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RESTRICTED



# [PeRM] House

Performance of Recycle Materials





# (PeRM) House

Architectural Undergraduate Thesis

By: Cristina Alonso

Advisors: Professor Daniel De Riva &

Professor Bruce Coleman

Thesis Preparation Book Vol. 1

Fall 2008

I would like to thank all the people  
who made this book possible.  
This thesis is the result of incredible  
collaboration and support of incredible people  
who believed. I am dedicating this book to you:  
KaKi | Francisco Alonso | Magali Galbis  
| Frances Alonso | Paquita Alonso  
Alfredo Mesa | Victor Santiago  
Neysha Mejia | Matt Chevedden  
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To all who believed and gave their  
words of wisdom and support.  
T h a n k y o u !

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## (ROMP) House

### Abstract

*"As modern day conditions with both people and planet change around us, it is becoming necessary to reassess how we conceive of and manifest shelter."*

(Reynolds, 2)

**The construction of single-family housing units will provide an opportunity to design using recycle materials. This thesis seeks to evaluate the effectiveness of the unit's performance in a tropical climate, through means of passive cooling; in particular the promotion of comfort ventilation during the daytime.**

I have chosen the single family dwelling as my program due to the need for this type of housing in Puerto Rico. I will design a dwelling using wooden pallets, bamboo, and tires as construction materials. Through means of passive cooling, in particular comfort ventilation during the daytime, I shall evaluate the effectiveness of the design by testing these strategies within the tropical climate. This project seeks to implement strategies of cross ventilation and stack ventilation as key gestures within the design. This thesis will provide a design solution for a site in Jayuya,

Puerto Rico called Hacienda Ana. It will provide a series of dwelling units for the coffee workers of this area. The design will be evaluated using EcoTech and WeatherTool software, which allow for ventilation studies of the design within a given site.

The information gathered in these pages is a guide to a different way of thinking about dwelling, which includes information on strategies that will tie this design better to the site and parameters to judge the success based on the climactic response of the structure within the site. Designing for less harm to the environment and using materials that would otherwise be wasted; while being able to take advantage of the local climate.

Hurricane struck houses in Puerto Rico 1998.  
Humble dwelling, tropical vernacular. Dump truck emptying garbage into landfill in Puerto Rico.

## Introduction

The construction of single-family housing units will provide an opportunity to design using recycle materials. This thesis seeks to evaluate the effectiveness of the unit's performance in a tropical climate, through means of passive cooling; in particular the promotion of comfort ventilation during the daytime.

Humans live in a constant cycle of waste and consumption. The aim of this thesis is to address the problem of adequate housing in the Caribbean region with a design for a housing unit that responds to the problems of waste and is able to perform successfully within the tropical climate of the region. This thesis asserts the ability to successfully employ tropical architectural design, using comfort-cooling strategies of cross ventilation, stack ventilation and shading, to enhance the performance of the dwelling. In particular implementing gestures in the design that allow for enhanced cross ventilation, stack effect, and shading.

I will design a house using wooden pallets, bamboo, and tires as construction materials. This thesis will test the limits of using reclaimed materials by being inventive with their placement within the design to better facilitate

passive cooling strategies. A secondary goal of this dwelling is to use principles of pre-fabricated architecture and combine them with recycled materials that are already abundant in Puerto Rico. Currently, half of all the materials that are collected for recycling are being packaged and shipped to other countries to be processed or re-used, since there is no sufficient local manufacturing that could process these materials on the island.

The design proposal is sited in Jayuya, Puerto Rico in a coffee farm called Hacienda Ana. This project will provide a series of homes for the coffee workers of this area. The design will be evaluated using EcoTech and WeatherTool software, which allow for ventilation studies of the design within the climactic data of the site.



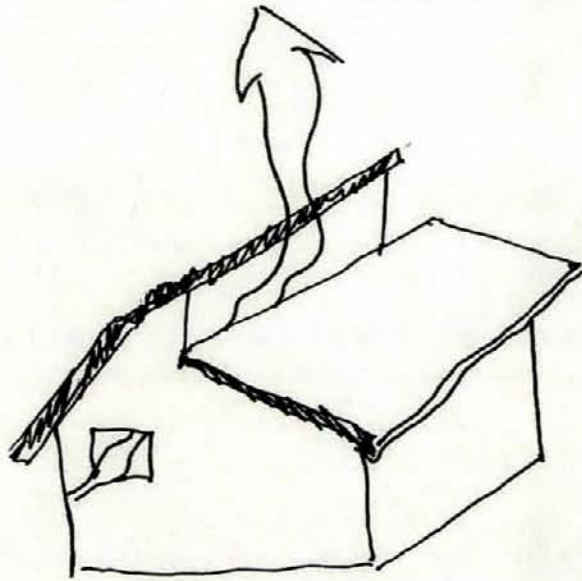
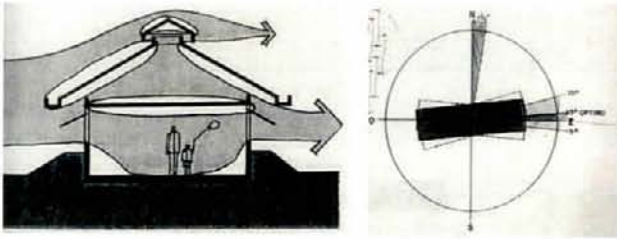
Diagrams showing initial interest in the topic of single family housing and developing a new dwelling type through design.

# (ROMP)House

## Introduction to terminology

transitional housing	<p><i>"These are 'transitional' as opposed to 'temporary.' Emergency shelter is temporary and is intended just to provide shelter for survival. Transitional implies something that is longer-term and gives you a space to carry out livelihood activities rather than just surviving."</i></p> <p>Babister, Elizabeth. Shelter advisor featured in <a href="#">Design Like You Give a Damn</a></p>
recycled materials	<p><i>"The process of converting materials that are no longer useful as designed or intended into a new product."</i></p> <p>From the online Oxford English Dictionary</p>
home	<p><i>"A shelter that people live in. A dwelling place together with the family or social unit that occupies it. An environment offering security and happiness. A valued place regarded as a refuge or place of origin."</i></p> <p>From the online Oxford English Dictionary</p>
passive cooling	<p><i>"Refers to technologies and design features that are used to cool buildings naturally without power consumption taking advantage of regional climate."</i></p> <p>Allard, Francis. <a href="#">Natural Ventilation in Buildings</a></p>
climactic specific design	<p>Process of designing that comes to terms with the importance of climate and the performance within site in order to evaluate the success and strength of the design.</p>





## Design Strategies

### Climate Specific Performance

This thesis project focuses on specific design strategies that can enhance the performance of the housing unit in a tropical climate. One of the main aspects of this focus will be in achieving passive cooling as a design enhancing solution. This contention aspires for a new climate specific design that will take into consideration orientation, dwelling layout, roof design, structure, openings, ventilation and humidity into account.

### House Layout

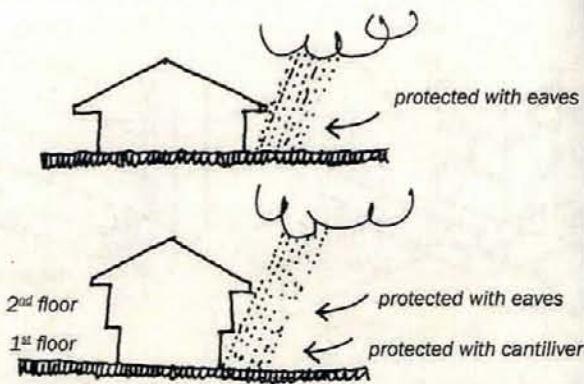
The design for the inhabitants (in this case single-family) will take into consideration: materials, surrounding vernacular, customs in use of space, regional climate, and site conditions<sup>1</sup>. All these variables will provide a specific direction for the design of this dwelling. The relationship to the context, the cultural and financial situation of the region will be appropriate for the site. In order to demonstrate the success and evaluate this contention, this thesis will focus on a chosen site in Jayuya, Puerto Rico. A tropical climate can be observed all over the island, but this project seeks to provide a site specific solution that can be tested for effectiveness, and could be tailored further for other sites within the region. It strives to find the most appropriate

design solution for the specific conditions observed within this particular site.

In a hot-humid climate a spread out building allows for better natural cross-ventilation than a more compact design. Additionally by providing more window openings the structure which take advantage of the prevailing winds of the site. Although air conditioning is commonly used as the solution for cooling spaces in modern-day Puerto Rico, there are a large number of people that cannot afford the expense of air conditioning. In the hot-humid weather that exists year round in Puerto Rico, no one should have to rely solely on air conditioning for cooling.

### Roof Design

The roof of a house in a humid and tropical climate should have steeper angled slopes than in other regions for issues of rain and heat. Sloped roofs allow for rain to drain off more quickly. The slopes also allow for less surface material to be affected by sun rays than a flat one; the air in the high area of the roof also serves as a buffer from the heat penetration. Openings within the roof design will improve ventilation strategies. Extending the ridge, eaves or louvers will prevent rain and undesired direct sunlight to enter the dwelling. The eaves should extend to protect the walls against deterioration from exposure to sun and rain. Separating the roof planes is another



Diagrams showing the advantages of proper site orientation, wind ventilation, and other design considerations (Van Legen & original diagrams)

<sup>1</sup> Johan van Legen, The Barefoot Architect: A handbook for green building (Shelter Publications: California, 2008) 143. The design parameters adopted from this book will be used as guidelines for the further development of the housing unit.

strategy for allowing proper ventilation is crucial for this type of dwelling.

**Ventilation**

*"The simplest strategy for improving comfort when the indoor temperature, under still air conditions, seems to be too warm is by daytime ventilation - providing comfort through higher indoor air speeds."*

Givoni, Baruch. Passive and Low Energy Cooling of Buildings

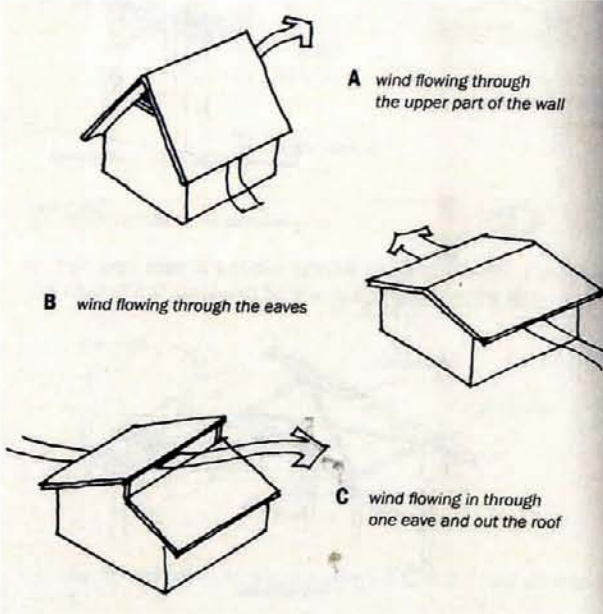
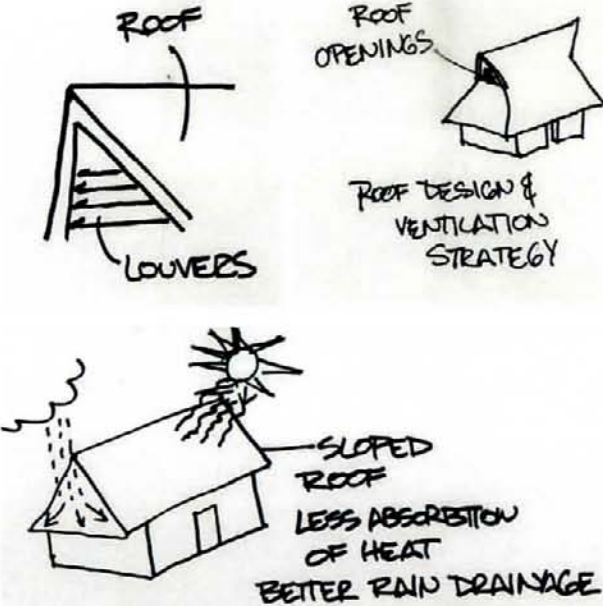
The basic knowledge of flow of outdoor air that is somehow pushed at higher speeds through a building, extending the limits of the comfort zone beyond the limit for still air conditions, should be essential when designing for a tropical climate. In Puerto Rico however, most houses do not take advantage of this basic low-tech way of improving the comfort levels in their homes. Puerto Rico is the perfect example of a hot-humid climate that Givoni relates to in his book. In his book, Givoni explains, the higher air speed increases, the rate of sweat evaporation from the skin, the more effective it can be at minimizing the discomfort from the sensation of wet skin<sup>2</sup>. A high indoor air speed also increases the rate of exchange of heat exchange between the indoor air and the interior mass of the building. In order to test the success of this thesis, I will strategize for climactic responsive design using mainly

wooden pallets and other materials already abundant Puerto Rico and implement them to facilitate passive cooling.

There are several strategies for implementing passive cooling. These include comfort ventilation, nocturnal ventilative cooling, radiant cooling, direct evaporative cooling, indirect evaporative cooling, soil cooling, and cooling of outdoor spaces. This project will focus mostly on, comfort ventilation, which consists of providing direct human comfort mainly during the daytime hours. This thesis will find solutions to comfort ventilation through alternate configuration and patterns using mainly wooden pallets. Experimenting with different alternative configuration and patterns that might best provide comfort ventilation for the different living areas. I will take advantage of the levels of porosity of these configurations to best comply with the inhabitants needs.

Examining strategies of radiant cooling, where the focus is on transferring into the building the cold energy generated during the night hours by radiant heat loss from the roof, or using a special radiator on the roof. Along with the other strategies of sun shading and heat reflectors, this project will consider soil cooling as a technique that cools soil below its natural temperature in a given region to utilize it as a cooling source for the housing unit.

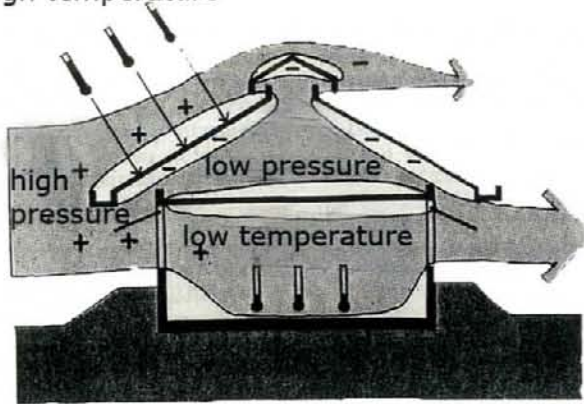
The design concern is finding a solution for creating comfort ventilation and other passive cooling systems that will alleviate the harsh heat and humidity of the region. The



2 Baruch Givoni, Passive and Low Energy Cooling of Buildings (John Wiley & Sons, Inc.: New York, 1994) 22.

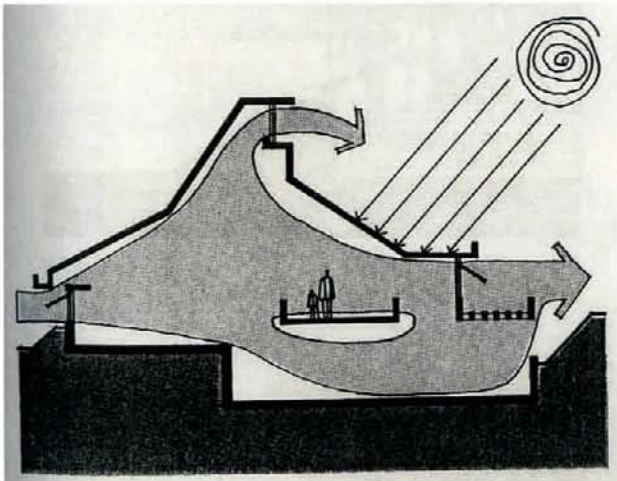
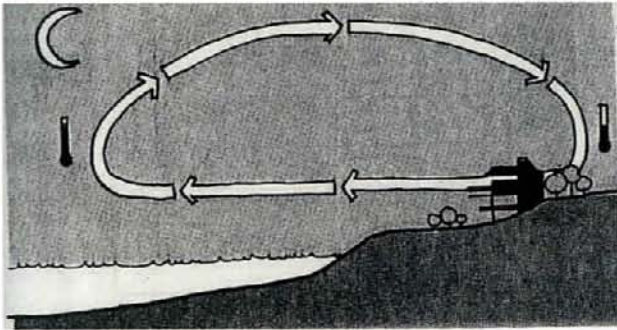
Images depicting design features that will influence design strategies for dwelling unit in tropical climate. (Van Legen, bottom images)

high temperature

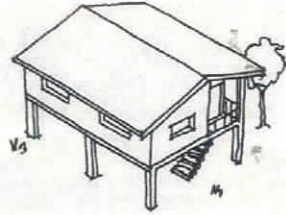


design priority is to achieve a high air speed and fast cooling of the interior during the daytime hours. This calls for designing relatively large but well shaded windows, and keeping materials from absorbing and storing too much heat during the daytime hours. Comfort cooling is also achieved by providing direct psychological cooling; the design will have openings that will direct the airflow path towards the areas where the inhabitants are during the day.

Another strategy is indirect evaporative cooling by roof ponds, which works by placing a cooled pond over the ceiling and under a shaded roof; the ventilation that flows in between this space then cools the building. It would lower indoor air and radiant temperatures without elevating the air vapor content. One option would be an insulated fixed shade over the pond, with wind flow between the insulation and the water. This type of system might be able to expand or double over as a water collecting system in times of water shortage.

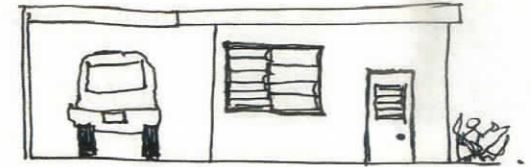
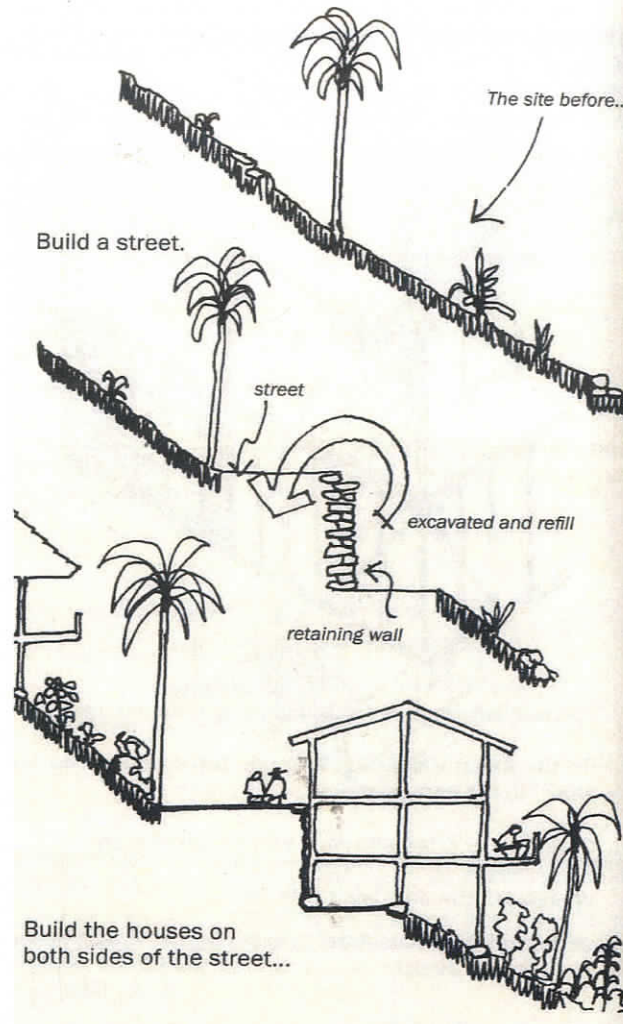


Ventilation and air temperature, circulation diagrams. Effects of natural ventilation. [translation and interpretation of diagrams by Pedro Muniz]



## Raised Foundation

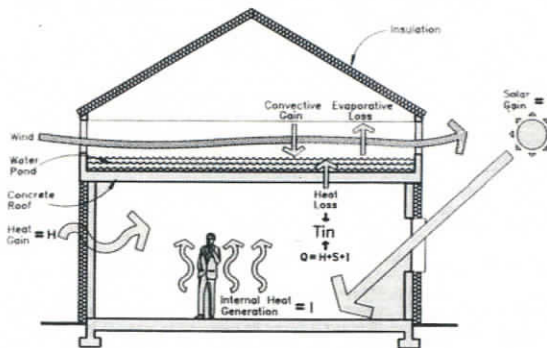
Raising the building off the ground and allowing air to flow through under the structure will make increase the air flow through the entire structure making it more comfortable for the inhabitants. If the dwelling is raised a full level, it allows for an outdoor covered space where many activities and social events could take place. This could also be used as parking under the dwelling, which provides shelter for vehicles too. In the case of Puerto Rico the soil will prove to be too hot for some cooling strategies, and considering the potential for flood threats means that raising the building up from the ground plane might be a successful gesture. The housing unit would also benefit from some privacy by elevating it several feet off the ground, and allow for better overall air circulation.



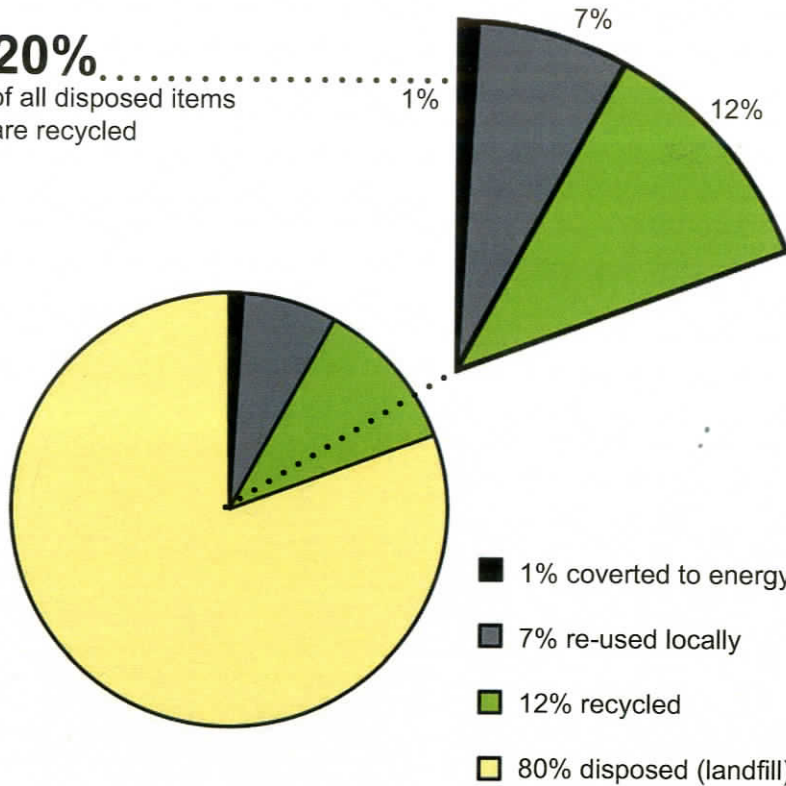
TYPICAL LOW END CONCRETE HOUSE  
TROPICAL VERNACULAR, PR



Benefits of raised foundations in tropical climates.  
Diagram and images of vernacular flat roof  
concrete houses in Puerto Rico



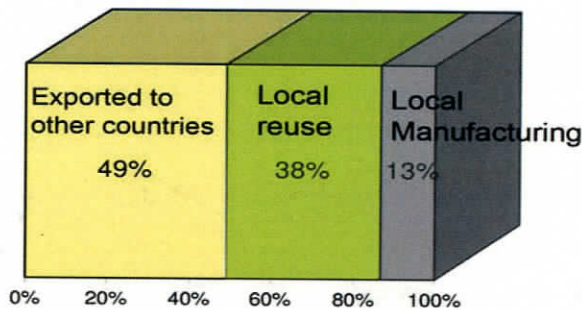
**20%**  
of all disposed items  
are recycled



- 1% covered to energy
- 7% re-used locally
- 12% recycled
- 80% disposed (landfill)

**Brief History**  
**Recycling in Puerto Rico**

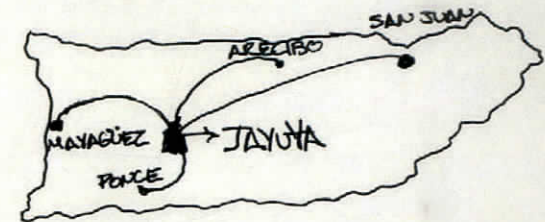
Since 1993 Puerto Rico's Waste Management Authority has gathered statistical information about the amount of recycling done in the island. Unfortunately, Puerto Rico only recycles approximately 20% of all waste products. There are one hundred collection centers on the island, and twenty-three of those have the facilities needed to complete the full recycling process and return a new product to the local market. Half of all the collected material for recycling are exported to other countries to complete the cycle.



Charts describing the recycling statistics in Puerto Rico. 20% of all waste is recycled and half of it is exported for completion of recycling.

There is currently infrastructure to recycle the following: organic waste, glass, batteries, metals, paper, electrical equipment, plastics, textiles, pneumatics, wood, gardening residue, and fluorescent lamps.

This project will focus on wooden pallets, bamboo, tires, and cardboard as construction materials for the housing units. Designing housing this way will deviate some of the materials from being exported and employ them locally towards housing.



**PUERTO RICO**  
**LOCALLY AVAILABLE MATERIALS**  
**WITHIN A 75 MILE RADIUS**

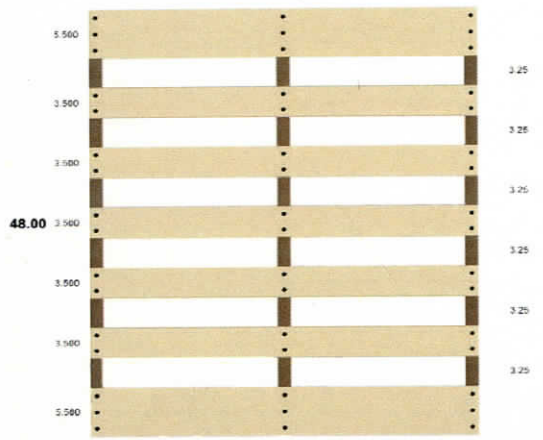
**Material Research | Wooden Pallets:  
History and Capabilities**

Pallets are the primary interface between the packaged product and today's highly automated handling equipment. Approximately 90% of all the US domestic products are shipped on pallets. Pallets range greatly in their price, material content, dimensions, and quality. Despite efforts by a standardization organization, there is still no universal pallet dimension used around the world. There are many different pallets one could customize to meet one's needs. There are half a billion new pallets produced each year, and more than two billion in use in the United States alone. One thing is clear, there is a clear abundance of this material.

Puerto Rico is no exception to this abundance. Its condition as an island in the Caribbean means everything is imported to the island and almost always involves wooden pallets. Wooden pallets are being locally re-sold, repaired and recycled to make their life cycle longer. However, this thesis asserts that through good design strategies this and other recycled content can be implemented to a livable dwelling. This enthusiasm over the material springs out of the lack of any creative initiative to promote the wooden pallet as a viable material for construction in Puerto Rico. Given the tropical climate and the abundance of the material, why not design responsibly with it.

There are two basic pallet types; stringer type and block type. They each have their advantages in terms of how they can be handled, transported and strength. The grocery industry has made it a point to use one type of pallet. The GMA pallets which stands for Grocery Manufacturers' of America use a pallet that is 48" x 40". Although this was not a specifically designed pallet it proves to be efficient in container shipping with only 3.7% wasted space inside the container. This is the best ratio you can get according to statistics. I will be using this type of pallet for my design since they will provide consistency in dimension and material content and because it is abundant in Puerto Rico.

There are some pallets that are known as being expendable or throwaway pallet that only intends for the life of the pallet for one trip. This is the most common type found in Puerto Rico. At a cost of \$11 as new pallets, they are usually re-sold for \$7 or demolished as part of recycling it by combining it into another product. Others are returnable or reusable pallets, but even these have an end to their life span. What to do with all this material? Companies do not like the idea of shipping back empty pallets because cost is high and essentially you are shipping back air. Some pallet companies have instituted a return policy or recycle policy were they don't charge for return shipping of pallets. Although these initiatives are taking place it is not nearly enough compared to the amounts that are being disposed off. This



Examples of variety of wooden pallets.  
Orthographic drawing of a GMA wooden pallet.



project proposes an alternative destination for some of these pallets by using them towards the design of a housing unit that will be able to perform adequately to the tropical environment of Puerto Rico.

There is software specifically available for the design and testing of such materials and how they might behave when being handled and transported. Among these programs is PDS Pallet Design Systems that can design pallets to specific dimensions, materials, coefficient of friction, material grade, moisture content, and performance, which includes strength, stiffness, and durability.

It was during WWII the United States had urgency of material handling reformed with pallets almost overnight. This meant the institution of pallets for transporting almost everything. Although the technology had been developed for the lift truck in the late 19th century, it was not until 1920's and 30's that it began being utilized. The addition of bottom boards on the skid in 1925 resulted in the pallet we know today. It was not until WWII that the development of the palletized unit load, pallet and lift truck, which would change the way material handling would change forever. It was originally developed to help the US armed forces to do more with less. Palletized loads could handle more goods with fewer people and less time, and it could also increase storage capacity. Pallets have been around for roughly fifty years.

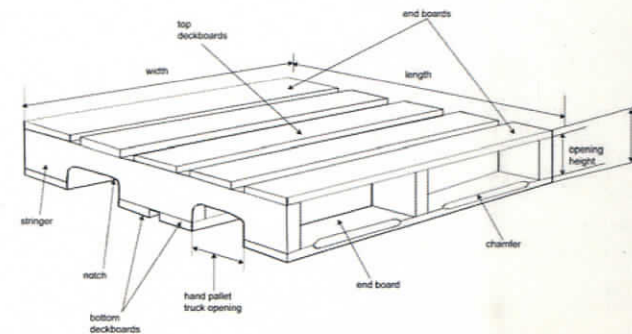
Before pallets; boxes, crates, barrels

and kegs were more commonly used to unitize, protect, store and transport goods. According to Emil Holzwart, skids, which were the first types of pallets, were often constructed with a solid deck, typically two-inch deck lumber and high seven-inch stringers. The other benchmark for the pallets was the development of the high lift fork trucks. Further advances could allow the trucks to lift loads several feet in the air and perform with cantilever gestures that were troublesome before. High lift trucks made it possible for vertical stacking of unit loads and a resulting dramatic efficiency in storage warehouses. According to an article in a 1931 railway trade magazine it took only four hours to unload a palletized load, which unpalletized took three days.

At first the pallets and skids were built from expendable and locally available lumber, and were poorly constructed and constructed in small lots. The earliest record of large-scale pallet production was NEPA Pallet of Snohomish, Washington according to Bill Sardo who was the first director of the National Wooden Pallet and Container Association. Their business was to supply the government with all the necessary pallets. During WWII its curious to note that most men were engaging in war and women took over the predominantly male shift at the pallet manufacturer. The war was the pressure needed to implement the already existing technology to make this new way of transporting, storing and protecting goods flourish.



Principal Parts of Stringer Wooden Pallets



Wooden pallet recycling and collecting facility in Puerto Rico. Axonometric labeled drawing with main parts of a stringer wooden pallet.

## Bamboo

Is from a group of woody perennial evergreen plants in the true grass family Poaceae, subfamily Bambusoideae, tribe Bambuseae. Some of its members are giant bamboo, forming by far the largest members of the grass family. Bamboo is the fastest growing woody plant in the world. Their growth rate up to 1.5-0.3 metres/day or 1.5-2.0 inches/hr. This incredible ability is due to a unique rhizome-dependent system, but is highly dependent on local soil and climate conditions.

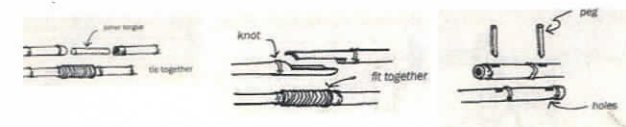
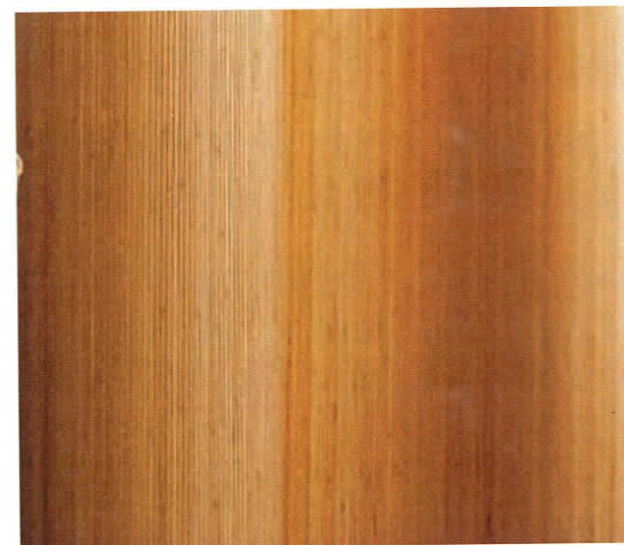
They are of economic and high cultural significance in East Asia and South East Asia where they are used extensively in gardens, as a building material, and as a food source.

There are around 1,000 species of bamboo. They are found in diverse climates, from cold mountains to hot tropical regions. In Puerto Rico it is found growing wild usually close to a body of water or in areas of more precipitation. There is a high density of bamboo in my site and in the general region of Jayuya, Puerto Rico. This is due to the high precipitation and humidity levels.

Bamboo has been used for construction for many centuries. It is structurally stable and a fast growing renewable material. This thesis will use bamboo as a construction material for the dwelling unit.

In combination with the wooden pallet, bamboo can add rigidity and reinforcement to the wooden pallets to create a better wall

unit. Bamboo can also be used in bundles for columns and beams.



Bamboo is abundant in Puerto Rico. Bamboo scaffold in China.  
Bamboo joinery from the book the Barefoot Architect





## Tires

Pneumatic tires are made of a flexible and elastic material, such as rubber, with reinforcing materials such as fabric and wire. Tire companies were first started in the early 20th century, and grew with the auto industry. Today approximately 1 billion tires are produced annually, in over 400 tire factories, with the three top tire makers commanding a 60% global market share.

Tires have been used for some housing projects as construction materials in the past. Scrap tires are plentiful all over the world and usually end up discarded. In Puerto Rico most end up in junkyards. They can be found all over the island, and after discarded, they are sold at little cost. Not only are they abundant, but they are a perfect low-tech form for an earth rammed brick module. This material provides a versatile mass building technique. They can also be used for anchoring down a structure. The construction of the housing units will use tires within the material pallet for the design.



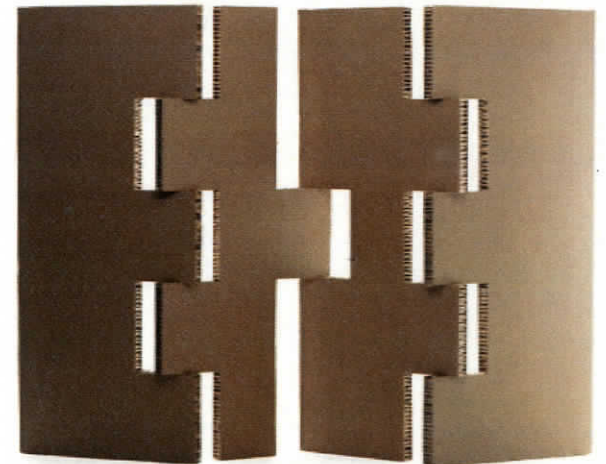
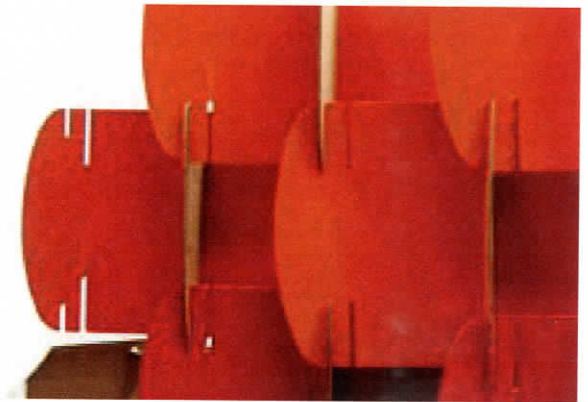


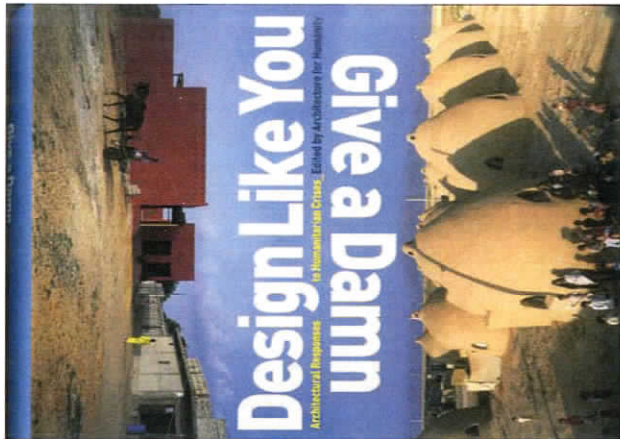
## Cardboard

Cardboard or corrugated fiberboard is a paper-based construction material consisting of a fluted corrugated sheet and one or two flat linerboards. It is widely used in the manufacture of corrugated boxes and shipping containers. The corrugated medium and linerboard are made of paperboard, a paper-like material usually over 0.010 inch thick. Cardboard might also be any heavy paper-pulp based board.

This project will incorporate the use of cardboard within the dwelling. The design will explore ways of employing this material as partitions, screens, and furniture. The material exploration will also look at sealants and fire retardant agents that could be coupled with the material.

Cardboard is 14% of all recycled materials in Puerto Rico. Approximately 127,000 tons of cardboard were collected in Puerto Rico, but the same amount was shipped out to several countries for recycling. Puerto Rico currently does not have the infrastructure to recycle cardboard. This project aims at finding a way to use scrap cardboard within the project as a way to promote the local reuse of the material.





Book titled *Design Like you Give a Damn* by Cameron Sinclair from Architecture for Humanity. Shigeru Ban's Paper Church in Kobe, Japan 1995

## Relevant Emergency, Temporary, & Transitional Housing Case Studies

*"The greatest humanitarian challenge we face today is that of providing shelter."*

Cameron Sinclair, Design like you give a Damn

This contention is actively participating within the discussion of the broader contemporary field of architecture trying to bring together expertise from material research and the awareness of the need of affordable and sustainable living to create one comprehensive design solution. There are great organizations and architects that have started to lead the way with this topic; Cameron Sinclair founder of Architecture for Humanity has compiled great precedents in a book titled "Design Like You Give a Damn" edited by Architecture for humanity.

The projects presented in this book allow me to get better insights on housing needs around the world. The book has the chapters divided into emergency, transitional, and permanent housing, which is the first time one can see the important difference in this terminology and what it means for the inhabitants. From high tech to low tech covering all types of materials and budgets and client needs around the world. The book includes a time line of natural and man made disasters and subsequent responses, which is great information on the progression of design responding to natural and man-

made crises in different stages in history.

The paper church in Nagata-Ku, Kobe, Japan (1995) by Shigeru Ban Architects, where the architect took fifty eight paper tubes enclosed in a skin of corrugated polycarbonate sheeting to form the structure of this transitional church. Shigeru Ban proves once and for all that unconventional materials can be used effectively for creating great spaces. Ban mentions in an interview the initial resistance he faced when trying to sell the concept of using these materials for construction<sup>3</sup>. This is a particular example that has had great success. Now is the time to push the boundaries of new materials within architecture. There should be a continuing effort to explore the potential of reclaimed materials and their potential as real sustainable built environments.

Another example comes from architect Nader Khalili who designed Cal-Earth and explained in an interview in 2005 that the purpose of the design was that anyone could build it. All that is needed was earth, sand bags and barbed wire. The domed dwelling units were finished with lime-stabilized earth. Tubes made from burlap or polypropylene with barbed wire placed between each course holds the bags in place and stabilizes the structure against seismic activity. He made a design that women would be able to build on their own, while making it safe for seismic activity in the region. This was all accomplished through unconventional and innovative combination of materials chosen for his design. Khalili explains how

3 Shigeru Ban, Architectural Record: interview by Naomi R. Pollok, AIA ( McGraw-Hill Companies: New York, November 2008) 90. This is an interesting interview done to Shigeru Ban where he mentions the initial oppositions he faced when trying to build a church out of paper tubes.

architects should take risks with their designs in order to discover great design solutions. Nader Khalili as quoted from this interview,

*“As the Persian mystic Rumi said, you have two duties in life [as architects]: to sharpen your pencil and scratch your paper. If you keep doing your work, the rest will happen...”*

Khalili explains how the pieces of the design puzzle will basically fall into place. It is only by pushing our design boundaries and doing our jobs as goodhearted architects, that we will be able to achieve great architecture that responds to the world’s need. It is important to realize that architects should be humble and sympathetic to their clients, and cultivate the ability to communicate at their level and with their language.

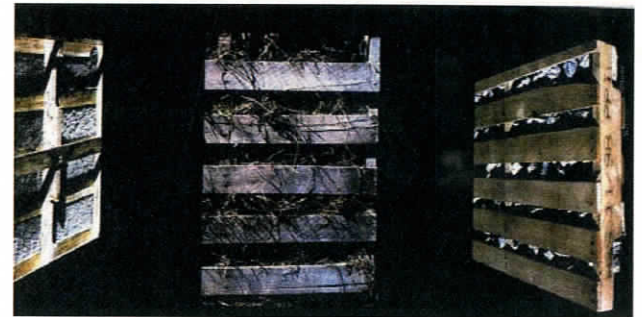
A different relevant case study can be seen in the Palette House designed by I-Beam Design, which relates to this thesis because of the material choice. This design team decided to use wooden pallets as their basic framework for a basic housing unit that was first done in Bronx, New York and then in Ball State University, Muncie, Indiana. The design was later adapted and tailored to meet the needs of a site in Sri Lanka.

Although never constructed for Sri Lanka or fully designed as a livable housing unit, it does suggest how wooden pallets should be considered as construction materials for housing. It also mentions the affordable cost

of the wooden pallets, where the total cost was \$1,900 and \$200 worth of pallets were donated. With a total of 1,200 square feet I-Beam Design first designed it in 1999 and has opened up the discussion for this material to be seriously considered left in the island after use. Although they are being used re-sold and recycled or demolished locally, nothing has been proposed to consider them as viable construction material. As shown in studies from this proposal, wooden pallets can be plastered in wattle and daub, or filled with straw, rubble and other materials for insulation. This makes a great case for using this material and its capabilities to adapting it to a given environment.

*“I have come to talk to you about prefabricated housing and I will come straight to the heart of the problem: in essence, it is economics.”*  
Prouve, Jean. *‘Il faut des maisons usinées’*, lecture given in Nancy, 6 February 1946.

In order to design a livable housing unit, one has to consider the needs of basic amenities and how they will play a role within the design. The shower, toilet and kitchen would be designed to fit within this scheme. In a project called ‘Extreme Housing’ by Deborah Gans and Matt Jelacic proposes a twenty-four square foot solution to these basic amenities. It consists of a rectangular zone that is connected by beams that connect two boxes, creating enough space in between them for a bed. The two boxes are the core freestanding



*Cal - Earth house designed by Nader Khalili.  
Pallet House by I - Beam Design and further material research done with the wooden pallets.*



system where one contains a toilet and the other a hearth, internal cistern, and shower. The concept can be shipped, and up to twenty units fit in a shipping container. This is an important consideration since transportability is an important factor that designers too often overlook. The design of the core amenities will be considered in the design to be effective for real livable conditions. It will also try to bundle it all into a bar or a section to keep these systems as simple and compact as possible. This thesis will adopt the design of such a core since its main focus is not in the design of the core, but the performance of the whole dwelling in the site.

On the topic of site, it is important to review climate and possible natural disasters that could affect the inhabitants of the region. The Safe(R) House, designed by the Harvard Graduate School of Design in 2005, provides houses with core walls able to resist tsunamis in Sri Lanka. Their design success consists of C shaped core walls at the four ends of the units where the dwelling's main amenities would be found. There are also design gestures that take ventilation and flooding into consideration within the ceiling and roof openings. At the cost of \$1,500 per unit, this scheme provides a competitive alternative by being as affordable as the typical value of housing in the region, while providing the better design alternative. Porosity of materials, air circulation, and cost make this scheme attractive and successful for this site. One may consider the possibility of making only part of the house

unit hurricane proof to cut cost and still make a safe haven during hurricane impact.

FEMA is a well known entity in Puerto Rico that has helped in post hurricane relief. Unfortunately, the help is usually temporary. Why not redirect these efforts towards a more sustainable and efficient approach through implementing funds towards more resistant housing instead of the typical plastic blue tarp? FEMA currently offers a \$25,000 funding after a disaster for housing replacement in some states through an application process. 20.0 House in Greensboro, Hale County, Alabama by rural studio and Auburn University introduces a 616 square feet full house for the funds given by FEMA. It is a great first step towards being less reactive and more pro-active. It is also positive to know that the organization has taken design initiatives towards safeguarding against future possible disasters by raising foundations, complying with codes and tackling energy efficiency. However, this option has not been made readily available outside the states. This thesis will attempt to provide an alternative that FEMA might adopt for Puerto Rico.

At Quinta Monroy Housing Project in Iquique, Chile by Serviu/Seremi Iquique and ELEMENTAL Housing initiative 2002-2005, the design team took ninety-three illegal household owners as their clients and proposed an organized duplex system that also allowed for controlled growth within the units. The cost of each duplex was \$7,500 including the land, which was expensive because of

Extreme Housing - service core design by Deborah Gans. Safe (R) House design for Sri Lanka by Harvard Graduate School of Design.

location, to create ninety-three innovative duplexes for the illegal squatters. Parking, u-shaped neighborhood planning and controlled methods for growth within the design made this project successful. It is important to consider the larger scale of the neighborhood and the possibility for this thesis to effectively engage in the bigger picture of a given 'barrio.'

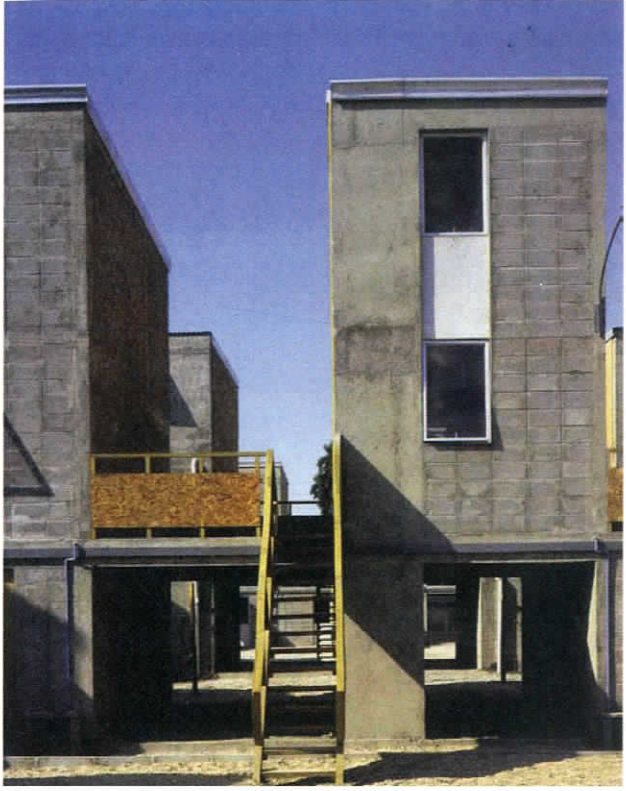
One of the main design goals is to create a document that can effectively illustrate the design to the inhabitants in a simple graphic language that is comprehensible to anyone outside of the design profession. A graphical catalogue of all the terms and key elements needed will foster communication and education more effectively with the inhabitants.

Huts and Low Riders is another interesting case study. This project by Mad Housers created huts for the homeless in Atlanta, Georgia. Each unit was about sixteen to forty-eight square feet and cost between \$300 - \$500 and voluntary labor. These were illegal installations, but met their purpose by providing basic shelters for the homeless. They even created an alternative design for low clearance locations. These smaller units were designed for the more restrained areas under bridges with a porch like platform to avoid contact with ground while entering and exiting the small sleeping unit. This one also came with a separate storage unit. This project empowers the idea that something small can make a big difference, the use of salvaged materials towards a very worthy cause.

Another project dealing with the homeless took the idea of flophouses, cubicle hotels, or single room occupancy hotels in Bowery, New York and turned some historic buildings back to serve the city's most needy. The idea for these flophouses is that, for approximately \$7 a day, the occupants could have a room and safe place to put their belongings for the night.



Huts and Low riders by Mad Housers a project to provide basic shelter for the homeless.  
Flophouse single room design in Bowery, NY.



20.0 House sponsored by FEMA in Greensboro, Alabama, and below Quinta Monroy housing project for illegal squatters in Iquique, Chile.

## Precedents in the Caribbean & other tropical regions

*"The physical design of our homes, neighborhoods, and communities shape every aspect of our lives."*

Cameron Sinclair, Design like you give a Damn

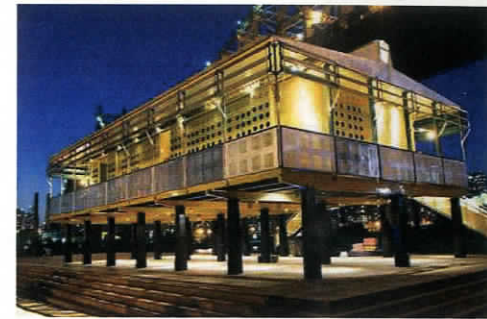
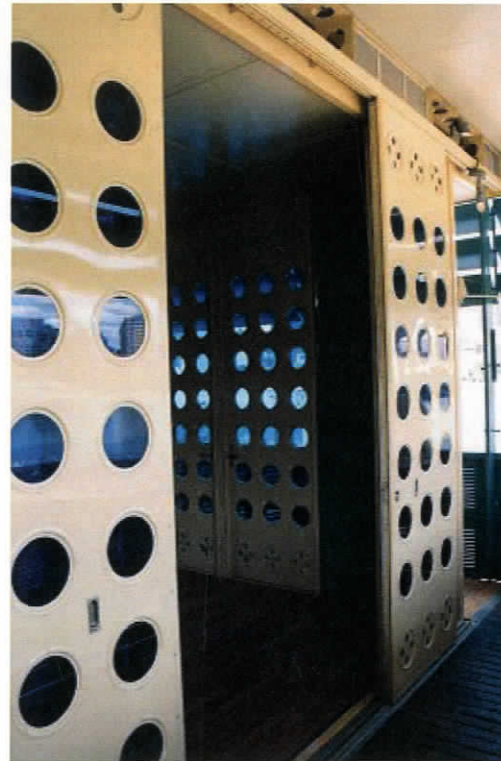
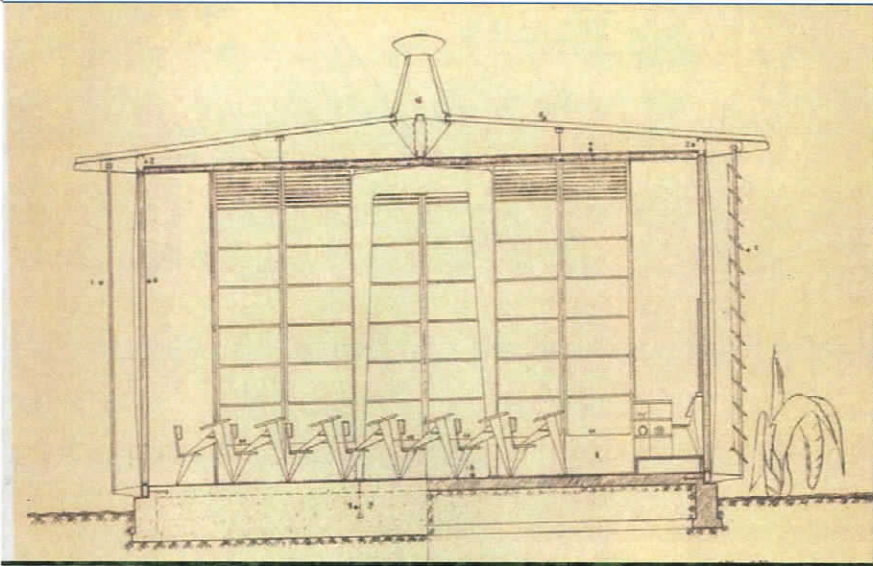
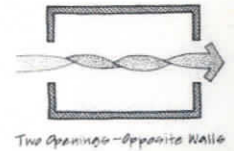
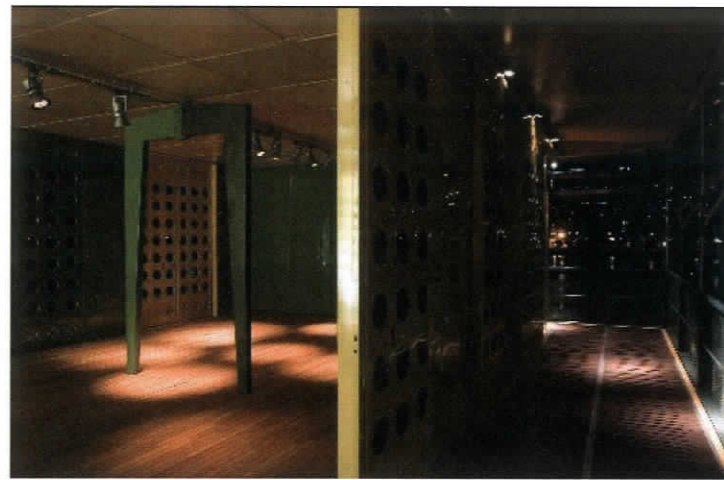
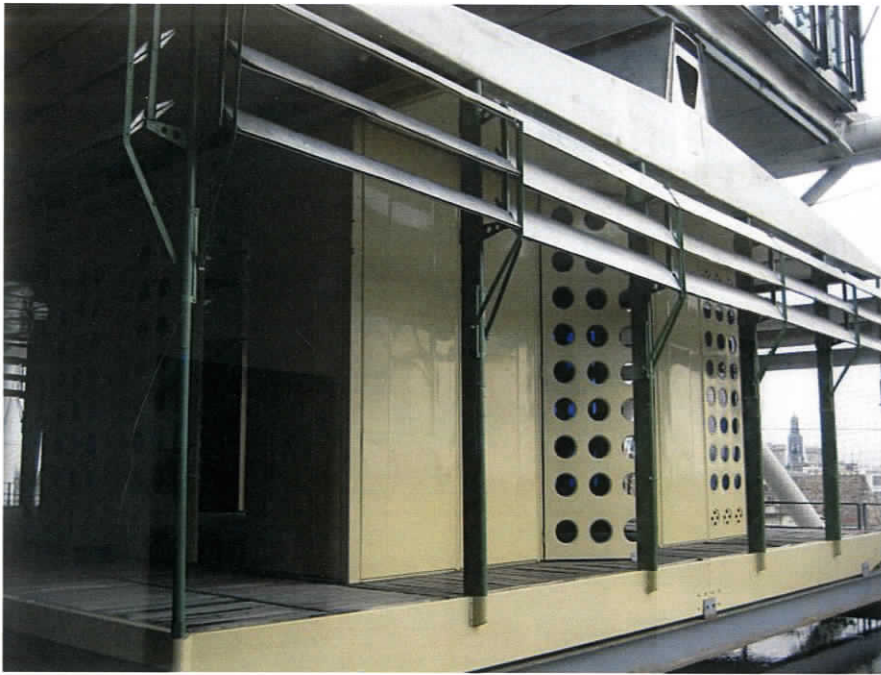
These are some passive strategies in housing design that have been executed before in tropical regions. They all take into account some of these as parameters for their design, layout of program, orientation, window openings and dimensions, shading devices, effective solar reflective surfaces, and vegetation around the site.

The architect Henry Klumb came to Puerto Rico and established himself as a prominent and very influential architect during the mid 20th century. His projects, particularly houses, show how he took full advantage of the tropical climate of Puerto Rico. This thesis will be paying close attention to his strategies for wind flow and shading.

This thesis will also view the strategies implemented for Jean Prouve's Maison Tropical and Andrade Morettin Arquitectos' Residencia RR in Brazil for further techniques to influence this design.

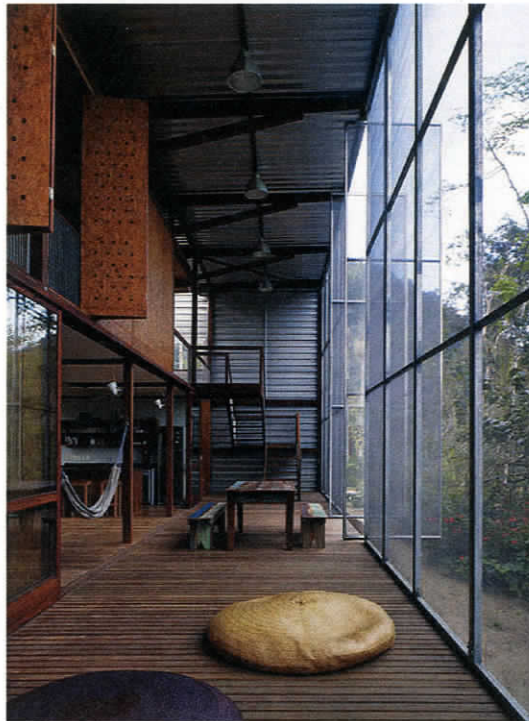
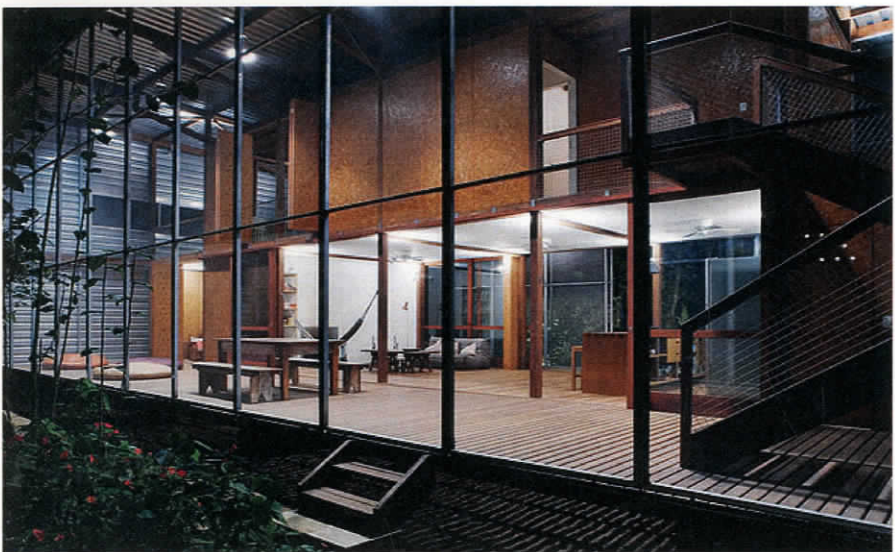


Architect Henry Klumb and his various design project in Puerto Rico including his own house using strategies of passive cooling for projects.



Jean Prové's Maison Tropical designed for Africa originally. Maison tropical was able to be deployed by cargo planes to the site.





Andrade Morettin Arquitectos , Residence RR in Brazil where they use passive cooling strategies. Precedent case study.

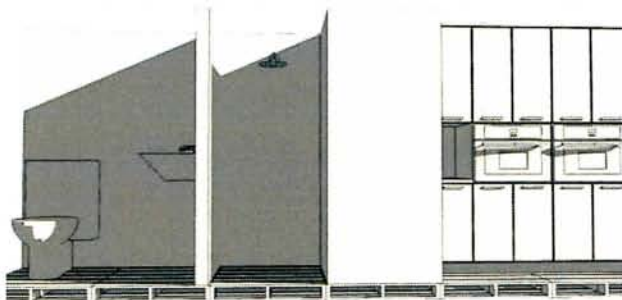
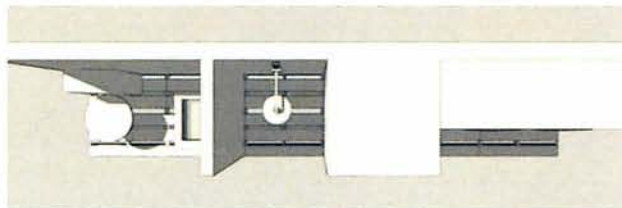
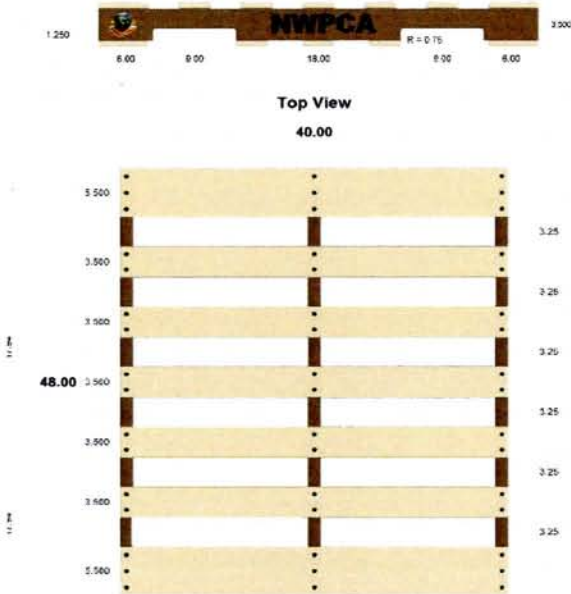
## Program

The program for this thesis is single-family dwellings. There will be three alternate designs for higher and lower occupations, but all will observe the same design strategies and approach to the site. These will be identified as dwell units (a), (b), and (c). Dwell unit (a) is an efficiency or studio, which is intended for one or two inhabitants. Dwell unit (b) is a one bedroom layout that can accommodate two or three inhabitants. Dwell unit (c) is a two bedroom layout intended to accommodate between four and six inhabitants. All the dwelling alternatives include all necessary amenities in a servant space core, an exterior covered terrace, living, eating and sleeping areas. The preliminary space approximations for these three alternatives are as follows, dwell unit (a) with 394sq. ft., dwell unit (b) with 458sq. ft., and dwell unit (c) with 672 sq. ft. These dimensions are subject to change during the design phase. The dwell unit is following a spatial model of a GMA wooden pallet. The GMA wooden pallet is 40" x 48." These measurements were adopted serving as parameters to regulate spaces in dwelling layouts. These GMA pallets translate very well to spatial modules since they have an intimate scale that works well with the dwelling program. They would also be used as one of the main construction materials for the dwelling.

Louis Kahn was the one who coined the terms 'servant' and 'served' spaces. This thesis will take on this approach for making important

distinctions of different spaces within the dwelling. The main emphasis is on designing a series of servant and served spaces. The service core would be bundled up and kept in a bar layout to become part of the servant space. Keeping all the servant spaces together frees up the plan and maintains the cost and construction of the core low. The served spaces are those spaces that benefit from the servant spaces; the living, eating, sleeping spaces become the served spaces. This provides a clear strategy towards program; by keeping all the servant spaces to one side or down a middle spine the rest of the served spaces can reach out from. This flexibility of the served spaces is great because it allows for different configurations in hopes of finding the best one for each dwelling unit in the site.

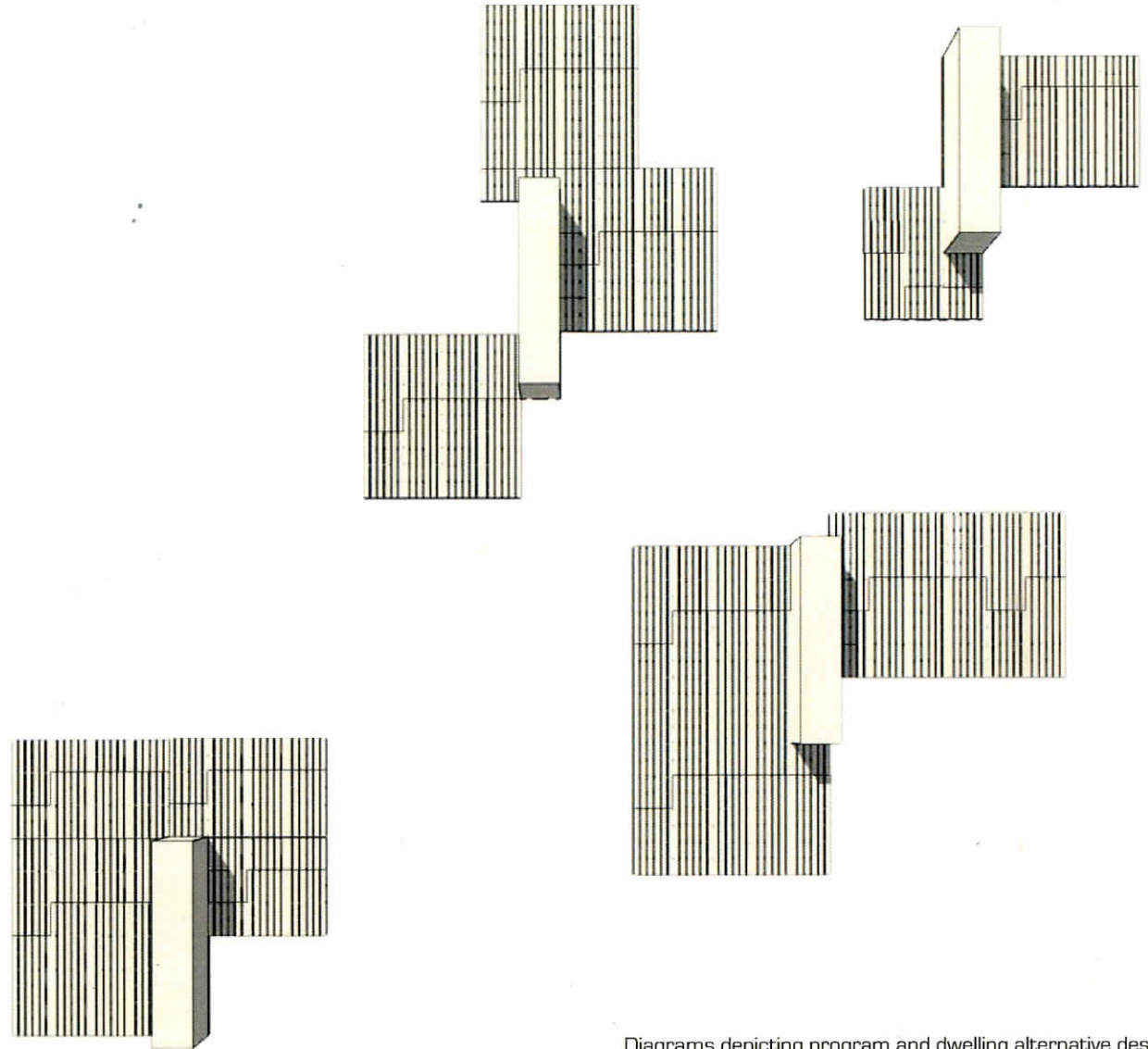
The dwelling as program will take into consideration the cultural norms of using space. For example, the importance of the kitchen in every Puerto Rican dwelling is key. Whether well designed or not, all the social gatherings revolve around food and everyone ends up in the kitchen. Also the use of the terrace as a space for relaxing and social gatherings, when properly designed it allows for many uses. Each dwell unit design will allow for controlled patterns of expansions in the future based on the same spatial module.



Diagrams of single family dwelling plan layouts and GMA wooden pallet dimensions to be used as spatial modules in design of the dwellings.



# single family units



Diagrams depicting program and dwelling alternative design for different occupancies. Dwell units (a), (b), and (c). They will have free arrangement of the served spaces, due to the reduced and compact core of servant spaces (amenities).

## Issues briefly addressed outside the scope of this thesis

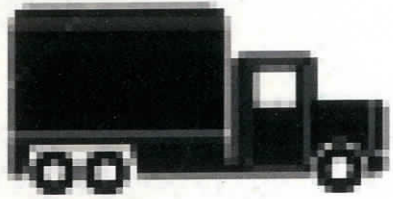
These units will have four secondary or supplementary goals. A way of establishing parameters for the design while noting that these are goals set outside of the primary scope of work for this thesis. They will serve as parameters and ways to evaluate further success or strength within the design, and they are: cost, aesthetics, transportability, and functionality. The first will be cost, by keeping the price of the units affordable for the target audience of the island's lower class. This is taking into consideration the people that actually need housing and cannot readily afford what the market has to offer or people who have lost houses due to a recent natural disaster. This offers great potential to design for the people who are too often underrepresented or ignored. This project will hypothetically address this sector of the population.

Unfortunately, the unconscious image of pre-fabricated affordable housing units suffers from the stigma of having inhumane aesthetics. Aesthetics is a key element for the success of this thesis and would not be dismissed on the premise that the unit will have prefabricated elements. In any case, the reclaimed materials used along with the notion of prefabrication would only add to the value and strength of the project's design. Consideration will also be given to the surrounding vernacular of the Caribbean

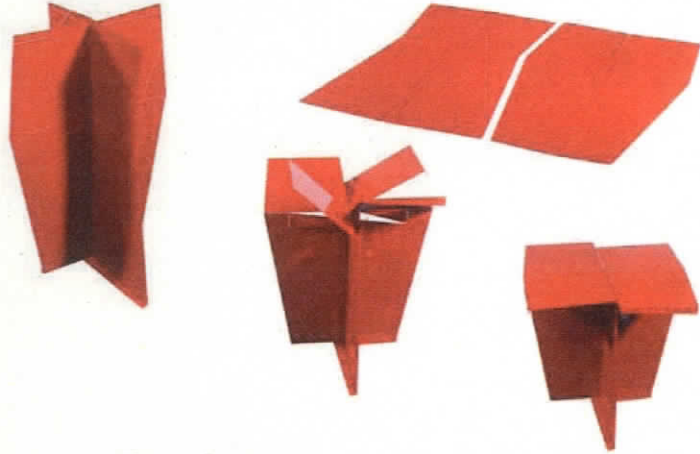
region. I seek to learn and be inspired by current examples of successful vernacular conditions as parameters for the design of the dwelling. This thesis is pursuing to find design potential with the chosen materials making them reach their maximum capabilities as a dwelling.

Another secondary goal is to aim for some level of transportability to be able to reach remote locations within the region. There is another specific focus that will remain out of the scope for this thesis due to time restraints. This would imply actual testing of the design against hurricanes and other severe weather situations. Although this is out of the scope of work, basic considerations will be made to acknowledge that this is a hurricane prone region, but will not engage in trying to make this design in any way hurricane guaranteed.

These units will be adaptable for various locations within the Caribbean region, but for the purpose of this thesis, I will be choosing one location. The design features can be tailored to fit different context of the given place. This design will have the future potential to be made available wherever needed in the Caribbean. These units are meant to be transitional housing solutions and not temporary installations, further considerations and maintenance issues could be addressed by the inhabitants to make these more permanent dwellings. They are not meant as permanent. They are meant as transitional housing design providing the family with a home for a couple of years.



transportable



adaptable



single family units

*Issues of transportability, and adptability that will remain outside the scope of this thesis.*



HACIENDA ANA



## Hacienda Ana | Brief History

Since forty-five years ago this farmland had cattle heads up to the property line with La Pica Encampment. These three hundred acres of land were part of the Seralles succession until 1987 when Sr. Felipe Ozonas bought the property and changed the name to finca Jauca. In less than twenty years Sr. Felipe turned the land into one of the biggest coffee plantations in the island. It also counts on the growth of 250, 000 mandarin oranges. On June 10th, 2005 a group of young entrepreneurs acquired the property and changed its name to what we today know as Hacienda Ana.

Following through with some cultivation plans of expansions, they are panning to plant twelve thousand in new tree crops. They are also renovating all the paths and trails and looking further infrastructural development to engage a wider audience.

The Hacienda has the production capacity to produce twenty thousand 'almudes' of coffee.

The property line is defined by the bordering river Jauca serving as a natural boundary to the property and runs all the way to the barrio saliente in Jayuya.

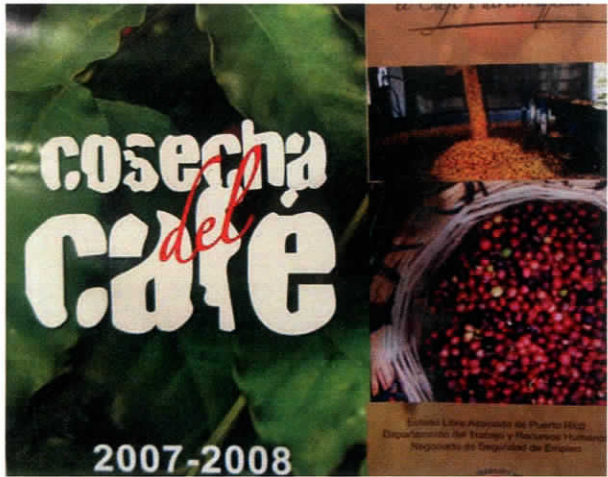
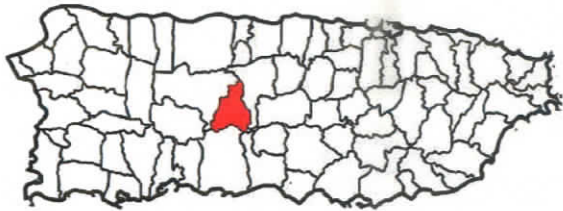
The Hacienda recently became active with a program that works in collaboration with the Departamento de Agricultura and the Departamento del Trabajo, called 'obreros al cafetal' which translates to 'workers to the coffee fields.' This program allows the Hacienda to bring people who are interested in participating in coffee harvesting and collection process. More than eighty people take advantage of this program each harvesting season. The Hacienda Ana was also declared an auxiliary forest land by the Department of Natural Resources in Puerto Rico for the conservation practices and reforestation taking place in the Hacienda.

The owners have envisioned expanding the Hacienda Ana by developing comprehensive dwelling development within the property which would allow for foreigners to get a unique



*Hacienda Ana located in Jayuya, Puerto Rico within the west, southwest part of the central mountain chain of the island. Home of Encantos Coffee.*

experience of staying within this sanctuary and being able to participate in the coffee harvesting. This vision calls for a unique architectural intervention.



*Hacienda Ana in Jayuya, Puerto Rico; a coffee farmland that will be used as the site for dwelling units for this thesis.*



Surrounding domestic vernacular of the area, more specifically on road 143 where Hacienda Ana is located in km. 11.1

## Site and context

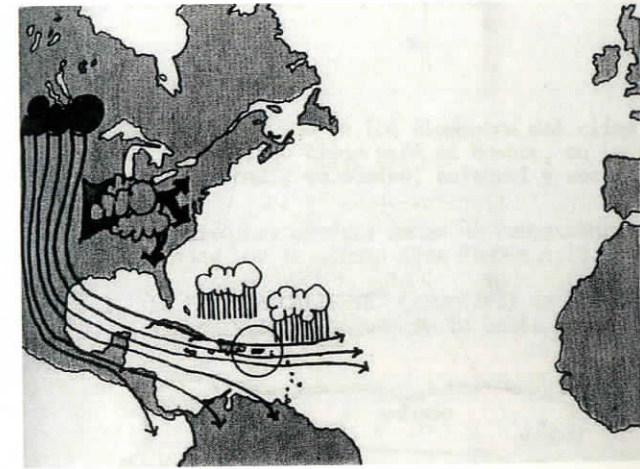
It is not difficult to understand that a great part of the architecture responds to the need of the masses without any discrimination for the varying climates. Puerto Rico is no exception to this phenomenon, and we owe part of it to the economic disposition of air conditioning units that our society takes for granted. The planet cannot take much more; however, on a positive note for us, everyone seems to be taking a shift towards managing and dealing with the worldwide energy crisis. This will find its crucial role within contemporary architecture.

This project will bring back some of the essential architectural techniques used in the past which have been ignored or taken for granted for some time now. This Puerto Rican society has been characterized by an incredible and almost exclusive dependency to mechanical control systems. This were used to cater to the particular needs of man in its most lazy and comfortable state. As architect we are called to do something about it and not ignore this issue. Inhabitants cannot stop using their mechanical air conditioning systems if their houses were not designed to work without them. It is our responsibility as architects to stop taking the easy way out with mechanical systems and pay closer attention to the advantages that can be gained from the surrounding tropical environment. This calls for a different type of dwelling that is creative and sensible to Puerto

Rico's humid-tropical climate. This would bring about a new attitude towards architecture; one that is closely tied with climate, location, sun, and local materials.

## Jayuya, Puerto Rico

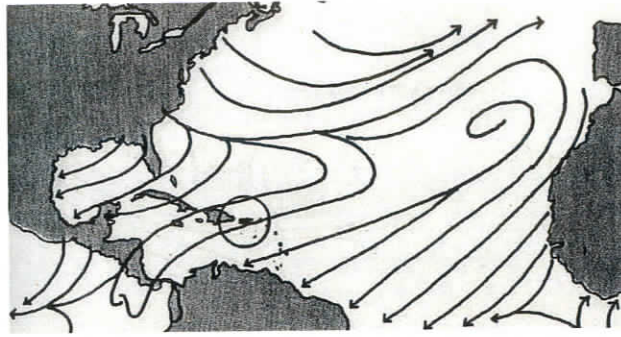
This thesis' site is Hacienda Ana. It is a coffee farmland located in Jayuya, Puerto Rico that is home to the production of Encantos Café. The property has 320 acres worth of land, where coffee, mandarin oranges and bananas are grown. The owner has envisioned developing a specific part of the land for infrastructure that would allow for people to live and work in the fields and invite a wider audience to participate in the harvesting of the coffee during the collecting season. This thesis will engage the site's climactic features through architecture that will be tested for its performance within the site. Passive technologies will become the





instrument to reduce the need for dependency on mechanical systems and provide parameters for the design process. The biggest reason for designing with these is because it serves to simplify the process. A wide range of materials can be used as part of the application of simple strategies that will work towards the passive cooling of the space. These passive cooling strategies are usually not widely used because of lack of acceptance or lack of knowledge. Since the climate does not adapt to our needs, then we must design to adapt to the climate that surrounds us. The broader goal is that although these dwelling are being proposed in Jayuya, Puerto Rico, they could be tailored and widely used throughout the island and the rest of the Caribbean.

Through the use of software called EcoTech, this thesis will be able to evaluate the performance and create the best design possible. This thesis will take into consideration analysis of wind, air temperatures, and humidity levels to determine the best design strategy. In hopes of creating a model that can be made available to the general public and anyone who might be interested. This dwelling will serve as a model for an attitude of commitment and harmony between architecture and the environment.

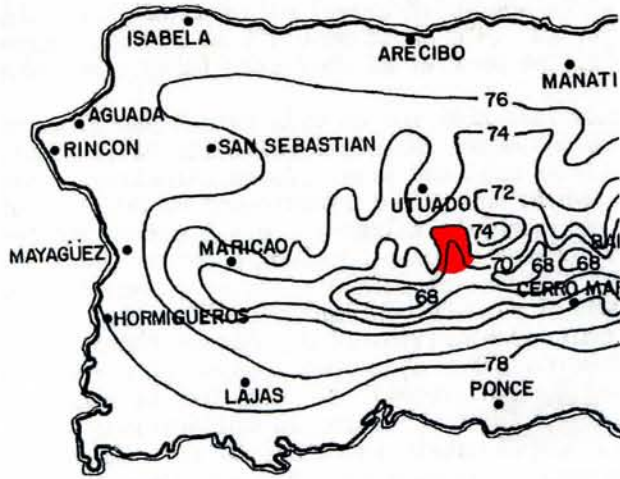


### Puerto Rican Climate

Puerto Rico, while being a relatively small island, is located in a tropical zone with oceans extending all around. Puerto Rico is found in between 17'52 and 18'30 degrees latitude north of the equator within the humid tropical zone. Due to the small size of the island, the ocean has the ability to act as moderator for the temperatures. Since water is slow in heating and cooling, it allows it to heat up the winters and cool down the summers. The temperatures never get into extremes. The island is affected by the Antilles Current that goes towards Florida passing through the north of Puerto Rico, Cuba and the Bahamas. The current of the Caribbean travels towards the Gulf of Mexico and passes through the south of the island. The warm waters facilitate the evaporation allowing for cloud cover and rainfall. The trade winds are from the north east and usually flow between 5' and 30' degrees latitude on each side of the equator. Puerto



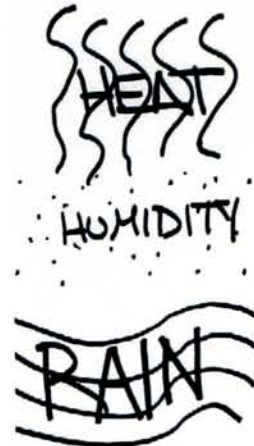
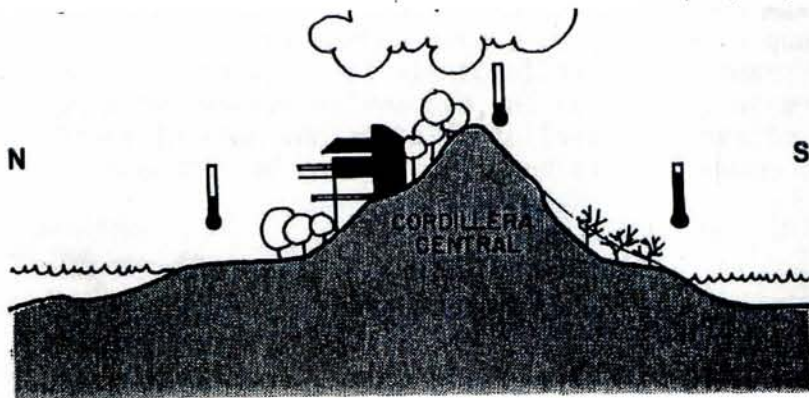
Surrounding domestic vernacular in Jayuya. This region has been categorized as the rainy mountains of the south west part of the mountain chain.



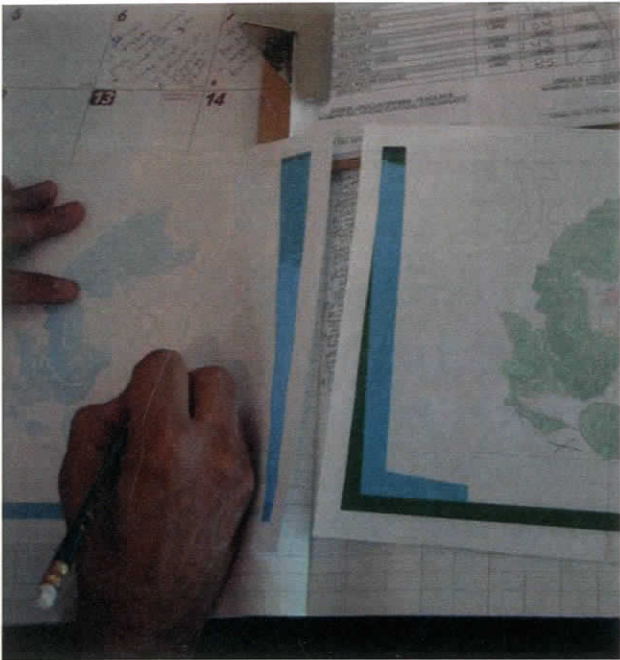
Rico falls permanently in this zone, and they are observed in the island almost year round. Normal wind speeds are observed at 10 to 15 miles an hour. The presence of the central mountain chain, in Spanish called Cordillera Central; create a climactic double-effect. With the heights of the mountains the atmospheric temperatures drop creating more appealing temperatures than those of the coastal regions. Jayuya is located in on the central mountain chain on the west, south-west part of the island. North of the city of Ponce, Jayuya is mostly in the mountainous terrain. According to a map made for the different precipitation regions in the island by Margaret Howarth in 1934, Jayuya falls under region ten, which is the rainy region of the west mountains and gets from 70" to 120" inches of rainfall a year. The average temperature for Jayuya is 78 degrees Fahrenheit. Hacienda Ana has a hilly terrain for most of the property. The river Jauca serves as the property line for the farm.

### Dwellings for coffee workers in Jayuya

There is one area that is relatively flat and clear from the crops. This is where this thesis will be testing the proposed dwelling's performance. This clearing is ideal for responsible development of dwellings. This thesis will propose ten dwelling units for the site. There will be three design alternatives that observe the same basic program but accommodate a different number of people. These dwellings are single-family since this is the most observed housing unit in Puerto Rico, and also the one in highest demand.



Municipality of Jayuya located in a map of Puerto Rico and below the effects on temperature the central mountain chain has in north vs south



56 Negocios



EL GOBERNADOR, Aníbal Acevedo Vila, comparte un café con Angel Santiago, presidente de Encantos de Puerto Rico Inc.

# Encanto empresarial con el sabor del café

## Compañía nativa inaugura una nueva torrefactora en el área de Bayamón

POR AURA N. ALFARO  
alfarod@nuevodia.com

ENCANTOS DE PUERTO RICO INC., empresa nativa de café, inauguró ayer sus nuevas operaciones de torrefacción en Bayamón, mediante una inversión de \$1.8 millones.

La empresa, establecida hace siete años por el joven ingeniero mecánico Angel Santiago, de 29 años, prácticamente en la marquesina de la casa de sus padres, proyecta ventas para el 2008 de unos \$34 millones, con 32 empleados, e ingreso neto de sobre 10%.

La inversión de \$1.5 millones fue financiada por el Banco de Desarrollo Económico, con \$300,000 del Departamento de Agricultura, préstamos de \$200,000 del programa de Jóvenes Agroempresarios; y \$100,000 del programa de La Llave para tu Agroempresa, el último para gastos operacionales.

La ampliación de la torrefactora le permitirá una capacidad para tostar 4,000 libras de café por hora. Cabe señalar que en su finca de café, la Hacienda Ana, en el barrio Jauca de Jayuya, emplea 110 personas en tiempo de cosecha y 54 en tiempo de procesamiento.

lo único que faltaba era meterle los mejores equipos, molinos y empaques, y el mejor tueste posible", dijo Santiago en un aparte con *El Nuevo Día*, durante la conferencia de prensa celebrada ayer.

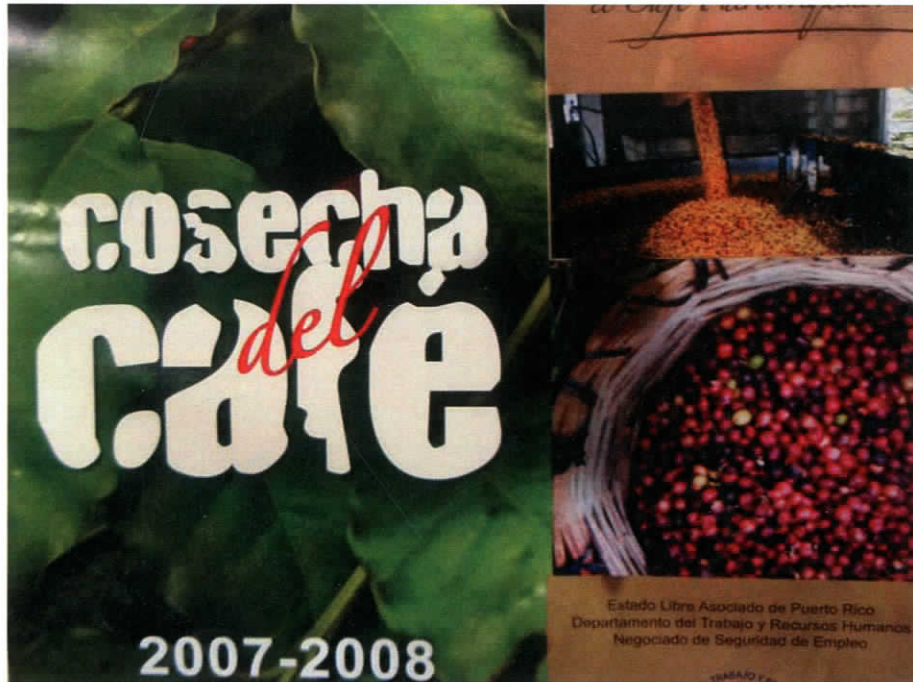
El empresario reveló que el primero de junio firmará "un contrato grande" con la empresa Avendra, proveedor oficial de varias de las principales cadenas de hoteles, entre ellas Marriott y Holiday Inn. Encantos proveerá la harina molida en bolsitas individuales, para las máquinas de colar café en los cuartos de hotel.

La nueva torrefactora, ubicada por la carretera 174, fue inaugurada por el gobernador Aníbal Acevedo Vila, quien señaló a Encantos de Puerto Rico como "ejemplo de lo que estamos haciendo para invertir directamente en los recursos empresariales de nuestra gente, particularmente del pequeño empresario".

El Primer Mandatario reveló que "ya empecé una relación Walmart con Encantos en las tiendas de Puerto Rico, y la aspiración de él (Santiago) es que se convierta en la posibilidad de exportar café de primer orden a través de las tiendas de esta empresa en los Estados Unidos y el exterior", al igual que a través de las tiendas Sam's Club.

Santiago informó que varios restaurantes locales sirven café Encantos, y recién comenzó a exportar café al sur de Estados Unidos y a Europa, donde ha enviado 10,500 libras a España. Encantos también vende máquinas de colar

Images of coffee collecting facility , drawings of the full farmland and its crops and newspaper clipping with PR governor enjoying Encantos coffee



Below full panorama of thesis site and other contextual images of Hacienda Ana



Above left the offices of Hacienda Ana in Jayuya and major views of the site. Other news published in local newspaper promoting the coffee.



Full site panorama located within Hacienda Ana





View of the dirt trails in between coffee crops in Hacienda Ana. Coffee harvesting season, courtesy of Hacienda Ana.





Aerial photograph of Hacienda Ana and site chosen for thesis proposal circled



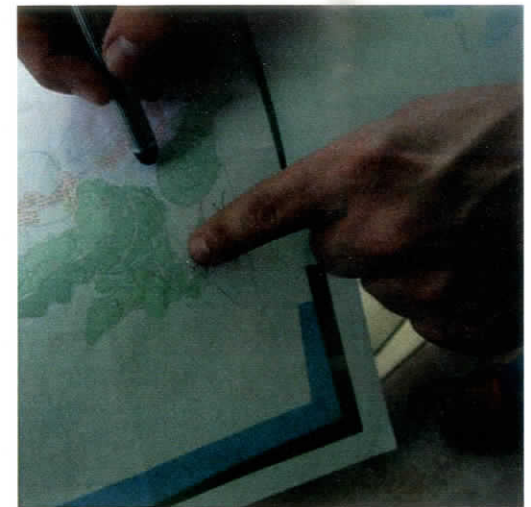
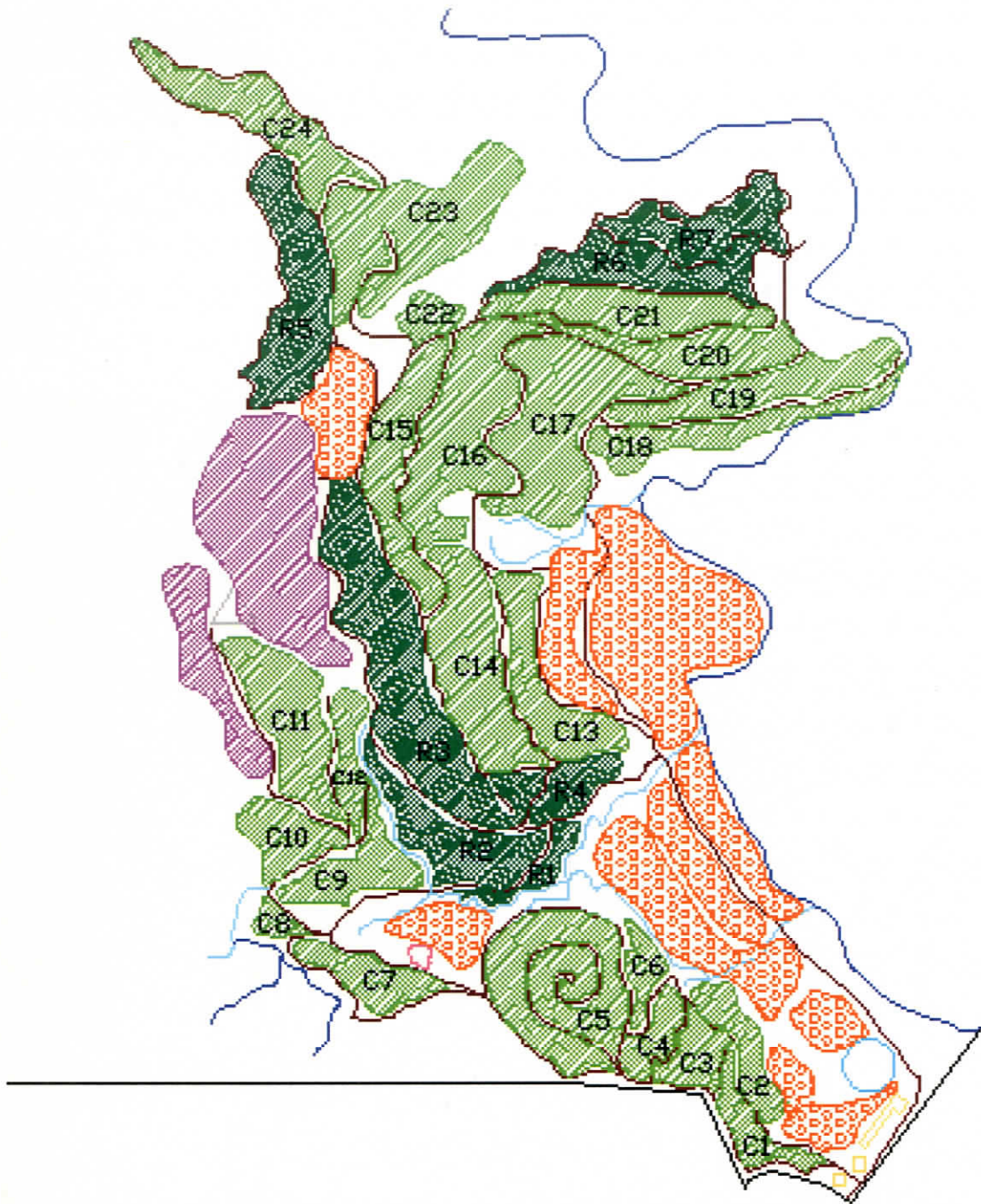
Encantos Coffee view of crops in Hacienda Ana, courtesy of Hacienda Ana.



Zoomed out aerial view of all Hacienda Ana Courtesy of Hacienda Ana

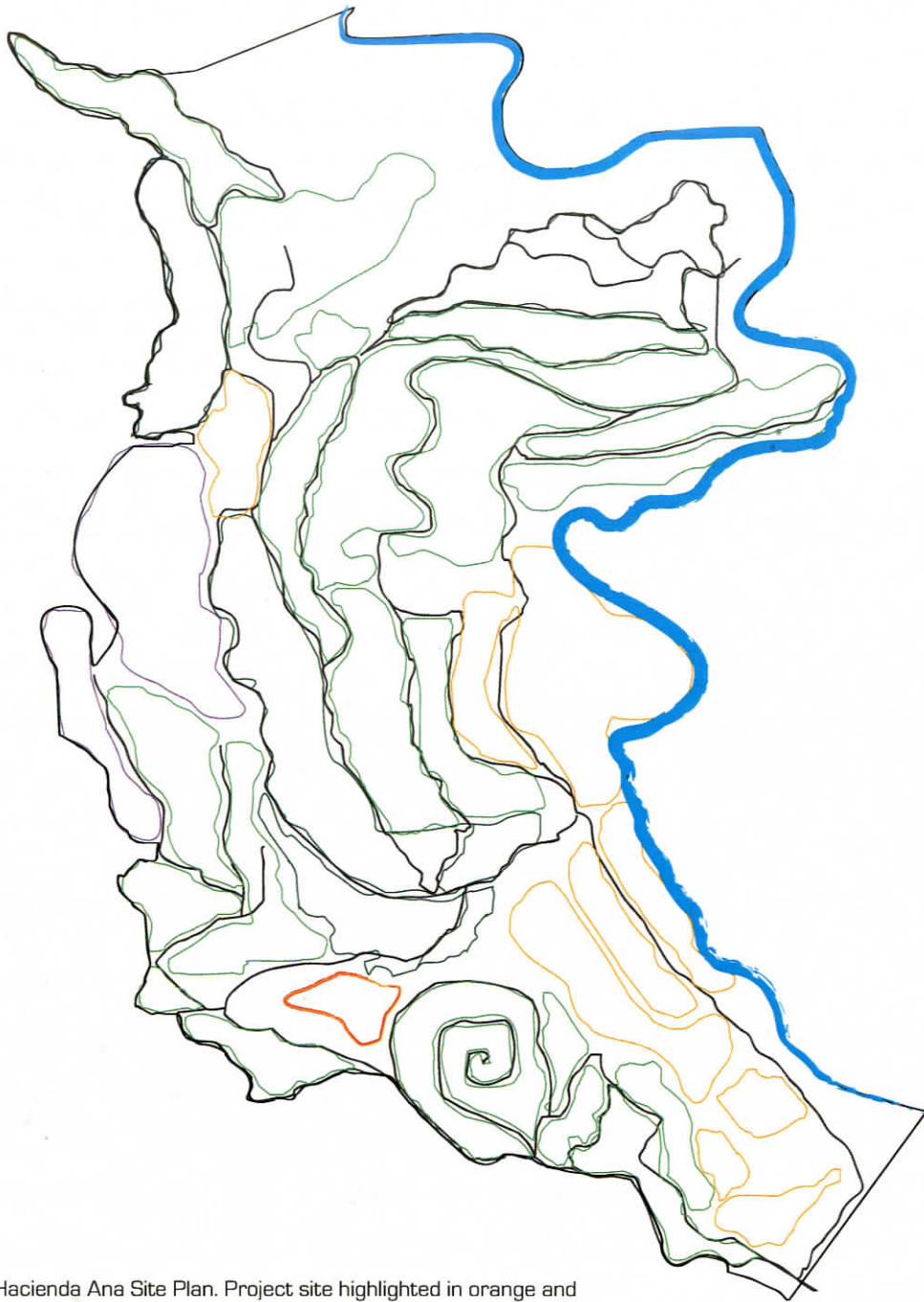


Promotion image for Hacienda Ana and Encantos Coffee.  
Courtesy of Hacienda Ana.

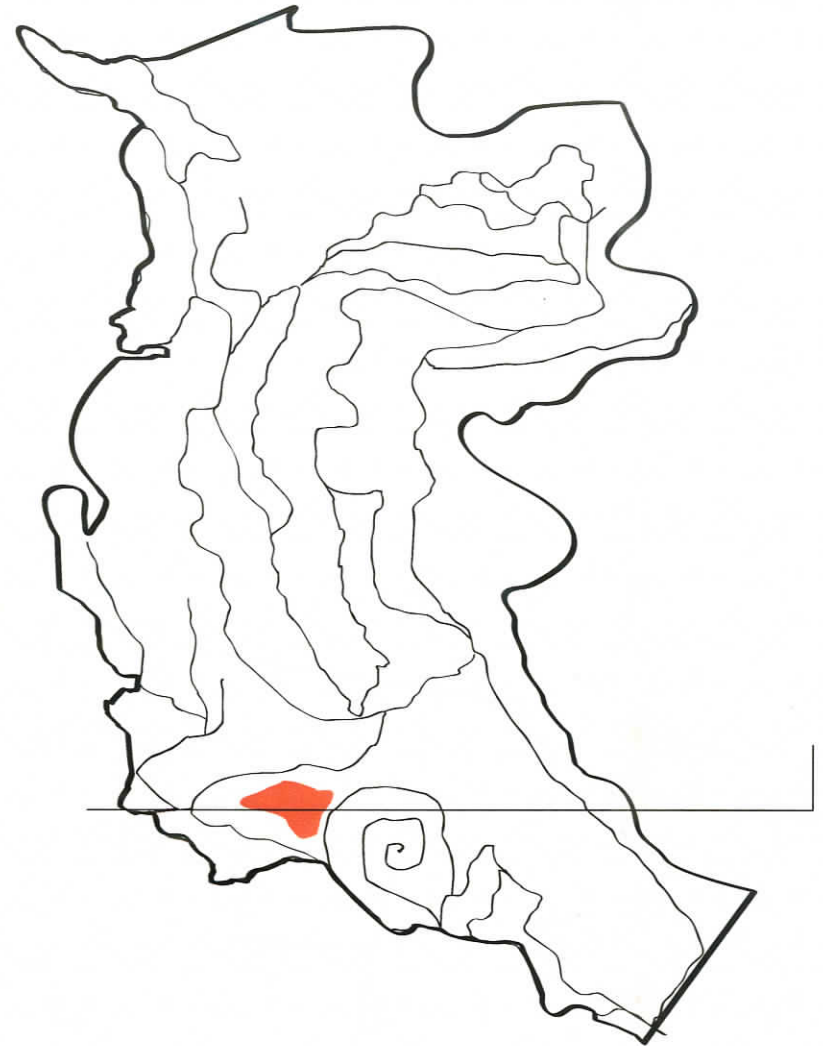


-  new first time crops
-  coffee arabic strand
-  coffee robust strand
-  mandarin oranges
-  plantains
-  bananas
-  pineapples
-  water runoff
-  Jauca river
-  trails

Existing documentation of Hacienda Ana. Documentation courtesy of Victor Santiago. Information translated by Cristina Alonso



Hacienda Ana Site Plan. Project site highlighted in orange and trails shown in brown.



Site section cut east to west.  
Above site plan.  
Above left zoom-in of site.



# Analyzing Optimum Orientation

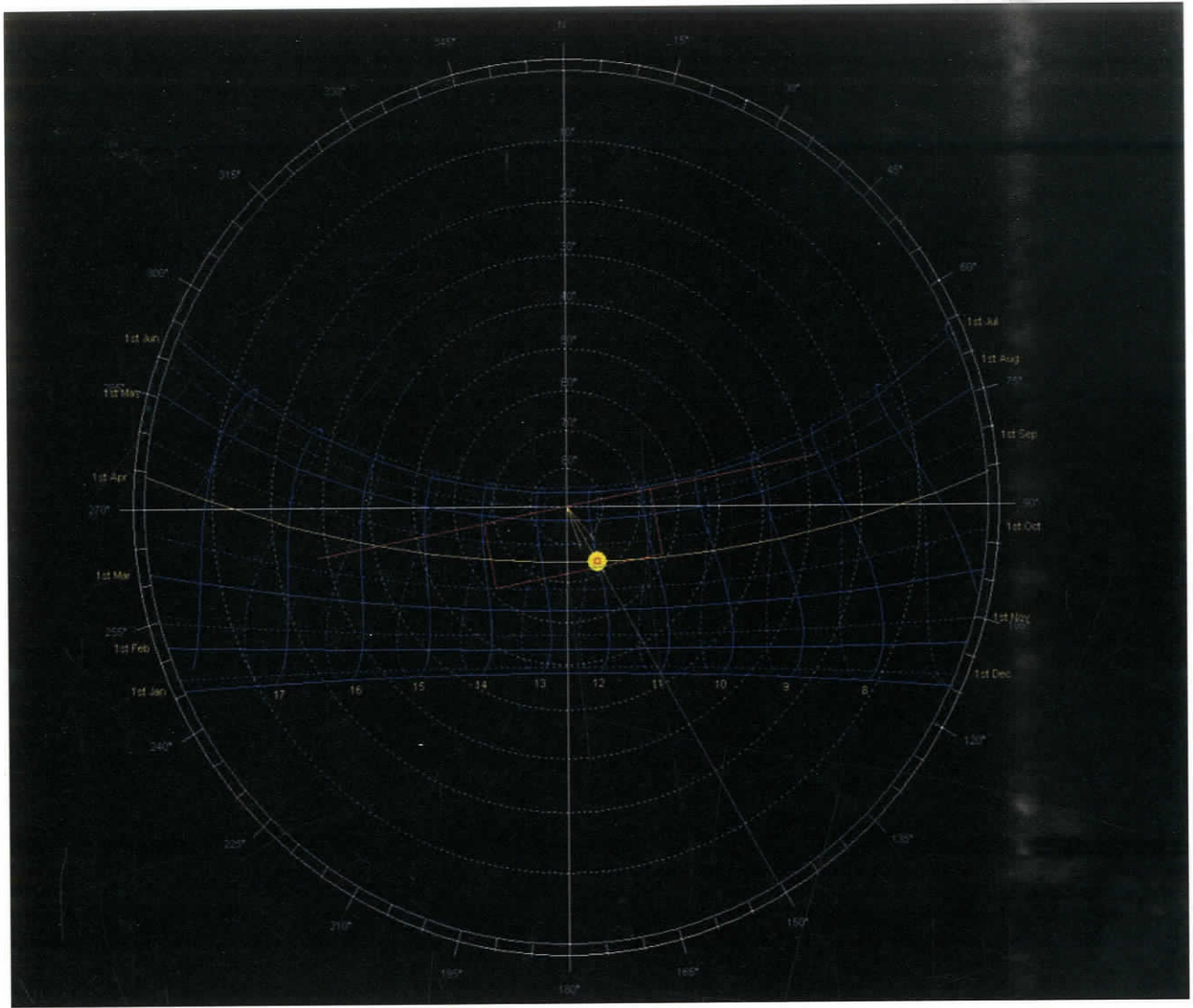
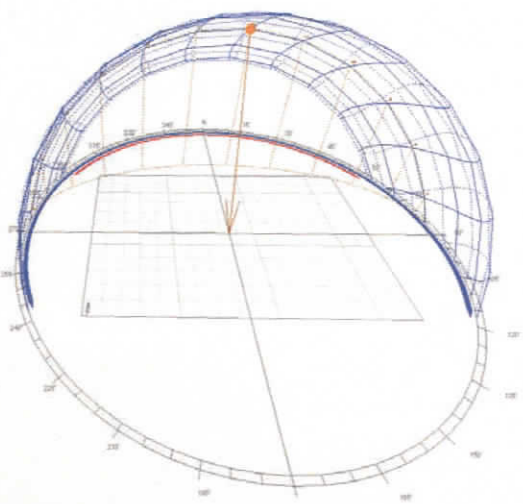
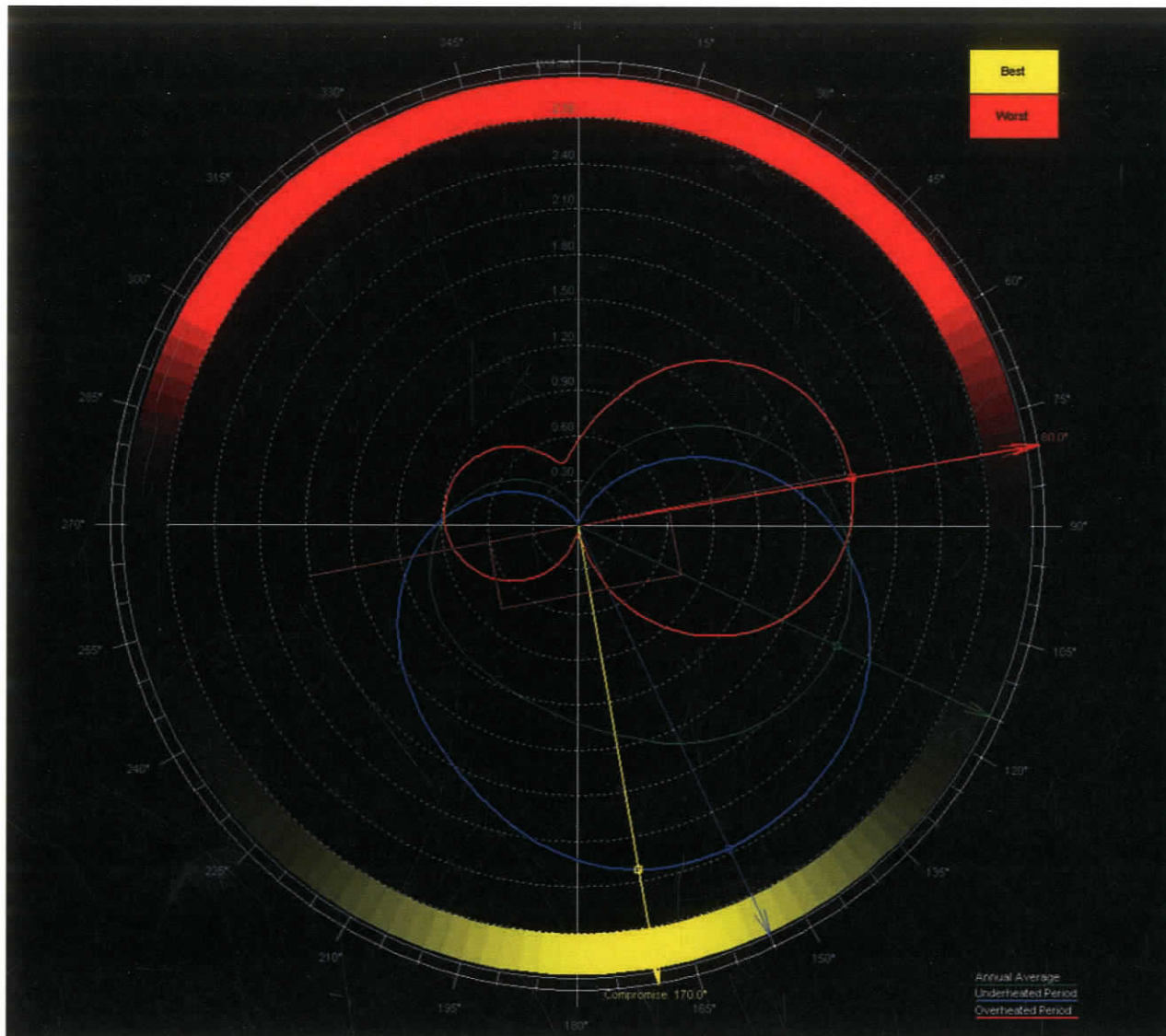
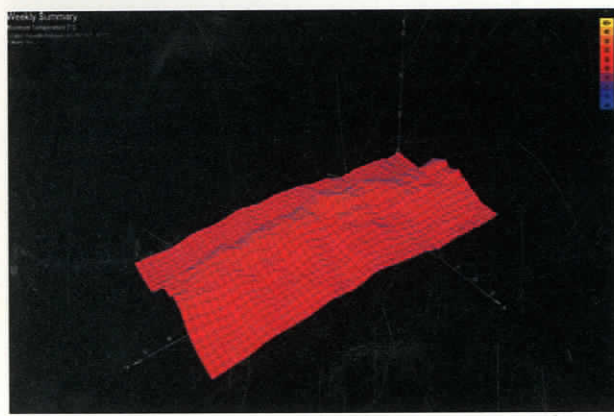
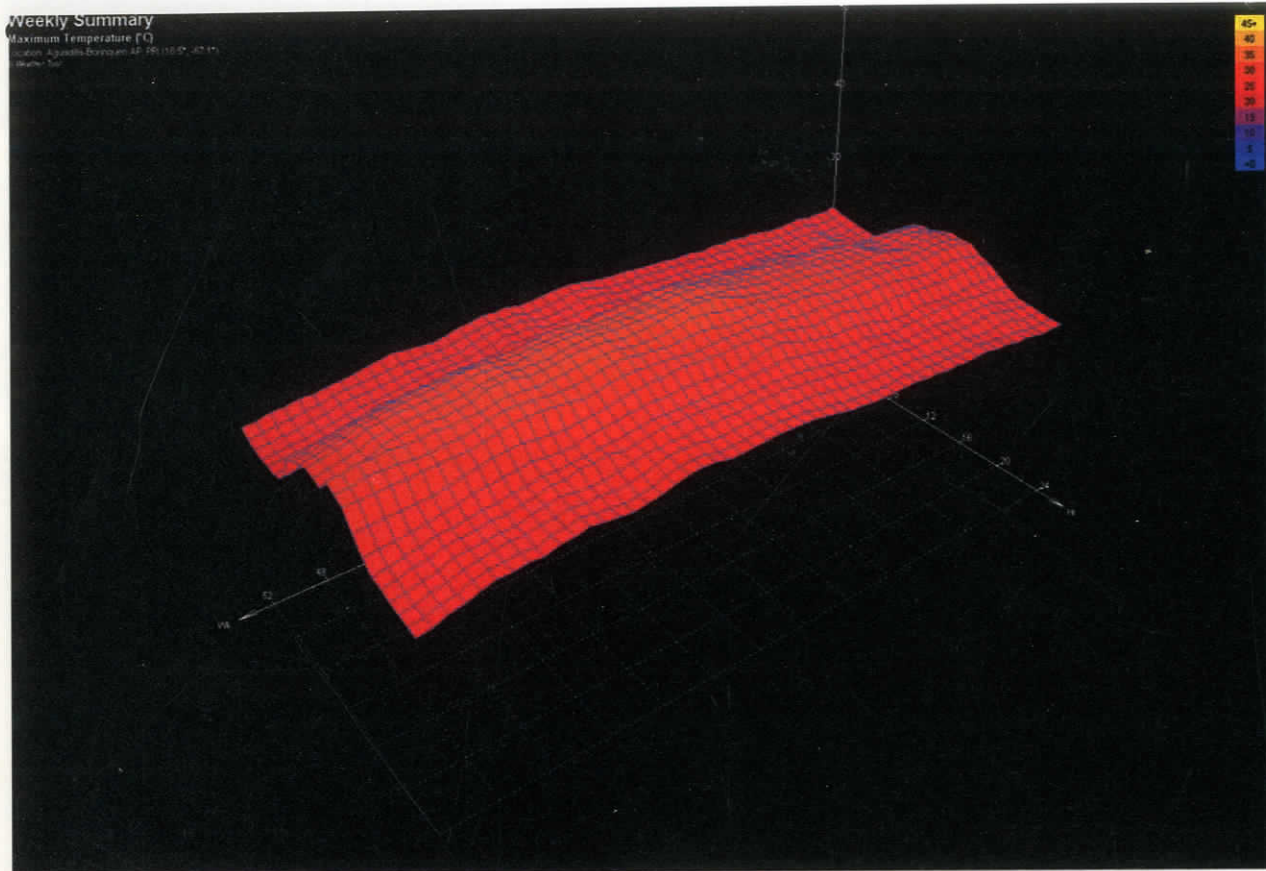


Diagram and data for optimum orientation for housing units in Jayuya, Puerto Rico. This is the best orientation in relation to sun angles and heat gain. Courtesy of WeatherTool.





Optimum orientation based on average daily incident radiation on a vertical surface.  
Courtesy of WeatherTool.



Maximum and minimum temperatures over the period of a year. Data for Agaña, Puerto Rico region of chosen site.

# Ventilation Patterns

## Prevailing Winds

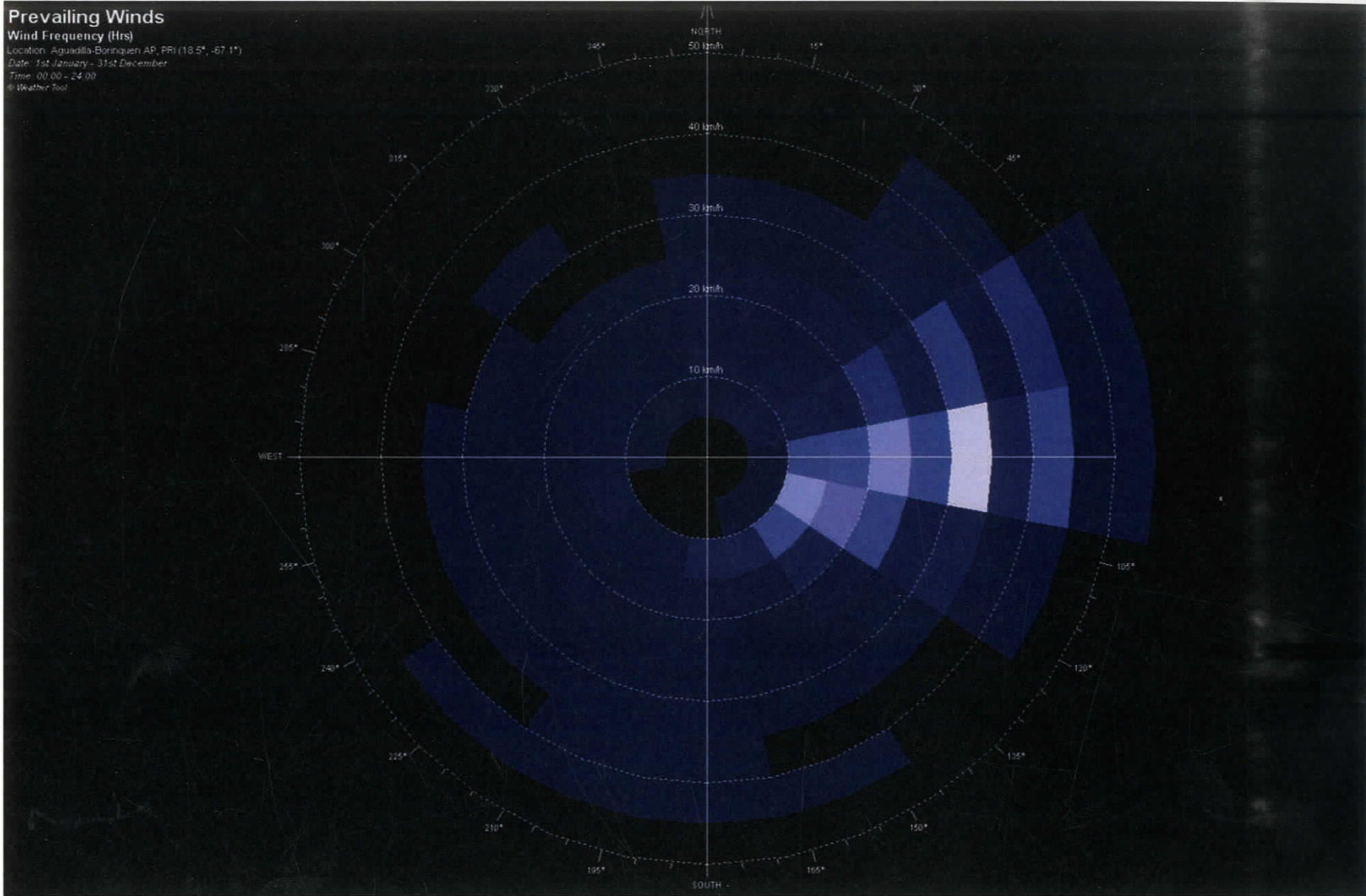
### Wind Frequency (Hrs)

Location: Aguadilla-Borinquen AP, PRI (18.5°, -67.1°)

Date: 1st January - 31st December

Time: 00:00 - 24:00

© Weather Tool

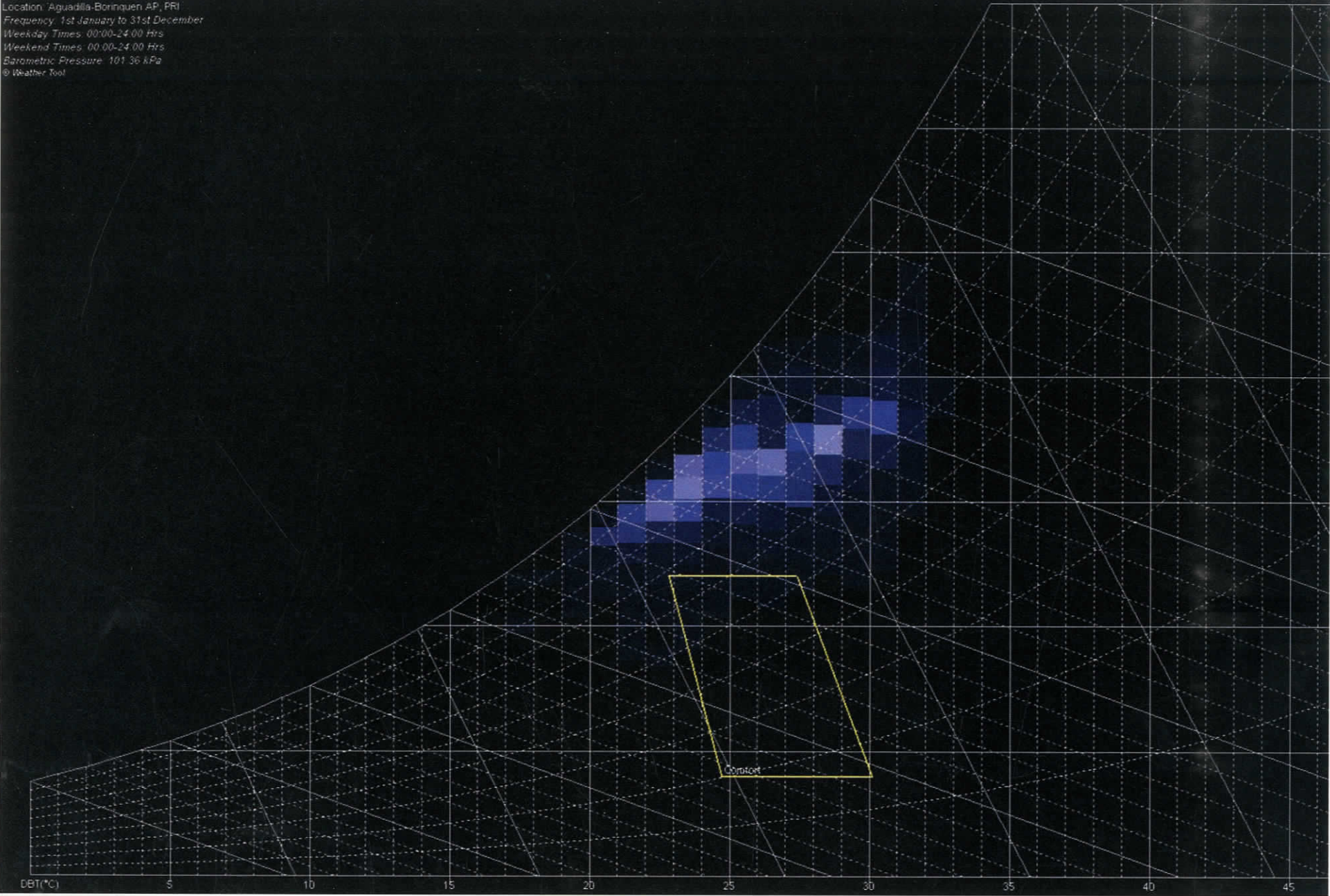


Wind rose diagram demonstrating the prevailing wind for the region and intensity of winds in any given direction.

# Observing Comfort Zones

## Psychrometric Chart

Location: Aguadilla-Borinquen AP, PRI  
Frequency: 1st January to 31st December  
Weekday Times: 00:00-24:00 Hrs  
Weekend Times: 00:00-24:00 Hrs  
Barometric Pressure: 101.36 kPa  
© Weather Tool

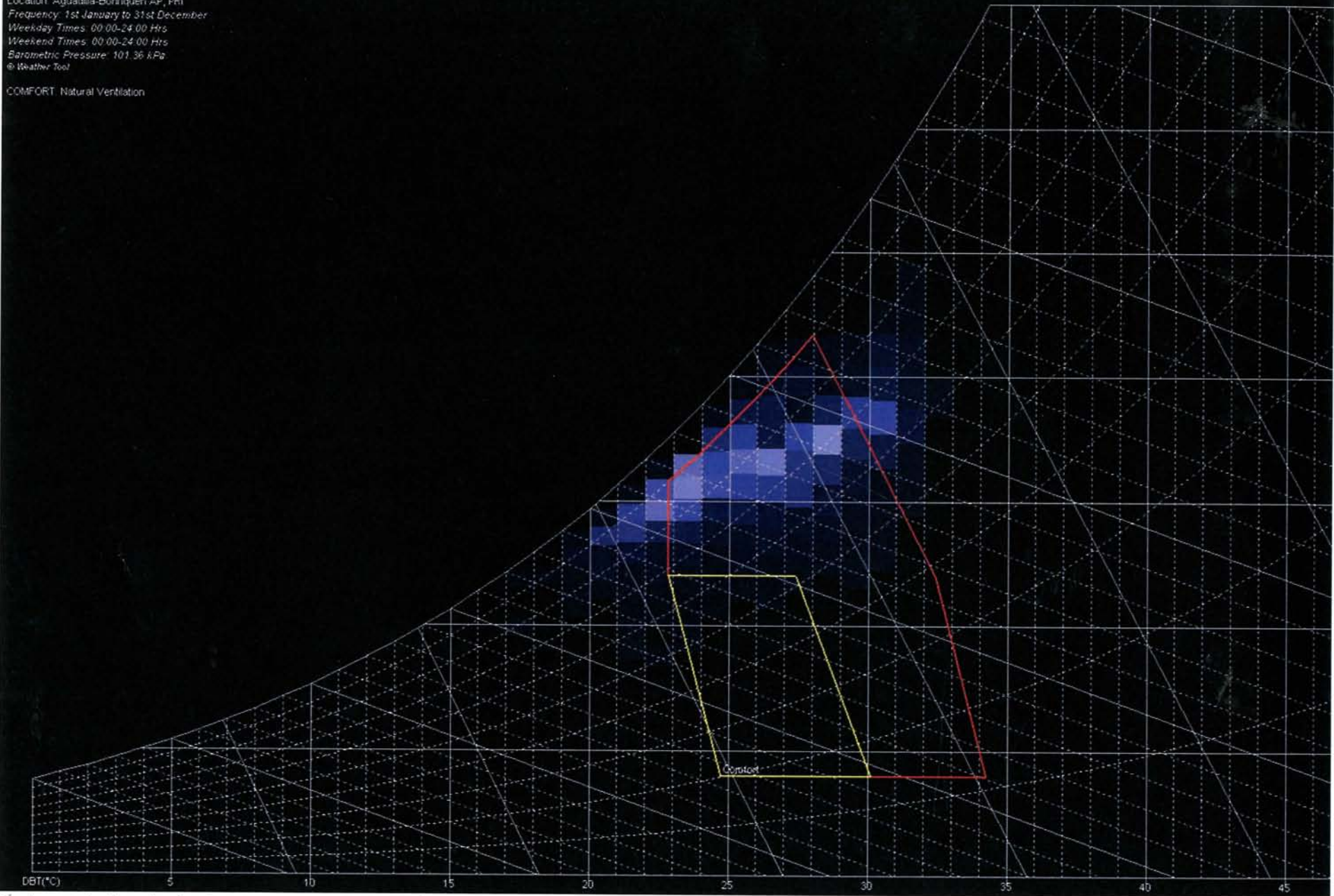


Psychrometric chart showing the comfort zone versus the climate observed in the region. This will influence the passive cooling strategies in design.

# Psychrometric Chart

Location: Aguadilla-Borinquen AP, P.R.  
Frequency: 1st January to 31st December  
Weekday Times: 00:00-24:00 Hrs  
Weekend Times: 00:00-24:00 Hrs  
Barometric Pressure: 101.36 kPa  
© Weather Tool

COMFORT Natural Ventilation

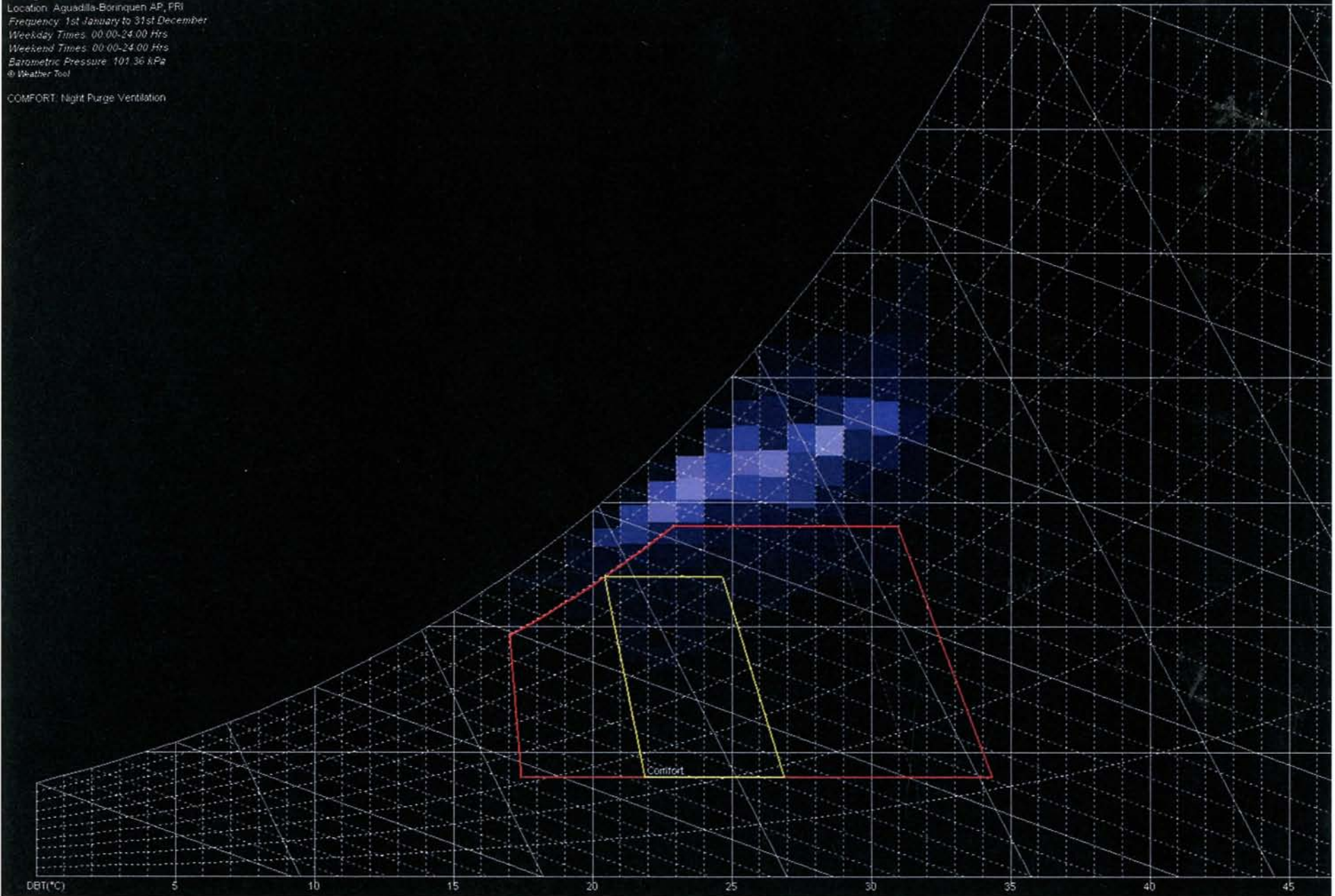


Psychrometric chart showing the advantage zone for implementing natural ventilation within this particular climate. This climate is ideal.

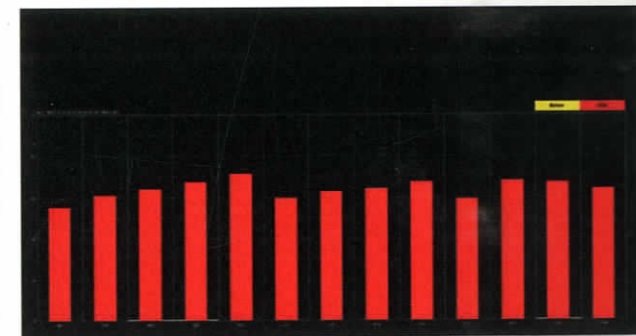
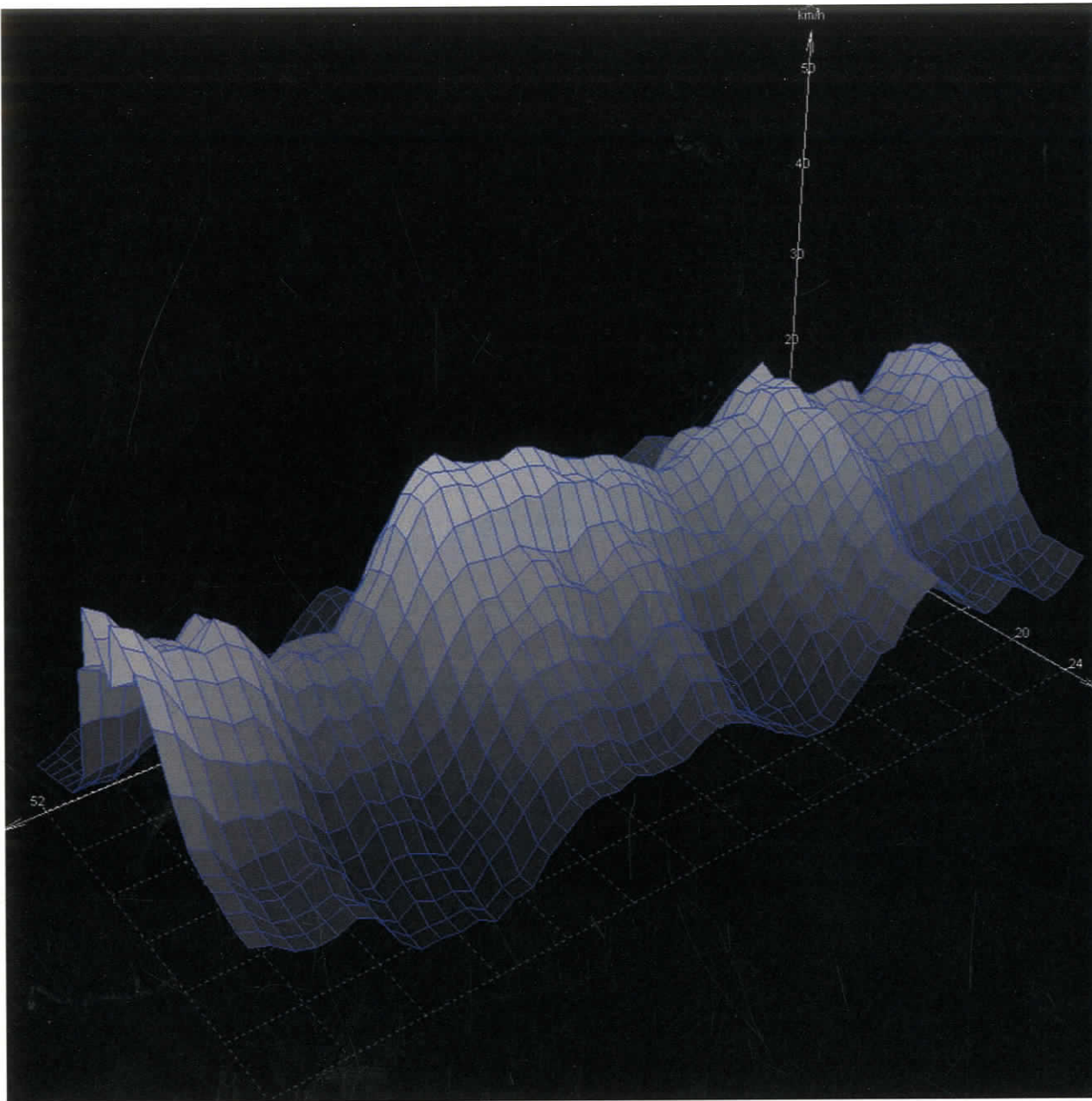
# Psychrometric Chart

Location: Aguadilla-Borinquen AP, PR  
Frequency: 1st January to 31st December  
Weekday Times: 00:00-24:00 Hrs  
Weekend Times: 00:00-24:00 Hrs  
Barometric Pressure: 101.36 kPa  
© Weather Tool

COMFORT: Night Purge Ventilation



Psychrometric chart showing the advantage zone in red for using night purge ventilation or night cooling for this given climate.



This diagram shows wind speeds for the region of Agudilla for a one week period. The column chart shows how successful natural ventilation strategies would be in this region.

## Direct Solar Radiation

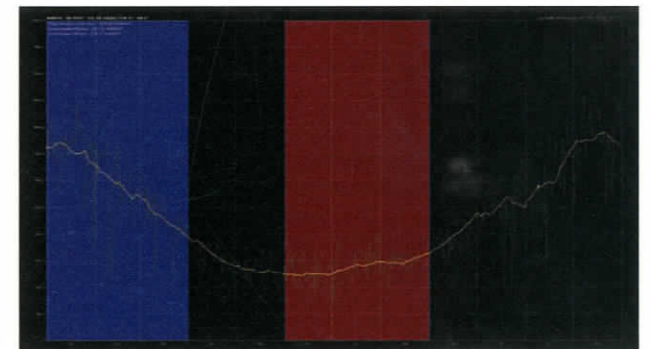
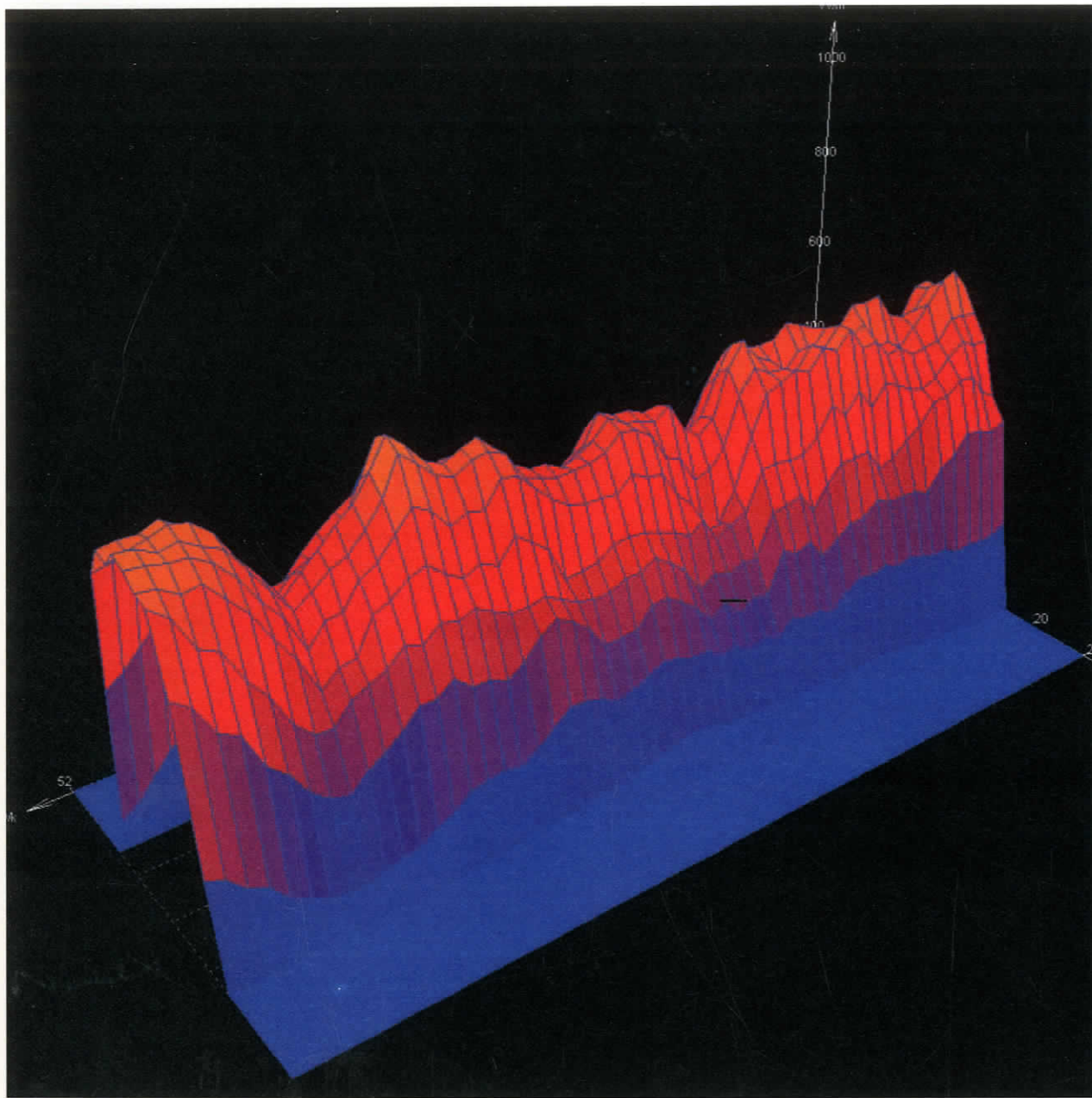
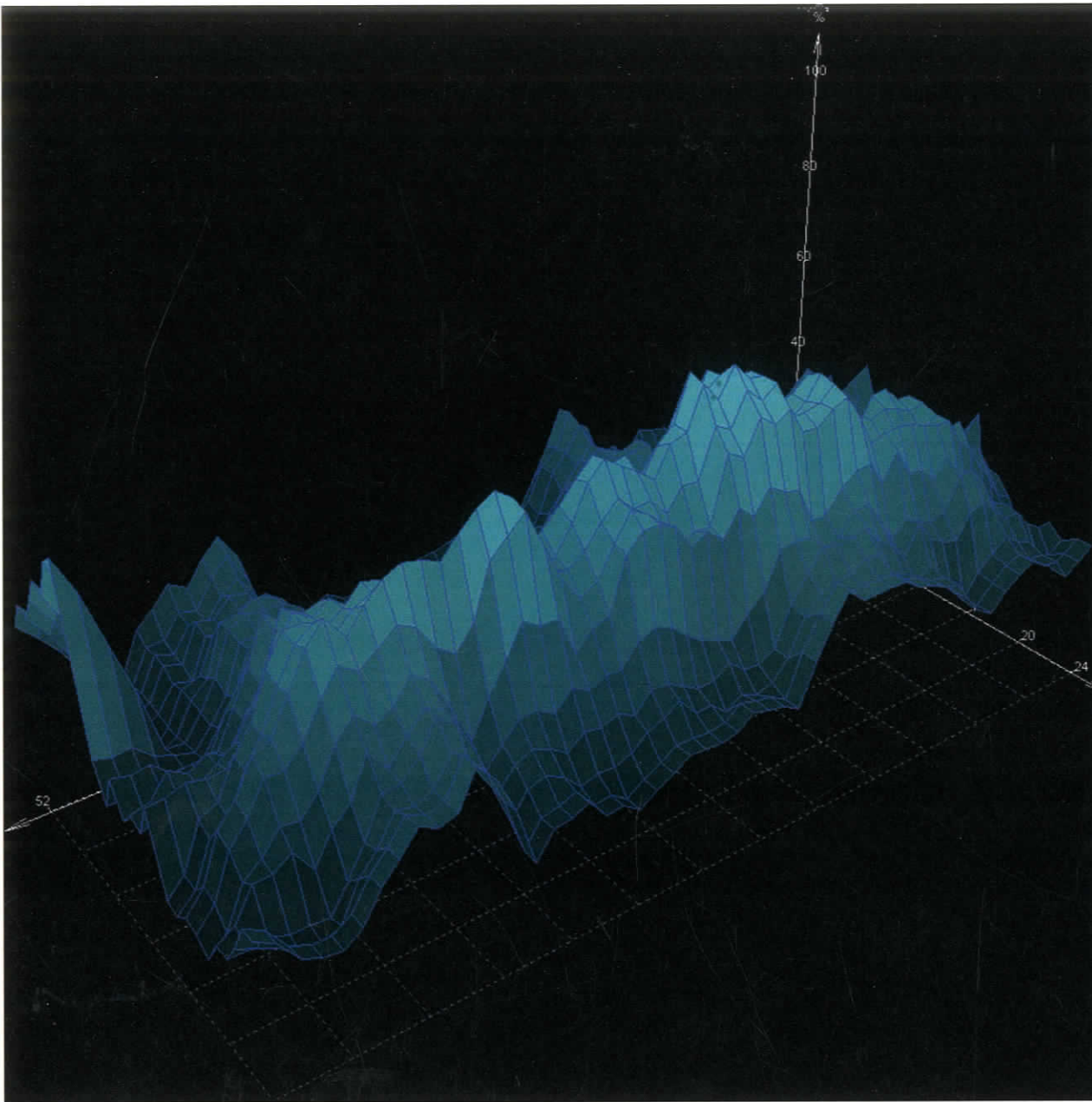


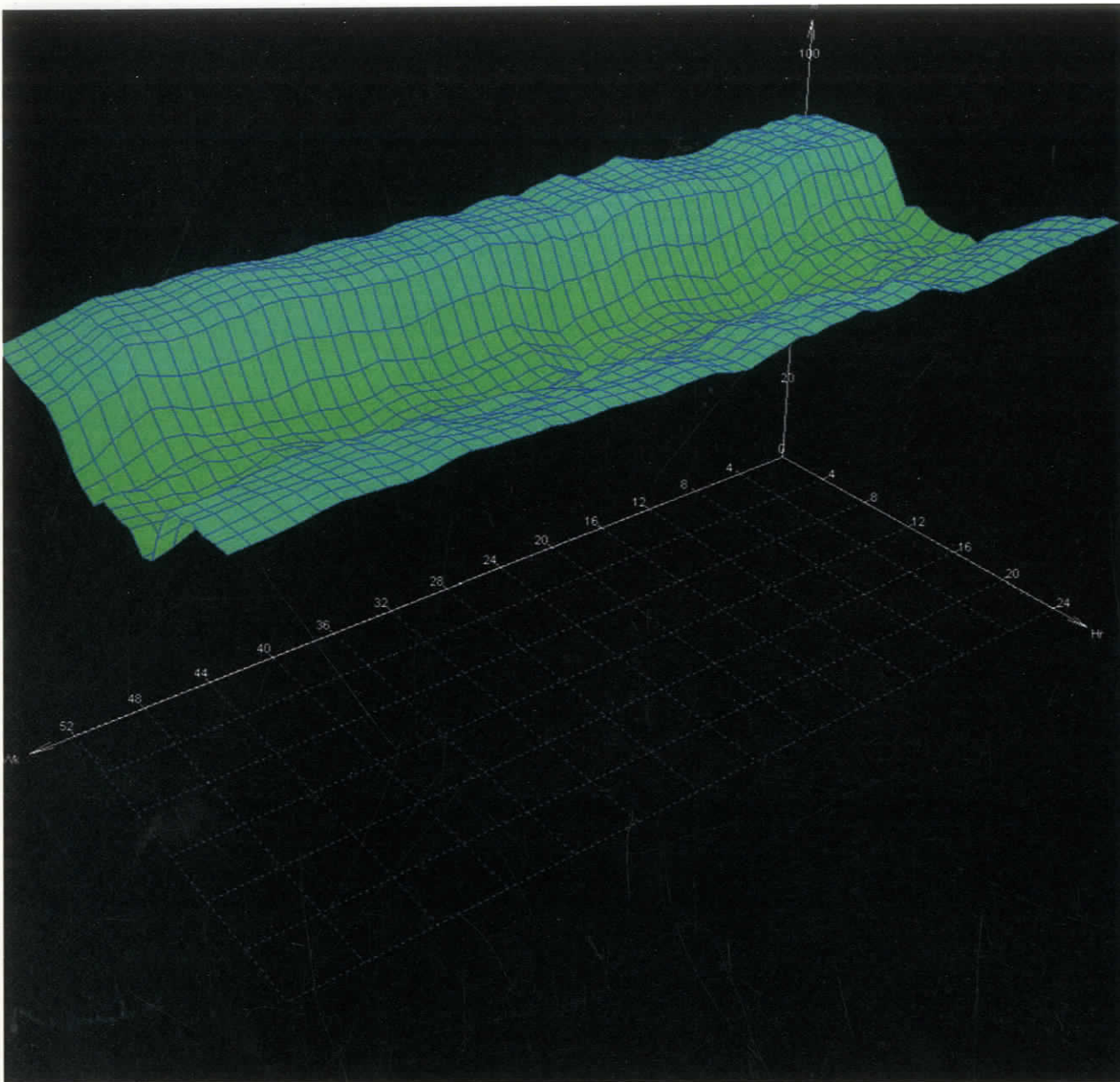
Diagram showing direct solar radiation for a one week period in the region of site.





This diagram illustrates cloud cover over a one week period in the site.

## Relative Humidity Analysis



This diagram shows relative humidity levels over a one year period for the site.

## An Annotated Bibliography

### Books

Abrams, Donald W. Low energy cooling: A guide to the practical application of passive cooling and cooling energy conservation measures. New York: Nostrand Reinhold Company, 1986.

Great source for insight on passive cooling systems. It contains a good introduction and chapter selection of topics that relate to implementing good sources of cooling through passive strategies. The other book I found on this topic seems to be more up to date and more recently published, but this is still relevant and will provide good background information for my thesis contention.

Allard, Francis. Natural Ventilation in Buildings. London: James & James Science Publishers Ltd, 1998.

This book has everything you might want to know or manually calculate for natural ventilation strategies. It is extremely detailed and offers all the formulas for calculating air flow and many other things involving air in space. It also offers good definitions and introductions to basic terms of passive cooling. At the end of the book it offers a chapter with in depth information on precedents and how they dealt with natural ventilation within their design strategies. I will be making references to the information offered on the single family residence in Porto, Portugal, as I believe it might influence climate conscious decisions I will be making for my own site in Jayuya, Puerto Rico.

Ambrose, James, and Dimitry Vergun. Simplified Building Design for Wind and Earthquake Forces. New York: John Wiley & Sons, 1980.

This book has a great introduction to the vocabulary and design strategies involved in designing well for wind and earthquakes. For the purpose of this thesis I will focus on the chapters dealing with lateral load resistance of buildings (ch. 2) and wind effects on buildings (ch. 3). This in depth understanding of the structural implications of a building and how it behaves in different wind conditions will allow me to explain how my design intends to address wind forces within the climate found in Jayuya, Puerto Rico. This information will prove crucial as a way of framing my design parameters for the dwelling units. At the end of the book there is a diagram and drawing of a seismic and hurricane anchor for trusses and rafters that might influence my own joints design.

Duran, Sergi Costa. Green Homes: New Ideas for Sustainable Living. New York: Harper Collins Publishers, 2007.

Relatively new book on ecological approach to housing design. The book provides a great introduction by Lance Hosey on the ecology of the home. It offers great photographs and technical drawings of all the houses featured from an array of different countries and climates. Each precedent project is clearly labeled with the ecological features that are incorporated into the design. These features range from passive solar, rainwater collection, waste, water managing, natural and reused materials among others. It offers insight to what makes these designs successful within their context.

Givoni, Baruch. Passive and Low Energy Cooling of Buildings. New York: John Wiley and Sons, Inc. , 1994.

This is a great source for my thesis contention. The book contains all the basics about passive cooling and how they can be applied and deployed in a specific climate. It has great quotes I could use for framing my thesis intentions. Overall essential information relating to my thesis, the book is divided into chapters that explain the critical aspects of each strategy towards passive cooling.

Patton, Carl. Spontaneous Shelter. N.p.: Temple University Press, January 22, 1988.

This publication offers insight about the different housing problems all over the world. The book is a little dated but provides good archival photographs of different slums and poor housing conditions around the world. It also elaborates for the strategies that were trying to be implemented to solve these circumstances in different countries. It includes an interesting account of La Perla, Puerto Rico an infamous slum not even the police go into. Perched in one of the most priced pieces of real-estate in Old San Juan, La Perla is home to well known drug traffic and prostitution. Has a great picture of La Perla I've never seen.

Reynolds, Michael. Comfort in any climate. Taos, New Mexico: Solar Survival Press, 2000.

This book provides a good introduction into the power of using earth as thermal mass. It has good diagrams and illustrations. It provides basic, concise definitions about terms relating to climate and how space can address climate effectively. Michael Reynolds has a series of books out on several themes relating to sustainable living. He was recently featured in the Weather Channel series Forecast Earth, where he

showed one of his green houses. His architecture is named biotecture and his projects usually referred to as earthships. The books are available on the website earthshipbiotecture.com. I will use quotes from this book to provide a framing for some definitions or introducing the topic of alternate means of construction.

Smith, Cynthia E. Design for the other 90%. N.p.: University of Chicago Press, May 4, 2007.

Great book that looks at life changing innovations that will save lives in countries with extreme conditions. It does not necessarily deal with architecture, but more to do with objects that are changing people's lives for the better in poorer countries. Devices for transporting water, and filtering straws that allow people to drink water directly from the source without risk of contamination or disease; these are some of the innovations featured in this book. It also features an affordable laptop for children in developing countries and solar powered hearing aids. It has interesting solutions for major problems in developing countries. Might want to look at this for innovative ideas involving water collection.

Steffen, Alex, and Al Gore (Foreward). Worldchanging: A User's Guide for the 21st Century. N.p.: Abrams, March 1, 2008.

A book that attempts to put all the necessary and unnecessary things any individual might want to know about going green. It has everything from water conscious bathtub installations, to do it yourself projects and useless facts about how the world's recycling and production is linked in weird ways. It is a recent publication, and so, it is up to date in the latest 'trends' in going 'green.' Useful book for coming to terms with the contemporary topic within popular culture.

Stohr, Kate, and Cameron Sinclair. Sponsored by Architecture for Humanity. Design Like You Give a Damn: Architectural Responses to Humanitarian Crises. N.p.: Metropolis Books; 1st edition, January 15, 2006.

This book is perfect for looking at relevant case studies for my project. Cameron Sinclair founder of Architecture for Humanity has great precedent projects to look at. They all have to do with housing and the chapters are divided into housing for emergency, transitional, permanent, and community and gathering spaces. From high tech to low tech covering all types of materials and budgets and client needs. This book is fantastic. Compile ideas from this book for my thesis book. The book includes a time line of natural and man made disasters and subsequent responses, great background information on the progression of design responding to crises in history.

Van Lengen, Johan. The Barefoot Architect: A handbook for green building. California: Shelter Publications, 2008.

Excellent reference for anyone who was thinking of constructing or learning how to construct their own simple and environmentally home. Geared towards a non-designer audience, the book explains in very simple terms what design decisions make the difference towards a better home. It also makes distinctions between climate types and design gestures that would be appropriate for each location. Provides a great break down for basic design principles, construction methods and site awareness towards literally building your own home.

Von Vegesack, Alexander. Jean Prouve, The Poetics of the Technical Object. N.p.: Vitra Design Museum, 2005.

This book has a lot of Jean Prouve projects including his Maison tropical and his Savannah House. It has essays by other scholars on Jean Prouve that write about each project and aspects of his work and design methodology. I will Also a look into his furniture and marketing

designs and strategies. A very holistic look into the career of Jean Prouve. I am personally looking at the Maison Tropical and his other prefab projects for inspiration and guidance for my own thesis. In my opinion, there is a lot to be learned from him and his aesthetics are industrial but very pleasing. I should look at him closely.

### **Magazine | Journals**

Towner, Betsy. "50 Tons of Trouble, A Brief History of Dumping." AARP Bulletin Sept. 2008: 35.

Good graphic material with simple statistics of how much trash was generated by someone who is 70 years old today. Good statistics about people produce 4.5 pounds of waste each day. This has gone up from 2 pounds since 1960. Great basic information about the contemporary waste production by a person. Published in the AARP bulletin.

### **Website Sources**

Alfaro, Aura N. "La basura nos arropa." Ciencia PR.com, Arcticulo del Periodico El Nuevo Dia 15 Mar. 2007. 3 Oct. 2008 <[http://www.cienciapr.org/news\\_view.php?id=443](http://www.cienciapr.org/news_view.php?id=443)>.

This article talks about the reality of what Puerto Rico needs to deal with the solid waste management from now until the government proposed deadline of 2025. Puerto Rico is only recycling 13% of waste products according to this source. It mentions the financial side of the major penalty fees Puerto Rico will have to pay if they do not begin to deal with the waste management problem.

Arieff, Allison, and Bryan Burkhart. "Conference. Prefab Now. Jean Prouve: Tropical House." arcspace.com. 31 Oct. 2005. Audi and Dwell Magazine. 26 Sept.

2008 <<http://www.arcspace.com/architects/prouve/hammer/hammer.html>>.

It was a three-day conference from Oct. 28 - 30 2005 exploring ideas of prefab architecture and difficulties in the field. They had a full-erected version of the Maison Tropical by Jean Prouve in the Hammer Museum courtyard.

Briaker, Brian. "Nomadic Museum." New York Architecture Images, Chelsea, Nomadic Museum. Spring 2005. Newsweek Inc. 26 Sept. 2008 <<http://www.nyc-architecture.com/CHE/CHE-037.htm>>.

This article follows a series of others and images about the nomadic museum by Shigeru Ban. It gives a more social scenario of how the artist and architect came into contact and how the design is perfectly suited for this client.

Caso, Laura. "La Bienal de Venecia propone casas alternativas para tiempos difíciles." [elmundo.es](http://www.elmundo.es/elmundo/2008/09/22/suivienda/1222073773.html). 22 Sept. 2008. 26 Sept. 2008 <<http://www.elmundo.es/elmundo/2008/09/22/suivienda/1222073773.html>>.

Article briefly discussing a few of the progressive projects featured in the Venecia Bienal. The Bienal will run from September 13 to November 23. I will gather first hand information from the exhibition from my colleague Veronica Castro. She is currently in Florence and will be in Venice during the weekend of the 17th of October.

"Desperdicios Solidos." Sierra Club Puerto Rico Chapter. 2008. Sierra Club. 3 Oct. 2008 <<http://puertorico.sierraclub.org/DesperdiciosSolidos.html>>.

Sierra Club in Puerto Rico gives general information about recycling and support networks about recycling. another useful element in this site is the look at the specific legislature that regulates all of waste management and goals towards recycling.

Huppertz, D.J. Critical Cities: Design for the other 90%. 27 June 2007. 26 Sept. 2008 <<http://djhuppertz.blogspot.com/2007/06/design-for-other-90.html>>.

This book explores the topic of designing for the other 90% of the population and is written by a current professor of Design History in Melbourne, Australia. Professor of Design History at Pratt Institute, Brooklyn, 2004-07. This blog is intended as a forum for extended discussions about contemporary culture, particularly design, architecture, literature and music. It says it will be updated every three to four weeks.

Donato, Jorge. Desperdicios Solidos. 2007. 2007. Sierra Club de Puerto Rico. 3 Oct. 2008 <<http://www.ictal.org/modules.php?op=modload&name=News&file=article&sid=2768&mode=thread&order=0&thold=0&POSTNUKESID=696b6e8f733e8ccfc2576e9cc514f4b9>>.

This is a streaming video recording of a lecture given at the University of Puerto Rico, school of Architecture on April 25th, 2007. The video of the lecture is about 22 min long and it covers a variety of themes, mostly on renewable energy and discussing what it takes for a person to get off the grid permanently. Very interesting. At the end of the lecture, Jorge Donato gives out his email and phone number. This might be a good person to contact in terms of getting the project realistically more energy efficient.

"Mercado, materiales reciclados, glosario." Estado Libre

Asociado de Puerto Rico, Autoridad de Desperdicios Solidos . 2008. Autoridad de Desperdisios Solidos (ADS). 3 Oct. 2008 <<http://www.ads.gobierno.pr/portada.html>>.

The best website with information about the market and full lists of recycling plants on the island. Full recycling report from 2007 with charts and graphics about all materials and what gets exported and what goes into local manufacturing. there is a vast need for more local manufacturing and processing of recycled materials. According to the report we are exporting 49% of all the recycled material to be processed in other countries towards new products. The recycling market, although small in Puerto Rico generated 222.4 million dollars in 2007! Impressive, yet we are still exporting lots of material that the island could make good use of it. From this source I have chosen to use wooden pallets and cardboard as the main materials for my housing units. I will use the listings provided here to contact some of the facilities and get local information about materials access and costs.

"Nomadic Museum by Shigeru Ban." New York Times Architecture Images, Chelsea, Nomadic Museum. Spring 2005. The New York Times Company- Copyrights 2005. 26 Sept. 2008 <<http://www.nyc-architecture.com/CHE/CHE-037.htm>>.

These are different articles compiled about the Nomadic Museum by Shigeru Ban to exhibit the work of photographer Gregory Colbert. The nomadic museum was also featured in popular television series Law and Order on NBC. The museums full construction materials and method of assembly are discussed in the following liked articles. Great example of temporary spaces with specific program and extending the boundaries on reclaimed materials in architecture designed in a beautiful way.

Perez Sanchez, Laura N. "A convertir Desperdicios Solidos an Energia." Periodico El Expreso. 28 July 2008. El Expreso. 3 Oct. 2008 <[http://www.elexpresso.com/index.php?option=com\\_content&task=view&id=899&Itemid=38](http://www.elexpresso.com/index.php?option=com_content&task=view&id=899&Itemid=38)>.

This article in a local, small circulation paper in Puerto Rico reports on the first plant that will turn solid waste into energy on the island. it also lists the 31 landfills that are working and the strategy to try and come back from them. It mentions that 85% of garbage ends up in landfills and only 15% actually gets recycled. What if this number went up? There is a need to establish ways to do a complete recycle cycle of a recycled product locally on the island. this would not only increase recycling

Smith, Cynthia E., and Jocelyn Groom (head of exhibition). "Design for the Other 90% - SHELTER Section." Design for the other 90%. 27 June 2007. Walker Art Center in Minneapolis May 24–September 7, 2008. 26 Sept. 2008 <<http://other90.cooperhewitt.org/design/?c=shelter>>.

Design for the other 90% the exhibition that was hosted until September 7th of this year. It explores the topics of designing for the less privileged and subdivides into major topics shelter, health, water, education, energy and transport. these are all major themes in my thesis I have ordered the book and will look into where the exhibition will be going next.

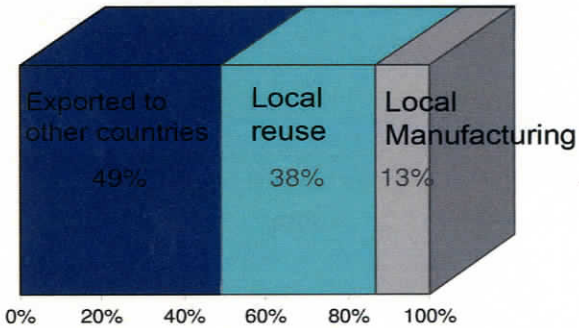


Renderings by Jeffrey Schulte



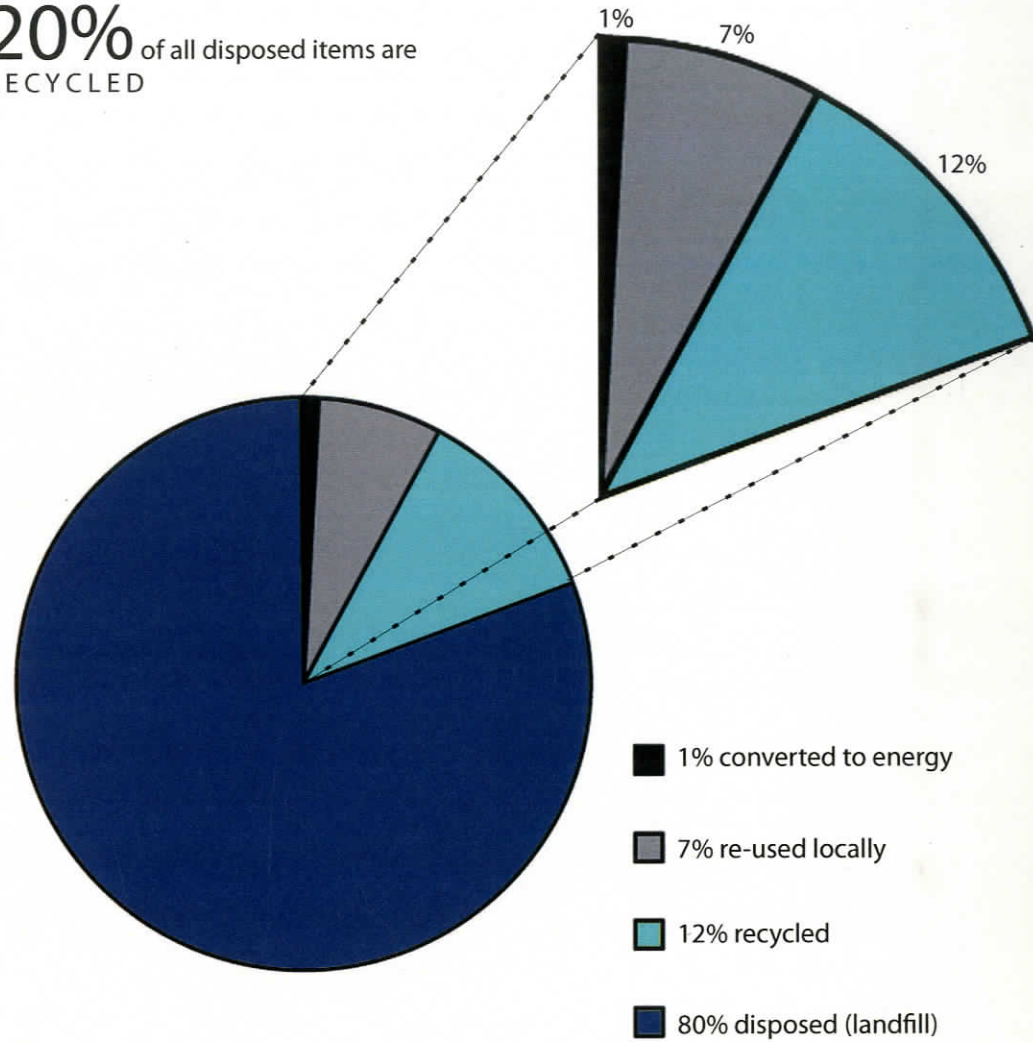
# RECYCLING REALITY IN PUERTO RICO

49% of all collected recycle content is exported



FRAMING EXISTING CONDITIONS  
trash and recycling problem in puerto rico  
only 20% of all waste is recycled

20% of all disposed items are RECYCLED

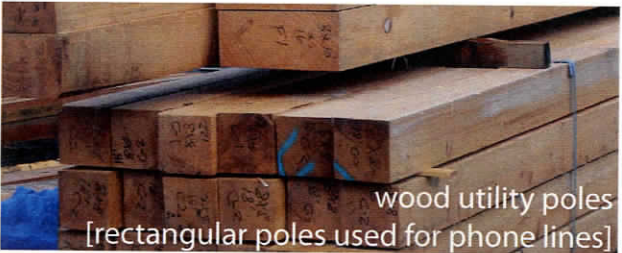
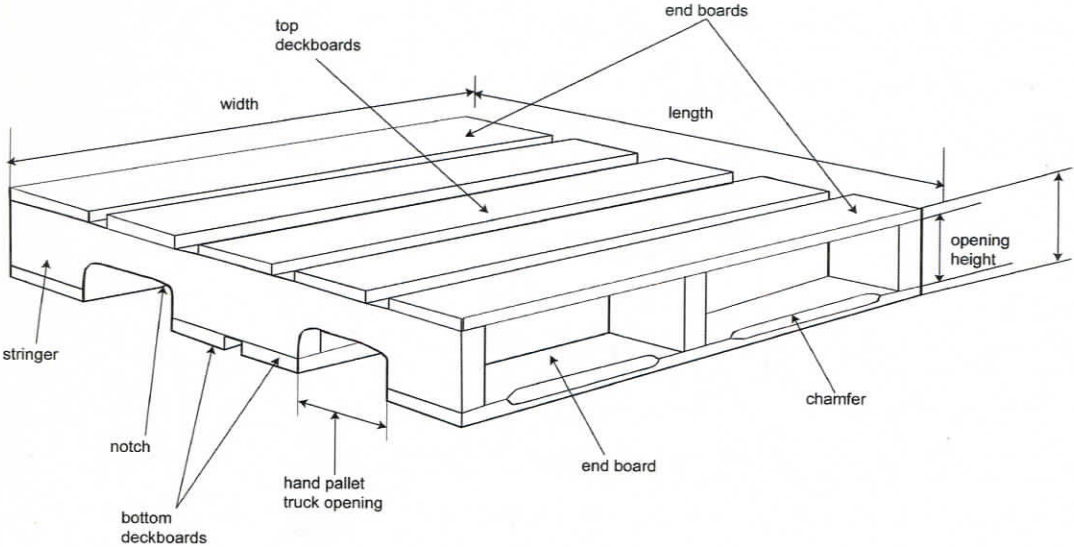


# AMONG RECYCLABLES in Puerto Rico WOODEN PALLETS, UTILITY POLES AND TIRES

Finding new potential for local re-use as  
building materials for housing units



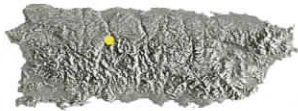
GMA wooden pallet  
[used by Grocery Manufacturer's of America]



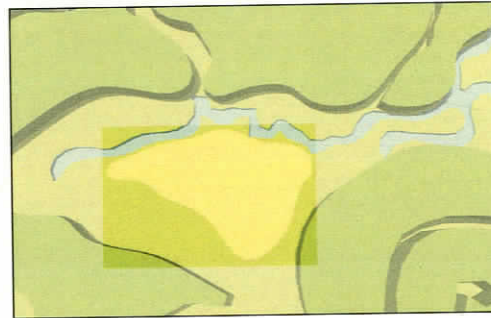
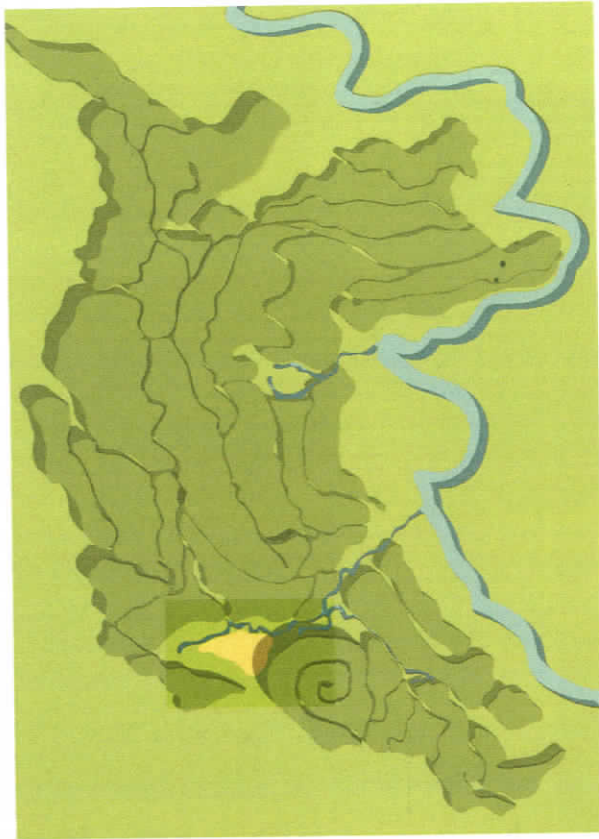
wood utility poles  
[rectangular poles used for phone lines]



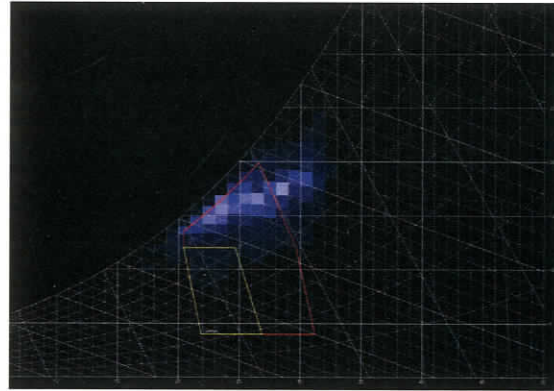
tires  
[discarded car and truck tires]



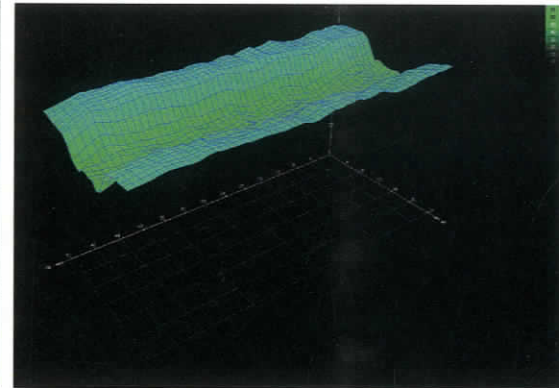
JAYUYA Puerto Rico  
Hacienda Ana SITE



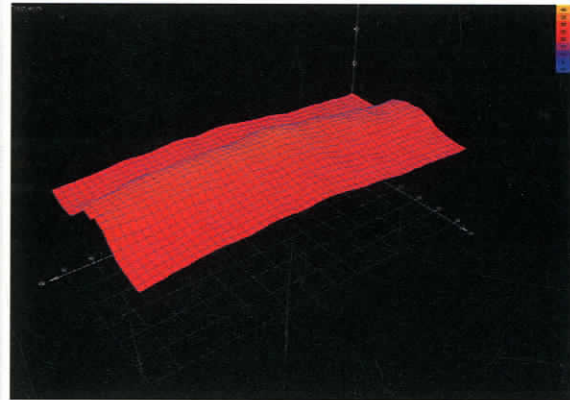
JAYUYA (hah - yoo - yah)  
Site Plan



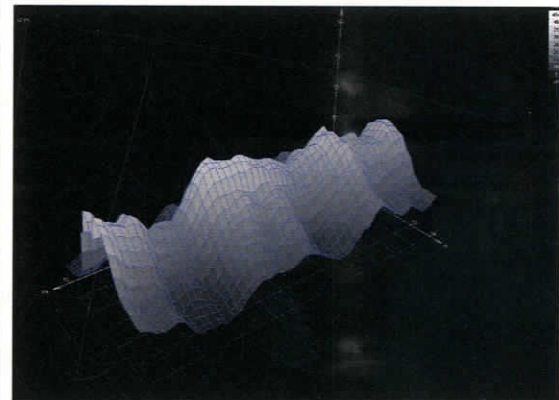
Climate & natural ventilation  
[enhancing comfort in design]



Relative humidity  
[average 80% all year]



Average temperature  
[72F - 84F daytime]



Average cloud cover  
[70" - 120" rainfall a year]

# JAYUYA (hah - yoo - yah) Context

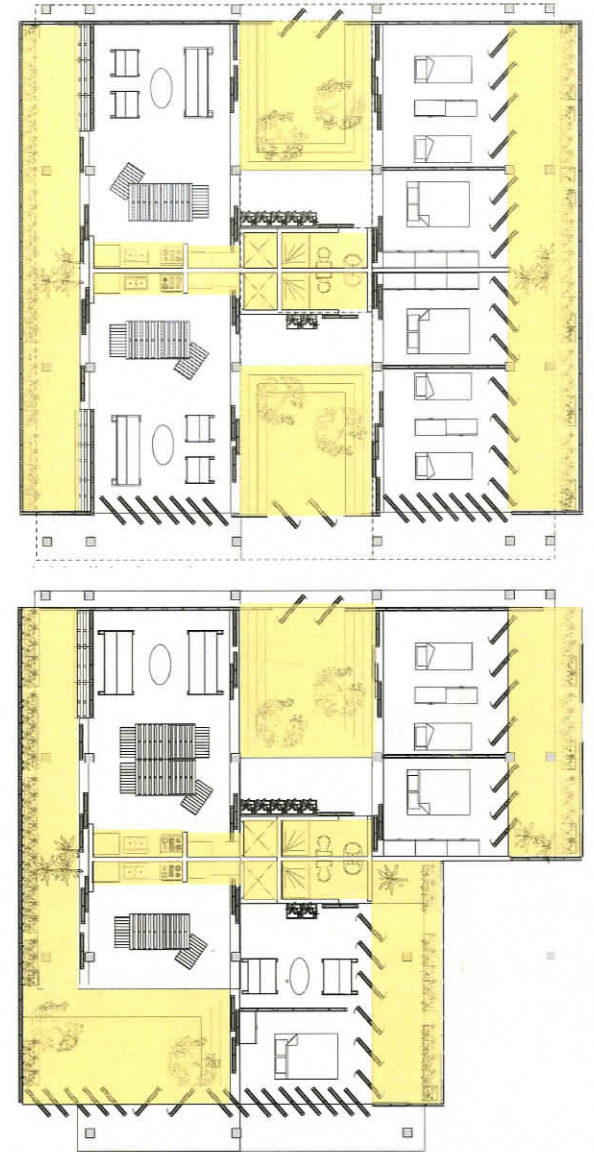
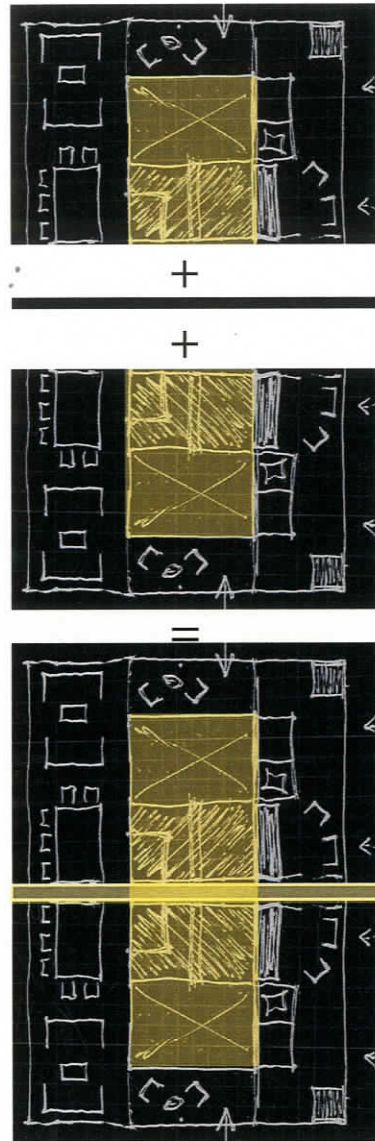
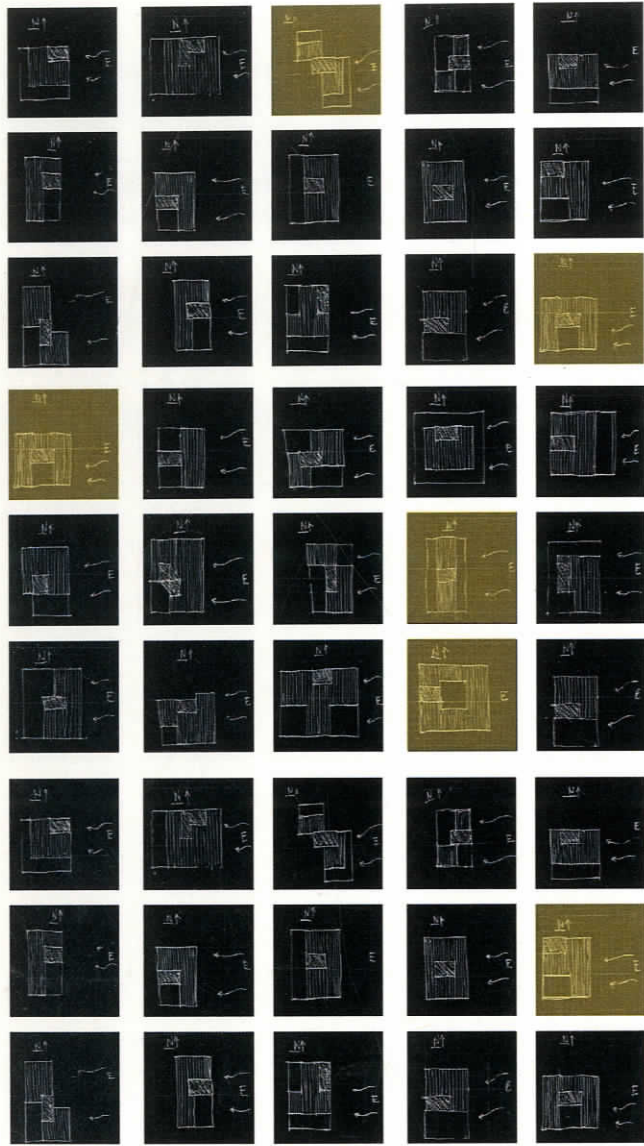
General Facts and Climate Data



People from Jayuya: Jayuyanos  
Driving Time: 1 hour, 50 minutes from San Juan [capital city]  
Land Area: 101 sq km (39.3 sq mi)  
Hacienda Ana [SITE]: 320 acres Encantos Coffee Plantation  
Population: 17,303  
Housing Units: 5,591  
Density [Rural]: 169.6 per sq. km. (440.6 per sq mi)  
Climate: Humid-Tropical [all year]  
Location: Central mountain chain [west rainy region]  
Terrain: Mostly mountainous  
Temperature: 72F - 84F max [day] and 58F - 70F [night]  
Winds: Prevailing winds are from the East [all year]  
Precipitation: 70" - 120" [yearly rainfall]  
Source: 2000 Census

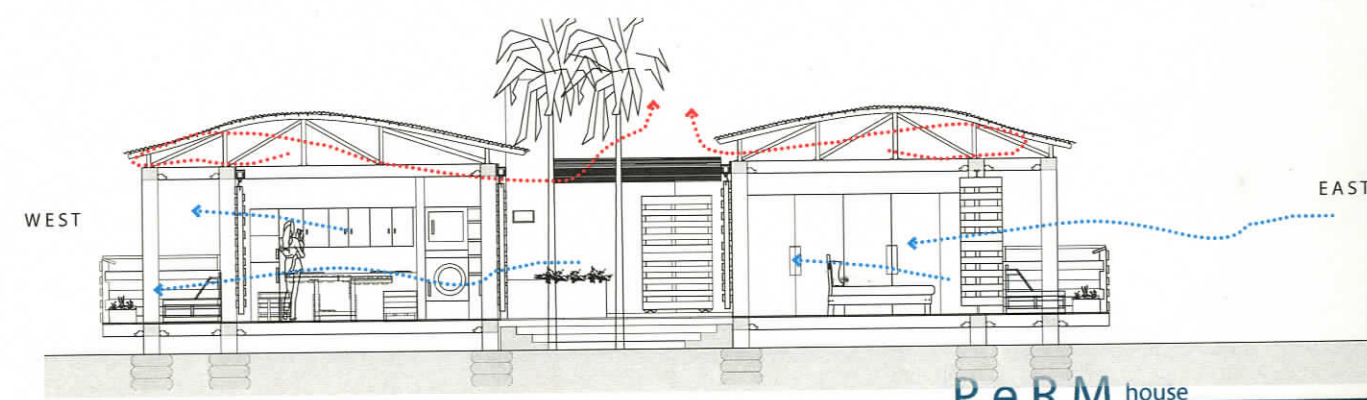
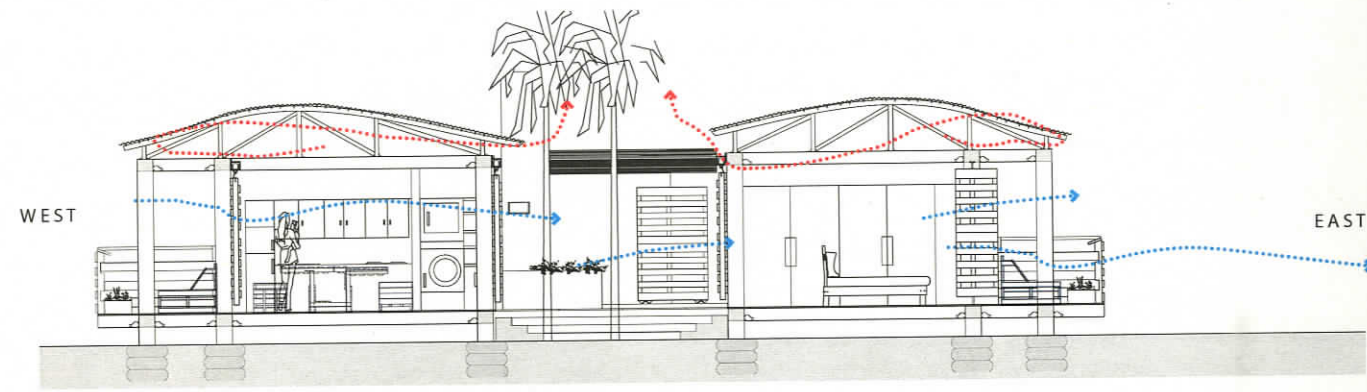
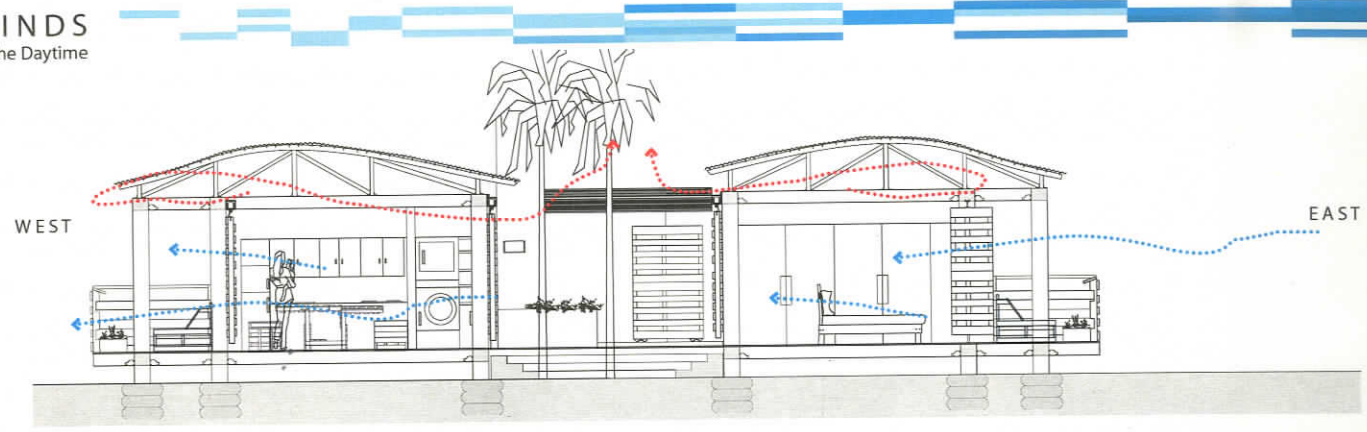
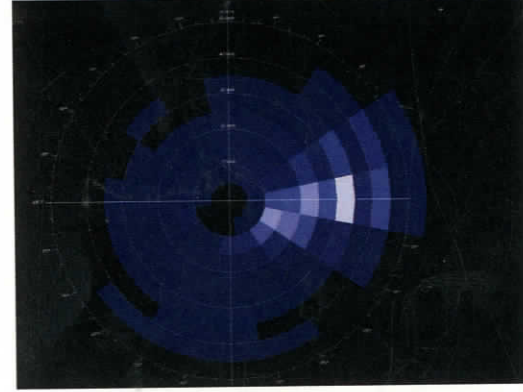
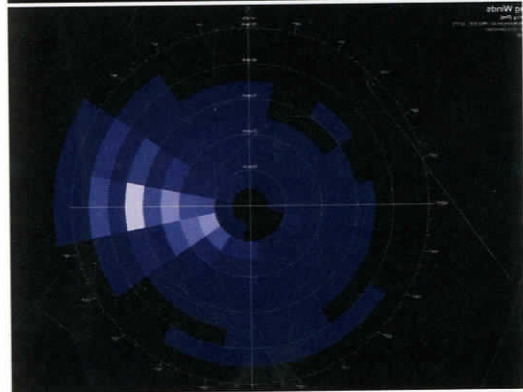
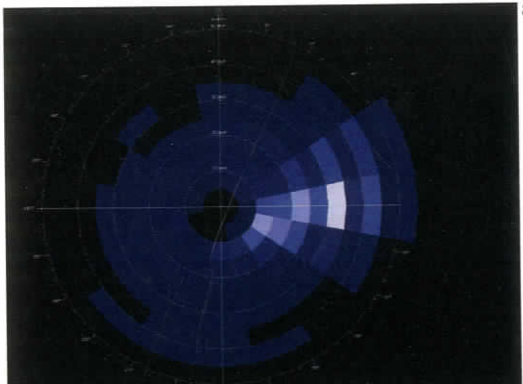


# DESIGN SCHEME REVOLUTION



# PREVAILING WINDS

Variations in the Daytime



# INVENTORY FOR PeRM HOUSE

Kit of Parts for the housing units



224 GMA wooden pallets [wall modules]



78 plywood 4'x8' panels [floor system]



72 discarded bus tires [foundations]



56 wooden utility poles [structure]



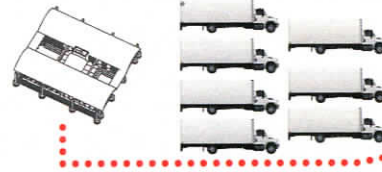
12 bowstring trusses [roof structure]



86 corrugated metal roof panels [roofing]

## GROUND TRANSPORTATION

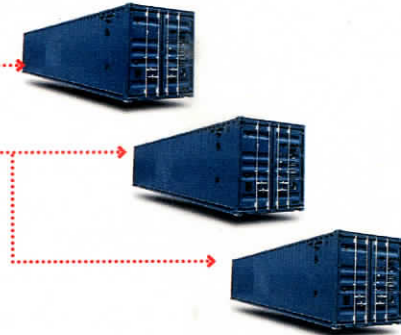
24' straight truck [best for reaching site]  
length 24'  
width 98"  
height 102"  
capacity 1,550 cu.ft.  
tare weight [empty truck] 10,000 lbs.



## EXPORTING OFF SHORE

shipping container [most common locally]  
length 40'  
width 8'  
height 8'6"  
capacity 2,385 cu.ft.  
tare weight [empty container] 8,380 lbs.  
maximum gross mass 66,139 lbs.  
net load 57,759 lbs.

Shipping possibilities of PeRM house for the Caribbean

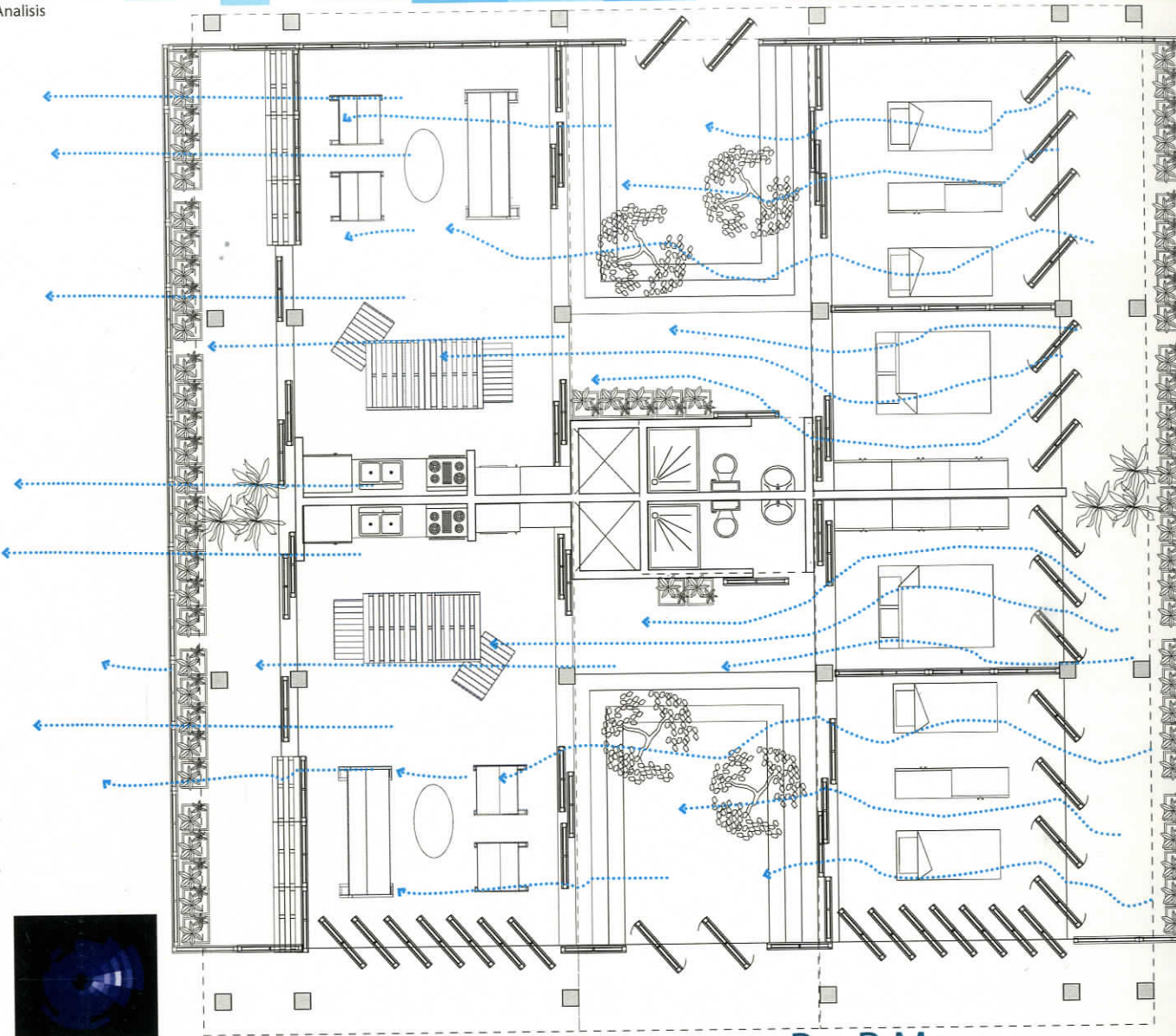
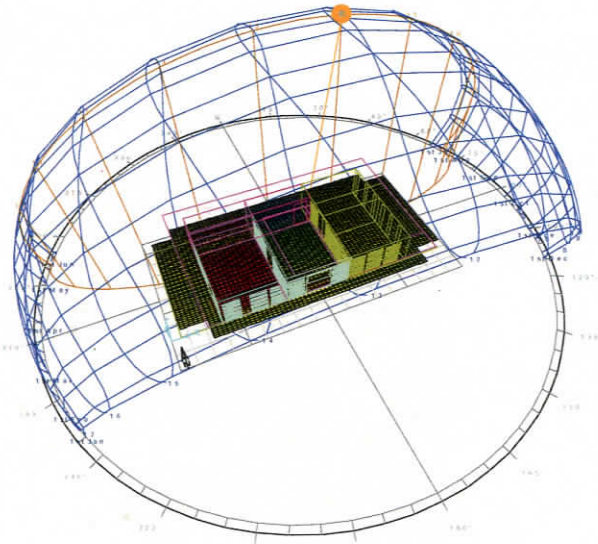
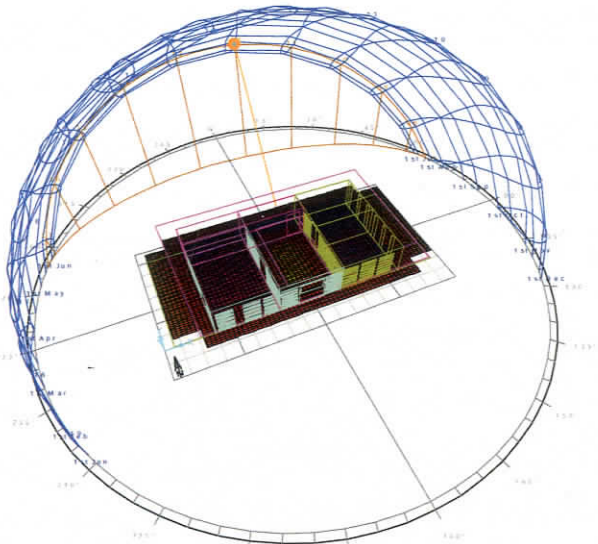


PeRM house



# PeRM HOUSE Design Scheme

Plan and Ecotect Analysis

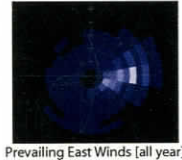
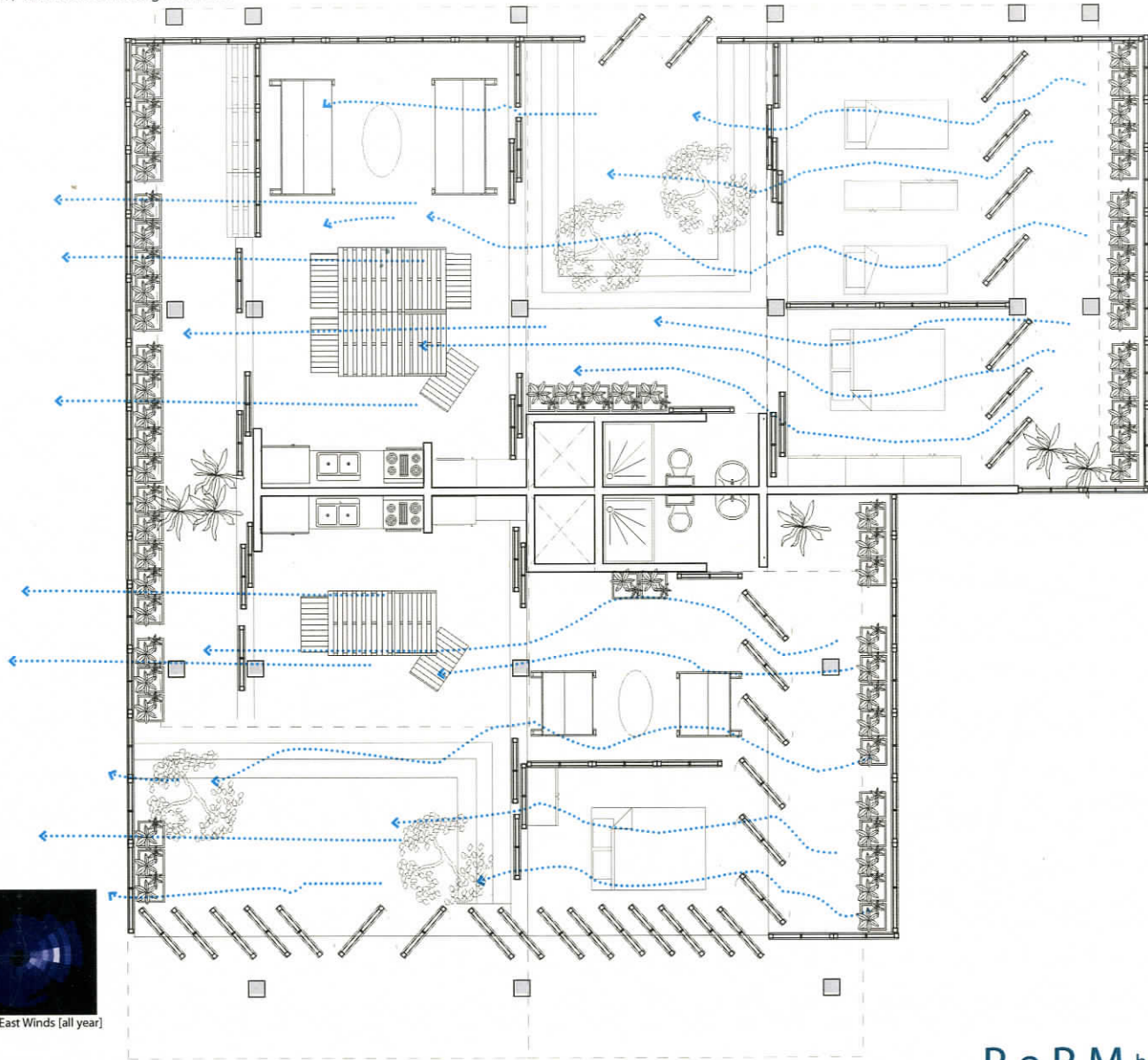


Prevailing East Winds [all year]

PeRM house

# PeRM HOUSE Design Scheme

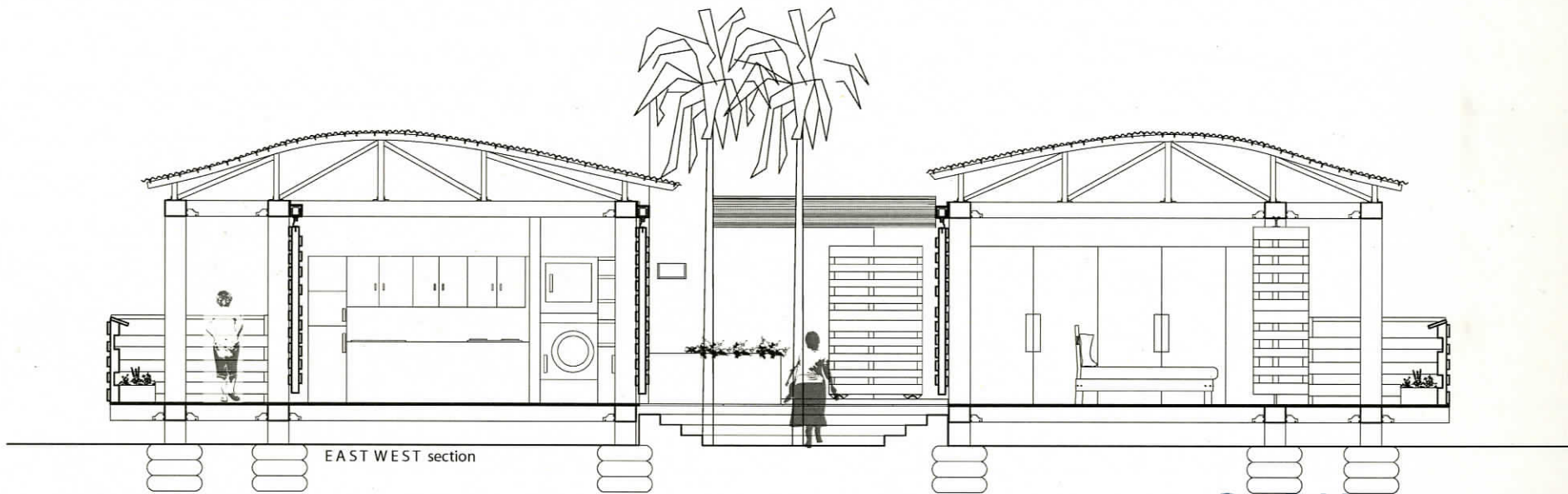
one bedroom / two bedroom design scheme



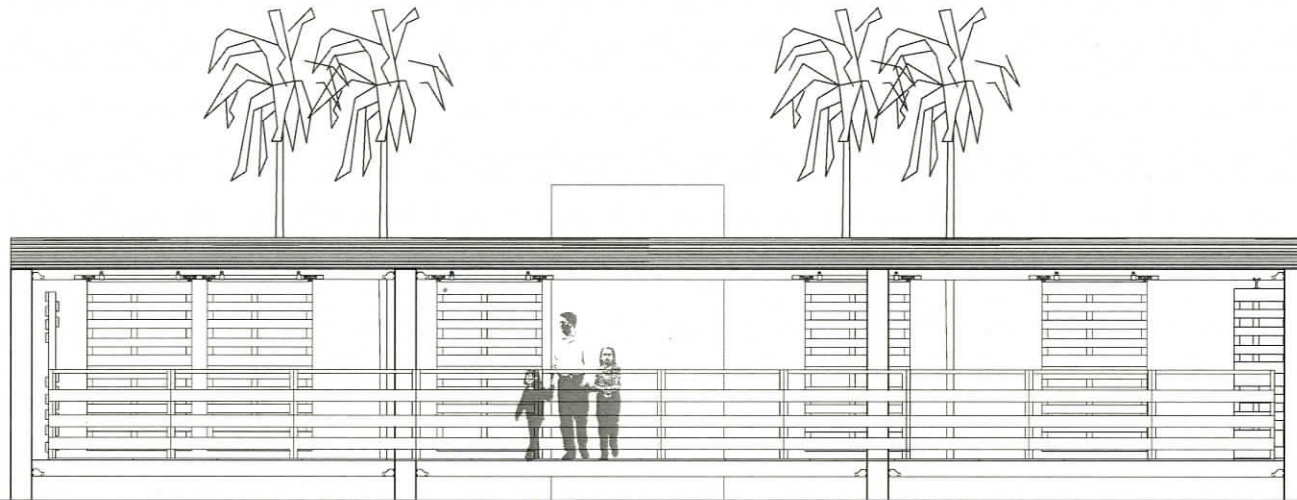
Prevailing East Winds [all year]

# PeRM HOUSE

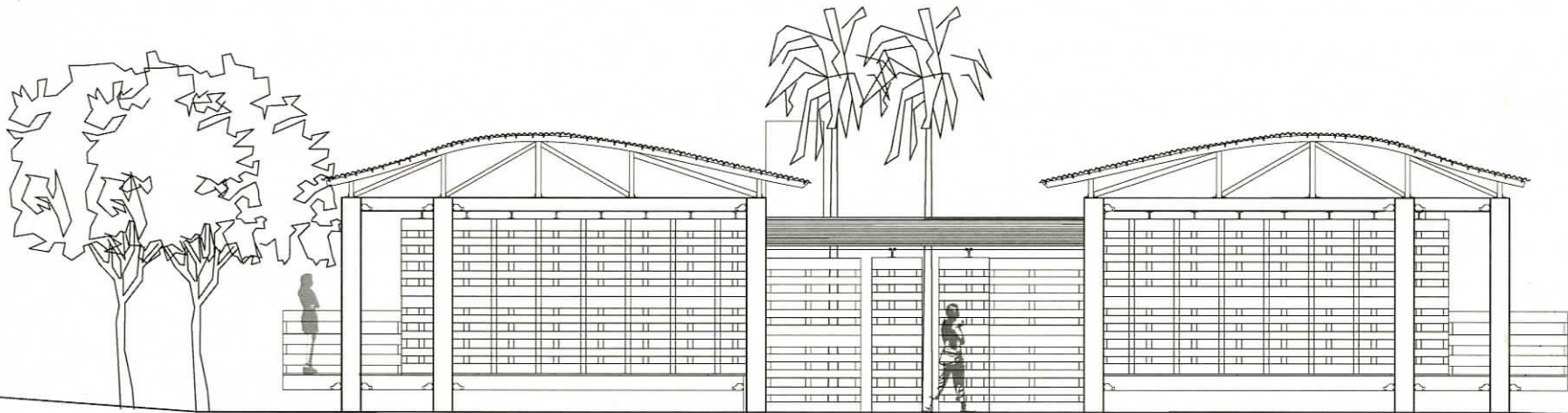
Sections



PeRM HOUSE  
Elevations

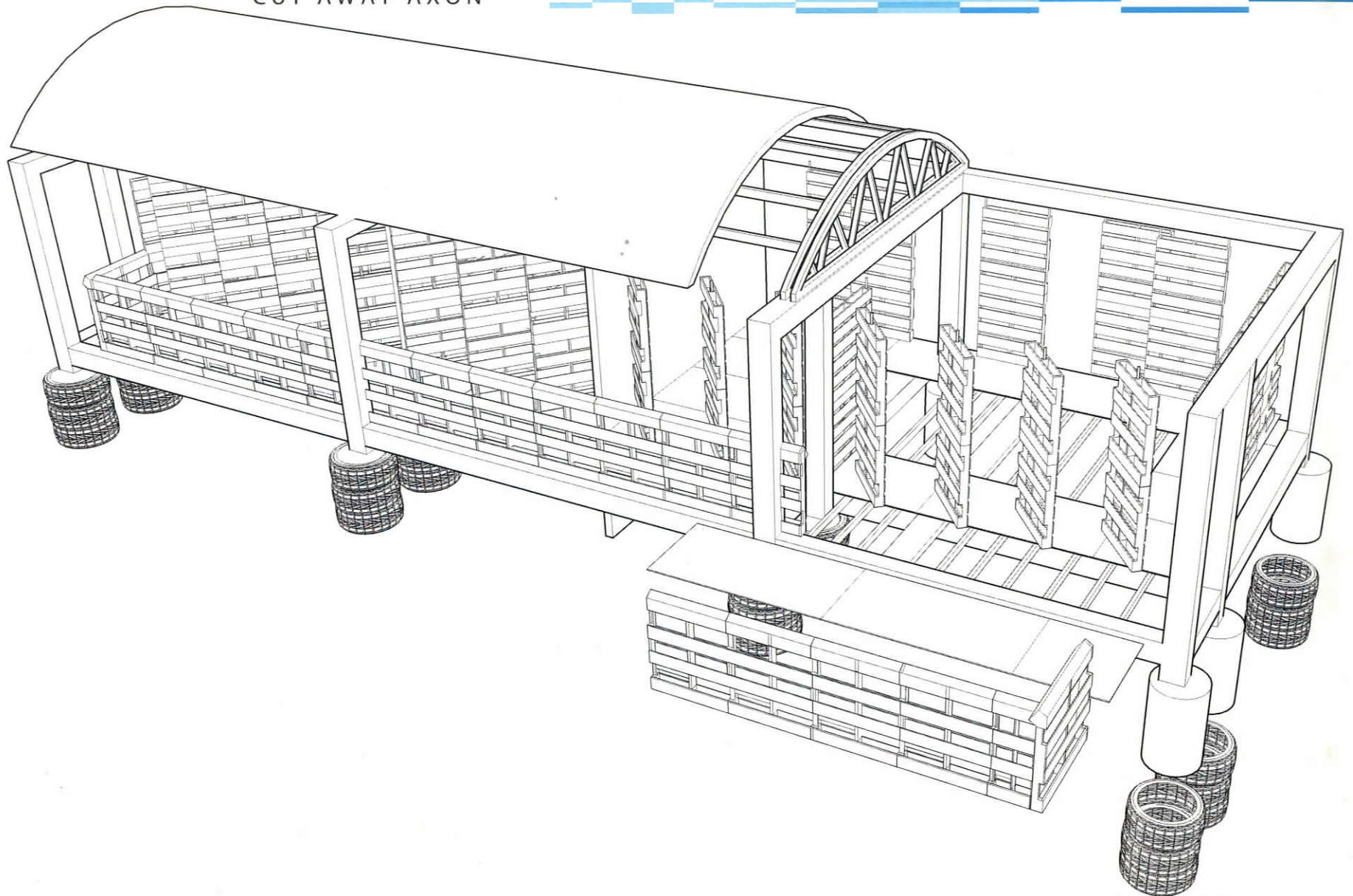


WEST Elevation



SOUTH Elevation

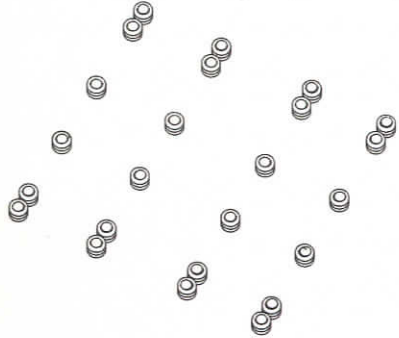
CUT AWAY AXON



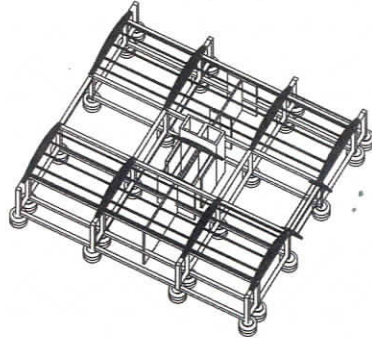
# ASSEMBLAGE AND DEPLOYMENT

Construction stages for PeRM house

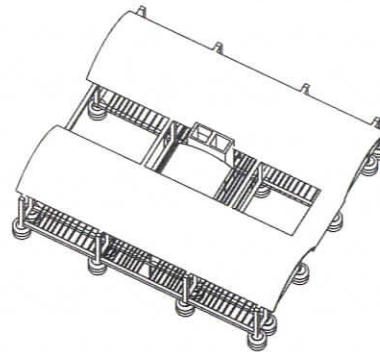
Construction stage 1.1 [foundations]



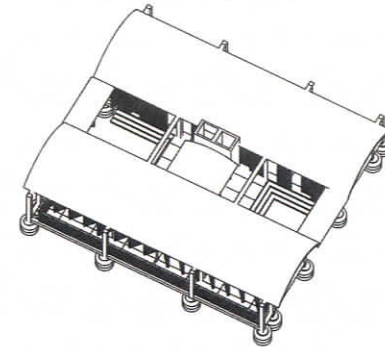
Construction stage 2.1 [roof structure]



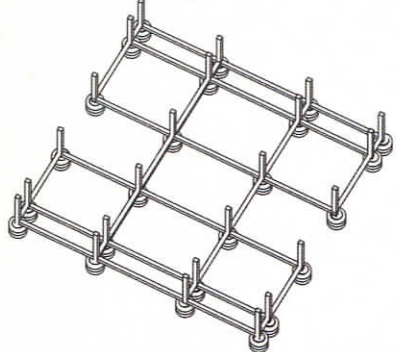
Construction stage 3.1 [floor sub-structure]



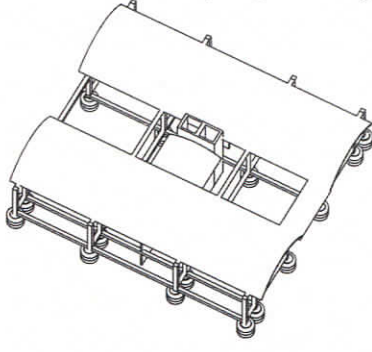
Construction stage 4.1 [pallet wall modules]



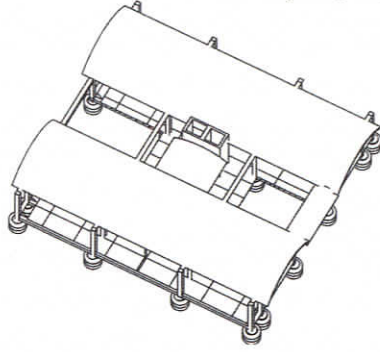
Construction stage 1.2 [columns & beams]



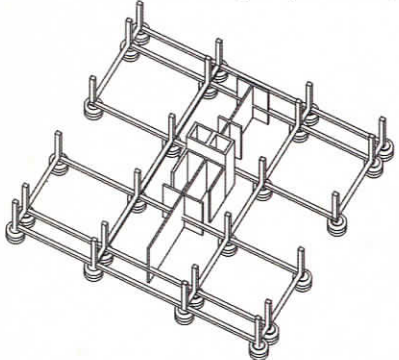
Construction stage 2.2 [roof cladding]



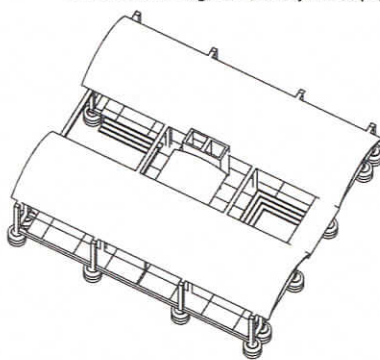
Construction stage 3.2 [floor]



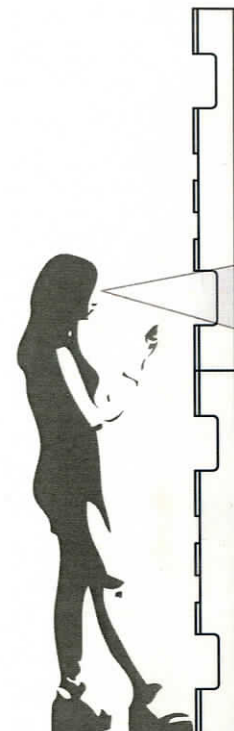
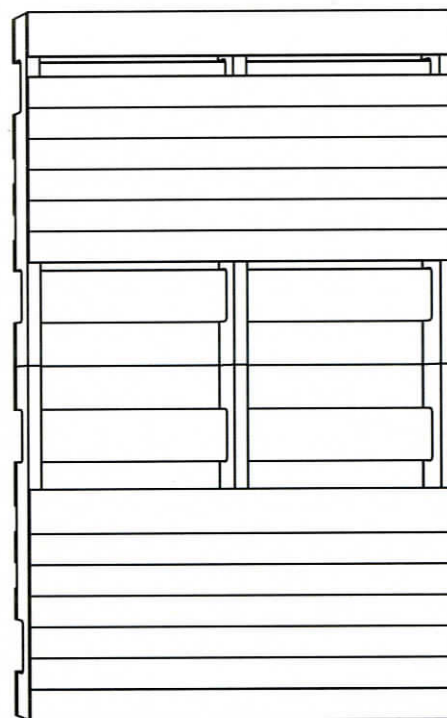
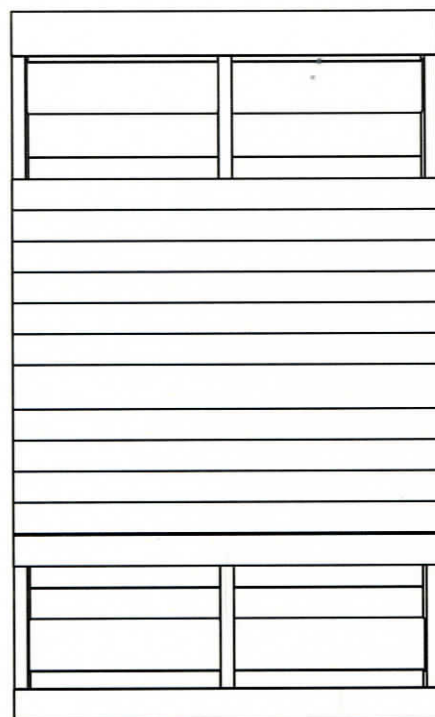
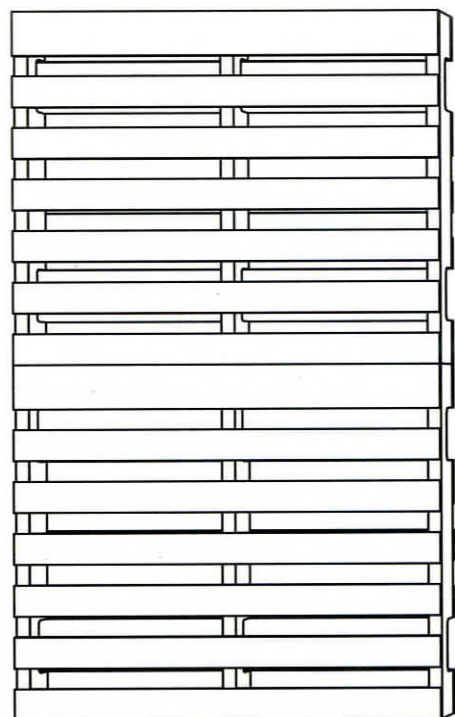
Construction stage 1.3 [service core]



Construction stage 3.3 [courtyard steps]

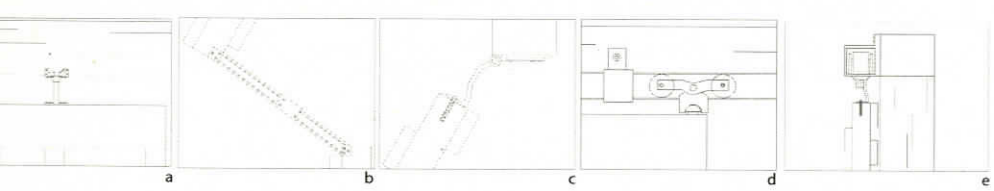
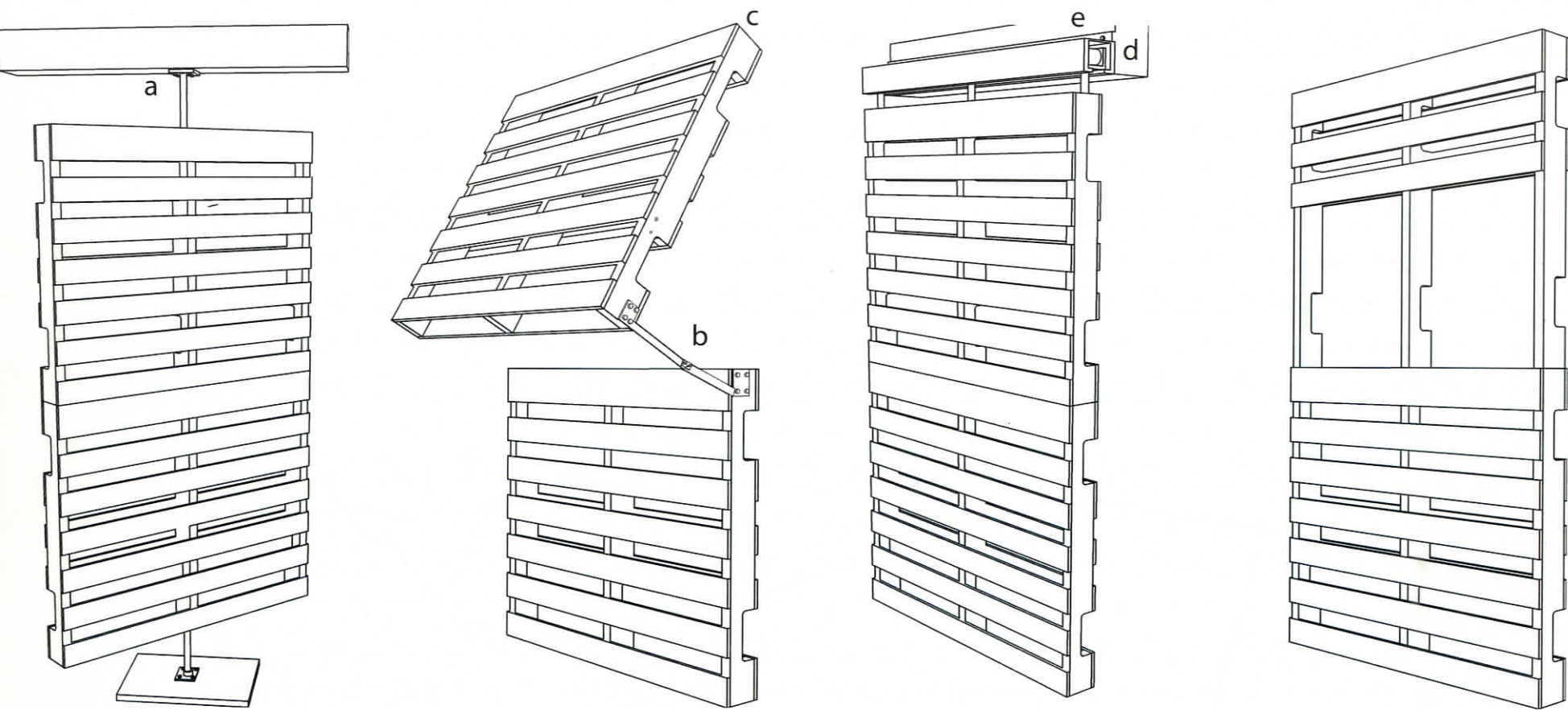


OPERABLE PRIVACY



# PALLET WALL MODULES

Operable and Flexible Facade Schemes





RECYCLING REALITY IN PUERTO RICO



Renderings by Jeffrey Schulte

PeRM house

PeRM HOUSE VIEWS



PeRM HOUSE VIEWS



Renderings by Jeffrey Schulte

PERFORMING FACADES



NORTH FACADE



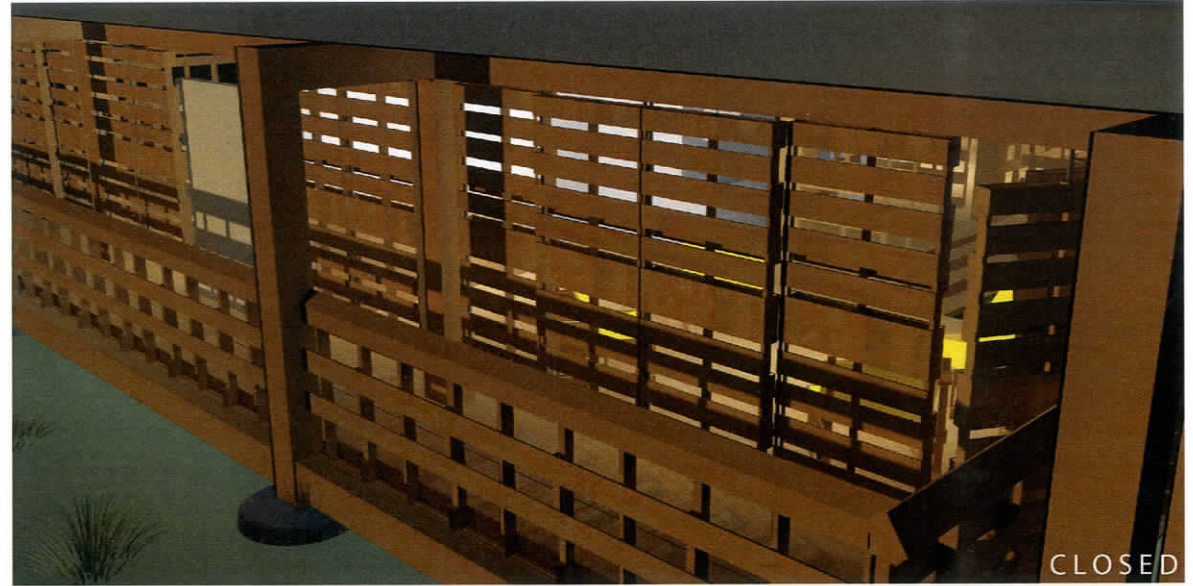
SOUTH FACADE



EAST FACADE



WEST FACADE



CLOSED



OPEN

PeRM HOUSE INDOOR VIEW



Renderings by Jeffrey Schulte

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