interviews.* [ONLINE] Available at: http://www.ewb.org.au/resources/download/2419P2012-02-27_21:03:41 [Accessed 05 September 2012]

2. In recent years, there have been an increasing emphasis on international business ethics. Due to globalisation and technologies, the engineering profession - along with many others - have found a global market, where projects overarch across the globe. Thereby, engineers may often be working under different cultures, and so it is worthwhile to develop sensitivity to different social norms. Section 1.3 of Engineers Australia's Code of Ethics is highly relevant and has been persistently considered through the course of this project. By understanding the ethics of Vietnamese culture, the overall basis of the project has developed even more effectively, morally, and ethically.

Governed by various forces at work, prudent strategy is sought to marginalise potential breaches of ethics. Considering the hot climate in An Minh, a good ventilation system will improve comfort and have flow on effects to the rest of their lives. In developing the design, there has been consideration for the social and cultural issues of the district and an informed decision was made in the approach to the design of the ventilation system. The design process has been conscious of the need to respect the inherent value of existing systems and the knowledge of the An Minh people. This impacts on the implementation process of the design.

The plans to improve the houses in the An Minh district will bring a greater level of comfort in houses, however the solution cannot be forced onto them. This means that the community's expectations should be upheld. Knowing the need for a better ventilation system, however means that we do need to emphasise the need to negotiate between community and team expectations for development to occur. Due to thorough consideration of the social, cultural and economic context of An Minh, the chances of a compromise occurring is slim. In situations of conflict a compromise can be reached through honest cooperation and effective communication between the team and community.

By overseeing the myopic decision-making presented dilemmas, incentives, and cultural sensitivities, our project will uphold personal, professional and societal integrity for the greater benefit of the An Minh community.

SUSTAINABILITY

Sustainability requires engineers to consider the scarcity of energy and resources, and ensure that they are used in the most efficient manner. They must take into account ecological, economic and social efficiency, which entails the prevention of natural environment degradation to ensure intergenerational equity, as well as meeting the social and economic objectives of their work[52] (refer to Appendix I). In considering the materials and methods used for the project, there is a need to promote sustainability by engaging with the community on all levels so that the community will have a unified vision of the project goal. This allows for the goal to be continued even after the initial team is done. In addition, the use of sustainable materials will ensure the objects of environment conservation and efficient waste emission are achieved. For instance, the use of bamboo has little impact on diminishing resources, for it can be used extensively without the danger of exhaustion of supply.

Engineers have the responsibility to practise sustainable developments, which leads to intergenerational and intragenerational equity. Equivalently, these are guidelines that ensure the activities of a generation of people do not compromise the environmental resources for the next generation of people. In our project, the production of bamboo charcoal results in bamboo vinegar as a by-product from the emissions of vapour that are distilled and collected. Not only does it provide economic value, but it is also environmentally friendly since it achieves intergenerational equity. This means that future generations can still take advantage of bamboo as a resource and thereby it is a feasible option of sustainable development.

Sustainability demand engineers to take into account not only the explicit costs of their project, but also the implicit costs of their actions on future generations and on society. In all, the viability of a project is judged by its ecological integrity, resource conservation, waste emission limitation, and industrial ecology, whilst accounting for the costs and benefits for all stakeholders. Throughout the course of our project, from material choice, design and implementation, in conjunction with heightened community awareness, we promote such sustainability objectives.

52 Dr. M.R.M. Crul and Mr. J.C. Diehl, *Design for Sustainability,* [ONLINE] Available at: http://www.unglobalcompact.org/docs/issues_doc/Environment/climate/design_for_sustainability.pdf. [Accessed 6 October12]

DESIGN SOLUTION

Our proposed design solution will approach the issue of improving the comfort levels within houses in a three stage process. Firstly by maximising the effectiveness of natural ventilation through the installation of louvres, secondly by the reduction of humidity through the use of passive bamboo dehumidifiers and finally through the use of a solar chimney for the promotion of airflow on hot and still days.

LOUVRES

The use of cross ventilation is crucial in regulating the temperature of a house, it is governed by wind availability and wind direction. Cross ventilation thus will vary at different times of day and indeed the year, affirming the need for adjustable openings to control the occurrence of cross ventilation. A louvre system can effectively and easily deal with the changing wind directions that occur in the An Minh district.

Our design solution seeks to have a minimal impact on the structural elements of existing houses, therefore our louvre system will be retrofitted to existing windows and even doors. Considering the changes in wind direction throughout the year, a plan for owners should be implemented which will maximise cool air intake into the house from a particular direction and facilitate cross ventilation. Houses in the An Minh district do not have a favourable orientation or standard of window sizes, thus louvre orientation plans need to be tailored to different houses.

Houses however will be subject to similar conditions, thus we will generalise the consideration of airflow. In Figure 18 a-c we see the air flow through the house with all the windows and doors open allowing wind to pass through the house easily, interrupted only by the partitions across the room. This is not always the most desirable situation due to the differing strengths of wind and a desire for only particular parts of the house to be ventilated whilst others are still.

In Figure 18 d-f we can see the impact of louvres being closed, represented by the thick red lines across openings. By closing those particular openings at different times of year we can change the air flow through the house to suit the needs of the owner, for example by promoting or restricting the air flow through a particular area ie. the kitchen or bedroom. The use of louvres in directing airflow through a house means that the ventilation through a particular area will also be greater than when all openings are opened, since the flow from the same number of windows is redirected to fewer openings.

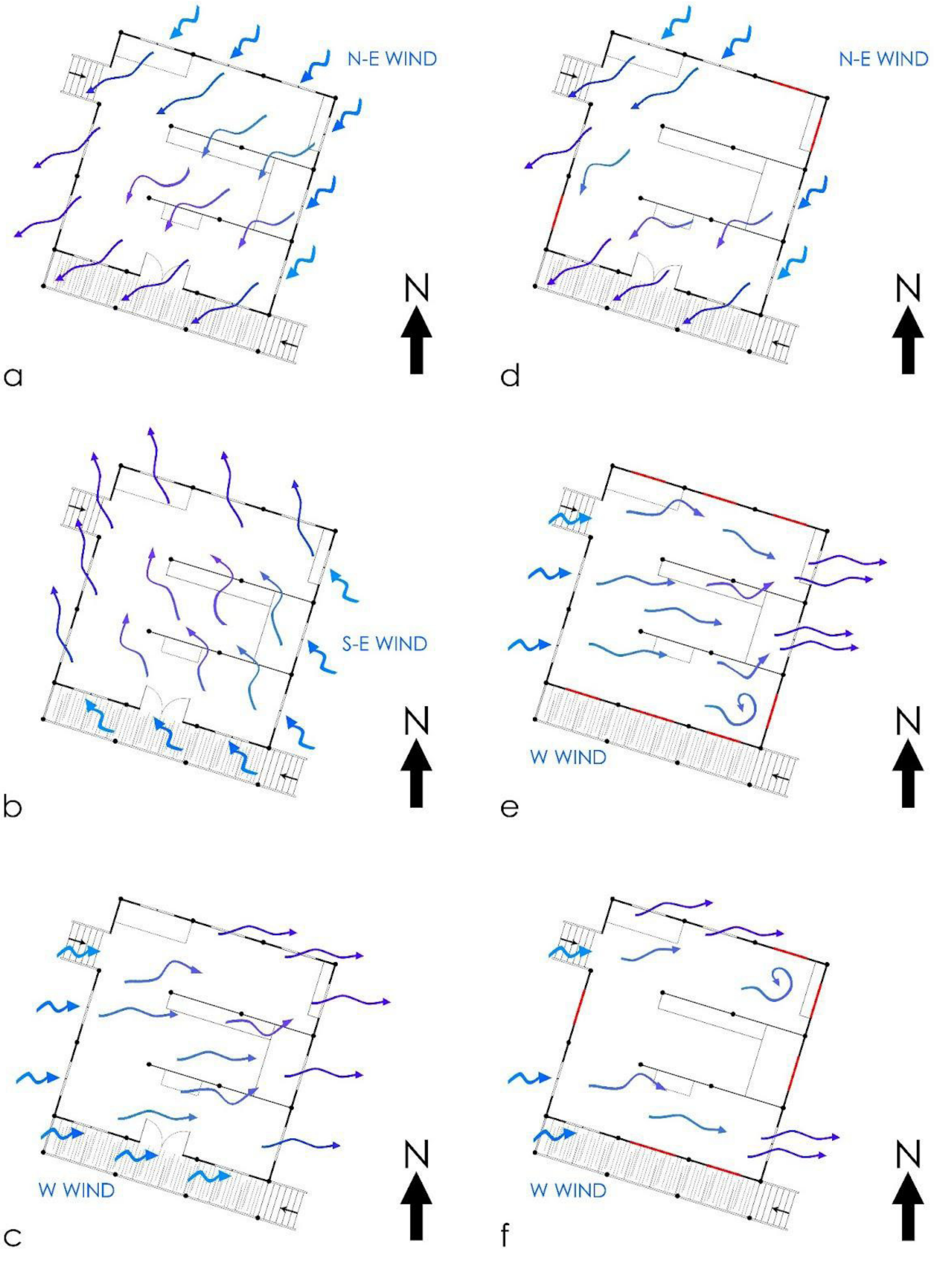

Figure 18 a-c Airflow diagrams for different times of the year
d-f Airflow diagrams for louvre orientation plans to promote airflow through particular areas of a house

In the Figure 19 we see the affect of louvres on the airflow in the house in the vertical plane. By orienting the louvres up, incoming air will rise and move the hotter air at head to ceiling height out of the house, this is especially desirable on hot humid days. Directing the louvres down, the incoming air will flow towards the floor moving the stagnant air out the opposite window. This is desirable if the occupant is engaged in activities on the floor or sleeping. Orienting the louvres to horizontal will result in a flow that will pass through the house a bit lower than window level due to incoming air being cooler. This orientation is helpful for achieving ventilation at a level associated with being seated on chairs or even at stove height.

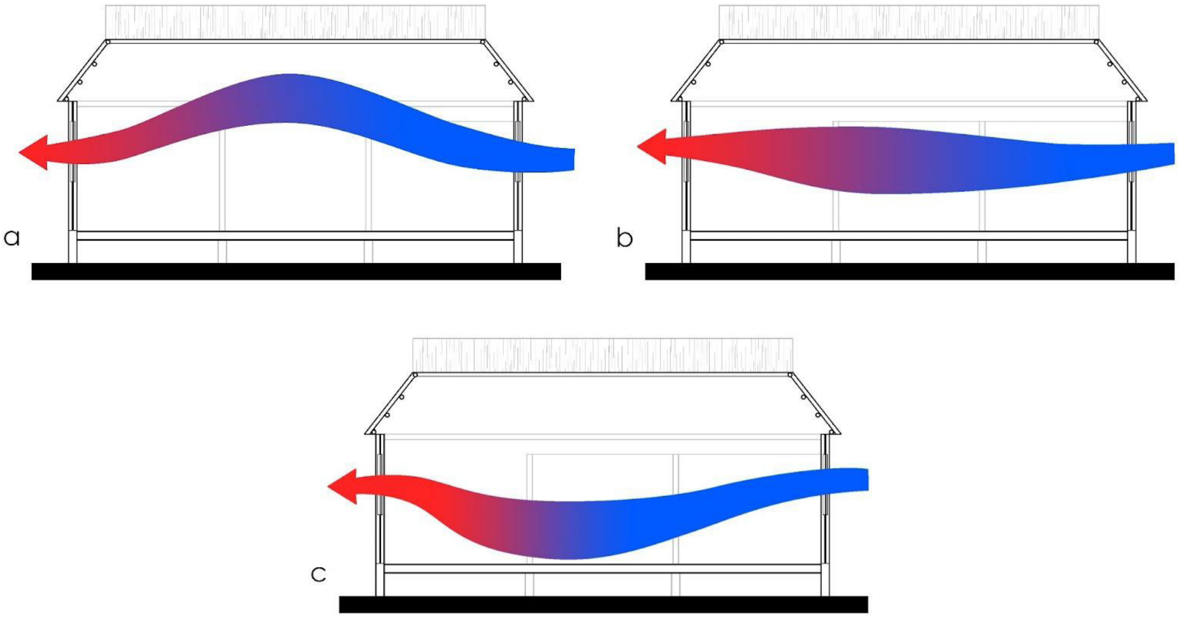

Figure 19 Airflow through the house with louvres directed a. up b. horizontal c. down

A louvre mechanism must be designed to control the flow of air. Keeping to the design criteria, this technology was made as simple as possible so that residents can quickly learn the necessary techniques to make the louvres and to be able to install them without having to buy or use new tools. By combining simple techniques and locally sourced materials there will be an increased rate of adoption since it would be low cost and locals would be familiar with the materials due to their existing building techniques. The design seeks to have minimal moving elements whilst having no extra components other than the base material for holding the system together. This reduces costs as well as increasing the life of the system due to lower probability of failure with less parts.

Two local materials were considered, being Moso bamboo and *Melaleuca* wood. Moso bamboo was originally considered due to availability and it's ease of splitting into usable sections for individual louvres. However by having louvres with the desired width, it would require bamboo with a large diameter to be sourced which would mean bamboo with a thick culm. A thick culm is not desired in the design due to the high ratio of its thickness to its width which would result in great difficulty in designing a suitable louvre mechanism. Bamboo is also subject to splitting down its length which would make it difficult to work with especially considering the initial louvre mechanisms we had in mind.

Thus we decided to use *Melaleuca* wood which is easier to fashion. *Melaleuca* poles can be milled into planks which can then be cut to size to fit existing windows. *Melaleuca* wood is inherently easier to use due to the nature of wood planks being flat which is desirable for even louvres resulting in louvres being flush when closed. The use of planks will also prevent difficulties arising from louvres jamming due to uneven surfaces.

Another positive impact of louvres is the ability to improve privacy without impacting on the airflow into the house significantly. However the orientation of the louvres can be changed at the discretion of the owner and so owners may completely close certain louvres due to the desire of more privacy.

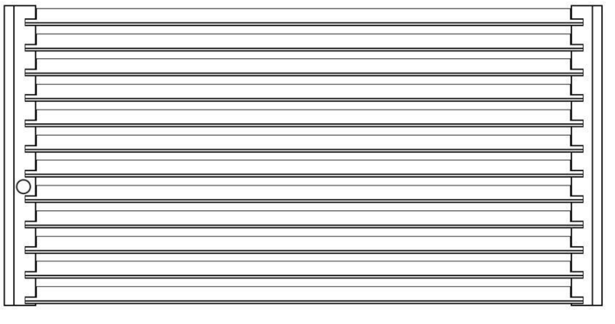

Figure 20 Interior elevation of Louvre system fitted to window

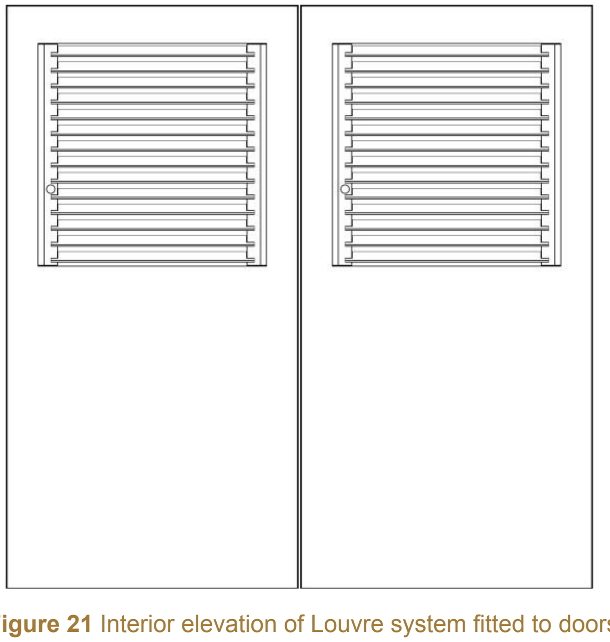

Figure 21 Interior elevation of Louvre system fitted to doors

BAMBOO CHARCOAL DEHUMIDIFIERS

To reduce the humidity within the houses in the An Minh district we have chosen a natural and effective solution of Moso bamboo charcoal used as a dehumidifier (see Appendix C). Even though bamboo charcoal is not the most effective moisture absorbing material available, it is the most applicable to this situation where cost and local materials are defining criteria. Its slightly lower water absorption ability is balanced by its large area for moisture absorption due to the physical structure of the charcoal pores.

Our designs come back to the fundamental belief that what we plan to implement must be as simple as possible to introduce and maintain. As such we propose that the Moso bamboo charcoal should be used in the condition that they will be in when they come out of the kiln. That is in small easy to handle cylinders. By doing so the charcoal can be easily removed from the hanging device and dried, without having to worry about charcoal chips being dropped. The alternative to charcoal cylinders would be charcoal chips or powder which would increase the effective surface area for absorption, however this form of charcoal is much more difficult to handle.

With an average relative humidity of 75%, the effective absorption of moisture from the air will be able to reduce the relative humidity to 60%, which is within the comfortable range for humans. Further calculations show that around 3kg of bamboo charcoal would be required to effectively dehumidify the house, which is still a relatively low cost solution considering the expensive nature of mechanical dehumidifiers and its ongoing costs. This charcoal will absorb the moisture in the air storing the water molecules in its pores. The charcoal will become saturated in about two weeks at which point they need to be placed in outside in direct sunlight to dry out. Once dried they can be reused. The charcoal will last one year with continual use, at which point the charcoal can then be used for cooking.

Humid air has a lower density than drier air at the same temperature, so it is best to locate the dehumidifier at a higher position within the house within the stream of airflow. In some houses this will occur by hanging the dehumidifier from the roof beams, otherwise they could be located on protrusions from the wall.

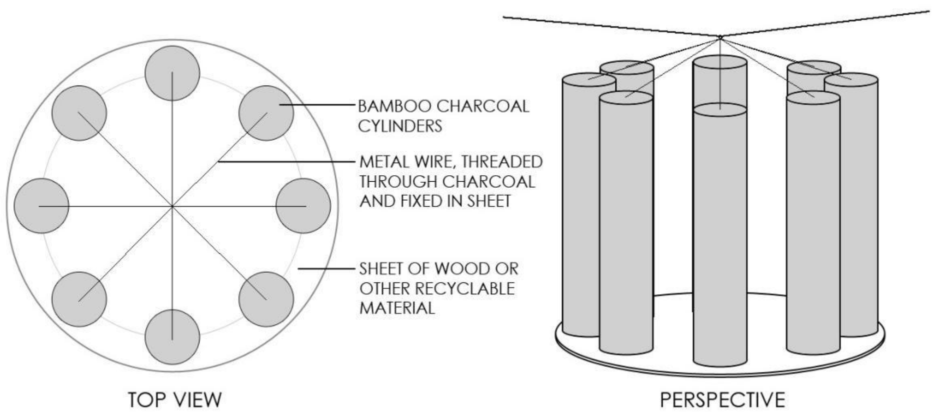

Figure 22 Top View and Perspective of dehumidifier mounted on sheet and hung from wire

SOLAR CHIMNEY

The solar chimney is the most notable change that is planned for households in An Minh. It is however, the most expensive to implement as it requires the use of metal in its construction. The narrow cavity of the chimney itself will be mainly made from bamboo and *Melaleuca* wood, which are naturally accessible materials in An Minh. The interior is then lined with mud to insulate the chimney, maximising the heat retained within the chimney as well as ensuring no heat escapes back into the house.

Traditionally, a solar chimney would use a glazed surface along the side of the chimney to absorb the radiation from the sun in order to generate heat within the chimney. In the design we plan to implement, a corrugated iron sheet will be used, and placed at an angle above the chimney. This would efficiently absorb the sun's rays and keep the rain from getting into the chimney. A metal plate within the chimney will be in contact to the metal sheet that absorbs the radiation, and through the conduction of heat, the plate within the chimney will be heated, effectively heating the air that is in the chimney. The heated air will rise from the chimney through a vent, and cooler air will be drawn into the chimney through convection, providing constant ventilation as long as there is enough heat generated in the solar chimney.

Adding a louvre to the opening between the chimney and the house was also considered. The louvre can be closed on cold days as well as to keep people from burning themselves if they accidentally place their limbs within the chimney. However, it is unlikely that the temperature inside the chimney will achieve a high enough temperature for severe burns to the human body to occur.

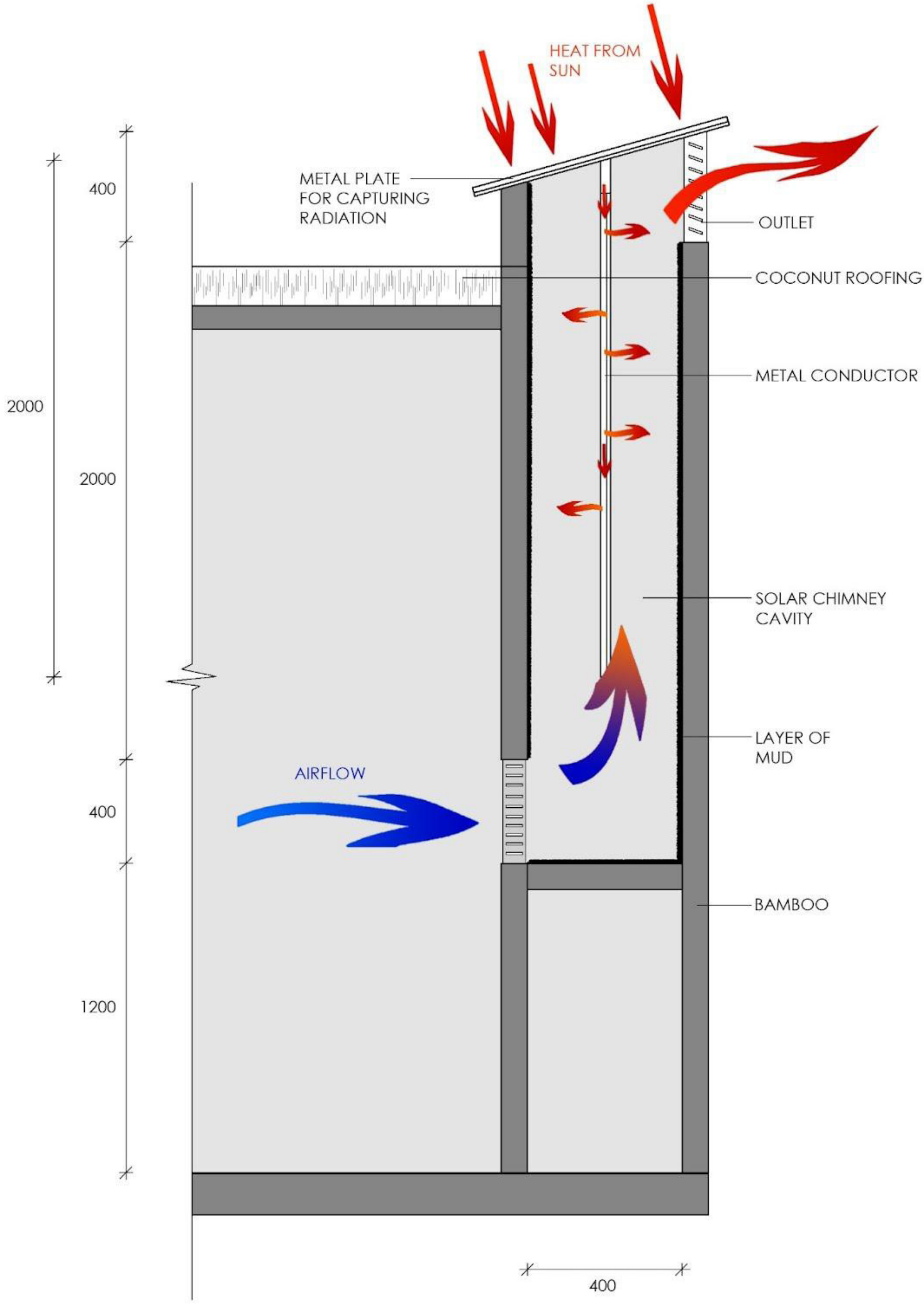

Figure 23 Sectional view of solar chimney indicating transfer of heat to air

TECHNICAL CALCULATIONS

LOUVRES AND WINDOWS

Outside wind speed range	Relative indoor air movement range	Ideal wind speed in cool or dry conditions	Ideal wind speed in humid conditions
5.5 - 18m/s or 20 - 65km/h	0.2 - 0.6m/s or 0.7 - 2.2km/h	0.2m/s or 0.7km/h	3m/s or 11km/h

Refer to Appendix D for detailed calculations.

If not measured next to the window, relative air movement indoors can range from 0.2m/s to 0.6m/s, which is a comfortable range for the occupant during the night, and during the dry season.

However, for the occupant to feel comfortable during periods of high humidity, it is generally feasible for the occupant to be near the windows. Hence, having more windows spaced around the house will provide the necessary ventilation for the house.

Wind speeds higher than 3m/s for prolonged periods of time will also cause discomfort. The placement of louvres in windows will allow the control of airflow and wind direction.

BAMBOO CHARCOAL DEHUMIDIFIER

Description	
Average temperature in An Minh	**30°C**
Average relative humidity in An Minh	**75%**
What 30°C feels like at 75% humidity	**43°C**
Comfortable relative humidity levels	**25% - 60%**
Percentage of own weight bamboo charcoal can absorb	**10% - 12%**
Amount of charcoal to dehumidify a typical house	**2.88kg**

Refer to Appendix E for detailed calculations.

To improve comfort of the occupants inside the house, relative humidity should be reduced by 15%, from 75% to 60%.

The bamboo charcoal should be placed within two metres of the bottom of the floor so the moisture in the space above head height is not unnecessarily absorbed. Since dry air is more dense than humid air, the dry air will remain low.

SOLAR CHIMNEY

Description	
Power from the sun's radiation entering Earth's atmosphere	**168W/m^2**
Maximum temperature of the metal components	**54°C**
Maximum velocity of air movement within solar chimney	**0.3m/s**
Time taken to circulate the air completely through the house	**36 minutes**

Refer to Appendix F for detailed calculations.

The temperature of the interior of the solar chimney is hot enough to cause appreciable ventilation through the house. If the temperature is too high, the solar chimney could pose a safety risk if someone touches it and burns themselves. It could also become a fire hazard, considering that coconut leaves is a dominant cladding material for houses in the An Minh district.

The velocity of the air moving through the solar chimney is low, considering the space in the house is much larger than the volume of the solar chimney. This ensures that there is little to no discomfort due to drafts near the solar chimney.

A turnover time of just over half an hour provides an effective rate to ventilate the air within the house, especially to remove smoke and particle build up that can arise from cooking or washing.

Prototype 1

Prototype 1 is a 1:20 scale model of a typical house within the region of An Minh. The model includes the ventilation system (openings for louvres and solar chimney) and is constructed from acrylic.

Aim
To test the effectiveness of the natural ventilation system through clear observations of the flow of wind and air within the household.

Conditions
Model orientation in wind tunnel: north orientation and north-east orientation
Fan speed: 35
Type of smoke: smoke machine (liquid smoke), incense burner

Testing Procedures

1. **Testing with 'real-paced' winds:** The model was placed to simulate the effect of northerly and north-easterly winds in the An Minh region. Using the smoke machine, the model was filled with smoke ("wind"). The way in which the smoke ("wind") left the model was observed. The test was filmed to further analyse what occurred.

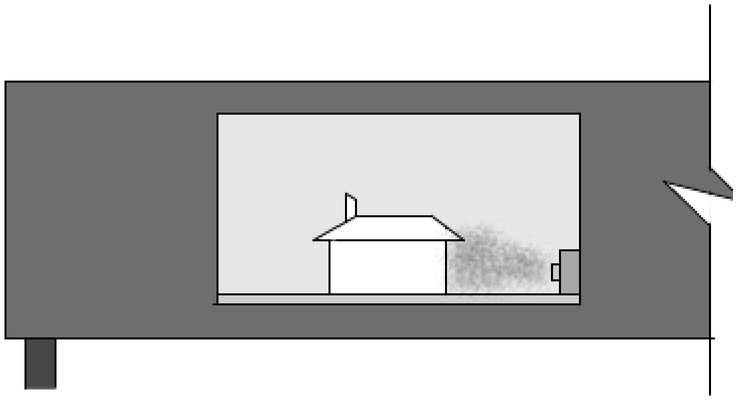

Figure 24 Illustration of wind tunnel testing procedure

2. **Testing with 'slow-paced' winds:** The model was placed in different orientations within a secure environment. An incense burner was placed outside the model, depending on 'wind direction'. The movement of the air/wind direction was more visible due to its slow movement with observations taking place accordingly. The process was also filmed to further analyse, as necessary.

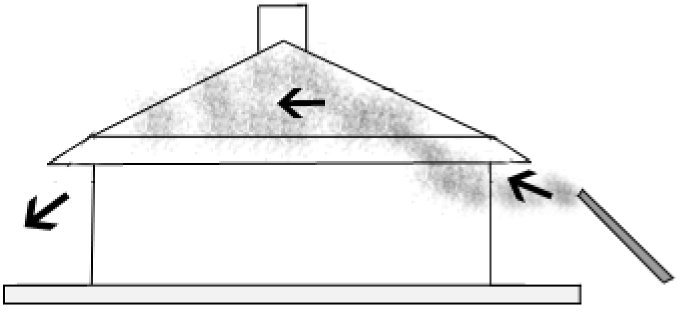

Figure 25 Illustration of incense burner testing procedure

Results

A number of tests within the wind tunnel were conducted, whilst observing the model from a various observation points. Moreover, incense was placed near each opening of the model, to further determine air movement within the household. The results for each testing procedure are as follows:

1 **Testing with 'real-paced' winds:** As smoke had completely filled the model, it demonstrates that air and wind are able to enter the household. During all test trials, the smoke managed to 'escape' the model over an average period of several seconds. As the smoke escaped from the model, it would leave from the openings that have been created, therefore exemplifying that the openings work. A particularly significant observation that was recognised during the testing was how smoke consistently escaped from all sides of the house.

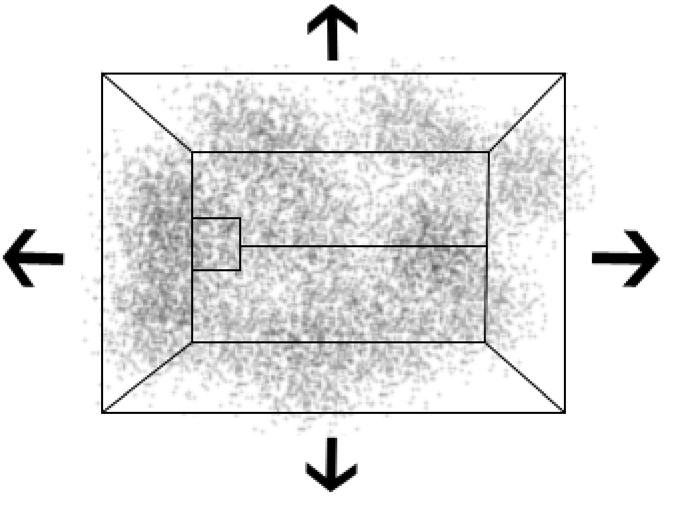

Figure 26 Illustration of an aerial view of movement of smoke from wind tunnel

2 **Testing with 'slow-paced' winds:** The use of an incense burner allowed 'wind' to come from only one 'point of source'. As the smoke was hot, when the smoke entered the model, it had risen and was difficult to clearly see whether it left the building or just dissipated inside the model. The use of a black background however, allowed it to become more apparent that some of the smoke did leave the model however, it was through a slow process of diffusion.

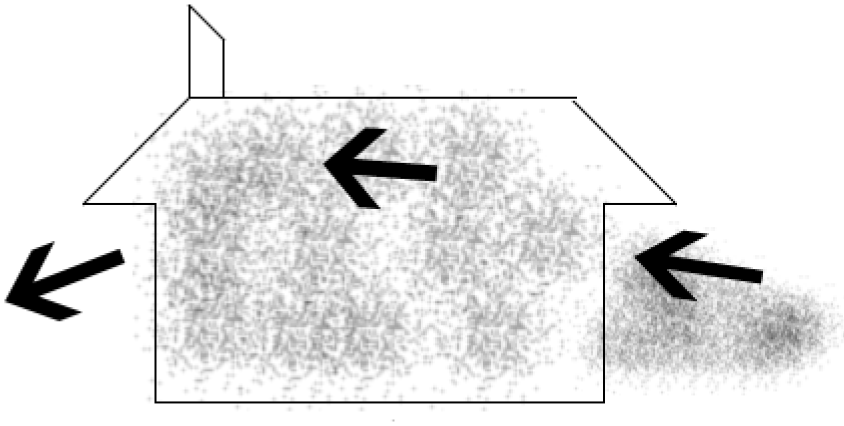

Figure 27 Illustration of movement of smoke from incense burner

Possible causes for testing failures

- The model being constructed completely from acrylic made the model entirely transparent. At time, it was difficult to distinguish the movement of the smoke. At least one side of the model could have been black, to allow for easier observations.
- The hot smoke from the incense burner made the smoke rise automatically, reaching the ceiling of the model when it was inside. As this was a slow process, the smoke leaving the model was also notably slow, and often dissipated within the model instead. A number of tests were required to confirm that the smoke was actually leaving the model.

Conclusion

Overall, the first test revealed that smoke (being 'wind' and 'air') were able to directly enter and escape the household model. The second test furthermore revealed that during hot weather, air would enter the household and rise to the ceiling and over a slow process, would then exit the openings.

Both tests have conclusively shown that all openings are effective in both allowing air to enter and exit the household. This therefore demonstrates that all openings work efficiently and are therefore successful in producing natural ventilation.

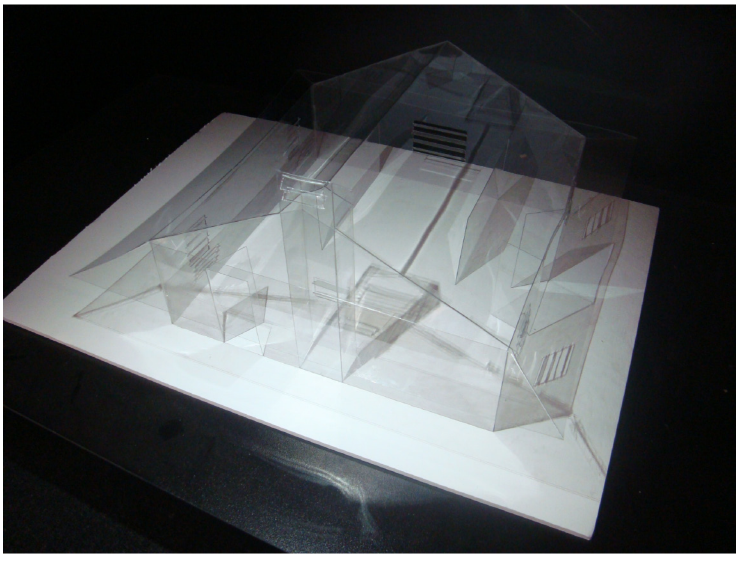

Figure 28 Model of a typical house in An Minh, completely made of acrylic

Figure 29 Smoke from smoke machine enters the model

Figure 30 As smoke on the outside clears, smoke from the interior can be clearly seen escaping from the model

Figure 31 The model almost clear of smoke, indicating effective ventilation throughout the whole house

Prototype 2

Prototype 2 is a 1:1 model of the louvre design for a small window to establish the practicality of the proposed louvre mechanism. The main objective of this model was to create the simplest design that would be robust enough in strong winds yet use simple construction techniques. We tried to use tools that would be easily obtained or owners would already be in possession of to make the louvres. This objective spanned to the use of no glue or screws for the proposed design.

In light of this we decided to use Pine planks that could be replaced by *Melaleuca* planks in Vietnam, due the difficulty of sourcing *Melaleuca* planks with the desired dimensions in Sydney.

All the cuts and holes in the prototype model were done with simple tools being a saw, a chisel, a hammer and an electric drill. With the exterior frame of the model being held together with glue and nails, this will not be representative of the window frames used in An Minh.

The system is based on the equal distribution of force exerted on individual louvres to cause them to rotate along their axis that is fixed to the window frame. The distribution of the force is achieved through the presence of another set of dowel-like protrusions connected to a mobile bracket which links the whole set of louvres together.

Figure 32 From top to bottom: single louvre member, side fixing member, mobile bracket

Due to movement of the louvres by their own weight and the lack of friction between the dowel-like protrusions and the frame, we decided to implement a simple mechanism for locking the louvres in place. This involved drilling holes at intervals around the turning arc of a predetermined hole on the mobile bracket. A small dowel is then slotted into the two holes to lock the louvres at a particular angle.

Figure 33 Detail of simple locking mechanism on mobile bracket

Figure 34 Image of connection between louvres, mobile bracket and side fixing member

By considering the construction process of the model we found that it was not too difficult an activity to complete, though it would take time to be acquainted with the methods used for construction. The louvre system is easy to assemble and requires no additional adhesives or fixing objects. It is reliable and should have a service life at least as as long as its surrounding materials.

Figure 35 Images of the different louvre orientations locked in place

Prototype 3

Prototype 3 is a test using normal charcoal to relate to the dehumidifying property of the Moso bamboo charcoal. Charcoal is a natural dehumidifier that lowers the relative humidity of its surroundings. Research shows that bamboo charcoal has ten times the pore spaces of a normal charcoal and is four times faster in absorption rate, thus it is a more effective dehumidifier.

Aim

To test the effectiveness of charcoal pieces in dehumidifying a room (bathroom)

Conditions

Bathroom is an enclosed room at a temperature of 30^{o}C
Dimensions of the region of bathroom: to be dehumidified: 1550 x 2650 x 1270mm (1270mm is the height at which the charcoal is placed)
Type of charcoal: 100% wood and no preservatives

Testing Procedures

1. Bake the charcoal in the sun to dehydrate, for about 3 hours.
2. Place thermometer in the bathroom a few minutes before running hot water.
3. Weigh the amount of charcoal before placing it in the bathroom using kitchen scale.
4. Place charcoal in plastic container/bag and place it on a 1.5m ladder, in order to resemble as much as possible the set up in a Vietnamese house, where it will be hung at the centre of the house. The setup of the experiment is shown in Appendix G.
5. Record the initial temperature of the bathroom from the thermometer.
6. Record both the weight of the charcoal as well as the temperature of the bathroom in hourly intervals. Repeat step (5) until the weight of the charcoal stays consistent.
7. Repeat the experiment, this time with charcoal in proportional amounts to the size of the bathroom. [The amount of charcoal used is calculated using the method shown in Appendix E. For the dimensions of the bathroom and where the charcoal will be placed, the amount of charcoal used will be 135g.]

Results:

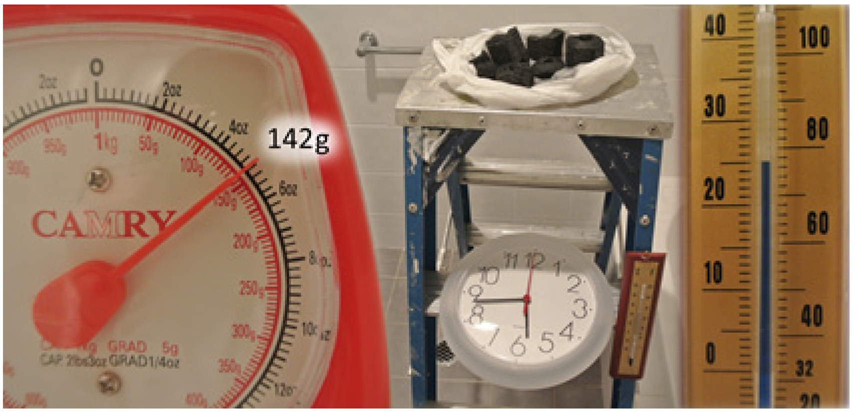

Figure 36 Image of weight 142g at 5.40pm, 25.5°C

Figure 37 Image of weight 147g at 6.40pm, 25°C

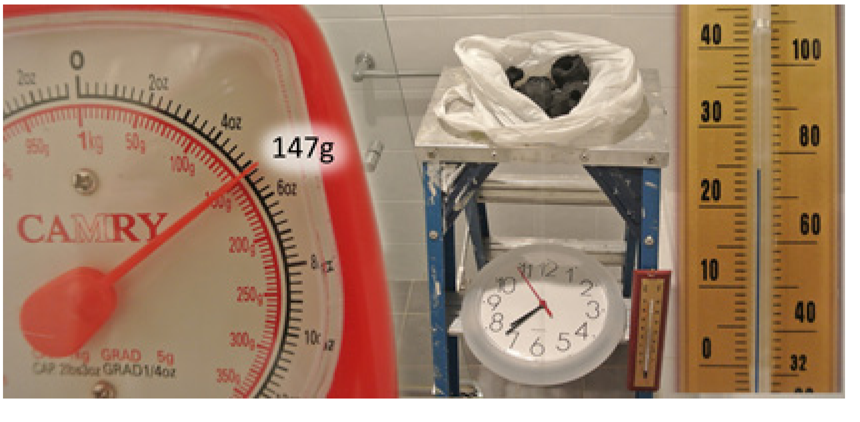

Figure 38 Image of weight 147g at 7.35pm, 24.5°C

Experiment 1

	Temperature (°C)	Mass of charcoal (g)	Time
	21	90	8.48pm
	19.5	95	10.15pm
	18	105	1.12am
Difference	**3**	**15**	**4.4 hours**

Experiment 2

	Temperature (°C)	Mass of charcoal (g)	Time
	26	135	4.30pm
	25	142	5.40pm
	24.5	147	7.30pm
Difference	**1.5**	**12**	**3 hours**

Experimental failure could be due to:

- The bathroom is not enclosed enough (has vent above, although exhaust fan is not turned on) since the outside temperature cools the bathroom faster.
- Interruptions during temperature recording influences results since air is exchanged by diffusion through the occasionally opened door.
- Dehumidifying process is too slow to observe changes.
- Water amount in the air after the shower is too little for detection.

Conclusion:

The experiment is still valid even though low quality charcoal was used for the experiment, as opposed to using bamboo charcoal. This is because the charcoal used in the experiment was still able to absorb about 8-9% of its own weight. In comparison, bamboo charcoal can absorb 10-12% of its own weight when operating efficiently, which is quite close to regular charcoal. Since the dehumidifying properties for regular charcoal can be proven, it can be assumed that the bamboo charcoal will be better and more efficient.

Prototype 4

Prototype 4 is a 1:5 scale model of the solar chimney, to determine the practicality of the solar chimney and its effectiveness. The solar chimney works on the principle that hotter air becomes less dense than cold air and rises. This hotter air is expelled from the top of the chimney, and air from the house is drawn into the solar chimney at the bottom. While the cost of the unit may be relatively expensive, it provides an effective solution to create ventilation in the house during dry conditions with no wind.

For the purposes of testing, materials such as boxboard and acrylic were used to build the structure. This reduces the amount of time required to construct the prototype, and allow for easy transportation of the model.

Figure 39 Various views of the solar chimney prototype used for the experiment.

Aim:
To test the effectiveness of a solar chimney's ability to circulate air through it.

Conditions:
The prototype was tested outside and placed in direct sunlight.
Time: 10.30am
Outdoor temperature: 30°C

Testing Procedure:
1. The model was placed in the sun for half an hour, to allow the metal components of the solar chimney to reach thermal equilibrium.
2. An incense burner was placed near the inlet at the bottom of the solar chimney. This allows smoke to enter the inlet naturally.
3. The flow of smoke (as a representation of the flow of air) was observed at the inlet, through the body of the chimney and at the outlet near the top. A black board was placed in the background to better observe the flow of smoke.
4. From the video recording of the experiment, the velocity of air flow was determined by observing the movement of the smoke.
5. The metal surface was touched by various group members, to feel how hot it was.
6. The temperature of the metal components of the solar chimney was measured.

Results:
- The smoke can be seen entering the inlet of the solar chimney. This is assumed to be a result of hotter air within the solar chimney rising, drawing in air from below, which included the smoke from the incense burner.
- From the video recording, the average velocity of the air exiting the solar chimney was determined to be 0.6m/s.
- As determined by various members, the metal surface was not "too hot" to touch.
- The thermometer recorded the temperature of the metal components to be over 50°C.

Discussion:
The experiment had to be conducted outside to replicate the conditions of the solar chimney in the An Minh district. The top metal surface was exposed directly to the sun, and with outdoor temperatures of 30°C, the prevailing conditions supported the validity of the experiment. However, since the whole prototype was outdoors, gentle breezes generated some difficulties in observing and recording the flow of smoke into the inlet.

The acrylic should have provided a clear surface to see the smoke rise inside the solar chimney. Unfortunately, the grey colour of boxboard did very little in providing a contrasting background to see the grey smoke within the solar chimney.

Incense smoke naturally rises, since it has a lower density than air. This may contribute to the perceived increased velocity of air coming through the outlet. This could affect the validity of the experiment, by increasing the velocity at the outlet to be a higher value than expected.

Due to fluctuations of the smoke as a result of the natural unsteady flow of air, it was hard to estimate the velocity of air at the outlet. This means that the average estimate of 0.6m/s may not be entirely accurate.

The thermometer was meant to record the temperature of the metal components accurately, but since the upper limit of the thermometer was 50^{o}C, it was not able to provide a direct reading. Unfortunately, the thermometer was also unreliable, as it provided a higher reading than expected in an indoor environment.

Conclusion:

The solar chimney demonstrated that it can provide a means of ventilation by drawing air through the body of the chimney. This was particularly well demonstrated in the left figure, where air is directly drawn into the chimney. While a speed of 0.6m/s may not be entirely indicative of air flow through an actual solar chimney, it can be assumed that the heating of the air within the chimney does contribute to the speed at which air exits the chimney, as depicted by the right figure. This is supported by the fact that air and smoke from the incense burner was drawn into the chimney in the first place as a result of hot air rising within the chimney.

The metal components were not hot enough to be dangerous, which provides an important safety aspect for the use of the solar chimney in An Minh. The occupants won't risk getting burnt in their house by having a solar chimney installed. While a fire risk could arise due to coconut leaves being used for the walls of houses, the low temperatures reduce the possibility of a fire occurring.

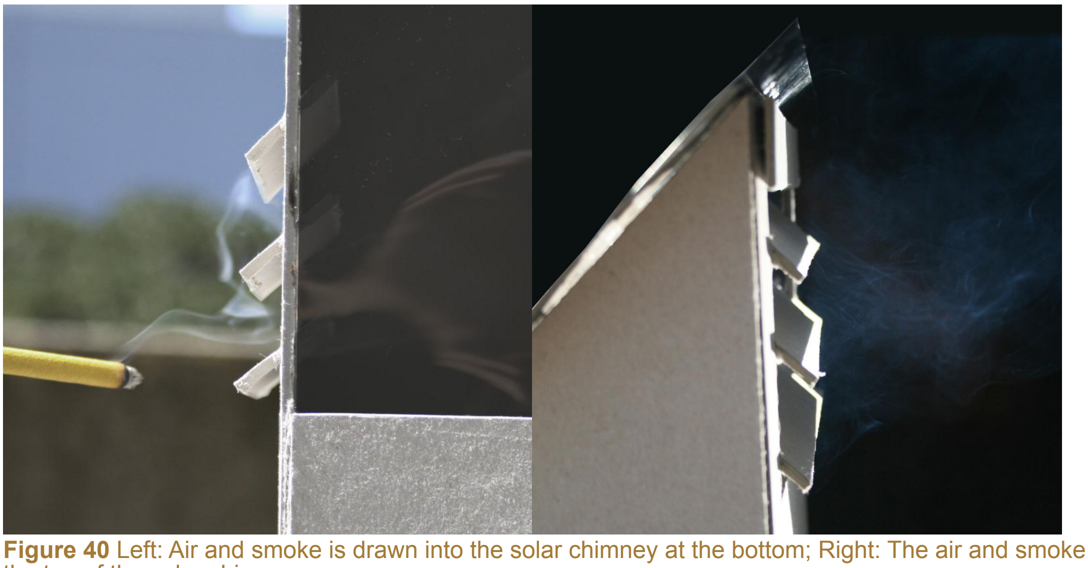

Figure 40 Left: Air and smoke is drawn into the solar chimney at the bottom; Right: The air and smoke is expelled at the top of the solar chimney

IMPLEMENTATION

TIMELINE

The implementation of our design will occur over an extended period of time due to the nature of the project being focused on the home owner making the changes to their individual house. The three stage solution of the louvres, dehumidifier and solar chimney will be implemented incrementally for higher adoption rates. In conjunction with the incremental introduction of these changes we believe that it is necessary to have the whole system implemented in selected houses in the An Minh district so that residents can experience first hand the changes that our solution will bring for comfort levels within their house.

The retrofitting of louvres to windows and the installation of doors with louvres will be a rather simple process once the necessary skills and techniques are given to the community. It is expected that the education of a group of residents will take one week, with construction initially taking two weeks. With more experience, the construction period can be reduced to one week.

The implementation of the dehumidifier will depend on the production of the bamboo charcoal. Thus we do not have a precise timeline for its implementation at the moment, but once the charcoal can be produced it is a simple matter of threading the charcoal on wire and hanging them in open areas of the house, taking only a few minutes once the best location for installation has been decided on.

The solar chimney as a larger installation within the house will take a significantly longer time to implement. Due to its inherent size and the materials used, we are wary that it will take time for the residents to see its positive impact within a house. Thus the solar chimney will only be implemented once the louvres and dehumidifier have been installed. Again we believe it is in the best interest of the community if we educate a group of residents all at once. We expect it will take less than a week to educate the residents and will initially take up to three weeks to install for this group, with construction time decreasing once the building technique has been refined.

Due to the initial start-up costs associated with implementing the full system in houses for display, it will be necessary to have local businesses involved to finance the costs. These businesses could include local *Melaleuca* wood plantations or mills, who will ultimately benefit as well when there is wide spread adoption of the louvre system.

	WEEKS													
STEPS TO IMPLEMENTATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Education about the impact of effective ventilation														
Louvre Construction education														
Louvre Construction														
Cooling Off														
Dehumidifier Education														
Bamboo Charcoal Production														
Dehumidifier Implementation														
Cooling Off														
Solar Chimney Education														
Soalr Chimney Construction														

Figure 41 Gantt Chart of the implementation process

MATERIALS

MOSO BAMBOO

Moso bamboo is a locally available material that will be used to construct the structural panels for the solar chimney. Bamboo culms or poles of a larger diameter will act as vertical members, while smaller bamboo culms will act as cross members to provide structural integrity to the solar chimney. This will support the mud lining that will be in the interior. Moso bamboo can also be made into a charcoal as the primary source for the dehumidifier.

Moso bamboo is an abundant source in Vietnam, with plantations across many regions of the country and spanning across almost a million hectares. Around 60% of bamboo is produced on private property, with the remainder on State land and commune forestland.[53] By sourcing bamboo from private property, damage to the habitats and environment is minimised through a reduction in access to forests, while increasing the support for the economy.

Bamboo charcoal can be sourced through local manufacturers that process the Moso bamboo. This involves a treatment process which takes two weeks, which involves burning the bamboo in a kiln in order to dry it. Increased temperatures inside the kiln will then carbonise the bamboo into charcoal, which allows the charcoal to actively dehumidify the air. This process also produces bamboo vinegar as a by product, which is used as an insect repellent.

The boats on the waterways will transport the bamboo and bamboo charcoal unless the home owner harvests the bamboo themselves. Since Moso bamboo can grow to heights in excess of 10m, they may need to be cut down to size in order to fit them into the boats for transportation.

Figure 42 Moso bamboo cut down to size
(Image URL:www.bikudo.com/product_search/details/184423/moso_bamboo_poles.html)

53 Non-Timber Forest Products Research Centre. 2001. *Bamboo production and trade in Cho Don, Vietnam.* [ONLINE] Available at: http://www.mekonginfo.org/assets/midocs/0002828-economy-bamboo-production-and-trade-in-cho-don-vietnam.pdf. [Accessed 5 October 2012].

MELALEUCA WOOD

Melaleuca wood will be used to construct the louvres for the windows and the solar chimney. Depending on local circumstances, Melaleuca wood could be used for the structure of the solar chimney, but the abundance of bamboo forests and plantations and its regenerative properties could make it more preferable for construction purposes.

There are around 50,000 hectares of *Melaleuca* wood forest and plantations within the Kien Giang Province.[54] Around 1,000 hectares would be harvested each year[55] for the purposes of construction. Resourcing the timber from local people, rather than cutting down regions of forest, will support the local industry that grow and harvest the timber. This reduces the impacts of deforestation on the environment within the region.

The canal and river system transports the *Melaleuca* wood across the region. These can be sent to factories where the wood is further refined into planks, or sent as poles directly to the home owner via boat. The transportation of timber rather than just poles will reduce the amount of labour required to construct the louvres, providing time benefits for the home owner that may have to construct the system.

Figure 43 Harvested Melaleuca wood ready for transportation
(Image URL:www.aseanpeat.net/view_file.cfm?fileid=182)

COCONUT LEAVES

Coconut leaves will be used as a surface for the mud lining inside the solar chimney, and as an exterior cladding outside the solar chimney. The inner layer is woven to increase the strength and allow it to support the mud, while the exterior is covered in leaves to match the look of the house and for aesthetic appeal.

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54 Thanh, P. & Fumiaki, S. 2012. *Conservation and Sustainable Use of Melaleuca Forests on Peatlands and Marshes area in Ca Mau, Vietnam.* [ONLINE] Available at: www.aseanpeat.net/view_file.cfm?fileid=182. [Accessed 5 October 2012].
55 German Development Coooperation. 2011. *Melaleuca Thinning Demonstration.* [ONLINE] Available at: http://kiengi-angbiospherereserve.com.vn/project/uploads/contents/thang_6/factsheet_/6.MELALEUCA_THINNING_DEMO.pdf. [Accessed 5 October 2012].

As coconut leaves are an abundant resource that can be sourced locally, they are the preferred choice of cladding for the walls of the current houses in An Minh. Coconut leaves are sourced from coconut trees that are either produced en mass, or grown on private property. The coconut leaves can be bought in the form of woven sheets or as layered or thatched coconut leaves. As the skills are passed down over generations and resources are readily available due to low cost and abundant supply[56], the production and sale of sheets of coconut leaves will provide support for the local community.

As with the resourcing of other materials, the boat provides the best method to transport the coconut leaves. This is due to the lack of roads in the area, which means the area is reliant on water transportation.

Figure 44 Left: Woven coconut leaves; Right: Thatched coconut leaves.
(Image URL:www.flickr.com/photos/nuls/107996824/in/photostream/)
(Image URL:www.flickr.com/photos/jessolo/6084161707/)

CORRUGATED IRON

Corrugated iron will be used for the solar chimney to absorb heat from the sun and the release the heat conducted through the metal to increase the temperature of the air within the solar chimney.

While corrugated iron is used for some roofing on houses and even as walls, it is a rather expensive product and should be used sparingly. It is feasible that recycled metal should be considered for use to reduce costs. These can be sourced from local recycling centres. Otherwise, corrugated iron is produced in factories and can be bought from suppliers.

The manufactured metal may require road transport from the factory to supplier, and then transported by boat using rivers and canals. The negative impacts of pollution from sourcing and transporting raw material can be reducing by obtaining recycled metal and transporting it to remote locations using a boat.

56 Biodiversity International. 2006. *Coconut in Vietnam - Midrib baskets: The art of giving* [ONLINE] Available at: http://www.bioversityinternational.org/fileadmin/bioversity/publications/pdfs/1158_Coconut_in_Vietnam.pdf. [Accessed 5 October 2012].

Figure 45 While it is a common material for roofing, corrugated iron can be used for the solar chimney to absorb heat (Image URL:www.secretsydney.com.au/userimages/user1001_1147528786.jpg)

COST

The table below details the cost of material per unit.

VND - Vietnamese Dong
USD - United States Dollar
1USD = 20,000VND

Material	Cost per unit (VND)	Cost per unit (USD)
Moso bamboo culm (poles) - diameter 6cm	4,000 per metre	0.20 per metre
Moso bamboo charcoal	12,000 per kg	0.60 per kg
Melaleuca wood poles - diameter 10cm	3,000 per metre	0.15 per metre
Melaleuca sawn timber planks - 65mm x 10mm	750 per metre	0.0375 per metre
Coconut leaf thatching	300 per m^2	0.015 per m^2
Coconut leaf woven	500 per m^2	0.025 per m^2
Corrugated iron	120,000 per m^2	6.00 per m^2

Assumptions
The cost of a 10 metre long moso bamboo culm is 40,000VND.

Moso bamboo charcoal is completely moisture free, and sealed inside packaging to protect it from weather conditions.

The cost of a 4 metre long *Melaleuca* wood pole is 12,000VND.

Six pieces of timber can be produced along the length of one *Melaleuca* wood pole.

The process of producing timber in factories, including labour and further transportation will cause the selling price of the timber to be 1.5 times the price of the raw material.

Woven coconut leaves require more effort and hence would be more expensive than thatched coconut leaves.

The table below details the total cost of each material required.

Description	Amount required	Cost per unit (VND)	Total cost (VND)
Moso bamboo culm	35.2 m	4,000 per m	140,800
Moso bamboo charcoal	3 kg	12,000 per kg	36,000
Melaleuca timber planks	261 m	750 per m	195,750
Coconut leaf thatching	6.82 m^2	300 per m^2	2046
Coconut leaf weaving	6.82 m^2	500 per m^2	3410
Corrugated iron	0.88 m^2	120,000 per m^2	105,600

	Solar chimney unit	Dehumidifier unit	Louvres
	= 140,800 VND + 105,600 VND + 2,046 VND + 3,410 VND	= 36,000 VND	= 195,750 VND
Total Cost	**251,856 VND**	**36,000 VND**	**195,750 VND**

Full cost of the whole system = 483,606 VND

CONSTRUCTION

LOUVRES

The specification for the louvres is variable depending on the circumstances of the owner and the particular window size, however the same construction method will be used. The following method must be considered in light of the different specifications of individual situations.

We recommend a suitable size for the louvres to be 65mm in width and 10mm in thickness with a length of no more than 1000mm. This maximum length should be noted, since louvres with a span that is too long has increased weight and thus difficulty in rotating the louvres, as well as a reduction in the service life of the louvres due to higher loads on the end protrusions.

Please refer to Appendix G for calculations used in the following construction method.

Tools required: hand saw, chisel, ruler, t-square, electric drill or similar

1. Measure the height and width of the window into which the louvres will be installed.
2. Cut the 65mm x 10mm planks into lengths the same as the width of the window.
3. At each end of these lengths saw off rectangular sections leaving the end as per the measurements in Figure 46.
4. Using a saw and chisel, saw the base of each protrusion into a cylindrical shape, then chisel along the grain from the ends of the protrusions to form the dowel like protrusions seen in Figure 47.
5. Drill holes of 10mm diameter at 56mm spacings into the mobile bracket and the fixing member to the existing window.
6. Drill a smaller 6mm diameter hole in each mobile bracket at 150mm from the base of the bracket and 10mm in from the edge in the same direction as the main holes.
7. Use a pencil to mark out the circumference of the circle that this hole traces when three louvres are fitted to the fixing member and bracket.
8. Drill 6mm diameter holes along the circumference of the circle that was marked, at 10° intervals.
9. Fit one side fixing member to the existing window.
10. Slot the shorter dowel like protrusions into the mobile brackets.
11. Use string to bind the louvres together with the mobile bracket temporarily.
12. Fit the other side fixing member to the respective side of the louvres.
13. Slot the remaining protrusions into the fixing member already fitted to the window.
14. Fit the other side fixing member into the window.
15. Remove string binding.

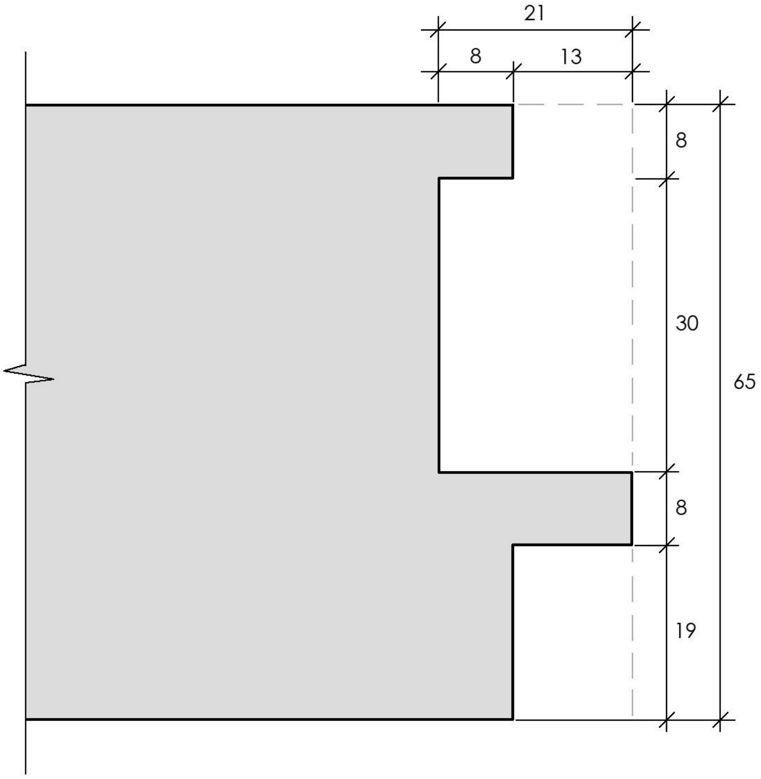

Figure 46 Measurements for the cutting of the end of each louvre

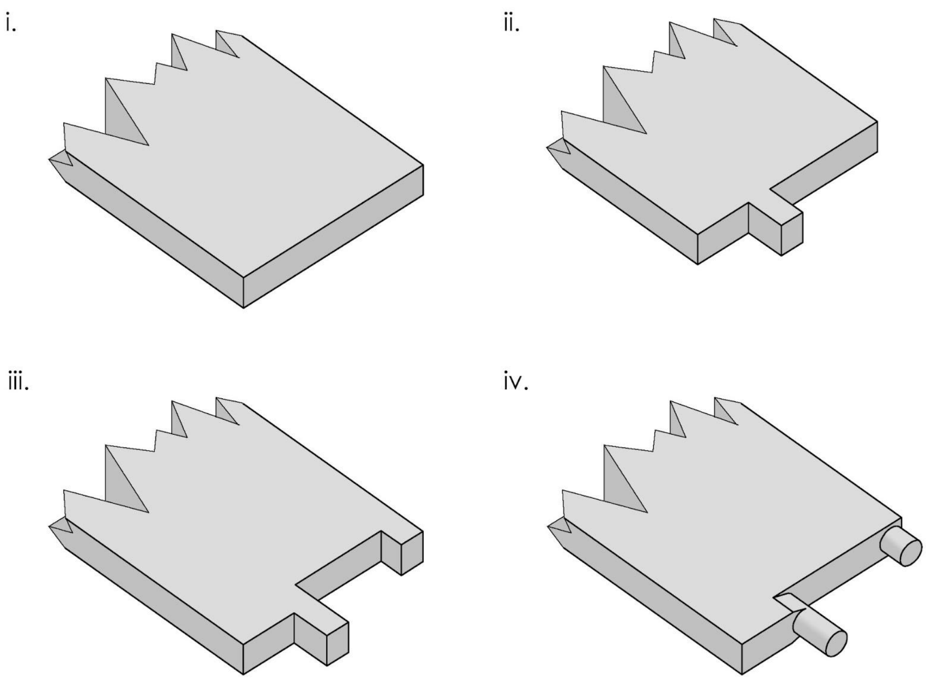

Figure 47 Steps to achieving dowel protrusions from the end of each louvre

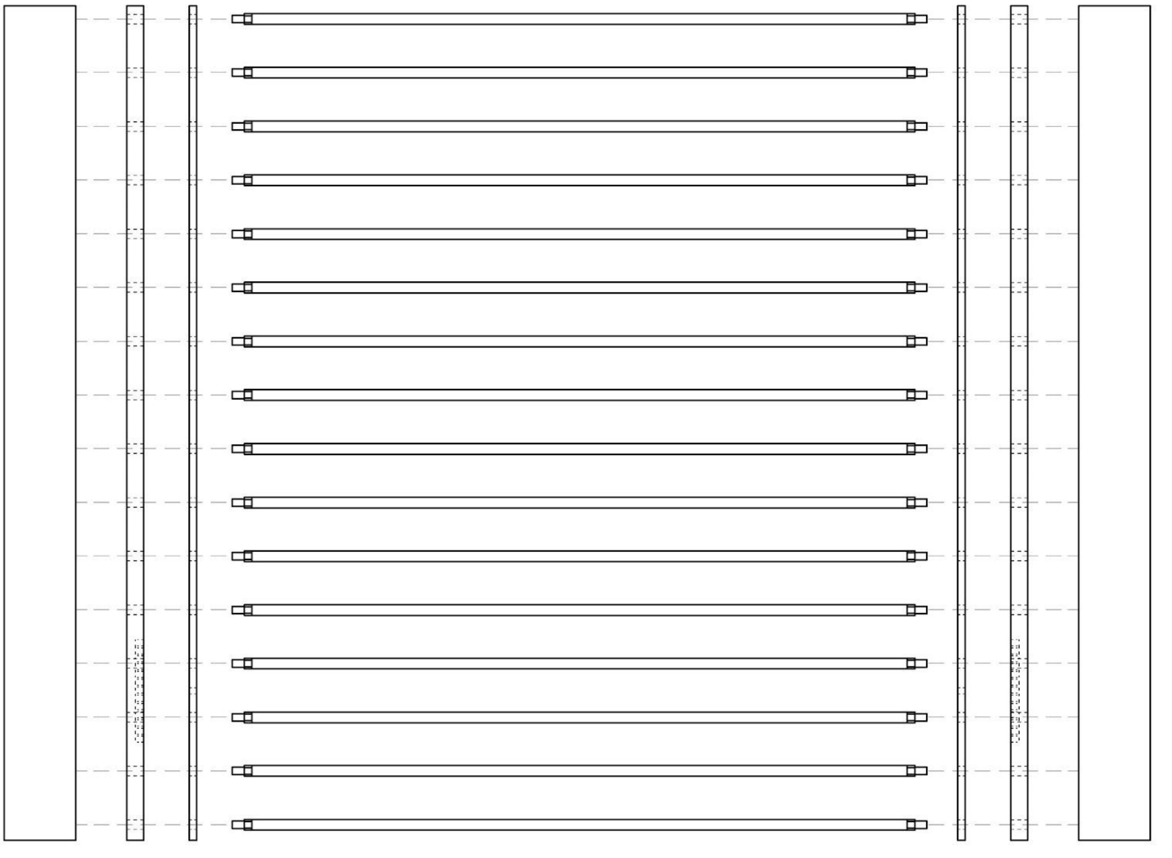

Figure 48 Exploded front view of louvre system fitted to existing window

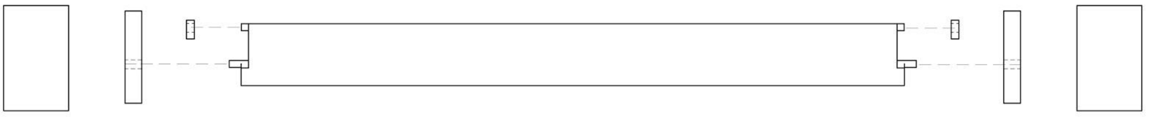

Figure 49 Exploded top view of louvre system

As mentioned in the report before, bamboo is a fast growing plant. In particular, the Moso bamboo is used extensively for multiple purposes, and it is different from the type of bamboos that the pandas consume. The growth rate of the Moso bamboo is so fast that it "*grows two feet or more in a single day, reaching a height of 60 feet in two to three months.*"[57] In five years time, the bamboo would have matured and created millions of tiny holes. This is the reason why charcoal made from this type of bamboo is much more effective than normal charcoal as a dehumidifier as well as a deodorizer. Its surface area is ten times greater and it is up to four times stronger in absorption of moisture.

The following details the making of bamboo charcoal at home:

Prepare bamboo branches.
1. First, dry the bamboo in the sun to get rid of moisture.
2. Wrap the bamboo branches with aluminium foil tightly.
3. As the bamboo is heated, the air inside will expand. Create a tiny hole so that the hot expanded air can escape.

Heat the bamboo
1. Place and heat the wrapped bamboo over a spirit lamp to carbonise it.
2. Heating the bamboo gets rid of water from the bamboo, producing white smoke that will escape from the tiny hole created in the foil earlier.
3. As soon as the aluminium foil turns yellow, the charcoal is ready. The colouration is caused by the bamboo tar.
4. Do not open the wrapping until it is cooled, which takes about five to eight days.
5. Hard charcoal is good and does not dirty one's hands, soft charcoal is caused by the oxygen present during processing and will be poor in quality.
6. This experiment produces an unpleasant smell and must be carried out outside.

On a larger scale, a brick kiln (See Appendix G for dimensions of brick kiln) heated at 500-1200^{o}C is used to slowly bake bamboo for seven to eight days after which it is allowed to cool for five to six days to mass produce charcoal.

57 Jiang S., Bamboo Engineering Research Centre, Nanjing Forestry University, Dehumidifiers made from bamboo - InfoBarrel. 2008. *Bamboo Charcoal Dehumidifiers [Sustainable +Reusable +Recyclable] Purify by nature!* [ONLINE] Available at: http://www.infobarrel.com/Dehumidifiers_made_from_bamboo. [Accessed 04 October 2012].

Carbonisation -- four part process[58]

1. Initial drying

The bamboo is heated below 120°C to evaporate the water in bamboo down to 20% to 25%.[59] It is especially needed for wet bamboo sourced during a rainy or monsoon period.

2. Precarbonisation

This process is taken between 120°C and 260°C where unstable chemicals decompose to form carbon oxides.

3. Carbonisation

Carbonisation then takes place at a temperature between 260°C to 450°C where bamboo decomposes into liquid and gas products. In this process, flammable products are released whilst carbon oxides decrease in emissions over time.

4. Refining

The final stage of carbonisation is the refining process, where non-volatile carbon changes to charcoal by releasing a vast amount of heat and other volatile compounds. *Other than being a dehumidifier, the bamboo charcoal possesses other properties like anti-bacterial, anti-fungus and absorbs harmful pollutants and odours*.[60] However, these characteristics are dependent on the temperature the bamboo is treated at during the refining process. The optimum temperature at which bamboo achieves maximum surface area to absorb odours and moisture is at 700°C[61] and heating it to greater than 1200°C would give it the ability to absorb and emit far-infrared radiation and release negative ions that are beneficial to the body. Then in their small cylindrical shapes, place them in groups of six in a circle on a plate which will be hung near the ceiling where most of the humid air will be.

58 Takano J. PYRO-ENERGEN®: A Wisdom in Electrostatic Therapy and its Technology, 2012. *How to Make Bamboo Charcoal in a Simple Way.* [ONLINE] Available at: http://www.pyroenergen.com/articles/how-to-make-bamboo-charcoal.htm. [Accessed 06 October 2012].

59 National Mission on Bamboo Applications(NMBA), *2012 Bamboo-based Charcoal Production* [ONLINE] Available at: http://www.bambootech.org/files/Charcoal.pdf [Accessed 06 October 2012].

60 Ibid

61 Takano J. PYRO-ENERGEN®: A Wisdom in Electrostatic Therapy and its Technology, 2012. *How to Make Bamboo Charcoal in a Simple Way.* [ONLINE] Available at: http://www.pyroenergen.com/articles/how-to-make-bamboo-charcoal.htm. [Accessed 06 October 2012].

SOLAR CHIMNEY

Construction of the solar chimney requires the building materials that the residents are already using, such as bamboo and coconut leaves. In addition, mud is required to line the walls of the chimney to provide insulation of the hot air in the chimney. Finally the dearer item, the corrugated iron.

There are four wall panels to be constructed using the dimensions as shown in Figure 54 and 55.

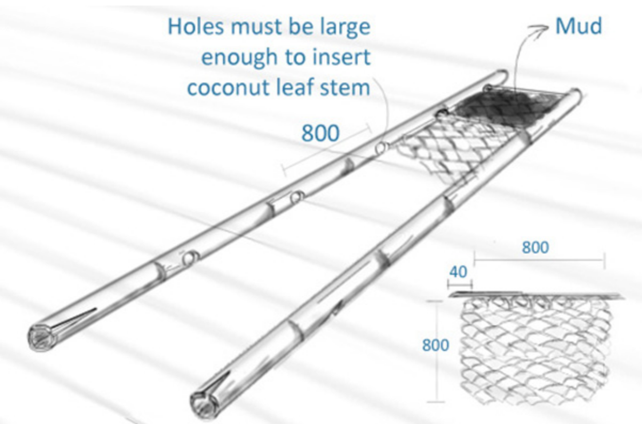

Figure 50 Construction of bamboo wall panels

1. For each wall panel, use 60mm diameter bamboo poles on each side of the panel to hold the panel up. Arrange and assemble the panel by laying the components flat on the ground, this not only keeps things straight, but it also makes it convenient to place mud onto the panels.

2. Drill holes at 800mm intervals on the bamboo poles large enough to insert the stem ends of the weaved coconut leaf sections.
3. Prepare coconut leaf sections by weaving coconut leaves together. Create 800x800mm pieces and leave about 40mm of stem on each end in order to insert into the holes in the bamboo poles.
4. When the coconut leaves are securely intact, the panels are lined with mud and allowed to dry before fixing it upright onto the existing walls. The mud is used to insulate the hot air within the solar chimney, therefore make sure the mud covers the panels completely.

Figure 51 Joint at bamboo pole

5. In the shorter wall panel, create a 400x600mm void at 1200mm height, this is where the louvre that directs air into the solar chimney will be situated. To create the frame of the louvre, drill 30mm diameter holes in the bamboo poles to insert the 30mm diameter bamboo studs (horizontal supporting pieces) in order to hold the louvre in place.

6. Lastly, create the last wall panel according to the dimensions in Figure 53. Ensure holes are drilled to insert bamboo studs to hold the louvre that will be situated at the top of the roof to let hot air out.
7. While the mud is drying, a hole in the roof is created to allow the extended height of the chimney to protrude as depicted in Figure 57.

8. After the wall panels are lifted upright, use coconut leaves to cover the wall panels on the outside as a cladding to cover up the mud that might have seeped through the holes and cracks from the weaved coconut leaf.

9. Then, cut out a 850 x 800mm corrugated iron sheet or recycled iron. This will be the cover of the solar chimney. Next, cut a slit into the the middle of the iron sheet to slot the 1000m long strip of metal into the iron sheet. After slotting, cut the strip vertically down the middle up to a distance of 200mm and bend one half forward and one half backward to secure the strip onto the iron sheet.

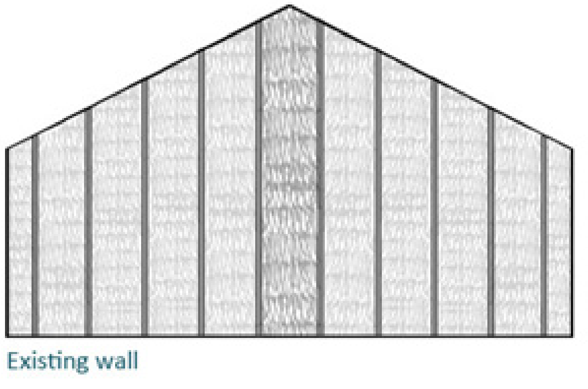

Figure 52 Existing wall

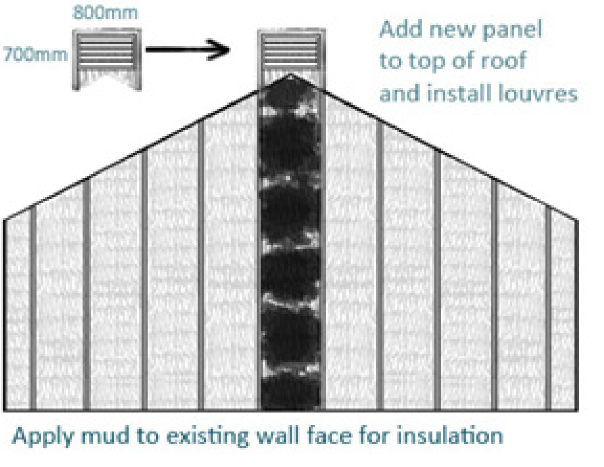

Figure 53 New Wall

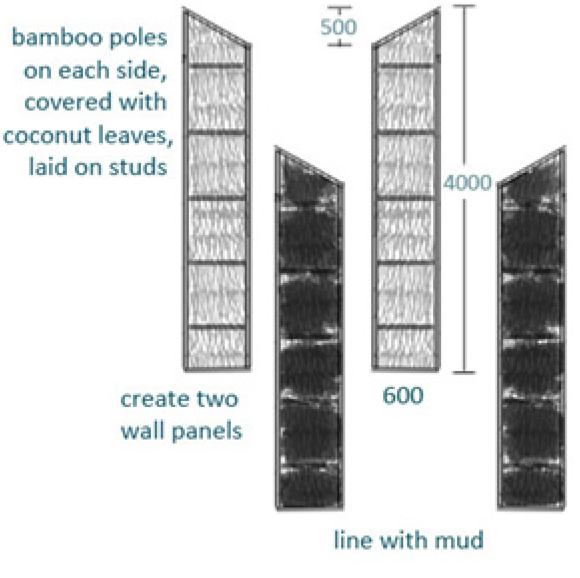

Figure 54 Side wall panels

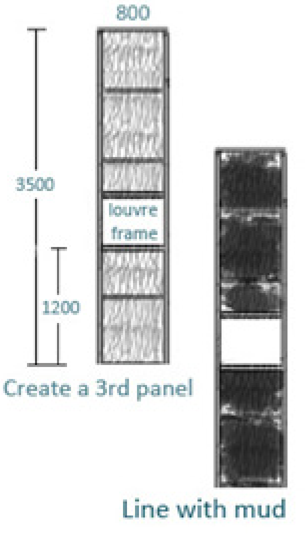

Figure 55 Shorter wall panel

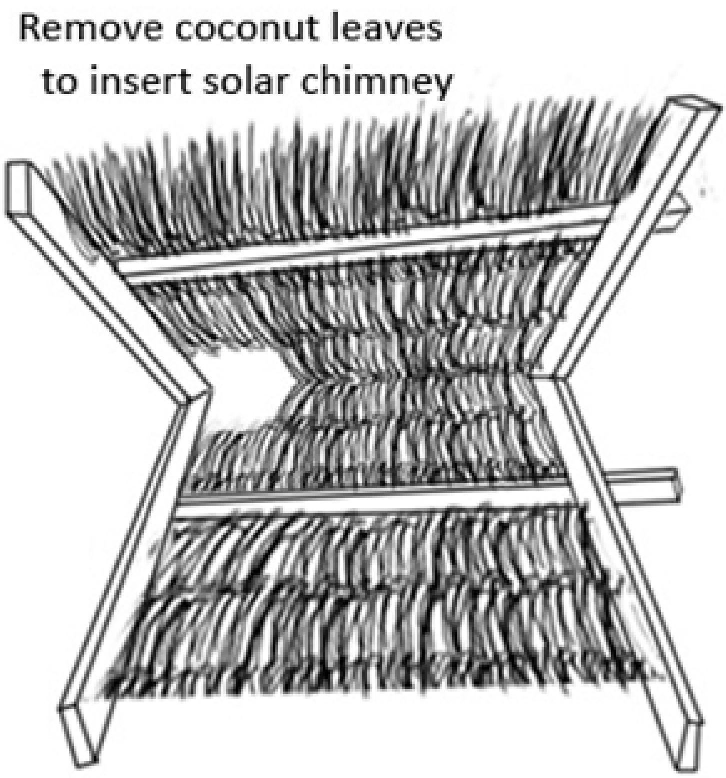

Figure 56 Underside view of the roof with hole created

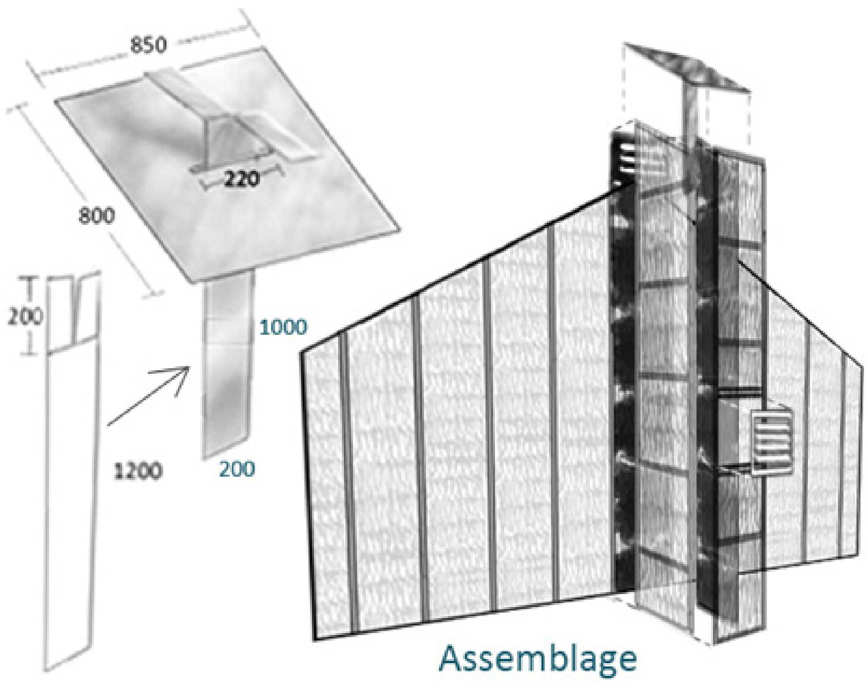

Figure 57 Assemblage ; left image shows dimensions for corrugated iron

INSTRUCTIONS

Louvres

To control the airflow within the house the louvres need to be adjusted to direct fresh air to or through a particular area of the house. The louvres are designed to be able to locked at a desired orientation by inserting a small dowel through the hole drilled in the mobile bracket and then into one of the holes in the side fixing member.

The locking mechanism is not advised to be placed at a height under 1.2m from the floor height. We recommend this due to the probability of children playing with the louvres and accidentally getting their fingers caught between closing louvres. In general however we recommend care when using the louvres as closing louvres can cause some pain, though we don't expect more significant injury or risk.

Solar Chimney

To optimise the effect of the solar chimney the louvres should be opened to allow maximum airflow into the solar chimney during still days. During nights the solar chimney will not operate as there is no sunlight to heat the top element. We recommend that the louvres be adjusted as with other louvres installed in existing windows to control airflow through the house, as the solar chimney can act as another opening (just not as effective) within the house to promote cross ventilation.

Dehumidifier

1. Prepare a 0.4m diameter wire mesh basket, 0.1m deep to contain the charcoal, illustrated in Appendix J
2. Create a 0.4m diameter metal base with a hole at the centre to insert a wooden stick with a hook at the top.
3. Create a 0.2m long wooden stick and insert it into the base.
4. Place 6 charcoal cylinders 0.15m tall and 0.055m in diameter into the basket, these would be around 2.88kg.
5. Hang the unit by the wooden hook in the middle of the house at the intersection of 2 strings attached to the opposite corners of the house (See Appendix J)
6. A house would require two units, one to dehumidify the house and the other to dry in the sun all day (except in the condition of wet weather), ready to be used the next day.

EDUCATION

In implementing the ventilation package it is necessary to educate the community of An Minh. Our proposed 'Education Scheme' will be divided into five components, addressing the following questions:

1. "Why do we need a ventilation system?"
To show the people of An Minh the necessity of a ventilation system a few houses within An Minh will be fitted with the entire ventilation system to show residents the difference between having and not having a ventilation system. The house will be open for residents to visit, with representatives present to answer any questions or concerns about the ventilation system. The aim of this is to show the community that a ventilation system can be implemented within their own household and the significant improvement it will create.

2. "What materials do we need to make our ventilation system?"
As the ventilation system uses local, natural and recycled materials, there will be an emphasis on how easy it is for residents to obtain the necessary materials to create the system. The materials required to make the ventilation system will be laid out, for residents to view and realise that they are all obtained within the village. A simple discussion of what the material is and what it is used for will also follow, to make the matter even more clear to the residents.

3. "How do we make our ventilation system?"
A step-by-step demonstration will be given to all interested residents, in how to make each part of the ventilation system. During the demonstration, residents will also be given the opportunity to be involved in the construction, to exemplify how simple the construction process is.

4. "How do we use our ventilation system?"
After the ventilation system has been assembled from the construction demonstration, the representative can then demonstrate how the system is used. This will involve a simple demonstration of how to use each component of the system. Afterwards, residents will be given the opportunity to operate the systems themselves, to allow them to become more familiarised with how it works.

5. "How do we take care of our ventilation system?"
Following the demonstration of how to use the ventilation system, the issues of care and maintenance will also be addressed. This will include identifying appropriate times for inspecting each element of the system and what aspects indicate that the system needs to be replaced or repaired. Common damages that may occur and how to repair them will also be focused on.

Alongside the 'in-house set-up', discussions and demonstrations that will take place, simple information pamphlets (that will be provided in Vietnamese) will be distributed amongst the village, so residents will be able to consult them after the event, if necessary. Moreover, the 'in-house set-up' will remain withstanding, for residents to visit and have a look at in the future.

IMPACT ASSESSMENT

ENVIRONMENTAL

Context

An Minh as with the rest of the southern tip of Vietnam is a fertile place for the growth of building resources such as *Melaleuca* wood and Moso bamboo. Each year a significant amount is harvested in plantations and by farmers, with only a small portion of *Melaleuca* wood being used for construction. Considering that the majority of houses in the An Minh district are constructed with these locally abundant materials there is a minimal effect on the environment in terms of necessary resources as their houses are small.

Benefits

By maximising the use of natural ventilation techniques we are able to reduce the necessity of energy use that may be associated with electric fans in the An Minh district. This in turn will reduce the production of greenhouse gases from the majority of unclean power sources in Vietnam.

Impact

Considering the amount of *Melaleuca* that will be needed for the louvres, we believe that we will increase the necessity of *Melaleuca* wood production by less than 25% of the 1,000 hectares currently harvested for construction in the Kien Giang Province. This will have a minimal impact on the overall production of the province which will increase by less than 0.5%, however we anticipate a boost in production within the An Minh district. The environmental impact depends on how the wood is harvested, if it is selective harvesting by owners on their own land, there is likely to be less of a significant impact. Even from plantations there will be a low environmental impact due to controlled harvesting. It is the uncontrolled harvesting by some farmers and other businesses that will cause the most significant impact.

Moso bamboo is an abundant resource in Vietnam with a fast rate of growth. We are therefore not too concerned with the impact our project might have on Moso bamboo population. Our solar chimney design will use less than four 10m poles of bamboo, whilst the bamboo charcoal dehumidifier will require 12 kg of raw bamboo for a household. Considering these relatively small amounts of bamboo compared to the total used for the house, we expect again a minimal impact on the current production and thus population of bamboo. In terms of the impacts of bamboo charcoal production heating of bamboo to high temperatures within a kiln will produce greenhouse gases and smoke. Again however for our purposes we will only be using a small amount of charcoal, which should not have a significant effect on current output in the industry.

Similarly coconut leaves are abundantly available and considering we require less than 7m^2 of each thatching and weaving, it can be easily sourced by owners themselves or bought from the local supplier, with minimal environmental impact. Coconut leaf is harvested dry and so it does not require harvesting of trees, however increased demand may increase the size of plantations which will effect the land use and cause some environmental problems.

The use of corrugated iron will have again a negligible impact on the existing industry as the solar chimney uses less than 1m^2 of corrugated iron. The production of iron does however have the greatest environmental impact of all the resources. Besides the effects of mining, there is the problem of greenhouse gases through the intensive use of energy to refine steel using some unclean power sources. This may be reduced as Vietnam moves towards using more energy from hydroelectricity sources.[62]

62 YKVN Lawyers. 2009. *Vietnam: Electric Power Industry* [ONLINE] available at http://vnm-hanoi.mofat.go.kr/webmodule/common/download.jsp?boardid=11016&tablename=TYPE_LEGATION&seqno=00cfe1fd602a051fe9f82024&fileseq=ff103805f06afd406902df95 [accessed 07 October 2012]

ECONOMIC

Context

Vietnam is credited to have *one of the fastest growing economies in the world*[63]*.* In 2002 the household income per capita of the rural sector is 3,620,000VND with 2,890,000VND household expenditure per capita and in 2004 the income and expenditure had increased to 5,210,000VND and 3,920,000VND respectively.[64] These figures can serve as approximate income for the people of the An Minh district, considering that the An Minh district is not a particularly prosperous area of Vietnam and assuming little or no effect of economic growth over the eight years since these figures were obtained. There is also a wide economic gap between the urban and rural sectors. The average household income and expenditure per capita in the urban sector is 6,980,000VND and 5,720,000VND respectively in 2002 and 10,100,000VND and 7,620,000VND respectively in 2004.

Benefits

The implementation of an efficient ventilation system inside the houses of the An Minh district has a number of economic benefits. The function of the ventilation system being implemented is completely natural and requires no energy to function. So in the long run, this will conserve on electricity from used for fans and other electrical appliances that might be used to cool the house. The only large cost involved in this process would be the initial implementation of the solar chimney. The other factors such as louvres and the bamboo dehumidifier use cheap and naturally available materials. The corrugated iron required for the solar chimney is estimated to cost 105,600VND which is a much more hefty expense than the other materials. Using the mean household income and expenditure per capita in 2004 mentioned above, the cost of the corrugated iron itself would surmount to a bit less than a month's savings. The solar chimney requires corrugated iron which is relatively expensive, however there is a benefit as any waste iron or other materials may be recycled and used, allowing better economic efficiency. After implementation, there would be little or no cost in maintenance or energy usage, so eventually, the conserved electricity would break even with the cost of materials.

Impact

The impacts this project for the economy are mainly positive. On a small scale, this project would reduce the living expenses namely in electricity for the residents of the An Minh district, while on a larger scale, this project would bolster the economic standing of the An Minh district and help bridge the gap between the rural and the urban sector economies. Ultimately, this would slightly assist the elevation of the economy of the An Minh District.

63 Hayton B., BBC News Hanoi, 2006 *Communist Vietnam rides consumer boom* [ONLINE] available at: http://news.bbc.co.uk/2/hi/business/5301086.stm [accessed 05 October 2012]

64 Cao T. C. V., Akita T., 2008, *Urban and Rural Dimensions of Income Inequality in Vietnam* [ONLINE] available at: http://gsir.iuj.ac.jp/publications/pdf/EDP08-2.pdf [accessed 06 October 2012]

Context

Children grow up to work and earn income for the family because they are taught to honour their parents and ancestors who watch over and provide for their well-being[65]. Such conditions also result from parents viewing this as a method of advancement for the family and society[66] and a source of income. While having wealth or material is not considered important, having knowledge and virtues are aspects that the people strive to achieve because these are the essential qualities that one must have to be respectable[67]. The Vietnamese society is a patriarchal one, thus the male of the family is seen as the most important and respected role because he makes economic provisions, family decisions and provides wisdom for the family. Therefore, it is seen that having a son is a must because he will inherit the role of the father. As a result, women are placed secondary in society; they are less educated and at times, are not allowed to work[68].

Benefits

Since the family's desire is for advancement in their current lives, they would be comfortable with acceptance of positive change to their property if it will benefit them, provided other concerns like costs are addressed.

In addition, providing solutions to their comfort with the help of dehumidifers, safety from the consequence of imbalance of pressure with adjustable louvres, and management of waste like corrugated iron scraps, shows them the respect that they desire because this not only provides them the knowledge that they can apply but also highlights that their comfort is seen as our priority and something they deserve.

Women have to and can only stay at home, thus it is important for women to feel comfortable at home. A good ventilation system not only provides comfort for the typical large family living under one roof, but also allows the father to make a difference in the family by the setting the ventilation system up himself.

In addition, the young and old who are not able to withstand the heat will benefit from the comfort and safety that the design brings and children have a better environment to study in. This also improves the social relationships between neighbours as they gather in one's house for a meal.

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65 Vietnamese Culture and Tradition. 2006. *Vietnamese Culture: Vietnamese traditional family values.* [ONLINE] Available at: http://www.vietnam-culture.com/articles-53-6/Vietnamese-traditional-family- values.aspx. [Accessed 05 September 2012]

66 Ibid

67 Vietnamese Culture and Tradition. 2006. *Vietnamese culture: Vietnamese Value System.* [ONLINE] Available at: http://www.vietnam-culture.com/articles-18-6/The-Vietnamese-Value-System.aspx. [Accessed 05 September 2012].

68 Butler R. Vietnam - SOCIETY. 2009. *Vietnam-The family, Background* [ONLINE] Available at: http://www.mongabay.com/reference/country_studies/vietnam/SOCIETY.html. [Accessed 04 October 2012].

Impact

Bringing change to the normal lives of the Vietnamese, despite their eagerness for knowledge and technology, is nevertheless something to be tackled and approached with gentleness and strategy. This technology and the idea of using natural means to ventilate their house is new to the residents of Vietnam. Getting used to the technology is one matter, accepting that good ventilation is an important aspect of life is another.

In summary, it is for these reasons that the proposal for implementation is taken in three stages. Not only will the cost involved to introduce changes be divided, but also the idea that better ventilation can be slowly introduced and assimilated into the lives of the people in An Minh with minimal environmental impacts.

COMMUNITY CONSULTATION

The community will need to be informed of the design and implementation process through effective consultation before the installation, and be provided enough training to be able to handle the system self-sufficiently. However, there may be a need for improvement through consultation with other members of the community and to make sure that individual and community needs are satisfied. After consultation, the design needs to be refined to suit the individual household, construction methods revised to suit the skilled labour in the area and redeveloping the timeline for the implementation process to suit the demand of the area.

Refining the design to suit individual circumstances

Whilst the project has been developed considering the general morals, beliefs and values of the Vietnamese community, it may not cater ideally for every Vietnamese person. Therefore, to allow optimal implementation within the An Minh community, the design should be simple to refine to suit individual circumstances. This aspect is generally solved through the construction process itself, refined by the household owner in order to meet any individual circumstances, if necessary. An example of this is whether an owner decides to install louvres to their doors in addition to installation to windows.

Construction methods

The prepared construction methods at this point are believed to be sufficient for an average Vietnamese man within An Minh to perform. What we have assumed to be the level of skill in An Minh however, may not adequately reflect those in the district and thus our construction methods and design will need to be refined accordingly. Since the level of labour skills is likely to vary amongst each household, the duration and difficulty of the construction process will also vary. What is likely to be the greatest difficulty is if a household is unable to construct the ventilation system due to the lack of tools that are required, since skills can be taught through the education program. Therefore, during the consultation process, the design will be assessed for whether the locals are able to execute the given construction methods followed by a refinement process, if required.

Timeline and implementation process

The time taken to implement the system for individual houses in An Minh may vary due to individual circumstance and the experience gained by the community as they gain knowledge and understanding of how the system works. Consultation with the community will allow a greater understanding of the required time and effort in implementing the project, and this would allow revision of the timeline for the implementation process to increase the efficiency of the project. However, a generalisation of the knowledge that the community has in implementing the project may not be indicative of the individuals that actually work on the project, and hence a general community consultation may not pick up on the individual issues.

Trust

The community in An Minh is not likely to willingly accept our proposal of the implementation of our ventilation system in alll houses. The likeliness of this rejection can be due to a number of aspects but overall, trust is the critical factor. With not being well acquainted with the An Minh community, there will be little trust given, especially when introducing a foreign idea. The consultation process will ideally provide a situation for trust to be developed. To facilitate the building of trust the An Minh community members should be treated equally with respect and dignity.

Improving consultation

The above factors have highlighted the major components of the consultation process however, if one component is proven to be ineffective or unsolvable, the project may not be accepted by the community. Therefore, when we consult the community, we should present them with our ideas and what we would like to do for them, as well as ask them of their opinion on ventilation. This approach should be taken right from the beginning of the planning and design process. This would not only set us off in the right direction but also show our respect for the people and their voice on the matter.

Alongside consulting the council of certain matters, communication should also occur with a larger group of the community, such as with local residents. This increases the representation of the whole community and promotes equality between all parties. A contributing factor to this is the time spent with the community in considering how the ventilation can be effectively implemented in An Minh. Moreover, a survey can be provided to engage the community with the design and this will ease implementation in the future, as residents will be informed and prepared if any changes are to be introduced. Our initiation to approach and communicate with the residents also shows that they are able to communicate with us and voice their opinion freely without obligation to adhere to any proposed solution. This creates a foundation of trust and harmony between both parties.

The use of effective communication with the community will furthermore only occur through an interpreter, which will also help in convincing the community to adopt this ventilation system. Inclusively, regular meetings should be held with the community, in order to keep the design in track of what the residents of An Minh need.

CONSTRAINTS AND DIFFICULTIES

Communication constraints and difficulties with the community

The language barrier is the major issue and constraint in having effective communication with the community of An Minh. It is expected that most of the residents of the An Minh district will only have a perfunctory ability or little knowledge of how to speak English due to the fact that An Minh has very little contact to English speaking people or western culture. This would limit the appeal and acceptance of the project we are proposing because of the difficulty in conveying the necessity of the project for the community.

Again the lack of any previous relationship or experience with the An Minh community means that it is necessary for the team to first develop a relationship of trust, which will break down any remaining perceptual and cultural barriers with the initial consultation team.

In addition to the difficulty in communicating orally with the people of An Minh we anticipate it will be difficult to communicate the concepts that enable our ventilation design to work. These include the ideas of convection and moisture absorption which are difficult to see and observe especially in relation to the components within our design. We expect that there will be difficulties in acquiring the first few houses to implement a full package which will physically demonstrate the concepts behind our design.

Other physical barriers that may occur include those of having physical meetings with members of the community as well as its leaders. Transportation is difficult due to distances between communes and the cost of maintaining a boat which prevents a portion of people from travelling far distances. Thus physical meetings with necessary people will be difficult, preventing effective communication of issues and ideas.

Proposal to overcome communication constraints and difficulties

In considering the problem of the language barrier it would be necessary for the team to employ a translator to effectively communicate with the community. It would be best if a member of the team could speak Vietnamese as they would have a direct relationship to the project and not be a third party. Instead of learning the language, we can offer a few Vietnamese locals to be involved in the project design, this shows that we are willing to engage with the community and this helps the residents confidence in serving their community.

We expect that consultation time will build trust between the team and the community in An Minh, whilst spending time with the community to understand their needs and circumstances, will build a strong relationship that will break down remaining barriers. In addition, patience is integral when communicating with the people, thus, clarification is important in getting message across and from the people to avoid any miscommunication. Whilst meetings through the internet can be convenient and effective, regular face-to-face meetings ought to be held, to resolve complicated issues that may raise misunderstandings. Moreover, one cannot rely that sent information through the internet will be read, different media must be utilised to allow the people to choose a preferred way of communication, one that they will respond to.

Language is difficult when expressing ideas, therefore, by building concept models and smaller prototypes we will be able to effectively convey the concepts behind our ventilation system. This shows our sincerity and helps them visualise the reality of all the effort that had been put into the meetings before.

Other constraints and difficulties

There are a few major constraints that may be encountered in the process of the implementation of the project. There may be difficulty based on religion, culture and beliefs of the An Minh district. It would be regrettable if any of their beliefs or cultural guidelines were violated during implementation of the ventilation system. Trust is a major aspect between the representatives and the locals and any loss in trust would cause difficulties concerning acceptance and would reduce the willingness of the residents to implement our new ideas.

The cost and availability of materials is also a slight difficulty. The louvres and charcoal dehumidifier are cheap, but the solar chimney requires relatively expensive material to implement. The primary constraint concerns the community's willingness to spend money.

Proposal to overcome other constraints and difficulties

In terms of difficulties concerning beliefs of the people of the An Minh district, these can be resolved with respecting the beliefs and understanding them. The ventilation system does not violate any obvious cultural or religious beliefs of Vietnamese culture in general; however different people may have different beliefs and it must be ensured that the cultural aspects of Vietnam mentioned previously in this report cannot be mistaken for a universal description of every person residing in Vietnam.Therefore, it is essential that an informative survey is carried out to interview the residents on various issues and concerns, to avoid offending the residents and losing mutual trust. Other similar factors, such as sentimental value for example, are also constraints that need to be respected and worked around.

The difficulties of materials and cost have been previously addressed and explained. The louvres and dehumidifiers will be implemented first to encourage trust for the representatives as well as the actual ability of the items that are presented before implementing the solar chimney. The desired response is that they would trust the products, and recognise that the ultimate benefits will outweigh the cost.

CONCLUSION

By undertaking this project, the main aim is to provide a solution that will ultimately be an improvement to the current conditions that the people in the An Minh district currently experience. The ultimate solution provides a ventilation system that caters for all aspects of climate, weather conditions and the local household. The louvres provide a level of control to redirect air flow during windy conditions, to improve the thermal comfort of the occupants, while maximising the use of natural ventilation. As humidity influences the temperature that the body feels and how it functions, bamboo charcoal dehumidifiers provide an optimal solution to decrease humidity during the wet season, considering that it comes from a naturally abundant resource and doesn't require energy to run. Finally, a solar chimney provides an ideal natural method of circulating air through the house during the dry season.

The solution considers the ethics and sustainability of the project for the community, economy and environment in the immediate future and in the long run. Of high importance is the consideration that the project is implemented one stage at a time, to increase awareness and acceptance by the community. Cultural and social practices will need to be adhered to, and will be crucial to the success of the project. The provision of education for the community provides the ongoing support required to successfully implement the system over the long term. The lower socio-economic background of the community demands that the resources used are of low cost, and that these resources are bought locally to support the local industry. These aspects are achieved through the implementation of all stages of the ventilation system, including utilising local labour to construct materials. By resourcing raw materials from plantations either on private property or state land, support for the regeneration of local forest is increased, which improves the sustainability of the environment.

With due consideration of all aspects of the project, it is ideal that the effective ventilation system as detailed in this report is implemented. This will provide an improvement in the quality of life for the people in the An Minh district over the long term.

TEAM

MEMBER ROLES

Chantelle
- Report Formatting

Gordon
- Editor

John
- Editor

Rebecca
- Motivator

Sammy
- Evaluator

Warren
- Moderator

MEMBER DIFFICULTIES

Chantelle
- Meeting team deadlines
- Communication with team members
- Having an equal contribution to the group

Gordon
- Communicating with team members
- Innovation
- Team management

John
- Communication with team members
- Working efficiently for long hours
- Time management

Rebecca
- Contribution to the group
- Language skills

Sammy
- Completing work

Warren
- Communication with team members

MEMBER CONTRIBUTIONS

Chantelle
- Introduction
- Background information
- Ideas and Technologies
- Issues
- Prototype
- Education
- Report Formatting

Gordon
- Prototype Louvre system
- Louvre construction
- Louvre Design solution
- Environmental Impact Assessment
- Current Ventilation
- Implementation

John
- Canopy Entrance Research
- Issues: Skills & Time
- Technical Calculations
- Prototype 4 [solar chimney]
- Resources
- Cost

Rebecca
- Societal and cultural issues
- Roof and Wall Insulation research
- Stack Ventilation research
- Sustainability of Materials
- Prototype 3 [charcoal dehumidifier]
- Dehumidifiers production
- Solar chimney construction
- Social and cultural impact assessment

Sammy
- Cross Ventilation
- Ethics
- Sustainability

Warren
- Solar Chimney research
- Solar Chimney design solution
- Weather and Climate
- Economic Impact assessment
- Constraints

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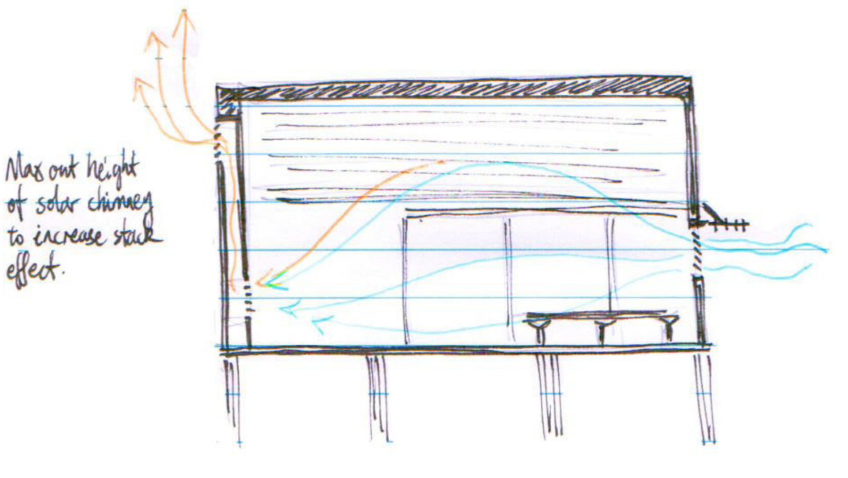
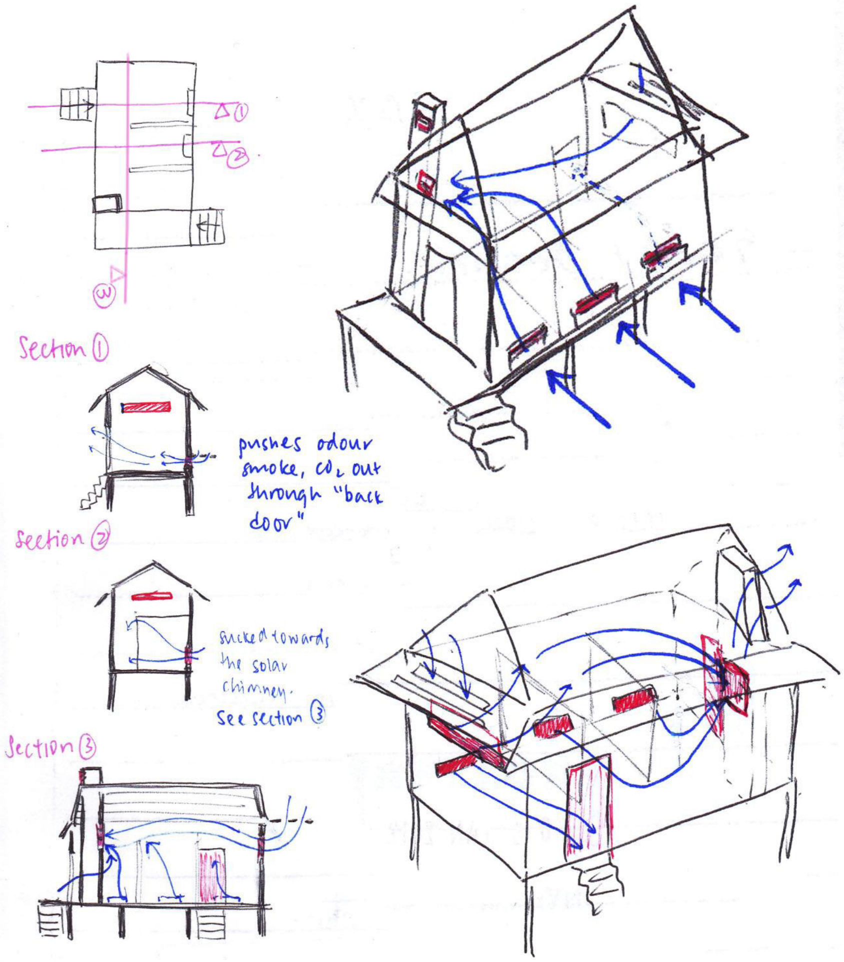
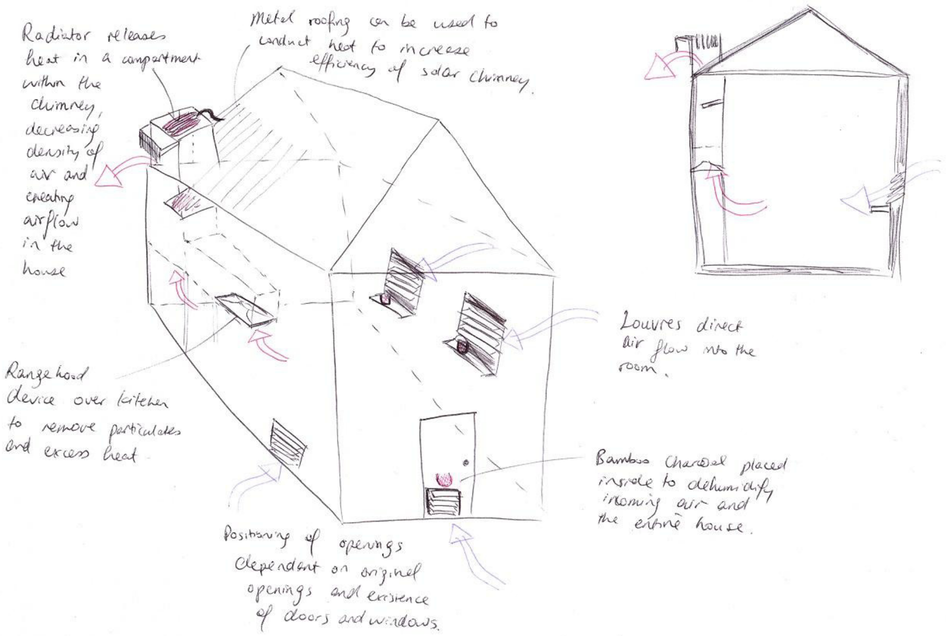
APPENDIX

APPENDIX A

Preliminary sketches of design solution




Section ①
pushes odour smoke, CO_2 out through "back door"
Section ②
Sucked towards the solar chimney.
See section ③
Section ③


Radiator releases heat in a compartment within the chimney, decreasing density of air and creating airflow in the house
Metal roofing can be used to conduct heat to increase efficiency of solar chimney.
Louvres direct air flow into the room.
Rangehood device over kitchen to remove particulates and excess heat
Bamboo Charcoal placed inside to dehumidify incoming air and the entire house.
Positioning of openings dependent on original openings and existence of doors and windows.

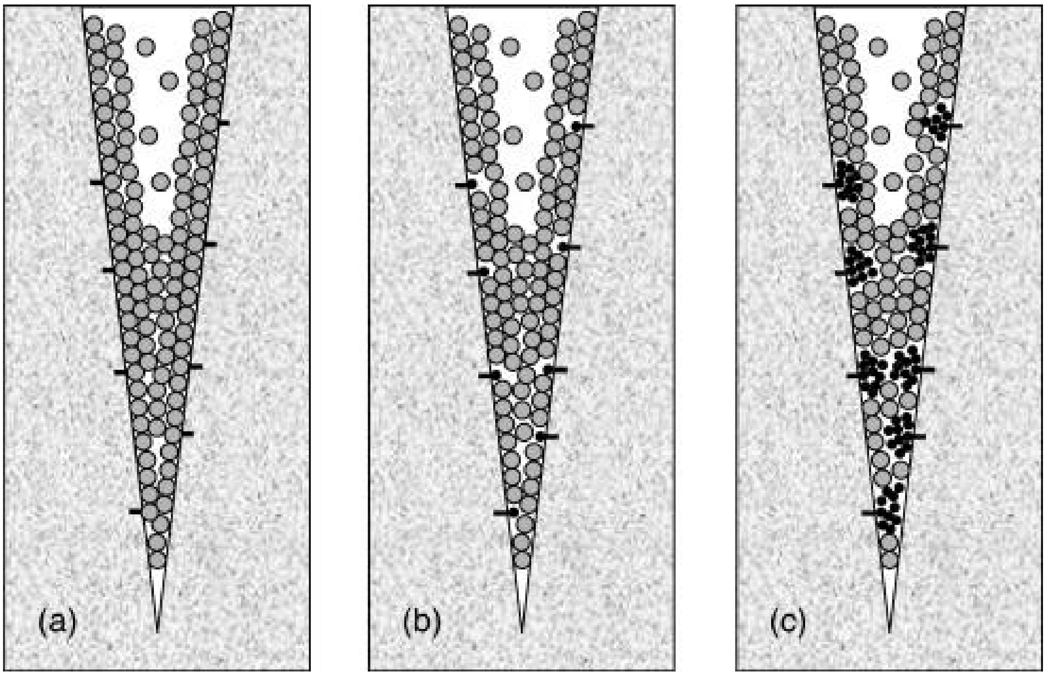
APPENDIX B

The following table summarises the climate in the An Minh region:

Month	Maximum Temperature (° C)	Minimum Temperature (° C)	Relative Humidity (%)	Precipitation (mm)
January	27	22	80	20
February	28	23	80	20
March	29	25	78	55
April	31	25	80	150
May	33	25	82	280
June	32	26	85	360
July	29	27	84	390
August	27	24	85	420
September	28	25	84	300
October	28	25	86	370
November	28	23	83	180
December	28	23	79	90

APPENDIX C

Below the limiting moisture content for coal, the CO_2 sorption capacity reduced by about 7.3 kg t^{-1} for each 1% increase in moisture. For CH4, sorption capacity was reduced by about 1.8 kg t^{-1} for each 1% increase in moisture.[69]



Schematic representation of CO_2 and moisture adsorption in coal pores (CO_2—grey circles; water—small black circles). The black marks on the edge of the pore structure represent polar sites. (a) CO_2 only; (b) CO_2 with water monolayer; (c) CO_2 with water clusters.

69 Day, S. et al,. 2008, *Supercritical gas sorption on moist coal.* [ONLINE] Available at: http://www.sciencedirect.com/science/article/pii/S0166516208000311. [Accessed 12 September 2012]

APPENDIX D - LOUVRES AND WINDOWS CALCULATIONS

The following will calculate the relative velocity of air within the house, as a result of wind passing through the window.

The flow rate Q is determined by multiplying the cross sectional area that the fluid flows through with the average velocity of the wind. Also, for a fluid flowing through a cross section,

$$Q = A_1v_1 = A_2v_2$$

where A_1 is the area at the window, v_1 is the velocity at the window, A_2 is the cross sectional area of the house, and v_2 is the relative velocity within the house

<u>Assumptions</u>

Window area of $1m^2$

Wind speed ranges from 20km/h or 5.5m/s to 65km/h or 18m/s

Cross section of house = 3.5m high x 8m wide = $28m^2$

At the lower speed of 5.5m/s, flow rate $Q = A_1v_1 = 1m^2 \times 5.5m/s = 5.5m^3/s$

At $A_2 = 28m^2$, $v_2 = Q/ A_2 = 5.5m^3s^{-1} / 28m = 0.196m/s$

At the higher speed of 18m/s, flow rate $Q = A_1v_1 = 1m^2 \times 18m/s = 18m^3/s$

At $A_2 = 28m^2$, $v_2 = Q/ A_2 = 18m^3s^{-1} / 28m = 0.643m/s$

Uncomfortable wind drafts occur above 0.2m/s[70], so light wind would be comfortable during the night and during the dry season. For wind speeds higher than a light breeze, louvres will be able to control the air flow entering the house by either redirecting the air or reduce the intake of air. For hot and humid days, it may be desirable to have higher air speeds of 3m/s entering the house; hence the louvres will be able to effectively manoeuvre the air flow. Also, multiple windows will provide greater air flow to cool down the occupants inside the house.

70 Aynsley, R. 2007. *Environment Design Guide* [ONLINE] Available at: http://www.yourbuilding.org/library/1_TEC25.pdf [Accessed 16 September 2012]

APPENDIX E - BAMBOO DEHUMIDIFIER CALCULATIONS

In An Minh, the average temperature during the day is 30°C with an average humidity level of 75%. This feels like the equivalent temperature of 43°C. Assuming the temperature remains unchanged, the humidity should be reduced to 25% to create optimal comfort for the occupants.[71] However, the amount of moisture to be removed from the air in order to achieve that level may be unachievable by using natural dehumidification.

Assuming the density of water vapour = 0.8kg/m^3 and at 30°C the maximum saturation factor is 2.5% (the maximum amount of water in air is 2.5%), the mass of water in 1m^3 of air at 30°C, assuming 100% humidity = 0.8kg x 0.025 = 0.02kg

Taking the dimensions of a typical house to be 6m x 8m x 3m, the amount of moisture in the house is 144m^3 x 0.02kg/m^3 = 2.88kg. Clearly, the amount of water possibly present in the air is way too much for bamboo charcoal to naturally dehumidify the air.

Dry air is denser than humid air, since water molecules with an atomic mass of 18 will displace the abundant oxygen and nitrogen molecules of atomic mass 32 and 28 respectively.[72] Hence the dry air will remain at the bottom of the house. Theoretically, this would reduce the height of the region to be dehumidified to around 2m, since that is the limit of the space that humans will occupy. The new volume is 6m x 8m x 2m = 96m^3.

Also, for moderate comfort, relative humidity can be within the range of 25%-60%.[73] Hence, to reduce the level of humidity from an average of 75%, only 15% of the maximum humidity needs to be removed by the bamboo charcoal to create an appreciable difference in comfort.

To reduce the relative humidity from 75% to 60% in a 2 metre high region inside the house, while assuming temperature of 30°C, the amount of moisture to be removed = 96m^3 x 15% x 0.02kg/m^3 = 0.288kg = 288g.

Within a relative humidity range of 50% - 75%, charcoal can absorb 10%-12% of its own weight.[74] Hence, to dehumidify the whole house we need 0.288kg x 10 = 2.88kg of bamboo charcoal. Ideally, the position of the charcoal should be kept within two metres from the bottom of the house so moisture in the roof space is not unnecessarily absorbed.

71 CSG. 2011. *Canadian Humidex Calculator.* [ONLINE] Available at: http://www.csgnetwork.com/canhumidexcalc.html. [Accessed 16 September 2012]
72 Haby, J. 2012. *Why is moist air less dense than dry air at the same temperature.* [ONLINE] Available at: http://www.theweatherprediction.com/habyhints/260/ [Accessed 15 September 2012]
73 Engineering Toolbox. 2012. *Recommended Relative Humidity.* [ONLINE] Available at: http://www.engineeringtoolbox.com/relative-humidity-d_895.html [Accessed 16 September 2012]
74 F.R. Humphreys. & G.E. Ironside. Forestry commission of N.S.W. , Research note No. 44., Sydney 1974. 3rd Edition,1980. *Charcoal from New South Wales Species of Timber.* [ONLINE] Available at: http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0015/390003/Charcoal-from-NSW-Species-of-Timber-3rd-Edition.pdf. [Accessed 16 September 2012]

APPENDIX F - SOLAR CHIMNEY CALCULATIONS

The solar chimney works by transferring heat absorbed from the sun to the cavity inside the chimney. This heats up the air inside the chimney via convection and radiation, which will rise due to buoyant effects of hotter air.

Calculation of the temperature of system

Radiation entering the Earth from the Sun[75], accounting for factors in the atmosphere = 168W/m^2.

Let the surface area of the corrugated iron capturing the radiation be 2m^2 and the absorption of 100% efficient. The power generated is 168W/m^2 x 2m^2 = 336W

In order to consider the temperature which the metal plate inside the chimney will reach, we consider the equilibrium condition in which the rate of radiation absorbed is equal to the rate of radiation released from the surface of the corrugated iron. The rate the metal absorbs the radiation is given as 336W. To calculate the rate at which the radiation is released, we use the formula
$P = Ae\sigma(T_f^4 - T_i^4)$

P is the rate the radiation is released, A is the surface area, e = emissivity of surface, which we assume equals to 1, σ is the Stefan–Boltzmann's constant = 5.67 x 10^{-8} W m^{-2} K^{-4}, T_f is the temperature that the metal will reach in Kelvin, and T_i is the surrounding air temperature in Kelvin.

For equilibrium, P, the rate the radiation is released equals radiation absorbed = 336W. Surface area A = 2m^2, T_i = 30°C = 303K

Hence to calculate T_f, substitute all the values into $P = Ae\sigma(T_f^4 - T_i^4)$

$$336\text{W} = 2\text{m}^2 \times 1 \times 5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4} \times (T_f^4 - (303\text{K})^4)$$

$$T_f = 327\text{K} = 54°\text{C}$$

This will be the temperature of complete system of metal components.

Calculation of the rate of heat generation

Assuming the heat is conducted at 100% efficiency, and the heat is released using convection and radiation in the metal plate within the chimney, we can find the rate which heat is released from the system.

75 Nielson, R. 2005, *Solar radiation*. [ONLINE] Available at: home.iprimus.com.au/nielsens/solrad.html [Accessed 15 September 2012]

The formula for convection is

$$q = hA(T_2 - T_1)$$

q is the rate of convection, h is the convection constant between metal and air = $50Wm^{-2}K^{-1}$, A is the area of the metal plate within the chimney = $0.2m^2$, T_2 is the temperature of the metal plate in Kelvin = 327K, T_1 is the surrounding air temperature in Kelvin = 303K.

To calculate the rate of convection

$$q = 50Wm^{-2}K^{-1} \times 0.2m^2 \times (327K - 303K)$$

$$q = 240W$$

The net radiation from the metal plate is also calculated from the formula $P = Ae\sigma(T_f^4 - T_i^4)$
$A = 0.2m^2$, $e = 1$, $\sigma = 5.67 \times 10^{-8}\ W\ m^{-2}\ K^{-4}$, $T_f = 327K$, $T_i = 303K$

$$P = 0.2m^2 \times 1 \times 5.67 \times 10^{-8}\ W\ m^{-2}\ K^{-4} \times ((327K)^4 - (303K)^4)$$

$$P = 34W$$

Hence, the total power of the system is 240W + 34W = 274W

<u>Calculation of time to generate heat</u>
The following will analyse the airflow within the house caused by the heating of air within the solar chimney:

The total volume of the solar chimney = 0.8m x 0.6m x 2m = $0.96m^3$

We assume that convection occurs for a temperature change of 1°C, from the average temperature of 30°C to 31°C

$$\text{Density of air at } 30°C = 1.164kg/m^3$$

$$\text{Density of air at } 31°C = 1.161kg/m^3$$

Weight of air in chimney is

$$1.164kg/m^3 \times 0.96m^3 = 1.12kg$$

Heat capacity is calculated using the formula

$$H = mc\,\Delta T$$

H is total heat energy, m is the mass of the air = 1.12kg, c is the specific heat capacity of air = 1.00kJ/kg.K, ΔT is the change in temperature = 1°C = 1K

The total amount of heat required to warm up 1.12kg of air by 1°C is

$$H = 1.12\text{kg} \times 1.00\text{kJ/kg.K} \times 1\text{K} = 1.12\text{kJ}$$

Amount of time taken to heat this amount of air is

$$1.12\text{kJ}/274\text{W} = 4.1 \text{ seconds}$$

This calculation shows that it doesn't take long for the radiation from the sun to generate movement of air within the house.

Calculation of air velocity within chimney

Buoyant force is calculated by the formula

$$B = \rho g V$$

ρ is the density of the air, g is acceleration due to gravity, V is the volume of displaced fluid

The buoyant force acting on the hotter air inside as a result of the air inside "displacing" the cooler surrounding air is found, using $\rho = 1.164\text{kg/m}^3$, $g = 9.81\text{m/s}^2$, $V = 0.96\text{m}^3$

$$B = 1.164\text{kg/m}^3 \times 9.81\text{m/s}^2 \times 0.96\text{m}^3$$

$$B = 10.96\text{N}$$

The new mass within the chimney is

$$1.161\text{kg/m}^3 \times 0.96\text{m}^3 = 1.11\text{kg}$$

Acceleration caused by 10.96N force on the mass within the chimney is

$$a = 10.96 / 1.11\text{kg} = 9.83\text{m/s}^2$$

Since acceleration due to gravity is $9.81 m/s^2$, the net acceleration is

$$9.83 m/s^2 - 9.81 m/s^2 = 0.02 m/s^2$$

To cover a distance of 2m, using the formula

$$v^2 = u^2 + 2as$$

where v = final velocity, u = initial velocity = 0m/s, a = acceleration = $0.02 m/s^2$, s = displacement = 2m,

$$v^2 = 2as = 2 \times 0.02 m/s^2 \times 2m$$

$$v = 0.28 m/s$$

Since air is being continually warmed up as it moves through the chimney, it can be assumed that this is the average velocity that air will flow through the chimney. Also the air speed is low enough not to be noticeable, especially considering how much larger the space of the house is.

Calculation of flow rate of air within the house

The formula for flow rate is

$$Q = A_1 v_1$$

A1 = cross sectional area of chimney = 0.6m x 0.4m = $0.24 m^2$, v_1 = velocity of air movement = 0.28m/s

$$Q = 0.24 m^2 \times 0.28 m/s = 0.067 m^3/s$$

Assuming the volume of the house to be $144 m^3$, the time taken to completely circulate the air through the house is

$144 m^3 / 0.067 m^3 s^{-1}$ = 2150 seconds or 36 minutes.

This is assuming the weather is calm with no wind.

APPENDIX G - PROTOTYPE 3 CALCULATIONS

Volume of linen cupboard
= 880x510x 2420
= 10860960mm^3
= 1.086m^3

Volume of bathroom take away volume of linen cupboard=8.85m^3

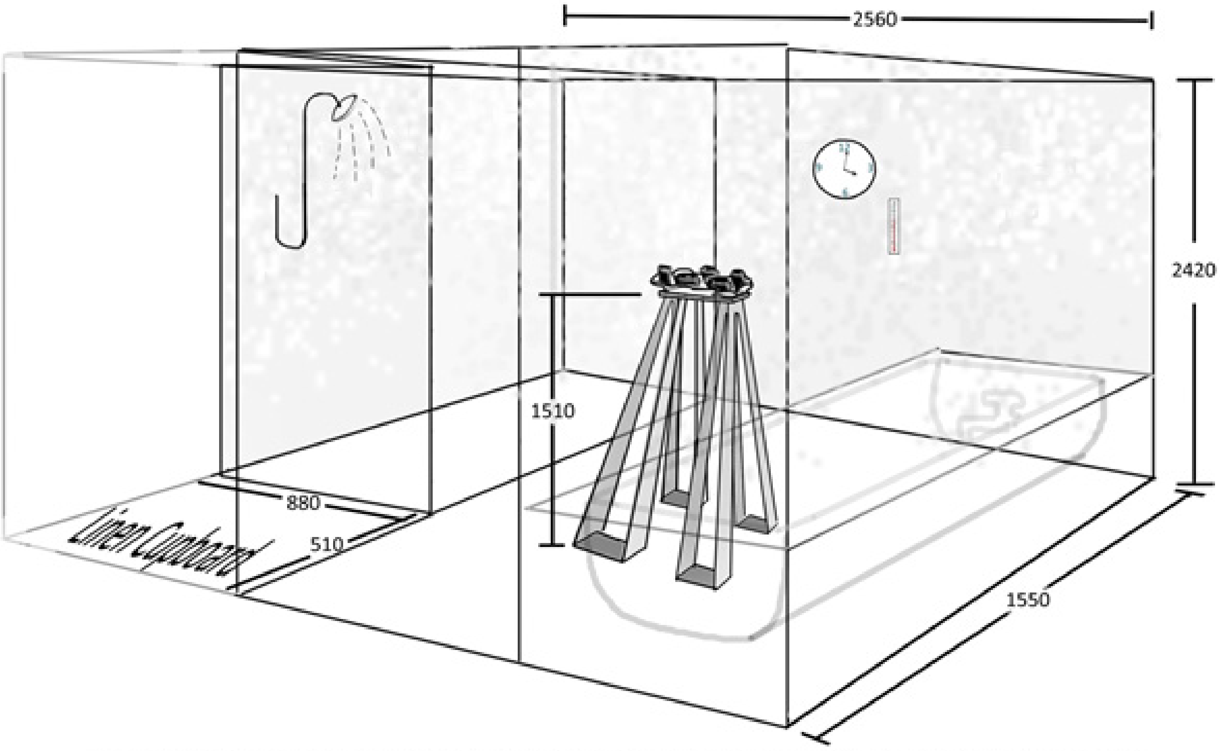
Volume of upper part of the room (where the dehumidifier is)
= 2560x1270X1550 - 880x510x1270
= 4469384000mm^3 = 4.47m^3

Amount of water in the air= 0.02kg/m^3 (saturated air)

Typical bathroom average humidity level after a 15 minutes shower is approximately 70%[76] which suggests about 0.014kg of water in air.
Reducing humidity levels of 70% down to 50% = reduce 20% of the water in the air
water to be removed is 4.47m^3 x 0.014kg/m^3 x 0.2 = 0.012516kg = 12.516 g

Assuming absorption capacity of regular charcoal is less than that of bamboo charcoal (10%-12% of its weight), that is approximately 9% of its weight, therefore,
12.516x 100/9 =139g of charcoal is needed

76 Martin W. Liddament, VEETECH Ltd. Registered in England. 2012. *Condensation: Bathroom Ventilation*. [ONLINE] Available at: http://www.veetech.org.uk/Bathroom%20Ventilation.htm. [Accessed 04 October 2012].



Set up of enclosed space (bathroom) to test the dehumidifier (regular charcoal)

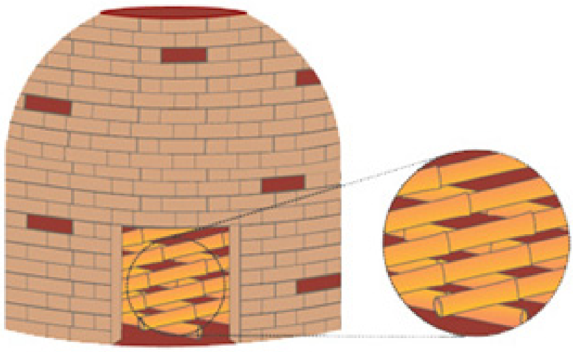


Figure Image of a hemispherical brick kiln used to bake the charcoal.

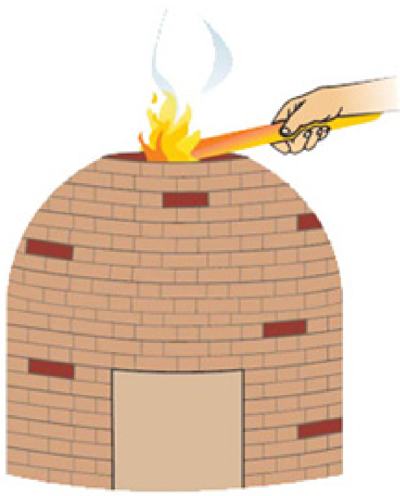


Figure Fire is fed from the top opening of the brick kiln [size of hand is out of proportion].

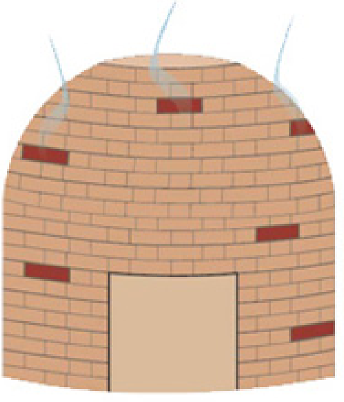


Figure Black smoke escaping from the upper part of the brick kiln.

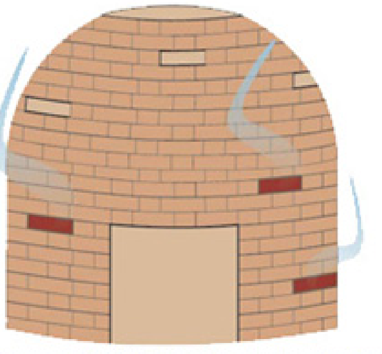


Figure As the black smoke slowly sinks, turns into white smoke and escapes from the lower openings,bricks are inserted to the voids in the upper part of the kiln.

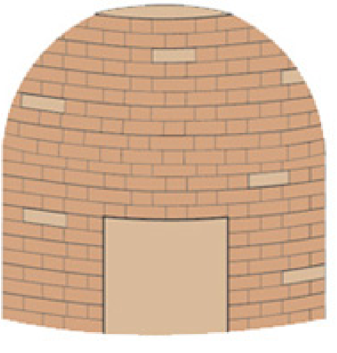


Figure All openings are closed after 2 days to prevent the charcoal from catching fire. The kiln is then left to cool for 5 to eight days.

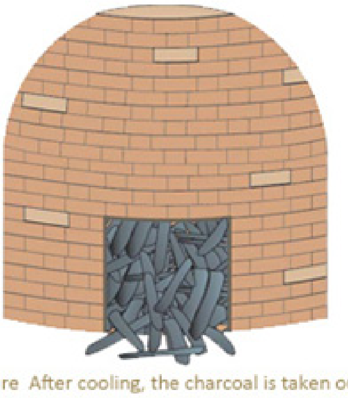
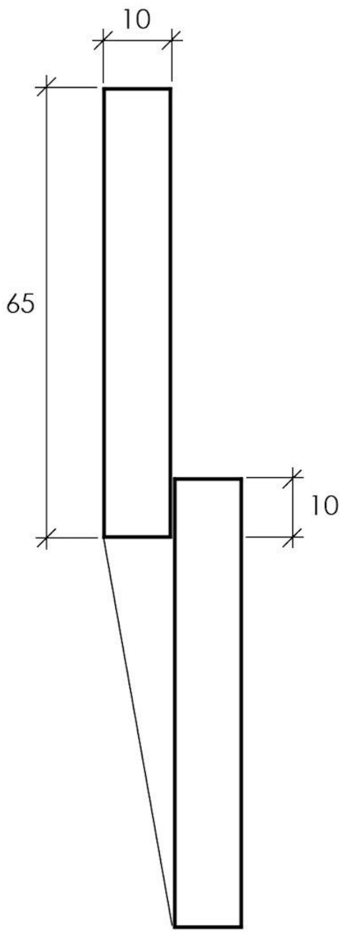


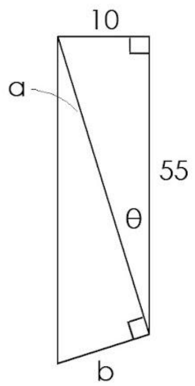
Figure After cooling, the charcoal is taken out of the kiln via the opening where the bambo was inserted

(IMG URL:http://www.bambootech.org/files/Charcoal.pdf)

APPENDIX H

Calculations regarding the vertical distance of louvres and the distance between the dowel like protrusions at the end of each louvre.





Louvres have a thickness of 10mm and are 65mm wide. With an overlap of 10mm the distance from the same point on each of the louvre's is a.

a=sqrt(10^2+55^2)=55.901..= approx. 56mm

This is also the vertical distance the louvres must be apart by to have the 10mm overlap.

Determining the perpendicular distance between the two protrusions when closed will identify the necessary width of the mobile bracket and whether or not this distance must be changed if it is too small to adequately withstand the forces exerted on it by the louvres. This distance is b.

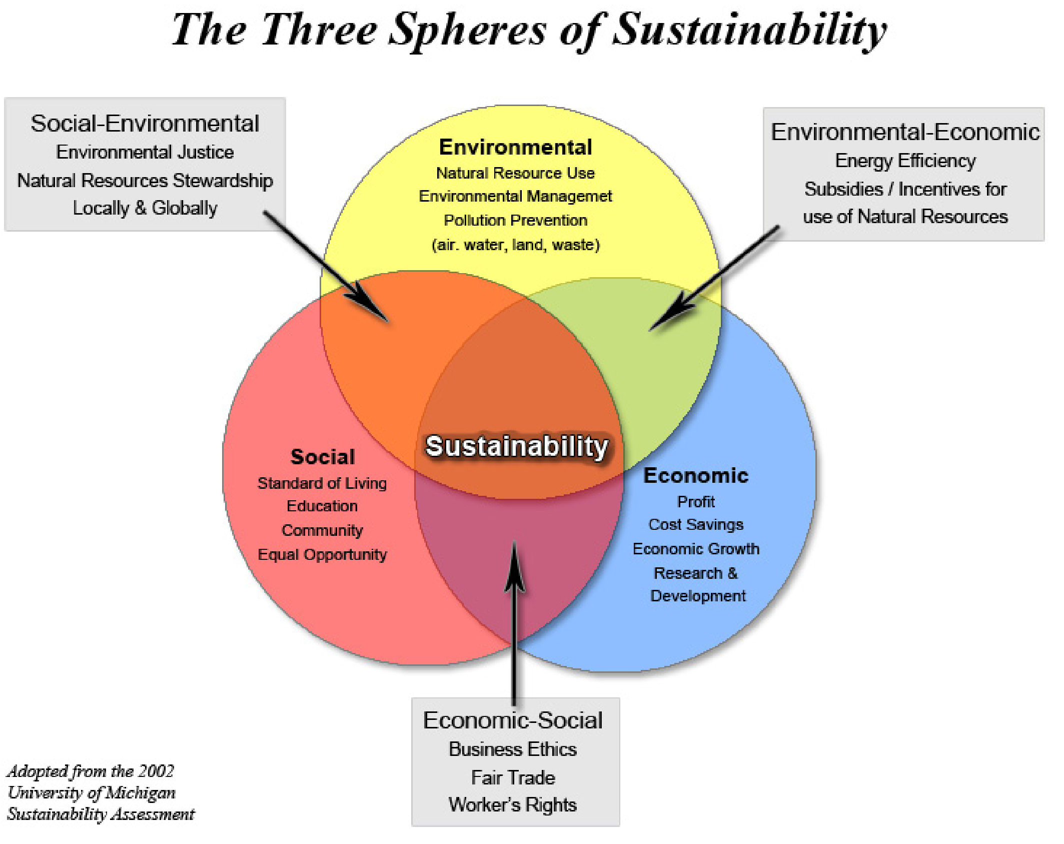
b=a*tan(theta)=10.163...= approx 10.1mm

With a distance of 30mm between the two protrusions we get a:

b'=30*tan(theta)=5.454... =approx 5.5mm

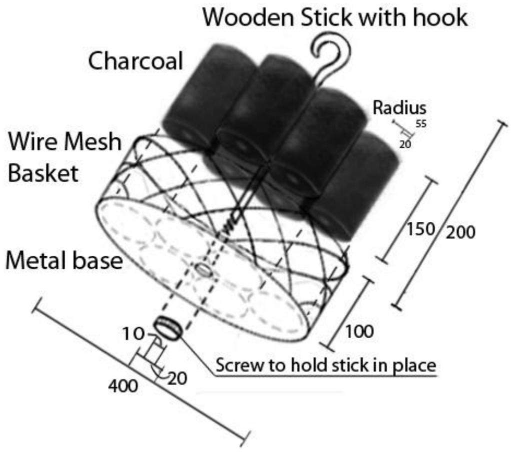
This is an adequate amount of cover for the mobile bracket.

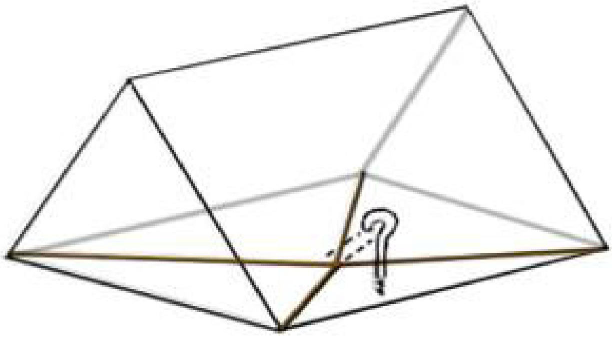
APPENDIX I



The Three Spheres of Sustainability.
http://www.wrsc.org/attach_image/three-spheres-sustainability

APPENDIX J





Components of the bamboo charcoal dehumidifier (left); Cables attached at opposite corners of the roof to hang dehumidifier at intersection by the hook (right).

APPENDIX K

Team Constitution

1. What is the purpose or objective of the team?

To design an effective and simple potable water gathering system along with a suitable filtration system, which will improve the life of those living in the An Minh district.

2. What measures of success will the team commit to?

Measures of success will be measured by simplicity, ability to be implemented, use of naturally occurring or existing technologies in the area, longevity of system, rate of filtration, ease of use, prototypes, cost effectiveness.

3. What are the deadlines that have to be met?

All dates required on the course outline as well as those set within the group to see progress. The deadline to hand in work to the editor for compilation and editing is **two days** before it's due.

4. How will the team members communicate with each other?

Communication will occur at face to face group meetings, over email, phone, LMS group blog and journal.

5. How often is the team expected to meet? How is the time and location of the meetings set? What are the penalties for late attendance, non-attendance, non-contribution?

Team is expected to meet during tutorials twice a week and at further group meetings outside tutorial times determined by the group that week. This will be set via phone conversations and LMS group blog notifications. This is a group project and this expected that everyone will meet attendance requirements at meetings, penalty - if one fails we all fail.

6. How many hours of work per week is the team committed to? How will you manage if individuals do not make their agreed contribution?

At least 3 hours per week of individual work on designated area + team meetings. The same process for managing non-contributing members applies (see 8).

7. What are the budget limitations for this team? How will the costs, and possible rewards, be shared?

Budget of $120, ie $20 per person, split evenly among members.

8. How are conflicts within the team resolved? Do you have an action plan for when a team member stops contributing?

Conflicts that require decision making can be resolved through a voting system. Other types of conflict caused by one person that degrade the ability of the team to perform will require team members to calmly advise the person of the consequences of conflict.

If a person stops contributing, that person will have to perform a task outlined according the number of times they have repeated the offence.

1. Buy a bag of Natural Confectionery Company lollies for team members to share
2. Buy all team members one cookie each from Subway
3. Buy each team member a pizza
4. Exclusion from the team

APPENDIX L

Team Reflection

By working on the project of ventilation to improve the quality of life in An Minh, we have learnt about the intricacies of the Vietnamese culture, the need for respect in the community, and how to appropriately apply the solution as a response to their needs. Along with many other aspects to consider, this made the overall task a challenge for the whole group. However, the ability to make informed decisions and apply problem solving to real life situations in the An Minh district makes the task a rewarding one. This included the consideration and practical implementation of a staged approach to delivering the project, and considering the cost of the project based on the community's socioeconomic status.

Our group has gained an insight of the roles and responsibilities that members of our team must possess as part of the group in order to successfully achieve our desired goal. For most members, especially towards the beginning of the project, the distinction between a set role and initiating individual responsibility wasn't clear. This would mean that members would take on the task at hand, but the responsibility for future planning would dither as one assumes the other would be doing the job. Through the duration of the project, tasks were still allocated to individual members, but responsibility became an apparent need for each person. With a united focus towards our aim for the project, the responsibility of meeting deadlines on allocated tasks, and making contributions towards group meetings certainly helped the development of the project and fostered a harmonious relationship between group "Dragonfly". However, it is clear that some members would benefit from more group work to actively achieve their roles and responsibilities.

For the entire project, there was no one single person that acted as a leader to actively engage the group. Rather, it was more of a communal sharing of opinion that allowed ideas to be thrown about. This approach may have lead to some people taking the back step and engage in groupthink, or the notion that the group has reached consensus without considering the alternatives. However, the group has engaged in debate to come with alternative options, which has allowed for effective decision making and appropriate choice of pathway.

Communication was an issue we had to overcome, since the main form of communication, apart from face to face, was through the university's online system. This has inherent disadvantages, since the system isn't the most engaging area that one would seek to access. Greater engagement of the group may have been achieved if communication was performed via a social networking site. Through the limitations of tutorial and separate group meetings, there was a greater need to distribute important messages, which sometimes may not be understood by the person receiving the message, which has affected work throughout the project. In future projects, this is an issue that all group members will have to consider.

Since all group members are doing other subjects, management of time was an issue we all had to face, especially since we all have different schedules and workloads. Generally, finding time to organise group meetings was achieved without too much stress, but some members could improve on juggling the work for the project and other subjects. With increasing time spent on the project, it was clear that allocating time to do the project became important, which allowed our group to effectively increase the efficiency that work is done.

The group has gained experience from the project by applying and improving communication skills through the writing of the report and the two presentations on our project. It also allowed for an appreciation of the world around us, and delve into an experience that engineers will have to consider as they go out to work in different parts of the planet. Our group welcomed the opportunity to work on a project to potentially make a positive difference, which the engineering profession strives to achieve.

Member Reflections

Warren

The project had been a very educational for me. Through the course of the project, I had found myself discovering things I would not have come across if I did not take part in this project. I have picked up knowledge in various areas in both practical and introspective sense. Beginning with the obvious case, I have learnt many concepts and styles of ventilation systems that I would have otherwise not known. In the beginning of the semester, I had no idea what would entail in designing a ventilation system and I personally would not have chosen to implement one in the project had I been doing the project by myself. However, through research and discussion, I had picked up a useful smattering of what it takes to build proper ventilation for a house. Our initial foray into water filtration before we decided to devote ourselves to ventilation also had its merits and had provided me with some briefly considered solutions of filtering water with some plants and minerals. Besides the detailed knowledge, this detour had enlightened me somewhat to the workings of a group and decisions made with a group.

Group work with actual discussions of ideas and meetings was a somewhat new experience, as in most cases in the past, I was involved in group work where things are set out and discussion comprised mostly of 'who does what?', and 'how should we do it?' rather then discussing 'what should we do?'. Also, I have not taken part in a group assignment of this level and scale before and the other group assignments that are fresh in my memory did not truly have much of a 'group' mentality besides to get your part due on time. This project has therefore exposed me to a form of group work I believe would be more similar to a professional standard then any past experience. Also the meeting of new people and working together is always an educational experience no matter how many times it occurs. One experience that I believe was very useful was the preliminary presentation. I have never been comfortable speaking infront of an audience and taking up a role as one of the speakers is a choice I believe was highly beneficial for my abilities and self confidence.

There are many other things that I have been learned through the process of this project, from how to reference websites using footnotes, the culture, economy, weather and the society of Vietnam, to the use of emphasis in presenting a speech. All in all, this had been a very educational, interesting and useful experience.

Chantelle

Before commencing this group project, I only had a basic knowledge of engineering and the work that it entailed. The lessons that I have endured throughout this project however, have allowed me to gain a multitude of knowledge that has significantly shaped how I now view the field of engineering. The notion of designing and creating a ventilation system I assumed would be a feasible task however, the weeks of being stuck within the design process cleared any assumptions I had about this challenge.

Persistent research and evaluation was required for not only the initial design process but throughout the course of the project. The thorough research this project has demanded has in turn, developed my investigative skills and I am now able to quickly scrutinise what information is most vital. Research methods proved to become further effective as the challenge progressed, allowing me to recognise that this challenge was also helping to shape how astute I was to our design problem. Now, having completed this significant milestone, I undoubtedly recognise that it requires more work to create a system which is able to provide thermal comfort.

Identifying the needs within a developing community has been another critical task throughout the course. This has made me acknowledge that there is an absolute importance and concern for the community - in terms of their needs, alongside how it will benefit and impact them. Ultimately, this required associating every aspect of the project with the community. Such a process was proven to be one that did require a lot of refinement and reflection however, if this was neglected it would only have driven our design into the course of a failure.

Alongside the needs of the task's content itself were also those of my fellow team members. Providing attention and acknowledgement amongst team members has also been a major aspect, in allowing myself to learn that there was an ongoing need to work effectively with other team members. Communication was found to be extremely vital, in ensuring that progress was always made. When there were times that communication was lacking, I realised that progress was notably hindered by this.

The prototype, which, I believed to be a determining factor in the practical success of our project's design was a highlighting task. The need to create and test a number of prototypes was a difficult process however, it allowed other team members and myself to ensure that all elements of our design did correspond with the speculations we had made.

Resulting in an experience completely different to what I had anticipated, the EWB challenge has ultimately given me a greater insight into what the field of engineering provides. This has been an unique experience that has required a variation of skills to be implemented yet also, developed and learnt. Introducing a project to a foreign community in need that will bring them great benefits has allowed me to further recognise the significant impacts and contributions that engineering brings to communities throughout the world. Gaining this insight from first hand experience has overall, become an invaluable lesson in learning the key role of an engineer.

Gordon

This project began as an interesting way to develop something that would have a genuine positive impact on a community in Vietnam. As the project unfolded, it became far more engaging than I had initially expected, as the idea of ventilation was not an issue I was very passionate about. In its struggles and highlights this project has shown itself to be a worthwhile experience that has developed my understanding of the engineering design process and group dynamics.

Personally this project was more challenging than expected as we tried to research and develop an effective system that would genuinely benefit the lives of those in An Minh, based on minimal information about the An Minh district. Working within such a constraint and developing the necessary design criteria was difficult as the project rested on the foundational information about the community that we gathered. This challenge was slowly overcome with a lot of research and assumptions, where I came to appreciate the measurable impacts of decisions grounded in effective research. Engaging in methods of research that I would not normally have done, such as analysing existing construction techniques by looking at photo resources, proved to be effective, growing and extending my vision of research.

The ventilation system design however was the most engaging component of the project for me as there were more technical details to grapple with as we tried to design the best systems for the louvres, dehumidifier and solar chimney. I chose to take on the louvres as my major input for the project and I do not regret it. The design and construction of the prototype was time consuming but incredibly enjoyable as I tried to make a design that would fit the design criteria. The necessity of using simple tools and construction techniques helped me to appreciate and connect with the design. The other components of our system and their respective prototypes were exciting as we were able to test our model in a wind tunnel and physically see the effects of the solar chimney. All these components of the project came together to help shape my understanding of the engineering design process as being far more complex and necessary than I had previously thought.

Through this whole process however our group did not function as best as it could have had. It was a challenge to communicate and delegate roles to individuals as we tried to move towards goals we had set. With technical difficulties to flaws in conveying the necessary requirements/ roles of each individual our project did not progress with the intended vigour. Group meetings could have been more effective as we designed the ventilation system, planned and delegated. More involvement from each member in terms of the design process could have been more effective in encouraging each member to take up more roles as the project progressed, rather than delegation which was forced due to a lack of progress.

All in all this EWB challenge has helped me see the need for a comprehensive engineering design process and the necessity of good group dynamics. It has not been an easy task but it has been engaging, learning to respond to the needs of a foreign community and to do it well with no engagement with the actual community.

John

Taking on a project to help a community in need of aid was never going to be an easy task, but the potential benefits that could be realised as a result makes for a truly rewarding experience. I've come to realise that a group project such as this requires cooperation, determination and passion.

Cooperation requires that all group members collaborate and decide on tasks to be performed and discuss potential solutions. In the group, there were members that I have known for a while and others that I had never seen before the beginning of the project. This made the balance between active and passive cooperation quite difficult at first. I would assume that the group members knew what they were doing, but at the same time, we would not be sure of the direction we were heading in. This was demonstrated through the struggle the group had when trying to piece together our original proposal for water filtration during the first few weeks.

Determination naturally follows after direction, and having chosen ventilation as our pathway to focus on, this allowed for more engagement with the details of the project. I've learnt to appreciate that there is a world out there that is not so well off, and being provided with the ability to improve the quality of the community in An Minh increases the determination to get the job done. This united focus allowed the group to explore more options and develop a stronger relationship with each other. I also found that as the weeks went past, the group was on track to do tasks, and decision making processes were more streamlined. For example, the decision to add another prototype, namely the solar chimney, was quickly followed by efficient gathering of materials, making measurements and construction. This was all done in just a few hours, which was quite quick compared to the hours we spent at the beginning of the project not really having any direction on what to do.

Importantly, passion arises from the fact that what we have achieved could actually be a real solution to a problem in the An Minh district. Before the beginning of the project, the area seemed like an abstract place that had no relationship to me. However, this project has developed the notion of what engineers strive to do: improve the lives of human beings by creating a positive contribution towards society. That is always something that I wanted to do, and this realisation made the whole project seem quite special. Testing the prototypes to validate our research and confirm our theoretical calculations makes the project even more realistic. These aspects made the course different to other courses in university, as it could actually make a difference to individuals somewhere in the world.

My engagement with the project has allowed me to appreciate how a team operates, and provide an insight to the pathways that engineering can provide. The project has also opened the world to me, and shows the complexities of different climates, cultures and economies in different parts of the world. The EWB Challenge has certainly been just that, a challenge, but the rewards are worth so much more.

Rebecca

I used to think that project outside of the study campus, requires one to be competent in their knowledge. But this project has moulded us and led me to change my perspective. A project does not mean to test you what you know, it means to test how you would solve a problem and forces one to learn to seek for information that the group lacks in order to proceed. This competition pulled us all out of our comfort zones and take up roles that we never knew we could. This project has given us the opportunity to taste the real world, working outside of school and university, outside the realm of given solutions. It gives one the opportunity to look for problems to solve, without readily given solutions “at the back of the book”.

In addition, extracting a specific problem from the many that the people of An Minh have, requires research into and understanding the people, their culture, society and their living conditions. From this, I begin to grasp the richness of culture that one ethnic group has, not to mention the rest of the world. We assume and take for granted that everywhere else in the world, people are like us and think like us. This is not the case, we’ve learnt that all effort can go to waste easily if the idea of the project does not spark an interest in the people, the changes may either be offensive or too expensive to implement. Keeping this in mind whenever doing a project alerts us to involve and engage the community , rather than impose and force an idea on them, even if it is for their own good.

It is always best to work with people who you know, but we learnt to co-operate and get along with people who were once strangers but now friends, and fellow work mates. Co-operation was one great lesson to learn as a group. Participation and contribution is very important for a group to work as a team and not individuals. We did not have a good start because we hardly knew each other and were afraid to speak up and voice our opinions in the group. This situation gradually improved when time was pressing.

Most importantly, I have a much bigger lesson to take away from this project, which is one’s own competence does affect the group’s performance. We can rely on the better members of our team to succeed in our project and achieve great results, but the question then would be, why then am I here? What I realised and have reflected and tried to improve on since, is the lack of abilities that I have that can contribute to the group. I was struggling to find areas that I can work on, not because I am reluctant to do it, but the fear of jeopardising my teams result by my offer to help. In the end, I volunteered to do the physical tasks that need to be done, researching sources to buy charcoal, information needed to proceed our design, note down important points in meetings, remind our group of deadlines and from a time frame for each task, run model-making-material errands and volunteer to speak in presentations. This project may have been a challenging area to work on, but it was working together as a group that is much more rewarding than having a successful project group and the result of supplementing each other’s weak areas.

Sammy

The journey has been a new experience to me. Altogether, to be selected and worked as a team with new acquaintances of people has not happened for the past six years, where my high school life have transform any feelings of alienation into the meekest of mutual understanding. My peers, as I have known them for the past six years, have changed. I find myself to be working with and engaged in another group of people; whom at the beginning are mere acquaintances, but now, hopefully, I can term them as friends.

The road thus far has not been one I am all too willing to tread on. To be honest, the project is too abstract, too distant and futile of fruition to sparkle a sense of inspiration and commitment to work. At least, those had been my thoughts at the start. Gradually, the theme and goal become apparent, as I re-evaluate my thinking that there really are much depth and meaning to the project at hand. It is true that the Vietnamese district of An Minh will forever remain a mystery and the notion of establishing any concrete project to be farfetched.

However, the workings of our project in essence does exist at our hearts. I ask you then, is that not enough?

Perhaps the most memorable moment for me thus far is the speech of the presentation in week 7. To sit in open space, ignoring bashful gazes by others, and to practice our frivolous play does yield a sense of comradeship and unity in our team.

As a final note, instead of looking back, I will look forward. I cannot conclude this reflection more agreeably to myself, than with a huge thank you to my team, and with smiling remembrances of Dragonflies.

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