


FLEXIBLE SUSTAINABLE ARCHITECTURE

MAJOR CHALLENGES BETWEEN NORTH AND SOUTH

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ABSTRACT

What does man need for survival? First, basic human needs, such water and food then a shelter- the indoor created since the beginning of Humankind to protect humans from a harsh outside climate. Furthermore, since we spend most of our time indoors, that space needs to meet basic key comfort parameters, such as temperature, CO2 levels and relative humidity, keeping good daylight conditions.

The placement of buildings in different climatic regions, lead to different answers and different key comfort parameters, adaptations and implications and it is necessary to go back to basics in order to understand a design from its initial phases together with the importance of passive solutions when achieving an integrated holistic sustainable product.

One option is to consider a flexible approach like using shipping containers. A shipping container is, from its definition “a large metal box of a standard design and size used for the transport of goods by road, rail, sea, or air”. However, this thesis suggests it can be recycled into special solutions: to design temporary housing.

Flexible sustainable architecture is a challenge that can be reached by giving more having less, integrating solutions, focusing on bioclimatic approaches that adapt to different contexts, designing for shorter spans of time - temporary- without excluding the normal human tendency to be sedentary, allowing the house to become, in time, permanent.

This thesis concludes that one building solutions cannot meet habitable and sustainable parameters proposed if implemented from North to South rather, the design needs to be though and adapted from its initial phases to the place where it will belong.

RESUMO

O que é necessário à sobrevivência humana? Antes de mais, necessidades humanas básicas, tais como água e alimento e de seguida abrigo, o espaço interior criado desde os inícios da humanidade como forma dos humanos se protegerem contra um clima exterior duro. Além disso, uma vez que passamos a maioria do nosso tempo em ambientes fechados, o espaço tem de cumprir parâmetros de conforto básicos, tais como temperatura, níveis de CO2, e humidade relativa do ar, mantendo boas condições de luz natural.

A implementação de edifícios em diferentes regiões climáticas de Norte a Sul, leva a diferentes respostas, adaptações e implicações e é preciso voltar aos básicos de forma a compreender um *design* desde as duas fases iniciais, juntamente com a importância das soluções passivas quando se pretende alcançar um producto integro e holístico sustentável.

Uma opção é considerar uma abordagem flexível como a utilização de contentores de transporte. Um contentor é, de acordo com a sua definição, “ uma caixa de metal grande, de um tamanho e *design standard* utilizado no transporte de mercadorias por via rodoviária, ferroviária, marítima ou aérea. Não obstante, esta tese sugere que este pode ser reciclado para soluções especiais: projectos de habitação temporária.

Arquitectura flexível sustentável é um desafio que pode ser atingido ao dar mais tendo menos, pela integração de soluções com foco em abordagens bioclimáticas e propondo soluções adaptáveis a diferentes contextos, projectando para períodos mais pequenos - temporário -sem excluir a tendência

humana de ser sedentário, permitindo que a habitação se torne, com o tempo, permanente.
Esta tese conclui que o mesmo edifício e as mesmas soluções não podem atingir os parâmetros de sustentabilidade e habitabilidade propostos quando implementados de Norte a Sul , em vez disso, o design deve ser pensado e adaptado ao local onde pertencerá, desde as suas fases iniciais .

KEYWORDS: Shelter; Sustainability; Shipping Containers; flexibility; North and South, temporary

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ACRONYM

ASHRAE: American Society of Heating, Refrigeration and Air Conditioning Engineers
CLIO: Code of Liberalisation of Current Invisible Operations
CO2: Carbon Dioxide
EPS: Expanded Polystyrene
EWB: Engineers Without Borders
FEMA: Federal Emergency Management Agency
HVAC: heating, ventilation, and air conditioning
IAQ: Indoor air quality
IDP: Integrated Design Process
IED: Integrated Energy Design
LCA: Life cycle analysis
NGOs : Non-governmental organization
NHS: Non heated spaces
NIOSH: National Institute for Occupational Safety and Health
NV: Naturally ventilated
OECD: Organisation for Economic Co-operation and Development
PBL: Problem based learning
PCM: Phase-change Material
PEL: Permissible Exposure Limit
RC: Red Cross
RCCTE: Regulamento das Características de Comportamento Térmico dos Edifícios
RH: Relative Humidity
TEU: Twenty-foot equivalent unit
TWA: Time-weighted average
UN: United Nations
UNHCR: United Nations High Commissioner for Refugees
WCED: World Commission on Environment and Development

UNITS

Ft: Foot
Kg: Kilogram
Kr: Danish kroner
kWh/ma: kilowatt hours per square meter per annum
m: Meter
Mg/m3: Milligrams per cubic meter
ºC : degree Celsius
Ppm: Parts per mil

INTRODUCTION

INTRODUCTION

SCOPE, DIRECTIONS AND OBJECTIVES:

CLIMATE AND EXTREME EVENTS: *"The single most pressing global issue of the current era is climate change. Politicians and policy makers may argue otherwise, but it must be clear that without addressing climate change all other issues become irrelevant. Poverty, disease, war and economy are not without consequence, but must be viewed through the less of climate change."* (Douglass, 2008) For most of us, the massive poverty that exists in the developing countries and consequently the everyday news that reaches us, concerning people that lost their home, is a far distant reality. However, basic needs are transcendent to humans everywhere and no matter where one is. What happens when the problem of losing our home strikes "richer" more developed countries (North) or the namely "developed world" (South)? Disasters and extreme events – natural or not- can occur everywhere. Don't we all human beings, as equals, need a place to stay: A Temporary solution?

TAKING ACTION: Over the last 100 years up until now, there have been increases on the number of disasters and responses given by experts from so many different fields- mostly architects-. This boost explains the need for temporary housing that has been recognised by so many: example such as the world known Pritzker winner Japanese architect Shigeru Ban can be referred. Nowadays, more and more professionals are being convinced to start acting as well. A need for shelter and for it to need to be sustainable is on today's agenda. Those two are indispensable due to the never stopping world, its changes and constraints. This need for a shelter could be more critical if in specific situations like refugees and natural disaster victims.

When looking for a solution, shouldn't it be a comfortable space that would work temporarily and allow to become permanent also? Shouldn't those housing units be answering today's sustainable needs - Economically, Socially and Environmentally, while respecting Aesthetic development - through architectural value and human scale? Can sustainable architecture be flexible? Moreover, can a design flexibility result in a sustainable product?

DIMENSION OF THE PROBLEM:

- "*The UN High Commissioner for Refugees estimates that there are 9 200 000 refugees in the world in 2004"* (UNHCR United Nations High Commissioner for Refugees, 2005); "*3 300 000 000 people are without proper sanitation facilities"* (Zehnder, Yang, & Schertenleib, 2003) ; *"More than 2 200 000 people die from preventable water and sanitation – related diseases each year".* (United Nations Human Settlements Program, 2003) Providing a shelter integrated with basic needs- such as proper sanitation and clean water- is essential for human sustainable development, and it concerns supplying the minimal necessary for survival;

- *"47% of the World refugees are female are children".* (under 18) (UNHCR United Nations High Commissioner for Refugees, 2004) This *place* to be built, this unit, this house will most definitely shape people –and mostly youth and younger ones- to the person they will become one day. The shelter is required to represent and be a safe place where nothing bad can happen and where its inhabitants are able to dream and feel vulnerable;

- *“200 000 000 people have been affected by natural disasters and hazards in the last decade”.* (Ahmed et al., 2011) Nature is uncontrollable and life can change drastically from one moment to another. Nature and change strikes everywhere and everyone, it is not influenced by colour, age or social status.

- “*In 2003 there were 38 different protracted conflicts in the world, accounting for some 6 230 000 refugees”.* (UNHCR United Nations High Commissioner for Refugees, 2004) Not everything referred as disasters, mean natural causes. War, cultural or religious differences and other problems such as poverty (figure 0.1) , might be the starting point for refugee situations.

- *“The average duration of major refugee situations has increased from 9 years (1993) to 17 years (2003)”.* (UNHCR United Nations High Commissioner for Refugees, 2004) The housing unit needs to be able to be flexible to life unpredictable situations. At the same time that it is temporary yet durable, it leaves space to become permanent.

More recently and with the dramatic Syrian situation (2014) some more updated values say that: *“50 million people in the world today have been forcefully displaced from their home — a level not seen since WWII.”; "Syrians are just looking for a quiet place where nobody hurts you, where nobody humiliates you, and where nobody kills you." Well, I think that should be the minimum..”; “You might imagine that being a refugee is just a temporary state. Well far from it. With wars going on and on, the average time a refugee will spend in exile is 17 years.”* Melissa Fleming, UN’s High Commissioner for Refugees, TED talks 2014

For the past years up until now -and increasing over time- due to personal or cultural issues or to the occurrence of natural disasters, the need for temporary houses has exploded. With an increase of the complexity on the interplay between individual circumstances and outside factors- out of a person’s direct control – one’s need for shelter is a primary need. The project focuses on human basic needs. A good quality design is not a luxury or extravagance, but a need. For everyone and everywhere.

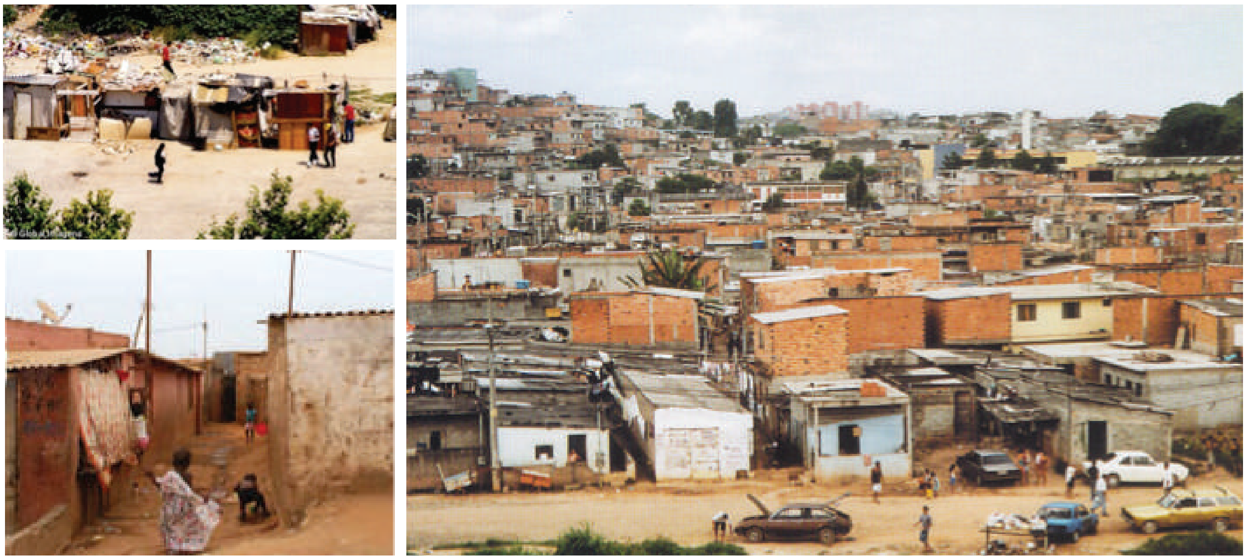


Figure 0.1- Solutions for housing units are urgent for thousands of people around the World. (Left, above) Casal Ventoso, Lisbon – bad neighbourhood and drugs (Left, bellow) Luanda’s Musseque and children in the street (Right) Brasilian’s “favela”, the end can not be seen. (Source: http://www.acorianooriental.pt/noticia/primeiros-realojamentos-terminaram-ha-15-anos; (Guedes, 2011a); http://www.taringa.net/posts/imagenes/2717064/Fotos-de-las-Favelas-de Brasil.html)

The need for temporary houses for a longer period of time may result in permanent housing, because of problems as mentioned above and the fact that problems can easily build up on other issues over the years. There is a need for transitional housing, for shorter or longer spans of time. Additionally, there is a need for alternative solutions from traditional shelters - the typical tent solution- that can transform temporary living conditions into permanent homes. A building that can grow naturally, logically and poetically out of all its conditions, because of its flexibility and modularity. It is crucial to answer those living in a constant state of emergency, as they live in precarious conditions, not habitable places not worth the name home.

UNDERSTANDING THE ROLE OF FLEXIBILITY ON MY EDUCATION: To overcome a need to be flexible and adapt to change, it is my belief that architecture should redraw inspiration from history. It brings examples to our days: portable and movable, transformable and light solutions, easily erected shelters and buildings that are built according to their context examples to understand and study the human's most basic needs. Inspired by these words: **"***It is the obligation of architects to provide dignified housing for the poorest communities, yet few architects have shown an interest in making such building the heart of their practice. Ethically it is appalling that architects remain uninterested in and out of touch with building for the most vulnerable and impoverished people. Entire countries, entire populations live precariously, day-to-day, in a perpetual state of emergency. We must find ways to house people. […] We have the skills and expertise to do this. We should not forget that the foundation of our metier is to provide all people with a decent place to live. […] "On the world architects tend to work on prototypes completely dissociated from technical and economic realities. Can an architect coming out of one of the world's excellent architecture schools create a good shelter on that budget (250 dollars)? Will it be decent, culturally appropriate, durable and safe? Will it be aesthetically pleasing, environmentally responsible and ethically made?"* (Ahmed et al., 2011) I believe that within my architectural experience and education received, I can try to be helpful by developing a design for temporary housing units. This idea can open windows towards helping people without a home.

Flexible sustainable architecture is a challenge. How can it be achieved? By giving more having less, integrating solutions focusing on bioclimatic approaches and proposing solutions that adapt to different contexts. Furthermore, designing for shorter spans of time - temporary- without excluding the normal human tendency to be sedentary, allowing the house to become, in time, permanent adapting and as an organism, to grow as you go.

OBJECTIVES The main goal of the project is to design temporary basic housing units, with point of departure on ordinary shipping containers -chosen for their price, mobility, logistics, durability, stackable features, etc- as a skeleton or structure. Those basic units would be adaptable "everywhere" and used by "everyone" around the globe. This unit represents a survival kit because it focuses on the human most basic needs- sleeping, eating and sanitation.

The project studies how realistic the slogan *"Think globally, act locally"* actually is.

This temporary housing is designed for people who need a home for shorter spans of time - temporary-without excluding the normal human tendency and prevalence of sedentarism in today world's population, allowing the house to become, in time, permanent. That means the comfort and human basic needs are focal parameters when designing temporary houses, still open for improvements and upgrades– following the idea "add as you grow"- meaning: not excluding human evolution and growth.

"Although it is necessary to be able to respond to an emergency with speed, short-term emergency shelter is not necessarily the best response. […] By this I mean rebuilding in a matter that is quick, durable and permanent" (Ahmed et al., 2011) This thesis will also try to reflect upon questions such as :

“Is nomadic life the new sedentary solution? What can I learn from nomads and their lifestyle? How much of what people have is actually essential and how much is superfluous?” It is necessary to go back to basics.

With these questions expressed above – and others- in mind, the intention is to try to provide an architectural fast response not to solve but improve the need for temporary solutions. The proposal concerns the study of comfortable spaces satisfying the basic need for the ordinary human. Nevertheless, those needs ought to be studied in more than one context to verify how much the design would stand as flexible and still sustainable. Does it make sense to, as some people might do, focus on the environmental side of being and living in a sustainable way? Working with major fields within sustainability, the work developed is more than a final solution, but a reflection. Social- through the work with modular flexibility that intends to accommodate different people, backgrounds and social levels; Economic- offering options for a design that allows the customer to build in less time and with less money a wallet -friendly project; last Environmental- through the study of the sun and its sustainable features, but still aesthetically sustainable when it seeks quality daylight and the sun as the potential lead role in design,

CONCLUDING- OBJECTIVES: Promoting the dignity in housing for any human being; Return the happiness and sense of belonging to those who are going through emergency situations ; Prove that, in my case, the core of our profession is being able to change the lives the most needy; DESIGN STRATEGY: Simple and fast to built; Use pre-fabricated materials combined with materials that can be found in the area to ensure a better performance from the shelter; Create a safe and comfortable home with an affordable cost; Recognize people’s sense of home and identity; Explore the concept of flexibility as a response to multiple needs of a temporary housing; Work with climates and reflect upon their influence in the design

MOTIVATIONS:

Now was the moment to decide the theme to work with. In my opinion, it should relate to me on a personal and professional level, to where I see architectural value at and be one of the fields I could possibly be working with in the future- realistic and human. This could be the chance to use the work developed along my five years of education and to have my stamp as an architectural student, working with real problems of real people, bringing together what I was given when I got my education, giving something back to the community, useful I hope. As soon-to-be architect and reflecting on what to study, I would like my work to reflect upon humanitarian causes. Architecture is not only a matter about building for those that can afford it and closing eyes to any economic concerns, but also, to the ones in need, the silenced voices needing help. What happens when we are all lead to the same situation and focus on basic human needs, when architecture unifies worlds and contexts and it does not create a bigger barrier than the existing gap?

“Flexible Sustainable Architecture – Major analysis of Challenges North versus South” is an attempt to reflect on my previous education on sustainability and work in pursuance of a better understanding of the energy demands on today’s world: Do more with less, and “less is more”. *“In the future we must do much, much more with much, much less. The lessons in this book move us well toward that important goal.”* (Bell et al., 2008) My motivation relies on reflecting upon the role of the architect as designer for

the masses- for the ones that need and the ones that want-, the importance of small parts within a design- decisions that influence a whole. Academically, the opportunity to work with something so different from other projects, where the reflection is not only needed but also essential is a motivation point. Furthermore the motivation comes from: having the chance to consider user groups that are so real and problems that are constant – preparing in a way to go from the academic world to the real life "outside" the school's walls and finally developing skills doing research on unknown fields.

Have architects forgotten they role as professionals? When has money gotten such a big influence on a project as decision maker, that architects don't use their education for making good for those in need, but only for those with means? Have we forgotten our civic duty to help building shelters, homes, places to dwell for everyone without looking at social strata or economic power? Can we design a place that protects from the harsh environment that is meant for everyone? Human Basic needs are the focal point from where the rest of the decisions are taking departure from: understanding the role of the architect one step further in the dream of making some tiny small change in the world.

Lastly, the thesis reflects on how big is a small change. How much does the window size influence daylight, reflects upon an increase on solar gains, and consequently need for cooling? In addition, "if and when" considering openings, do they compromise the structure and for that reason weaken the concept behind the project? How much of architecture works interdisciplinary and how crucial is working within different fields from early phases of a project?

THE IDEA AND CONCEPT: WORKING WITH SHIPPING CONTAINERS

THE CONCEPT is to think outside the box, within it, globally, acting locally. The concept takes its point of departure on the contrast between tactility and architectural expression of a restricted limited box - as a safe and strong element that enclosures - and the warm textile- the tent-, capable of wrapping around and dwell.

The proposal concerns the study of a "*Conscious Architecture that can be exported to any place in the world".* (Argency, 2012) Besides architecture, a sustainable product. There has been an increase on successful examples and case studies that allow us to understand how sustainability is not equal to lack of aesthetic values and where architecture can be thought 'out of the box', within it. What is this box? A common shipping container – for its price, mobility, logistics, durability, stackable features-, a closed box that will be opened to accommodate various different new realities and needs. The project's main focus is flexible sustainability working with the potentiality of the modular architecture from shipping containers, as a skeleton and structure, adjustable in the most varied contexts.

Due to the fact that at school students are taught how to conceive and erect architecture from one place and architecture that needs to be placed in that specific country or site, the project works with the sense of place in a reflective way. Once it is known that the design needs to adapt to a place, be part of it and the site part of the design, this unit is a box that can be implemented everywhere. It adapts to people's needs -once its interior is flexible- and to climatic changes -when its outside is designed and changes according to the needs and qualities- geographical, phenomenological, energetic, etc. - or the place where it is implemented. This project is focusing most in passive solutions being important because it relates to the built itself.

Even though the active solutions not are a part of the design there will be some active solutions suggestions or comments given in a more general elementary way. So after designing the temporary home the people who have money can add solar cell by themselves, and try to make the building also relate the design of the roof with a structure that can collect water, etc. Furthermore, the project is not trying to follow any energetic local standards but try to reflect on the existing and its influence on the design sustainable footprint. Due to the fact that waste and drinking water are such a big fields, they could not be included on the reflection. However, there is still awareness about the subject and this project would mostly rely on technologies other people have developed -such as some organizations referred before and firms. The focus is to give its users a good comfort level.

Nomadic lives, or more precisely nomads, are a good example of economy of space, lightness of materials and efficiency in solutions. So, if after focusing on the human basic needs, everything else is left behind, a design and a dwelling are left with three basic things: a place to eat, a place to sleep and a place to go to the toilet. Taking the point of departure in the idea that those three spaces or areas should be included in the plan of the dwelling to be created, the temporary home can then be a space where those basic needs are provided. These temporary houses will provide shelter and an answer for instant needs, while still allowing some freedom and openness to be adaptable, changed and improved. Like a shelter, the temporary house is "equipped" with a survival kit, then it can grow as parts, and other elements are added to its initial shape and purpose.

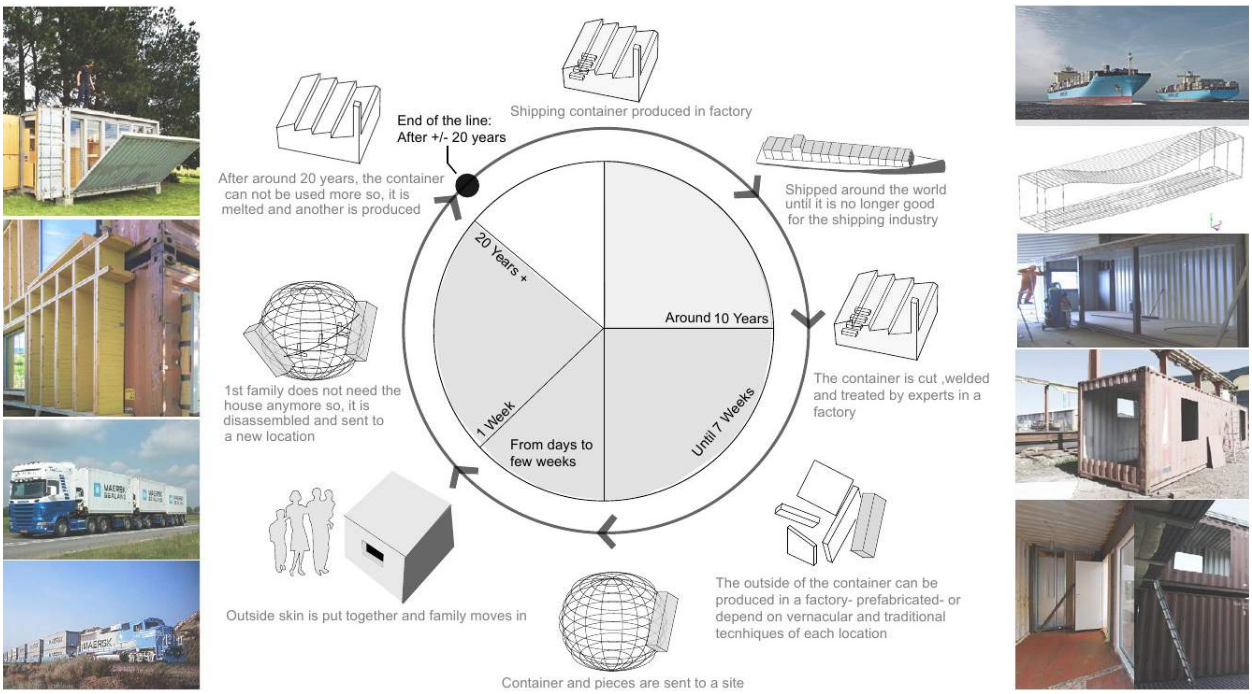


Figure 0.2- The conceptual idea- working logistics. From shipping container to temporary housing units (Source: (Middle) Mafalda Melo Oliveira, 2014)

"Human beings are flexible creatures. We move about at will, manipulate objects and operate in a wide range of environments" (Kronenburg, 2007). Figure 0.2- The conceptual idea: Containers-when their lifetime finishes- end up on being abandoned somewhere, or most times just melted. Their useful time as cargo elements is usually 10 years, if there are not bad formations, too much rust or something that compromises the structure and therefore, its purpose. When the container is no longer good for shipping- due to heavy regulations that allow to use them for around those 10 years (Information by Maersk correspondent, Ib Vind-Hansen, by phone) , they are melted. Additionally, since the energy used in this

operation is so high- 3,629 kg of steel, which takes 8,000 kWh (28,800 MJ) of energy to melt down- it makes sense to consider the option of the “3 R’s”: recycling / reusing / reducing. After that 10 year period, the container would be sold or offered and sent into the factory, where the inside layout, cuts , window instalation and tasks depending on specific expertise would be hold. After this, the container could be sent to a specific location and the outside and extra elements would be added and adapted according to the specificities of the climate. This stage would rely on materials from the area and known construction techniques. After, a family could move in and when that house was not needed for that same user any longer, its second skin added on site would be taken out- disassembled. At that point, the house would be ready to either be sent to another location, to closest factory- if there was damaged-, stay in the same place and be used on a different situation or for last and in the worse case scenario, it would finish its useful life –when too damaged to be used as living structure.

Basic/ primary human needs -like eating or sleeping- or the ones defined as important for a place to be comfortable- bathroom-, will be the main design parameters and point of departure for the layout of the modules. This means that the core of the module, the inside, is set and finished before it is implemented in a specific location. The intention is to create a new structure that can survive independently from other structures or installations on the surroundings, by including what is needed in a daily basis. The analysis of the site and the area surrounding gives an overview, for example, on materials available in an attempt to use the resources of the site where the building is located.

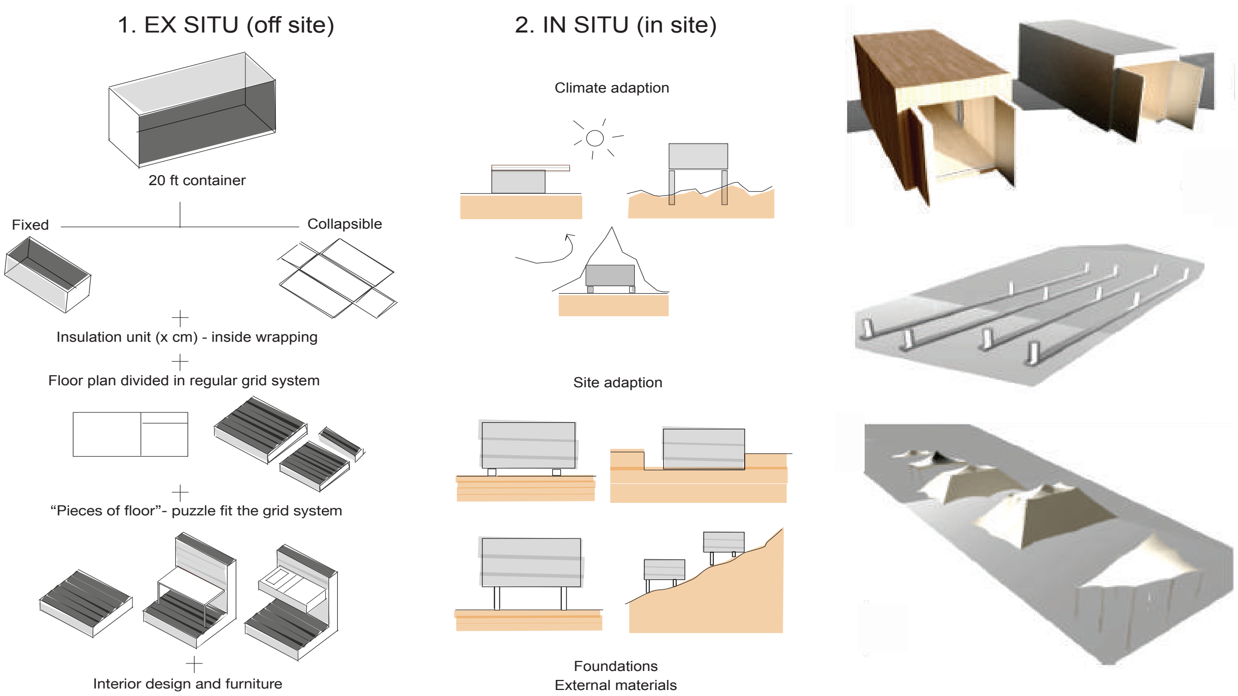


Figure 0.3- (Left) The project phases and division between works off site and in site ; (Right) Step by step - The three elements of the project: Container and second skin, poles and tent or textile (Source: Mafalda Melo Oliveira, 2014)

The process divides between in and ex situ. Inside core of the container -> fixed and designed before site- ex situ ; Outside skin and extra elements -> designed according to site – in situ. (Figure 0.3 , left): Off site, the container is given or bought: a standard High Cube 20ft container. (see annex 1 for specifications) In order to be able to answer very fast calls and go inside of a plane, and even though the solution was designed for a fixed box, openable container solutions can also be considered. This

compatibility between openable or fixed containers happens due to the fact that standards mean “same measures” – for the same standard, same floor area, same volume- and for that reason it makes it possible to “fit” the same elements in one and the other when needed. After, an insulation unit is added inside and wraps this cold box converting it into a warmer, cosier place to be at; the floor is divided into a grid, boards together with furniture work as “puzzle pieces” and are fit into that grid and the rest of the interior design takes place. After, the container is moved to the site and foundations, external materials (second skin) and everything that relates to the climate variation of the box and its modified form an orthogonal limited shape, happen. The climates and the different contexts represent more than specific countries or locations, but features : more precipitation or less, sunny or cloudy area, existence of snow or rain, wind direction and speed, etc. (think globally , act locally – refers to thinking about climates in general and what they represent , acting upon their specific features or elements that define them)
STEP BY STEP (Figure 0.3, Right) The three elements always present : container ; poles - for the roof structure that can from a tent to a more complex design and more expensive materials ; a tent – that can be used for the roof, for extra protection or other. Then the design can adopt different solutions: STEP 1: Shipping container + insulation inside + poles+ tent . The container is wrapped inside with insulation and plywood giving it a completely different expression from the one existing before. Together with this container with inside insulation, some poles and a tent are provided – to work as roof or extra external skin. The tent is the basic way of protecting the container from direct solar radiation- by placing it around the container supported on the poles ,but it is not a preferable solution because it is not durable and breaks too easily and because if there is air moving between the container and the tent, then it will overheat; STEP 2: Step 1 + prefabricated solutions. In this case, the money spent is a higher amount; the container is protected against the harsh outside environment with an quite cheap solution – prefabricated wooden panels that due to this standardisation, can be cheap, modular and mass produced. This outside wall is called “second skin”. It includes shading and cladding; STEP 3: Step 1 + customized resource. If the container is supposed to be adaptable to different climates, then, the last solution is the one that considers those changes and the needs in each climate and requires more money to be built and time to be erected. The second skin in those cases can go from wood – from the specific country or surroundings – to other less traditional materials such as textile. It relies on traditional and local techniques and available materials -Adobe, brick, *terra cota*, etc.

The idea behind the design is to keep everything as cheap, as fast, as simple as possible. By not adding too many things in the container and keeping it quite orthogonal, limited and restricted, the contrast with the organic element that is the tent will be even greater and the cost will be considerably lower. The poles are available for each temporary house sent in five beams. Every beam has 3 poles that can be used to push and pull the tent or another textile to put it to place and later those beams can also be used to upgrade the temporary tent roof to a permanent metal sheet curved roof, or another. No matter which one is the point of departure: if the container without any materials outside or the container that has been added a second skin, the poles and tent are always included in “unit package”.

METHODOLOGY AND STRUCTURE OF THE THESIS:

GENERALLY: The thesis was divided in 2 phases: first the research on containers, sustainability and solutions, along the sketching and calculation phases. Secondly, calculations and simulations were made and the design was developed. For the current thesis, both phases were essential. Initially, the thesis started slowly with some sporadic meetings with the engineer Manuel Pinheiro at IST together with some support from a former teacher and energy engineer Claus Topp from Aalborg University.

LITERATURE: The research on PHD thesis and books on sustainability took place mostly in Denmark, through Aalborg University Library and those same books were used at a later stage as digital resources, online special purchases or borrowed in libraries and the University. Wiley and Science direct were the main search motors in order to gather as much scientific information as possible- mainly for the chapter 1 and 2.

SOFTWARE: In terms of software used: Bsim – not so commonly used in Lisbon- was the key software to test and run simulations in the different solutions. Be10 was used initially but once it applies mostly to Danish context, soon it showed not to be the most suitable for this work. Daylight analysis, simulations and information were reached using Daylight Velux Visualizer. Ecotec was important once it was used to verify some questions such as run solar optimization or to gather information that would allow easier and more direct comparison between different contexts: such as psychometric graph , wind direction or speed roses , temperature, humidy, etc. Excel was the software used to document the results achieved on the simulations hold on Bsim. In Excel there also some basic calculations such as the need for ventilation and construction resistance. Some online software or estimators – such as time and price estimator for shipping container trade; RS Means for container solution price and scheduling- were key elements when gathering information and reaching results in this thesis.

STEP BY STEP: In order to answer some questions and due to the fact that emergency and temporary solutions are usually hand in hand with organizations and humanitarian causes, the first step was to contact some NGO's. First and before everything, collaboration with Engineers Without Borders Denmark- an humanitarian aid organization- was established. This helped getting an open and knowledgeable view upon the initial ideas and the concept for the project, moreover, this "partnership" with EWB, allowed direct contact with an entity that could give an insight on what happens on the site and in reality and what is needed when dealing with disaster areas. Along the design process, working with Engineers Without Borders was very useful in order to show what thoughts and concerns should be incorporated within the result as design parameters and this work resulted in the achievement of a more realistic and developmental solution. It was also establish some contact with Red Cross, United Nations, UNHCR and others, but those were secondary. Those represented less of a collaboration and more of an "advices and questions answered" kind of contact.

Just after that and knowing that the theme was valid and it had good grounds, it was necessary and imperative to investigate upon existing literature and built examples, together with analysing them and selecting the important aspects to be taken care of in the thesis. In the beginning, the research was mostly about container, container structures, case studies using shipping containers for housing or other -and positive and negative aspects within those- and went through the revision of all the concepts within sustainability in order to build a solid base to justify the choice made on the use of this very specific structure. For this phase, the communication with companies such as Maersk and Titan – both Danish shipping companies- was essential. Knowledge about the industry, the products- the containers- and others, helped build a stronger point of departure for the presentation and sketching phase. Additionally, during a second research big phase, all the analysis and research in minimalist architecture, flexible structures, movable, modular, prefabricated and portable solutions were also crucial. All the extensive research, as noted above, was depending on not only books from Aalborg University Library or other physical places, but also special books and articles, news, thesis and other found online. Nevertheless, because those materials were not enough, it was essential to take advantage of all those contacts hold: from container companies – such as Maersk and Titan to organisations- such as Melinda and Bill Gates Foundation, Red Cross, UNICEF, Engineers Without Borders, among others to get more specific information. Even TED talks were material used for this thesis information gathering phase, once those are always very realistic, up to date and innovative- a good place to start looking for valid answers.

The design phase took place at the same time simulations would be taking place and research was still on. When a design proposal worked in one field, it would also be tested for the other elements of the design. The texts and information was written in their final version, but the practical work was added after hand. Due to the complexity of the theme, a lot of extra information and potential developments and ideas were found and conceived after the design was closed. All this thesis and material developed, was achieved by withdrawing inspiration from the Integrated Design Process by Mary-Ann's Knudstrup- merging many components of my education together and going back and forward in perchance of a good design- , while keeping in mind Alan Bryman's Mixed Methods and Integrated Energy Design.

THESIS STRUCTURE

Chapter 0- The introduction of this thesis: First the motivations for the theme and title, then the concept and ideas of the thesis together with the challenges and restrictions faced during the work with the theme proposed in the thesis are given in this chapter. Furthermore, it provides an initial overview on the problem presented and the directions taken along the thesis.

Chapter 1- State of the art: It gives a summary on the most relevant definitions and concepts within the thesis and later on the cases, such as Sustainability, Flexibility, North and South, and climate. In this chapter, the ideas are explained by quoting and referring some authors, in order to try to clarify some fundamental questions- scientific papers were primary source of information, together with books. This is the most theoretically section of the work where some of the information will later be used more in practical terms and in detail. By the end of this chapter, shipping containers are shown from their most historical side to their practical potentiality for being converted into housing units. Last, some limitations on some concepts are underlined.

Chapter 2- Service, comfort and examples: Comfort, basic needs and practical solutions are presented in the chaper that most relates to organisations and humanitarian problems. Organisations, standards and authors such as Abraham Maslow are presented and referred to in this chapter. Some practical inspiration and examples of designs are shown.

Chapter 3- One design and four climates: In order to understand if flexible architecture is sustainable and study the challenges North vs South, the suggestion is concerning a design that relies on the hypothesis that 1 solution alone could fulfil requirements around the World: it would cover different locations, representing distinct climates. Case one leads to a dead end: The results just show that climates have too many specifications and it is impossible to present one product that includes and integrates them all. Even though representing an interesting theoretical solution, it is not possible in practical terms.

Chapter 4 – The intervention solution: After reaching the dead end in the reflective suggestion, a solution is proposed: case two. It involves a concept that is flexible and changes adapting to different climates: from openings and shading to the building envelope, two contexts are analysed and generally compared. The intention is, not to give the best possible solution and exhaustive study on all the elements but to compare extremes and reflect upon how much a small change actually means so big difference on results. Through this chapter, the aim is to share insights and knowledge by giving specific advice and concrete documentation on the effects and benefits key elements in buildings. In connection with creating new buildings – as well as by renovating existing buildings – the specific solutions need to be considered in a holistic perspective – where usage, personal needs, function, location, orientation, and building geometry and window configuration play very important roles.

Chapter 5 – Analysis and Discussion of results: At this stage, calculations were presented (chapter 3 and 4) and solutions, or proposals, were found. This chapter is where the different sections from last chapter are put together and the two cases are further discussed and analysed as results.

Chapter 6 – Conclusions: Last section of the work, where the information from all the other parts is summed up. Mostly it represents not only going back to the initial considerations and intentions on the first chapter (Introduction), but also to a final reflection redrawing inspiration mostly from the study cases (chapter 3 and 4). On one hand it intends to justify if those challenges and intentions were achieved, what limitations the project reveals and what would be the next phase and working stage. On the other hand, it is a way of trying to conclude upon the potentiality of shipping containers as structure to be used, their limitations and some other solutions are proposed.

References

Annexes: The elements presented here help understanding the thesis as a hole, as they are part of the results and analysis done along the process. The thesis should be understood without the use of the section that represents an extra and more detailed gathering of information. In this section, there are other elements but the biggest and most important part is related to shipping containers and the design results- qualitative or quantitative-, where the case studies are developed, and where the calculations take place. Here are presented tables in excel, calculations taken from Bsim software with the results of the simulations, graphical data, extra information on containers, inspiration, etc.

1

STATE OF ART.

1. STATE OF ART

1.1 SUSTAINABILITY AND FLEXIBILIY

1.1.1. SUSTAINABILITY

HISTORICALLY: *"While the motivation to live sustainably dates back to ancient times, its vocabulary is but three decades old."* (Thiele, 2013) Even during vernacular architecture, there were attempts of sustainable practice (Guedes, 2011a) provided by constructive techniques- product of years of knowledge being transferred from generation to generation. Those generations have found a way to adapt to environment resorting local resources. The expression "green architecture" and the word "sustainability" have constantly been used in the last decades but *"The concept of sustainability assumed since the late 70 is different from the present, which was based on the logic of the support of society, a very economic view, with reduced environmental concerns".* (Pinheiro, 2006) This concept was only defined generally in the late 80's, in the report "Our Common Future"[1] known as the "Brundtland Report" from 1987. This report do among other things conclude that: a *"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs"*. (World Commission on Environment and Development, 1987a).

THE CONCEPT: Although the Brundtland report – also known as "Our common future"- mainly addresses the problem with depleting our resources leading to future generation not getting the same living conditions as the present generation, this broad definition leads to many different understanding of the word sustainability. Is sustainability just a gathering of technical and environmental aspects? The concept of sustainable development or sustainability differs among different authors. If in 1987, a sustainable development directly related to future generation, some other definitions are broader than this: *"To live sustainably is to be fair to future generations while also appreciating our biological and cultural inheritance. To put the matter concisely: Sustainability is equity over time. Nevertheless, sustainability extends moral concern not only across expanses of time, but also across geographic space. To practice sustainability is to move beyond the national, political, economical, ideological, racial, ethnic, and gender borders and cleavages that fragment and divide us"* (Thiele, 2013)

In fact he adds: *"Learning to live and work sustainably is the practical challenge of our times." (Thiele, 2013*) Sometimes, blinded by world recognizing prizes or due to the fact that architects and generally designs have forgotten how to build with less, designs are unbalanced. Some designs are amazingly beautiful and complex, but to those it is better not to ask about the price or sacrifices; or on the other hand, if a house cost was a small amount of money, to what cost has that happened? Is the place habitable? Is temperature inside so high or low that the house is barely used? What is declared by Manuel Correia Guedes answers the questions before:*"A good building is naturally sustainable"* (Guedes, 2011a). Moreover, it is an ethical matter *"of the designers on all fronts of activity, to conceive and design physical structures supporting human life that do not contribute to environmental degradation and can contribute to its regeneration and ecological balance".* (Guedes, 2011b) The aim of the project concerns the future generations and the people who are going to live there, reflecting on the relation

[1] World Commission on Environment and Development (1987). Our Common Future. Oxford: Oxford University Press.

sustainability and architecture.

To live in a sustainable way is to live in an holistic way, where the different parts of equation are balanced. "*The concept of sustainability, closely relates with the discovery, by the contemporary world, of the overriding need to ensure humanity's survival -threatened by unregulated consumption of natural resources and the phenomenon of heating the planet, which are primarily the result of malpractices in various sectors of activity human, and particularly in the construction sector structures and infrastructure that support society"* (Guedes, 2011b) Not only a bad use of resources will lead to their depletion, but also , one of the problems with building not "climatically aware " is too high values concerning pollutants.

As stated by Leslie Paul Thiele in his book entitled "Sustainability" (Thiele, 2013), in the past last years and within a short time span, sustainability, as a theoretical and practical idea has triggered and originated changes in lifestyles all around the globe through initiatives in municipal, regional, national and international scales. During a time where resource dwindling and global climate chances have such a big impact in the world's agenda, sustainable was given the task of "saving the planet"; in a way, we are conscious and more aware of our role in maintaining the world as I know it today.

"According Kibert (Kibert , 1999) , the concept of sustainability has a number of aspects and limitations that will be presented . The philosophy of reducing , reusing and recycling has implied this perspective and issues of population's growth , quality of life , standard of living and technological solutions, that are assumed to be recorded , are part of this approach sustainability ." (Pinheiro, 2006)

SUSTAINABILITY- THREE DIVISIONS: The definition of sustainability is mostly divided in three categories by most of the authors: Environment, Economic and Socio-political (figure 1.1-left). It is summed up as: *"A practice (…) is not sustainable if it undermines the social, economic, or environmental conditions of its own viability". (Thiele, 2013*) or even *"Thus, it can be concluded that sustainability involves the environment, society and the economy"* (Pinheiro, 2006) and "*While the three dimensions of sustainability -environmental, economic, and social- are interdependent"* (Boström, 2012)

THE INTRODUCTION OF AESTHETICS: If the division of sustainability in three main areas is quite shared among authors, this last field that is not considered by all. The discussion of aesthetics begins with Plato – ancient Greek philosopher- and Roger Scruton, in *The Aesthetics of Architecture* describes: *"The concept of aesthetics appreciation as a compound experience of thought and analysis.*" (Scruton, 1980) But other authors state that: "*To truly be effective, sustainable architecture must go beyond checklists and material choices. Architecture needs a cohesive and holistic sustainable philosophy, a driving force behind the design and construction of buildings. Architecture needs sustainable aesthetic philosophy."* (Douglass, 2008). Vitruvius – as early as in the first century after Christ- developed a worldwide system *firmitas, vetustas, utilitas* (strength, beauty and function) that defended a sustainable project. If those elements would be in the vertices of a triangle, every time one would be closer, and in order to keep the triangle balanced, then the other vertices would also be closer together. The design would be an integrated process and a balanced equation, where nature observation together with the use its natural resources, solar illumination and natural ventilation are part of that same system. For that same balanced triangle, then "beauty" is included, showing that aesthetics should also be integrated part of a sustainable design So, relying in some other studies and authors such as Thiele, David Barrett Douglass and the Vitruvius system, in this thesis, therefore sustainability is considered to be divided not only on the three categories mentioned above, but divided in four categories: Social, Aesthetic, Technical and Economic Sustainability. (Figure 1.1, Right)

Due to the fact that Sustainability is such a broad term and it can include almost anything that relates to "not compromising future needs", in this thesis it is proposed another area that is related- to be sustainable through flexibility- that puts together the other concepts the concept of Flexible sustainability will appear from the other expressed above, related to the project developed.
Sustainability does not only concern developed countries. The world is the same and the harm done to it is by all. Thiele (Thiele, 2013, defends that Resources are not only materials or products but also money that can run out if economic considerations are not taking part on the project decisions. The present generation needs to discover answers to minimize the energy consumption – through bioclimatic design- and encourage the use of renewable sources – not always available- in order to assure the future generation's quality of life on Earth. This reduction can be obtained by integrating passive solutions from the early phases of the projects and long lasting materials, together with training people to be climate aware and try to minimize motorized transportation, living in more compact cities.

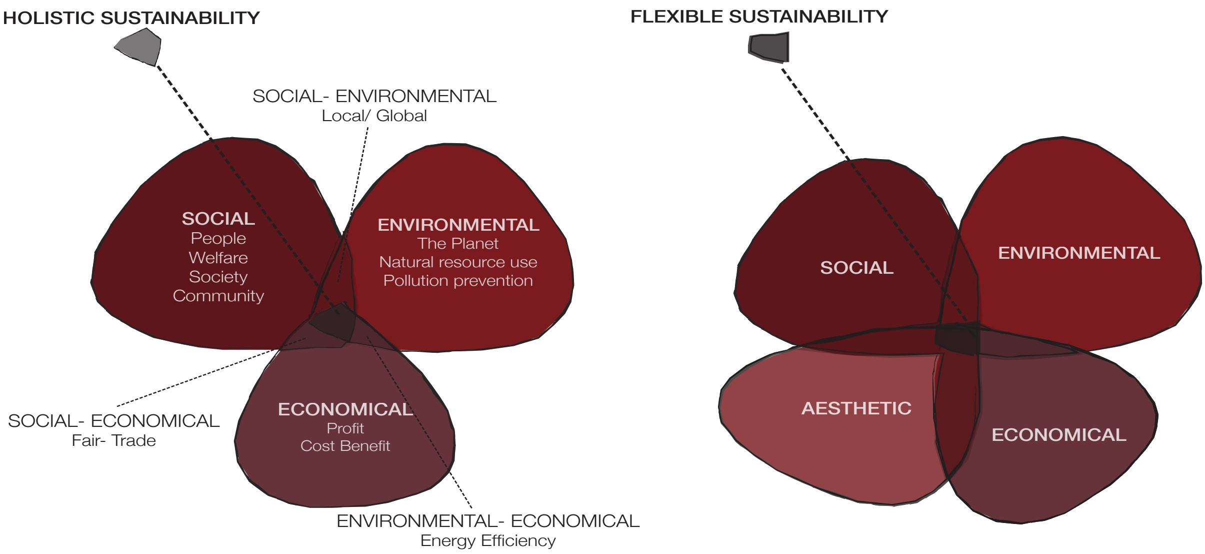


Figure 1.1 - Sustainability major fields: Some definitions divide sustainability in three areas while some other authors consider aesthetics as part of a sustainable design, when considering identity and beauty. Flexibility is the product of a balanced result, from merging all those fields together. Flexibility answers sustainability. (Source: Mafalda Melo Oliveira, 2014)

A. SOCIAL SUSTAINABILITY: Due to its to the complexity and subjectivity of the term, the definitions are different: *"What is social sustainability? […] It is particularly difficult to define, realize, and operationalize social sustainability*" (Boström, 2012). According to Bebbington and Dillard (2009), the reasons for this difficulty are *"Social sustainability appears to present different and more severe challenges than environmental sustainability because there is no widely accepted scientific basis for analysis, unlike the ability to debate population ecology, acceptable levels of toxicity, or acceptable concentrations of greenhouse gases in the atmosphere*." (Kandachar, 2014). For others , it reflects on individual influence, putting apart developed and developing contexts: "*The average ecological footprint per person in developed nations now exceeds the per capita carrying capacity of the planet, although the consequences of this are not yet evident, masked by the many nations with far lower footprints. Part of* *the footprint is technology driven, a direct result of increased transport, manufacture, and domestic consumption."* (Ashby, 2014). Lastly, *"Social sustainability is the neglected component of sustainability. Our world during the last decades has focused, however, only on economic sustainability. Although this approach has delivered extensive material welfare to some parts of the world, a large part of the world is still struggling to make a decent living."* (Kandachar, 2014)

THE DIFFERENT LEVELS- FROM INDIVIDUAL TO THE ROLE OF COMMUNITY: The issue of transportation and dense cities has been researched by Petter Næs (Næs & Andrade, 2010) in an article from the magazine Nordic Journal of Architectural research. The writer explores how people living in dense cities with all the daily functions and actives close by would rather walk, take the bicycle or use public transportation and how it would help to reduce the emission of carbon dioxide. Petter Næss also investigated which qualities people are looking for and conclude that it is things like having your own garden, privacy and freedom, which attracts families to move to those houses. So if these elements are integrated in to the architectural strategy, *"people might choose to live denser".* (Ebbe, Lauring, & Petersen, 2007) A social sustainable project should also consider how able a design is to adapt to a specific location and is flexible to different contexts. The new developed dwellings should still possess the desirable qualities for people to want to use them or at least feel good on them, at the same time they are according to environment and place. In achieving a well-designed housing unit with social sustainability as design parameter there should be place for having your own private space - with green garden, terrace or other- and a place where people can meet. It is important to design spaces for diversity still with the feeling of individuality. Inhabitants are an important part of the design and should be taken in consideration the results.

When searching for sustainability, its is necessary to look upon and to communities, since humans are not only individuals that should be unique and special – represented by identity-, but also part of a bigger whole and piece, that should also achieve sustainable ways of living- the community. That is of course a step harder to reach -due to its complexity -than just a sustainable construction as stated in " Sustainable communities" (Pinheiro, 2012): *"Based on creating environmental and economic health, promote social equity and wider citizens in the organization, participation in planning and implementation".* Sustainability increases the level of complexity hand in hand with intervention agents: starting from constructions, to environments, to communities towards a holistic sustainable development.

B. ENVIRONMENTAL/ TECNHICAL SUSTAINABILITY: Concerns many strategies that can be divided up in two strategies: the passive and active solutions. The passive solutions covers elements like building location, orientation and the use of solar radiation, while the active solutions relate to what contributes to the energy balance like solar cells, heat pumps, windmills and solar collectors. According to the studies of energy reduction in buildings made by "Henning Larsen Architects", the energy consumption of the building is 40-50 percent locked by the design of the buildings envelope. Which means that changes in the envelope has a large influence on the design. This proves that architecture is a huge part when developing sustainable buildings. With technical sustainability, the consideration for the world's consumption of non-renewable energy is considered and the aim is to use renewable energy resources and materials to ensure the resources for the future generations. (Jan Aagaard in *Focus Denmark no 4, 2012)*

B.1 PASSIVE SOLUTIONS: Passive solar systems are using the energy generated by the sun to heat or cool a building, so that the indoor environment is comfortable. Some of the strategies relate to building orientation and location, building envelope- insulation and materials-, shading devices, openings, etc. *"Passive design strategies aim to provide comfortable environments inside the buildings, and simultaneously reduce their energy consumption. These techniques allow the buildings to adapt to the external environment through architectural design and the intelligent use of building elements and materials, avoiding the use of mechanical systems that use fossil fuel energy."* (Guedes, 2014)

B.1.1. ORIENTATION AND LOCATION: influence the design, from placing the design on top of a hill or its lower point, a shaded area or shield from the wind, to an exposed location: "*The location of the building is creating the fundamental design parameters for exploiting the natural resources of wind and sun. This can be achieved by orientating the building with knowledge and strategy about demand of daylight, solar heat and natural ventilation, and it can be used more efficiently and become a dominating part of the construction succeeding in becoming a sustainable building".* (Albjerg 2008)

B.1.2. SOLAR RADIATION AND SHADING DEVICES (Figure 1.2): The largest natural resource in the world is the sun, supplying up to 15.000 times more energy everyday than the entire world consumes today. This energy resource can be used efficiently with concern of orientating the building to exploit the sunray to heat the building when required and supply efficient daylight. The heat and the light from the sun can be controlled with external and internal shading or integrated overhang. The external shading protects the rooms from overheating by blocking the heat from entering the room. The internal shading solutions can control the amount of sunlight entering the room, but does not prevent the heat from entering the room. The solar shading can also be an integrated part of the building design by creating an overhang, which provides shelter from the sun in certain times, and still leading sunlight in other times. (Albjerg 2008)

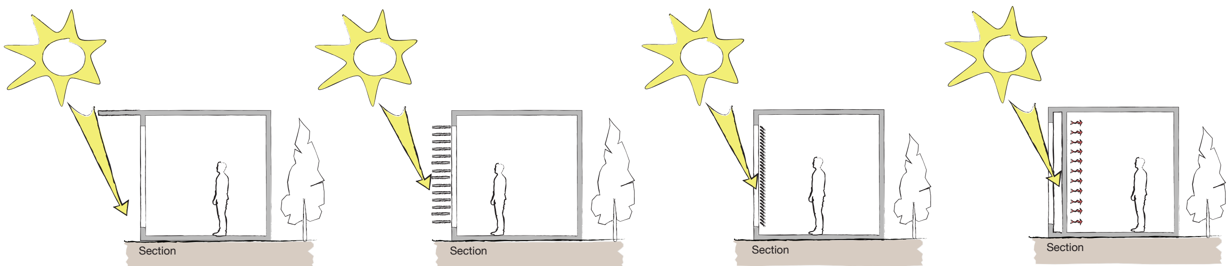


Figure 1.2 - Solar radiation: shading devices. a) Fixed shading: overhang; b) Fixed shading: blinds; c) Flexible shading: blinds; d) Thermal mass (Source: Mafalda Melo Oliveira, 2014)

THERMAL MASS (Figure 1.2,d)): Is also used for passive energy store, once it has the capacity to "*attenuate temperature fluctuations inside buildings. Heat is withdrawn from the interior at hot times of the day by natural convection and radiation and released back in cold periods".* (Richardson & Woods, 2008) *"The volume and thickness of thermal storage determines the magnitude of interior temperature swings. The time necessary for heat to be released by various thermally massive materials is called thermal lag. The optimal size, color, and location of the thermal mass depends on the building's design strategy, energy requirements, occupancy patterns, and climate."* (Haglund & Rathmann, n.d.) Both authors defend that: *"By minimizing deviations from the comfortable temperature range, the need for energy intensive heating and air conditioning can be significantly reduced".* (Richardson & Woods, 2008) "*A better understanding of thermal mass behavior under these complex circumstances will result in* *properly integrated strategies for managing interior temperature swings and reducing mechanical system energy use."* (Haglund & Rathmann, n.d.) Construction materials such as adobe, brick, concrete and others are preferable to others such as glass or metals. *"Among common building materials, wood does not make a good thermal mass because it not only has a low heat storage potential, but is also not very conductive. Therefore, heat is not conducted readily to the material's interior to be stored for later use, but is rejected prematurely (as surface temperature rises) by radiation to cooler objects. Steel, while having a seemingly high potential for heat storage, has two drawbacks—its low emissivity indicates that a large majority of the incident radiation is reflected […] and its high conductivity signals an ability to quickly transfer heat stored in the material's core to the surface for release to the environment, thus shortening the storage cycle to minutes. Glass also seems to have a high potential for heat storage, but it is relatively transparent to near infrared radiation and reflective of far infrared radiation. Adding pigments to glass (especially blue and green) increases its ability to absorb radiation, which can become a thermal problem during the cooling season. In the case of both steel and glass, masses that are large enough to act effectively as diurnal thermal masses are so large, heavy, and costly that they are not practical. Concrete and other masonry products are ideal, having a high capacity for heat storage, moderate conductance that allows heat to be transferred deep into the material for storage, high emissivity to allow absorption of more radiation than that which is reflected. When sized properly, concrete is effective in managing diurnal energy flow. Conveniently, structural concrete and thermal mass share common dimensions, so there is no wasted mass when building a structure. Water is also effective as a thermal mass […] when stored in clear or translucent containers can provide light and/or views through the (normally opaque) thermal mass".* (Haglund & Rathmann, n.d.)

PHASE CHANGE MATERIALS (PCM): increasing over time and due to the integrated balanced result of combining the different sustainable areas, cost and aesthetics are taking their role in the final design and along the design process decisions. A constant concern is if it is possible to achieve a good thermal mass by using light weight materials. PCM[2] have been considered in order to answer this, but their implications and potentiality as solution are yet in an initial phase of research. *"Adding phase change material (PCM) to thermal mass increases the effective heat capacity during the phase transition. This can anchor the temperature of the mass in a narrow band around the melting point of the PCM, further reducing the temperature swings perceived by occupants of the room. […]. Nevertheless, the advantages of a thermally massive building often conflict with practical considerations in the design process. Aesthetics and cost pressures often require modern buildings to be increasingly lightweight. Solutions that increase the thermal mass of a building without increasing the structural weight are therefore particularly desirable. Phase change materials (PCMs) can be used as thermal mass by microencapsulating paraffin waxes within small polymer spheres, approximately 10 mm in diameter. These are then mixed directly into the building material or facing wallboard"* (Richardson & Woods, 2008) (Some examples of PCM in Annex 3)

B.1.3. NATURAL VENTILATION *"The purpose of ventilation is to freshen up the air inside buildings in order to achieve and maintain good air quality and thermal comfort. The effectiveness of natural ventilation, i.e. its ability to ensure indoor air quality and passive cooling in a building, depends greatly on*

[2] PCM: A phase-change material (PCM) is a substance with a high heat of fusion which, melting and solidifying at a certain temperature, is capable of storing and releasing large amounts of energy. Heat is absorbed or released when the material changes from solid to liquid and vice versa

the design process. […] ventilation systems using only natural forces such as wind and thermal buoyancy need to be designed together with the building since the building itself and its components are the elements that can reduce or increase air movement as well as influence the air content (dust, pollution)" Furthermore, *"Natural ventilation can be used to provide fresh air for the occupants, necessary to maintain acceptable air quality levels, and to cool buildings in cases where the climatic conditions allow it".* (P. K. Heiselberg, 2006). *"In a flat terrain, room ceiling can be in different heights so it makes it easier air flow and ventilation."* (Lengen, 2010). Ventilation also has important psychological aspects, which can be summarized as "creating a link to nature" (the outdoor environment).

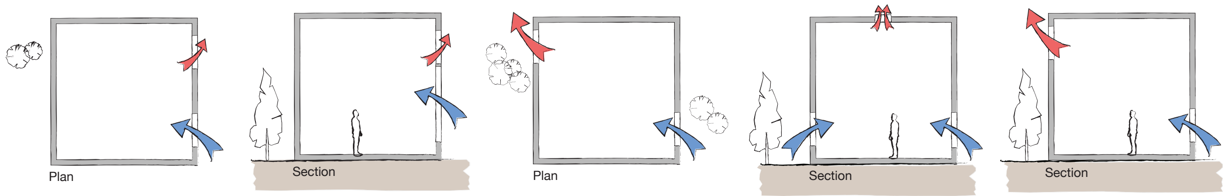


Figure 1.3- Natural ventilation diagrams. a) and b) One side ventilation: limited efficiency; c) Cross ventilation: Uses the principal of under pressure from wind to lee side and can be increased by shielding next to the openings; d) Upward force ventilation: The hot air raises and can be increased by principle of under pressure on top of the building; e) Combined ventilation (Source: Mafalda Melo Oliveira, 2014)

Ventilation has two primary functions; first: to ensure the supply of clean and fresh air and secondly to secure the indoor climatic quality, comfort and well-being: when removing pollutants such as CO_2. By regulating the venting it can remove the waste heat, humidity and polluted air and cool the building. There are four kinds of natural ventilation principles- Figure 1.3 (Albjerg, 2008) : a) *"Single Sided - Ventilation is applied in rooms with only openings to the outdoor from one side. The principle can be used with wind turbulence during the summer and thermal buoyancy in the winter. Comparing this principle with others the ventilation rate produced is lower and the ventilation air does not penetrate so far into the space"*; b) *"Cross Ventilation is applied in rooms with two openings one in each side. The force of the wind can ventilate the room by using the wind pressure entering the windward side and leaves through the leeward side. This principle gives a higher ventilation flow rate, […] but the wind is hard to control. Can be applied in rooms with a large depth and work efficiently"*; c) *"Stack" or "Chimney Ventilation is a strategy where ventilation openings are both at a low and at a high level. The main driving force is thermal buoyancy, using the difference between the cold fresh air and the polluted heated air.";* d)*"Cross and Stack ventilation combined is using both principle in one building with having cross ventilation with openings in both sides of the building and having a chimney where the hot air is exhausted by. By combining the strategies, a wider building can be efficiently ventilated."* (P. K. Heiselberg, 2006)

B.1.4. VEGETATION can exploit and improve the natural ventilation and protect areas against the harsh wind. Accordingly to Per Heiselberg's research in "Design of Natural and Hybrid Ventilation", that the main functions of vegetation - as far as an air movement is concerned – are (Figure 1.4): wind sheltering, wind deflecting, funnelling and acceleration of air and air conditioning. The type and layout of vegetation should be included in the site plan with consideration for the airflow patterns for the area and as well as aesthetics and the environmental factors. (P. K. Heiselberg, 2006) Vegetation directs wind, maximizes wind speed and also works with the wind as evaporative solution.

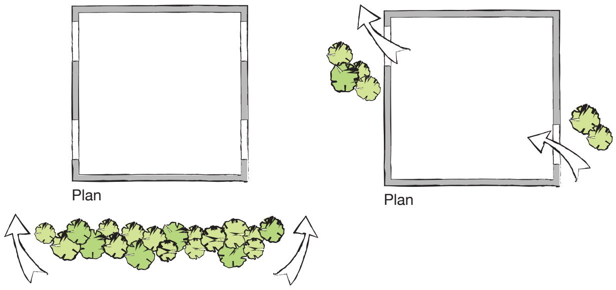


Figure 1.4 – Vegetation: (Left) The vegetation shelters the building from undesirable strong wind but (Right) the vegetation can also increase the wind by shielding openings and direction the breeze. (Source: Mafalda Melo Oliveira, 2014)

B.2. ACTIVE SOLUTIONS: Strategies that produce energy without contributing to pollution and global warming. The strategies are all based on unlimited and continuous renewable sources such as the sun, wind and waves. (Figure 1.5) The following information is on Heisselberg's book 'Passive Solar Heating'. (Heisselberg, 2006) After reducing the energy consumption, by using passive strategies as previously described, the next step is to apply active solutions- when and if possible. The four most know and used methods are solar cells (PV), solar collectors, heat pumps and windmills (Fig.1.5 c), d) e)). The preferable and traditional solution to produce renewable energy is to invest and integrate solutions as a part of the building -placing them on footprint, on the built volume, integrating them in the building mass. In placing the solutions on the building site, there is a risk of no integration with the design. The last solution is the offsite placement, achieved by buying a share in a windmill not located on the building site: this will not produce energy directly to the building, but the owner of the share can add it to their energy consumption and save money. Besides those four, and if natural ventilation (venting) is not sufficient- often occurring in winter time-, mechanical ventilation can be applied (Fig.1.5, a), b)). Using mechanical ventilation, allows getting advantage of a heat recovery system: The system provides fresh air and improved climate control, while also saving energy by reducing heating and cooling requirements. The outdoor air is heated up to the required temperature and then distributing it to the apartments. The Hybrid Ventilation is applied when having a system with both natural and mechanical ventilation strategies. The two types of ventilation strategies can be turned on and off according to the required needs for the residence. Mechanical ventilation with heat recovery will be preferred during the winter to reduce heat loss and during the other seasons, the natural ventilation is to be preferred to reduce energy consumption.

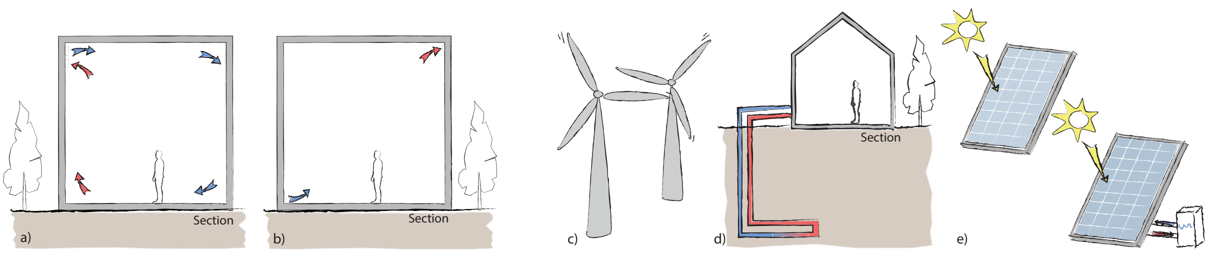


Figure 1.5- "Extra solutions": active solutions and geothermal. From left to right respectively: a) Mixed ventilation: Cold air is blown inside at the roof level and extracted again from the roof level; b) Displacement ventilation: Cold air is added at the floor level and the hot air are extracted at the roof level; c) Wind mills; d) Geothermic energy (passive); e) (Above) Solar cell (bellow) solar collector. (Source: Mafalda Melo Oliveira, 2014)

Even though active solutions improve a lot the design and its negative impact on the energy consumption and environment, it is not always possible to get to use expensive active solutions. For that reason and to reflect upon how much "LESS" can mean more and how much passive solutions -available for cheaper or no price- can make a big difference when well thought through in this thesis they will only be considered passive solutions.

C. AESTHETIC SUSTAINABILITY: In designing a sustainable building the concern for achieving the energy frame and reduce energy and heat consumption can comprise the architectural quality of the design. To create new homes for the future it is important to create buildings with an integrated design where the functions, geometry and applied technology are connected together to create architecture with a strong and high quality of aesthetics. *"The interplay between architecture and technology can be a way to design beautiful, comfortable and energy correct buildings."* (Kongebro, 2012) Many previous designed sustainable buildings project have resulted in an weird architectural expression with all the technical solutions plastered on the building: looking like a huge sign to say that people living there are better than the rest of us. Instead of making the building scream sustainability with its technical appliances, the integrated greenery on the building site should make the people perceive the building as a healthy place to live. This can be solved in many ways e.g. by using green walls and terraces with greenery etc. The technical aspects will be an aesthetical part of the building and enhance the social sustainability, and create a building which people perceive as sustainable and the future way to live.

D. ECONOMIC SUSTAINABILITY It is crucial do design dwellings focusing is on making a wide range of types of families being able to afford living in modern homes. The economic can be applied in different ways; the economics of building the project, how long the building can last, choosing materials requiring almost no maintenance, choosing local materials and building methods and being able to transform the building to fit the future generation's requirements, how long it takes to be erected- time is money, etc. Creating a system that can be flexible, adaptable and modular is also economically sustainable. *"There is plentiful evidence that human activities are leading to levels of resource use and pollution beyond environment's capacity to assimilate without significant degradation, and that critical planetary boundaries are being exceeded beyond which unpredictable non linear and "catastrophic" changes in the Earth system may result.*" (Pullinger, 2014)
Some concerns haven't been there always, but they start to increase in importance: *"Amidst this apparently peaceful material world, a book The Limits to Growth (Meadows et al., 1972) appeared some 40 years back showing us by modelling the consequences of unchecked economic and population growth with finite resource supplies. Nevertheless, the concern about the diminishing resources to sustain our material world is of recent origin."* (Kandachar, 2014)

The term Sustainability has been developing since the Brundtland report specific and not broad definition to integrating other fields such as social and economic aspects and finally to be considered a holistic result that puts together all the values referred before and also its aesthetical and humanistic, personal, identity value. Because sustainability does not need to be only a gathering of technical mathematical values or equations but a result of a balanced and altruistic way of living. Building not screaming "I am green", plastered with energetic and expensive solutions –Figure 1.6- that should be integrated from initial stages. If planned integrated from its initial phases, studied the best balance and options available:

“In many circumstances, achieving sustainability can achieve a balance in integrated materials and systems, and may even be more efficient in costs that the traditional projects”. (Pinheiro, 2003)

Figure 1.6 - Is landscape going to be this in the future? Plastering last minute solutions to fix problems not solved in earlier stages of the project? (Left) Solar Panels shooting up houses; (Right) A blue landscape of solar cells. (Source: http://goinggreen12.blogspot.pt; (Right) http://inhabitat.com/40-cheaper-solar-cells-get-20-million-to-commercialize product)

FROM EMERGENCY TO SUSTAINABILITY: What better to prove man’s ability to adapt to change, than emergency states of living? *“Evidence shows that not all the beneficiaries of reconstruction projects are as lucky as Oscar Bermudez. [one of the victims of an earthquake that was able to rebuild his house in a 4 month period , to a even better version compared to the house he had before] This is particularly because, rushed by the urgency of attending to immediate need, reconstruction projects rarely develop into sustainable solutions in the long term. […] Which type of sustainability? […] In order to avoid the debate about the needs of each generation [reference from the Brundtland Report], Stephen Wheeler proposes that sustainable development corresponds to “development that improves the long- term health of human and ecological systems.”* (Lizarralde, Johnson, & Davidson, 2010)

SUMMING UP: “Sustainable architecture challenges architectural design at various levels. (1) Minimizing the negative environmental impact of buildings by enhancing efficiency and moderating the use of materials, energy and development space. (2) Developing measures to relate form and adapt the design to the site, the region and the climate.(3) Establishing a harmonious, long lasting relationship between the inhabitants and their surroundings by addressing the essence of good form-giving (Abidin et al., 2008). In summary, sustainable architecture shall be well built, easy to use and beautiful.” (Keitsch, 2012) Words that lead to the conclusion that the design ought to be integrated and merged. In additon, *“Sustainable design should be irresistible design”* (Beckler, 2013) It is not only the architects responsibility to create a sustainable design, but it is also his role in the big picture and the general intervention as a decision maker. “*Internationally, key agents in the construction sector, such as CIB (International Council for Research and Innovation in Building and Construction), defined an Agenda 21 for Sustainable Construction (CIB, 1999), as a key strategy for the suitability of the sector. The basis for the intervention focuses, according to the consensus reached, on defining sustainable construction that involves all agents from users to designers and contractors*” (Pinheiro, 2003)

1.1.2 FLEXIBILITY: REDRAWS INSPIRATION FROM HISTORY AND THE PAST

SHELTER: is a structure easily erected on a remote location from manufacturer. Throughout centuries, man has found a way to build himself structures that would work as protection from harsh environment and the outside conditions. Those constructions-shelters- have been developed to answer the specific conditions of climates as better as possible, adapting to wind, sun or other. Shelter intends to protect or shield from something harmful.

To overcome a need to be flexible and adapt to change, architecture should redraw inspiration from history –Figure 1.7– tents, primitive shelters, caravans, portable and movable solutions and nomads. In order to understand and study the human's most basic needs and the adaption to specific conditions such as climatic or natural human growth, examples are described. Among them, the North African tent, a big sealed and closed element, turns itself to its inside and shades for sun protection; the North American tipi with its peculiar pointy shape works as a wind shield and last, the Asian yurt representing modular solutions existing among us and being used a long time ago.

Figure 1.7- Redrawing inspiration from portable/movable solutions (Source: (Left and Middle) (Kronenburg, 2007); (Right) http://www.academylane.com/news/national-train-day)

Not only shelters represent humankind survival for centuries adapting their constructions to the climatic and geographical conditions those were living at, but also most of the constructions also illustrate nomad way of living with either light, easily erected structures or more complex but still temporary or transitional.

NOMADS AND SEDENTARS: What are nomads? "*Nomads are people with no fixed residence. They move from one place to another usually seasonally and within a well-defined territory".* Is nomadic the new sedentary way of living? Nomadic life, or more precisely nomads, is a good example of economy of space, lightness of materials and efficiency in solutions- Figure 1.8. "*Economy, lifestyle and constant immigration have contributed to changes in the Qashqaiis' way of thinking, moral and artistic characteristics. As housing units, tents have to be compatible with nomadic lifestyle and constant immigration. It must also be easy for people themselves to make, pack, carry and raise these tents. Therefore, tents must meet the following minimum requirements: they must (1) be light, small and portable, (2) be warm in winter and cool in summer, (3) be resistant against wind, rain and winter storms, (4) be affordable by all people even the poor ones, and finally (5) be easy to make by local people themselves" (Hematalikeikha, 2012)*

Figure 1.8 – Nomads have no fixed home, their constructions are easy to erect, movable, modular, light, cheap, and adaptable to climatic specifications (Source: (Left) http://archaeologynewsnetwork.blogspot.pt/2012/02/rethinking-social-structure-of-ancient.html; (Right) http://www.wanderingearl.com/challenges-of-a-permanent-nomad/)

The Australian architect Glenn Murcutt (examples, in chapter 2) is an example of this "going back to basics", through his designs -that relate and are built part of the environment- and focus on basic human needs together with the character of place. His buildings, erected on the most amazing and difficult contexts and climates, count on the use of materials easily produced, his close attention to the movement of the sun, moon and seasons. He is able to exemplify a dwelling in its simplest forms. *"The topographic features of land and its efficient use is one of the issues to which nomads pay much attention in their choice of settlements. Safety and sheltering, The direction of adverse winds, protection against torrential flows of water, sufficient light and a good vantage point on the pasture and the surrounding environment, all have been important factors for nomads" (Hematalikeikha, 2012)*

Life is temporary as much as a building or construction. From natural causes or disasters to man made situations such as poverty, when there is nothing else to hold on to, a place to call home, gives not only a physical comfort but mostly emotional. *"Early man lived under trees and stars. At some time he found or improvised shelter"* (Kahn & Easton, 1973) With today's changes, climate or human made, people might find the need for a shelter from the real world, a place to rest and be shielded from the aggressive outdoor environment: a temporary place. That "second home" is space efficient, compact but comfortable, functional but aesthetically valuable, architecturally interesting yet aware of climate and realistic on its approaches. The never stopping world, with its changes and constraints, demands for openness to an architecture that can adapt to the current and future needs. Those needs relate to various matters from economic concerns, to sustainability and the possibility of change, allowing flexibility and adaptability. *"From the FLEXspace there is access to all spaces. […] It is possible to insert larger openings from the FLEXspace into the spaces, creating flexible solutions within the same system."* Moreover, *"The FLEX space is the heart of the house. […] It can be used for multiple purposes. […] There is access to the surroundings and daylight. The boundary between inside and outside disappears, when the doors open. This is fundamental part of the design; to be able to open let nature in."* (Arcgency Architects, 2012) Tradition and history are basis for understanding the needs faced now. Humans learn from their ancestors and copy what there is to do right: "*The wisdoms of building traditions in Southeast Asia is the rational outcome of local climate, available building materials, articulation of building typologies, development of construction techniques, manifestation of beliefs and rituals, cosmopolitan urban culture, tangible and intangible traditions, and lessons of sustainability learned over many generations. This keynote paper discusses […] how we can learn from history, real experiences, and local wisdoms on tangible efforts to achieve environmental, cultural, and economic sustainability in holistic way."* (Widodo, 2012)

1.1.3 FLEXIBLE SUSTAINABILITY - FLEXIBLE: THAT ADAPTS TO CHANGE

"*Human beings are flexible creatures. We move about at will, manipulate objects and operate in a wide range of environments." (Kronenburg, 2007)* Not too long ago, during evolution, human survival as species was due to the man capacity of changing, to be adaptable and movable. Man and shelter would shape each other. Changes in a cave's shape, for example, could happen and additions of other chambers could be done on the simplest caves – added to one side or the other, above or bellow and behind the main space, adapting to the existing needs. *"A simple cave could be enlarged, changed in shape, have another chamber added to it behind, to one side, above or bellow, linked by ramp, stair or doorway, and then another chamber beyond that, and yet another, perhaps, in a different direction, or branching off from one of the new chambers"* (Kahn & Easton, 1973) Even though man has, is most places and cultures, lived a sedentary life, flexibility may be raising as priority in human development. Economic, social and technological changes, based on the cheap and fast transportations and the wide web, are encouraging, if not even forcing, a new form of a nomadic life and existence. Is nomadic the new sedentary way of living? *“Flexible architecture adapts to new uses; responds to change rather than rejects it.” (Kronenburg, 2007).*

Architecture is kinetic instead of being steady. Almost like a creature that never sleeps, it moves, it changes. Flexible architecture is form and shape that is innovation, multi disciplinary and it is on the edge of nowadays-contemporary matters and questions. By understanding the way it is visualized and apprehended, drawn and delineated, produced and experienced by users, enables us to understand the potential it has when talking to solving problems, both nowadays and future, which are related to social, economical and environmental changes.

Figure 1.9 - Shelters: Traditional techniques and climate adaption examples over history (Source: (Kate Stohr, 2009), (Ahmed et al., 2011) and (Kahn & Easton, 1973))

"Logically, the house orientation on the land depends on the access to infrastructures and roads and sun position. In dry climates, we include a internal courtyard. A room can no longer be squared to become rectangular. When drawing, we should not be rigid. A little of flexibility makes it possible the appearance of new shapes." (Lengen, 2010) *"Flexible buildings are intended to respond to changing situations in their use, operation and location" (Kronenburg, 2007).* The possibilities with a flexible building are immeasurable and endless. For example, a house designed to allow and propose changing occasions to its inhabitants. Flexible buildings can evolve from a reality to another and accommodate new purposes and needs, such as for example, if a building, designed for a specific number of people, needs to suddenly give an answer and allocate five more. Maybe it is a building that fits individual needs in the present moment, a "now", but that allows investment, adaption and change along diverse phases of a human life. Flexible is the architecture that adapts to change and that moves, transforms, is flexible and interacts, as an organism always alive. A possibility of architecture, that depends not only on its own form, but also in the shifting arrangements of its neighbouring environment. Widrawing inspiration from other examples from the past, such as caravans, trains, boats and other movable structures, in order to investigate how structures designed to be in constant motion, work. Flexible sustainability departures from the other fields within sustainability - referred before- in the way it is social, economic, aesthetic and technical sustainability. Furthermore, it adds the qualities of something that adapts to change, a building that results for cheap but comfortable solutions, a building that accommodates various purposes, and that evolves and is shaped by its users. Figure 1.10: Movement, change and kinetics dictate the environment we live in and our everyday life: It might apply to either our routine journey from A to B or the growth of a plant. All the progressions of time and the frames that constitute our lives. Change influences our nature and ends up commanding the way our life is being lived. Humans and others, should adapt to the ever changing surroundings and become flexible in our response. Buildings can change bringing less energetic cost to their users. Can buildings adapt to the passage of time, the change that characterizes our world and adapt to this concept of flexibility? Can buildings recognise and answer the various changes of our life and adapting to become more efficient? Flexibility within architecture allows seasons and passage of time . Flexible buildings- modular, light, transformable, adaptive- can have a big part to play when it comes to respond the never steady environment we live in: It is not static, rather, it is movable, and it is flexible, *"it is a sustainable product."* (Argency, 2012)

SUMM UP: Kenneth Frampton's text in "The Architecture of Glenn Marcus Murcut" puts together all those aspects: *"I'm very interested in buildings that adapt to changes in climatic conditions according to the seasons, buildings capable of responding to our physical and psychological needs in the way that clothing does. We don't turn on the air-conditioning as we walk through the streets in high summer. Instead, we change the character of the clothing by which we are protected. Layering and changeability: this is the key, the combination that is worked into most of my buildings. Occupying one of these buildings is like sailing a yacht; you modify and manipulate its form and skin according to seasonal conditions and natural elements, and work with these to maximize the performance of the building. Architects must confront the perennial issues of light, heat, and humidity control yet takes responsibility for the method and the materials by which, and out of which, a building is made. The considerations, context, and the landscape are some of the factors that are constantly at work in my architecture (Glenn Murcutt, 1996)* Frampton continues: *"Designing with nature […], is not a mere slogan with Murcutt, and* *in all of his works he has remained extremely aware of the way in which every intervention impacts the ecosystem in which one is working, from the drainage of storm water to the modification of native vegetation, from the erosion of soil to the embodiment of energy in all its hidden aspects. To this end, he has habitually adopted a series of strategies to mitigate this impact both within and without the confines of his architecture; from the provision of southern thermal walls to ward off the winter cold, to the opening of the structure to the north to admit the winter sun; from the provision of storage tanks to collect rainwater to the manipulability screening of windows that open onto the landscape, from the installation of vents and fans to facilitate cross ventilation to paving walkways in dark gray tiles that absorb the heat during the day and release it at night. […]."* (Frampton, 2002)

Figure 1.10- Sliding house: creating a movable sleeve the house is able to adapt along the seasons changes and benefit from the sun as a heating source. The covering sleeve, slides along tracks to allow the sun to penetrate through warming the building in cooler months. In warmer periods, the sleeve can be positioned to enclose the space, creating cooler conditions inside the space. The process takes around 6 minutes and it moves with a small motor. (Source: http://laurbana.com/blog/2013/02/07/sliding-house-de-drmm-architects-la-casa-deslizante/)

1.2 NORTH Vs. SOUTH: THE CLIMATES

SENSE OF PLACE – *GENIUS LOCI:* It is defined and recognised by many from beginning of times. In classical Roman religion a genius loci was the protective spirit of a place: *"It means not so much the place itself as the guardian divinity of that place. In the eighteenth century the Latin phrase was usually translated as 'the genius of a place', meaning its influence. We now use the current version to describe the atmosphere to a place, the quality of its environment. (Jackson, 1994, pp. 157–158)"* (Jivén & Larkham, 2003) *"There is no mysterious essence I can call a 'place'. Place is change. It is motion killed by the mind, and preserved in the amber of memory."* (Baker, 2011) *"Genius loci means literally genius of the place. It is used to describe places that are deeply memorable for their architectural and experimental qualities."* (Baumann, 2010) Described in the book Nightlands, by the Norwegian architect and phenomenologist Christian Norberg- Schulz (Norberg-Schulz, 1997), the genius loci – *"A sense of place"* - enlightens and relates to more than geographic place: it includes the site, - it is the physical context but also the social and cultural context. It is a realm in its general idea. Despite globalization, a design and building, has to have the ability to be general and international, but regional and answer of local conditions.*" A manifestation of the environment in which it is placed."* (Norberg-Schulz, 1996) This statement has a dichotomy in character; on one hand it is about the building form and material relating to the site physical, visual, sensorial features and on the other hand there is a tendency to adapt the expression and the architectural arrangement to the society's norms and traditions. When man experiences the environment as meaningful, he dwells. He is able to, not only orientate himself within a specific environment, but also to identify himself with that same environment. For this reason, a dwelling is more than a "shelter"; dwelling implies that the life occurs in spaces that are "places". In *"Genius Loci"* (Norberg-Schulz, 1980) Christian adds, *"A concrete term for environment is place. […] It is meaningless to imagine any happening without reference to a locality. Place is an integral part of existance."* A space with character results into a place, where events "take place" and where the whole is perceived and experienced as more than its parts or it sum. For someone to be able to understand the "genius" of a place, it is implied that there is identification with it, achieved and fulfilled through architecture that suggests the visualization of the "genius loci". The role of the architect is to help the man to dwell, due to the creation of meaningful places. Can this spirit of place be global? Can a design be for everywhere and still be related to its context? In the "Ocidental Architecture" (Norberg-Schulz, 1983) *"In architecture, special form means place, path and area, meaning the concrete structure of human existence"*

"SUSTAINABLE" EUROPEAN NORTH VS SOUTH: *"Global inequity, and the tension between industrialised countries ('The North') and less economically developed countries ('The South'), have been defining factors in the evolution of international environmental policy, including the UN Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol".* (Boydell, 2008) North and South within Europe (local relation) *"like day and night"* – *"European South is dominated by a hot, maritime climate , the north by a temperate cold one. […] Up North, the heating demand is the most important concern for house builders. Down South, it is the need for cooling. […] the house needs to be adapted to :windy, shady, close to a river or the sea. […] none of these factors are impedimental […] but they need to be considered when designing an energy- efficient building. […] Not to forget the sun: It's not only air temperature that needs to be calculated when designing a house, but also solar radiation. Even if temperatures are low, solar radiation is so high in some regions that houses can be easily heated without further energy. A desirable effect in some countries- too much of a good thing in others. Naturally , there is more solar radiation in Southern Europe than up to the North."* (ISOVER, 2007b) (Figure 1.11) Cold climates "keep the cold out : *"Air temperature ranges from 20-23 °C, relative air humidity 30-50 %.*While in hot climates": *"Air temperature 20-26 °C, relative air humidity 30-70 %."* (ISOVER, 2007b).

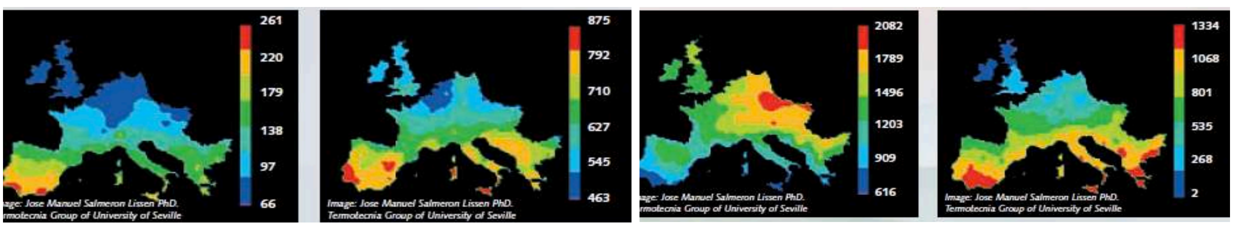


Figure 1.11- Europe - North vs South: (Left) Solar radiation over horizontal surface in winter and summer, respectively (kW/m2); (Right) Winter and summer degree days (respectively) (Source: (ISOVER, 2007b))

NORTH OR SOUTH OF THE EQUATOR LINE – North and South Hemispheres, different sun path, how to place the house facing North or South. There is more solar radiation when closer to the Equator line than there is further – as seen bellow in the quote relating to a local north VS south- Europe. Europe can be used as a smaller scale comparison to the expression North Versus South: *"The climatic zones in Europe range from the Mediterranean in the South to the Arctic in the North. While there is still snow in Lapland, Sicily might already suffer from summer heat. And while it's raining again on the Shetland Islands, Andalusia is going through just another dry spell". As it is generally hotter in the South, insulation must be good but not necessary as thick as in the North. Also triple glazing is not required in most cases."* (ISOVER, 2007b). *"The cardinal points of the compass offer associations of meaning that can enhance architectural experience. EAST: youthfulness, innocence, freshness; SOUTH: activity, clarity, simplicity; West: aging , questioning, wisdom,; NORTH: maturity, acceptance, death. Such associations, while not absolute, can help you decide where to locate various spaces and activities on a site or within a building."* (Baumann, 2010) North vs South also represents the contrasting realities between developed and richer countries (North) and developing countries (South)- Figure 1.12

Figure 1.12 – Contrasting images from North to South: Here poverty from the South (Developed countries) (Source:(Left) http://commons.wikimedia.org/wiki/File:Shimelba_refugee_camp.png; (Right)http://www.coutausse.com/#/photojournalism/zaire-goma-1994/goma-21)

CLIMATES: There are different ways of dividing the globe into climates, from a more specific division - that ends up with many small subdivisions- to a more broad division that includes the bigger differences. *"Even in one and the same country, all kinds of climates can be found"* (ISOVER, 2007b) *"Efficient can be adapted to every climate. […]"* (ISOVER, 2007b). "The problems of environmental sustainability and energy saving are universal and common to all countries and regions worldwide." (Guedes, 2014) The simplest division in climates is dividing the world into climates defined by wider and general features: Polar - very cold and dry all year; Temperate - cold winters and mild summers; Arid - dry, hot all year ; Tropical - hot and wet all year ; Mediterranean - mild winters, dry hot summers ; Mountains; (tundra) very cold all year. Some authors and institutes have different ways of dividing them, but the UK Metereological Institute uses the The Köppen system- developed by Wladimir Köppen.

KOPPEN'S WORK: "The word 'climate' is derived from the Ancient Greek 'klima', meaning 'zone' or 'region'. Different climate zones arise because the Sun heats the tropics much more strongly than the poles. This sets up atmospheric circulation and ocean currents which try to reduce the imbalance by moving heat (the energy cycle) and water (the water cycle) around the Earth. […] The somewhat simplified classification of today's climate zones that you see here is broadly based on the work of

Wladimir Köppen, […] he came up with an idea of classifying the climates around the world […]. It is still used today. The map (Figure 1.13) *shows where the broad zones are located throughout the world, but what might it be like to live in these conditions?"* (MetOffice, 2012). The simple classification that follows is based on his system: *"Equatorial* [Tropical]: *Lying between the Tropics, equatorial climates are home to the world's rainforests, where rainfall and humidity are high. Surprisingly, temperatures are not that extreme, generally 25-35 °C, and vary little […]"; "Arid: Our deserts - the hottest, driest and most inhospitable places on Earth - are found mainly across the subtropical continents. Here, […] cloud-free skies virtually all year round. Annual rainfall is low and, in some deserts, almost non-existent. […] Because they're so dry, the temperature range in our deserts is huge, regularly exceeding 45 °C by day in summer and often falling to below freezing overnight in winter"; "Mediterranean: Low summer rainfall is matched by many months of warm, sunny weather. But, at times, dangerously hot spells of weather engulf the region with fiercely high temperatures of up to 45 °C. In winter, there is more rain and cooler temperatures, but little frost"; "Snow* [Montains]*: In the higher northern latitudes, […] long, hard winters with short, bountiful summers, separated by rapid climatic changes during spring and autumn. The landscape here is contrasting. […] To the north, where summer temperatures are lower, there is the relatively featureless tundra. Typical summer temperatures are around 15 °C but there could already be frosts by August and ice on lakes by September"; "Polar: The poles experience the coldest temperatures on Earth but the two poles' climates are different. The Arctic is mostly frozen ocean, while Antarctica is a vast continent of mountains and high plateaus buried under more than 3 km of ice. The Arctic […] winter temperatures fall to below -60 °C in the coldest regions, while summers range from a few degrees below zero to about 20 °C. Temperatures in the south are colder: winter temperatures often dip below -80 °C. The Antarctic interior is very dry - drier than many deserts"; "Temperate: This classification covers a range of climates from near-Mediterranean climates and humid, sub-tropical zones to maritime climates influenced by the oceans. Mostly found on the western side of continents at 30-45° latitude. Some temperate climates have wet and dry seasons while others have no marked dry season at all. But all have four distinct seasons."* (MetOffice, 2012)

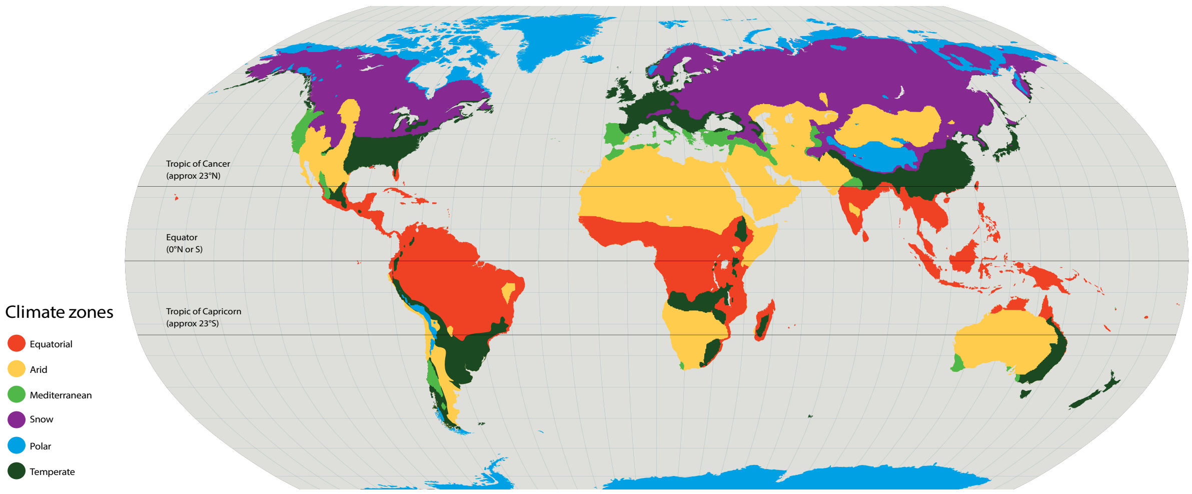


Figure 1.13- Map of different climates. Division of the world and countries into climates may experience a difference from author to author , nevertheless, more general classification is usually similar. In a simplified way : the UK Metereo Office uses The Köppen system (Source: http://www.metoffice.gov.uk/media/pdf/4/d/Weather_and_climate_guide.pdf)

There is not a really definition or concept of what is North and what is South and what their differences are. Many study North and South, then again does it refer to North from the Equator and South from it or even a more local division- north and south within a country or area? Is it geographical or also social? When presented as North vs. South, it emphasizes the contrasting reality beyond “vs.”. One “against” the other. Versus implies differences, comparison and in this thesis it will be studied as extreme situations, contradictory realities, appositive contexts, etc. The intention is to use this expression as the one that relates to contrasting concepts –Shadow Vs light, global versus local, high versus low- and mostly refereeing to locations where features and sense of place is different. Meaning with this that North Vs South refers to the different elements characterizing places. From their social and cultural elements to the way the sun moves, how many hours of sun there is in the summer, how long the day is in the winter, how low and how high the sun gets, how much wind blows, from with direction and at what speed, more humidity or less, if it snows, rains and how much etc. It ends up on being a relation of climate definition not forgetting a sense of that place, that is always present and it is more than geographical and climatic elements- relates to constructions techniques, use of materials, traditions, etc

1.3. INTEGRATED HOLISTIC APPROACH TO SUSTAINABILITY

Disasters are not only the ones concerning the nature or war, but poverty or others. What happens if we think about cases where people constantly live with less? What if we think about Luanda and their “*musseques*”? A big part of the population lives in slums, where constructions do not differentiate so much from what containers provide, but a construction that in the end proves to offer less durable solutions and poorer habitable conditions. *“Those in the developed world are not immune, as extreme temperatures and increased flooding and droughts are expected to expose vast numbers of people to the status of eco-refugee.”* (Ahmed et al., 2011) *“Natural disasters are not really natural […] they are the result of the fragile relations between the natural and the built environment”.* (Lizarralde et al., 2010). There is therefore, an urge to well design buildings from their initial stages. In the book *Rebuilding after disasters – from emergency to sustainability* (Lizarralde et al., 2010), quoted above, it is also stated that the most effective rebuilding does not always only depend on the speed of the reconstruction process but mainly on the crucial understanding of the role and capacities of the different actors involved. Moreover, reconstruction, no matter which type, does not always gain from the separating into phases: permanent, temporary and emergency housing.

“Sustainable design is passive first,” says Duncan Phillips of RWDI. *“If we have to introduce a system to solve something, it’s because we haven’t solved it passively.”* So we need to start with bioclimatic solutions and an integrated design that allows the different areas to be designed and though hand in hand, providing a more holistic result. It is possible to establish a balance between what is built and the climate where it is placed, as Manuel Correia Guedes (Guedes, 2014) refers “*through the use of a number of strategies – referred and bioclimatic or of passive design”*. The focus on passive solutions first restrains the need to plaster the building with expensive and not integrated solutions considered and included too late in the design process. *“The focus areas concerning environmental sustainability are all about creating high thermal comfort (experienced temperature, heating and cooling) visual comfort (light and shading), high air quality (fresh air, removal of pollution, surplus heat etc.) and architectural quality. All these circumstances are affected by the passive qualities of the building, which deals with qualities regarding geometry, design and choice of materials and affect the light, temperature and air in the building.”* (Andersen et al., 2009) Comfort goes beyond standards and numbers. It related also to the

human scale and perception, which can only be given by qualitative methods. Quantitative rely on values, simulations and calculations, rationality, so when putting them together, the result is a holistic approach that becomes more than pre determined rules or standards, but apply those to the human existence and architectural experience.

INTEGRATED DESIGN PROCESS, MIXED METHODS AND INTEGRATED ENERGY DESIGN: Architecture, and the subjects that it covers, is about merging and integrating engineering concerns and architecture values. *"To ensure a healthy and comfortable environment […] the engineer and architect needs to be better at working together from project start so that architecture is optimized […] found in optimized shape of the building, integrated solar protection, proper orientation, use of passive measures, etc."* (Larsen, 2014) It is not enough to simply add elements, rather have the working together: *"The sustainable projects that are completed often achieve their sustainable status by implementation of solar panels, glassed verandas, or low-flushing toilets. However, this does not necessarily ensure sustainability, as the systems in the building do not really work together, and often the users do not use the building as intended."* (Tine, 2005) Architecture can't result only of an addition of parts that are not related or complete each other, but there is a demand for a methodology that will allow a more holistic sustainable architecture, where the whole is made of parts working together. As a far-reaching and widespread field, it needs to extract and transfer methodologies from theories already delineated. The primary method used during this period seeks the combination of Mary-Ann Knudstrup's Integrated Design – learned along the Master at Aalborg University-, partly with Integrated Energy Design and Mixed Methods by Alan Bryman. The methodology chosen intended to help achieve a design that gathers tectonic qualities in daylight and building materials while keeping in mind structure and the building's parts, but also concerns sustainable aspects like social, environmental and economic issues.

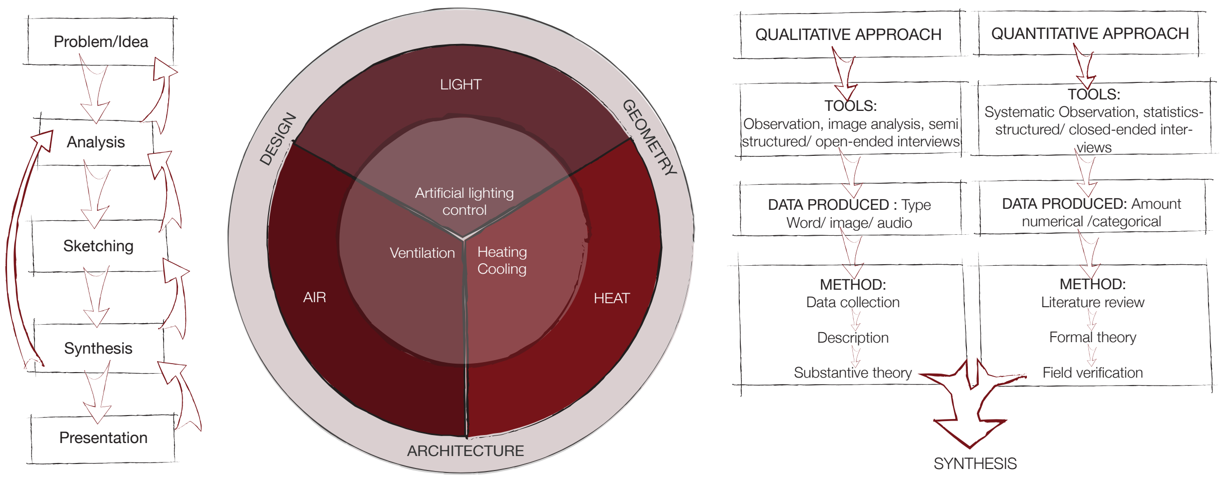


Figure 1.14- Working methods: (left) Integrated Design Process (IDP); (Middle) Mixed Methods; (Right) Integrated Energy Design (IED) (Source: Mafalda Melo Oliveira adapted from (Knudstrup, 2004); Alan Bryman theory ,(Andersen et al., 2009))

INTEGRATED DESIGN PROCESS (IDP): (Figure 1.14, Left) By redrawing inspiration from Mary Ann's method, and working with an the Integrated Design Process, energy consumption, indoor environment, functional aspects, architecture and design can be merged. *"The Integrated Design Process is a synthesis of the pedagogical method (PBL), the students' personal learning efforts, and the professional learning components from architecture and selected components from engineering".* (Knudstrup, 2004) Since the act of designing a building is a very complex process "*Integrated Design Process is combining knowledge from architecture and engineering in order to solve often very* *complicated problems connected to the design of buildings."* (Tine, 2005) From this method, the role that different tools may have in the design process will also be acquired in order to optimize different questions along the way. More specifically connected to the sustainable approach of this work, it is essential to comprehend that the IDP does not secure sustainable or aesthetic solutions. However, due to the various parameters that are included and worked along the process, the designer is able to manage those different parameters, taken into consideration and integrated into the project, in order to create a more holistic architecture and fulfill greater sustainable solutions. "*Maureen Trebilcock proposes that the Integrated Design Process in practice is closer to a C/A model that suggests that designers would propose an idea that is holistic in nature before attempting to do any analysis."* (Tine, 2005)

The approach to this project is the *Integrate Design Process* method, divides into five phases. The phases are not to be followed chronologically, but more iterative by jumping back and forth in-between them, which enables on going evaluation and thereby ensuring a possibility for optimizing the project. The starting point is to initiate a problem which provides the project with an idea of a direction. In the *Analysis Phase* it is necessary to check out how the problem could be solved and which considerations the design should take. In this phase all factual data is collected and different analyses are made, such as a site analysis. Discovering the basic of the problems, the solution starts to take form in the *Sketching Phase*. From here, the final design is emerging and it is also here new problems are exposed, inviting for more analysis. Through this phase, the proposal is hold up against the information from the analysis phase. The *Synthesis Phases* is where the design starts to take its form, in the details, the logistic, the construction, the materials etc. The final solutions for the problems are discovered in the previous phases and it all starts becoming one unity and, by optimizing the parameters, the final design emerges. The final phase is the *Presentation* where all the works are presented. "*The most important thing here is the way the presentation is made to show what is necessary to get an understanding of the developed design*" (Knudstrup 2004).

"The method copes as well with technical as with aesthetic problems that must be solved in an integrated building design, and focuses on the creative element in the process, in order to identify new opportunities and to derive innovative solutions in a new building design. Therefore the architect's artistic approach to the creation of ideas; his ability to see new possibilities and his ability to work in a strategic and interdisciplinary manner, interacting with the engineer's strategic and creative ideas for developing energy and environmental concepts, are very important. Doing this, without losing creativity in the process, is always very important in designing new integrated building concepts." (P. Heiselberg, 2007)

Through designing with the *Integrated Design Process* it is important to remember that not everything can be measured or analysed. Sometimes it is the un-measurable element that could give the design a higher undefined quality, "The aesthetics". It is all about solving the problems with a combination of phenomenological and empiric approaches. Evaluating *"[…] the indoor environment through both quantitative measurements in the houses and qualitative interviews with the occupants about their experiences of the indoor environment. These two sets of knowledge together give a more complete and holistic picture of the indoor environment. The study shows that we need an accentuated focus on the goal to aim for in the design process, the documentation of the designs and on the occupant's life and behavior. Finally, it is important to ''educate'' the occupants to live ''correctly'' to achieve a comfortable indoor environment"* (C. Brunsgaard, Heiselberg, Knudstrup, & Larsen, 2011)

MIXED METHODS: (Figure 1.14, Right) On the other hand, *"the complexity of the topic under assessment and, at the same time, of the system in which it emerges, have led to the implementation of a mixed-methods approach"*. (Castelli, Ragazzi, & Cattaneo, 2014) Even though it is not the main method applied, mixed methods in social research is also crucial - reason to be referred briefly below. *"The amount of cases, where mixed methods – or research that integrates qualitative and quantitative research have been used, has increased since the 80´s[3]. Today you find more publications about the subject e.g. Journal of Mixed Methods Research and more general publications about mixed method in social research e.g. Alan Bryman¹¹, Abbas Tashakkori and Chales Teddlie[4]"* (Camilla Brunsgaard, 2011). The conflict between the quantitative and the qualitative, expressed in Alan Bryman's theory brings qualitative and quantitative conclusions together, allows an insight that cannot be reached in other way. A fusion of these two approaches may help clarify each one, while understanding both. *"Completeness: refer to the notion that the researcher can bring together a more comprehensive account of the area of enquiry in which he or she is interested if both quantitative and qualitative research are employed"* (Bryman, 2008) *"The combination of qualitative and quantitative methods can give more nuanced result of the investigated issues. An example could be: Measurements of the indoor temperature in a room show too low temperatures 25% of the time. The measurement can not give the answers to why the temperatures are too low - Unless we for example have observed that the window has been open, and then suggest that to be the reason. The observation and the measurements only explain how the situation is, but cannot tell why e.g. the window was open."* (Camilla Brunsgaard, 2011) The Qualitative and *qualitative approaches rely on gathering information and data that will, at a later stage, complement each other.* *"The key issue is whether in a mixed methods project, the end product is more than the sum of the individual quantitative and qualitative parts."* (Bryman, 2007) Qualitative works with questionnaires, interviews, observation, etc and produces audio, imagines and words as data, while quantitative focus on collection data through official statistics, analysis and is a closed-ended structured approach producing numerical and categorical data. The benefits from working with Mixed methods, besides others: *"Gives researchers an opportunity to creatively rethink research design and the various different ways they can be linked to research questions"*; *"Challenges taken for granted assumptions across a wide range of research methods topics"*; *"Potential to generate new insights and levels of analysis"* (Bergman, 2008). Architecture is about combining engineering of construction with aesthetics. This leaves a conflict between the qualitative and quantitative. The scientific method of the project draws inspiration from the combination of phenomenological and empiric methods. *"In a case study design both qualitative and quantitative methods can be used, which means that many kinds of data can be collected through e.g. interviews, surveys, observations, documentation etc"* (Yin 2005). *"Architects and engineers need to acquire qualitative and quantitative information about the interactions between building characteristics and natural ventilation in order to design buildings and systems consistent with a passive low-energy approach."* (P. K. Heiselberg, 2006)

INTEGRATED ENERGY DESIGN (IED) (Figure 1.14, Middle) Lastly, another method taken in consideration and was used as a design decision, related to the fact that from the initial decision taken in the design, one of the most important things was to use only passive solutions and evaluate until what

3 (Bryman, 2008) Bryman, A. (2008) Social Research Methods. Third edition, Oxford: Oxford University Press.

4 Tashakkori, Abbas and Teddlie, Charles B (2009) Foundations of Mixed Methods Research : Integrating Quantitative and Qualitative Approaches in the Social and Behavioral Sciences. Thousand Oaks, Sage Publications, California.

extend those measures would fulfill reasonable comfortable values*. "In a Integrated Energy Design process focuses firstly on achieving as much comfort as possible through the passive qualities, (second circle of the chart). Subsequently, focus will be on supplementing with as few but efficient active qualities as possible in terms of installations, adjustments and other technical systems (Inner circle of the chart)"* (Andersen et al., 2009) *"Passive solar heating is one of several design approaches collectively called passive solar design. When combined properly, these strategies can contribute to the heating, cooling, and daylighting of nearly any building. The types of buildings that benefit from the application of passive solar heating range from barracks to large maintenance facilities. Typically, passive solar heating involves: The collection of solar energy through properly-oriented, south-facing windows; The storage of this energy in "thermal mass," comprised of building materials with high heat capacity such as concrete slabs, brick walls, or tile floors; The natural distribution of the stored solar energy back to the living space, when required, through the mechanisms of natural convection and radiation. Window specifications to allow higher solar heat gain coefficient in south glazing."* (Fosdick, 2012)*"Passive design responds to local climate and site conditions in order to maximise the comfort and health of building users while minimising energy use. The key to designing a passive building is to take best advantage of the local climate."* (Taleb, 2014) To reach a good design with both high tectonic and sustainable qualities, it is essential to reflect on the contrasting features of the rational, technical and scientific versus artistic and immeasurable.

It is very important that the project is developed as an iterative process where the methods complement each other to create a design that is perceived as a unity. The engineering aspects of the project have an empiric-analytic approach where hypothetical deduction is used to approximate the best constructional solution. During the sketching phase, when energy frame and the indoor climate conditions are described and clarified, the design is defined shaper and better compared to a project where only part of the parameters are defined, artistic parameters or engineering, for example if the project is more with an artistic setting. If, for example, the climate screen of a building is optimized, then the economic part will also improve, due to the fact that, the building's operating costs will be minimized, energy for cooling and heating can be saved.

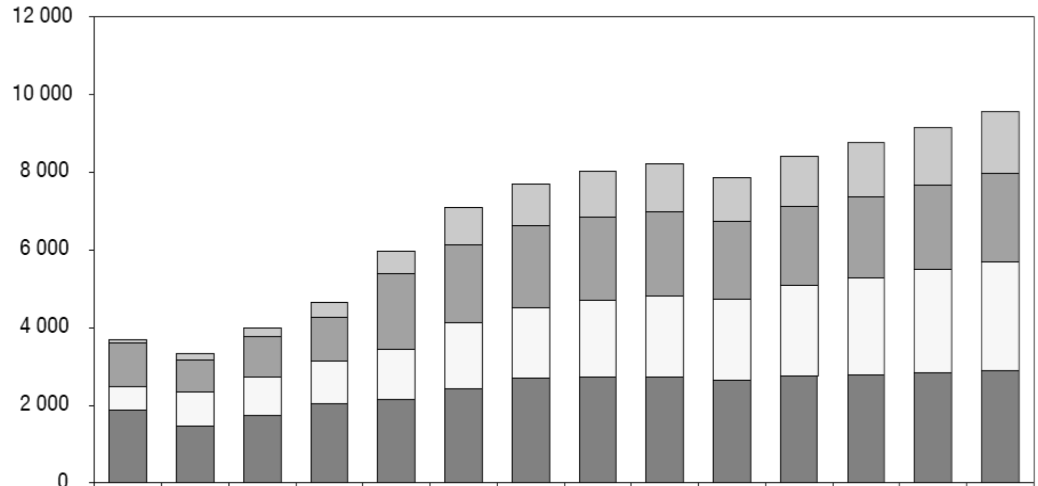
1.4 SHIPPING CONTAINERS: FROM A BOX TO HOUSING UNITS (More in annex 1)

Shipping containers have been used more and more in the past years and some examples of housing units or office blocks, do deserve to be taken as serious examples of good architecture. Even though, in some projects, shipping containers have been used due to trends and sometimes not taking full advantage of their features, they can still be very valuable structures for housing purposes.

HISTORICALLY –SETTING STANDARDS: *"Containers were the talk of the transportation world by the late 19 50s. Truckers were hauling them, railroads were carrying them, Pan-Atlantic's Sea-Land Service was putting them on ships, the U.S. Army was moving them to Europe. But "container" meant very different things to different people. […] This diversity threatened to nip containerization in the bud. If one transportation company's containers would not fit on another's ships or railcars, each company would need a vast fleet of containers exclusively for its own customers. A European railroad container could not cross the Atlantic, because U.S. trucks and railroads were not set up to handle European sizes, while the* *incompatible systems used by various American railroads meant that a container on the New York Central could not readily be transferred to the Missouri Pacific. So long as containers came in dozens of shapes and sizes, they would do little to reduce the total cost of moving freight. […] In 1965 gave way to the standard sizes approved internationally. […] Finally, it was becoming possible to fill a container with freight in Kansas City with a high degree of confidence that almost any trucks, trains, ports, and ships would be able to move it smoothly all the way to Kuala Lumpur. International container shipping could now become a reality*." (See annex 1 Standard Shipping Containers); "*The world's cargo carrying fleet in 2011 is 55,138 ships of 991,173,697 GT and 1 ,483,121,493 dwt and the average age is 19 years. In January 2011, there were 103,392 commercial ships in service with a combined tonnage of 1,396 million dwt. The containership fleet reached 184 million dwt in January 2011(8.7% over 2010)"* (Centre Maritime Knowledge, 2012) .

*Dwt: Deadweight: the weight a ship can carry when loaded to its marks, including cargo, fuel, fresh water, stores and crew; **GT: Gross ton: internal measurement of the ship's open spaces.

"Driven in particular by a rise in China's domestic demand as well as increased intra-Asian and South–South trade, international seaborne trade performed better than the world economy (Figure 1.15) *[...]. About 9.2 billion tons of goods were loaded in ports worldwide […]."* (UNCTAD United Nations Conference on trade and development, 2013) More information , see annex 1.



	1980	1985	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013
Container	102	152	234	371	598	969	1 076	1 193	1 249	1 127	1 275	1 421	1 480	1 578
Other dry cargo	1 123	819	1 031	1 125	1 928	2 009	2 112	2 141	2 173	2 004	2 027	2 084	2 184	2 300
Five major bulks	608	900	988	1 105	1 295	1 709	1 814	1 953	2 065	2 085	2 335	2 486	2 665	2 786
Oil and gas	1 871	1 459	1 755	2 050	2 163	2 422	2 698	2 747	2 742	2 642	2 772	2 794	2 836	2 904

Figure 1.15 - International seaborne trade, selected years (Millions of tons loaded) UNCTAD Review on Maritime Transport (Source: UNCTAD United Nations Conference on trade and development, 2013)

Container boats can transport a very large number of goods across the seas and around the world. For example, Maersk Triple-E (Figure 1.16) is the largest ship and best mean of transportation for container (or generally any big amount of goods). It is able to carry, not only a lot more units and goods than any other- nowadays up to 18 000 TEU[5]- but it is also competitive due to its environmental improvement. With this new ship, Grams of CO_2 emitted by transporting 1 ton of goods 1 km are down to 3g while by ferry, truck and plane it would go up to 18g, 45g and 560g, respectively – for the same 1 ton, 1km rule. (Information taken from Maersk Line webpage (Maersk Group, 2014b).

[5] TEU: Twenty foot equivalent unit

Figure 1.16 – Maersk (and World's) biggest container boat, Triple E has a capacity of 18 000 TEU. Triple E stands for Efficiency, Economy of Scale and Environmental improved. A lot of houses would be given to a community if the boat would transport some housing units among other common shipping containers with goods.
(Source: http://www.maerskfleet.com/#vessels/Maersk_Line/Triple-E)

REASONS TO USE SHIPPING CONTAINERS AS HOUSING UNITS: There are several reasons why containers are a reasonable and realistic choice skeleton for housing purposes. The author Jure Kotnik describes the reasons why shipping containers are not only interesting but logical choices: *"Containers have many characteristics that make them convenient for use in architecture. They are prefabricated, mass-produced, cheap and mobile.* (Table 1.1 and Figure 1.17 for some more common standard containers) *Because they are compatible with practically every transport system, they are easily accessible all around the world. They are strong and resistant, while also being durable and stackable. They are modular, recyclable, and reusable"* (Kotnik, 2008)**.** AVAILABILITY: Containers are available in large- sometimes excess- quantities around the world. They are cheap relative to other construction materials, if they are not actually for free, in all those cases when found abandoned. There are containers dumped around the world due to the shipping industry itself: *"Since the majority of the world's goods are manufactured in the Far East and shipped to the West, Western countries import far more containers than they export. It costs approximately $900 to ship back an empty container to where it came from, which means that it is usually easier to buy a new container in the country of origin rather than ship them back from the Western countries"* (Kotnik, 2008) .

Some of the shipping companies' decisions around the world, expressed above, have been responsible for hundreds of thousands of empty, sometimes barely used containers that are then sold by port operators for very low prices. At some places, these containers can even be for free, when left behind and not reclaimed as someone's. (Annex 1 - World Container Traffic by Destination Region 1989-96)

Table 1.1- Most common standard container measures and capacity: 20 and 40ft Dry Standard Shipping Container

Length (exterior)	Width (exterior)	Height (exterior)	Length (interior)	Width (interior)	Height (interior)	Capacity (interior)
20 ft (6.05 m)	8 ft (2.44 m)	8 ft 6 in (2.59 m)	19 ft 4 in (5.90 m)	7 ft 8 in (2.35 m)	7 ft 10 in (2.39 m)	1 172 cu ft (33.2 m^3)
40 ft (12.19 m)	8 ft (2.44 m)	8 ft 6 in (2.59 m)	39 ft 5 in (12.04 m)	7 ft 8 in (2.35 m)	7 ft 10 in (2.39 m)	2 390 cu ft (67.7 m^3)

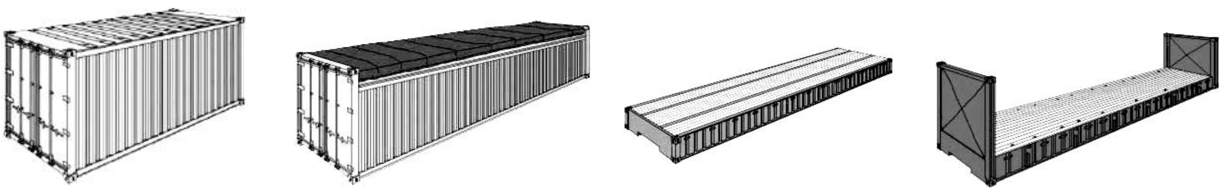


Figure 1.17- Most common shipping containers (Left to right) Dry Standard / High Cube; Open Top; Platform ; Flat track (Collapsible or not) (Source: http://wifc.ge/documents/1.html) -More on container specifications and features in annex 1

MODULARITY: There is also another reason or motivation for utilizing shipping containers as housing skeleton and building element: their modularity. They remind giant Lego pieces- that can be put together and arranged in vary different ways. Modular construction gives the chance to a low cost and easier construction, since most of the "pieces" that are used for the building can be assembled within the container in an off site location- those being mass produced can be stored and used when necessary. Furthermore, the modified units- the containers- can be moved and transported to the construction site where needed, depending on the vast logistic and infrastructure of transportation already available and fully working nowadays.

COST: Once the majority of the work – assembled parts- is finished earlier at an off-site location, the work on the site is considerably decreased, what allows the cost to decrease. Moreover, all the containers can receive the same design (case 2, with some minor changes) that can be always applied inside, leading to an efficient construction process that also helps in the reduction of costs.

EXCAVATION: *"Also, construction projects with containers typically use no groundwork excavation processes, are quick to set up and complete, and generate less waste than traditional construction projects".* (Kotnik, 2008) Keeping in mind that renewable resources and energy efficiency are in the vanguard of the world's reflections and awareness, containers fit the call for efficient construction materials. Besides this and inspired by Glenn Murcutt, containers can gently touch the ground only and not damage it. Because there is no deep excavation, the soil and the surrounding trees are protected. Figure 1.18

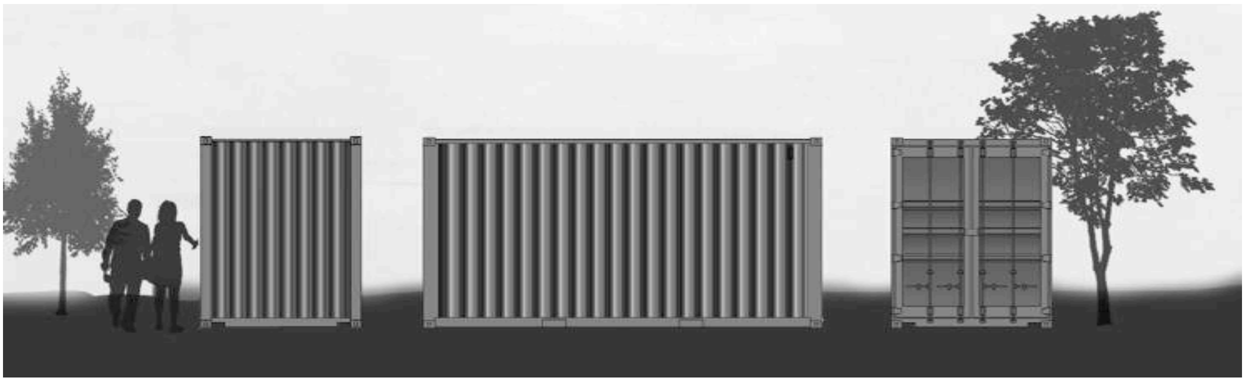


Figure 1.18 - Illustration: The 20ft High Cube shipping container (Source: Mafalda Melo Oliveira, 2014)

CONTAINERS TERMINOLOGY AND STRUCTURE: *"On some ISO shelters, some of the primary structural components may be concealed within the wall, roof, and floor panels*". The primary structure is constituted by the 8 corner standard fittings (casting) *"to provide means of handling, stacking and securing containers"* – and Corner Posts- *"Vertical structural member located at the four corners of the container and to which the corner."* (Department of Defense - United States of America, 2002) -See annex 1 for detailed terminology on structure.

CONTAINERS PROBLEMS AND LOGISTICS: Paul Sawyer in his report "Intermodal Shipping Containers for use as Steel Buildings" (Sawyers, 2005) states: *"Air ventilation is a primary concern for anyone utilizing a shipping container for shelter. The locking steel doors can be a great deterrent to would-be thieves, vandals, and also mother nature […] Containers are by their very nature, mobile. Thanks to the increasing number of transport companies, units are now available just about anywhere. Drop delivery operations require fair road access (gravel or dirt is ok), and a 75' cleared area. It is possible to purchase a container from one source, and have another trucking company pick it up*. […] *For the container purchaser who only requires the unit delivered to a firm surface, at the end of a easily accessible road (for a delivery truck), the process will be easy."* He still adds: *"An obvious problem you* *will encounter as a container builder; filling the gaps around door and window frames. You can also use expanding foam. A gable roof can help prevent heating via the sunrays, but the best defence against condensation or 'container sweat' is constant use of your building. If you are in and out, opening doors and windows, providing lots of ventilation, you probably will not experience much of a problem. Still, it is a good idea to take a lesson from the many seasoned boat and RV owners, and install a series of small closeable vents for those times when you can't be there to open windows yourself. These vents can be un-powered, or powered with small AC or DC motorized fans, and all should have a seal or louver that can be closed in cold weather".* (Sawyers, 2005) *"Corner posts of all containers are known to have been tested, a safety factor of about 1.5 is adequate for a stack of containers on land.* Table 1.2 *shows the safety factor on the corner post loading of the bottom container in a stack, for stacks of various heights. This table is based on the application of the equation for safety factor, with Fcp-fail = Fcp-proof = 190,480 lbs, and containers of 52,910 lbs gross weight. The table shows that we can stack 9-on-1 on land, and maintain a safety factor of greater than 1.5"* (J. Cooper et al., 2003)

Table 1.2 - Safety factors on land for various stack heights on land with container corner post capacity of 86 400 kg (Source: Mafalda Melo Oliveira, 2014, adapted from (J. Cooper et al., 2003)

Number of container stacked on one	Total height of stack	Safety factor on corner post loading
8	9	1.80
9	10	1.60
10	11	1.44
11	12	1.31

POSSIBLE CONTAINER HOUSE TYPOLOGIES- FROM A BOX TO A HOUSE: In the arranging of the building mass on the site, the focus of optimal use of the square meters is one of the first priorities, this still while the users are in focus. By building more compact, it creates possibility of using the area better together with a decreasing the use of transportation and a reduction of the resources for running the building. Building with a higher density can result in less open spaces for privacy on ground level and therefore spaces above ground level has to be included to create intimate spaces, but at the same time the energy consumption can be reduced by having less envelope area. Table 1.3 and Figure 1.17: The three most common typologies there are examined, the urban villa, the slab and the urban block. (Pedersen, 2009)

Table 1.3 – Housing typologies: from the container box to a habitable volume (Source: Mafalda Melo Oliveira, 2014, Based on (Pedersen, 2009))

Typology	Description	Density study	Obtained by
URBAN VILLA (Fig.1.16 Left)	With the possibilities of individuality, this type of typology can create diversity between the buildings where the opportunity for different kind of use is possible. Because of the spread of this typology the individuality often shines through, but this spread can also result in isolation from the community. In the contents of the city the surrounding areas has to have some size to make the user comfortable. The planning of the open spaces is controlling the privacy for the residents and how the common spaces are. If it is more open for the public the life in the area is increased, while the privacy is minimized. By changing the orientation of the typology different open spaces will appear with different directions. It is a relative open plan which makes it hard to create shelter against the wind without any implementation of extra shelter-giving effects. (Pedersen, 2009)	The typology was spread out on a possible site and because of the grid the spaces between the buildings turn into the same size as the volumes.	Putting together two containers side by side – parallel on the long side- and space in between (outside corridor)
SLAB (Fig.1.16 Middle)	This typology has a clear direction and it often looks organized with a clear rule of placement. This structure is giving an open space that can be used for both private and common spaces. But the narrower the space becomes the less private it becomes and the privacy will take place above ground level. The spaces between	As the urban vila this typology was also spread out on the site, though creating more open spaces	Keeping one container standing alone.

	the volumes will also function as a distribution area where the residents get guided to their destination. With all these functions the spaces will be occupied a lot. (Pedersen, 2009)	than the urban villa due to the density of the building volumes	
URBAN BLOCK (Fig.1.16 Right)	This typology is often related to the city center where the enclosed shape is creating a shelter for the more private human activity but also shelter against the weather. The courtyard has a clear distance to the city as an enclosed space for the residents. It has to have a certain size for not to get a claustrophobic feeling. In this clear form, the typology is creating the need for other open urban spaces beyond the boundaries to create some activity in the surrounding areas. Often this typology has a unity in the arrangement of the apartments despite the orientation, e.g. that the kitchen always are placed towards the courtyard regarding the sun and view. (Pedersen, 2009) *"This is significant in energy terms because heating energy is related to external wall area and window area. Flats tend to have less external wall area compared to their floor area (so have less heat loss in winter), while detached houses typically have more external wall and more windows than equivalent homes of other types".* (I. Cooper & Palmer, 2011)	The city would be more dense and compact, as a lot more dwellings or other function buildings could be placed in such a big building mass. Since there are some spaces within the buildings, the space between the buildings can be taken in consideration in a slightly different way,	Three containers put together and creating a shape with a courtyard inside.

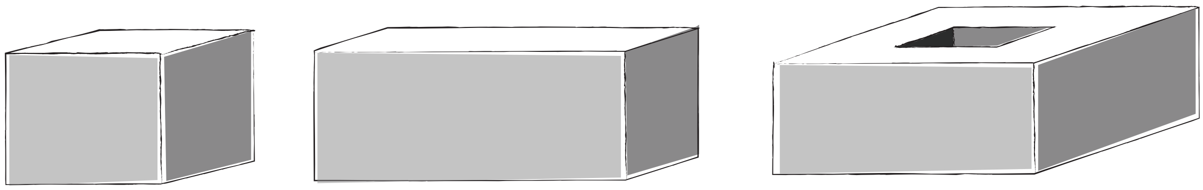


Figure 1.19- Building typologies: (From left to right) Urban villa, slab and urban block . (Source: Mafalda Melo Oliveira, 2014 based on (Pedersen, 2009))

RETHINK RECYCLING- REDUCE/ REUSE / RECYCLE: *"The end of the '60s saw the arrival of a counterculture, mostly in the west of the US. Its protagonists established complete idealist villages with peculiar self-wrought shelters. Designer Victor Papanek, famous for his book 'Design for the Real World', advocates the reuse of waste and simple technology to be applied in Third World countries. The cover of his most famous book shows a radio entirely made out of waste materials. These days reuse and recycling are accepted strategies. In the case of buildings, reuse can work very well if it involves waste from the immediate surroundings, because obviously that minimizes transportation. Recycling is a useful way to cleanse the cycle of production and disposal. The disadvantage of recycling, however, is that the value that was created before in useful buildings or products is entirely demolished to be created all over again. Both destroying and reproducing involve effort and consume energy, which can be quite inefficient. Sustaining added value over a long period of time can in many cases be a smart alternative to the shredder."* (Neelen, Hinte, Vink, & Vollaard, 2003). If one does not have the need to keep or use something that was his, it can be passed through until it reaches someone in need. There is no need to produce new when old can be converted into new, through recycling: economically , environmentally and mostly socially. *"Prefabricated informal housing: Architects and urban planners interested in reconstruction have much to learn from the way in which the informal sector produces buildings for the poor. This informal sale of prefabricated shacks in the townships of South Africa* (figure 1.18) *delivers prefabricated housing solutions that can be customized and installed in 30 minutes. Using recycled materials and a simples technology, these solutions are well adapted to the needs of a sector of the population for which no architect has been able to produce a viable, large-scale solution."* (Lizarralde et al., 2010)

REUSE: *"Units that were used for temporary housing may be reused for another purpose, even at another location. […] The steel structure allowed the building to be easily transported, and the interior partitions could be removed or reconfigured to allow for flexibility in interior spaces. […] The reuse of temporary housing in a new location of course requires more investment because there are costs associated with taking down the units, transporting them and reassembling them. Furthermore, the units must be designed with flexible interior spaces to accommodate different functions and must be strong enough to withstand the move".* (Lizarralde et al., 2010). Once the lifespan of a temporary house is over, that unit can be collected, refurbished or fixed if there is a need for that, stored and used on the next emergency. Parts of those units, such as doors, windows or other, can also be useful for permanent rebuilding, if the whole cannot be reused or saved. – Figure 1.18

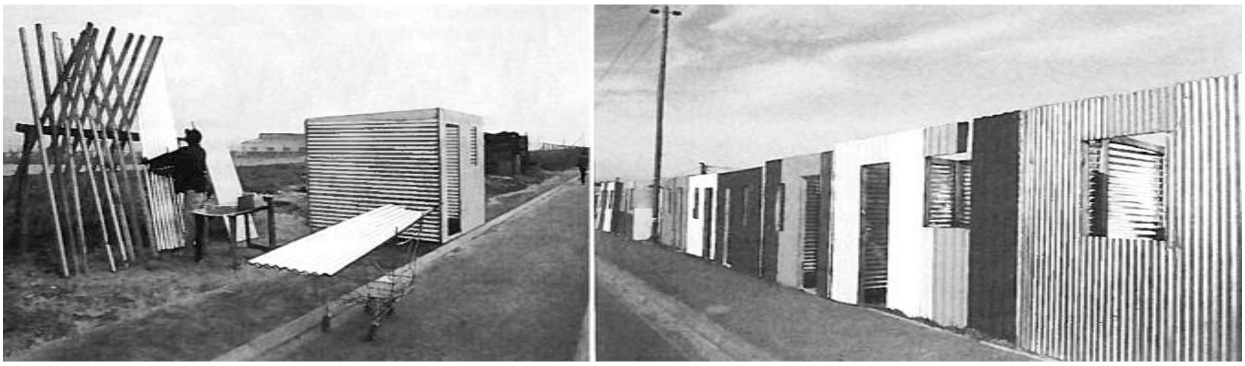


Figure 1.20- Informal shacks in South Africa (Source: (Lizarralde et al., 2010))

Figure 1.21 – (Left above and Right) Villa Welpeloo a house mainly built out of demolition materials and manufacturing residues. It is a smart example of how the topic of recycling can be developed into a unique and elegant architectural style. To decrease the carbon footprint even more, all the materials were sourced within a nine mile radius of where the home stands. Through a process the architects call recyclicity (rather than the more commonly used term of salvaging), 60% of the exterior and nearly 90% of the interior are composed of reused and repurposed materials. (Left bellow) Sustainable Bamboo Dome : The base of the self-standing shelter was made from gas pipes from a local shop, ensuring the structure can be move to another location if required (Source: Villa Welpeloo: http://www.archello.com/en/project/villa-welpeloo ; Dome: http://inhabitat.com/iranian-architect-builds-sustainable-bamboo-dome-from-bamboo-and-dry-rice-plants/pouya-khazaeli-parsa-bamboo-and-rice-dome-iran-2/?extend=1**)**

"Temporary housing is continually deployed after disasters so that families have a place to live, in dignity, until permanent housing is built. In a large- scale disaster, the number of people affected, the amount of damage to infrastructure and the overwhelming demand for building materials, contractors or even building permits can mean that permanent reconstruction takes time, at least several months and perhaps, a couple of years." (Lizarralde et al., 2010). Types of temporary housing requiring new construction include: Self-built shelters, where *"families themselves build a temporary shack out of available materials"* (Lizarralde et al., 2010); Tents, wallet friendly, easily and fast erected are usually provided by organizations or military just after the disaster before getting into the phase of temporary housing. However, due to their low quality, they might not be suitable for longer time span; shipping containers or mobile homes, concerning structures delivered to the disaster areas assembled off site, used and recuperated for other disasters at another stage; Lastly temporary housing units *"self contained houses, often constructed with prefabricated parts. […] Each unit usually includes kitchen and bathroom facilities or facilities are shared between a few adjacent units."* (Lizarralde et al., 2010)

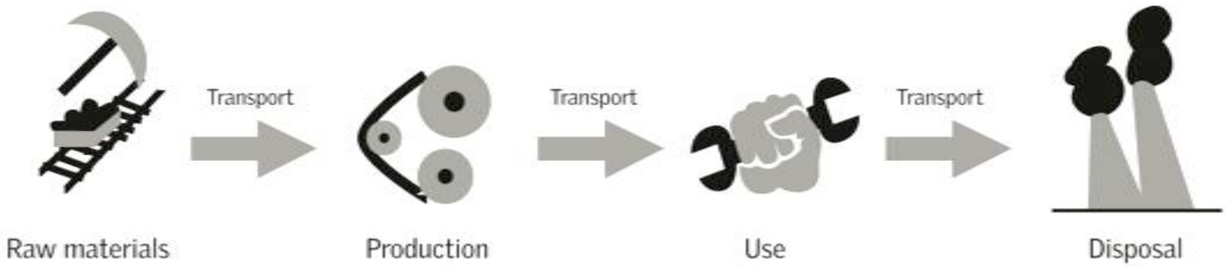


Figure 1.22 - The different phases in an LCA. (Source: (Velux Group, 2010))

Steel does use a lot of energy to be produced and it is easy to contest that it is not a sustainable option, but due to the LCA[6], a material or element life cycle does not confine to its production, rather, it includes transport, use and disposal also. In this sense, it only makes sense to consider options to delay the cycle, and allow use to be spread over a longer time span*. "The essence of an environmental assessment is to identify environmental impacts throughout a product's life, from the first raw material to disposal of the product. […] Life cycle analyses (LCA) is used to evaluate the environmental impact of e.g. a product from raw material, production, use, disposal and transport. A full LCA results in an inventory of the global, regional and environmental impacts of the product, e.g. green house gasses including CO2. (*Figure 1.20) *The CO2 equivalents impact is sometimes called a Carbon footprint and is typically assessed in tons or kg of CO2 While LCA looks at the life of a product from cradle to grave another assessment model called Cradle to Cradle goes a step further. The philosophy of Cradle to Cradle is different from the LCA philosophy, with a main difference being that waste materials are considered as resources for the next product"* (Velux Group, 2010) The intention is to delay the grave and allow resources to be fitted for the next product.

CORE HOUSES: *"One of the most sustainable ways to design temporary housing is through an approach in which the basic unit used for housing families in the emergency becomes the "core" for a larger permanent house. The initial base unit may contain the plumbing and electrical services and a small amount of living space onto the unit, as well as a more formal entrance, a veranda or storage rooms. This model works well in rural, peri-urban settings or anywhere where the family has their own*

[6] A model to assess the environmental impact of a specific process or product.

plot of land on which to build. It allows the family to expand the house to meet their needs and within their budget. This approach becomes more complicated if a family is landless; in some cases, the temporary house can be moved later to a plot of land where the family can stay permanently." (Lizarralde et al., 2010) What makes a good temporary housing program? According to the book, "Rebuilding after disasters (Lizarralde et al., 2010)" , some of the key concerns for planning temporary housing are: quickly available, comfortable units, not too expensive, if it has been product of reuse, maintains social networks, convenient location and integrated with overall reconstruction strategy. Within those elements, some stages need to be planned in advance. Appropriate design for environment and culture – comfortable unit-, offer of basic accommodation and possibility to recycle units to another use – not too expensive - and lastly figure out how long those houses will be needed for and estimate a budget for the housing units, are some of them. Respectively, those measures to be planned, relate with comfortable units, not too expensive and an integrated reconstruction. (Figure 1.21)

Figure 1.23 - (Left) Front view of the house; (Right) Side view of the housing showing the shipping container, Duzce, Turkey (Source: Book "Rebuilding after disasters" (Lizarralde et al., 2010))

COST: *"One of the problems with temporary housing programmes is that they are extremely expensive in relation to their lifespan. The cost for building the unit, maintenance and finally de-installation may amount to almost as much per square meter as permanent housing (as found by Geipel).[…] The cost is very much related to the unit design and choice of materials. The most important aspect of the design is that it provides a private and safe place for the family to go about their daily activities. However, what can be considered an appropriate design and level of comfort is very much dictated by local housing standards."* (Lizarralde et al., 2010) Concerning temporary housing, while on one hand in some countries an access to bathroom (if possible to be private) and a kitchen in a wooden unit, is enough, on the other hand , in others- such as developed countries- it might be too little. In those countries, high quality prefabricated solutions are usually supplied by FEMA. *"The large expenditure on temporary housing can be offset if the design of the unit allows for reuse for another function after the unit is no longer used or needed"* (Lizarralde et al., 2010) The inside can be kept as flexible as possible to create not only a compact living are but also a adaptable space using minimal area. (Cost overview on the solution is provided at a later state when analysing the economic sustainable feature of the solution).

2

SERVICE, COMFORT AND EXAMPLES.

2 SERVICE, COMFORT AND EXAMPLES

2.1 SERVICE AND COMFORT

2.1.1 HUMAN BASIC NEEDS

BACK TO BASICS-HUMAN RIGHTS: For some time now, some architects, constructors, philosophers, or ordinary people have been looking back to the very basic structures existing along human evolution. Human evolution and design shape each other. When buildings are plastered with unnecessary and redundant elements, people tend to forget what is actually necessary to survive. What is needed and essential? The basic is forgotten, what is really needed is hidden and human beings are constantly being blinded by what is desired and superfluous. What happened when instead of choosing to live with less, someone is put into a situation where there is nothing to be done, where money doesn't exist, where everyone is equal? *"Scientists are to outline dramatic evidence that global warming threatens the planet in a new and unexpected way – by triggering earthquakes, tsunamis, avalanches and volcanic eruptions."* (McKie, 2009) "Water is essential for life, health and human dignity" (Red Cross, Red Crescent Movement, & NGOs, 2013)

HUMAN RIGHTS: "*Human rights are rights inherent to all human beings, whatever our nationality, place of residence, sex, national or ethnic origin, colour, religion, language, or any other status. We are all equally entitled to our human rights without discrimination. These rights are all interrelated, interdependent and indivisible. Universal human rights are often expressed and guaranteed by law, in the forms of treaties, customary international law, general principles and other sources of international law. International human rights law lays down obligations of Governments to act in certain ways or to refrain from certain acts, in order to promote and protect human rights and fundamental freedoms of individuals or groups."* (United Nations Human Rights, n.d.) *"The emphasis on making the poor more productive has remained an important component of the basic needs approach. Its distinct contribution consists in deepening the income measure of poverty by adding physical estimates of the particular goods and services required to realize certain results, such as adequate standards of nutrition, health, shelter, water and sanitation, education, and other essentials."* (Streeten, Burki, Ul Haq, Hicks, & Stewart, 1981) *"All peoples, whatever their stage of development and social and economic conditions, have the right to have access to drinking water in quantities and of a quality equal to their basic needs"*. (United Nations, 1992)

If thinking for example about natural catastrophes – occurring more and more on an scary accelerated rate- what happens if from one moment to another life takes everything from us? What happens if the materiality, the comfort, the "too much" is not available? To design is crucial to take in consideration human basic needs. The Australian architect Glenn Murcutt is an example of this "going back to basics", through his designs that relate and focus on basic human needs together with the character of place. He is able to exemplify a dwelling in its simplest forms and designing, in his words, should go through : Use Simple Materials , touch the Earth Lightly, follow the Sun, listen to the Wind.*"To meet the basic human needs, natural materials such as wood and stone to build shelters have already been used for thousands of years"* (Kandachar, 2014)

"The satisfaction of human needs and aspirations in the major objective of development. The essential needs of vast numbers of people in developing countries for food, clothing, shelter, jobs - are not being

met, and beyond their basic needs these people have legitimate aspirations for an improved quality of life. Sustainable development requires meeting the basic needs of all and extending to all the opportunity to satisfy their aspirations for a better life. Living standards that go beyond the basic minimum are sustainable only if consumption standards everywhere have regard for long-term sustainability. Meeting essential needs depends in part on achieving full growth potential, and sustainable development clearly requires economic growth in places where such needs are not being met. […] Hence sustainable development requires that societies meet human needs both by increasing productive potential and by ensuring equitable opportunities for all." (World Commission on Environment and Development, 1987b)

Design is a meditation between an interior experience – within space and ourselves- and the exterior world from which the temporary house will work as a shelter.

Organisations, such as Humanitarian, define also human basic needs and try to use those when meeting their objectives in their actions: The sphere project – or 'Sphere' – was initiated in 1997. *"They based Sphere's philosophy on two core beliefs: first, that those affected by disaster or conflict have a right to life with dignity and, therefore, a right to assistance; and second, that all possible steps should be taken to alleviate human suffering arising out of disaster or conflict. Striving to support these two core beliefs, the Sphere Project framed a Humanitarian Charter and identified a set of minimum standards in key lifesaving sectors: water supply, sanitation and hygiene promotion; food security and nutrition; shelter, settlement and non-food items; and health action."* (Red Cross et al., 2013)

Transcendent to all definitions, santitation and water are essential in order to provide the minimal to live with. Proper sanitation, according to The World Health Organization, is: *"Sanitation generally refers to the provision of facilities and services for the safe disposal of human urine and faeces. "The word 'sanitation' also refers to the maintenance of hygienic conditions, through services such as garbage collection and wastewater disposal."* Other authors relate basic services as essential for well being: *"For urban dwellers affordable access to improved secured accommodation and basic services such as water and sanitation is essential for well-being."* (Mitlin et. al., 2013)

"Even in the short-term there is considerable scope for improving basic needs performance by the better management of resources" (Streeten et al., 1981). Human basics needs are also strictly related to a sustainable development through sociality: *"To clarify what might be meant by the term social sustainability and highlight different ways in which it contributes to sustainable development more generally. We present a threefold schema comprising: (a) 'development sustainability' addressing basic needs, the creation of social capital, justice and so on; "Social sustainability has three components. 'Development' social sustainability, is concerned with meeting basic needs, inter- and intra-generational equity, and so on."* (Vallance, 2011);

ABRAHAM MASLOW –HUMAN NEEDS*:* The two lowest levels of the pyramid concern human most basic needs, according to Abraham Maslow's well received hierarchy. Even though not all agree with his theory, it is generally well accepted and used. (Figure 2.1) *"The first level, at the bottom of the pyramid, consists of our short-term basic needs, also known as physiological needs: food, water, warmth, and sex. The second level consists of longer-term safety needs: security, order, and stability. Are important to the physical survival of the organism. Then, once we have our basic physical and safety needs sorted, we feel more ready to share ourselves with others and accomplish things in the world"*. (Barry, 2010)

Here are certain conditions, which are immediate prerequisites for the basic needs satisfactions. Danger to these is reacted to almost as if it were a direct danger to the basic needs themselves. Authors' interpretation for this pyramid is different. In "Abraham Maslow's 'The Needs Hierarchy': *"Physiological needs are the biological needs of the human being for air, water, food, shelter and so on. These are the needs that human being will seek for and satisfy before the other needs in the growth needs will emerge. Physiological needs are the human instinct to survive. Human tends to have the hoarding behaviour such as eating or drinking too much because they are afraid that they might not have another meal next time".* (Yahaya, n.d.), in "Abraham Maslow hierarchy of needs: A Christian perspective": *"Physiological needs: These are the basic body needs for continued existence, such as food, water, and air. People deprived of these needs will seek to satisfy them by any means possible, including working for slave wages, begging, and stealing. Safety needs: To grow and learn we need to feel secure in our lives and jobs. We need certain stability in our lives. We need some structure and order in our everyday living such as a safe place to rest our heads and nourish our souls, a "territorial" place that is ours, were we are safe and warm. A castle of protection, as it were."* (Pfeifer, 1998)

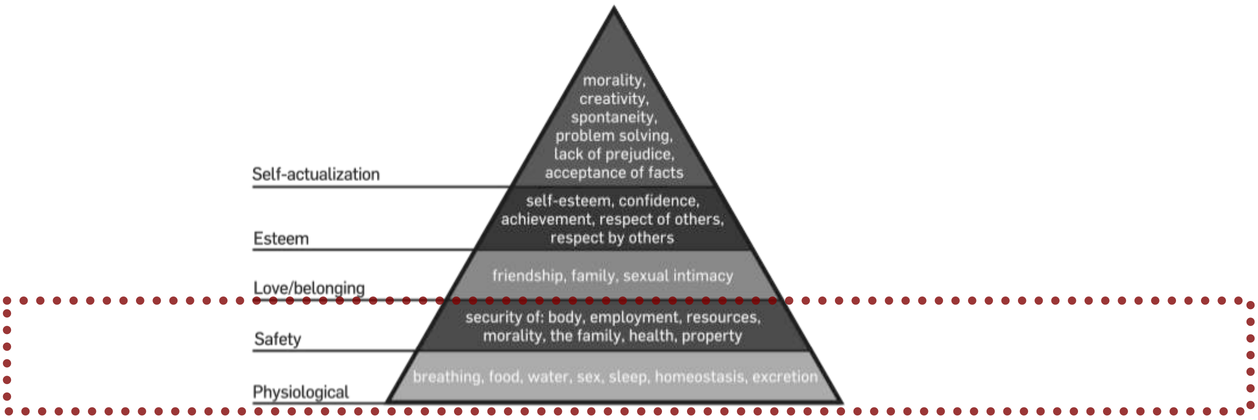


Figure 2.1. - Abraham Maslow's hierarchy of needs, represented as a pyramid with the most basic needs at the bottom (Source: Internet - http://commonswikimedia.org/wikiUser:J._Finkelstein)

2.1.2 COMFORT: INDOOR CLIMATE AND AIR QUALITY

HISTORICALLY: *"We spend most of our time indoors. Yet, the indoor environment is discussed much less than the outdoor environment. Buildings provide shelter, warmth, shade and security; but they often deprive us of fresh air, natural light and ventilation. The positive health effect of light, in this case of sunlight, was acknowledged by the Egyptians, ancient Greeks and Romans, each of whom worshipped their own sun god. Much later, at the beginning of the 1900s, sunlight as a healer was put to practical use. Sanatoria were built for light therapy for people suffering from skin diseases, among other ailments. The importance of the indoor environment, and of indoor air quality in particular, was recognized as early as the first century BC. However, it was not until the early decades of the twentieth century that the first relations between parameters describing heat, lighting and sound in buildings and human needs were established. In the late 19th century, the environmental factor 'thermal comfort' was introduced as being part of the overall concept of indoor comfort. It was recognized that poorly ventilated rooms, besides being responsible for poor air quality, could also result in unwanted thermal effects both through temperature and humidity. Although we spend our time indoors, we are still "outdoor animals". The forces, which have selected the genes of contemporary man, are found in the plains, forests and mountains, not in centrally heated bedrooms or ergonomically designed workstations. We have adapted* *to the life indoor, but our gene code is still defined for outdoor life. Sick building syndrome, winter depressions, asthma, allergies, etc. are symptoms linked to the quality of the indoor environment as regards our biological needs. It is imperative that buildings and spaces where we spend much of our time are designed with those needs in mind; going back to nature, with natural ventilation and natural lighting."* (Velux Group, 2010)

THE CONCEPTS: From North to South and depending on various factors, the time spend indoors may suffer a variation, but in the end, and that is even a possibility, we spend most of our times indoors. There is potential for the indoor climate in buildings to be improved, around the world. *"We spend 90% of our time indoors"* (Tecnhical University of Berlin NEST project, 2007) *"But up to 30 % of the building mass neither contributes to nor provides a healthy indoor climate."* (United States Environmental Protection Agency, 1991) Limiting the environmental impact of a home without compromising the quality of the indoor climate represents the effort to achieve 'Sustainable Living'. The optimal use of venting in summer period, daylight and solar shading represent examples of solutions that when integrated with an intelligent and integrated building design, can help reducing the energy consumption of buildings. (Velux Group, 2010). According to (C. Brunsgaard et al., 2011) , 40% of the energy consumption in EU accounts for built environment. For studying the Indoor Environment field, it is based in both qualitative interviews and quantitative measurements of the indoor environment, measured wither continuously or spot at certain periods. (Also visible in figure 2.6)*: "In industrialized countries about 90% of the time is spent indoors. The ambient parameters affecting indoor thermal comfort are air temperature and humidity, air velocity, and radiant heat exchange within an enclosure. In assessing the thermal environment, one needs to consider all ambient parameters, the insulating properties of the occupants' clothing, and the activity level of the occupants by means of heat balance models of the human body. Apart from thermal parameters, air quality (measured and perceived) is also of importance for well-being and health in indoor environments. Pollutant levels are influenced by both outdoor concentrations and by indoor emissions. Emissions from cooking play an important role, especially in developing countries. The humidity of the ambient air has a wide range of effects on the energy and water balance of the body as well as on elasticity, air quality perception, build-up of electrostatic charge and the formation or mould. However, its effect on the indoor climate is often overestimated".* (Höppe & Martinac, 1998)

Daylight and ventilation by windows are inseparably connected to indoor climate. Indoor climate encompasses all the elements: temperature, humidity, lighting, air quality, ventilation and noise levels in the habitable structure. How to evaluate the quality of the indoor climate? There are no general methods that describe "everything" in a formula or in a single number. There are several indicators for how we can support our biological and physiological needs; ventilation rate for natural ventilation, daylight levels to be achieved, solar radiation exposure levels, comfortable temperature levels, relative humidity levels, sound levels etc. It is, just as important to evaluate the indoor environment with our senses; do we feel well indoors? Human factors, including physiology, perception, preferences, and behavior make every individual a very accurate sensor.*"The aim is to predict the combination of thermal variables (temperature, humidity and air velocity, which will be found comfortable. The thermal variables are measured at the same time as the subjective reactions are taken, where subjects taking part are asked in the survey to assess their thermal sensations." (Nicol and Humphreys, 2004)".* (Akande et al., 2010)

HUMANS TAKE PART- THE PERCEPTION OF INDOOR ENVIRONMENT: The indoor environment is more than the sum of its parts, and its assessment has to start from human beings. **“***The human senses, “windows of the soul” are basically the instruments we have to report or indicate whether we feel comfortable in the indoor environment and how we feel our health is affected by it. Sunlight is a natural anti-depressant, which helps us synchronize with the natural rhythm of life and direct sun and high daylight exposure levels are shown to be effective.”* (Velux Group, 2010)A good indoor climate, with specification of fresh air from outside together with high daylight levels, is the solution for making homes, offices etc. healthy. *“Several studies have shown that there are some non-quantifiable elements of comfort that influence the thermal sensation. Aspects like culture, habits and traditions, mental states and expectations can vary the level of tolerance toward certain thermal conditions. […] However, in ‘uncomfortable’ warm and cold environments or in a changing climatic condition, adaptation will often have an influence because people have a natural tendency to adapt to changing conditions in their environment. It is recognised that psychological adaptation actually play an important role in people’s perception of thermal conditions and also could explain the differences in observed and predicted thermal sensations on different environmental contexts like office vs. house and AC vs. NV buildings ”* (Tablada et al., 2005)

That leads to refereeing the perception of indoor environment, briefly referred before: *“IAQ[7] is about what we breathe. IEQ, more comprehensively, is about what we breathe, see, hear, and feel inside a building. IEQ includes IAQ as well as other physical and psychological aspects of life indoors. IAQ is part of indoor environmental quality (IEQ), which includes IAQ as well as other physical and psychological aspects of life indoors (e.g., lighting, visual quality, acoustics, and thermal comfort).”* (KMC Controls, 2014) Indoor environment is perceived physically and psychologically. (Figure 2.2) Either way, it reflects on thermal environment, atmospheric environment, lighting environment and acoustic environment. The last one, even though important and since the space is so small and tight, will only be taking into consideration but not really calculated- Figure 2.2.

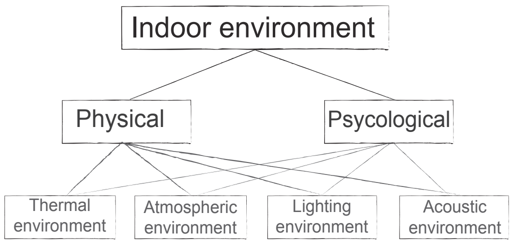


Figure 2.2 - Indoor environment is perceived physically and psychological (Source: Mafalda Melo Oliveira, based on (KMC Controls, 2014))

STANDARDS AND GUIDELINES: *“Whether heating or cooling , the energy needed […] can be reduced by proper design and passive components. The small rest can be covered by renewable sources. […]offers its inhabitants a comfortable and healthy indoor climate in every region- low –cost and environmental sustainable.”* (ISOVER, 2007b) The focus is to develop a bioclimatic design that depends on passive solutions. It is mostly, since European standards don’t apply to outside Europe , and each countries standards won’t be the same , it is about defining what is indoor quality and what is defined as

[7] Indoor air quality (IAQ). The characteristics of the indoor climate of a building, including the gaseous composition, temperature, relative humidity and airborne contaminant levels.

a possible comfortable and habitable place- no matter where to go and place it In the globe. So no standards, but focus on Daylight, Co2 concentration levels, Temperature inside and Relative Humidity.

Some European or specific country regulations used, may be refereed in order to situate and position a statement, however, due to the projects need to be adaptable for different locations, it is diffiult , rather impossible to underline only one standard to be used for all- considerations are mostly general. *" It is the consequence of an effort to give the building users the best possible indoor environment by good ventilation, comfortable temperatures and sufficient light. The building industry in Denmark and the rest of Europe is facing challenges in fulfilling the EU Directive of 2002*[8]*"* (C. Brunsgaard et al., 2011)

Thermal comfort and indoor air quality is evaluated by using the guidelines set out in CR 1752[9] to situate the results on a known guideline. Daylight is more difficult to evaluate since there is not exactly an European or international recognized guideline. Nevertheless, if evaluated by the demands in the a local regulation, for example Danish building regulations, paragraph 6.5.2, which says: *"Working areas, occupiable rooms in institutions, teaching rooms, dining areas and habitable rooms must have sufficient daylight for the rooms to be well lit. Windows must be made, located and, where appropriate, screened such that sunlight through them does not cause overheating in the rooms, and such that nuisance from direct solar heat gain is avoided." (BR08) In evaluating the results, a daylight factor of 2% will be used as a minimum limit of the daylight factor. The measurement method follows the instructions in the SBI instruction 219"* (Johnsen et al 2009).

SUMMING UP: IQA can be affected by various sources due to different reasons, expressed in Table 2.1.

Table 2.1- Reasons and Sources affecting Indoor Air Quality (IAQ) and Comfort (Source: based on (Velux Group, 2010))

Reason	Source
Temperature and extreme humidity values	Poor humidity control, inability of the building to compensate for extreme weather, number of installed equipment and stocking density
Carbon dioxide - CO2	Number of people, fossil fuels combustion (gas, heaters, etc.)

A. DAYLIGHT *"A room is not a room without natural light"* Said Louis Kahn during his lecture, "Law and Rule in Architecture in 1961. Daylight is described as the combination of all direct and indirect light originating from the sun during daytime- Figure 2.4, Left. Parameters influencing daylighting performance are: location of the building, site properties, Orientation of the building, building geometry, material properties- such as colour and windows together with type of shading applied. *"It is of great importance that the solar shading is chosen as an external solution, since this type of shading is the most effective solution"* (Larsen, 2014) Sun is the main focus of most designs, as renewable and endless sourve: *"It is all about the sun; without solar radiation there will be no light, no wind, no heat, no life. And the solar radiation reaching the ground is far larger than the energy needed. Solar energy is often viewed as a set of niche applications with a useful, but limited potential."* (Perez, 2009)

"The U-value of a building component expresses the amount of energy that is transmitted from the warm side to the cold side. The lower the U-value, the less energy is transmitted. It is often the aim to reduce the U-value of building components to reduce the heat loss, and thereby the heating demand, of the

[8] Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings: Official

[9] DS/EN/CR 1752. 2001: Ventilation i bygnin- ger – Projekteringskriterier for indeklimaet (Ventilation in Buildings – Planning Criteria of the Indoor Environment). Denmark, Dansk standard (Danish Standard), 2001

building. In glazing constructions, heat is transferred from the inside through the insulating glass unit to the outside by radiation, convection (warm air rises, cold air falls), and conduction. By adding internal or external shading devices to the window, the U-value can also be reduced by reducing the radiation to the sky and by improving the heat resistance. The g-value (total solar gain transmittance) is quantified by the amount of solar gain entering through the window". (Velux Group, 2010)

Daylight and no artificial light, leads to more comfort and lower temperature inside- Figure 2.4, Right: *"For each location the lowest primary energy demand is achieved by the building with light from the windows. The energy demand of the building without windows is aprox. 5 times higher than the one with windows, when using electrical light to reach the same light levels. Windows are low energy light sources."* (Wargocki et al., 2002) Furthermore, it is impossible to refer to daylight without talking about openings and when referring to the, it is not possible to put aside their integrated influence on other parameters. Windows not only allow daylight but also allow ventilation that decreases the need for mechanical cooling and consequently it helps dissipating pollutants such as CO2.

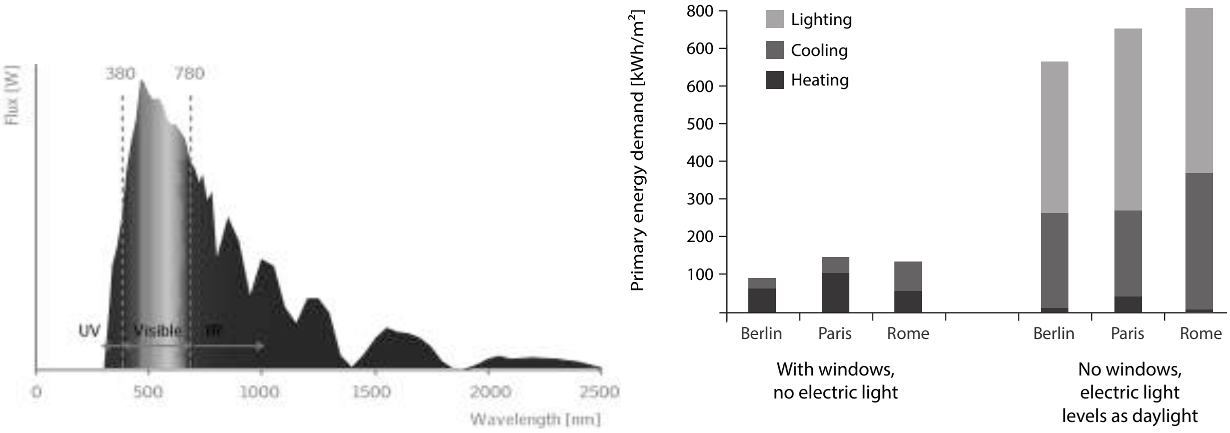


Figure 2.3 - (Left) **-** Diagram of electromagnetic spectrum showing the location of the visible spectrum and Daylight factor calculation ; (Right) Graph on relation between daylight and need for artificial light, resulting on different values for energy demand in different locations (Source: (Left) (Velux Group, 2010); (Right) Mafalda Melo Oliveira, 2014, based on(Velux Group, 2010))

As stated in Integrated Energy Design: *"Average daylight factor (DF)[10]/ demand for artificial lighting: > 5% relatively high level of daylight. Artificial lighting is normally not necessary during the day; 2-5% The daylight is the main light source in the room but it would normally be necessary to add artificial lighting at workstations; < 2% Artificial lighting is necessary and will be the main light source in the room.[11]"* (Andersen et al., 2009)

"An exclusive focus on energy optimization could lead to weird lighting solutions. Pure technical driven installations might demonstrate a minimum power consumption, but if architecture, aesthetic and health is ignored users will not likely stay at these sites and all energy efforts would be unsuccessful. Therefore, lighting qualities need to incorporate the individual well-being, architecture and economics, as Jennifer Veitch, researcher at the National Research Council of Canada, has pointed out. However, the first step for good light should really begin with sustainable daylight architecture." (Schielke, 2014)

SOME SUGGESTIONS ARE PROPOSED: For interior spaces working with daylight – Figure 2.4: *"Work*

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10 The DF expresses – as a percentage – the amount of daylight available in the interiors compared to the amount of unobstructed daylight available at the exterior under standard CIE sky conditions.

11 "Beregning af dagslys i bygninger" [Calculation of daylight in buildings] and SBi Guidelines 219, "Dagslys i rum og bygninger, 2007" [Daylight in rooms and buildings, 2007].

with bright interior surfaces: Plan your interior surfaces with high reflectance to enhance the reflection of light in the space, but be careful with shiny or very bright surfaces that could cause glare. It is best to use matte light colours to improve the visual comfort. For a bright room impression, keep away from dark surfaces. Creating walls of light are another effective method for increasing the apparent brightness of a space. […] Avoid glare and spill light: Glare interferes significantly with visual tasks and pleasant surroundings. Direct glare comes from luminaires, whereas indirect glare originates from reflections on surfaces. […] For example, in outdoor lighting the negative effect of spill light becomes apparent when the dark sky with its stars is not visible any more .The second form of glare, the indirect type, occurs when the lighting is reflected from shiny surfaces like computer screens or glossy images on walls." (Schielke, 2014)

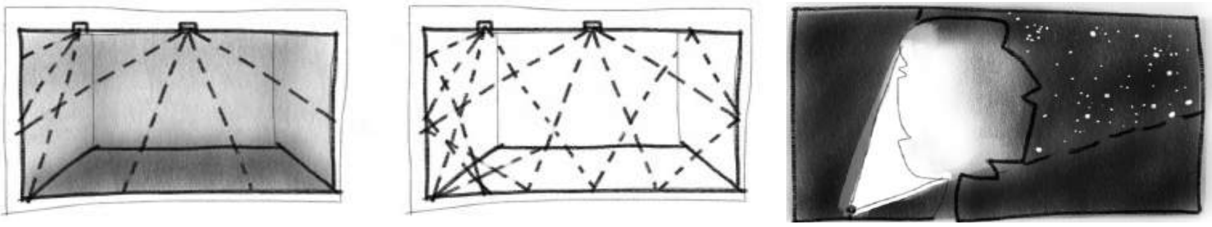


Figure 2.4 -The importance of designing according to different elements. Too little light or too much light should be avoided. (Left) Bright and light colors amplify the light reflection while (Middle) darker absorb light. (Right) In some cases, glare poses as a problem. (Source: Axel Groß ,http://gobo.io)

LACK OF REGULATIONS: Daylight is, not only a challenging parametrs to work with but also to set into regulations. Countries have their own set of rules, but those are mostly guidelines for architects, designers etc, rather regulations : *"In the United States for example, the BOCA Building Code stipulates the following: "the standard for natural light for all habitable and occupiable rooms shall be based on 250 foot- candles (2691lux) […] In contrast, the Department of Public Works of Canada recommends an average daylight level of 200 lux along the perimeter of the office space. […] However, these are only recommended levels not enforceable by law. […] In France, requirements for lighting of workplaces can be found in the Decret no. 83-722 of August 2, 1983 concerning general lighting and Lettre-circu- laire DRT no. 90/11 of June 28 1990 relative to daylighting and the provision of view towards the out- doors. The 1997 Cahier des Recommendations Techniques de Construction of the French Ministère de l'Education (Minitère de l'Education, 1977) recommends a Daylight Factor at a minimum of 1.5% under overcast sky conditions in classrooms. There is currently no real daylighting legislation in the UK of any kind but only a set of recommendations established by the Building Research Establishment (British Standard 8206, 1982) . The British Code BR 8206 (Part 2) recommends that windows should be, at a minimum, 20% of the external window wall for room […]In Germany, the standard DIN 5034-4 Daylight in interiors- Simplified regulation for minimum window sizes is more comprehensive as it is more fitting and specific to daylight supply and the role of window as a daylight source. […]he Building Code of Australia has a10% floor area requirement for habitable rooms in residential buildings (Australia DCP, 2002). […]Article 28 of the Japanese building code stipulates that habitable rooms of con- tinuous occupancy buildings shall have window sizes no less than 14% or 1/7 of the total floor area in a house and between 20% and 40% of the floor area in other types of buildings. In other countries, these practices are more descriptive in terms of levels of daylight illumination suitable for building interiors. Table 4 illustrates a sample of recommended day- lighting levels according to the 1982 British Draft Development DD 73*

Standard (British Standard Institute, 1982). Data are provided in terms of electric lighting levels, electric glare index, whether daylighting should be the primary source of illumination (full) or only supplementary, the average daylight factor (DF) and the maximum glare index level (DGI) […]Several countries have recommended practices for daylighting. In the United States, the IESNA RP-5-99 latest Recommended Practice of Daylighting pro- vides some basic design aides and strategies for con- trolling light levels and glare without prescribing any kind of indoor daylight illuminance levels for build- ing interiors (IESNA, 1999) " "This review of daylighting standards indicates the deficiency of building codes in regard to daylighting. If one is to think of daylighting as the active use of daylight in building interiors to achieve a particular purpose, then there are not any existing daylighting standards that are enforceable by law in any country. […]Several countries have some recommended practices for daylighting but none of them actually re- quire it or make it mandatory." (Boubekri, 2004)

B. AIR QUALITY: principally consists of 3 parameters: Appropriate CO_2 –level, Low content of pollution from particles and degassing from materials, Appropriate air humidity. Air quality can e.g. be simulated with software like BSim and as a result, the demand for fresh air supply is determined. The fresh air demand is defined in l/s (litre/second) or air change per hour (h-1). An air change of 1 h"1 means that the air volume in a room is changed during one hour. (Andersen et al., 2009)

RELATIVE HUMIDY: air humidity is affected by a number of factors as sweat, air humidity in the outdoor air, moisture load from cleaning, cooking and plants plus a relatively large contribution from respiratory air. *"The air humidity usually only has a small influence on the human perception of the air quality, and therefore the recommended interval for the relative air humidity is also relatively large and is between 30-70 %. Above this limit one could feel the air as damp and sultry - the clothes will stick to the body. Below this level some may experience symptoms as dry mucous membranes and dry skin. However, the air humidity can have large influence on the moisture accumulation in building materials and thereby formation of mould fungus. The air humidity is therefore an important design."* (Andersen et al., 2009) *"If this moisture is allowed to further enter a wall system, it will condense. If the cool surfaces and moist air meet within the building space, then moisture problems can occur throughout the building. Thus, the building envelope plays a vital role in minimizing uncontrolled moisture and air movement into a building and in preventing moisture entrapment within the wall system".* (MacPhaul & Etter, 2010)

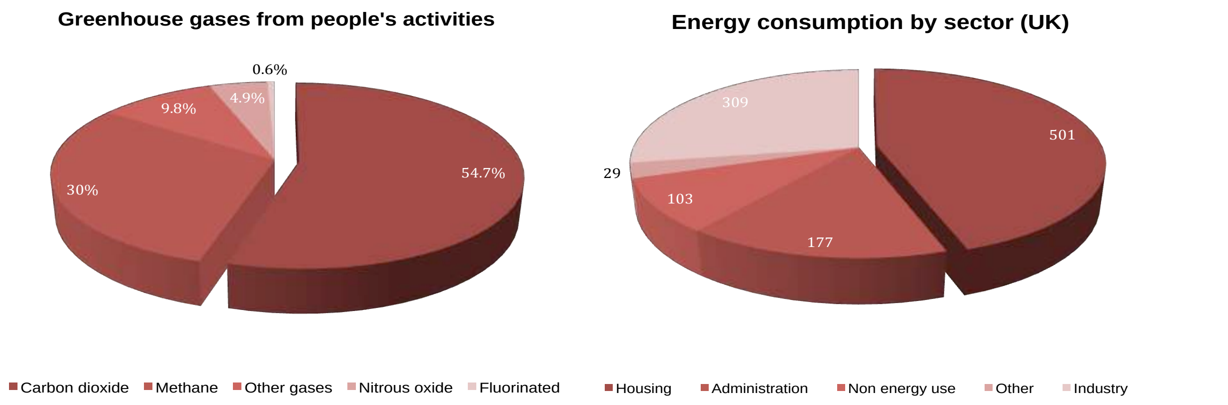


Figure 2.5- (Left) CO_2 levels and sources; (Right) Housing (and humans) produce more gases. Housing is the sector that consumes more energy (Source: Mafalda Melo Oliveira, 2014 based on (Left) "Intergovernmental Planet on climate change, Fourth Assessment Report" (2007); (Right) (I. Cooper & Palmer, 2011))

CO_2 Carbon dioxide is the most important greenhouse gas emitted by humans, but several other gases contribute to climate change, too – Figure 2.6. *“Carbon dioxide is a natural component of air. The amount of CO in a given air sample is commonly expressed as parts per million (ppm). The outdoor air in most locations contains down to about 380 parts per million carbon dioxide. Higher outdoor CO concentrations can be found near vehicle traffic areas, industry and sources of combustion.”* (Prill, 2000) *“CO2 concentrations in outdoor air typically range from 300 to 500 ppm. Thus indoor CO2 concentrations of 1000 to 1200 ppm in spaces housing sedentary people is an indicator that a substantial majority of visitors entering the space will be satisfied with respect to human bio effluents (body odour).”* (ASHRAE, 2013)

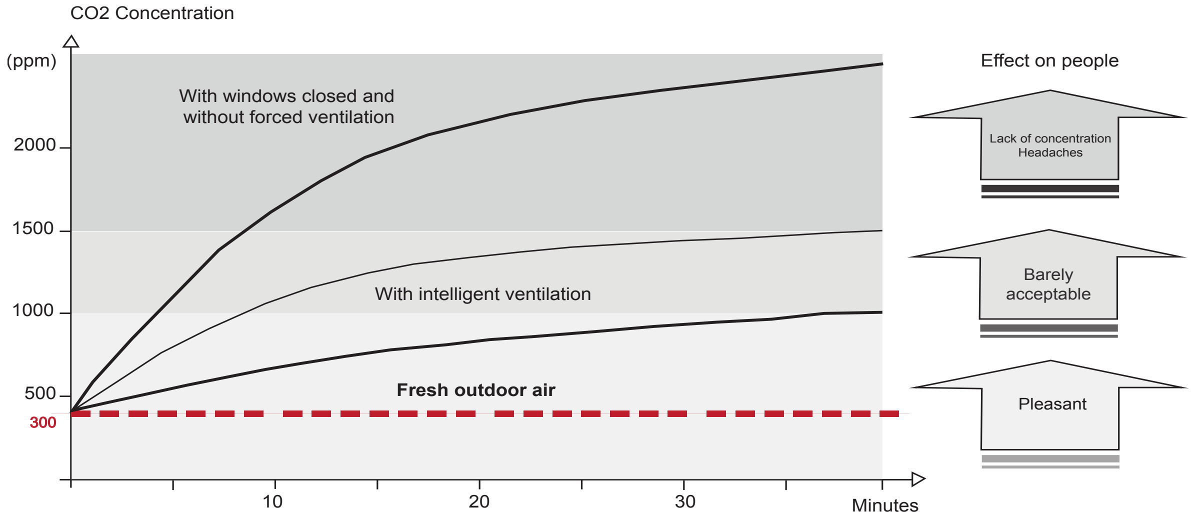


Figure 2.6 - Relation between CO2 levels and effect on people (Source: Mafalda Melo Oliveira, 2014 based on “Report “Summary of ASHRAE'S position on carbon dioxide (CO2) levels in spaces”)

“Since it is not a requirement it is neither a ceiling nor a time weighted average value. Rather, it can be considered a target concentration level. (Figure 2.6) *Since comfort (odor) criteria are likely to be satisfied when the CO_2 does not exceed 1000 ppm the converse is also likely to be true, i.e., when the CO_2 level exceeds 1000 ppm, the comfort (odor) criteria may not be satisfied.”* (Petty, P.E., & C.I.H., 1986) *“Humans are the main indoor source of carbon dioxide in most buildings. Indoor levels are an indicator of the adequacy of outdoor air ventilation relative to indoor occupant density and metabolic activity. To eliminate most complaints, total indoor carbon dioxide should be reduced to a difference of less than 600 ppm above outdoor levels. NIOSH considers that indoor air concentrations of carbon dioxide that exceed 1,000 ppm are a marker suggesting inadequate ventilation.”* (NIOSH, 2013)

These higher limits are concerned with avoiding loss of consciousness (fainting), and do not address impaired cognitive performance and energy, which begin to occur at lower concentrations of carbon dioxide. Carbon dioxide concentrations increase as a result of human occupancy, but lag in time behind cumulative occupancy and intake of fresh air. “*DS 474 -Code for Thermal Indoor Climate”: The requirements for the CO2 concentration are among other things dependent of the ventilation type: Mechanical ventilation: CO2 < 1000 ppm; Natural ventilation: CO2 < 1000 ppm (mean) ; CO2 < 1500 ppm (max)”* (I. Cooper & Palmer, 2011)*“Human perception is still considered better than chemical measurement because of our unmatched sensitivity to the many. “A particular challenge lies in discovering how to mimic the human perception of odours and air quality.”* (Kasche, 2007)

CONCLUDING *“The thermal comfort and indoor air quality were evaluated by using the guidelines set out in European criteria for indoor environment, CR 1752, which are developed for office buildings.*

Therefore, it can only be used as an indicator, because firstly, the comfort levels at work and at home might vary due to different activity and clothing levels, and secondly, the requirement for the indoor environment of the occupants is very individual. This also underlines the necessity to combine the measurements with qualitative interviews. […]" An holistic approach would always merge qualitative and quantitative -as seen with Mixed Methods in chapter 1- and other authors, when referring to comfort in more extreme conditions refer to this same merging of analysis approaches: *"The comfort sensation section was divided into six questions. 1 and 2 consider the ASHRAE thermal scale and the Bedford comfort scale respectively, both of them with seven points: -3, -2, -1, 0, 1, 2, 3.The preference scale and the acceptability scale are considered in questions 3 and 4. It also included an evaluation of the responders about their sensation of the air movement and air humidity. Finally, a question about the actions people performed in order to feel cooler/warmer was also asked. The questions and possible answers are as follow: 1. Rate how you feel the temperature at this moment, (cold, cool, slightly cool, neutral, slightly warm, warm, hot); 2. Do you feel comfortable now? (much too cool, too cool, comfortably cool, comfortable, comfortable warm, too warm, much too warm); 3. I would like to be: (warmer, no change, cooler); 4. How would you rate the overall acceptability of the temperature at this moment? (acceptable, not acceptable); 5. How do you feel about the air flow at this moment? (much too still, too still, slightly still, comfortable, slightly breezy, too breezy, much too breezy); 6. How do you feel at this moment in terms of humidity? (much too dry, too dry, slightly dry, comfortable, slightly humid, too humid, much too humid); 7. Which kind of actions you have taken in the last hours in order to feel better in terms of thermal comfort?"* (Tablada, et al., 2005) It comes to explain that only relying on standards or scientific measures can be not conculsive and if conclusive in itself, it may not be realistic according to human perception.

"Regarding the atmospheric indoor environment, the CO2 level in the houses must not exceed 660ppm above the outdoor level (outdoor average is 370 ppm). Regarding RH, the European criteria for indoor environment, CR1752, recommends a range between 30 and 70%. A RH lower than 30% may result in discomfort in the form of dry air, static electricity and desiccated mucosa. The upper limit of 70% should be respected to avoid problems with moisture and mould in the dwelling. "Microbiological organisms, such as fungi and bacteria, are important components of our ecosystem. […] However, if these microorganisms proliferate in buildings, they can adversely impact indoor air quality (IAQ), create hazardous health conditions for the occupants and contribute to the deterioration of building components" (Morse & Acker, 2009).

"Indoor thermal comfort is essential for occupants' well-being, productivity and efficiency" (Akande et al., 2010), nevertheless, it is not easy to define what standard, values, measures, rules to follow, rather it is challenging to think globally of such a crucial local parameter . From European Standards that don't included a big part of the planet's other countries, to national regulations that follow a very specific and directioned set of equations (wind, sun, etc), it is hard to define where comfort starts and ends and how a house is habitable, comfortable. In ASHRA, *"Thermal comfort is defined as "the state of mind, which expresses satisfaction with the thermal environment"* (ASHRAE, 2004). There is a level of subjectivity to this definition , *"[…] comfort is a subjective sensation. However, this definition is difficult to capture in physical parameters (van Hoof, Mazej, & Hensen, 2010). Based on the ASHRAE definition, the zone of thermal comfort is the span of conditions in which 80% of sedentary or slightly active persons find the*

environment “thermally acceptable” (ASHRAE, 1992). The zone of thermal comfort sensation represents an integration of a range of environmental parameter; radiation fluxes, air temperature, humidity and wind speed. According to Olgyay (1963, pp. 14e23), although the comfort zone does not have real boundaries, the zone of thermal comfort and acclimatization is subject to geography and seasonality. In hot climates, the comfort zone shifts toward warmer climate conditions, while in cold climates the comfort zone is lower than in the hot climates and during winter the comfort zone lies a little lower than the summer comfort zone.” (Cohen, 2013) Even though it is subjective and not trivial to fit into a specific definition, it relates to adaption and users: *“Thermal comfort index is evaluated and compared with human responses. Findings indicate the need to review the fundamentals of the requirements for thermal comfort and adaptation by the occupants.”* (Akande et al., 2010)

“Thermal comfort basically has to do with the temperature that the resident considers as comfortable to stay in. Indoor thermal comfort is achieved when occupants are able to pursue without any hindrance, activities for which the building is intended. Hence, it is essential for occupants’ well being, productivity and efficiency. ISO 7730 as well as ASHRAE use the results of an extensive research carried by Fanger (1970) to define thermal comfort as that condition of mind which expresses satisfaction with the thermal environment. In reality, occupants are comfortable in wider range of conditions. This is because people are able to adapt to the environment that they are used to and also because several other factors could also contribute to the adaptation of their indoor environment.” (Akande et al., 2010) In Autodesk sustainable workshop, some suggestions are made: *“Predicted Percentage of Dissatisfied (PPD) predicts the percentage of occupants that will be dissatisfied with the thermal conditions. The maximum number of people dissatisfied with their comfort conditions is 100% and, as you can never please all of the people all of the time, the recommended acceptable PPD range for thermal comfort from ASHRAE 55 is less than 10% persons dissatisfied for an interior space.”*

Generally, Thermal comfort calculations according to ANSI/ASHRAE Standard 55 can be performed by an online free application CBE Thermal Comfort Too found at http://smap.cbe.berkeley.edu/comforttool. Psychometric graphs from Ecotec show the area, according to human activity, respectively to where it is comfortable indoors, helping to understand the diversity that occur among different realities and how much human beings can adapt to existing situations. Since it depends on air temperature, mean radiant temperature, air humidity, air speed, metabolic rate (level of activity) and clothing level, a comfort calculator can be used to get a fast and intuitive sense of the factors that play into human comfort. (http://sustainabilityworkshop.autodesk.com/buildings/humanthermal-comfort-Based ISO 7730-1993).

Psychometric graphs help understanding better the indoor comfort of a building. They represent the balance between individual and social parameters –such as metabolic rate (met) and clothing thermal resistance (clo) - and ambiental parameters –such as temperature, humidity and air speed. Comparing psychometric graphs based on exterior location and level of activity, in annex 6.

2.2. EXAMPLES AND INSPIRATION FROM SHIPPING CONTAINER OR OTHER

Micro apartments together with flexible unfoldable furniture (Figure 2.10) - in places such as Japan where each square meter counts – and their compact design, inspirer because of their efficient use of space and surprise effect into the playful design they create. Inspiration can also be redrawn from versatile , adaptive and flexible elements that convert from horizontal shading to vertical, open a space or enclosure it ; from modular dwellings – due to their easy arrangement capacity and numerous ways of being put together; prefabricated designs – where elements are cheap and mass produced, etc. Container homes are also source of studies, because they allow to understand what works and what does not, what has been tried and where some strong features may be. Last and more important, All those solutions are able to somehow adapt to changes, to be converted and to be open to various solutions. Many architects and local architectural have been inspirational along my education and for this thesis, examples such as Shigeru Ban's innovative construction ideas, Japanese light movable partitions and houses, Scandinavian buildings' way of blending with the surroundings without screaming for attention and Australian architects such as Gleen Murcutt and Sean Godsell, because of they way of working with the place, the site and the existent conditions and limitations – while still proposing a integrated and cohere beautiful final piece of architectural value and engineering quality.

Most container solutions (figure 2.13 and 2.14) have a lot of changes to the shipping container original. Even though they look nice in the final result, sometimes all those changes compromise the structure and the facility for that structure to be then still moved around. (container homes websites in annex 2)

2.2.1 A PORTUGUESE MODULAR SOLUTION: Modular construction is an emerging industry in Portugal, but the results and projects can get a lot cheaper. This particularly solution ends up being an expensive solution due to artists' special work in the inside of the rooms. Nevertheless, understanding modular architecture can be very beneficial to understand the potentialities being able to organise pieces resulting into countless number of combinations.

Figure 2.7- "A Casa Ideal"- Intercasa – Futureng (http://www.futureng.pt/2011-10-08-16-intercasa)

2.2.2 RESOURCE FURNITURE AND MICRO APARTMENTS Beds and tables falling from the walls and so many different functions in the same space and piece of furniture, are some points in common within solutions where space is a limitation and a challenge to overcome.

Figure 2.8- Efficient use of space: compact living: (Left) Micro apartment (Middle and Right) Resource furniture http://resourcefurniture.com/product/

2.2.3. INSPIRATIONS FOR PASSIVE APPROACHES: SHADING AND CLIMATE ADAPTION

Adapative structures can be very complex and some examples -such as Jean Nouvel's Institut du monde arabe or the Al Bahr Towers, in Abu Dhabi by Aedas- are not always possible or feasible, since some resources are not available and scale does not fit such a small project like this. Nevertheless, all those structures have in common the possibility of using the existent conditions and working with them, rather than against. Dwellings in extreme conditions that do not rely on a big amount of money to reach good values on comfort need to adapt to the climate and be designed according to it from its initial phases.

Figure 2.9- (Above) Hut on Sleds by Crosson Clarke Carnachan Architects, Whangapoua, New Zealand Flexible shading solutions (Source: http://architizer.com/blog/hut-collection/) ; (Middle) Housing units in Luanda: House in Luanda from Trienal de Arquitectura de Lisboa 2010 Exhibition (Bellow , left) Villa Reiteiland –Oost by Egeon Architecte http://www.urdesign.it/index.php/2013/01/07/villa-rieteiland-oost-by-egeon-architecten/ (Bellow, Right) Sean Godsell's House in Australia (http://www.pinterest.com/pin/370984088027413468/)

ARCHITECTURE FOR PLACE: GLENN MURCUTT'S PASSIVE SOLUTIONS Glenn Murcutt uses the simplest shapes to take everything from the nature as he possible can and he believes: *"Architecture should be an answer. Not an imposition."* (Glenn Murcutt Interview to "El paìs", 2005). *"His works are not large scale, the materials he works with, such as corrugated iron, are quite ordinary, certainly not luxurious; and he works alone[…] Add in the fact that all his designs are tempered by the land and climate of his native Australia, and you have the uniqueness".* (Thomas J. Pritzker)

Figure 2.10- (Above) Magney house 1984 , Bingie Point; (Middle) Marika- Alderton House (Bellow, left) Arthur & Yvonne Boyd Art Centre, West Cambewarra, New South Wales, 1996-1999 (Bellow, right) Marie Short / Glenn Murcutt House, Kempsey, New South Wales, 1974-1975 – (Above)http://www.bellevarde.com/project/magney-house-bingie-point/91-96/view);(Middle)http://dab310gosschalk.blogspot.pt/2011_03_01_archive.html;(Bellow,left) http://www.pinterest.com/pin/133489576428210646/ ; (bellow,Right) http://www.civa.be/sub/01_1_show.asp?agid=108

2.2.4. FROM A BOX TO A HOUSE CONTAINER SOLUTIONS

Figure 2.11- They open and barrier between inside and outside vanishes (Above) All the terrain cabin when opened (Middle) Port-a-Batch; (Bellow) Yellow shipping Container Home. (Source:(Above) http://teejay5.blogspot.pt/2006/11/vancouver-home-interior-design-show.html;(Middle) http://www.designboom.com/architecture/shipping-container-retreat-port-a-bach-by-atelierworkshop/);(Bellow) http://inhabitat.com/sunset-idea-house-hybrid-architectures-yellow-shipping-container-home-shows-off-small-space-living/sunset-idea-house-hybrid-architecture-13/

ARMY AND MILITARY FLEXIBLE EXPANDABLE OR NOT SOLUTIONS Military and Army were most of the initial solutions that were built and used with shipping containers, since they those can be transported together with other goods in the eventuality of a disaster or fast intervention.

Figure 2.12 - (Above) Solar Tents for Hot climates ; (Bellow) Soft wall shelter (Source: (Army & Command n.d.))

3

ONE DESIGN AND FOUR CLIMATES.

CASE STUDY 1

3. ONE DESIGN AND FOUR CLIMATES: CASE STUDY 1

3.1 NORTH VS SOUTH CONTEXT: 4 CLIMATE ZONES

MAPPING- 4 CLIMATES, 4 COUNTRIES: The point of departure is the idea of thinking globally, while reflecting upon locally. In order to study some different conditions, the project was applied , studied and calculated in 4 different climatic zones – Arid, Tropical, Cold (Temperate) and Mediterranean , considered as the extremes that need to be taken in consideration. Those 4 climates are exemplified by 4 countries : Saudi Arabia, Malaysia, Denmark and Portugal, respectively. By working with extreme climates, not only the "space in between" or climates in the middle or similar, are tested and in a way proved , but also it allows a deeper understanding on the changes climate asks for. A reflection upon climate adaption is essential when working within so many different conditions. Site and specific locations will, at a later stage, influence: thickness of insulation and walls, orientation of the house, sizes of windows, and materials used, etc. The climates and the different contexts represent more than specific countries or locations, but features : more precipitation or less, sunny or cloudy area, existence of snow or rain, wind direction and speed, etc. Think globally , act locally – refers to thinking about climates in general and what they represent , acting upon their specific features or elements that define them, when adjusting and adapting to local conditions: construction techniques, extra elements, materials, etc

3.2.PROPOSAL AND RESULTS

THE DESIGN STEP BY STEP First of all, for this project, it was used only a container type: 20ft Dry High Cube (Table 3.1 for container measures. See annex 1 for container drawings) The container is made of steel, which it is not a good material to start with - in terms of sustainability. Metal overheats when exposed on the sun - direct solar radiation- and it is poor in terms of energy transmissions and losses. Besides this, metal requires a lot of energy to be produced and the project only makes sense if it relays on used shipping container – recycling them to new uses for some more years after they are no longer suitable for shipping purposes. To take care of the question related to the transmission losses, and since the building envelope is critical when designing sustainably, it was necessary to create a system that would allow everyone and everywhere to get the same but at the same time a building that would survive the harsh different climates and conditions.

Table 3.1- 20ft High Cube shipping container external measures, area and volume

Shipping container: 20 ft High Cube	Length (m)	Width (m)	Height (m)	Area (m²)	Volume (m³)
Measurements (exterior)	6,058	2,438	2,896	13,825	37,258

INSIDE WRAPPING- INSULATION UNIT: Due to the fact that it was defined that the inside of this container would be fixed off site – so furniture would be placed inside of the container before it was shipped to a specific location- it was also included within this basic unit, a basic insulation unit. The intention was to create a nice and comfortable indoor climate together with a design that would add architectural value. It was decided that the container inside walls should be wrapped with plywood, material that is simple, cheap, easy to work with and representing an human touch to this very tiny space looking for identity.

The insulation need was studied and analysed according to the architectural parameters – related to how much free space the inside would have after adding inside walls- and the impact resulting on adding specific thickness of plywood and insulation inside. This process of dimensioning and designing the inside “wrapping” elements needed a very balanced compromise between engineering and architecture and resulted on the use of an insulation + wood unit of 100 mm - for walls and roof. Those 100 mm of “extra wall” represent 85 mm of Rockwool insulation + 15 mm of plywood. The floor insulating unit is different from the one expressed before, due to the metal C shaped cross elements, structure that supports the wooden boards, that represent thermal bridges and decrease the “usable” space for insulation, every 300 mm. In this case, 116mm of Rockwool insulation was added, together with 21mm above those elements and above all the plywood panels. The 21 mm, because of the very small thickness to be used and also because the lambda value needed to be better than just “normal” Rockwool – but still not an expensive solution- glass wool panels were used. In both units, (floor and wall/roof) a moisture barrier prevents moisture in climates such as the Danish- where outside temperature is lower than inside. It is clear how much the influence of such a simple gesture is, not only in terms of the comfort it provides and in terms of expression it gives, together with specific tactility, but also considering the improvement in the U value of the envelope. (table 3.2). For other thickness and options, see in the annex. As shown before, the container is not the same in terms of materials or structure all the way around so floor does not represent the same in terms of U value. Not only it is different because the Resistance to vertical flow (floor) is different from the resistance to an horizontal flow (walls) but also because if the container stands alone – to keep it general and simple- then it connects to the outdoor and not to another room bellow; but because the existing structure of container, (see annex) the floor is made of some wooden secondary structure that stands parallel to the smallest measure (width). Those elements and the fact that there is also air between the steel and the top material inside, change the Uvalue calculation -there are thermal bridges.

Table 3.2- Transmission values for container before and after insulation unit (Source: Mafalda Melo Oliveira, 2014, based on Bsim simulation results)

	Copenhagen, Denmark	Riyadh, Saudi Arabia
External wall	qTransmission (mean)	qTransmission (mean)
Only steel container	-4288,43	-2877,16
Steel + inside wrapping	-3185,91	-2107,95

THE BOARD: For the final design, as explained before, plywood was the material decided upon, for all the inside walls, roof and floor, covering the space in all directions : x, y and z. The idea was to create a safe environment with the container perceived as a strong enclosed element and provide a very different tactility to the space, by including something that has such a human scale to it – wood- , a material that is sustainable and has so many different meanings to it. First of all, the intention was to create as less waste as possible – environment and economic sustainability- and use as much of the material as possible. For that reason, the plywood board with 1220m*2440mm was used as the module to create the divisions within the container. Starting with the original board and redrawing inspiration from the Japanese Tanami (Annex) , a piece of 296mm at the end of the board would be taken off (figure 3.1) – that would result on the 2144mm length that could fit inside of the container. More details in the annex 5.

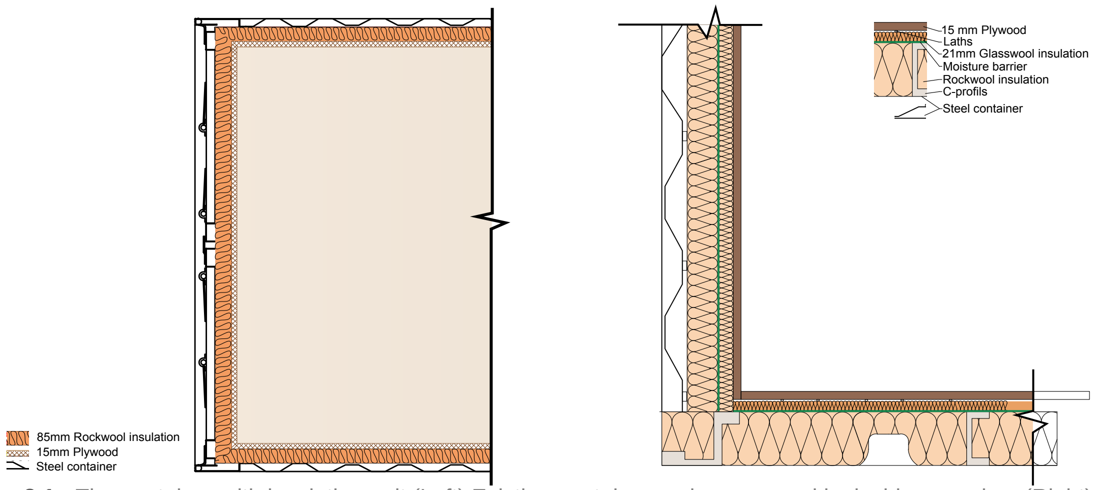


Figure 3.1 - The container with insulation unit (Left) Existing container and space used by inside wrapping; (Right) Wall and floor materials detail (Source: Mafalda Melo Oliveira, 2014)

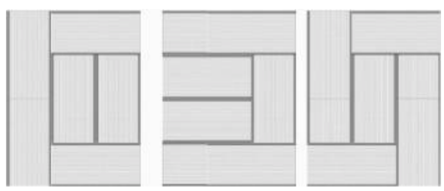
Table 3.3- Results for the thermal resistance of the container wall before when it is only a steel wall, and after when the inside unit is added. (Source: Mafalda Melo Oliveira, 2014, based on Bsim simulation results)

	External wall A (Only steel)			External wall B (Steel+ inside unit)		
	Dist d (m)	λ (W/mK)	R=d / λ (m² K/W)	Dist d (m)	λ (W/mK)	R=d / λ (m² K/W)
Resistance, in	-	-	0,13	-	-	0,13
Plywood	-	-	-	0,0150	0,11	0,1364
Insulation (rockwook)	-	-	-	0,0850	0,035	2,4286
Steel	0,0018	54	3,33F-0,5	0,0018	54	3,33F-0,5
Resistance, out	-	-	0,04	-	-	0,04
Σ	0,0018	-	0,17	0,1018	-	2,73
Uwall= 1/ Σ R			5,88 W/ m²K			0,37 W/ m²K

All the dimensions were thought coming from the idea that, everything that is a basic need- sleeping, going to a toilet and eating- would be given a measurement that would relate directly to a plywood board size and everything else – the called "free areas" would just be an area of waste put together to create something unique in each container. What meant that first, the piece of plywood would be cut 296mm, then the most basic bathroom would occupy half of a board in width, the kitchen would use 1 board so 1220m width and finally the sleeping are would be suited for 2 board size, 1220*2 mm. Because the container is a rectangular regular form and because the intention was to create a grid or some kind of system that would allow the inside to be flexible even if it was fixed, the inside was divided into a puzzle of boards. The initial big area boards would then be cut into smaller boards parallel to the length – in 3 pieces- in order to make it possible to transport, to replace easily and to put together.

Table 3.4 Plywood board (B) measures and respective house function given; (Source: (Left) Mafalda Melo Oliveira, 2014; (Right) Japanese *Tatami* layout inspiration (more in annex 6): http://www.tatami.ca/tatami-mat-layouts

Container board	1x B	2 x B	B / 2	B / 4
Measurements (mm)	1220 x 2144	2440 x 2144	610 x 2144	205 x 2144
Area (House's function of the piece)	Kitchen	Living Area	Toilet	Extension (free area)



The free areas – made by putting extra pieces of plywood together- would either make the bridge between inside and outside, and erase the limits between house and outdoor when placed close to the end of the container or if placed in the middle of the house, those would represent the space that divides wet area of the house – with bathroom and kitchen- and dry area – the bedroom.

Figure 3.2- (Left) Board division: Initial Plywood board and Initial Board - cut area= board used in the house; (Right) board division and relation to space functions (Source: Mafalda Melo Oliveira, 2014)

PLANS AND OPENINGS: There are 2 scales that shape the inside of the container. Scale 1- for a smaller number of people, probably with more money to spend; Scale 2 - a medium size group of people - from 3 to 5 , and with less money opportunities; Scale 3 - large groups that probably need to stay ay a place like this and do not really have conditions for those.

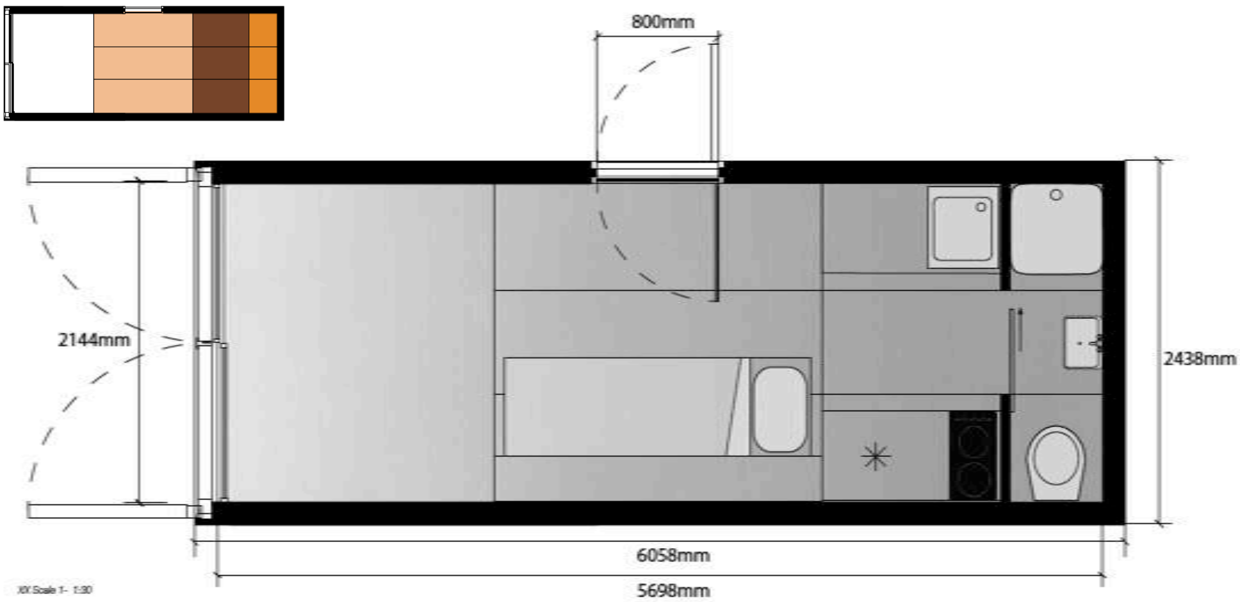


Figure 3.3- Plan showing the openings and some of the areas with basic furniture. On the left side, the "free area" (Above) A diagram with the three main areas of the house – the basic human needs: place to sleep, to eat , and go to the toilet. (Source: Mafalda Melo Oliveira, 2014)

The plans are flexible (Annex 6 for other plans) and they are a result of a division between wet areas of the house and dry. (Figure 3.3) The wet area of the house is related to the place where sink or shower is and for that reason the kitchen and bathroom are. Furniture is movable, flexible and adaptable, relating to the rest of the design and concept. The plans are clean of unnecessary additional things. The only physical division in scale one and two is the wall to the bathroom, so that the plan does not seem even smaller for those living there.

LIGHT: Flexible shading devices and openings allow a big quantity and quality of daylight inside the space (Figure 3.4)- There is no need for a lot of big openings that would make more difficult the energy canculations, due to the reduced size of the container and facility to allow daylight inside it.

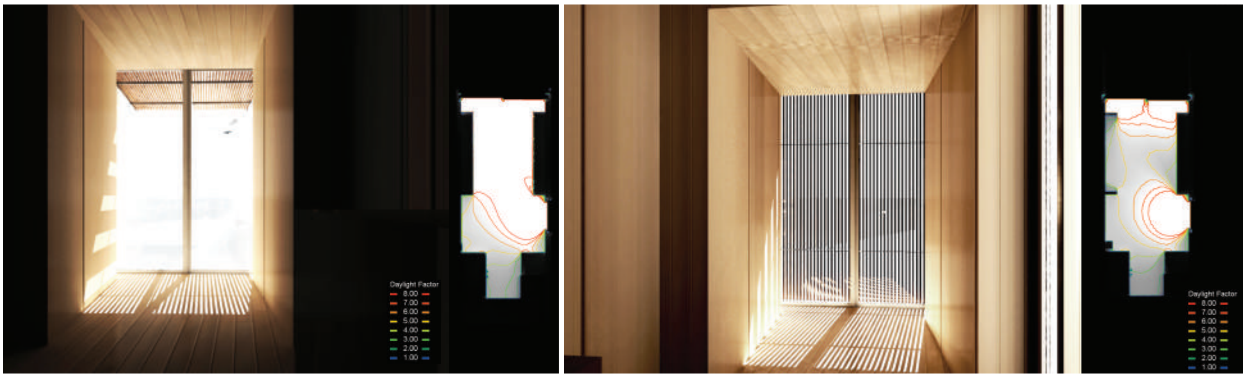


Figure 3.4- Daylight inside the container (Left) container with the overhang (Right) Container with external shading device. (Source: Mafalda Melo Oliveira, 2014 based on Daylight Visualizer software simulations)

FROM BASIC NEEDS TO BASIC SOLUTIONS AND BASIC COLOURS: All around the house, for basic needs, basic furniture, basic colours, basic solutions. Due to the fact that storage spaces and installation areas were difficult to get in such a small space and because it was important to think in three dimensions and use not only the square meters but also the cubic, the height needed to also be part of the design and give answers to some of the restrictions in plan. Inspired in Le Corbusier's Cabanon, the ceiling was lowered or raised according to the space beneath it, to the feeling or intention to be created or intensified and also to the need for places where tubes for water, electrical wires or small storage spaces could fit. The placement of the openings in the house and the need for storage and fake roof influenced the divisions inside. Those 2 big moments inside are one of the features that makes the design so small but so diverse. (Figure 3.5) Mondrian served as background and based on his work, the idea came clear: if designing based and focusing on basic needs , shouldn't the colours be the basic?

Figure 3.5 – 3D Visualisations for the inside moments: (Left and middle) Open and informal space versus comfortable area embraced by the surrounding (Right) Inspired on Mondrian and basic colours, the inside is kept colourful (Source: Mafalda Melo Oliveira, 2014)

Yellow, blue and red were chosen. In some places, something as simple as treated plywood would be used- mostly on walking areas, where wear would be a constant. It was decided that the magic box would be revealed as soon as people would live there and they would interact, so that habitants and house would reveal each other some of their secrets. The free areas are covered in vivid colours and are shown in bright colours to all of those that walk around the inside, however, the playful furniture that comes from the walls, the colours that are inside and the magic to be discovered, is given to those that dwell, to those that are part of that place. Even thought the space seems empty of complex structures and difficult to grasp details , the intention was to keep it not only clear and minimalistic , but cheap and adjustable, so when people grow or their conditions get better, there is space for change- as where in life also. New elements can be added according to proposals given for this specific project.

INSIDE/ OUT-INTEGRATED EXPRESSION: OPENINGS, SHADING AND SECOND SKIN: (Figure 3.6) Sean Godsell is one of the architects that the project redraws inspiration from. The listing, wooden elements placed all around the building close to each other, provides an architecture expression to it together with the function of shading from the Australian hot sun. In the project " temporary houses", the listing on the entrances and shading devices denotes where the "widen" passages or elements are. It breaks the bareness of the façade and creates a rhythm that accompanies the visitor along his tour around the house. The shading devices are a great help in keeping the sun and heat out of the building and together with the rest of second skin, the temperature drops considerably from de point of applying only the container and inside insulation to the result obtained after adding the second skin and the shading elements to the design. For the design of the windows, their glass area, number and other, it was necessary to take in consideration not only daylight but mostly be aware of the solar gains that are more when the glass are increases. In the end, double glass was used and solar shading was applied in between the glass layers and also as external shading for the bigger window. Due to the very efficient shading devices, the house does not overheat to a point that is not possible to be inside and the daylight achieved is higher than needed. It is possible to see the influence of the shading devices not only in terms of overheating but also in terms of blocking daylight. Again, it is important to keep a balanced design and compromised in both directions, sustainability and architectural value.

Figure 3.6- (Left) The outside expression of the house with the second skin (2D visualisations); (Source: (Left) Mafalda Melo Oliveira, 2014; (Right) Inspiration from Sean Godsell 's flexible and movable second skin of the building (https://www.tumblr.com/search/godsell)

RESULTS: The intention was to study different contexts representing different energy needs, temperatures, different problems and then use 4 countries representing those climates , not really important by the country but by the climate those represent. The country is merely used for a more specifc and detailed analysis on wind, orientation and other specifications needed for the calculations and conclusions. Apart from that, the ones chosen were the ones with available information to be use don the software such as Bsim and the spreadsheet and trying to represent contradictory realities. Denmark and Portugal as developed countries where infra structures are a reality and where in grid system is used, while Saudi Arabia or other African contexts and Malaysia represent more desert and remote locations where some considerations on grid and infrastructures would need to be done. The need for air is bigger when calculating in terms of smell (Olf) than in terms of Co2 levels inside. When referring to need for air, the volume of 13,825 m3 needs 1.64 renovations per hour (h-1). If cross ventilation, possible in this case, is calculated for such a big opening area, the renovations per hour would result on higher values than the ones needed. It is a good sign, since it means that, to avoid overheating, window size could be smaller and still provide enough fresh air inside.

The final general results can be seen in Figure 3.5. First, it shows how much the inside and outside insulation does not really fit all the proposes and contexts the same way. If for colder climates such as the one represented by Denamrk, insulation helps balancing the swings and mostly, keeping the cold out, in others –where it is about the excessive heat and very hight temperatures that intensify the need for cooling- creating a building too tight will not solve the problem. If there are big temperatures swings, then thermal mass is a solution, since when insulation keeps the cold out , it also keeps the heat in- not wanted in hot climates.

The more “problematic” climates for the use of too much insulation, would mostly be Hot climates- represented here by Malaysia and Saudi Arabia. That can be verified in the results shown bellow. The table in figure 3.5 , bellow, shows that even if only used inside unit – the inside wrapping- that would already reflect on an building envelope too tight for some contexts.

Applying the same solution everywhere, is not therefore possible. Bigger changes apart from the outside need to be considered and the contexts divided into smaller and more specific analysis groups.

Table 3.5- (Above) 24H Average results Average calculations (Bellow) Bsim results for steel container with inside basic unit (Source: Mafalda Melo Oliveira, 2014 based on Bsim simulations)

	Portugal	Malaysia	Saudi Arabia	Denmark
July (outdoor)	25,1 ºC	27,7 ºC	38,4 ºC	21,0 ºC
Shipping container: only steel	24,5 ºC	28,1 ºC	37,5 ºC	19,9 ºC
Steel + inside/outside wrapping	27,7 ºC	30,6 ºC	40,0 ºC	22,5 ºC

	Rel. Moisture (%)	CO2 (ppm)	Hours > 20ºC	Hours > 24ºC	Hours > 26ºC	Hours < 20ºC
Portugal	59,4	950,8	67,5 %	45,2 %	34,3 %	32,5 %
Malaysia	45,5	992,8	100%	100 %	99,9 %	0,0 %
Saudi Arabia	22	954	93,8 %	89,9 %	76,9 %	6,2 %
Denmark	70,9	943,8	29,6 %	11,1 %	5,6 %	70,4 %

4

THE INTERVENTION SOLUTION.

MIX OF ADJUSTMENTS AND CLIMATE ADAPTED DESIGN

4 THE INTERVENTION SOLUTION: MIX OF ADJUSTMENTS AND CLIMATE ADAPTED DESIGN

4.1 THE INTERVENCTION SOLUTION: THE MIX OF ADJUSTMENTS

After trying to get one design to be only partly adapted to the climate - same window area, position and type; same insulation inside, etc- it is clear it doesn't work to only party depend on passive solutions or work bioclimatic "half way". The design hits a dead-end, due to the that fact. Some adjustments such as number of openings and their area and type of walls, shading devices used need to be taken in consideration and some specific changes need to take place in the initial design. What could change in a design that would influence the final result and improve the values achieved before?

"Any design decision should be justified in at least two ways". (Baumann, 2010) It is important to integrate the process and the design, allowing the decisions taken to be as complete as possible. Opening a window will influence not only positively, when it allows more daylight and ventilation, but also negatively when it contributes to the raise of temperatures – through solar radiation on the glass façade.

"Shading, orientation of windows and openings are of major importance for the total energy balance of the buildings. Comparison of building codes and valuation or selection of best practices is rather complicated." (International Energy Agency, 2008)

"The sizing of the openings and the insulation of the opaque envelope, and protection against solar radiation, also prevent the entry of heat gain by conduction, caused by the flow of heat from the warmer outside air, through walls and glass areas, when the outside temperature is greater than the internal temperature. They are a cause for concern, especially in those regions where summer temperatures reach 40°C, as occurs in many regions of Africa." (Guedes, 2014)

A. ORIENTATION / LOCATION: Orientation of the design first, depending on wind direction and speed and mostly depending on the optimization related to the sun. *"The selection of the place, shape and orientation of the building are the first options to consider for optimal exposure to the sun path and prevailing winds. In hot climates, it is essential that the design of the houses takes into account the wind regime for efficient ventilation and consequent improvement of indoor comfort. In mountainous areas, the houses must be located in the lower zones of the mountain and above the riverside, where there is more air circulation. Priority should be given to the slope side with more hours off. On the coast, the façades facing the sea should be protected by generously proportioned porches, to lessen the impact of the sun's reflection on the sea inside the house. The exterior arrangements are essential to protect the interior from excessive solar gain. As the outdoor environment is hot, ventilation and indoor comfort are criti- cal. In urban areas the impact of solar radiation on the roofs and the façades of buildings and the circulation of the cool breezes around buildings should be studied. Otherwise there is a risk of creating a very uncomfortable environment inside the houses"* (Guedes, 2014) That "best " or optimized orientation is achieved concerning wind and sun using considerations and diagrams, which can be seen in annex. East/West is the best orientation for a building representing an elongated form.

"The slopes exposed to the moist air masses from the northeast are subject to greater rainfall." (Guedes, 2014)

B.INSULATION (AND MATERIALS): The air circulation between the two roofs refreshes the space bellow the ceiling. In cold climates, that space can be covered with insulation so that heat is not lost. Palm leaves can be put on top of the roof between the concave shapes. If possible, the concave shapes should be orientated contradictory to the dominant wind direction. Roof can also be covered with green solutions due to its good thermal results and low cost. Insulation and radiant solutions summed in table 4.1. Thermal mass is an important aspect to take in consideration. Not all contexts allow the use of insulation. Some benefits of thermal mass can be read bellow and seen in table 4.2

"The role of insulation: Insulation is essential to protect the occupants from external temperature extremes that are exacerbated by the external brick skin. The right climate for thermal mass: Correct use of thermal mass can delay heat flow through the building envelope by as much as 10 to 12 hours producing a warmer house at night in winter and a cooler house during the day in summer. However, a high mass building needs to gain or lose a large amount of energy to change its internal temperature, whereas a lightweight building requires only a small energy gain or loss. This is the reason why thermal mass is primarily beneficial where there is a big difference between day and night outdoor temperatures, typically exceeding 10˚C."; *"They (bricks) do that because thermal mass stores and re-radiates heat while insulation stops heat flowing into or out of the building. A high thermal mass material is not generally a good thermal insulator and it certainly isn't a substitute for insulation."* (Light home, n.d.)

"Thermal mass acts as heat and cold storage, regulating and smoothing fluctuations in temperature. The high thermal inertia of the massive building components reduces the maximum temperature values in the summer, providing more comfortable conditions. The heat stored during the day can dissipate at night, by night ventilation. Inertia slows the heat exchanges by conduction to the outside, which is particularly beneficial during heat waves. Unlike other heat sinks, like the atmosphere, the sky or the ground, which provide an almost unlimited resource for this purpose, the use of thermal mass is a temporary, transitional solution. After a certain point, heat starts to accumulate in the mass of the building and decreases its efficiency. Therefore, the use of thermal mass should be combined with ventilation strategies to remove the accumulated heat, especially night ventilation. Night ventilation strategies coupled with a good thermal mass can reduce the average inside temperature during the day to below the outside daytime average temperatures. However, in buildings with high internal gains, such as office buildings with a lot of occupants and equipment, this is more difficult to achieve. But even in these particular cases, the average daytime temperatures inside can still be reduced to values close to the average outside, or a little above this, with a still reasonable performance in terms of passive cooling. When auxiliary cooling systems are necessary, as in the case of 'mixed mode' buildings, the use of thermal mass can delay the need for and reduce the periods of time during which cooling becomes necessary." (Guedes, 2014)

Table 4.1 – Insulation and radiant barriers (Source: Sustainable Architecture in Africa (Guedes, 2014))

	Description	Performance
Insulation	Insulation material can be added either to the inside or the outside surface, or by filling the cavities within the wall structure. In terms of heat avoidance, insulation materials prevent heat conduction due to the existence of trapped gas in many layers (fiberglass bat) or in cells (polystyrene), increasing the material's thermal resistance to conduction in proportion to their thickness, but do not necessarily restrict radiant heat. External insulation can be added using pre-fabricated insulating panels. Should have a light color.	The insulation of the external opaque elements, or the use of additional insulation to the façades, is one of the simplest and most effective measures for cooling and heating load reduction. The air existing in the brick's cavities or in the space between walls (double wall façade) also provides insulation to the building, but this can be significantly improved with additional material (external or cavity wall insulation). External insulation is preferable to internal insulation, making maximum use of the internal thermal storage mass, and has a better performance in preventing heat gains in summer. It plays an optimum role in passive cooling, when associated with thermal mass. It also minimizes or even eliminates thermal bridges and condensations. Internal insulation should be avoided, as it reduces the amount of exposed thermal mass, reducing the benefits of thermal inertia. Roof insulation is also very important, as it decreases the risk of high temperatures on the top floor of buildings in hot conditions.
Radiant barriers	Radiant barriers, made from aluminum foil-coated products, can be installed in the ventilated air gap of cavity walls and roof. The aluminum foil reflects long wave radiation, and the airspace prevents heat movement downwards by conduction.	The effectiveness of this method depends on the ventilation required to transport the heat from the foil by convection. When cooling is the main concern it is preferable to use a foil radiant barrier, as an alternative to high insulation levels that could create moisture and increased roof temperatures. This system can however be more expensive than simple insulation

Figure 4.1 – Construction and materials (Left) Constructive system of colm on top of the metal sheets in Angola. Colm adds insulation properties to the impermebiality and durability features of the metallic sheet (Source: Manual Boas práticas); (middle) Single-Family House in Feldkirch- Walter Unterrainer : The entire facade, with the exception of the windows, is clad with a matt-black fabric normally used in horticulture http://detail-online.com/inspiration/single-family-house-in-feldkirch-103673.html (Right) Green walls and roofs – living walls in Caixa Forum, Madrid (Source: http://www.pinterest.com/pin/472948398339115095/)

MATERIALS AND INNOVATION (Some in Figure 4.1 and some in annex 3): Bio facades- vertical gardens and green rooftops-, PCM that are combined with lightweight construction to achieve the features of good and big thermal mass and others such as textiles, paper tubes, cork, bamboo, or even cans, tires and glass/ plastic bottles, are experimental materials that can be used and considered in further developments. Pam tree leaves and straw have been used for centuries in construction, even though those do not pose as "traditional" known or commonly considered building materials. There are also the more traditional materials, such as wood, glass, adobe, brick, metals, etc.

Sometimes it is necessary to innovate in order for a solution that did not work before, be able to. (Annex 3 for building materials and inspiration)

TEXTILES " How to Dress Buildings Up:Textiles can be used as building skins, adding new aesthetic and functional qualities to architecture. Just like we as humans can put on a coat, buildings can also get dressed. Depending on our mood, or on the weather, we can change coat, and so can the building. But the idea of using textiles to create human habitation is not new. As Diether S. Hope phrases it, referring to tents: The history of development of humanity would be barely conceivable without free spanning textile membrane structures." ("Textile Architecure," 2010)

Table 4.2 – Techniques to optimise the use of thermal mass (Source: Sustainable Architecture in Africa (Guedes, 2014))

Thermal mass	Description	Performance
Night ventilation	Massive elements, like walls, structure, slabs. Night ventilation of the thermal mass provides an efficient means of cooling the building. At night, when outside air temperature is considerably lower than inside, night ventilation is used to dissipate and exhaust the heat accumulated during the day in the building's mass into the low temperature atmospheric heat sink, preventing overheating the following day. The outside air is introduced to the building, either through special channels that contact with the building structure (allowing higher air speeds for convection), or through the windows. In night ventilation using windows, these can have openings on top for this type of ventilation. For reasons of safety and privacy, ground floor windows remain closed, and safety window screens are used.	Performance Night cooling systems may be one of the most efficient passive cooling techniques. This system requires amplitudes of 8 to 10°C between day and night, ventilation rates of 10–25 ach/h, and the structure to be massive enough to store the cooling effect until the next day. It is most suitable when daytime temperatures are higher than 30°C and lower than 36°C. The storage mass can be cooled up to 2 or 3°C above the outdoor minimum. It is recommended for climatic regions such as in Cape Verde, Angola, and some zones in Mozambique (e.g. Tete, Lumbo, Lichinga, Quelimane and Maputo), and Guinea-Bissau (inland areas). The walls and the structure must be sufficiently exposed to the air stream, avoiding the use of false ceilings, and any other elements that could prevent this contact. This system does not usually require complex and costly actions – it may be enough to increase the thermal mass exposure, e.g. by removing false ceilings and opening existing windows; keeping in mind safety precautions, insect protection. To facilitate night ventilation, windows can be left opened overnight. This type of ventilation can be natural or assisted by fans

MATERIALS difficult to measure IN BSIM- so it is according to knowing features of different climates that some materials are better or worse- Besides the climate, there is a balance between cost – financial sustainability (Do more with less) and life span of the materials – need for long lasting materials and resistant options**.** THE SOLUTIONS proposed, they would of course influence other aspects such as acoustics and humidity – choice of materials – and for that reason the materials are also put aside and kept open only suggested. Wood and palm tree trunks/ textile tents – as already used in traditional arch or used more now.

C.OPENINGS: For the calculations it is important to reflect upon three things: location (positioning) , area and number of windows. *"An window can frame a view, bathe a wall with light, orient a building user to the exterior landscape, express thickness of the wall"* (Baumann, 2010), allow ventilation or just a feeling of not being suffocated inside. The placement, size and design of the openings will be essential for the total air change and for the airflows in the building. The thermal buoyancy can be increased by increasing the vertical distance between the inlet and outlet. This can be done by increasing the room height, open the building between the floors, establish vertical channels or ventilation chimneys, and also by using an atrium as chimney. In addition, it is important that the neutral plane is placed so high that sufficient fresh air is coming into all occupied zones. Natural ventilation can also be made by single sided ventilation or cross sided ventilation where the contribution from the wind is very important but where the thermal buoyancy also can contribute by an appropriate placement of the openings (e.g. more openings in different heights). When the outdoor air is being used as a refrigerant typically in combination with natural ventilation, it is called passive cooling. Figure 4.2 represents the most common ventilation solutions related to their limitations.

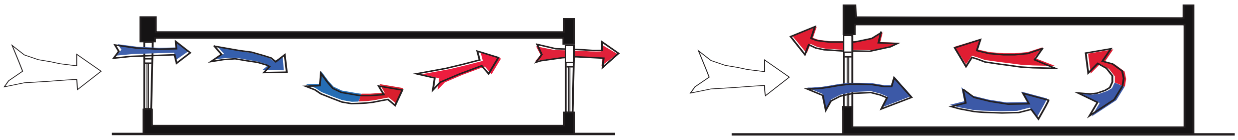


Figure 4.2 - (Left) Cross ventilation Depth ≤ 5*Height ; (Right) Single sided ventilation Depth ≥ 2,5* Height (Source: Mafalda Melo Oliveira, 2014)

"When the air intake openings are smaller than the air outlet, there is greater effi- ciency in the suction of cooler air, which flushes hot air out" (Guedes, 2014)

"North-facing windows create a significant energy problem in temperate and cold climates and should be minimized (Randall, 2006) Randall confirms the general rule that energy performance will be optimized as long as the main facade – the facade with the greatest solar-oriented window area – is oriented to within 45° of the midday sun. "Brown and DeKay, […] define the limits more closely, stating that if the facade is within 30° of south the fall-off in solar performance will be less than 10%". (Huw, 2012) *"Windows alone, however, do not provide satisfactory daylighting of deep spaces due to poor penetration and distribution of the illumination within the space; this can result in glare and local overheating. Skylighting in combination with properly designed windows can effectively illuminate deep interior spaces and offers opportunities for natural ventilation."* (Hampton, 2008) Roof and ceiling light gives more daylight than sidelight, partly because a larger part of the room receives direct skylight, and partly because the amount of vertical light is 3 times bigger than horizontal light. Furthermore, *"roof windows have in general a better energy balance than façade windows during the heating season"* (Velux Group, 2010)

"The distribution, size and shape of the openings are fundamental elements for achieving efficient ventilation. The openings should be widely distributed in different façades, according to wind patterns, ensuring they will have different pressures, to improve the distribution of airflow in the building. The entrance and exit openings (windows, doors, other openings) should be located to create an effective system of ventilation in which air flows through the occupied space. One should also consider the elements that can act as obstacles (internal partitions). The openings located in high positions allow high rates of ventilation for heat dissipation. Openings located on a lower level can provide air circulation throughout the occupied zone. The markedly vertical windows facilitate high- level ventilation, and achieve a better performance in terms of natural lighting and arrangement of interior space." (Guedes, 2014)

If possible, when houses are only one floor and few openings, the door should be placed in the middle of the walls, but if the building has a lot of separated rooms and in order to facilitate circulation and furniture position, then the door should be placed in one of the extremes of the house. Sizing and glazing (Table 4.3) of windows are important aspects when dealing with openings: *"In summer, low-e double glazing is always advantageous: it not only reduces transmission heat loads from hot ambient air or hot exterior blinds, but also the solar heat loads. In spite of the many influencing factors, it can generally be said that the use of double low-e glazing in most cases reduces the total energy demand. Otherwise, the increase is insignificant."* (ISOVER)

"Modernist building in Praia, with façade ventilation openings at various levels: high, for air exchange and

cooling of the building mass, and lower (windows) for the comfort of occupants. The need for natural ventilation and shading were factors that were considered in the design. The interior of a school in Mindelo. (1): The inner openings have a generous height, allowing the flow of ventilation at a higher level, and contributing to a good performance in terms of natural lighting. (2): open windows for natural ventilation when the outside temperature is comfortable during the day" (Guedes, 2014)

"It is estimated that for 1KWh saved for lighting in the cooling season, about 0.3KWh of electricity used by air conditioning is saved. Consider that the space area that can be effectively daylit is around 6m, corresponding to twice the floor-to-ceiling height. As a rule of thumb, high-level windows have a better performance than low-level windows and tall windows perform better than wide windows (as daylight goes deeper into the space). The use of clear (reflective) colors in wall painting and decoration, as well as light shelves also increases illumination levels. The use of skylights in the top floors can cause overheating during summer, as well as glare. Glare control is essential when using computers. Glare and contrast can be avoided by using splayed reveals, light shelves, prisms or reflectors, light ducts, or fiber optics." (Guedes, 2014) Another question to take in account: Will distributed windows allow more distribution of daylight and air, instead of a big concentration in the same place, causing problems of glare?

Table 4.3 – Description of strategies involving window sizing and glazing (Source: Sustainable Architecture in Africa (Guedes, 2014))

	Description	Performance
Window sizing	Windows, glazing ration, façade orientation	Windows also influence performance of daylight and natural ventilation, acoustics, and the visual contact with the external environment. They must be designed to allow this integration. Windows must also be sized according to orientation. There is appropriate software for this purpose, such as DOE, Design Builder (Energy Plus), or Ecotect. These can be used both in new design and in refurbishment. Glazing area should be reduced to the indispensable. It is recommended that it is not greater that 30% in north and south façades, considering adequate shading (or up to 40% in more tropical climates). In the east façade this value should be reduced to a maximum of 20%. In the West façade openings should be, if possible, avoided. Horizontal glazing areas should only be used with adequate shading, and in zones with high floor-to-ceiling height (at least 6 to 8 meters), as they can easily cause overheating problems. Large areas of horizontal glazing should be avoided.
Glazing type	Double-glazing,low-emissivity glazing, HOE.	Double-glazing increases the insulation value of the glazing area, and also has the advantage of reducing condensation at the window back, draught risk and infiltration rates. Compared to single glazing, its use can significantly reduce heat gains. A greater reduction in heat gains is achieved if low-emissivity glazing is used. Amortization of double glazed windows can be achieved in between 5 to 25 years, according to the quality of the materials and size of the windows. Low-Emissivity glazing can be almost opaque to infrared radiation, reducing the solar transmission by more than 50%. This glazing type and HOE do not reduce daylight levels, although they are efficient in reducing solar radiation. However, they can be expensive. The use of tinted and reflective glass for shading and glare prevention should be avoided, as these materials also substantially reduce daylight levels, increasing the use of heat producing artificial light. It is preferable to use clear glazing (double, low-e.), shading, and a reduced glazing area.

"Much of the heat gains of a building are obtained via the glazed areas of the façades, as windows offer very little resistance to the transfer of radiant heat. The orientation and sizing of the glazed areas, as well as the choice of glass, to a large extent determine the penetration of solar radiation into the building. In a warm climate with high incidence of solar radiation, it is important to avoid large glazing areas on the façades, which lead to overheating and the need for air conditioning. In general, the area of glazing should not exceed 30% of the northerly and southerly façades' areas, considering that windows have adequate shading. This value can rise up to 40% in the case of tropical cli- mates with high humidity values and low temperature amplitudes between day and night, such as in Guinea-Bissau. On the

easterly façade, this value should be reduced to a maximum of 20% in any situation. Openings on the westerly façade should be avoided if possible. The use of double-glazing can also reduce heat gains and losses. One can also use a type of glass that selectively transmits only the parts of the visible solar spectrum required for natural light, reflecting unwanted radiation – the so-called low-emissivity glass." (Guedes, 2014)

D. SHADING DEVICES: **"**As solar radiation is generally intense in Southern Europe, shading has a large impact on the indoor climate and thus on a building's energy design. There are many forms of shading which can be adapted to the region with its climatic particularities – from movable shadings to fixed constructions. They ensure cost-efficient, comfortable living." (ISOVER, 2007b)

It is important to consider the height of the sun when planning solar shading. The position of sunlight on the sky is dependent on the location on earth and time of day and year. The height of the sun is e.g. used to determine whether the shading should be vertical or horizontal. *"When the sun is positioned high in the sky horizontal shading is the most effective, while vertical shading works better when the sun is positioned low in the sky*". (Andersen et al., 2009)

"The chart (Table 4.4) *shows the advantages and disadvantages of various solar shading types. Notice that many variations may occur depending on the regulation strategy and the climatic conditions."* (Andersen et al., 2009)

Table 4.4 - Advantages and disadvantages of different solar shading devices. (Source: Based on (Andersen et al., 2009)

	Heat screening	Glare	Daylight access	Field of vision	Regulation	Wind sensitive
Awnings	++	+	+	+	+	+
Projections	++	+	+	+	+	+
External blinds	+++	+	+	+	+	+
Internal blinds	+	+	+	+	+	+
External screen	++	+	+	+	+	+
Internal screen	+	+	+	+	+	+
Shutter	+++	+	+	+	+	+
Solar shading glass	+	++	+	+	+	+

Solar shading must be chosen as an external solution, since this type of shading is the most effective solution. Many technical solutions are available. Figure 4.3 shows four different solutions. Illustration a. shows an automated solution where blinds run up behind the facade cladding when not in use. In the illustrations b. and c. solutions with fixed overhangs above the windows are shown. In such cases it is essential to make a careful calculation, that happens when the sun drops below the shading device causing direct radiation into the house. In Illustration c. louvers fixed on rails are seen. These can manually be run in front of the windows when needed. At the house in Illustration d. it is planned to grow deciduous vegetation (not yet planted in this photo) over the rooftop, which, during the summer will provide shade on the windows around the terrace, but during the winter will allow the sun to come into the house. Solar shading is used for screening the direct sunlight, in order to either reduce the heat load or to avoid glare from the windows. External solar shading is most efficient in terms of reducing heat radiation, as the rays of the sun will not pass through the windows. Internal solar shading has limited effect as heat screenings, but work well as glare screenings. (Andersen et al., 2009)

Figure 4.3- External shading. (Left to right: a., b., c. d., respectively) (Source: (Velux Group, 2010))

Shading and sun screening are just as important as the window itself for good daylighting performance and are essential for controlling the radiation and consequently the overheating inside- Figure 4.4. Pleated blinds and Venetian blinds can be used for adjusting the amount of daylight entering the spaces and reducing window luminance to control glare. The venetian blind can also be used to redirect the light into the room. Examples of external shading are roller shutters and awning blinds- Figure 4.5.

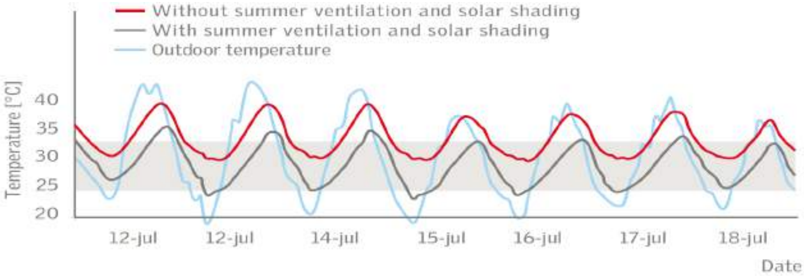


Figure 4.4- Evaluation of indoor temperatures showing solar shading influence on indoor temperature (Source: Velux Group, 2010))

A dark grey screen will reduce the illumination and luminance levels significantly to a level where the risk of glare can be avoided." (Velux Group, 2010) Solar shading improves both the U-value and g-value of window systems and can be controlled dynamically for optimal performance.

Figure 4.5- Different shading solutions. (From left to right) Interior shading: Venetian blind and Pleated blind; exterior shading : roller shutter and awning blind (Source: (Velux Group, 2010))

"In terms of shading of the glazed areas, the building should be especially protected from solar gains on windows oriented to the east and west, due to the low angle of the sun in the early morning and late afternoon. This is especially true for poorly insulated and low inertia buildings. A wide variety of shading devices are available: fixed or adjustable, internal or external, admitting more or less light" (Guedes, 2014). Besides the "traditional" or more used shading devices applied at the openings, on or within them, there are empty other solutions that also contribute to the building shield from the sun and consequently the decrease of direct radiation: Table 4.5 indicates features of various shading strategies. The solutions that are adjustable, and for that reason, in my point of view, flexible, allow the building to organically

change according to need. Tents are good solutions and for that reason, together with their relatively low cost and easy erection feature, those pose as a good alternative

Table 4.5- Features on different shading strategies (Source: (Guedes, 2014))

Shading Type	Description	Performance
Fixed device	Usually external elements like horizontal overhangs, vertical fins, egg crates, or fixed external louvers.	Performance Horizontal overhangs, generally used above a southern window, can provide shading during summer and allow for solar heating during winter. In the east and west façades a horizontal fixed device is better than vertical, but the façade is never completely shaded. Vertical fins can protect the north façade from the rising sun and sunset. The use of grid systems (from wooden gelosias to pre-fabricated ceramic or cement elements) can also be very effective, and offers advantages in terms of privacy. However, they may reduce view to the exterior. Daylighting and natural ventilation must be considered in their design. Light-colored shading is preferable to dark colored, as it performs better in reflecting solar radiation, reducing its penetration in the building's envelope. It can also have a better performance in terms of daylight.
Intermediate spaces	Balconies, courtyards, atriums or arcades.	These features can be very useful as a form of fixed shading, if their design is adequate. As in all shading strategies, design should also consider daylight and ventilation requirements. Shading performance depends on the building configuration , or balconies design
Neighbouring buildings	Buildings across the street can provide shading of the façades, particularly for lower floors.	Neighboring buildings can provide efficient shading, although in some situations, such as in narrow streets, they may decrease daylight availability. The impact of this type of shading should be considered in the design process, in terms of the choice of shading devices and window sizing, e.g. increasing window size in permanently shaded areas, to improve daylight.
Vegetation	When possible, vegetation can be used to shade the lower building floors.	Trees generally have the effect of reducing wind speed. However, a row of trees with bare trunks for the lower 3m of their height may, if the foliage is dense above, deflect and enhance the breeze at ground level. In situations where some passive heating may be necessary during the dry season, deciduous trees are used preferentially, in order to provide shading in the hot season, and let solar radiation and daylight in during colder period.
Adjustable devices	These devices can be external–such as shutters (hinged, sliding), rotatable fins, horizontal plates, retractable venetian blinds, canvas awnings, tents, blinds or pergolas –made of wood, metals, plastics, fabrics, etc.They can also be internal – like curtains, roller blinds or venetian blinds, or positioned between the glass panes of the window.	Adjustable devices are more effective than fixed, as they can admit all the solar radiation when it is desirable, like in winter, and offer more protection in summer. Their flexibility also allows a better use of daylight, when compared with fixed shading. They also allow for occupant control. External shading devices are more efficient than internal ones, as they prevent solar radiation from falling upon the glass, while internal shading devices aim only to reflect back the already entered radiation. Louvers between panes of double gazing can also have a good performance, similar to external shading. However, roller blinds, found in various cases of domestic-type offices in the present survey, can be a poor choice in terms of view, daylight and ventilation. Light-colored external opaque shading devices can reflect up to 80% of the radiation impinging on the building, if properly controlled. Translucent white external devices (such as adjustable canvas devices) can reflect up to 60 % of this radiation.

E. COMPACT / DENSITY: Complicated designs increase the energy demand compared to plain, compact building styles. Compact design is most favourable.

"In terms of the shape of the building, the configuration and arrangement of internal spaces influences exposure to solar radiation as well as the avail- ability of natural lighting and ventilation. In general, a compact building will have a relatively small area of exposure, i.e., a low surface to volume ratio. For small and medium-sized buildings, this offers advantages for the control of heat exchange through the building envelope; however the sizing of the openings should be adequate to enhance natural ventilation. In hot humid climates such as in Guinea, the window size should be maximized, whereas in more arid regions such as in Cape Verde, with higher daily temperature amplitudes (allowing for night ventilation), window size should be reduced. The twinning of the buildings in the band also has advantages, by

reducing the area of exposure to the sun, hence reducing risks of overheating. The areas of the building that can potentially be lit by natural light and naturally ventilated, the so-called passive areas, can be considered as having a depth of twice that of the floor-to-ceiling height (i.e. usually about 6 meters). This depth can be reduced when there are obstacles to natural light and ventilation, arising because of inadequate internal divisions, neighboring buildings, or in the case of spaces adjacent to atria. The ratio of the passive area of a building in relation to its total area provides an indication of the potential of the building for the use of bioclimatic strategies" " (Guedes, 2014) In such a small building, and since the longest measure is the inside length of 6 meters and the smallest is almost 2 meters, the building is a potential for the use of these blioclimatic- passive- solutions.

"In general, a compact building surface will have a relatively small exposure, i.e. a low ratio Surfaces/ volume. For small and medium-sized construction, this offers advantages for the control of heat exchange through the building envelope. The twinning of the buildings also offers advantages; to reduce the area of social exposure home are reduced risks of overheating " Translated from (Guedes, 2011a)

Hot air is lighter than cold. When those two meet each other, the hot air goes up and allows the intake of cold air. When there is not a lot of vegetation or none at all (Figure 4.6), the house in a hot dry climate should have a courtyard, shaded so that air is refreshed. When an opening is built, then the air exhausts from there. If there is a courtyard and even better, shaded, with vegetation and water, then the air-cools down beneath the shade before going inside. Those elements will allow a nice breeze to go inside the rooms around that space, freshening them.

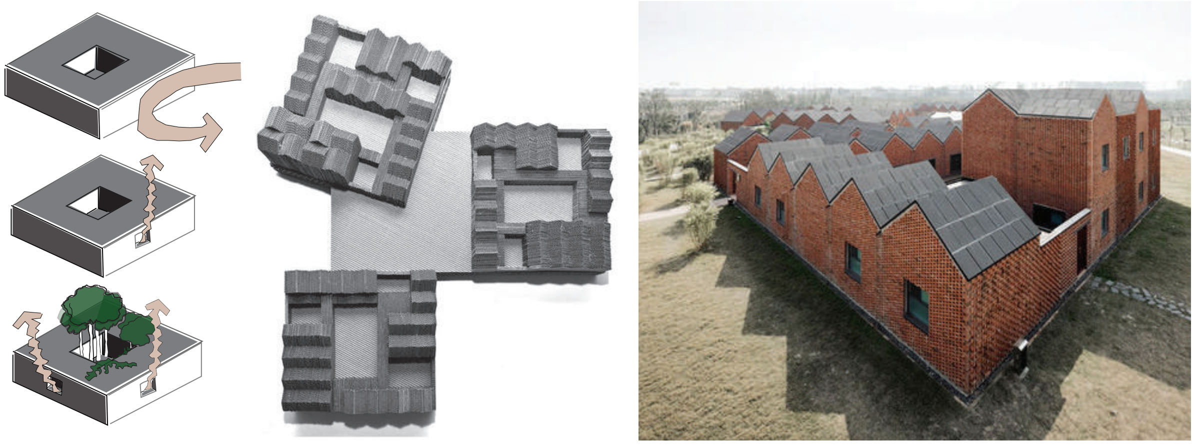


Figure 4.6- By putting together units that just stood alone, there is the possibility of creating other spaces, such as a courtyard that helps cooling the building mass. (Above) Diagram with cooling through a compact design and an interior courtyard that can be filled with water or vegetation (Middle and Right) Three Courtyard Community centre: The three courtyard blocks each feature a different element of a traditional Chinese garden: bamboo, stones, and water. Around each themed courtyard, brick-clad units congregate to form a village atmosphere. (Source: (Left) Mafalda Melo Oliveira, based on (Lengen, 2010); (Middle and Left) - http://www.archdaily.com/132163/three-courtyard-community-centre-azl-architects/)

F.EVAPORATIVE / COOLING : Vegetation and trees in particular, very effectively shade and reduce heat gain. It also causes pressure differences, thereby, increasing and decreasing air speed or directing airflow. They can, therefore, direct air into a building or deflect it away.

Free cooling is a process where like, passive cooling, there is no extra energy needed to run the cooling process but instead the cooling capacity of cool outdoor air, groundwater, seawater, water from lakes etc. can be utilised directly. These cooling sources are not distributed directly to the building itself as is the case with the air for passive cooling, but they are transferred via a heat exchanger. The advantages are the fact that the possibility for accurate control is large and that the energy consumption to run the system is very low compared to conventional cooling system. The disadvantage is that the temperature span is rather limited due to the temperature of the cooling source and even if capacity being slightly larger than passive cooling, it can still be necessary to supplement free cooling with active cooling in areas in the building with high cooling demands. (Andersen et al. 2009) Passive cooling, here the outdoor air is being used as a refrigerant typically in combination with natural ventilation. Capacity can be increased through the use of night time cooling in combination with exposed thermal mass or to utilize buried channels, where the heat capacity of the surrounding earth will contribute to cool the incoming air during summertime and temperate the incoming air during winter time. Another cost effective and energy efficient form of passive cooling is to use cool materials on the building envelope. Cool materials (paints, tiles, shingles etc.) can reject solar heat remaining cooler under the sun. This is due to their two main properties high solar reflectance and high infrared remittance. At building scale the use of cool materials results in lower energy consumption for cooling, improved thermal comfort and lower carbon footprint. These effects are far more important if the building is poorly or not insulated. (Andersen et al. 2009) Capacity can be increased through the use of night time cooling in combination with exposed thermal mass or to utilize buried channels, where the heat capacity of the surrounding earth will contribute to cool the incoming air during summertime and temperate the incoming air during winter time. (Figure 4.7- chimneys or wind towers and wind tunnels)

Figure 4.7- (Left and Right) New vs old and traditional, (Right) Wind Tunnel and chimney view for cooling in hot climates (Source: (Left) http://en.wikipedia.org/wiki/BedZED; (Middle) http://wikitravel.org/en/Kashan; (Right) Mafalda Melo Oliveira, 2014 based on (Velux Group , 2010))

"The use of fountains and vegetation (Figure 4.8) *in the courtyards, or the act of pouring water on the floor, or the use of large porous clay pots filled with water in the rooms, are good examples of direct evaporative cooling techniques, many of which are used in some of the warmer countries of Africa, and hence which can also be applied successfully in Cape Verde, and also in Angola and Mozambique during the dry season, when the relative humidity level does not exceed 60%. Indirect evaporative cooling techniques also exist, in which the air is cooled without increasing its water vapor content. In this type of system the air tem- perature can be lowered to match the wet bulb temperature. The water consump- tion is much lower than in direct systems. However, indirect systems involve the use of mechanical devices, which can be expensive and require complex maintenance"* (Guedes, 2014)

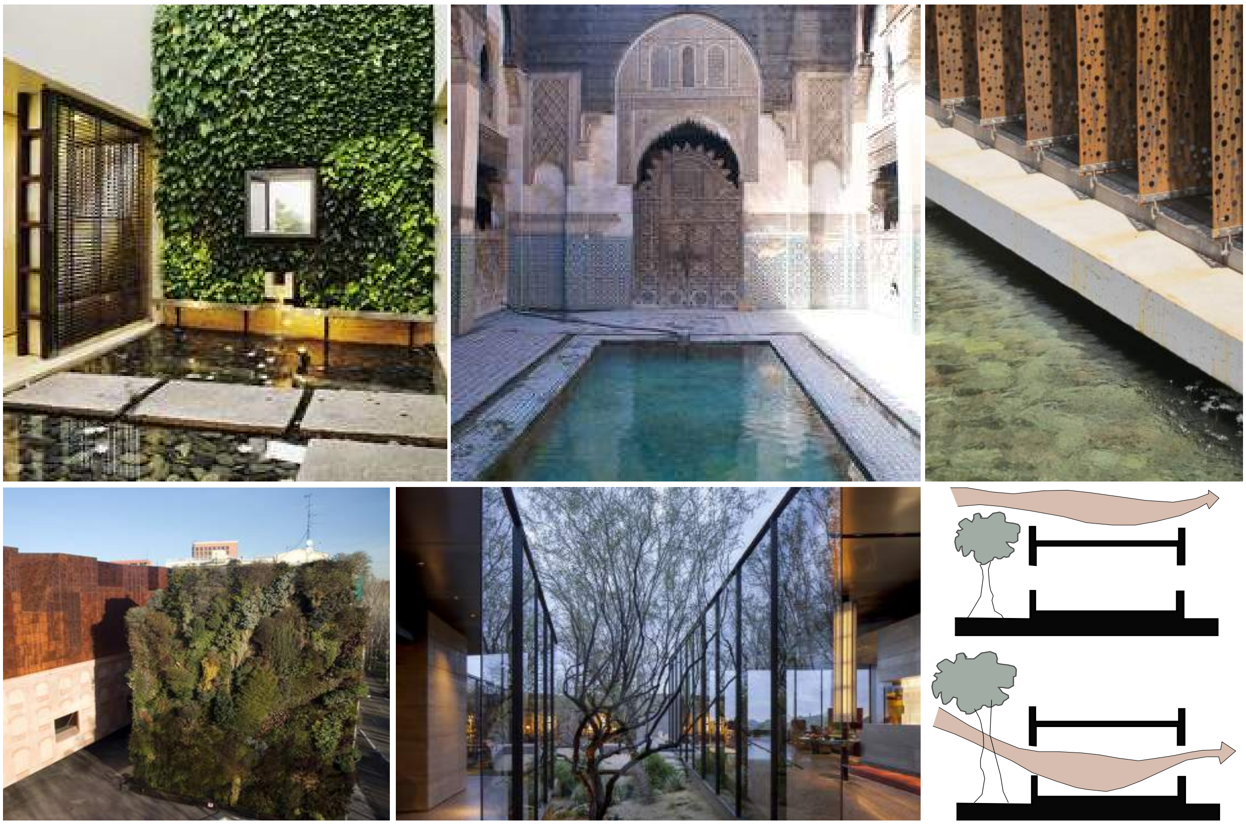


Figure 4.8- Use of water and vegetation for cooling (Source: (Above, right) http://wikitravel.org/en/Kashan; (Bellow, left) http://www.pinterest.com/suryapethi/mac-greggor-downs/; (Bellow, Left) http://verynicethings.es/2013/04/caixaforum-en-madrid-y-barcelona/; (Bellow, Right) http://www.weimag.cn/weMag/pc/view/MAG917ac711-50bf-43dc-9497-45bc8eb5065c

The BRE document Environmental Site Layout Planning: Solar Access, Microclimate and Passive Cooling in Urban Areas (2000, pp37–43) provides references to research which confirms our intuition that bodies of water will provide a source of cooling. The larger the body of water the better is the rule. A lake might provide a reduction in air temperature in its vicinity of up to 2°C. However, a small pool in a garden, if it replaces materials which would otherwise readily absorb and re-radiate heat, will have a much larger local cooling effect. Trees, which absorb radiation and cool the surrounding air, can lower the air temperature near buildings and therefore lower the indoor temperature, although there seems to be little hard evidence and few agreed rules. In Environmental Site Layout Planning (Littlefair et al) (2000, p40) evidence suggesting that the temperature will be lowered in this way for a distance of up to five times the height of an orchard, and that the temperature drop within and downwind of a forest might be as much as 6°C . Green spaces in cities do not merely provide an environment for recreation but bring beneficial cooling for a considerable distance, 150m or more into the urban fabric according to Baruch Givoni in Climate Considerations in Building and Urban Design (1998, pp308–310)

“Evaporative cooling is achieved by an adiabatic process, in which the sensible air temperature is reduced and compensated by latent heat gain. The use of fountains and vegetation in the courtyards, or the act of pouring water on the floor, or the use of large porous clay pots filled with water in the rooms, are good examples of direct evaporative cooling techniques, many of which are used in some of the warmer countries of Africa, and hence which can also be applied successfully in Cape Verde, and also in Angola and Mozambique during the dry season, when the relative humidity level does not exceed 60%. Indirect evaporative cooling techniques also exist, in which the air is cooled without increasing its water vapor content. In this type of system the air temperature can be lowered to match the wet bulb

temperature. The water consumption is much lower than in direct systems. However, indirect systems involve the use of mechanical devices, which can be expensive and require complex maintenance"

"Wind towers, such as the ones used in some hot countries (2 to 20m tall) can also be useful to create air movement, when wind for cross ventilation is not available at the building's level. The stack supply and extract is wind driven, reverting to stack in the absence of wind. In certain hot and dry regions, pools or ceramic pots with water are placed in the base of the wind tower tp provide addional evaporative cooling" (Guedes, 2014)

SUMMING UP: Requirements for cooling of the human body and description of convective and evaporative- Table 4.6

Table 4.6- Besides the Objective of Ventilation of provision of fresh air and heat removal from the building, ventilation also allows convective and evaporative cooling of the human body. (Source: (Guedes, 2014))

Objectives	Description	Requirements
Convective and evaporative cooling of the human body	A higher air speed increases the sweat evaporation from skin, broadening the comfort temperature upper limit. A thermal sensation corresponding to an effective temperature of 27°C can be achieved if air movement of 1m/s is applied to a room with an air temperature of 30°C.	This process requires air speeds between 0.5 and 3m/s. It is accepted that each increment of 0.275m/s increases 1°C to the upper comfort limit. The upper velocity recommended in offices is 1.5m/s. In houses, this value can increase to 2.5–3m/s.

G.EXTRA CONSIDERATIONS:

1. COLOUR: influences daylight and temperature. "The absorption of solar radiation varies with the color and texture of surfaces." (Guedes, 2014)

When bright, allows more daylight and reflects sun rays cooling the inside temperature in contrast with darker colours that absorb light and for that reason also get hot making the rooms adjacent warmer.

"ENVELOPE COATINGS The light colors of some coating materials reflect a considerable amount of solar radiation. The use of whitewash (limestone based white paint) to paint buildings is an example. Light-colored coatings help to reduce the temperature of the building envelope and avoid the conduction of heat into the building. Light colors reflect more energy, and dark materials absorb more energy (more heat). Examples are lava fields, black sand and paved roads. Table 4.7 describes the characteristics of light-colored reflective coatings" (Guedes, 2014)

Table 4.7- Use of light color on the building envelope (Source: (Guedes, 2014))

Reflective coating	Description	Performance
Light color paint or tiles	Light color paint of the opaque external envelope (e.g. white or bright). Light color	White paint is a very cost-effective way of reducing the building's heat load in summer. The color that reflects most radiation is white. Painting the internal walls in a light color can also improve the internal levels of daylight, hence reducing the need for artificial light. Near the houses, one should avoid the use of dark colored pavements, in order to reduce solar radiation absorption. In some urban situations, the reflectance of solar radiation to other buildings may sometimes be undesirable, but it may constitute an advantage in terms of daylight. Undesirable reflection from neighboring buildings can be avoided through the use of shading devices. Metallic foils are only effective when they are facing a void between building elements. This is because heat is transferred across air gaps partly by radiation, which the foil reduces due to its low emissivity. They have no effect at all when in contact with materials on both sides. When heat transfer is downwards across avoid e.g. an attic space, the largest proportion of heat is transferred by radiation. This is when reflective foils are most effective tiles can also be used in façades. The roof, when possible, should also have a light color.

2. INSIDE ORGANISATION: It is important that the services- kitchen and bathroom- are placed in order that the wind does not bring the heat and smell to the other common areas of the house, such as living

room or sleeping areas. If possible in the North Hemisphere, the kitchen should be placed in North- so that it does not get direct sun radiation, while in South Hemisphere should be South. Sleeping rooms are better at the eastward side. In cold areas, the sun heats the areas where people get up in the morning, while in warmer areas, afternoon sun- coming from West- should not overheat those rooms. At sleeping time, a colder room to sleep at is nicer so those rooms should be in East. Living rooms are better to West. In cold areas, those are the warmer places in the afternoon- as meeting place for the family – and time when those divisions are being used by the inhabitants

"In terms of the shape of the building, the configuration and arrangement of internal spaces influences exposure to solar radiation as well as the avail- ability of natural lighting and ventilation." **(Guedes, 2014)**

3. URBAN SCALE- PLANNING: In a dry place, the land is narrow and long while in areas where there are more rain, the land should be large in the front of the house facing the road. In hot dry, if there is a high building and the houses are placed before, than the wind is directioned to the smaller houses, cooling them, while taking the heat out of the inside of the building. In a cold climate, and since wind always brings cold, sometimes higher buildings can be used as block and protection, working as a shield leading the winds to pass above the houses. Urban planning should allow natural ventilation along the roads , the houses on one side of the road should not block ventilation for the rest of the houses on the other side. (Figure 4.9)

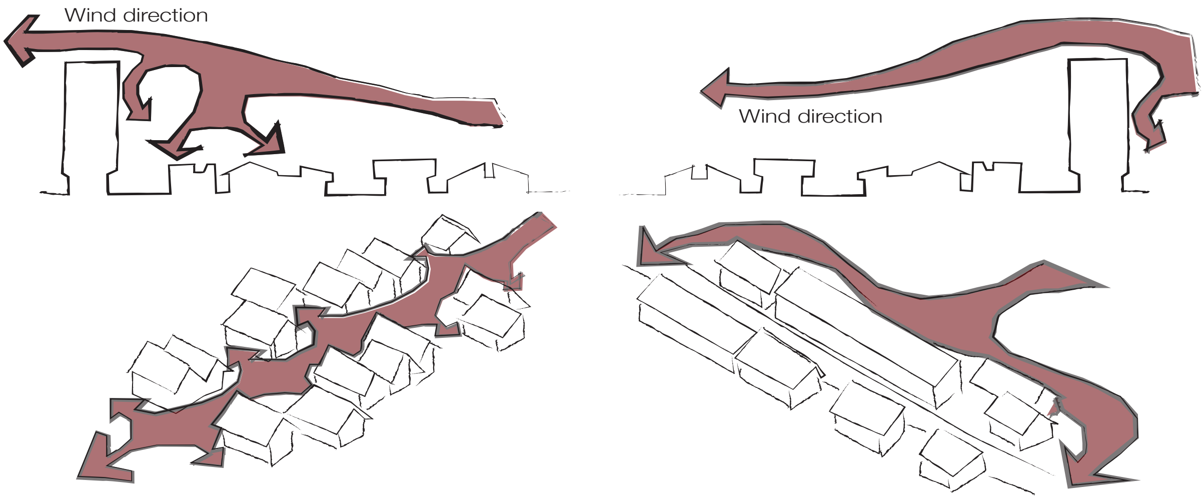


Figure 4.9 – The influence of street orientation and urban planning according to wind direction: Protect / Intensify breezes. (Source: Mafalda Melo Oliveira, 2014, based on (Lengen, 2010))

Some decisions are a little more detailed and shown in real calculations and results, while others – due to the lack of space on such a short paper- are referred and kept more "theoretical" and research based.

Conclusion: there are five important things and main focus **:** Optimal building orientation **:** Reduce large glazed facades towards east, south and west for a Northern hemisphere**,** Ensure daylight availability for lighting and efficient solar shading, Location of rooms with high internal heat gains or demand for low temperature towards orientations with small solar gains **;** Reduce all internal heat gains (anthropogenic loads, equipment, artificial lighting)**;** Zoning of the building according to patterns of use and internal loads o Location of areas with high internal heat loads, such as server and printing rooms in separate rooms **;** Apply external solar shading**;** Make use of a daylight control system to minimize the heat load from the artificial lighting (Andersen et al., 2009)

Some questions such as adding more windows to allow cross ventilation, will of course make the results better in terms of ventilation (lower temperature) and higher air exchange – less CO2 concentrations – but it is necessary to be careful with solar gains and losses, when providing too much glass area compared to the floor area – small value of approximately 13m2 – Lastly, when changing and proposing some of the changes expressed here, the design would have to be changed and adapted further to meet the conclusions and results obtained.

4.2 CLIMATE ADAPTED DESIGN-THE CASE STUDY 2: NORTH AND SOUTH CONTEXT

As far as designing and proposing one only solution for all the climates and everywhere around the world, it is easy to see why it did not work. In order to get a deeper understanding and more detailed results, together with a stronger “on one hand, …on the other” comparisons, in this section, not 4 climates are studied but only 2: Hot dry and Cold. It could be argued that it is too little and it will not be detailed enough, but this was mostly to have an idea how the initial – case 1- solution wasn’t appropriate and also the fact that it is for some reason that people haven’t just created a working example using shipping container- it is harder than initially it seems.

Since the design would already slightly change, and because compact shapes make more sense and were considered, there would be 2 scales of intervention. Scale 1 -for one person up to 5 living inside- and a Scale 2 where more people would fit and where activities would be divided: container a for sleeping, container with drinking water and place to cook and container 3 with waste products and sewage infrastructures related. This way some problems would be solved with smell, space would be very efficient, and 2 or 3 containers could be put together forming a block within same family, friends or community. Some solutions are shown in chapter 5, but combining containers in different ways and adding to the equation the possibility of using others with different measures and potentialities, would constitute a future development to take into account.

The climates and the different contexts represent more than specific countries or locations, but features : more precipitaion or less, sunny or cloudy area, existence of snow or rain, wind direction and speed, etc. (think globally , act locally – refers to thinking about climates in general and what they represent , acting upon their specific features or elements that define them)

NORTH VS SOUTH For “major challenges between North and South” , given as subtitle for this work, the intention was to propose a mix of adjustments that would work in different contexts and their results – such as less vs more daylight (need to unveil and open vs need to cover and close); high temperatures vs low ; dry climate vs more humid. To use those four climates, it wouldn’t allow a deeper level of information, therefore, the decision went through choose only two climates (and respectively, two countries) to study those adjustments and not only compare them and the differences in the adjustments needed for each, but also to compare them with the earlier results achieved in case 1. The bigger difference between those two climates, would have to be related to sun and to temperatures, so a cold and a warmer context: the coldest of all last 4 was represented by Denmark and in terms of hot climates, Saudi Arabia – hot and dry- was chosen as a climate contrasting to cold where it snows and rains. Besides this, the wind conditions and directions are different and the problems and special features of buildings in those areas would make the work differentiate enough for an analysis. What defines those places and differentiates them? Could they adopt the same solution? In case 1, it has been shown that the same solution does not adapt to such different climates. “Cold climate – a climate where winter is cold and summer temperatures never or only rarely reach a level above comfort level (22 - 25 °C). In this climate, there will hardly ever be a need for cooling, nevertheless, overheating should be taken in consideration. This is the case for large parts of Russia, Scandinavia and Canada” (International Energy Agency, 2008) while, “Hot dry climate or Arid – he general characteristics of climate plateau plains are as follows: hot dry weather, very low vegetation cover high temperature difference between night and day the desert and desert areas , combined with wind and dust”. (Medi, Hosseini, & Mottaqi, 2010) “Quite often, during the "cool" dry season, daytime temperatures peak between 35 and 45 centigrade and fall to 10 to 15 centigrade at night. Daytime temperatures can approach 45 centigrade during the "hot" dry season and drop to 15 centigrade during the night. In many situations, these diurnal temperature fluctuations restrict the growth of plant species”. (FAO- Food and AGRICULTURE Organization of the United Nations, 1989)

DENMARK it is part of the temperate climate zone. The winter is not extremely could with average temperatures around 0ºC in January and February and summer is fresh with average temperature in August of 15,7ºC. In Copenhagen , over the course of a year, the temperature typically varies from 2ºC to 22ºC and is barely bellow -8ºC or above 26ºC. The warm season lasts from June 3 to September 8 and the cold season lasts from November 21 to March 22. The shortest day is December 21 with 7:02 hours of daylight; the longest day is June 20 with 17:32 hours of daylight. Over the course of the year typical wind speeds vary from 2 m/s to 9 m/s (light breeze to fresh breeze), rarely exceeding 13 m/s (strong breeze). The wind is most often out of the west (24% of the time), south west (17% of the time), south (15% of the time), and east (11% of the time). The relative humidity typically ranges from 51% (mildly humid) to 96% (very humid) over the course of the year. Precipitation is most likely around December 15, occurring in 73% of days. Precipitation is least likely around May 7, occurring in 50% of days. (See sun path, wind direction and other information in annex)

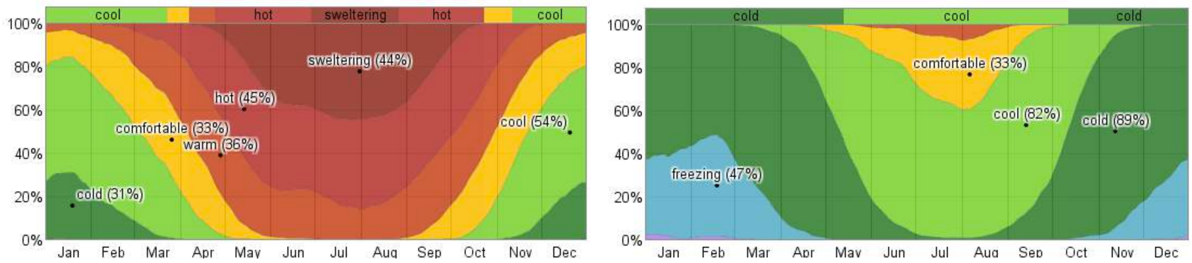


Figure 4.10 - Level of comfort in different stages and months (Left) Saudi Arabia (Right) Denmark (Source: http://weatherspark.com/averages/28823/Kastrup-near-Copenhagen-Capital-Region-of-Denmark)

SAUDI ARABIA it is part of the arid climate zone , temperatures during the summer months are extremely hot, being the average high temperature in July is 42.6 °C, while winters are warm with cold, windy nights. It is a climate with extremely big temperature swings with high day-time temperatures and a sharp temperature drop at night. It is also known to have many dust storms, where dust is often so thick that visibility is less than 10 m. In Riyadh, the capital, Over the course of a year, the temperature typically varies from 8°C to 43°C and is rarely below 3°C or above 45°C. The warm season lasts from May 14 to September 26 and the cold season lasts from November 29 to February 25. The shortest day is December 21 with 10:36 hours of daylight; the longest day is June 20 with 13:41 hours of daylight.

Over the course of the year typical wind speeds vary from 0 m/s to 7 m/s (calm to moderate breeze), rarely exceeding 11 m/s (strong breeze). The wind is most often out of the north (17% of the time), south east (12% of the time), north west (11% of the time), and south (10% of the time). The wind is least often out of the south west (3% of the time). The relative humidity typically ranges from 6% (very dry) to 71% (humid) over the course of the year. Precipitation is most likely around April 10, occurring in 22% of days. Precipitation is least likely around August 25, occurring in 0% of days. (See sun path, wind direction and other information in annex)

Copenhagen and Riyadh stand in two opposite corners, representing a substantial difference in their climate, so those two places are good examples to analyse. In the warm climates, heating is less of a problem than in colder countries and it is about how to keep cold out, while in colder, it is important to decrease the need for heating. Either way, it is necessary to be careful about overheating and temperature swings. According to the adjustments set and proposed before, some calculations and results will be shown and analysed.

On the other hand, there is now a large body of evidence that shows that people living in countries with warmer climates are satisfied by temperatures that are higher than those which feel comfortable to people living in countries with colder climates, and these temperatures are significantly different (upper and lower, respectively) to the temperatures considered 'ideal' by conventional standards. Buildings that use passive cooling techniques can be efficient and economic, energy efficient and environmentally friendly alternatives to air conditioned buildings. These bioclimatic buildings also offer more satisfactory thermal environments – not in their ability to meet strict standards, but in improving the physiological and psychological comfort of the occupants.

4.3 CLIMATE ADAPTED DESIGN- THE CASE STUDY 2: APPROACH AND RESULTS

DESIGN GUIDELINES: Starting with the shelter design, that includes: the house typology (slab, block or villa), the form and shape, orientation and location, interior design guidelines and colours. Then, following, the essential building elements related to the building envelope such as: the openings and windows- together with thinking about the shading devices-, walls and roof. For last, all special details or extra features: the vegetation near or around the building, materials and extra solutions- such as geothermic and evaporative.

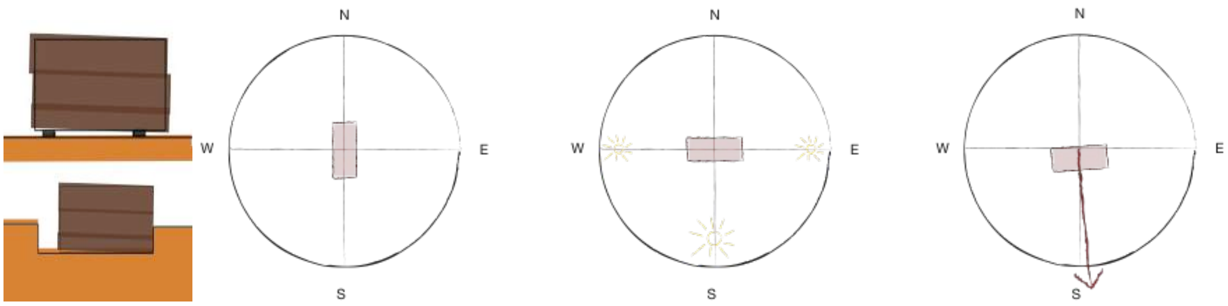


Figure 4.11 - (Left, above) In a cold climate, the floor should be protected from the cold of the ground, while (Left, bellow) ground temperature should be used to balance temperatures in a Hot dry climate ; B. (Right) Solar orientation according to the cardinal points. From left to right, respectively: Orientation along North/South axis first; The building longer walls should be orientated East/West, because the sun on those points is more difficult to control and therefore more solar radiation on the north and South facade is preferable; According to the optimized rotation, the building is rotated exactly 85º (Source: Mafalda Melo Oliveira, 2014)

A.ORIENTATION AND LOCATION: In hot climates, building in a depression implies relatively lower air temperatures. When building on a slope, the leeward side is preferable, as long as the orientation is acceptable. In both cases, warm breezes would be minimized. The collection of water in a depression might allow for a water body. This would also be beneficial in cooling the place. On the other hand, in cooler climates, not only do we not place our building in the depression we also avoid the path of the cool air down the slope. Here again, vegetation could help in protecting from cool breezes. For the Northern Hemisphere, a building should be oriented east/west rather than north/south in order to take advantage of day lighting, passive heating, and easier sun control.

For orientation, the same two rules apply to both contexts. They are both in North Hemisphere. Their optimized orientation given by Ecotec (see annex), would show that the building should be rotated 175º for less radiation. Besides this, using a container that poses as an elongated shape, clearly unidirectional, and in order to avoid West/East sun – more difficult to control, the axis of the container should be East/West. It did not make sense to use Bsim to prove that this orientation would be the best so; calculations and results are not shown for North/South axis. The model in Bsim starts already in its best-optimized orientation given by Autodesk Ecotec, rotated 85º (figure 4.11).

B.INSULATION (AND MATERIALS) : More insulation in less swing tem and colder, and more thermal mass – bigger heat capacity when there are big temperature swings. For this section, first of all the model was used only with steel (unfortunately the software does not always give good results when using so thin layers of materials , such as the metal). Since steel is a material with very big transmission losses and gains, in Denmark – due to the cold climate- temperatures when the simulation is done only with the steel container are very low (93.20% bellow comfortable 20ºC).

Table 4.8- Trasmission for container and after applying a thick layer of insulation- tight construction such as passive houses (Source: Mafalda Melo Oliveira, 2014, based on Simulation in Bsim)

	Copenhagen, Denmark	Riyadh, Saudi Arabia
External wall	qTransmission (mean)	qTransmission (mean)
Only steel container	- 2507,55	- 2517,05
Steel + inside wrapping (50 cm insulation)	- 1014,44	- 1176,73

It is visible – figure 4.12 and table 4.8- that when the container only uses steel, and as said before, the curve of the inside temperature (red colour) accompanies the blue colour- What shows that steel is a bad conductive materials (as known in general for metals) and there are high values of transmission when working with this solution, and therefore a lot of gains and losses through the thin 1,8mm container steel walls. In the second graph, the simulation is more balanced and regulated, due to the fact that since there is a lot of insulation, transmissions are not a problem as before (other problems will obviously arise).

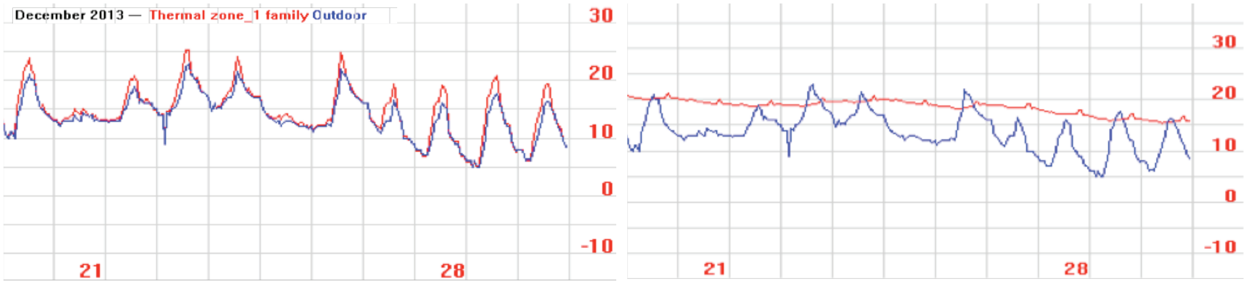


Figure 4.12 - Transmission values for container in. Riyadh, Saudi Arabia (Left) Only steel material.(Right) Steel container with 2 cm insulation on walls . The red colour represents the inside and it is clear the temperatures are a lot more balanced due to the insulation (Source: Mafalda Melo Oliveira, 2014 , based in simulation in Bsim)

The best solution for Denmark, and considering that heavier materials – such as brick, concrete, etc- are being used, the solution relies mostly on a lot of insulation that blocks the heat to go leave the building, while in Saudi Arabia , there is very little insulation- that helps balancing the values and the difference of temperatures , but the walls and structures relay on construction with high heat capacity- good thermal mass. Results shown in Table 4.9 Concern Denmark and Saudi Arabia and some comparison between the constructions that best suit those climates.

Table 4.9- Temperature, Co2 level and Moisture for different exterior wall simulations (Above) Copenhagen ,Denmark; (Bellow) Saudi Arabia (Source: Mafalda Melo Oliveira, 2014 , based in simulation in Bsim)

Thermal zone	Steel	Steel + 50cm insulation	Steel + 30cm insulation	Steel + 20cm insulation	Steel + 30/40 cm insul. (Wall and floor/ roof)
Rel. Moisture (%)	88,5	34,1	47,6	56,7	46,8
CO2 (ppm)	830,5	1416,9	1134,2	1024,6	1159,2
Hours > 20 ºC	6,8 %	94,3 %	63,4 %	47,3%	65,6 %
Hours > 24 ºC	1,7 %	74,2 %	45,7 %	31,0%	47,4 %
Hours > 26 ºC	0,8 %	66,9 %	37,0 %	20,8 %	38,8 %
Hours < 20 ºC	93,2 %	5,7 %	36,6 %	52,7 %	34,4 %

Thermal zone	Steel	Steel + 50cm insulation	Steel + 10cm insulation	Steel +2cm ins.	Steel + 2/10 cm insul. (Wall and floor/ roof)	Steel + 2/10/none cm insul. (Wall/roof/floor
Rel. Moisture (%)	32,8	11,5	23,7	30,1	29,8	31,4
CO2 (ppm)	848,1	1385,9	935,1	861,8	875,9	874,3
Hours > 20 ºC	72,7 %	100,0 %	90,7 %	78,5 %	79,1 %	76,6 %
Hours > 24 ºC	61,6 %	100,0 %	80,4 %	66,6 %	67,0 %	64,5 %
Hours > 26 ºC	55,8 %	100,0 %	74,3 %	61,2 %	61,7 %	59,0 %
Hours < 20 ºC	27,3 %	0,0 %	9,3 %	21,5 %	20,9 %	23,4 %

In a cold climate and where there are materials close to the place where the building is being erected or constructed, wood can be used .For Denmark, a solution of brick + insulation + wood or even wood + insulation + wood , allows the envelope to contribute to the lower energy demand and can be used sustainably, however, a lot of insulation is needed . In Saudi Arabia, it is harder to get the same good results due to the extreme temperatures swings, and since it is necessary to use a thermal mass, materials such as brick , concrete , blocks are more appropriate.

Humans have the ability to adapt and for that reason the human comfort expectations vary. The thickness of insulation than also varies in different contexts. ASHRAE RP884 adopts an algoritm concerning adaptative comfort in naturally ventilated buildings (Also explained in annex 6)

In a climate such as the Danish, insulation should be placed around the building wrapping it and blocking the heat to escape from the walls, while in a dry and hot climate, it is good to try to use the temperature of the ground to work as a balancer. When the ground is colder than the house, the cold transfers to the inside and when the ground is cold, it cools down the house, all passively.

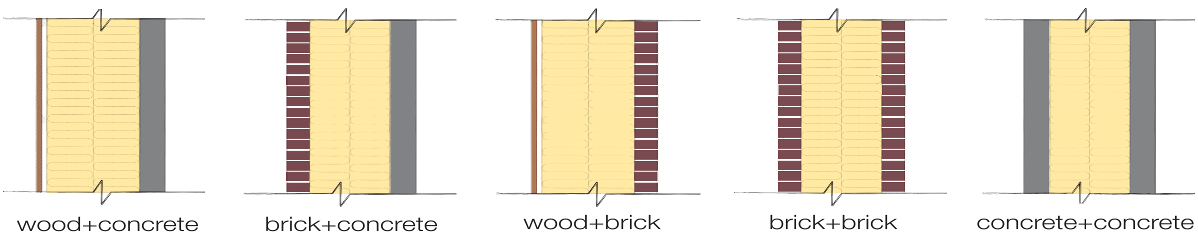


Figure 4.13- Different wall constructions tested (Source: Mafalda Melo Oliveira, 2014)

“Use of wood outside in hot climates is not preferred as wood decimates very quick in hot climates like middle east. And yes use of wood normally outside is good as it brings a lag in the heat transmittance to the internal layer which is brick. Bricks get heat late and is stored slowly and in night it is released back inside. And for Denmark, as of my knowledge, sun shines very less. In this case there will not be sufficient time for heat to be stored in the internal layer of brick. So i suggest use of glazing on south so the sun heat is rather captured by the inside floor, that will transmitted back easily. And the envelope is rather a tight drywall system, no thermal massing. Or if thermal massing is a must to use, a trombe wall system can be used."

Materials such as earth, sand and textile are difficult to predict and to study the behaviour and for that reason, those are referred theoretically and based on examples, but not used for calculations. In Bsim, it is not possible to predict sharply how so thin or specific materials behave. In terms of inside and outside architectural expression, wood is used for calculations in order to keep the influence similar and in order to represent pre fabricated cheap solutions.

C and D.OPENINGS AND SHADING: It is difficult to completely separate opening a hole in a façade and creating a window with not thinking about how to shade it. So due to that fact and because it would result in a lot more results to be shown, some shading is applied together with the openings. However, some results will be shown separately for windows and their shading. According to Hopkinson "the deep blue sky may have a very low luminance from the horizon up about 30° elevation during the hours around midday, and may consequently be insufficiently bright to act as the principal source of interior illumination" (Hopkinson, Petherbridge, & Longmore, 1967). Resulting on, sidelighting- that tries to detain this illumination- not being the best solution in terms of daylight when refereeing to hot dry climates. Intense sunlight, clean atmosphere, and reflective ground surfaces bring about the problem of glare. Glare results from excessive brightness in the visual field originating from sky luminance, light reflected from the natural landscape and/or from man-made features of the environment such as buildings. In hot dry climates, Hopkinson estimates "the ground can be 4 times as bright as the sky and as such can be the primary source of glare". (Hopkinson et al., 1967) "Windows transmit this glare into building interiors". (Hampton, 2008) So in climates like the hot dry, since the sky is clear and there is reflectance, glare should be taken more into consideration when designing. Number of windows influences daylight and ventilation- Table 4.10

Figure 4.14- Container position on the landscape. Housing units relations (Source: Mafalda Melo Oliveira, 2014)

The choice of glazing in the facades is important. Double glazing is now becoming available at an affordable price, and they should be chosen. In warm climates with high direct and/or diffuse radiation, solar control glazing (or spectrally selective glazing) should be chosen. This glazing allows visible light in, whereas infrared and ultraviolet radiation, which is heat only, is reflected. Low emissivity glazing does not allow a part of the radiation inside so that could also have a potential use in a climate like the Saudi

Arabian. It is important to take into consideration the fact that in Saudi Arabia, the sky is mostly clear and for that reason the sun rays are stronger and too much daylight reflects on glare problems, so windows should be positioned higher and be smaller. On the other hand , less windows will increase the need for electrical power for artificial lighting. How much is enough and how much is too much?

Table 4.10- Danish results from the simulation using Bsim. It was tested the influence of windows and openings. (Source: Mafalda Melo Oliveira, 2014, based on Bsim simulation)

Thermal zone	1 Window	2 Windows (S/ E)	2 Windows (N/ S- South big)	2 Windows (N/ S- smaller South)	3 Windows (N/ 2xS/ E)
Rel. Moisture (%)	65,4	63	72,9	55,1	60,3
CO2 (ppm)	1557	1799,4	1866,9	1495,6	1002,2
Hours > 20 ºC	56,0 %	60,2 %	54,0 %	63,0 %	63,5 %
Hours > 24 ºC	36,4 %	47,8 %	34,3 %	48,3 %	49,6 %
Hours > 26 ºC	25,0 %	40,6 %	22,8 %	39,7 %	40,7 %
Hours < 20 ºC	44,0 %	39,8 %	46,0 %	37,0 %	36,5 %

Model tests performed under actual site conditions remain the best method for simulation and evaluation of skylighting options. Due to the extremely short wave-length and speed of visible light, the lighting levels measured within the model will he virtually identical to those in the actual space.

In summary, the design of openings for a hot dry climate requires that window/skylight areas be minimized to control thermal loads on the structure and yet allow for effective lighting of interiors. For conditions in hot dry lands, the Building Research Station in the United Kingdom suggests that a minimum glass area as low as one-sixteenth of the floor area to be lit should be adequate for normal residential buildings. To maintain physiological and psychological comfort within a space a high quality of daylight is desirable but the quantity of daylight must be minimized to avoid thermal complications. The primary concerns for natural lighting must be the following: 1) to maximize the amount of daylight penetrating through an opening, and 2) to minimize the effects of heat gain, glare, and deterioration and fading of materials. (Hampton, 2008)

Shading devices shoud be defined accoding to context and openings.- Table 4.11 shows some results on the influence of shading on the two climates.

Table 4.11- Shading devices and influence on temperature (Above) Saudi Arabia (Bellow) Denmark (Source: Mafalda Melo Oliveira, 2014, based on Bsim simulation)

Shading device / Out "Comfort range"	No shading	Horiz.shad (overhang)	Vert. shad. (Shutters)	Horiz. and vert. shad. (flexible)	Extra: roof overhang	Extra: Neighboor	Extra: Covered alley (courtyard)
Hours > 26 ºC	61,9 %	60,2 %	59,6 %	58,2 %	56,1 %	55,2 %	53,9 %
Hours < 20 ºC	20,0 %	20,4 %	20,6 %	20,7 %	21,6 %	21,6 %	21,8 %

Shading device / Out "Comfort range"	No shading	Horizontal shading (overhang)	Vertical shading (Shutters)	Horizontal and vertical shading (flexible)
Hours > 26 ºC	41,0 %	38,8 %	32,4 %	31,4 %
Hours < 20 ºC	38,4 %	40,4 %	41,8 %	40,6 %

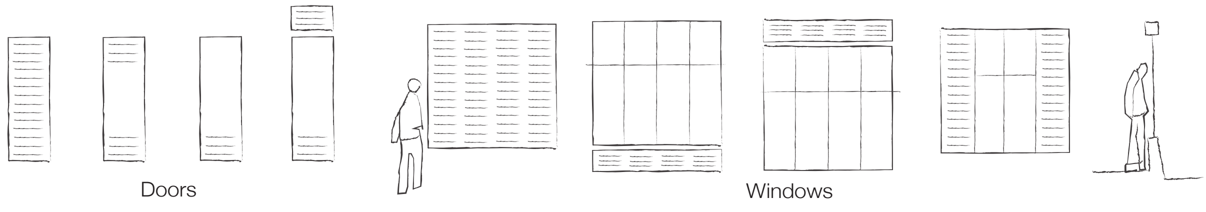


Figure 4.15- To guarantee that wind can come in, even when doors and windows are closed, venetian sheets for doors and windows are good option (Source: Mafalda Melo Oliveira, 2014 , based on (Lengen, 2010))

E.COMPACT SHAPE /DENSITY: In hot climates the P/A ratio should be kept to a minimum. This would cause minimum heat gain. Plan form for enhancing ventilation is not a compelling proposition as breezes are often quite warm. In cold climates too the P/A ratio should be minimal. This ensures minimum heat loss. Heat gain can often be achieved by solariums etc. In hot dry climates S/V ratio should be as low as possible as this would minimize heat gain; In cold-dry climates also S/V ratios should be as low as possible to minimize heat losses heat. (Andersen et al., 2009)

In hot-dry climates, compact planning with little or no open spaces would minimize solar heat gain. If the heat production of buildings is not low, the size and scale of open spaces should be optimized to have also sufficient heat loss at night. In cold climates open spaces should be small. Surfaces could be hard and absorptive. Compact planning is preferred. They should allow the south sun into buildings.

It is shown in the Saudi Arabian case, how the courtyard would help decreasing the solar radiation, lowering the temperatures in the building studied. If, The building is organised around a central patio , it maximises natural ventilation and keeps the interior cool in hot weather.

F.EVAPORATIVE / COOLING: Vegetation and trees in particular, very effectively shade and reduce heat gain. It also causes pressure differences, thereby, increasing and decreasing air speed or directing airflow. They can, therefore, direct air into a building or deflect it away.

In hot-dry climates where heat gain is to be minimized, trees can be used to cut off the east and west sun. Hot breezes can be effectively cut off. Planting deciduous trees is very useful because they provide comforting shade in summer and shed their foliage in winters allowing sun, while in cold climates evergreen trees can be used to cut off breezes. However, they would also absorb solar radiation and, thereby, cool the place. In hot-dry climates, water/ water bodies can be used both for evaporative cooling as well as minimizing heat gain. Taking into account wind patterns and vegetation they can be used to direct cool breeze into the house. A roof pond minimizes heat gain through the roof; In cold climates, water bodies are beneficial only if their heat gain and loss can be controlled. However, we may be faced with a large water body in a cold region. The best thing to do then is to stay away from it.

Capacity can be increased through the use of night time cooling in combination with exposed thermal mass or to utilize buried channels, where the heat capacity of the surrounding earth will contribute to cool the incoming air during summertime and temperate the incoming air during winter time.

“In order for an opening to provide for air movement, it must be small which however, reduces natural Lighting for the room. This is why wind towers, called Badgirs, are made which serve the sole purpose of air movement. Wind captured at the top of the tower has less solid material such as sand and is cooler and stronger than at ground level. Houses are commonly constructed with one or two wind towers often rising 15m above grade. Towers allow cool air passing across the sky to be caught and brought down through enclosed rooms at and below grade. Wind velocity at this height is generally 1.5 times the velocity of that at 1 m above ground level. Wind towers are either open on all four sides or just two depending on whether the cold winds from the north are isolated” (Medi et al., 2010)

G. EXTRA CONSIDERATIONS

Figure 4.12- Results and influence of wall outside color on the temperature inside from Bsim simulation

	Medium color	Reflective bright color
Hours > 26 ºC	53,9 %	51,1 %
Hours < 20 ºC	21,9 %	23 %

A. COLOUR Light colours on the exterior of the building help cooling down inside the constuction because the sun rays to are reflected instead of being absorbed – happens with darker colours. In addition, if the inside is also made of bright colours , then daylight is reflected, the room gets brighter and looks bigger . For this reason in places such as Saudi Arabia and hot climates, it is important to consider having the brightest colours outdoors to keep the sun out. The roof is one of the most exposed surfaces so it already has an influence when that surface has a light colour to it. If there is a problem with lack of light, for example in Denmark , then painting it inside allows- as meantioned above- the reflection and amplification of sun light. Table 4.12 for some results on the infuence of a bright color in a hot context.

B. INSIDE ORGANISATION It is important that the services- kitchen and bathroom- are placed in order that the wind does not bring the heat and smell to the other common areas of the house, such as living room or sleeping areas. If possible in the North Hemisphere, the kitchen should be placed in North- so that it does not get direct sun radiation , while in South Hemisphere should be South. Sleeping rooms are better at the eastward side.

C. URBAN SCALE: PLANNING Figure 4.16- Street lay-out and orientation affects the urban ventilation conditions and solar exposure of buildings. In hot-dry climates, small street width to building height ratio ensures shading. In particular, streets running north-south should be narrow to enable mutual shading from the horizontal morning and evening sun. East-west streets are avoidable as they allow uncomfortably low sun in the mornings and evenings. However, if unavoidable, they too should be narrow. In cold climates, wide streets, especially the east west streets allow buildings to receive the south sun.. North-south streets should be narrow. Low building heights are preferred. This would enable heat gain from the roof to be maximized. However, heat loss also has to be minimized. Bigger squares in colder climates not shading builds contrast with small squares intending to shade in hot dry. Narrow streets in hot climates while wider streets in colder – same reason of not shading the neighbour. Some individuality in the unity of a street view, facades – Figure 4.17

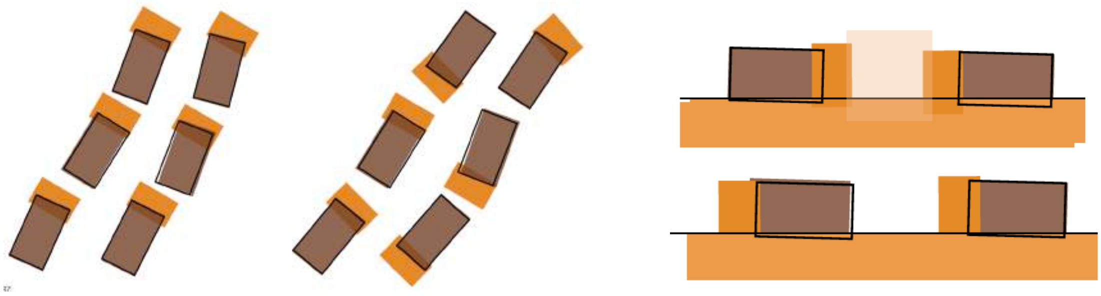


Figure 4.16 - Private spaces for community or privacy (Source: Mafalda Melo Oliveira, 2014)

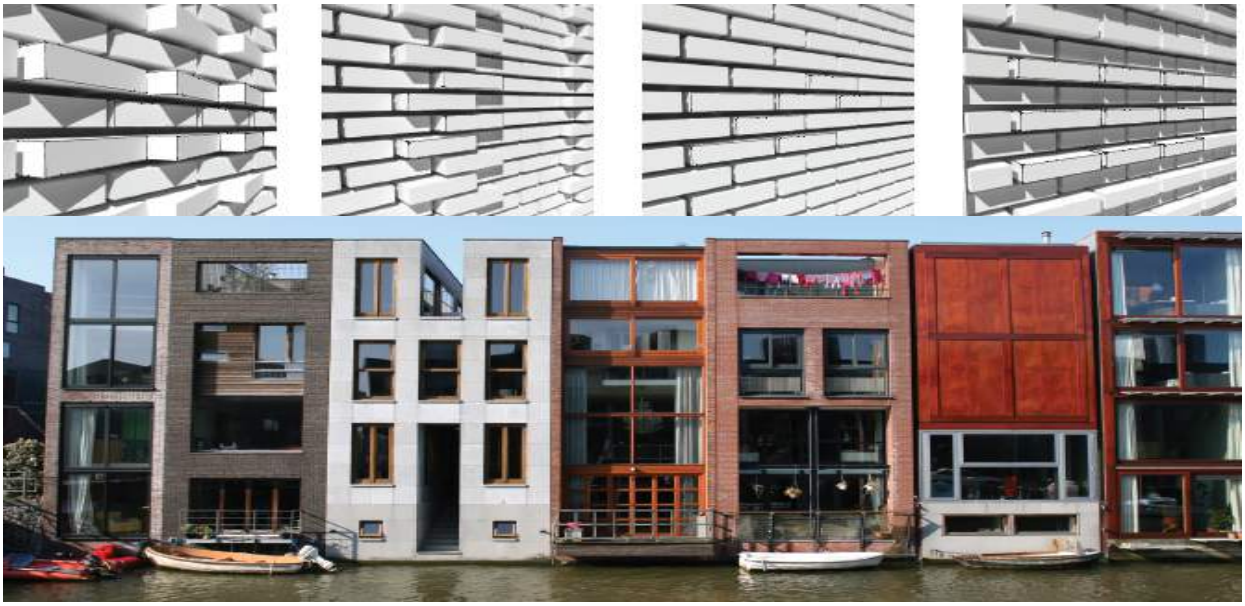


Figure 4.17- Identity within unity (Above) Material flexibility- Brick decoration: Rotated ; pushed and pulled vertically; "traditional" arrangement; pushed pulled horizontally (left to right respectively) (Source: Mafalda Melo Oliveira, 2014**)**; (Bellow) The Scheepstimmermanstraat Houses in Amsterdam is creating a unity even though they are different.

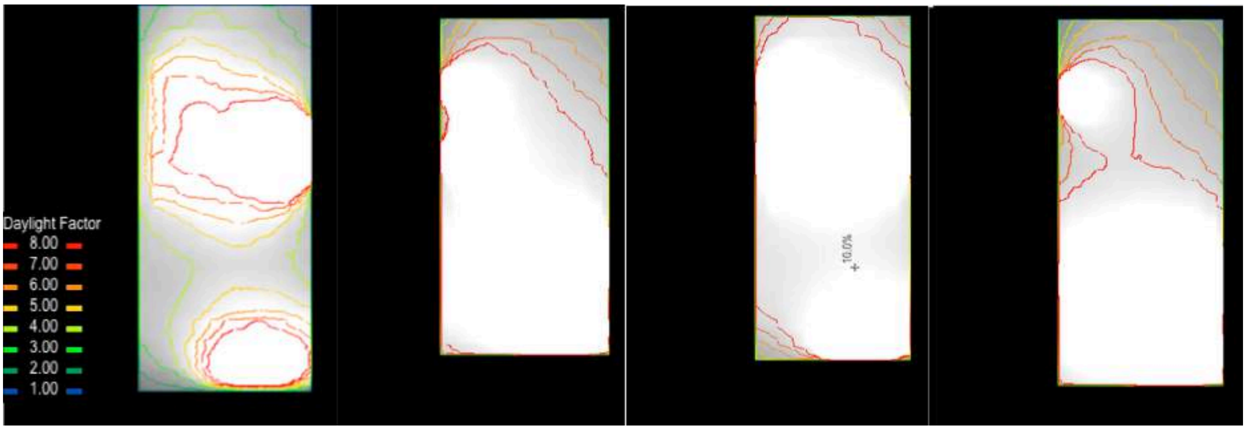


Figure 4.18- Daylight inside of the housing units with different solutions of number of openings, location, (Source: Mafalda Melo Oliveira, 2014, Daylight Visualizer simulation)

After a general overview comparing the adjustments referred in chapter 4 , section 4.3 and in order to get closer to a design solution, Saudi Arabia was chosen to be a little further explained and detailed- theoretically and in practice. Even though some of the solutions given here were mostly to propose some comparison elements between climates, they don't represent the only solutions available, rather, the ones possibly shown, studied and calculated with simple tools such as Bsim.

SAUDI ARABIA – FURTHER CONSIDERATIONS

INTERIOR Deep room arrangements can be used as a cooling contrast to intense outdoor heat. Use of flow emissive "cool" colours reduce heat reflection on interior surfaces. Connections with patio areas, verandas and courtyards covered with pergolas have cooling effect on adjacent spaces.

COLOUR light external colours will minimizing internal daytime temperatures, and is better than increasing thermal resistance or capacity It has added advantages that comfort at night is also improved White paint has high reflection ratio on sun exposed surfaces. Dark absorptive colours are adaptable

VEGETATION NEAR OR AROUND THE BUILDING The roof, walls, windows and play and rest areas can be shaded with trees and plants. Vegetation in turn reduces the temperature and filter's the dust in and around the house and elevates the humidity level in too dry climates. It may reduce as well as increase the wind speed where it is desired. Vertical Pergolas shade the façade, adobe building surrounded with vegetation and main building connected with patio areas usually getting advantage of cooling elements . "In leafy streets , dust is 5 times smaller than in those without trees" (Lengen, 2010)

OPENINGS AND WINDOWS Relatively small openings reduce intense radiation. Openings should be tight closing as protection against high diurnal heat. Openings should be located on South, North, to a lesser degree, on East sides. Low solar angles may bring radiation deep into the house from windows placed on either the eastern or western sides.

SHADING DEVICES Effective shading of windows and other glazed areas is one of the major requirements for indoor comfort in these regions during hot summer. Such shading can be provided either by fixed shading devices; which are integral elements of the building's structure, or by operable shades. Multi-storey apartment Building with units shading each other ,Visors are designed so that sunrays never hit the facades. The bioclimatic design is enhanced by climbing plants.

WALL The walls of daytime living areas should be made of heat-storing materials, while walls of night rooms of materials with light heat capacity East and west walls should preferably be shaded. Heavy masonry walls are desirable on the west and should be shaded by trees if possible. Double wall construction with proper air ventilation hould be constructed on westward side. High reflective qualities are desirable for both thermal and solar radiation.

ROOF Roof of hot climate- flat construction you can sleep outside- It is essential to include external spaces and that is also why in warmer climates stay outside in some parts of the day- its colder But a shaped roof- such as dome or cupola because the wind is directional and the sun doesn't have such a big surface to irradiate. Generally, heat storage insulation is the best, which uses the flywheel effect of out-going radiation for daily heat balance. This can be accomplished by thick insulating materials, evaporative cooling on the exterior or radiation screen with ventilation between it and the roof. A double roof or a damp-proof or white single roof will reduce the accumulation of heat. Water spray or pool on roof is effective. High solar reflectivity is a basic requirement; emissivity is essential for long-wave radiation. The internal or semi-internal courtyards with access to the rooms of the house through openings cool the interior from several sides rapidly during the evening in hot dry regions. Therefore, the roof should slope down towards the courtyard, and be surrounded by a parapet at the upper edges. Although the temperature of the whitewashed roof will be close to that of the outdoor air during the day, long-wave radiation to the sky reduces this to 6- 10oC below the outdoor level at night. Thus air in contact with the roof will be cooled at night and channelled by the slope into the courtyard and then into the rooms.

MATERIALS : Adaptability (Traditional building materials and methods are still widely used in tropical lands). Tent option(Textile) and other such as palm or more innovated solutions are not tested here due to the limitations of the software but are considered as possible solutions, together with wood.

URBAN SCALE: small squares and higher buildings means more shading; commercial areas with porches help shading, Main roads should be North-South in order that one of the sides also has shadow; narrow streets, houses built closer together with courtyards.

5

ANALYSIS AND DISCUSSION OF RESULTS.

5 ANALYSIS AND DISCUSSION OF RESULTS

5.1 APPROACH AND RESULTS

First of all, the container- There is a need for transitional housing, for shorter spans of time or longer. Additionally, there a need for alternative solutions of shelters - the typical tent solution- that can transform temporary living conditions into permanent homes. A building that can grow naturally, logically and poetically out of all its conditions, because of its flexibility and modularity . It is crucial an answer for those living constant in a state of emergency, as they live in precarious conditions , not habitable places not worth the name home.

There were two cases presented. On the first, the intention to answer the slogan "Think globally, acting locally" showed that , as already expected, the idea of creating something to be suited everywhere and to be mass produced as one product, it is difficult due to the differences between contexts and consequently their needs. On the other hand, the case 2 would propose a mix of different adjustments and study some of them more into detail. Those adjustments were thought as major elements that influence a design and its response as a sustainable product.

It was shown that sustainable solutions and therefore architecture relays on a specific location and are defined and ruled by their features. For case 2, Denmark and Saudi Arabia were used as extreme examples, besides the fact that the landscape – architecturally- and the final design would look very different and also that Denmark can also be studied and verified a little further in energy terms through the use of the Danish software Be10. In Be10 , and to further understand the changes, it was developed a model for case 1 and case 2 (see annex -).

For the second case, where those two contexts were analysed, some considerations on daylight, temperature and Co2 levels ..

CASE 2   Some elements about cooling or heating. There are options to keep the sun in and to "open" to solar radiation and daylight and options when glare is a problem and solar radiation needs to be decreased. To avoid higher temperatures, the solar rays can be kept far or reflected away through the use of bigger roofs , overhangs or roof eaves, with trees or vegetation on the building- such as green roofs or walls-, protecting larger walls from the sun or as simple as painting the external walls with bright colours. Such basic things as the high of the tress around the house, are also relevant: a small tree – same height as the building- makes the air go up and not enter the house- it behaves as a air block , while a taller tree allows the breeze to go down and refresh the building. Ventilation should occur from bellow to higher heights, from a window placed in lower levels to one placed higher in the wall or in the roof. Distance between the building and the trees or vegetation also decreases or increases the breeze strength entering the windows: The hedge placed at 6m distance is better than 3 meters because the wind gets stronger inside the house, but a tree placed 6 meters from the building mass is worse than one distant 3 meters- where breeze enters the building colder and in bigger quantities. If lack of light is a problem, then the surrounding elements are also important: while for example grass absorbs the rays, concrete reflects the light; vegetation does not reflect light while glass surfaces do. Light colours also help: a light colour gives the sense that a room is bigger and brighter and it actually has more light because it reflects better than darker colours. When there is too much light, there is a need for curtains, slats, shutters or other, but if the proble is the opposite, than it is important to reflect light, open more windows etc. Vegetation that has leaves in the summer but not in the Winter, might be a solution for a cases where sun is necessary in the cold season.

Concluding from the analysis done in case 2, its concluded that: In hot dry climates, the house should be built in a hilly landscape- when there is one- on the highest points, where there is higher air movement; Walls should be thicker in order to reduce heat penetration during the day and cold during nighttime; Materials used should be stone, adobe, brick and blocks due to their high thermal capacity therefore their function as good thermal mass; windows should be placed higher and should be less and smaller to avoid dust and sun getting into the room; houses should be built close together, more compact, with less exposed surface to the sun. One provides shading to its neighbor; use of interior courtyards allow natural ventilation to the rooms and provide more daylight entering the room as the windows facing the courtyard can be bigger; use of vegetation and water bodies close to/on the building mass to work as cooling strategies ; and lastly , the floor should be touching the ground, as much as possible, in order to use its freshness to passively cool the house. In the other hand, for climates as the Danish one, temperate/ cold : houses should be placed in sun exposed areas; walls are thick and insulated so that heat is not lost to the outside; the roof should be tilted some degrees; materials such as adobe , brick and blocks can be used but also wood; smaller windows facing North and South not exceeding 20% floor area and from floor to ceiling to allow as much daylight as possible; Protect the building from stronger wind areas by using vegetation and last, isolate the floor from the cold temperature of the ground. In a warmer country, dry, the land is narrow and long while in areas where there are more rain, the land should be large in the front of the house facing the road.

CASE 1 VS CASE 2 It is clear that a solution that covers all cases ends up by not covering any. By building globally in all senses of the word, then locally it does not adapt or work. The case 1 leads to an dead end and therefore, case 2 is studied in order to achieve a better understanding of the influence of different parameters and end up with better simulations and better results in each case. It is not good to design one element according to what fits better another place, because building elements, materials and type of construction depend on the region. For example, if a window in a cold place allows the sun to go in and for that room to be heated it is a good thing, nevertheless the same window placed in a hot area will make the room overheat too much to a degree that is unbearable. This same rule of not "copying and pasting solutions" also applies to walls , roofs and floor construction and their insulation thickness, etc. As an example, a solution that works okay in the Danish climate was set to be studied for the hot dry represented by Saudi Arabia and the results are shown bellow- Table 5.1.

Table 5.1- Danish almost best solution (windows and construction) placed in Saudi Arabia, showing how negative the results are. (On the right, light colour) The difference made by the building envelope can be seen when applying the same design as before , but replacing the envelope by the adequate for Saudi Arabia climate

Thermal zone	Denmark	Saudi Arabia	Same windows and shading and inside arrangement, different building envelope- better for hot dry climates- in Saudi Arabia
Rel. Moisture (%)	60,3	43,6	50
CO_2 (ppm)	1000,2	5000	2300,1
Hours > 20 ºC	63,5 %	100 %	80,9
Hours > 24 ºC	49,6%	99,8 %	68 %
Hours > 26 ºC	40,7 %	99,1 %	60,8 %
Hours < 20 ºC	36,5 %	0,00%	19,1 %

It is, without a doubt, interesting to confirm that for a very thigh house such as passive houses would not work a hot climate such as the arid in Saudi Arabia. If a construction has too much insulation, than it helps when it gets cold, but when it is too warm, then, it will work as an oven keeping high temperatures inside. What happens in a climate such as the Saudi Arabian is that, there a lot of temperature swings and for that reason, not only the construction needs to be able to answer too high temperatures but also the very low temperatures achieved in the night-time. If that context would have a lot of insulation, then the heat would not love the building. In the Danish context, it is necessary to use thick layers of insulation, because temperatures outside reach very low values. Windows and openings in general also make a difference and there are changes when going from a hot climate to a cold. Furthermore, it is not only about the difference in temperatures, but also about the whole climate where rain/snow and wind also take their part. In Saudi Arabia, humidity is low while in Denmark it is a lot higher – changes things such as roof. The wind is also a big factor when designing since, if there is a lot , then it needs to be restricted, if there is not enough then it needs to be amplified and the same with too much daylight – leading to glare- and not enough daylight- that needs more openings.

5.2 DOES THE PROJECT HAVE GOOD PERFORMANCE?

5.2.1 COST OVERVIEW- CONTAINER vs TRADITIONAL HOUSE As an example to have examples of built homes, two cases are shown: two built container houses and their prices. These two cases are simple and do not include expensive furniture or elaborated solutions. Moreover, it is also briefly and generally made an estimate using RS Means, with some of the construction work, activities and cost of materials.

See annex 13 for some more detailed overview on cost- examples of built projects, tables with step by step major building phases and associated cost and last an estimate that relies one the cost of activities, materials and work/ hours – partly representing reality.

What is the cost of using containers compared to traditional construction? Defining traditional construction as sticks, bricks, CMU, light gauge steel or heavy gauge red iron, SG Blocks' hard and soft costs are typically below those of conventional options for both Green Steel and full modular build out. For urban settings and buildings of multiple stories, cost savings are significant.

The estimated cost -without the transportation of the container before and after renovation to the factory and to the site, respectively- costs 17 571,14 dollars, meaning 14,133,17 € approximately. If shipping costs between 2 957,65 dollars and 6 452,15 (from Denmark to Portugal and Denmark to Malaysia, respectively) It could be estimated that the final value would be the addition of those 14 133,17 € with (maximum) 867,23 € from long distance shipping – added 2 times to consider going back and forward fro factory to site in the housing unit life cycle). So the final cost would be 14 133,17+ 1 734,46 summing up 15 867,63 € in the end. Depending on where the project is located -country and within a city or not-, of course the price would change a little. Containers are flexible , somehow light and movable temporary solutions so those allow to be implemented into special locations such as rooftops or floating barns: predict a cost for temporary solutions such as this, is difficult.

5.2.2. INDOOR CLIMATE AND AIR QUALITY: From the values given before in chapter 2 and 3: CO_2 – remember- up to 1000ppm inside (max 1500); TEMPERATURE: Traditionally it could be said that as long as temperatures are kept in cold climates within 20-26ºC and warmer 18-30ºC, the values should garabtee comfortable thermal indoor, but depending on psychrometric chart, that range and adaptability of humans to the environment they are put on changes from context to context.; DAYLIGHT: Even though there is not really a standard to follow, an Average daylight factor / demand for artificial lighting > 5% Relatively high level of daylight. Artificial lighting is normally not necessary during the day.2-5% The daylight is the main light source in the room but it would normally be necessary to add artificial lighting at workstations < 2% Artifcial lighting is necessary and will be the main light source in the room; Finally, RELATIVE HUMIDITY : Also not necessarly mandatory to satisfy these range of values- 30-70%- but it is indicated as a good level to to guarantee indoor air quality.

RESULTS: Overall, these values are respected and the house, even though moved around and tested in different climates, could be defined or stated to answer the need for a comfortable space. It does not answer very demanding parameters but just enough to allow habitable and comfortable , dignified living conditions within a sustainable indoor.

5.2.3 DECISION OF USING SHIPPING CONTAINERS AND MATERIALS: Designing temporary housing with point of departure on ordinary shipping containers chosen for their price, mobility, logistics, durability, stackable features, etc.

(Could it depend on other solutions that would be modular but not fixed the same way? It would allow the same kind of strong, ready to place structure, but it would give it a different flexibility.)

MATERIALS Thermal mass is archived through the use of blocks, cement, brick and other heavy construction, but that makes the disassembling option difficult to execute.. how can prefab solutions give good results and allow more flexibility? The joints of heavy construction, makes it harder to allow translation or relocation or destruction and later reconstructions.. But elements such as prefab panels makes it cheaper to mass produced and easier to disassemble. Nevertheless, it is not a good thermal mass as brick or others.

5.3. INITIAL CONCEPTS AND VERIFICATION: SUSTAINABILITY AND FLEXIBILITY

Good comfort and habitable spaces? Is it flexible enough? Is is sustainable?

“The architect has a responsibility not only to the residents who need new homes but also to the environment. A key protocol […] is to make maximum use of local materials and building techniques that can be best adapted to the context. Good architecture reduces the need for long-distance transport and thus environmental impact (as well as expense) (Ahmed et al., 2011). Are the results enough to prove that by prioritising users, environment is still part of the equation and the same the other way around? Can it be balanced? Is the project flexible (Figure 5.2) ? The container is not flexible as it is a box, enclosed, dark and limited. Flexible: “adapts to change, rather than rejects it”, it is modular so it can be added as family grows, is changeable to something else when needed, then the inside is so small that it relies on flexible furniture and versatility . shading devices work according to sun path, either manually or automatically- according to economic questions, flexible because it can be moved around, flexible for reusing and recycling another element with such a different focus.

Is the project sustainable?

A. TEMPORARY / TRANSITION HOUSE - SOCIAL SUSTAINABILITY *“ To play our part fully in the unfolding story of sustainability, we must respond not only as responsible costumers but also as* *responsible stakeholders and citizens. Changing light bulbs or even lifestyles is not enough, unless lifestyle changes include becoming more socially and politically active." (Thiele, 2013*)

The focus of this project is to create possibilities for people that need a temporary home. Social sustainability is an essential part of this project, and one of its main focus, proposing a design that adapts not only to different places around the world – different contexts, environments, backgrounds and realities-, but mostly to the life changing rhythm. The dwellings should not have the appearance of a temporary home, even though that is their purpose, but possess the quality of a "standard home" – the comfort, beauty and feeling of secure similar to places where people live long, "primary homes". In order to achieve a good design, it is important to define the intention to keep spaces for individuality and sociality: your own space and space with others – common area-, if you are to live with more people than you – most probably happening. Due to the flexibility within and outside the building, the locations and uses it allows, and since it works with the potentiality of modular architecture, the unit created is designed to accommodate everyone and everywhere. The Social sustainability becomes , without doubt, one of the most important elements for the design. The vision relates to this aim of creating a place to live for everyone. Temporary since it can evolve to be permanent and because it can be added to be more than its initial design or layout. Its modularity and playfulness together with how easy it is to be put together, makes this solution something like a LEGO piece (Figure 5.1)

Figure 5.1- The same container and its openings can be put together in countless number of ways and combinations. It is due to its modularity – orthogonal box- that reminds of a gigantic LEGO piece to be played with. (Source: Mafalda Melo Oliveira, 2014)

Figure 5.2 – Between social and aesthetic sustainability, respecting economic and environmental, the detailing of the bricks allow a more personal twist to the similarity on the designs. By using brick- a layer- pushed and pulled, rotated, etc. Each person can feel this cheap accessible solution as their own. Individuality and feeling of belonging. Inspired by The Scheepstimmermanstraat Houses in Amsterdam -creating a unity even though each house is different from the next and the one before. (Source: (Left) Mafalda Melo Oliveira, 2014)

B. " 7 Weeks + 1 Week" -ECONOMIC SUSTAINABILITY The project is wallet friendly. The design is intended to be built in less time than other type of houses – around 7 weeks off-site and one in site-based on research, -and be flexible and open to a big range of people in less favorable conditions. The economic matter can affect three different questions: Choice of materials, life span of the building, and building construction methods. The choice of materials: choosing materials that need little or maintenance and last for many years and the option for those exiting in the site or country where the design is being implemented- minimizing transportation costs- will allow saving money; The life span of the building: by building a strong and durable structure that can be used for a long time and in different places, there is no need to start from scratch always. There is the possibility to use the "old" as new, since those are long lasting structures that can survive extreme conditions and through time; The building construction methods: since it is important the house is flexible and can accommodate changes through a person's life or changes in site where is implemented, it is essential that there is some kind of section of the module that may be changed, moved, adapted, if there is a need for it.

C. COMFORTABLE MAGIC BOX - AESTHETIC SUSTAINABILITY *"As human beings are naturally attracted to beautiful things, aesthetics becomes a crucial component of shaping of behavior" (Thiele, 2013)* When designing and proposing sustainable solutions – for example buildings- there is a point where architectural quality of the results may be compromised. This fact happens when trying to reach a demanding energy frame and minimize energy and heat consumption and focusing too much on those aspects only. As referred before, in the methodology, the Integrated Design Process, by Mary-Ann Knudstrup, allows the design to be coherent and holistic, where architecture and engineering work together in order to create higher quality designs- technically strong solutions and aesthetically beautiful homes. *"The interplay between architecture and technology can be a way to design beautiful, comfortable and energy correct buildings". (Kongebro, 2012)*

The materials, should be more than sustainable choices, but also the answer to the senses, – the touch of the untreated wood, the smell of new wooden plates, etc- , answer to the human interpretation of home – a comfortable, warm place, a shelter from the world outside.

D. TECNHICAL SUSTAINABILITY The technical sustainability is a large field that can be divided up in two strategies: the passive and active solutions. With technical sustainability the consideration for the world's consumption of non-renewable energy is considered and the aim is to use renewable energy resources and materials to ensure the resources for the future generations. This project is focusing most in passive solutions while the money to use active solutions is not there, the passive is most important because it is related to the build itself. With using the passive solution the focus is to give a good comfort and focusing in the things there can be explored and be thinking a little bit more of the things we can change with using the passive solutions and see what influence it get into the design, and from that on make a good comfortable home. Even though the active solutions not are a part of the design there will be some active solutions idea in a cheaper way and more essential and basic way. So after designing the temporary home the people who have money can add solar cell by themselves, and try to make the building also relate to that way of collate water where there design of the roof can collect water. The project is not following any standards but try to reflect on the existing and see what there is more basic. Waste and drinking water is such a big filed, which is not that most devolved to this kind of project, but aware to relay on technologies other people have developed such as some organizations referred before and firms.

For this project, the users relay on natural ventilation due to the building's large window area. In order to achieve other levels of comfort and to improve the indoor climate inside of the container, the users are able to install, in a later stage, mechanical ventilation within a space that was thought throw in order to accommodate this improvement. Even though the values of solar gains and ventilation are not comparable to other solutions, such as passive houses or even can be included in any kind of standard, the focus of the project is to achieve a comfortable way of living through the minimal

Containers have been used for other purposes at the end of their voyaging lives. A container has 3,629 kg of steel, which takes 8,000 kWh (28,800 MJ) of energy to melt down. Repurposing used shipping containers is increasingly a practical solution to both social and ecological problems. Shipping container architecture employs used shipping containers as the main framing of modular home designs, where the steel may be an integrated part of the design, or be camouflaged into a traditional looking home. So means that re using them is a social – by reaching other people and proposes, economic- since they are cheap solutions, prefab and allow modular arc; environmental because even though it is steel, they are reusing something that already exists and giving it another purpose before it is melted again and last- aesthetical since It has architecture value, is made for human scale and for that reason, flexible, since it allows all the realities in one and results on the combination on all and an adaptable and changing organism.

Sum up: Reasons for the design to be flexible and sustainable, rather: flexible sustainable. Table 5.2

Table 5.2 - Analysis : Is Flexible , sustainable? Summary (Source: Mafalda Melo Oliveira, 2014)

Result	Social sustainability	Economic sustainability	Aesthetic sustainability	Environmental sustainability
Holistic design: Flexible Sustainability	Temporary house/ shelter; Private vs Public spaces ; Community part of reconstruction process; equality; Human basic needs; traditional building techniques; temporary to permanent	Recycled materials; 7+1 weeks to construct and erect; long lasting materials, disassemble pieces; passive (free) approaches; add as you grow	Comfortable magic box; multi functionary space; unfold-able, adaptive and extensive inside and outside solutions;	Thermal comfort; passive approaches; back to basics ; think globally while acting locally

5.4 CHALLENGES: It is difficult to separate most of the different sustainable features into the 4 areas, due to the fact that they are merged together and the design is cohere and integrated.

Temporary housing deliver an enclosed space – a place- where people -affected by natural disaster, human made problems or only looking for something different and fresh new- not only feel like their own but where they can call home, for longer or shorter periods of time. Temporary homes can vary from "random housing" units -constructed by the families or the ones needing them- erected on the sides of the road, tents in a refugee camp, clandestine constructions, etc. or programmed and organized places to live, such as pre fabricated solutions. Something that is general and answers many purposes but at the same time specific and is suited for a precise location, specific people and their needs. Once temporary housing and all the subjects treated here – sustainability, flexibility- are very broad terms; the research shown and the results presented only covered a part of the universe of the meanings. Once it is difficult to test something to be applicable everywhere, in a period of 6 months of research and work, the results given refer to broader and general ideas and comparison proposes. Through where, values, calculations and conclusions taken- from the specific to the general-, trying to prove it would work also in other cases when implemented. Some of the information related to drainage systems, sewage and drinking water are not going to be given and detailed in the solutions, but mostly referred to in theory, due to the fact that that matter would, by itself, be a theme for a thesis.

Nowadays many organizations face problems in dealing with complex systems and infrastructures such as listed above and for that reason the research developed does not cover a lot of this subject. Lack of information on general terms is a challenge. There are not a lot of successful cases in terms of natural disaster solutions or inn terms of something more general for everyone, there is not a lot of information that can collaborate with some of the intentions, ideas and questions.

Another question to take in consideration and that would pose as an obstacle, is the fact that, if 15 000 € for a temporary house is feasible in an European context, when moved and considered another context such as Africa, then the price would be way too high and the solution would become inadequate. Besides this, even though it represents a big number of possibilities, it would also pose as an obstacle for not being high enough to represent a solution that could always use the number of available containers around the world. These two questions should be though through very carefully.

The building techniques of the hot arid climatic zones, developed over a long history of construction, have progressed to promote passive climatic conditioning to protect inhabitants from their harsh environments. Those ideas and techniques of city planning, building form, and constructions methods offer great insight to the contemporary designer of Middle Eastern desert (Medi et al., 2010).

6

CONCLUSIONS

CONCLUSIONS

GENERAL CONCLUSIONS

GENERAL CONCLUSIONS ON FLEXIBILITY AND SUSTAINABILITY- THE INTRODUCTION:

This thesis did not intend to give one unique, working solution, but to gather information, reflect upon it and compare solutions based on the intention and objective of the work: design temporary housing from shipping containers. Therefore, what is presented is theory and some practical examples on how it could work and how the design could look like.

This report was put together to consider the potential usage of shipping containers as a means for providing temporary shelter for those in need – humanitarian causes or other, when and if necessary. To accomplish this goal, feasible designs were developed; building systems were carefully evaluated in consideration of both cost and functionality (time planning). In addition, focus on explaining and detailed only one- through with the work developed in communication with Engineers Without Borders and Red Cross.

In addition, the creation of applicable designs, the study considered location, logistics, cost, and project duration in an effort to evaluate the overall feasibility of the project. On the other hand, project schedule revealed that if all possible factory modifications were finished before the onset of a disaster, a container development could be prepared within approximately three days.

To begin with, although basic HVAC, plumbing, and electrical system components were selected, detailed consideration of the installation of such systems was outside the scope of this study. Another limitation of the study was the absence of a detailed drainage analysis. A third limitation of the study was the absence of accurate cost estimate data on items which were designed specifically for the project at hand, such as the precast concrete panels used in the walkway and the sloped roofing panels. Any further continuation of this study should consider the aforementioned limitations. Overall, the study proved to be worthwhile and engaging. Although the usage of shipping containers for low income and sustainable housing design and has been explored across the globe, the potential application of containers to emergency housing has not been thoroughly considered. The methods for disaster relief explored in this report remain relatively unorthodox, and this report certainly presents a unique perspective on the issue. The study was particularly interesting because of its relevance to many disciplines including civil engineering, construction management, and architecture.

Even though the intention was to provide the closest feasible and realistic solution to working with containers, this thesis and my work helps understanding that there is an opened window to use containers for housing and even though somehow doing that means social sustainability is the main field, the other should also be integrated part of the final design. It is my belief that, even if this work is not ultra detailed neither achieves accuracy of some other practical solutions, it could and should be considered as a solution to be used in some cases – not always in all situations.

GENERAL CONCLUSIONS ON NORTH VS SOUTH – THE DIFFERENT CLIMATES:

Sun and shade, insulation and mass – there are many different aspects to a green home. Finding the right combination of ingredients depends on the climate zones you live in. The blioclimatic design plays a crucial role in the design and it influences the results. Passive approaches are small steps into sustainable designs, but their influence on the final design are great. If some finals conclusions based on the research and calculations could be done (North Hemisphere):

A. TEMPERATE CLIMATES (Mediterranean –Portugal): Artificial cooling and heating – respectively in warm and cold season- can be almost eliminated if winter passive design for heating and summer design for passive cooling combination is just the right balance (psychographic graph). When building new, it should be taken into account: location for good solar access, cold wind protection however exposure to breezes that help cool down the building mass. The preferable orientation for living areas would be South and East and West wall and glazing area should be avoided or at least reduced. When possible, passive solar design should be used, combined with good thermal mass- a slab on the ground. Ceilings with bulk insulation: Use reflective insulation under the tile roofs and for the walls to keep out heat in summer and bulk insulation to keep heat in during winter. For openings, carefully balance the orientation of glazing to provide optimum north-facing passive solar access for the living areas, while minimising east, west and south-facing glazing. Use cross-ventilation and passive cooling in summer. Design eaves and other sun shades in correct proportions for summer shade to both walls and glazing, and use adjustable shading for windows. Outdoor living areas should have extended pergolas, providing shade in summer while allowing sun in winter. Consider planting deciduous trees and shrubs to provide summer shade and winter sun.

B. COOL TEMPERATE CLIMATES (Denmark) : With walls well insulated on the outside, the benefits of free solar energy are combined with obtaining the best value from the artificial heating, which is required at least some of the time. It's best to minimise external wall areas, especially east and west-facing. New homes should be sited for solar access and protection from cold winds, although exposure to cooling breezes in summer is still desirable. Some thermal mass is desirable, so where possible, consider a slab on the ground that's well insulated on ground edges. Bulk insulate the ceilings and use reflective sarking under tile roofs. Under metal sheet roofs, use insulation blanket with downward-facing foil. Use reflective insulation in walls to keep out heat in summer and bulk insulation to keep heat in during winter. Take care with the placement of the vapour-proof membrane. Place opening for effective summer ventilation and nighttime cooling in summer. For passive solar design, maximise South-facing walls and glazing (especially in living areas), while minimising east, west and south-facing glazing. Use double glazing or triple where possible with insulated frames and/or use heavy drapes with sealed pelmets to insulate glass in winter. Use door and window air seals and provide airlocks to entries. Design eaves and other sun shades in correct proportions for summer shade to both walls and glazing, or use adjustable shading.

C. HOT HUMID CLIMATES (Malaysia): In the hot, humid tropics, good design makes full use of shading, sheltered outdoor areas, and elevated lightweight construction. At times, the coolest area may be on the bottom floor and more thermally massive, which also suits other considerations, such as building for cyclones. Site new homes for exposure to breezes and shading all year round. Elevated construction should help ensure access to breezes and create shaded outdoor space. Use plans with one-room depth for ideal cross-ventilation. If appropriately designed, a thermally massive lower-floor living area can provide cooler refuge during the hottest part of the day. Use lightweight construction, elevated on bearers and joists to permit airflow beneath the floor. Create some full-height recreational areas under elevated floors, which will receive indirect evaporative cooling all year round from the shaded ground surface. Use light-coloured roof materials and ventilate roof spaces. Consider high or raked ceilings – or even a ‘fly roof’ for permanent shading. Use reflective insulation, and bulk insulation if mechanically cooling. Choose light-coloured wall materials, designed and built for cyclonic conditions. Minimise exposed east and west-facing walls, and shade all walls from the sun. Choose any James Hardie® cladding material in combination with carefully placed reflective foil insulation to ensure appropriate condensation control. Shade the whole building in summer and winter, and provide shaded and screened verandas for indoor-outdoor living and sleep-out spaces. Extended vertical screens can modify otherwise unfavourably oriented openings to improve natural ventilation. Consider shading buildings with HardiPanel compressed awnings, and use HardiPanel® compressed sheets for decks, verandas and terraces (design and detail appropriately).

D. HOT DRY CLIMATES (Saudi Arabia) Good design with well-placed thermal mass and sheltered, shaded outdoor spaces can dramatically reduce the impact of high temperatures. Careful provisions for night-time ventilation take advantage of the cool nights, reducing or eliminating air-conditioning loads. Build more compact-shaped buildings with good cross-ventilation for summer nights. Protect from dusty summer winds (by placing windows higher or protecting them from dust with extra elements), but also from cold winter winds. Provide solar access for winter combined with exposure to cooling breezes or cool-air drainage in summer. Use a slab on the ground where possible to incorporate high thermal mass. Insulated the slab on ground edges. On sloping sites, use bearer-and-joist construction in steel or timber. Insulate the sub-floor while minimising sub-floor ventilation. In addition, close ventilation cavities through walls from the sub-floor to the roof to prevent heart leakage. Choose light-coloured roofs to minimise solar gain in summer. Use bulk insulation in the ceilings, with controllable ventilation of roof space above the ceiling. Use reflective insulation in the walls for effective summer and winter application, as well as bulk insulation. Ventilated reflective cavities can minimise solar gain through walls in summer. Consider lightweight construction for sleeping areas that are not during the day. Choose any James Hardie® cladding material in combination with carefully placed reflective foil insulation. These climates favour reduced glazing areas, with very good shading in summer. Maximise night-time cooling ventilation. Consider a design that uses connective (stack) ventilation, which vents rising hot air while drawing in cooler air. Use evaporative cooling, not air conditioning, if required. Place correctly proportioned eaves for summer shade to both glazing and walls. Provide shaded outdoor living areas, and consider adjustable systems to control solar access. Use airlocks for entries and draught-seal thoroughly throughout. Use garden ponds and other water features in shaded outdoor courtyards to provide evaporative cooling.

CHALLLENGES AND DIFFICULTIES:

First of all, a problem of space to write, so it is difficult to know when exactly it is enough or too much. These themes have a lot more to it, the research developed was more extended and not everything was covered, besides this, what was covered risks being shown too superficially or not detailed due to lack of space. Sustainability is such a broad term and field. Within it there are so many different aspects and questions to take care of. Fields of sustainability, active and passive solutions, a big number of calculations and values to take in consideration, so many aspects that influence results.. Small changes that mean big end results. The difficulty was to get to a point where it gives something for the scientific

community, that it contributes to a level of detail that matters and explains enough, but at the same time, respecting the small amount of information that can be exposed in these pages and trying to touch more than just one small drop of water in the whole ocean.
Unfortunately, It is difficult to express all points of view. Moreover, even in the elements considered for the thesis, it is essential to try to detail some questions – in order to show some level of understanding and deepness but also to keep it general to allow more fields to be studied and later studies to be held. This thesis is written as a point of departure of some pre researched elements and it keeps out a lot of information gathered and reached, in order to be a possible work to be used for other and myself to be developed and continued at another time.
It is a too short paper for the information that the author wanted to share and for the work done on the subject. It intends to be a contribution to knowledge rather than a concluded piece of work. For the solutions proposed, they would of course influence other aspects such as acoustics and humidity – choice of materials – and for that reason the materials are also put aside and kept open only suggested. Can we think globally while acting locally? Can design be Standard for everyone and everywhere? How does place and location influence a design? How important are passive solutions? Can we go back to basics when designing with less? Can a container – existing in our daily life and barely noticed as more than a dark box- be used as more than a trend, rather a potential modular solution that competes in cost with traditional solutions, respecting temporary housing? Are there enough containers in the world to answer lack of shelter with this solution? And is the price in some places worth using this option over some other?

ACHIEVEMENTS AND MISSED ELEMENTS:

What has been achieved? With this work, there was the chance to simulate dozens of models of different designs and different locations. Even though there is a lot of information that can not fit in this thesis, the work developed now could allow further developments in the future.
What is missing? More accurate adjustments and results. In this thesis, there have has been a suggestion about using shipping containers for housing and solutions were found based on comparisons, so they lack a final specific and very concrete solution that could just be used. Many comparisons and a lot of different context limit the possibility to go more deep into a final solution. The fact that I didn't use ECOTEC – that is missing because different ways f evaluating the solution- and also the fact that there were some questions left behind- such as the different materials- due to the fact that bsim doesn't process thin layers of materials, such as 1.8 mm of the steel container wall and 1-2mm of textile very well. If used another software, those elements can be better taken in consideration and be evaluated more in practice to prove the theory behind it.Besides the materials, there are other questions such as evaporative , geothermic option, etc that would be taken into account if there was only one case study and more into detail.- such as Luanda for example, for next step. Last, active solutions were not really considered in this case because of the nature of the project, as temporary, cheap and for disaster areas or special conditions, but those could and should be also integrated and thought since they can improve the building footprint largely.

This thesis did not intended to end up with presenting the best optimized sustainable solution , rather reflect on the influence of the different "puzzle pieces" of a dwelling, combining that with the curiosity upon the possibility to recycle and "reabilitate" shipping containers into new and very humanistic needed solutions. The work developed briefly analysis different parameters to take in consideration when desining shelters or temporary solutions with shipping containers and concluded that it would be a feasible solution if mass production is possible and if in the end, solutions can actually be shipped and moved around. Besides all this, taking point of departure in a very box like element, confined, dark, limited , small and tight and strict, a more flexible design is proposed: flexible because it can be converted from its initial function to something completely different and still deliver good results, flexible because if thought throw in a intregrated way, it can be improved and end by being a volume that is designed "out of the box", flexible because it allows different designs, different people and different climates and locations and for that reason flexible because it adapts to change, not rejecting it.

POTENTIAL DEVELOPMENTS:

What should be the follow up to this thesis? Work more in detail, analyse more locations. Use Ecotec and use structural analysis software to see until what extend the modifications would influence the container. Materials such as earth, sand and textile are difficult to predict and to study the behaviour and for that reason, those are referred theoretically and based on examples, but not used for calculations. In Bsim, it is not possible to predict sharply how so thin or specific materials behave. Later at another stage and with more precise software- such as Design Builder-, it could be studied the influence on materials such as textile, wood, bamboo and others. In terms of inside and outside architectural expression, wood is used for calculations in order to keep the influence similar and in order to represent pre fabricated cheap solutions. In the case of using metallic sheets on the roof- and since it is a material that allows heat and cold to pass through easily- it is necessary to add other solutions, such as the use of fake roof or lining under the sheets.

Saudi Arabia has been chosen to be further developed, but other phases on this same theme , it would be important to actually develop a design into its more detailed solutions and design based on a even more specific location instead of many. Besides this, using tropical and cold climates would always work better in terms of solution due to the difficulty of working with the need of good inertia – in places such as Saudi Arabia. As thought in the beginning of the work, the thesis could be converted into a kind of very basic guide book " do it yourself" that allowed people to, based on notes about the climate and the location they would be at, could follow a check list of how to implement the building on site and which steps to take after. The design and idea was thought to be able to be implemented by people without expertise, so that the design would arrive ready for the community to be part of the rebuilding phases. So the container would be sent with a guide book so that volunteers and inhabitants could work together. After building and erecting some, the first to be helped could help the second and develop a chain.- as it has been done and explain for example with sanitation and waste questions in remote areas – see TED talk for.. – So the follow up would be conceiving or finishing the design and guide book started intended to give a help to builders and who would receive this unit. The book should explain in a direct, fast, simple and clear way basic elements such as the ones given above (chapter 3 and 4) – on the users' control and depending on the site : Vegetation around and within the house, proper using of the shading solutions, position of the container on the site and respective orientation according to cardinal points, outside (second skin) wall – if not sent as prefabricated . It should de delivered with each container so that some elements are taken in consideration all the way through the process and lifetime of the unit.

This thesis represents only some of the considerations and equations needed for studying a building, to prove a theory or something else. It would need further investigation, maybe a prototype, having people moving in – they are a big part of the equation that is sustainability and good energetic solutions – as users. It would have been interesting and could also be done in other works at other points in time, to consider the container as mostly the area that needed to be followed and as a module in its literal sense of the word. Meaning with this, that if the plan was divided in pieces as indicated along the thesis, than those pieces could fit any module – fixed, openable or not – that would have the same floor area. In terms openings and furniture, some other considerations would have to be taken in consideration, but in order to have a more flexible design, that could be an option. Considering daylight and openings along the building, it is important to balance the influence of certain aspects or decisions, such as, in this case- the cut of the container to create openings. Due to the fact that the container's stability relay in its fittings and partly on the walls, the cuts executed on the walls , would make the construction weaker. In this project, it was necessary to know how to compromise between the aesthetic intention and desire to open to the outside, with the limitation on the structure - that would be compromised more with more openings. Furthermore, there is no reason why this box element needs to be limited and square in all its dimensions. By complementing the box with different tactile and allowing those limitations to be explored, the initial space that was seen as enclosed, safe, but also claustrophobic, dark and cold, gains a new dimension of cosiness, of dwelling around its users. The safe box is put together with textiles that will ensure a space for breathing, thinking, dreaming together with the initial the feeling of a steel strong shelter that the textile wraps around , softly and lightly, while the box is strong and can't be destroyed, due to it's construction. Even though the container works as a good structural idea, because of its logistics and other reasons expressed above, it has of course its limitations related to its strong closed box characterisation.

When describing the Danish weather, the wind direction and the season are fundamental – the weather simply changes according to the prevailing wind direction. What is more, it is often windy in Denmark and calm situations are rare. The wind power industry and sailors enjoy this state of affairs. At all events, the wind is a key factor of daily life in Denmark. (Cappelen & Jorgensen, 1999) Wind turbines and mills for Denmark and when referring to Saudi Arabia–solar collectors, solar cells potentiality on the hot sun. Due to lack of wind, inspiration can be redrawn in boats and how those direction the wind to ventilate the inside – nowadays with the use of specific tents as a very basic and cheap solution- but also architectural inspirations such as Gleen Murcutt organic shapes- making the building potential.

For the solution to be even possible, there should be factories and people that could do the modifications to the containers and the insides, spread in the world. The biggest waiting time that makes the process slow is the fact that a shipping from Denmark to Malaysia can take up to 25 days, one from Denmark to Saudi Arabia , around 10 and one from Denmark to Portugal 4- of course this is just indicative. Based on http://www.searates.com/reference/portdistance/, with port distance and relies on the ship logistics and also trucks and other from when it leaves the factory until it reaches the final destination.- depends on the ship . For solutions with planes, rail or trucks, I is also possible and used. Some are a lot faster.

Lastly, I believe that without a prototype and having qualitative measurements – given by interviews on people moving in those units, there is a level of lack of accuracy and to certain extent, it would probably influence a lot the results.

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ANNEX

ANNEX 1 -TRADITIONAL CONTAINER

A. Container Ships, Logistics and Transport

As referred before and stated by Jure Kotnik, most goods come from Far East (Table 1): *"Since the majority of the world's goods are manufactured in the Far East and shipped to the West, Western countries import far more containers than they export"* (Kotnik, 2008)

Table 1 - The World's largest cotainer ports: container handled (Million 20-Foot Equivalents) (Based on (Levinson, 2006))

Port	Country	1990	2003
Hong Kong	China	5,1	20,8
Singapore	Singapore	5,21	18,4
Shanghai	China	0,5	11,4
Shenzhen	China	0,0	10,7
Busan	Korea	2,3	10,4
Kaoshung	Taiwan	3,5	8,8
Rotterdam	Netherlands	3,7	7,1

GROWTH IN CONTAINER TRADE: *"Global traffic in containerised cargoes has expanded rapidly since the late 1980s, rising from an estimated 80 to 185 million TEU between 1989 and 19994. This equates to an average growth of about 10% p.a. Such a gain has been closely associated with the industrialisation of the Asia-Pacific economies, with traffic in that region increasing by over 160% to around 80 million TEU over the same period. This destination thus accounted for 44% of total container traffic in 1996, against 22% for Europe, 16% for North America and 18% for other regions. This data is partially shown in Figure 1. By 1999 the quantities were: Far East-80 million TEUs, Europe-41 million TEUs, North America-30 million TEUs and Other-34 million TEUs."* (Organisation de Coopération et de Développement economiques, n.d.)

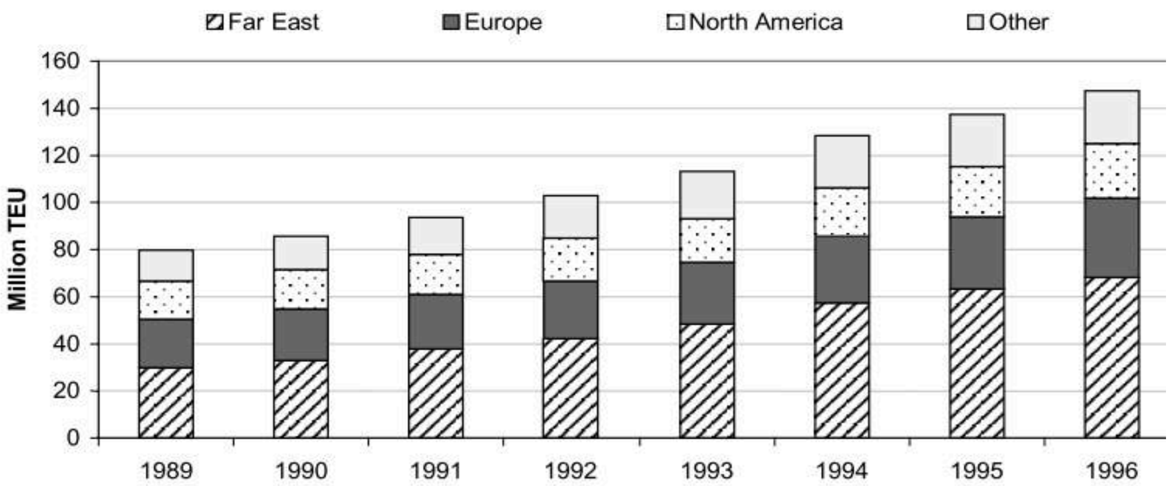


Figure 1- Growth in container trade: World container traffic by destination 1989-1996. Far East starts with the highest values and is also the biggest increase from 1989 to 1996 (where good come from). (Source: Organisation de Coopération et de Développement economiques, n.d.)

Besides the container traffic by region, Table 2 "*provides a breakdown of container movements on a number of world's more important trade routes."* (Organisation de Coopération et de Développement economiques, n.d.). These values allow to have a better grasp on how the indusry works and what to be depending on.

Table 2 – Container movements on major liner trade routes for 1995-2000 [000 TEU] (Source: Review of Maritime Transport , UN, 2000 and various issues of Containerisation International)

	Asia-USA	USA-Asia	USA-Europe	Europe-USA	Europe-Asia	Asia- Europe
1995	4009	3471	1208	1448	2306	2834
1996	4104	3520	1219	1421	2584	3142
1997	4662	3615	1276	1556	2734	3290
1998	5221	3326	1327	1695	2710	3487
1999	5840	3370	1340	1710	2850	3950
2000	6130	3540	1410	1800	3050	4150

"A further measure of the recent development of shipping services can be found in container vessel earnings. Container ship time charter rates can provide a useful indication of the movements in rates that may be charged to shippers. The emergence of surplus tonnage – as net fleet growth has outpaced even the rapid expansion of world trade in containerised cargoes - has resulted in stagnant or declining vessel earnings. For example, for ships of 2 000-2 999 TEU capacity it is estimated that average time-charter rates fell from US$8.70/TEU in 1996 to US$6.20 in first-half 1998 (figure 2). This trend continued for the remainder of 1998, although it has since reversed. Declining vessel rates such as this generally indicate surplus capacity, strong competition, or both." (Organisation de Coopération et de Développement economiques, n.d.)

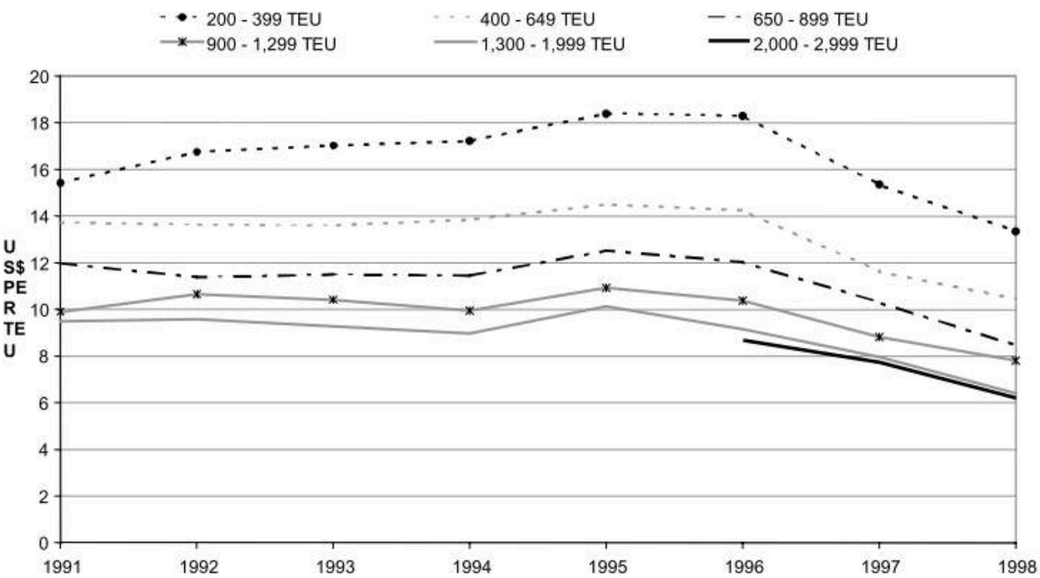


Figure 2- Graph of the annual average container ship time-charter rates. (Source: Maersk Broker)

"Statistics for the overall number of vessel total losses by year show a downward trend since the late 1970s (figure 3). Based on all merchant ship types, figures from Lloyd's Register of Shipping indicate a general reduction in the number of ships lost (absolute total losses and constructive total losses) on average from 373 vessels p.a. in the 1970s to 308 p.a. in the 1980s and 242 p.a. in 1990-99 inclusive. In fact, the preliminary figure for 1999 (129 total losses) was lower than for any year from 1970 onwards and apart from a blip in 1989 represented a seventh successive annual decline since 1991" (Organisation de Coopération et de Développement economiques, n.d.)

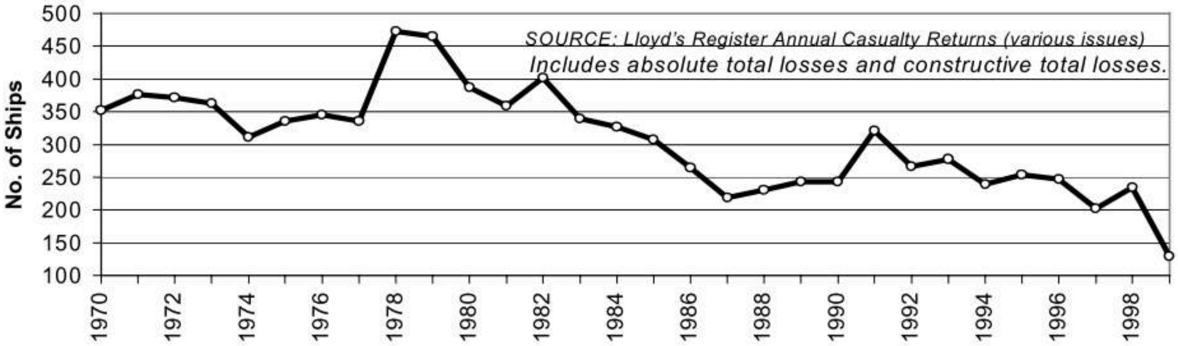


Figure 3- Merchant Shipping total losses 1970-1999 (Number of ships lost) , (Source: Lloyd's Register Annual Casualty returns)

Area	Year	Goods loaded			Total goods loaded	Goods unloaded			Total goods unloaded
		Oil & gas		Dry cargo		Oil & gas		Dry cargo	
		Crude	Petroleum products and gas[a]			Crude	Petroleum products and gas[a]		
World total	2006	1 783.4	914.8	5 002.1	7 700.3	1 931.2	893.7	5 053.4	7 878.3
	2007	1 813.4	933.5	5 287.1	8 034.1	1 995.7	903.8	5 240.8	8 140.2
	2008	1 785.2	957.0	5 487.2	8 229.5	1 942.3	934.9	5 409.2	8 286.3
	2009	1 710.5	931.1	5 216.4	7 858.0	1 874.1	921.3	5 036.6	7 832.0
	2010	1 787.7	983.8	5 637.5	8 408.9	1 933.2	979.2	5 531.4	8 443.8
	2011	1 759.5	1 034.2	5 990.5	8 784.3	1 896.5	1 037.7	5 863.5	8 797.7
	2012	1 785.4	1 050.9	6 329.0	9 165.3	1 928.7	1 054.9	6 200.1	9 183.7

Source: Compiled by the UNCTAD secretariat on the basis of data supplied by reporting countries, as published on the relevant government and port industry websites and by specialist sources. Figures for 2012 are estimates based on preliminary data or on the last year for which data were available. Historical statistics on world total volume of international seaborne trade are available electronically at http://stats.unctad.org/seabornetrade.

Figure 4- World seaborne trade : 2006 to 2012 (Millions of tons).The majority of goods is transported by vessel, which proves that it is a working logistic. (UNCTAD United Nations Conference on trade and development, 2013)

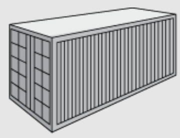
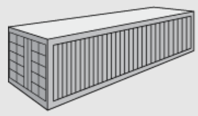
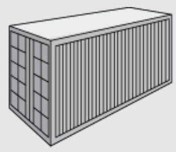
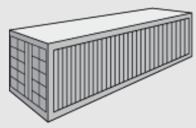
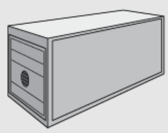
If the prices get down, together with the industry being safer and this mean of transportation representing less risks for those that depend on them and last if the majority of good is dry cargo, then it seems reasonable to state that the soultion is feasible and beyond idealisms.

(For further readings on regulations, laws and other relevant practices : "Bernaerts' Guide to the Law of the Sea, the 1982 United Nations Convention, Fairplay Publications", "Intergovernmental Maritime Consultative Organization (IMCO)" , "The OECD Code of Liberalisation of Current Invisible Operations (CLIO)" and "The OECD Common Shipping Principles ", "The UN Convention on a Code of Conduct for Liner Conferences (UN Liner Code)" , The "International Safety Management (ISM) Code" and more specifically National environmental and safety regulations : IMO Conventions and EC Regulations, for Portugal.)

B. Container standards and measures

The most common type of freight container is the general purpose dry cargo type. This container completely encloses its contents by permanent steel structures and provides cargo loading access through end opening doors. Typical steel containers can be 10, 20, 30, or 40 feet long by 8, 8-1/2, or 9 1/2 feet high. The standard width of an intermodal container is 8 feet. The walls of a typical steel container are usually constructed of corrugated sheet steel panels that are welded to the main structural steel top and bottom side rails and end frames. The end frames are fitted with standard corner fittings (steel castings) at all eight corners that are welded to the four corner posts, top and bottom side and front rails, and rear door sill and header. The roof is usually constructed of either flat or corrugated sheet steel panels welded to the top side and end rails and door header and may have roof bows for support. The doors are usually either shaped steel frame with steel panels or plymetal (steel faced wood) panels fitted with locking and anti-rack hardware and weatherproof seals (gaskets). The flooring may be soft or hard laminated woods, planking, plywood, or composition material either screwed or bolted to the floor cross members. The floor cross members may be box, C, Z, or I shaped steel beams bolted or welded to the bottom side rails. Some containers are configured with an all-steel flooring or a combination of wood and steel. (Department of Defense - United States of America, 2002)

Table 3- Some other containers and values (m), (kg)

Length (interior)	Width (interior)	Height (interior)	Door width	Door height	Capacity	Max cargo	Illustration
20 and 40 ft Standard							
5.90 m	2.35 m	2.39 m	2.34 m	2.28 m	33.1 m^3	28 770 Kg	
12.04 m	2.35 m	2.39 m	2.34 m	2.28 m	67.6 m^3	28 800 Kg	
20 and 40 ft High cube							
5.90 m	2.35 m	2.70 m	2.34 m	2.57 m	37.4 m^3	28 130 Kg	
12.04 m	2.35 m	2.70 m	2.34 m	2.57 m	76.4 m^3	28 620 Kg	
20 ft Half height							
5.90 m	2.35 m	1.10 m	2.34 m	0.9 m	15.3 m^3	20 490 Kg	
20 and 40 ft and 40ft High Cube Reefer (Refrigerated container)							
5.43 m	2.28 m	2.26 m	2.26 m	2.22 m	28.0 m^3	27 490 Kg	
11.49 m	2.27 m	2.20 m	2.28 m	2.16 m	57.4 m^3	28 580 Kg	
11.56 m	2.29 m	2.50 m	2.29 m	2.44 m	65.3 m^3	29 480 Kg	

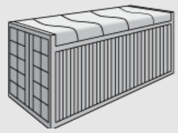
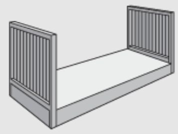
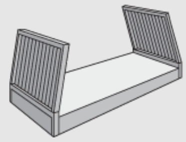
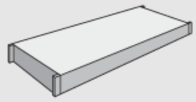
20 and 40 ft Open top							
5.89 m	2.31 m	2.35 m	2.29 m	2.18 m	32.0 m^3	21 600 Kg	
12.03 m	2.35 m	2.35 m	2.34 m	2.27 m	66.4 m^3	26 630 Kg	
20 and 40 ft Flat rack							
5.62 m	2.20 m	2.23 m	-	-	-	21 470 Kg	
12.08 m	2.44 m	2.10 m	-	-	-	39 000 Kg	
20 and 40 ft Flat rack collapsible							
5.62 m	2.21 m	2.23 m	-	-	-	17 730 Kg	
12.08 m	2.13 m	2.04 m	-	-	-	39 000 Kg	
20 and 40 ft Platform container							
6.06 m	2.44 m	2.23 m	-	-	-	24 000 Kg	
12.18 m	2.40 m	1.95 m	-	-	-	39 200 Kg	

Table 4- Based on (Maersk Group, 2014a), (Interfreight, n.d.) ; Figures ref : eplshipping.com

Length (exterior)	Width (exterior)	Height (exterior)	Length (interior)	Width (interior)	Height (interior)	Capacity (interior)	TEU
Standard							
20 ft (6.05 m)	2.44 m	2.59 m	5.90 m	2.35 m	2.39 m	33.1 m^3	1
40 ft (12.19 m)	2.44 m	2.59 m	12.04 m	2.35 m	2.39 m	67.6 m^3	2
High cube							
20 ft (6.05 m)	2.44 m	2.90 m	5.90 m	2.35 m	2.70 m	37.4 m^3	1
40 ft (12.19 m)	2.44 m	2.90 m	12.04 m	2.35 m	2.70 m	76.4 m^3	2

Besides this, there are companies with insulated containers, double door, side open, 8 and 10 ft long (2,4m and 3 m long) Standard containers, etc. Some companies, even though there are regulations and standards, differ in their measures 1 mm and most differ sligtly when it comes to the inside measures. The exterior measure is the standard and important measures due to the fact that it allows compatibility with all other means of transportation. Inside will depend on sheet thickness, corrugated shape, floor inside, thickness of the door, etc. Container capacity changes from company to company , being difficult to establish in the table a very feasible value. Since Maersk is the biggest shipping container company, the values are given first from that company specifications and later added other companies
http://www.maerskline.com/en-us/shipping-services/dry-cargo/equipment-and-services/specifications

C. CONTAINER’S TERMINOLOGY AND SPECIFICATIONS

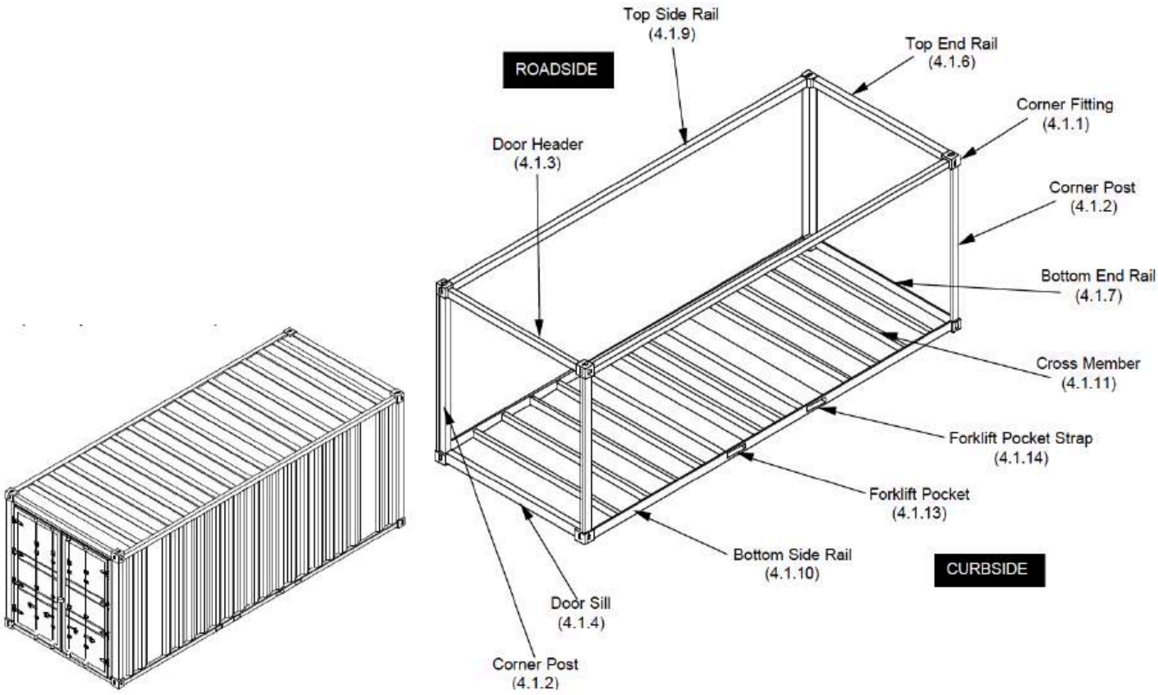


Figure 5- ISO container and container terminology (Department of Defense - United States of America, 2002)

CONTAINERS TERMINOLOGY

4.1.1 Corner Fitting. Internationally standard fitting (casting) located at the eight corners of the container structure to provide means of handling, stacking and securing containers. Specifications are defined in ISO 1161.

4.1.2 Corner Post. Vertical structural member located at the four corners of the container and to which the corner fittings are joined.

4.1.3 Door Header. Lateral structural member situated over the door opening and joined to the corner fittings in the door end frame.

4.1.4 Door Sill. Lateral structural member at the bottom of the door opening and joined to the corner fittings in the door end frame.

4.1.5 Rear End Frame. The structural assembly at the rear (door end) of the container consisting of the door sill and header joined at the rear corner fittings to the rear corner posts to form the door opening.

4.1.6 Top End Rail. Lateral structural member situated at the top edge of the front end (opposite the door end) of the container and joined to the corner fittings

4.1.7 Bottom End Rail. Lateral structural member situated at the bottom edge of the front end (opposite the door end) of the container and joined to the corner fittings.

4.1.8 Front End Frame. The structural assembly at the front end (opposite the door end) of the container consisting of top and bottom end rails joined at the front corner fittings to the front corner posts.

4.1.9 Top Side Rail. Longitudinal structural member situated at the top edge of each side of the container and joined to the corner fittings of the end frames.

4.1.10 Bottom Side Rail. Longitudinal structural member situated at the bottom edge of each side of the container and joined to the corner fittings to form a part of the understructure.

4.1.11 Cross Member. Lateral structural member attached to the bottom side rails that supports the flooring.

4.1.12 Understructure. An assembly consisting of bottom side and end rails, door sill (when applicable),cross members and forklift pockets.

4.1.13 Forklift Pocket . Reinforced tunnel (installed in pairs) situated transversely across the understructure and providing openings in the bottom side rails at ISO prescribed positions to enable either empty capacity or empty and loaded capacity container handling by forklift equipment.

4.1.14 Forklift Pocket Strap. The plate welded to the bottom of each forklift pocket opening or part of bottom siderail. The forklift pocket strap is a component of the forklift pocket.

4.1.15 Gooseneck Tunnel. Recessed area in the forward portion of the understructure to accommodate transport by a gooseneck chassis. This feature is more common in forty foot and longer contain.

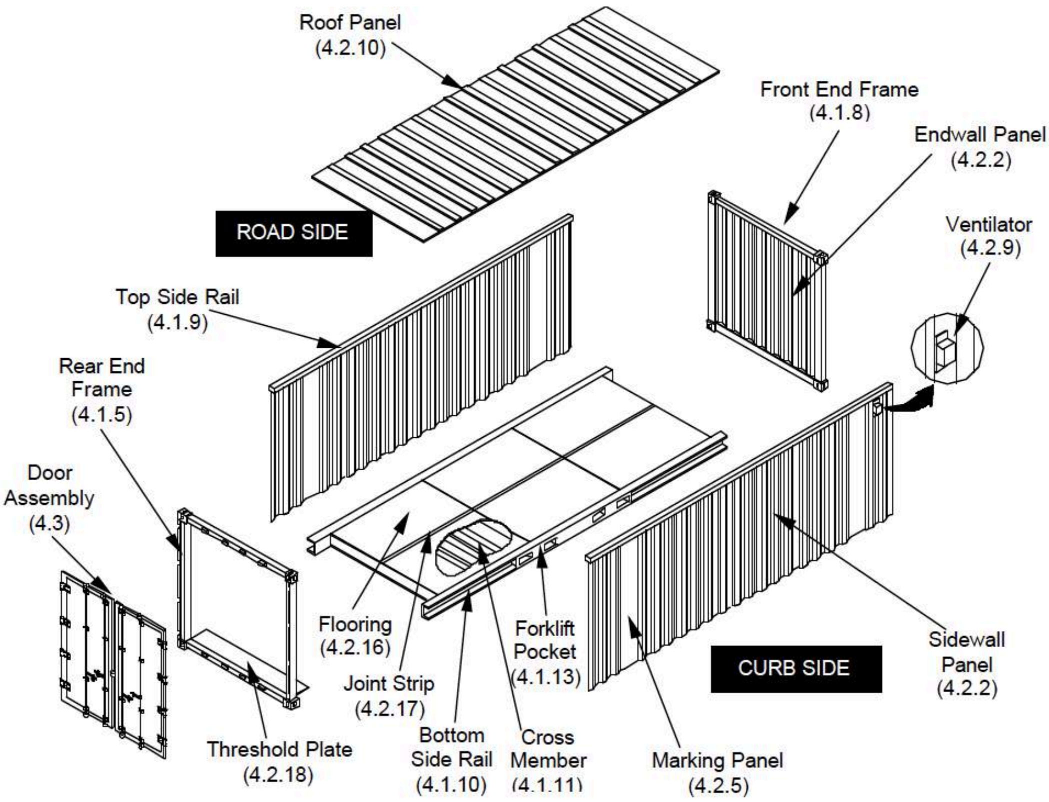
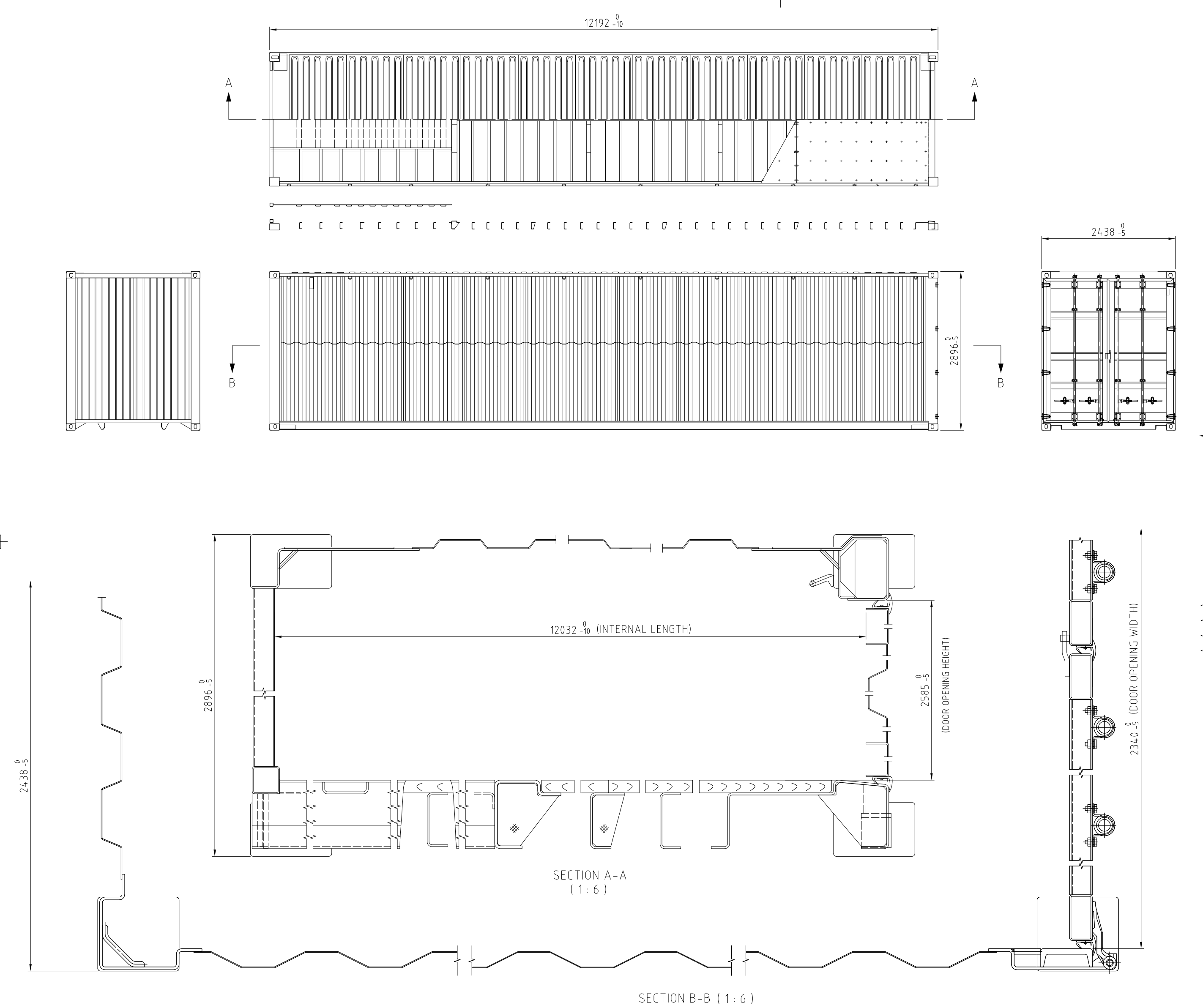


Figure 6- Exploded perspective to show different elements (Department of Defense - United States of America, 2002);

"Corner fittings are typically cast and machined from A-216 steel, which has a minimum specified yield stress of 40,000 psi. Therefore, under maximum load, a corner fitting of the cross section shown below operates with a safety factor on yield of nearly 2.0" (J. Cooper, Kilmer, & Wands, 2003)



EXTERNAL	LENGTH	12,192 $^{+0}_{-10}$ MM	40' - 0" $^{+0}_{-3/8"}$
	WIDTH	2,438 $^{+0}_{-5}$ MM	8' - 0" $^{+0}_{-3/16"}$
	HEIGHT	2,896 $^{+0}_{-5}$ MM	9' - 6" $^{+0}_{-3/16"}$
INTERNAL	LENGTH	12,032 $^{+0}_{-10}$ MM	39' - 5 11/16 $^{+0}_{-3/8"}$
	WIDTH	2,352 $^{+0}_{-5}$ MM	7' - 8 5/8" $^{+0}_{-3/16"}$
	HEIGHT	2,698 $^{+0}_{-5}$ MM	8' - 10 1/4" $^{+0}_{-3/16"}$
DOOR OPENING	WIDTH	2,340 $^{+0}_{-5}$ MM	7' - 8 1/8" $^{+0}_{-3/16"}$
	HEIGHT	2,585 $^{+0}_{-5}$ MM	8' - 5 3/4" $^{+0}_{-3/16"}$
MAX. GROSS WEIGHT		32,500 KG	71,650 LB
TARE WEIGHT		3,810 KG	8,400 LB
MAX. PAYLOAD		28,690 KG	63,250 LB
INSIDE CUBIC CAPACITY		76.4 CU.M	2,700 CU.FT

TITLE	GENERAL ARRANGEMENT				
APP'ED		CUSTOMER NAME			
VERIF'D		CONT. SIZE	40' HC	DATE	2013-09-09
DESIGN		SCALE	1:50	PRO-JECTION	
DRAWN		DRWG NO.			

MAERSK CONTAINER INDUSTRY

20-02-2014 08:54:01, ivh001

D. CONTAINER'S STRUCTURE AND DEFORMATION

Figure 7 – Gap between each container http://www.physicsforums.com

The side beams of a container are not designed to withstand the loads from the vertical stack; they are supposed to hold the ends together when the container is lifted on or off the vessel. There is a gap between the top of the lower container and the bottom of the upper container (Figure 7), so that no load can be transmitted except by the corner posts *"While the minimum performance of a corner post is standardized via ISO, the actual geometry of the post is not. Manufacturers have explored many different designs for many different types of containers, all of which will pass the ISO test load of 86,400 kg or 190,840 pounds.* Figure 8 *shows the most common corner post cross-sections at the door and walled ends of a Series 1 container. These posts are made of 6mm thick pressed steel shapes welded together along the length of the post. In the case of the door end post, a piece of hot rolled channel 113 x 40 x 10 mm is welded to the 6mm plate. Both posts in Figure 8 have adequate cross sectional area from the standpoint of compressive stress. However, the Door End post (a), has a collapse load which is less than the load required by the ISO standard, and therefore must rely on interaction with the walls and doors of the container to produce the necessary load-bearing capacity. The cross section shown, with walls, has a critical load of approximately 252,000 lbs, which is well above the 175,000 lbs of the corner post alone, and well above the 190,480 lbs required by the ISO Standard".* (J. Cooper et al., 2003)

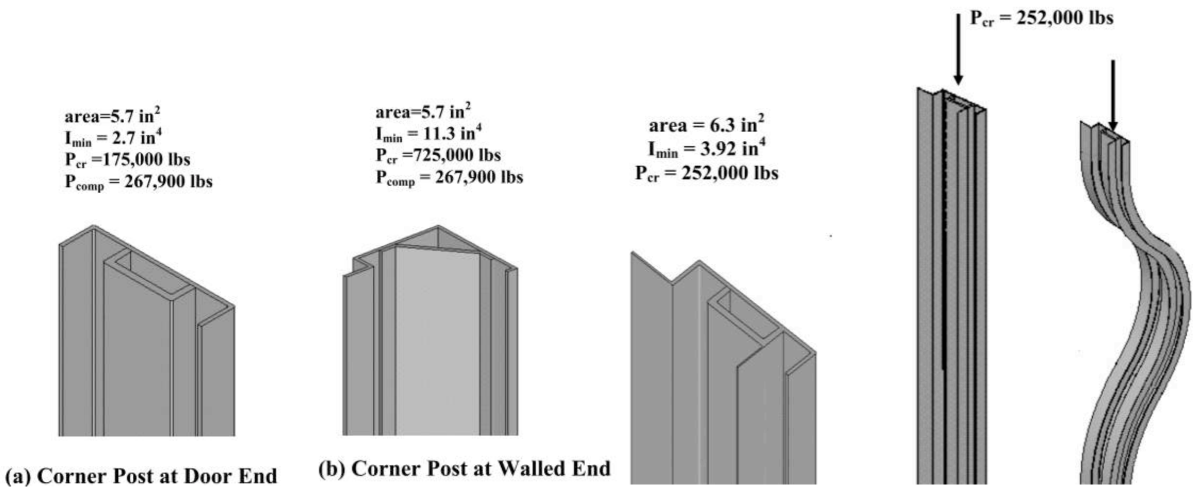
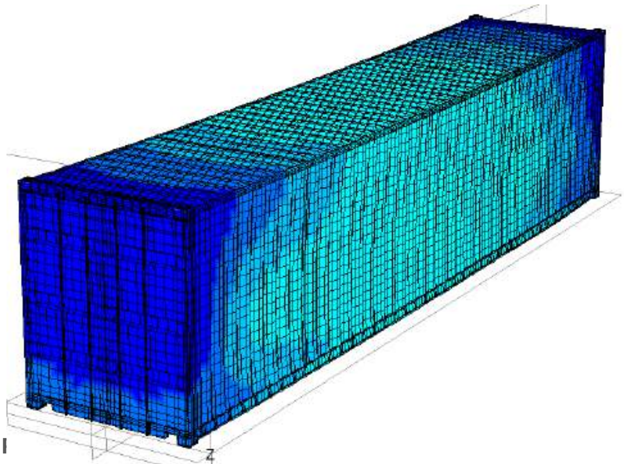
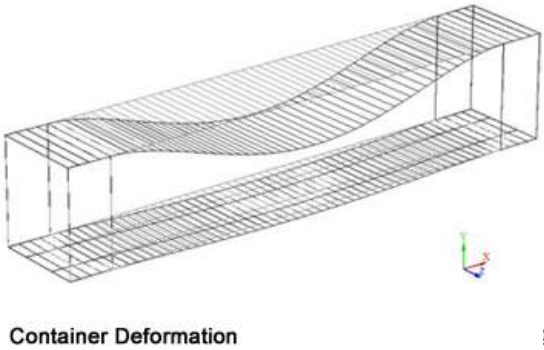


Figure 8 – (Left) Corner post cross section – load capacity without door participation; (Right) Corner post from the same figure (a) showing increase in buckling strength due to participation of the wall (Department of Defense - United States of America, 2002)





I ers ght)
Cotainer deformation ttp://www.residentialshippingcontainerprimer.com/action%20it

“Shippping containers have monocoque bodies. The corrugation panels (roof, sides, and back), floor, purlins, front doors, frame, and rails form an integrated structural skin. They are strong and made to carry floor loads far in excess of what is required for typical home construction. But, when you modify them, cutting holes or penetrating members, they are weakened. As we said above, when cutting a shipping container or removing any of the paneling, it's structural integrity is compromised. As an extreme example, consider the removal of all a container's corrugated paneling along the length of one side (see the images below). Without reinforcement, the container deforms and then fails structurally. As a general rule, whenever you remove portions of the panelized corrugation, steel framing will be required to frame out the opening. In addition, column and roof support will be necessary depending on the size of the opening(s) and roof/wind loads.Steel cutting, framing, and welding is a large part of shipping container home design and construction. Typically, steel construction is not used much in single family or smaller home design because of expense. Cost of steel vs. wood/light guage framing is substantial and the labor cost for steel vs.carpentry is also higher. To combat this, it is best to have as much of the welding and reinforcing done off-site before setting the containers on site and starting the interior fit-out. Most (if not all) container re-sellers have the facilities to make these modifications. If you don't have experience in metal work, or are not hiring a general contractor, you should plan on doing most of the container modification work off-site prior to delivery. More information on Cor-Ten steel (the weathering steel shipping containers are made from) is available at the CorTen - Shipping Container Weathering Steel link in the RSCP Reference section”

http://www.residentialshippingcontainerprimer.com/action%20it

ANNEX 2 LIST OF WEBSITES ADDRESSING THE RECYCLING OF SHIPPING CONTAINERS

This list is not intended to be all-inclusive or in any way complete. The list was developed from those sites referred by members of the engineering group, and is provided as a starting guide to what information is available on the Internet).

-A Comprehensive Overview From Wikipedia :
http://en.wikipedia.org/wiki/Shipping_container_architecture
-An Conversion Industry Website: http://www.shipping-container-housing.com/index.html
-These units are being used in our far north at mine sites: http://www.habitaflex.com/
-Inter modal Shipping Containers for Use as Steel Buildings (by Paul Sawyer)
-Militaries around the world have made containers into wash huts, mess halls, hospitals, though of course now they prefer to have special made buildings that take the same footprint as a container:
http://www.weatherhaven.com/military/products/expandable_container_shelters.asp
-Some units have their own containers. The Army refers to its unit-owned family of containers as Equipment Deployment _Storage System_ (EDSS) containers.
http://www.globalsecurity.org/military/systems/ground/container.htm#
- Department of Defense Standard Family of Tactical Shelters (by JOCOTAS) http://www.chem-bio.com/resource/1999/jocotas.pdf
- 10 brilliant boxy & sustainable shipping container Homes
http://www.logisticsallianceofcarolinas.com/documents/10-brilliant-boxy-and-sustain.pdf
-Container Housing Project By Group 41 http://www.containernation.com/img/UtahPR.pdf
FA Ecotecture design study http://www.ecohouse-plans.com/zoneFiles/04/04_Descrip_Shipping_Container_Homes.pdf
-World Wide Trade Services website with floor plans
http://www.worldwidetradeservices.net/images/WWTS_Portable_Container_Units_2008.pdf
ISBU http://www.isbu-info.org/
-This site illustrates ISBU's can and do exceed most if not all building codes. Shipping container houses
http://www.shippingcontainerhousedesign.com/containerhome_11201.html
-ISBU shipping container architecture http://firmitas.org/
-ISBU House plans and design. ISBU Bob Vila http://www.isbu-info.org/bob_vila_video.htm
-Strong Affordable Storm Ready Housing (by Bob Vila)
http://www.energyroofsandwalls.com/pdf/Container_Homes_Bob_Vila.pdf
-Container Bay http://www.fabprefab.com/fabfiles/containerbayhome.htm
-The latest Gizmag has an article on shipping containers. http://www.gizmag.com/seed-project-shipping-container-sustainable-emergency-housing/13902/

Good container article and further down the page lots of related articles. Converting shipping containers into living quarters, for the offshore oil Industry:www.livingquartertech.com

ANNEX 3 SOME CONSTRUCTION SOLUTIONS NOT CALCULATED

A. THERMAL MASS AND PHASE-CHANGE MATERIALS (PCM)

Material	C_p (Btu/lb-°F)	ρ (lb/ft^3)	Q (Btu/ft^3-°F)
Wood	0.57	27	15.4
Steel	0.12	489	58.7
Glass	0.18	154	27.7
Concrete	0.156	144	22.4
Water	1.0	62.3	62.3

Table 5 Common building materials thermal storage characteristics. When a cubit foot of wood is raised in temperature by one degree it has stored 15,4 Btu, (Haglund & Rathmann, n.d.)

"Thermal mass can buffer temperature oscillations in the interior of a building caused by ventilation from the outside air and heat sources and solar gain within the space. The latent heat of microencapsulated PCM distributed throughout the mass offers the potential for improved performance while requiring less structural weight. mass. PCM provides a substantial benefit on all three measures Worked examples have quantified the surface temperature and energy storage of construction wallboard and concrete with and without PCM. As well as improving performance, the PCM significantly reduces the thickness of mass required. Using this simple methodology, the thermal mass potential of typical wallboard impregnated with PCM was shown to rival that of a heavyweight concrete construction." (Richardson & Woods, 2008)

B. CHEAP "RUSTIC" CONSTRUCTION IDEAS / INNOVATIVE MATERIALS

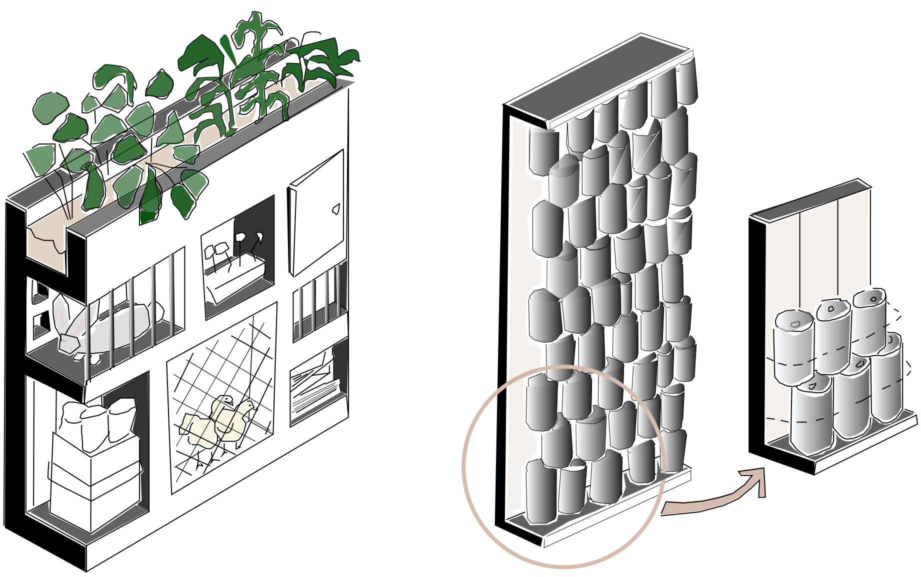


Figure 10- Wall construction solutions : (Left) Wall for food and resources production. When houses are put close together and there is a problem of space, a wall (limitation of the site) can be added using brick and while the top can have plantations with vegatables and fruits to feed the animls – bellow in the same wall- that produce the fertilizer for the ground.; (Right) Solar wall: It works as a solar panel . The board can be turned by the end of the day so that heat is realised to the inside. There are also solutions with vegetation, plastic bottles filled with sand or earth, water etc.

Figure 11- Sigeru Ban's Paper tube Shelters

Figure 12- Materials and innovative solutions

Figure 13- Materials and innovative solutions 2

Figure 14- Materials and innovative solutions3

ANNEX 4 – CALCULATIONS AND EQUATIONS

A. CONSTRUCTION MATERIALS, REGULATIONS AND STANDARD VALUES

e vidro incolor corrente ($g_{\perp}$)

Tipo de protecção	Vidro simples Cor da protecção			Vidro duplo Cor da protecção		
	Clara	Média	Escura	Clara	Média	Escura
Protecções exteriores:						
Portada de madeira	0,04	0,07	0,09	0,03	0,05	0,06
Persiana:						
- réguas de madeira	0,05	0,08	0,10	0,04	0,05	0,07
- réguas metálicas ou plásticas	0,07	0,10	0,13	0,04	0,07	0,09
Estore veneziano:						
- lâminas de madeira	-	0,11	-	-	0,08	-
- lâminas metálicas	-	0,14	-	-	0,09	-
Estore:						
- lona opaco	0,07	0,09	0,12	0,04	0,06	0,08
- lona pouco transparente	0,14	0,17	0,19	0,10	0,12	0,14
- lona muito transparente	0,21	0,23	0,25	0,16	0,18	0,20
Protecções interiores:						
Estores de lâminas	0,45	0,56	0,65	0,47	0,59	0,69
Cortinas:						
- opacas	0,33	0,44	0,54	0,37	0,46	0,55
- ligeiramente transparentes	0,36	0,46	0,56	0,38	0,47	0,56
- transparentes	0,38	0,48	0,58	0,39	0,48	0,58
- muito transparentes	0,70	-	-	0,63	-	-
Portadas de madeira (opacas)	0,30	0,40	0,50	0,35	0,46	0,58
Persianas de madeira	0,35	0,45	0,57	0,40	0,55	0,65
Protecção entre dois vidros						
- estore veneziano, lâminas delgadas				0,28	0,34	0,40

Table 6- Solar factor

Cor da protecção	Clara	Média	Escura
Coeficiente de absorção solar da superfície exterior da protecção	0,4	0,5	0,8
Cor	Branco Creme Amarelo Laranja vermelho claro	vermelho escuro verde claro azul claro	Castanho verde escuro azul vivo azul escuro preto

Table 7- Solar absorption

Tipo de Superfície	Coeficientes de Reflexão (%)
Tectos	60 - 80
Paredes	40 - 60
Mobiliário, Planos de Trabalho	25 - 45
Máquinas e Equipamentos	25 - 45
Pisos	20 - 35

Material	***Coeficiente de Reflexão (%)***
Relva	6
Vegetação (média)	25
Água	7
Asfalto	7
Macadame	18
Terra Húmida	7
Pedra	5 - 50
Ardósia	*8*
Cascalho	*13*
Mármore (branco)	*45*
Cimento	27
Betão	30 - 50
Ladrilhos, Tijolo (barro)	25 - 45
Vidro	
Incolor, Bronze ou Cinzento	7
Reflectante	**20 - 40**
Espelho (vidro)	*80 - 90*
Pinturas	
Preto	*5*
Vermelho Vivo	*17*
Azul Pálido	*45*
Laranja Pálido	*54*
Amarelo Pálido	*70*
Branco	*85*
Madeira	*5 - 40*
Neve	60 - 75

Table 8 - Recommended reflection coefficients for the inside surfaces ; (Right) Surfaces reflection coeficients

Sentido do fluxo de calor	Resistência térmica superficial ($m^2.°C/W$)		
	Exterior - R_{se}	Local não aquecido (*) R_{se}	Interior - R_{si}
Horizontal (**)	0,04	0,13	0,13
Vertical (***):			
Ascendente	0,04	0,10	0,10
Descendente	0,04	0,17	0,17

Sentido do fluxo do calor	Espessura do espaço de ar (mm)	Resistência térmica R_{ar} ($m^2.°C/W$)
Horizontal (*)	5	0,11
	10	0,15
	15	0,17
	25 a 100	0,18
Vertical (**) Ascendente	5	0,11
	10	0,15
	15 a 100	0,16
Vertical (**) Descendente	5	0,11
	10	0,15
	15	0,17
	25	0,19
	50	0,21
	100	0,22

(*) Paredes (até +/- 30° com a vertical).

Table 9 - Superficial thermal resistances ; (Right) Thermal resistance of non ventilated spaces

Material		Massa específica seca (kg/m^3)	Condutibilidade térmica (W/m·°C)
Pedras	Granitos, basalto, etc…	2500 – 3000	3,50
	Mármores	2600	2,90
	Calcários duros, grés	2350 – 1580	2,20
	Calcários brandos e semi-duros	1470 – 2150	0,95 – 1,40
Material cerâmico (barro vermelho)		1800 – 2000	1,15
Betões de inertes pesados	Compactos	2200 – 2400	1,75
	Cavernosos	1700 – 2100	1,40
Betões de inertes leves	De argila expandida estrutural	1600 – 1800	1,05
		1400 – 1600	0,85
	De argila expandida isolante	1200 – 1400	0,70
		1000 - 1200	0,46
		600 – 1000	0,33
	Jorra ou pozolana com finos	1200 – 1600	0,44 – 0,52
	Jorra ou pozolana sem finos	1000 – 1200	0,35
Betões de inertes muito leves (vermiculites)		400 – 800	0,24 – 0,31
Betões celulares		400 – 500	0,16 – 0,33
Argamassa	Reboco	1500 – 2100	1,15
	Estuque	750 - 1300	0,35 – 0,50
Fibrocimento		1400 – 2200	0,65 – 0,95
Madeiras	Maciças	450 – 1000	0,12 – 0,29
	Painéis de partículas	350 – 750	0,10 – 0,17
	Contraplacados	350 – 550	0,12 – 0,15
Cortiça	Comprimida	500	0,10
	Granulado expandido	100 – 150	0,043
Fibras minerais	Lã de vidro ou lã de rocha	20 – 300	0,041
Plásticos alveolares	Poliestireno expandido	10 – 35	0,037 – 0,044
	Poliestireno extrudido	25 - 45	0,027 – 0,034
	Poliuretano	30 –60	0,033 – 0,039
Materiais para impermeabilizações	Borrachas sintéticas, poliesters, polietilenos, etc…	900 – 1500	0,40
	Policloreto de vinilo	1200 – 1400	0,20
	Mastiques para juntas	1000 – 1600	0,40
	Feltros betuminosos	1000 – 1100	0,23
	Asfalto	2100	0,70 – 1,15
Metais	Aço	7780	52
	Alumínio	2700	230
	Cobre	8930	380
	Zinco	7130	112
Vidro	Normal	2700	1,15
	Celular	120 - 180	0,050 – 0,063

Tabela 10 – Thermal Condutivity and specific mass of some construction materials (Instituto Superior Téncico, Formulário: Tabelas e Ábacos disciplina de Física das Construções para Arquitectura, 2009

Building Element		Heat-Transfer Coefficient (Btu/hr ft² °F)	Heat-Transfer Coefficient (W/m²K)
Doors	Single sheet - metal	1.2	6.8
	1 inch - wood	0.65	3.7
	2 inches - wood	0.45	2.6
Roofing	Corrugated metal - uninsulated	1.5	8.5
	1 inch wood - uninsulated	0.5	2.8
	2 inches wood - un-insulated	0.3	1.7
	1 inch wood - 1 inch insulation	0.2	1.1
	2 inch wood - 1 inch insulation	0.15	0.9
	2 inches - concrete slab	0.3	1.7
	2 inches - concrete slab - 1 inch insulation	0.15	0.9
Windows	Vertical single glazed window in metal frame		5.8
	Vertical single glazed window in wooden frame		4.7
	Vertical double glazed window, distance between glasses 30 - 60 mm		2.8
	Vertical triple glazed window, distance between glasses 30 - 60 mm		1.85
	Vertical sealed double glazed window, distance between glasses 20 mm		3.0
	Vertical sealed triple glazed window, distance between glasses 20 mm		1.9
	Vertical sealed double glazed window with "Low-E" coatings	0.32	1.8
	Vertical double glazed window with "Low-E" coatings and heavy gas filling	0.27	1.5
	Vertical double glazed window with 3 plastic films ("Low-E" coated) and heavy gas filling	0.06	0.35
	Horizontal single glass	1.4	7.9
Walls	8 inches - poured concrete 80 lb/ft³	1.5	8.9
	12 inches - poured concrete 80 lb/ft³	1.1	5.9

Material	R-value (hr ft² °F/Btu)	R-value (m²K/W)
Wood bevel siding 1/2" x 8", lapped	0.81	0.14
Wood bevel siding 3/4" x 10", lapped	1.05	0.18
Stucco (per inch)	0.20	0.035
Building paper	0.06	0.01
Plywood 1/4"	0.31	0.05
Plywood 3/8"	0.47	0.08
Plywood 1/2"	0.62	0.11
Hardboard 1/4"	0.18	0.03
Softboard, pine or similar 3/4"	0.94	0.17
Softboard, pine or similar 1 1/2"	1.89	0.33
Softboard, pine or similar 2 1/2"	3.12	0.55
Gypsum board 1/2"	0.45	0.08
Gypsum board 5/8"	0.56	0.1
Fiberglass 2"	7	1.2
Fiberglass 6"	19	3.3
Common brick per inch	0.20	0.04

R-values of Some Common Wall Constructions

Material	R-value (hr ft² °F/Btu)	R-value (m²K/W)
2 x 4 stud wall, uninsulated	5	0.88
2 x 4 stud wall with 3 1/2" batt insulation	15	2.6
2 x 4 stud wall with 1" polystyrene rigid board, 3 1/2" insulation blanket	18	3.2
2 x 4 stud wall with 3/4" insulation board, 3 1/2" batt insulation, 5/8" polyurethane insulation	22	3.9
2 x 6 stud wall with 5 1/2" insulation blanket	23	4
2 x 6 stud wall with 3/4" insulation board, 5 1/2" batt insulation, 5/8" polyurethane insulation	28	4.9

Tabela 11 – Extra values for Rvalue of some common building materials (Source: http://www.engineeringtoolbox.com/heat-loss-transmission-d_748.html)

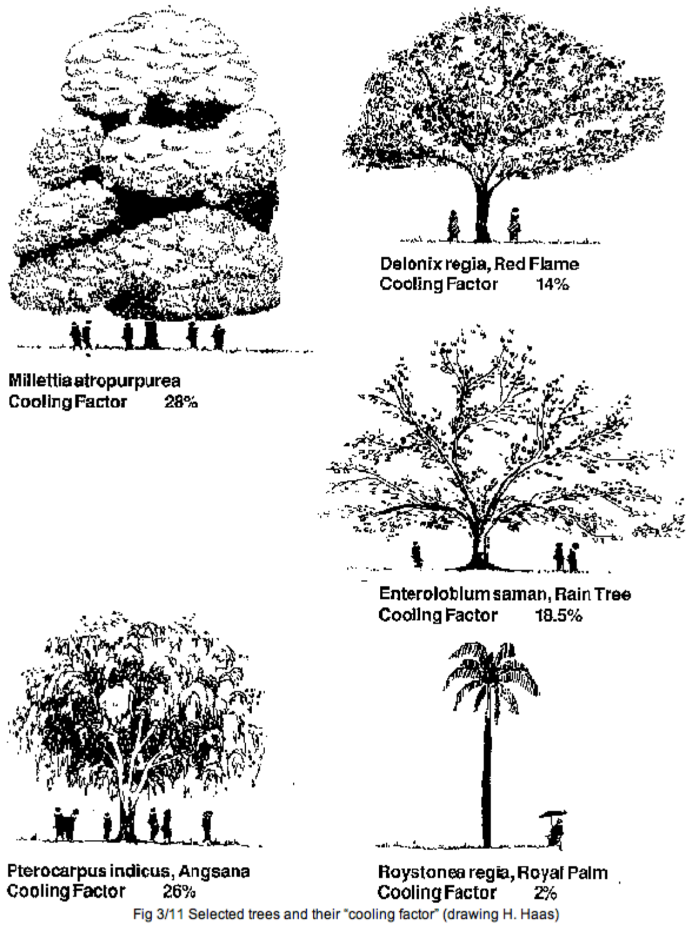


Figure 15- Vegetation that would fit better or worse the propose of passive cooling. (H.Haas)

B. CALCULATION, EQUATIONS, STANDARDS: REFERENCES

Tipo de Trabalho	DF-Factor de Luz de Dia Mín. (%)
Estúdio de Arte	4.0-6.0
Fábrica, Laboratório	3.0
Escritório, Sala de Aula, Ginásio	2.0
Sala de Jantar, Sala de Espera	1.0
Quartos, Corredores	0,5

Table 12 – FDL mínimos recomendados (Instituto Superior Téncico, Formulário: Tabelas e Ábacos disciplina de Física das Construç ões para Arquitectura, 2009

Daylight may similarly be deemed to be adequate in habitable rooms and kitchen when calculation can demonstrate that there is a daylight factor of 2% in half of the room area. In workrooms, daylight may also be deemed to be adequate when calculatio can demonstrate that there is a daylight factor of 2% in the work zone. (The Danish Ministry of Economic and Business Affairs, 2010)

Factor de luz de dia:

$$DF_{médio} = \frac{(M \times t) \times A_w \times \theta}{A \times (1 - \rho^2)} \ (\%)$$

C. VENTILATION NEED DUE TO OLF AND CO2 LEVEL

	INTERIOR	EXTERIOR
AREA CONTAINER (m2)	**13.825**	**14.769**
VOLUME CONTAINER (m3)	**37.258**	**42.772**

Ventilation Requirements

1.Smell Load - Olf

To calculate the required air supply, V_L, rewritten following formula (fra GKB):

$c = 10+(q/V_L)+c_i$

$V_L=(10*q)/(c-c_i)$

q, pollution source strength in everything in the room, divided into q_{pers}, pollution from the people in the room and q_{byg}, pollution from the building itself. These can be seen in Table 1.6 of the GKB:

q_{pers} for 1 - 1,2 met =	1	olf
q_{byg} for "lav-olf bygning" =	0.1	olf/m² gulv
q_{byg} = 0,1olf*13,825m² =	1.3825	olf
q = (1olf+1,4olf) =	2.3825	olf

c, the perceived air quality in the room from the table (from lecture RK7, p 60) shown below, based on category B:

Category	Perceived air quality, c		Thermal comfort
A	PD ≤ 15%	dp ≤ 1,0	PPD ≤ 6%
B	PD ≤ 20%	dp ≤ 1,4	PPD ≤ 10%
C	PD ≤ 30%	dp ≤ 2,5	PPD ≤ 15%

c = 1.4 dp

c_i, the perceived quality of the outside air is set to 0, assuming that only exhausted and no added pollution to the room.

c_i = 0 dp

Under these conditions, the necessary air supply:

V_L= (10*2,4olf)/(1,4dp-0dp) =	17.0	l/s
V_L = (17,0/1000)*3600 =	61.3	m³/h

From this, as well as a room volume of 40m³, the necessary air exchange, n, is calculated:

$n = V_L/V_R$

n = (61,3m³/h)/(37,258m²) =	1.64	h^{-1}
n/m² = 1,67h^{-1}/13,825m² =	0.12	h^{-1}/m^2

2. Pollution Load - CO2

$c = (q/nV)*(1-e^{-n\tau})+(c_0-c_i)*e^{-n\tau}+c_i$

q, the amount of pollution is determined on the basis of the CO2 in the person's breath depends on his energy conversion / activity level, this 1.2 system:

$q_{pers,CO2} = 17*M$

$q_{pers,CO2}$ = 17*1,2met =	20.4	l/h pr. adult person
$q_{pers,CO2}$ = (20,4l/h)/1000 =	0.0204	m³/h

c_i, concentration of pollution in the injection air is assumed to be perfectly clean, which ci = 0
At the same time, the initial concentration, c0, most often be equal to 0 (According to GKB, p 28).
This makes the concentration of pollutants in the room:

$c = ((20,4l/h)/(1,64h^{-1}*37,258m^3))*(1-e^{-1,64h-1*8h})+(0-0)*e^{-1,64h-1*8h}+0$

c = 6.4E-07 m³/m³

To calculate the required air exchange, n, V_L first determined by the following formula:

$V_L = q_{pers,CO2}/(c-c_i)$

Here are calculated respectively. c and c for pollution maximum and minimum limits.
Max, ci, is set to 1000ppm and minimum ci, is set to 350ppm (according to SBI 202, p 53).

V_L = (0,0204m³/h)/(650*E-6)

V_L = 31.38 m³/h

In this way, n is calculated from the formula:

$n = V_L/V_R$

n = (31,38m³/h)/37,258m³ =	0.84	h^{-1}
n/m² = 0,78h^{-1}/13,825m² =	0.061	h^{-1}/m^2

This air exchange needs are met, then, by air exchange with the load of smell is higher.

$1,67h^{-1} > 0,84h^{-1}$

VENTILATION NEED IS 1,67 BECAUSE OF SMELL IS BIGGER THAN BECAUSE OF CO2 PRODUCTION

D. BSIM MODEL AND SIMULATION

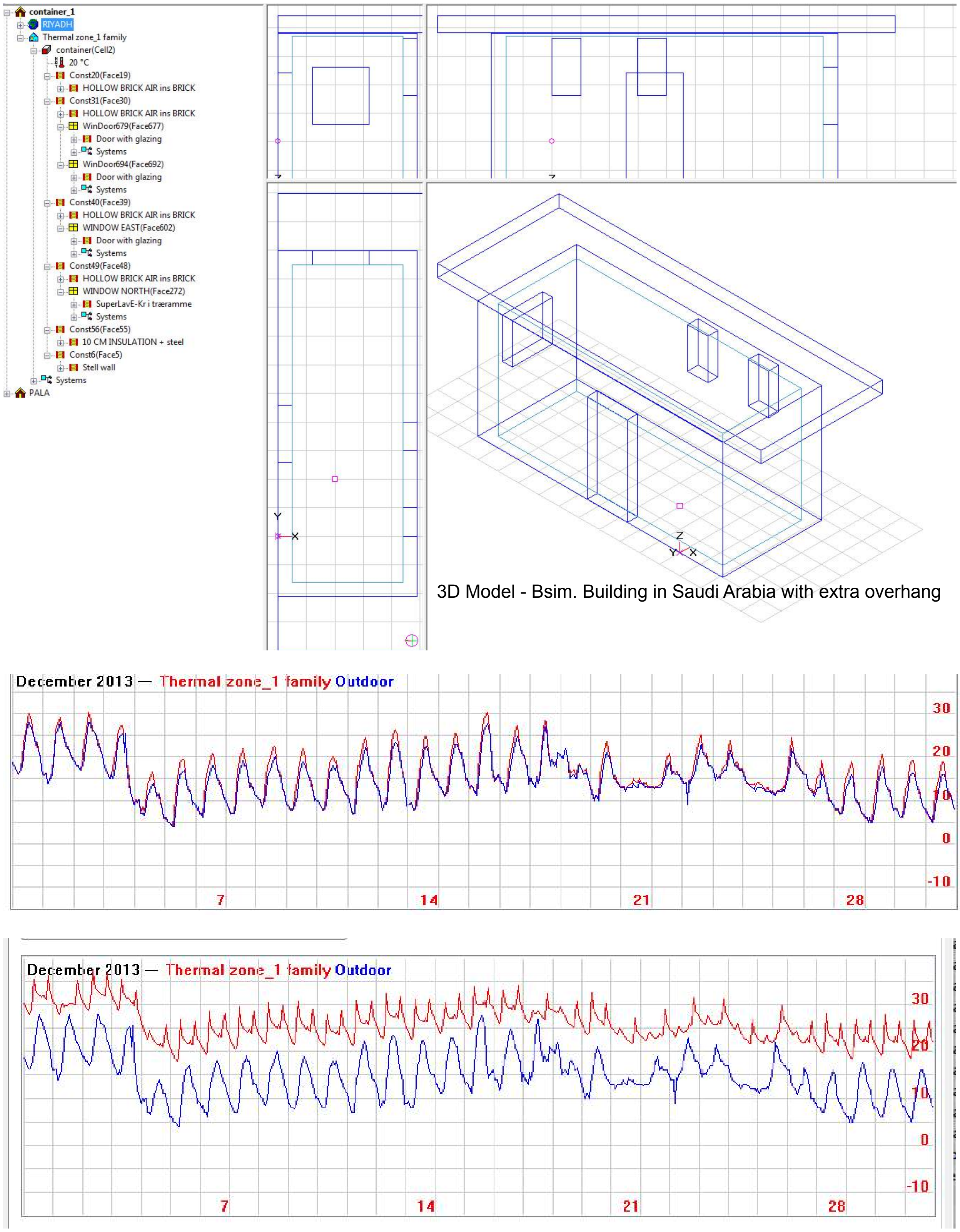


Figure 16 - Simulation in Bsim, Above the 3d Model for Saudi Arabia with roof overhang. Middle, simulation for the container only with steel walls in Saudi Arabia; Bellow, The simulation for the container with outside insulation also in Saudi Arabia

ANNEX 5 – WALL AND FLOOR CONSTRUCTION DETAILS

A. CONSTRUCTION DETAILS

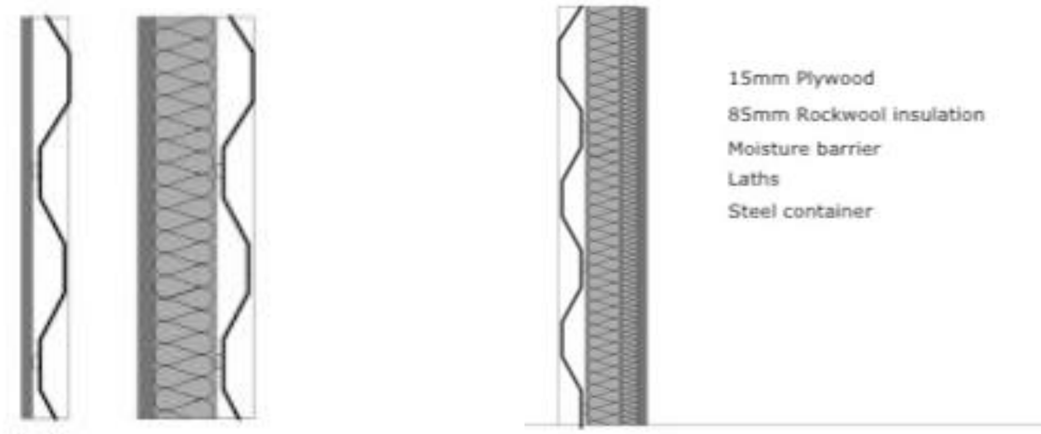


Figure 17- Details inside and (left)outside container, case 1

Construction details and a material list for each wall specimen are illustrated in Figure 3. The first eight wall specimens were designed specifically for verification of MOIST . These specimens utilized a design strategy that varied a single parameter of construction from specimen-to-specimen. For example, specimen 1 was constructed with three layers of materials: gypsum wallboard, glass-fiber insulation, and sugar pine siding. Specimens 2 through 8 varied one item of construction; 2, added a vapor retarder; 3, interior latex paint and exterior oil paint; 4, interior and exterior latex paint; 5, fiberboard sheathing; 6, plywood sheathing; 7, cavity airspace; and, 8, cellulose insulation. This strategy examined the relative effects of each of these parameters on the movement of moisture through the specimens.

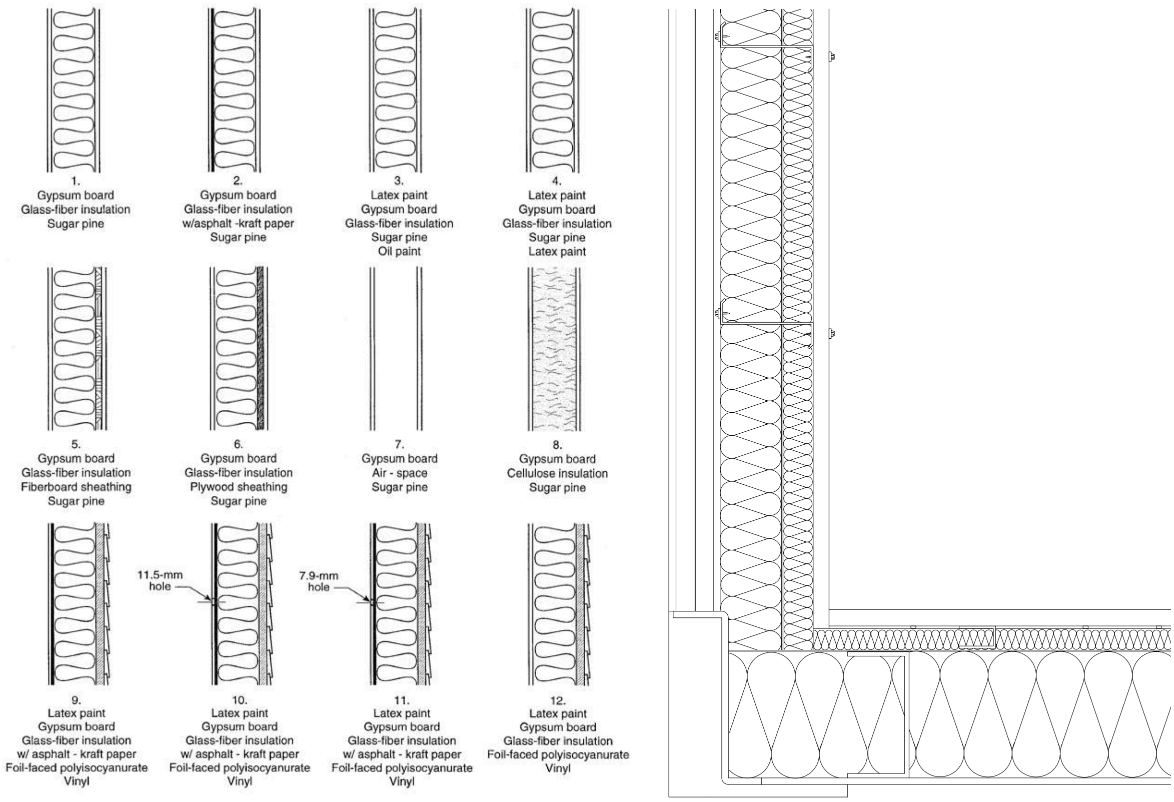


Figure 18- Details container, case 1

B. CONSTRUCTION ELEMENTS AND TEMPERATURE RESULTS

External Wall (10cm)	*d* *m*	*λ* [W/mK]	*R=d/λ* [m²K/W]
Resistance, in			0,13
Plywood	0,015	0,11	0,136364
insulation	0,085	0,035	2,428571
Steel	0,0018	54	3,33E-05
Resistance, out			0,04
Σ	0,1018		2,73

External Wall	*d* *m*	*λ* [W/mK]	*R=d/λ* [m²K/W]
Resistance, in			0,13
Steel	0,0018	54	3,33E-05
Resistance, out			0,04
Σ	0,0018		0,17

Portugal	Celcius ˚C
Choosen month July	25,1
Steel container with two openings	24,5
Steel container with in/outside wrapping	27,7

Portugal	Celcius ˚C
Choosen month July	25,1
Container it self	24,1
Container with opening	24,5
Container with inside insulation	27,6
Container with wood	27,7

Denmark	Celcius ˚C
Choosen month July	21,0
Steel container with two openings	19,9
Steel container with in/outside wrapping	22,5

Saudi Arabia	Celcius ˚C
Choosen month July	38,4

Figure 19- Some wall resistances and some temperature final values on different climates

ANNEX 6 - CONTAINER DESIGN

A.THE TATAMI MATS – INSPIRATION

There are no standard ways to layout tatami mats. While most homes in Japan will employ some perpendicular placement, it is more a matter of personal or cultural aesthetics than convention. Displayed below are some general ideas on tatami mat placements and layouts.

TATAMI ROOM MEASUREMENTS

# of tatami mats	Honma		Chukenma		Go-Hachima	
	1.9m x 0.95m = 74.8" x 37.4"		1.8m x 0.9m = 70.87" x 35.43"		1.7m x 0.85m = 66.93" x 33.46"	
	Area (Sq. Mt.)	Area (Sq. Ft.)	Area (Sq. Mt.)	Area (Sq. Ft.)	Area (Sq. Mt.)	Area (Sq. Ft.)
1	1.81	19.44	1.62	17.43	1.53	16.47
2	3.61	38.88	3.24	34.87	3.06	32.95
3	5.42	58.3	4.86	52.30	4.59	49.42
4	7.22	77.75	6.48	69.74	6.13	65.90
4.5	8.12	87.47	7.29	78.46	6.89	74.13
5	9.03	97.19	8.10	87.17	7.66	82.37
5.5	9.93	106.91	8.91	95.89	8.42	90.61
6	10.83	116.63	9.72	104.61	9.19	98.84
6.5	11.73	126.34	10.53	113.32	9.95	107.08
7	12.64	136.06	11.34	122.04	10.72	115.32
7.5	13.54	145.78	12.15	130.76	11.48	123.55
8	14.44	155.50	12.96	139.48	12.25	131.79
8.5	15.34	165.22	13.77	148.19	13.02	140.03
9	16.25	174.94	14.58	156.91	13.78	148.26
9.5	17.15	184.66	15.39	165.63	14.55	156.50
10	18.05	194.38	16.20	174.35	15.31	164.74

DIMENSIONS OF TATAMI MATS LAYOUT

Layout	Honma		Chukenma		Go-Hachima	
	1.9m by 0.95m=74.8" by 37.4"		1.8m by 0.9m=70.87" by 35.43"		1.7m by 0.85m=66.93" by 33.46"	
	LxW in Metres	LxW in Ft	LxW in Metres	LxW in Ft	LxW in Metres	LxW in Ft
Slide 1: 1 x 1.5	1.9m x 2.85m	6.23ft x 9.35ft	1.8m x 2.7m	5.91ft x 8.865ft	1.75m x 2.625m	5.74ft x 8.61ft
Slide 2: 1 x 2	1.9m x 3.8m	6.23ft x 12.46ft	1.9m x 3.6m	5.91ft x 11.82ft	1.75m x 3.5m	5.74ft x 11.48ft
Slide 3: 1.5 x 1.5	2.85m x 2.85m	9.345ft x 9.345ft	2.7m x 2.7m	8.865ft x 8.865ft	3.5m x 3.5m	8.61ft x 8.61ft
Slide 4: 1 x 2.5	1.9m x 4.75m	6.23ft x 15.575ft	1.8m x 4.5m	5.91ft x 14.775ft	1.75m x 4.375m	5.74ft x 14.35ft
Slide 5: 1.5 x 2	2.85m x 3.8m	9.345ft x 12.46ft	2.7m x 3.6m	8.865ft x 11.82ft	2.625m x 3.5m	8.61ft x 11.48ft
Slide 6: 1 x 3	1.9m x 5.7m	6.23ft x 18.69ft	1.8m x 5.4m	5.91ft x 17.73ft	1.75m x 5.25m	5.74ft x 17.22ft

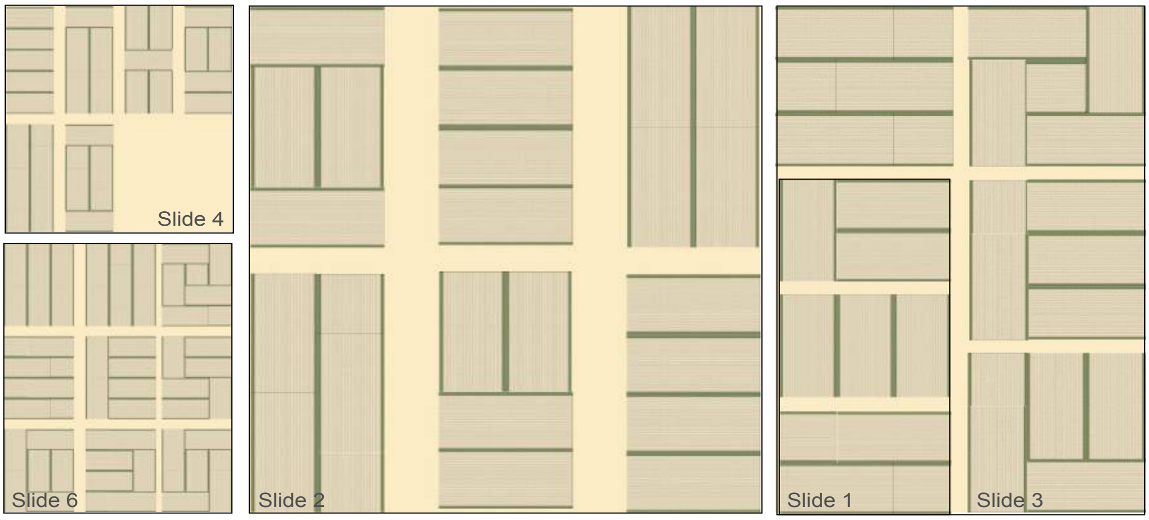


Figure 20- Tatami inspiration for the boards

B. SECOND SKIN AND OPENINGS POSSIBLE SOLUTIONS

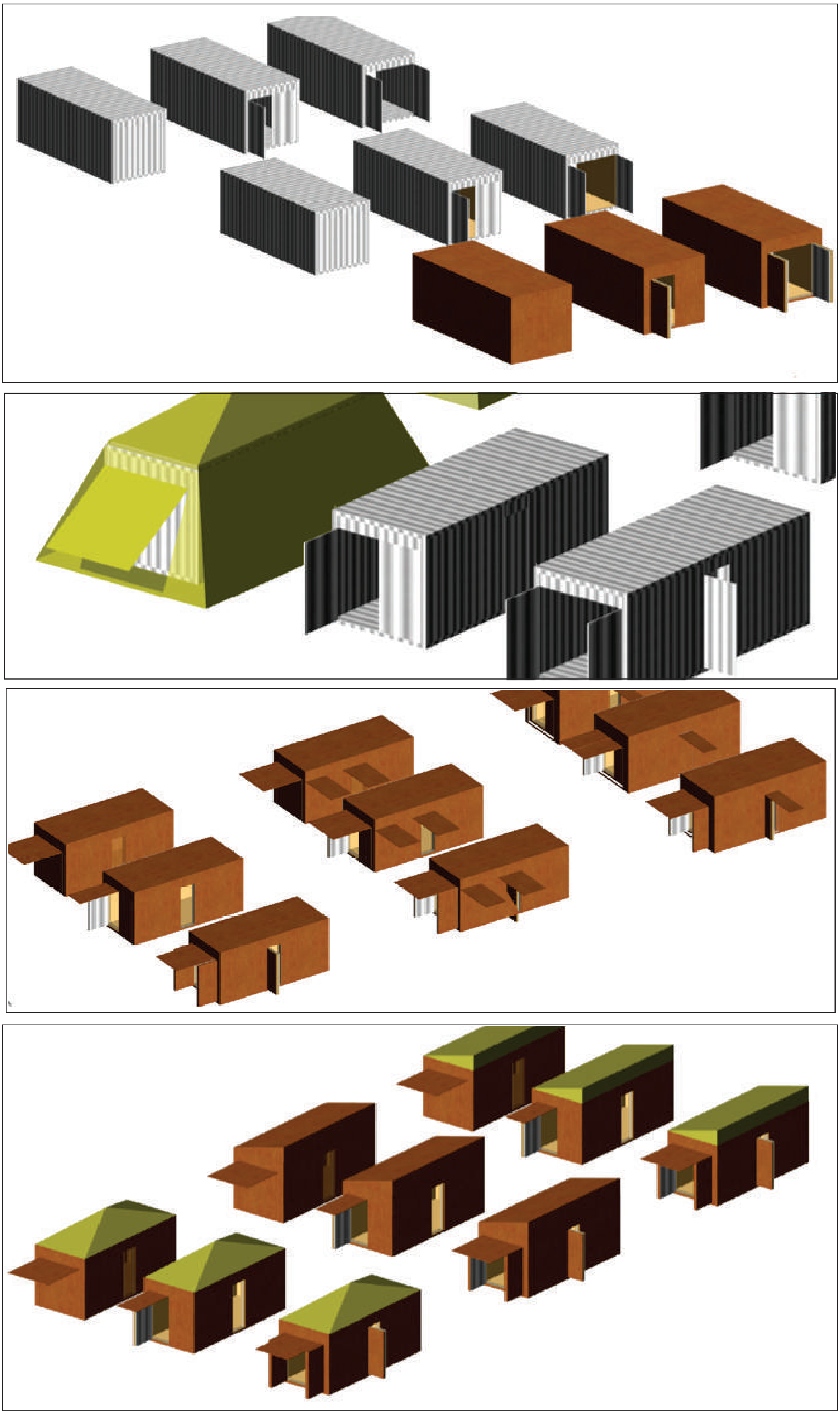
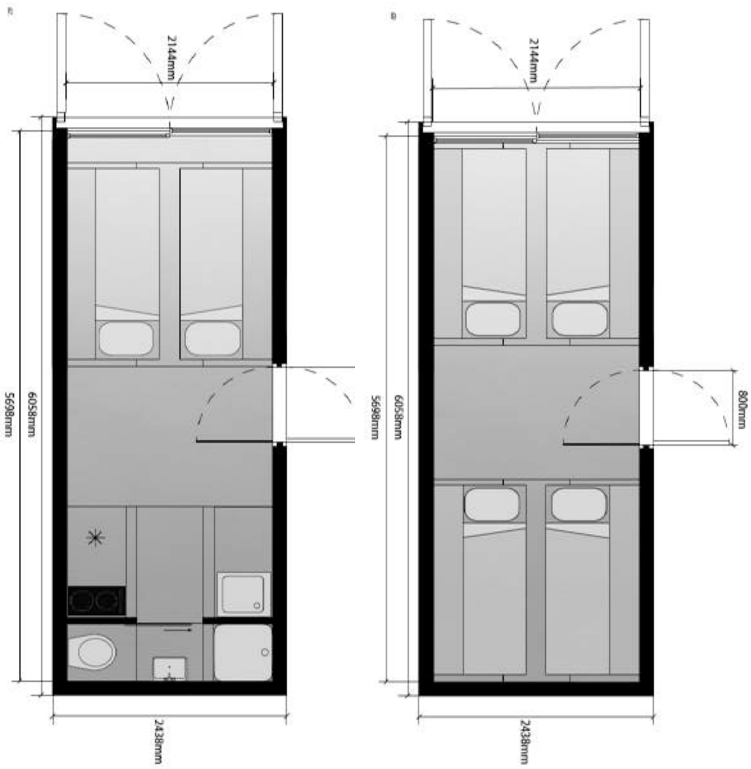


Figure 21- Different roof and shading solutions

C. FLEXIBILITY WITHIN THE PLAN: DIFFERENT USERS, DIFFERENT SOLUTIONS

Small scale: 1 to 3 People- More comfort and all included



Medium scale : 4 or 5 people- A little less space and comfort, all included; (Right) Large scale: 8 to 9 people Each unit is one function: sleeping, bathroom and kitchen are separated

Figure 22- Flexibility in the plans. Moving puzzle pieces: Scale 1 and 2

ANNEX 7: ECOTEC

A. PSYCHROMETRIC GRAPH: To better understand what the interior comfort in a building might mean, figure 23 shows the psychometric graphs for the same location and different activity levels. The yellow limits represent ASHRAE conventional comfort area. The adaptive comfort model is based on the idea that indoor climate is influenced by outdoor climate, because humans are able to adapt to various temperatures along the year. Analysing a database from some buildings revealed that naturally ventilated buildings' occupants admit and prefer a wider range of temperatures than their counterparts in sealed, air conditioned buildings because their preferred temperature depends on outdoor conditions. These results were incorporated in the ASHRAE 55-2004 standard as the adaptive comfort model.

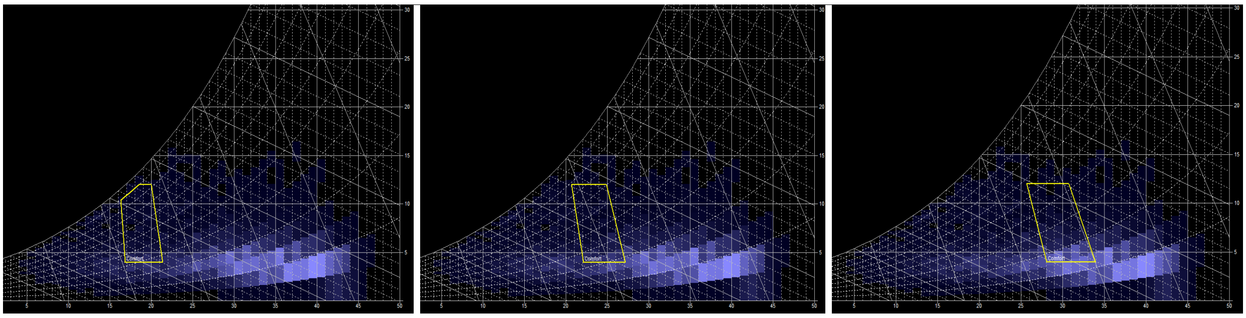
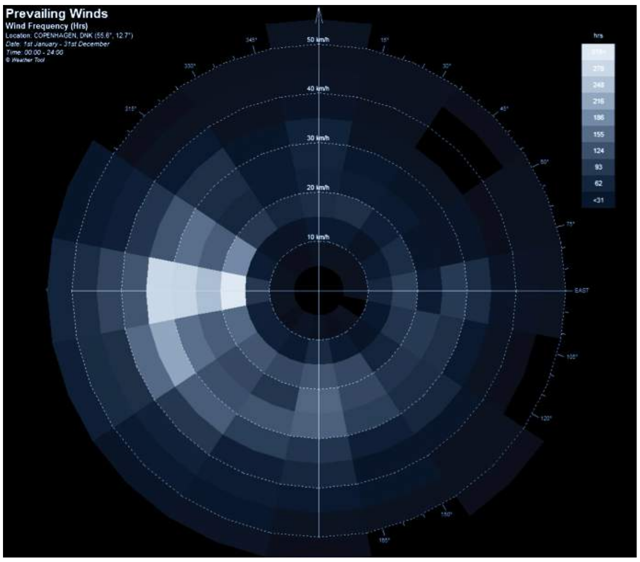
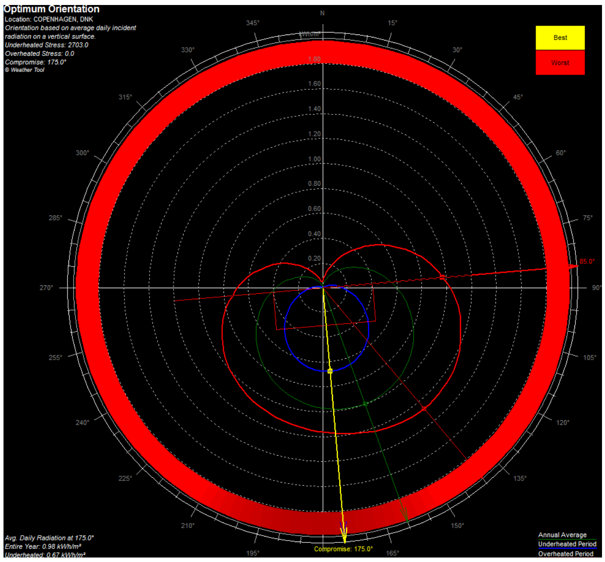


Figure 23- Psychometric charts for a (left) hot and (right) cold climate, taken from the software Ecotec Analysis. The level of activity set to light (standing, relaxing), the comfort conditions change from one to another due to the human's adaptive capacity

B. DENMARK





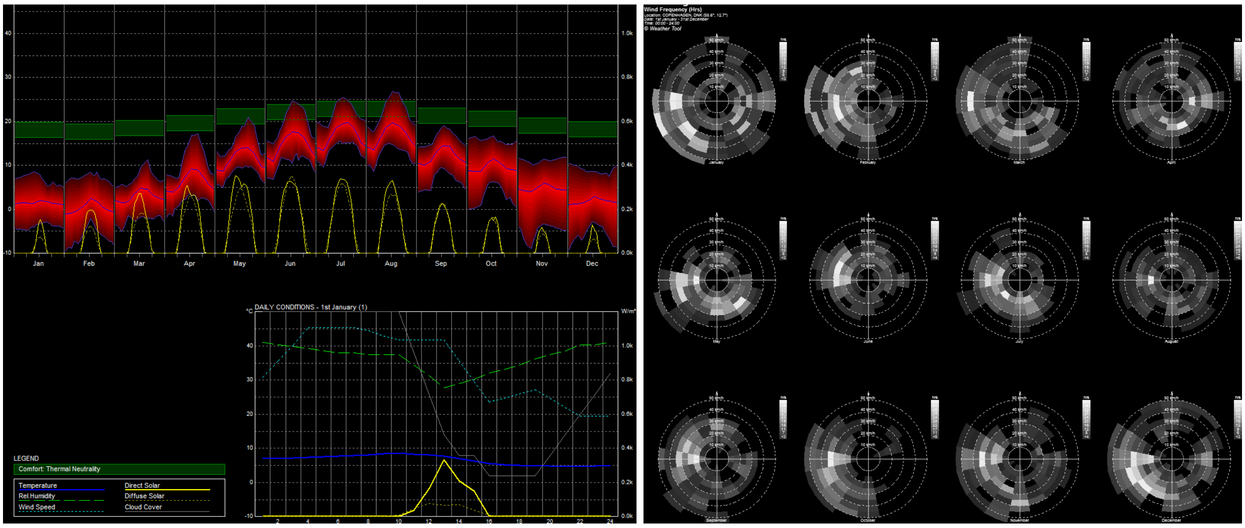


Figure 24- Ecotec Analysis elements used for the design process in Denmark. (Above, Left) Prevailing winds ; (Above, Right) Optimised orientation; (Bellow, Left) Comfort : Thermal Neutrality; (Bellow, Right) Wind direction – Monthly.

C. SAUDI ARABIA

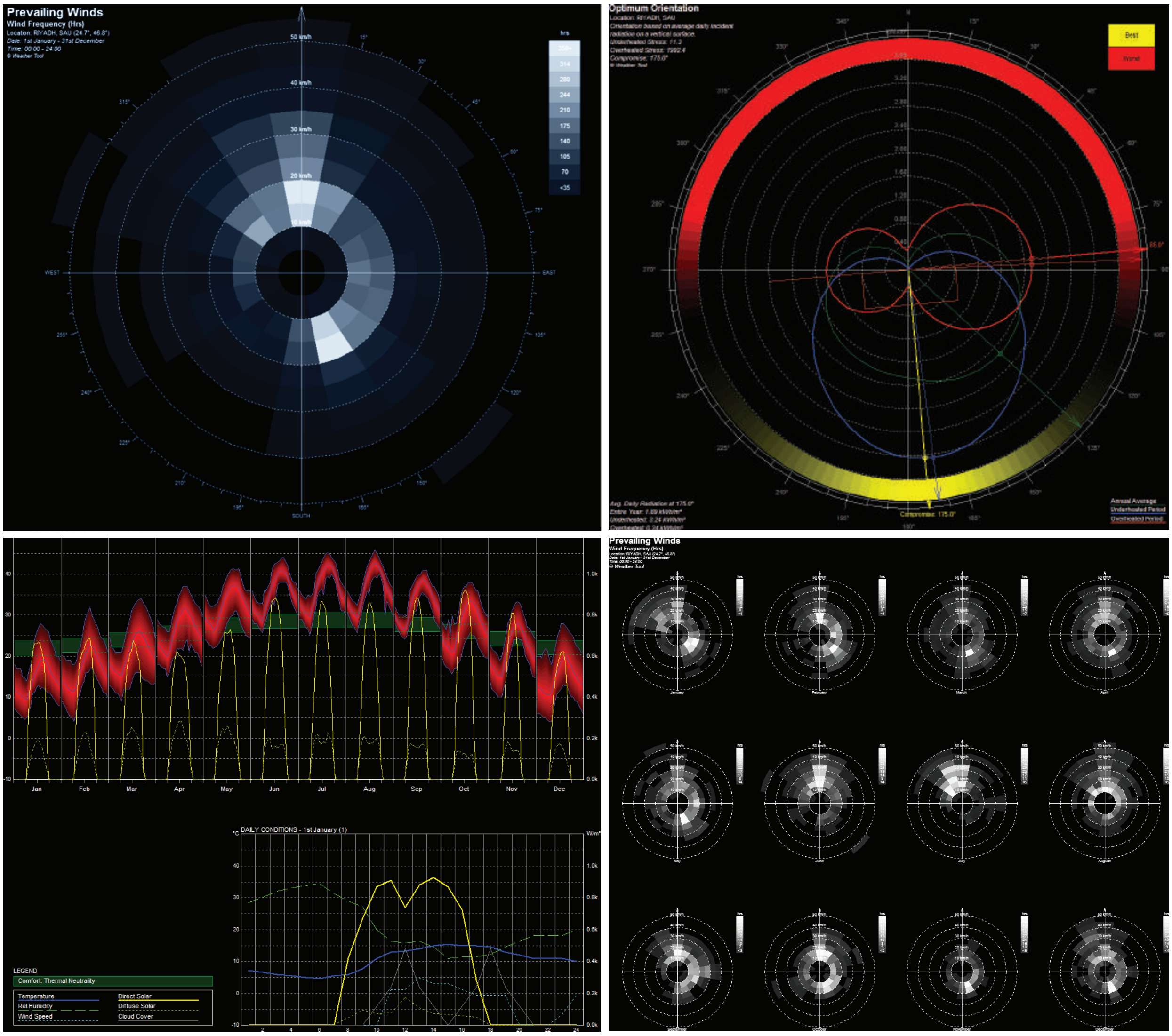


Figure 25- Ecotec Analysis elements used for the design process in Riyadh. (Above, Left) Prevailing winds ; (Above, Right) Optimised orientation; (Bellow, Left) Comfort : Thermal Neutrality; (Bellow, Right) Wind direction – Monthly.

D. DENMARK VS SAUDI ARABIA

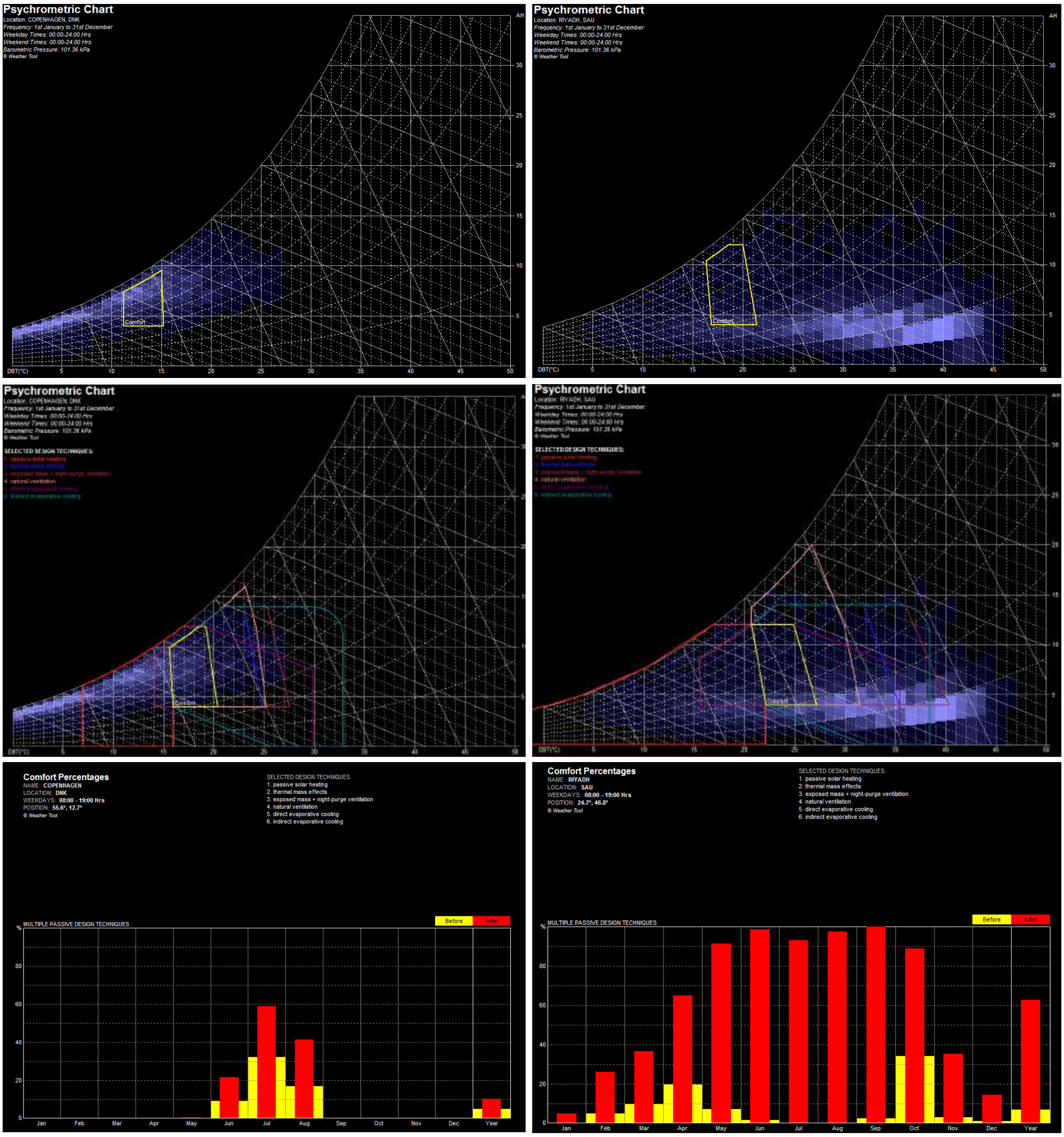


Figure 26 – Using Ecotec to compare Denmark and Saudi Arabia. (Above): Psychometric charts for a (left) hot- Saudi Arabia- and (right) cold climate- Denmark-, taken from the software Ecotec Analysis; (Middle) Psychometric charts showing passive solution's influence on each climate: (Left) Copenhagen and (Right) Riyadh; (Bellow) Before the effect of passive solutions and after the effect/ result of the different passive solutions on the two climates: (Left) Copenhagen; (Right) Riyadh.

ANNEX 8- BSIM VALUES

Denmark

CASE 2 - SIMULATION 1 - ONLY STEEL DENMARK- NO OPENING EAST/WEST AXIS- ROTATION 85º

Year 2013, tstep=100, RadModel=Perez, Options: optimized xsun longwsky longwave

Thermal zone	Sum/Mean	1 (31 days)	2 (28 days)	3 (31 days)	4 (30 days)	5 (31 days)	6 (30 days)	7 (31 days)	8 (31 days)	9 (30 days)	10 (31 days)	11 (30 days)	12 (30 days)
qHeating	0	0	0	0	0	0	0	0	0	0	0	0	0
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-58.96	-2.73	-3.48	-4.84	-5.97	-7.26	-7.3	-7.13	-6.55	-4.77	-3.75	-2.7	-2.48
qVenting	-108.71	-5.72	-6.21	-9.98	-10.43	-12.97	-12.81	-12.77	-10.99	-8.76	-8.05	-5.19	-4.84
qSunRad	0	0	0	0	0	0	0	0	0	0	0	0	0
qPeople	1178.45	100.36	90.65	100.36	97.12	100.36	97.12	100.36	100.36	97.12	100.36	97.12	97.12
qEquipment	1496.77	127.47	115.14	127.47	123.36	127.47	123.36	127.47	127.47	123.36	127.47	123.36	123.36
qLighting	0	0	0	0	0	0	0	0	0	0	0	0	0
qTransmission	**-2507.55**	-219.38	-196.1	-213.01	-204.09	-207.61	-200.37	-207.94	-210.3	-206.95	-216.04	-212.6	-213.17
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mea	8.3	1.5	0.2	2.9	6.2	11.5	14.7	16.6	16.9	12.3	9.7	5.1	1.5
tOp mean	9.1	1.8	0.7	3.7	7.2	12.7	16	17.8	18.1	13.1	10.3	5.5	1.8
AirChange/h	1.4	1.6	1.4	1.5	1.4	1.4	1.3	1.4	1.3	1.4	1.5	1.5	1.5
Rel. Moisture(	88.5	97.3	96.8	89.4	86.9	81.4	76.7	77.1	84.3	87.8	89.6	96.1	98.2
Co2(ppm)	830.5	794.9	852.6	809.2	855.3	850.4	843.4	838.8	854.5	830.9	791.1	820.4	824.9
PAQ	0.7	1	1	1	0.9	0.6	0.4	0.3	0.2	0.5	0.7	0.9	1
Hours > 20	6.80%	0.00%	0.00%	0.00%	0.10%	3.60%	18.30%	29.60%	27.20%	1.10%	0.00%	0.00%	0.00%
Hours > 24	1.70%	0.00%	0.00%	0.00%	0.00%	0.00%	3.50%	6.70%	10.30%	0.00%	0.00%	0.00%	0.00%
Hours > 26	0.80%	0.00%	0.00%	0.00%	0.00%	0.00%	1.10%	1.70%	6.60%	0.00%	0.00%	0.00%	0.00%
Hours < 20	**93.20%**	100.00%	100.00%	100.00%	99.90%	96.40%	81.70%	70.40%	72.80%	98.90%	100.00%	100.00%	100.00%

perde-se muito pelo envelope, tal como se ganha, o valor da transmissao é elevadissimo e radiacao nao é tao complicada pois é apenas uma pequena janela - neste caso a nao ser avaliado, as aberturas. Pe
problema de moisture obvios, aqui demonstrados
maioria de horas abaix do intervalo de comforto de 20 a 26ºc - 93% - normal uma vez que o steel nao retem o calor e sendo clima frio onde temperaturas variam de -2 a 22ºc , Maioria dos valores teria de
Na curva da simulação dá para ver que a curva das temperaturas para o contentor segue praticamente da mesma forma a curva do ambiente exterior.. O steel é bom condutor.. O NÍVEL DE U é muito elevad
valor da transmissao é mUITO elevado pois é ferro
HR average is 80%

CASE 2 - SIMULATION 2 - 50 CM INSULATION DENMARK- NO OPENING EAST/WEST AXIS- ROTATION 85º

Year 2013, tstep=100, RadModel=Perez, Options: optimized xsun longwsky longwave

Thermal zone	Sum/Mean	1 (31 days)	2 (28 days)	3 (31 days)	4 (30 days)	5 (31 days)	6 (30 days)	7 (31 days)	8 (31 days)	9 (30 days)	10 (31 days)	11 (30 days)	12 (30 days)
qHeating	0	0	0	0	0	0	0	0	0	0	0	0	0
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-457.99	-38.7	-37.61	-38.82	-38.67	-39.26	-37.79	-38.83	-39.56	-36.89	-35.87	-37.3	-38.67
qVenting	-1202.87	-103.7	-85.77	-104.39	-97.56	-102.03	-98.42	-101.97	-98.7	-100.96	-112.32	-100.17	-96.87
qSunRad	0	0	0	0	0	0	0	0	0	0	0	0	0
qPeople	1178.45	100.36	90.65	100.36	97.12	100.36	97.12	100.36	100.36	97.12	100.36	97.12	97.12
qEquipment	1496.77	127.47	115.14	127.47	123.36	127.47	123.36	127.47	127.47	123.36	127.47	123.36	123.36
qLighting	0	0	0	0	0	0	0	0	0	0	0	0	0
qTransmission	-1014.36	-85.43	-82.41	-84.62	-84.25	-86.55	-84.27	-87.04	-89.57	-82.64	-79.65	-83.01	-84.94
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mea	8.3	1.5	0.2	2.9	6.2	11.5	14.7	16.6	16.9	12.3	9.7	5.1	1.5
tOp mean	32.3	24.9	25.3	26.4	30.6	35.8	39.2	41.1	42.1	36.1	31.7	28.6	25.5
AirChange/h	1.8	1.8	1.6	1.8	1.8	1.8	1.8	1.8	1.8	1.9	2.1	1.8	1.7
Rel. Moisture(	34.1	41.1	42.1	36.6	33.5	29.4	26.9	26.6	28.7	31.6	34.3	37.2	41.3
Co2(ppm)	1416.9	1435.4	1571.9	1423.9	1451.4	1403.9	1387	1375.5	1411	1359.5	1282.2	1405	1496.1
PAQ	-0.2	0.2	0.2	0.2	-0.1	-0.4	-0.6	-0.7	-0.9	-0.5	-0.2	0	0.2
Hours > 20	94.30%	78.40%	80.10%	92.10%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	99.20%	81.00%
Hours > 24	74.20%	34.30%	36.20%	45.70%	80.40%	99.60%	100.00%	100.00%	100.00%	98.60%	89.40%	63.60%	39.60%
Hours > 26	66.90%	24.60%	26.80%	32.30%	66.40%	97.40%	100.00%	100.00%	100.00%	94.40%	76.10%	50.80%	30.00%
Hours < 20	5.70%	21.60%	19.90%	7.90%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.80%	19.00%

HOW VALUES CHANGED SO MUCH
BELLOW 20ºC IS A BETTER VALUE, BUT THE VALUE ABOVE 26ºC IS TOO HIGHT
too many hours above 26ºc - overheated

CASE 2 - SIMULATION 2 - 30CMM INSULATION denmark- NO OPENING EAST/WEST AXIS- ROTATION 85º

Year 2013, tstep=100, RadModel=Perez, Options: optimized xsun longwsky longwave

Thermal zone	Sum/Mean	1 (31 days)	2 (28 days)	3 (31 days)	4 (30 days)	5 (31 days)	6 (30 days)	7 (31 days)	8 (31 days)	9 (30 days)	10 (31 days)	11 (30 days)	12 (30 days)
qHeating	0	0	0	0	0	0	0	0	0	0	0	0	0
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-501.87	-41.65	-40.33	-42.7	-43.45	-43.43	-41.21	-42.16	-42.78	-40.53	-40.57	-41.36	-41.7
qVenting	-1023.41	-90.07	-73.67	-88.74	-79.5	-86.3	-85.36	-88.91	-85.82	-85.95	-93.24	-82.88	-82.98
qSunRad	0	0	0	0	0	0	0	0	0	0	0	0	0
qPeople	1178.45	100.36	90.65	100.36	97.12	100.36	97.12	100.36	100.36	97.12	100.36	97.12	97.12
qEquipment	1496.77	127.47	115.14	127.47	123.36	127.47	123.36	127.47	127.47	123.36	127.47	123.36	123.36
qLighting	0	0	0	0	0	0	0	0	0	0	0	0	0
qTransmission	**-1149.94**	-96.11	-91.79	-96.4	-97.54	-98.1	-93.92	-96.76	-99.23	-94	-94.03	-96.24	-95.81
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mea	8.3	1.5	0.2	2.9	6.2	11.5	14.7	16.6	16.9	12.3	9.7	5.1	1.5
tOp mean	23.5	16	15.7	17.9	22.1	27.1	30.2	32	32.7	27.5	24.2	20.2	16.4
AirChange/h	1.5	1.6	1.4	1.5	1.4	1.5	1.6	1.6	1.5	1.6	1.6	1.5	1.5
Rel. Moisture(	47.6	56.5	59.5	49.8	46.5	41.2	38.2	37.9	41.8	44.6	46.5	51.6	57.4
Co2(ppm)	1134.2	1118.5	1215.4	1141.6	1203.4	1137.1	1101.4	1088.5	1112.2	1097.8	1075	1151	1168.6
PAQ	0.2	0.6	0.6	0.6	0.3	0	-0.2	-0.3	-0.5	-0.1	0.1	0.4	0.6
Hours > 20	63.40%	14.50%	13.70%	19.80%	62.20%	99.90%	100.00%	100.00%	100.00%	98.10%	84.50%	43.30%	19.90%
Hours > 24	45.70%	8.10%	8.50%	8.50%	20.60%	69.50%	93.60%	100.00%	99.90%	76.70%	36.20%	14.40%	8.50%
Hours > 26	37.00%	7.90%	7.70%	8.20%	11.50%	42.60%	78.50%	95.80%	98.30%	51.40%	21.90%	9.00%	7.80%
Hours < 20	36.60%	85.50%	86.30%	80.20%	37.80%	0.10%	0.00%	0.00%	0.00%	1.90%	15.50%	56.70%	80.10%

more balanced oberheating and "lower heating"
VALOR MAIS PERTO DE 30CM ISOLAMENTO

CASE 2 - SIMULATION 2 - 20CMM INSULATION denmark- NO OPENING EAST/WEST AXIS- ROTATION 85º

Year 2013, tstep=100, RadModel=Perez, Options: optimized xsun longwsky longwave

Thermal zone	Sum/Mean	1 (31 days)	2 (28 days)	3 (31 days)	4 (30 days)	5 (31 days)	6 (30 days)	7 (31 days)	8 (31 days)	9 (30 days)	10 (31 days)	11 (30 days)	12 (30 days)
qHeating	0	0	0	0	0	0	0	0	0	0	0	0	0
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-474.27	-38.35	-37.07	-39.56	-40.6	-41.96	-40.19	-41.04	-41.41	-39.11	-38.46	-38.22	-38.3
qVenting	-879.9	-80.78	-65.89	-79.77	-69.83	-71.83	-70.14	-73.1	-70.32	-70.84	-80.26	-73.09	-74.05
qSunRad	0	0	0	0	0	0	0	0	0	0	0	0	0
qPeople	1178.45	100.36	90.65	100.36	97.12	100.36	97.12	100.36	100.36	97.12	100.36	97.12	97.12
qEquipment	1496.77	127.47	115.14	127.47	123.36	127.47	123.36	127.47	127.47	123.36	127.47	123.36	123.36
qLighting	0	0	0	0	0	0	0	0	0	0	0	0	0
qTransmission	-1321.05	-108.7	-102.83	-108.5	-110.06	-114.05	-110.16	-113.69	-116.1	-110.53	-109.12	-109.17	-108.14
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mea	8.3	1.5	0.2	2.9	6.2	11.5	14.7	16.6	16.9	12.3	9.7	5.1	1.5
tOp mean	19.6	12.1	11.4	13.9	17.9	23.3	26.6	28.5	29	23.8	20.5	16.1	12.3
AirChange/h	1.4	1.6	1.4	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.6	1.5	1.5
Rel. Moisture(	56.7	66.7	70.7	58.7	55.7	49.4	45.5	45.3	50.3	53.3	54.9	61.7	68.1
Co2(ppm)	1024.6	981.6	1062.1	1001.4	1065.1	1053.2	1034	1021.5	1040.9	1023.3	973.3	1015.9	1023.4
PAQ	30.00%	80.00%	80.00%	70.00%	50.00%	20.00%	0.00%	-20.00%	-30.00%	10.00%	30.00%	60.00%	80.00%
Hours > 20	47.30%	8.30%	8.30%	8.50%	20.10%	74.90%	97.90%	100.00%	100.00%	80.80%	42.10%	14.70%	8.20%
Hours > 24	31.00%	7.40%	6.70%	8.10%	9.20%	30.40%	65.70%	86.00%	89.50%	35.00%	15.20%	8.90%	6.50%
Hours > 26	20.80%	5.10%	4.60%	7.10%	8.30%	14.00%	41.10%	60.50%	63.80%	18.60%	10.90%	7.90%	5.60%
Hours < 20	52.70%	91.70%	91.70%	91.50%	79.90%	25.10%	2.10%	0.00%	0.00%	19.20%	57.90%	85.30%	91.80%

too many hours bellow 20ºc
underheated

CASE 2 - SIMULATION 1 - ONLY STEEL SAUDI ARABIA- NO OPENING EAST/WEST AXIS- ROTATION 85º

Year 2013, tstep=100, RadModel=Perez, Options: optimized xsun longwsky longwave

Thermal zone	Sum/Mean	1 (31 days)	2 (28 days)	3 (31 days)	4 (30 days)	5 (31 days)	6 (30 days)	7 (31 days)	8 (31 days)	9 (30 days)	10 (31 days)	11 (30 days)	12 (30 days)
qHeating	0	0	0	0	0	0	0	0	0	0	0	0	0
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-62.81	-5.54	-5.12	-5.53	-5.03	-4.63	-5.66	-5.34	-4.91	-5.1	-6.15	-5.01	-4.8
qVenting	-95.35	-8.62	-7.38	-8.72	-7.92	-6.87	-9.35	-9.53	-7.8	-7.35	-8.7	-6.11	-7.01
qSunRad	0	0	0	0	0	0	0	0	0	0	0	0	0
qPeople	1178.45	100.36	90.65	100.36	97.12	100.36	97.12	100.36	100.36	97.12	100.36	97.12	97.12
qEquipment	1496.77	127.47	115.14	127.47	123.36	127.47	123.36	127.47	127.47	123.36	127.47	123.36	123.36
qLighting	0	0	0	0	0	0	0	0	0	0	0	0	0
qTransmission	-2517.05	-213.67	-193.29	-213.59	-207.54	-216.33	-205.48	-212.96	-215.13	-208.04	-212.98	-209.37	-208.67
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mea	26.2	14	16.7	20.3	25.9	32.1	35.2	36.2	36.4	33	27.6	21.6	15.1
tOp mean	27.2	15	17.7	21.3	26.8	32.9	36.4	37.2	37.4	34	28.7	22.5	15.9
AirChange/h	1.2	1.2	1.2	1.2	1.3	1.2	1.3	1.3	1.2	1.2	1.2	1.1	1.2
Rel. Moisture(	32.8	57.8	47.1	40.2	30.6	20.4	16.6	13.1	15.1	21.1	28.3	36.2	67.5
Co2(ppm)	848.1	876.6	861.9	842.8	825.2	832.6	815.6	799.5	812.1	851.1	869.7	916.3	873.3
PAQ	0.2	0.7	0.6	0.4	0.2	0	-0.1	0	-0.1	-0.1	0.1	0.4	0.5
Hours > 20	72.70%	17.50%	32.10%	56.60%	87.60%	100.00%	100.00%	100.00%	100.00%	100.00%	91.80%	60.60%	22.60%
Hours > 24	61.60%	4.30%	15.20%	31.70%	62.20%	95.80%	100.00%	100.00%	100.00%	99.90%	75.10%	41.80%	9.30%
Hours > 26	**55.80%**	1.90%	8.30%	21.00%	50.80%	88.70%	99.70%	99.90%	100.00%	95.00%	62.90%	32.20%	4.90%
Hours < 20	27.30%	82.50%	67.90%	43.40%	12.40%	0.00%	0.00%	0.00%	0.00%	0.00%	8.20%	39.40%	77.40%

Moisture nao é problema neste caso.. MAX IS AROUND 40% And its a case of hot dry climate

Mais de metade das temperaturas estao acima do máximo do intervalo de 20-26ºc (50%)

need for ventilation is bigger

HR nao e um problema pois os maximos atingem apenas 50% (detrno do intervalo posivel e razoavel)

valor do equpamento e pessoas é igual , se bem que se transpira mais.. A transmissao e muito elevda

o valor do co2 e um pouco superior para o mesmo numero de pesspas

HR AVARAGE IS 30%

CASE 2 - SIMULATION 2 - 50CMM INSULATION SAUDI ARABIA- NO OPENING EAST/WEST AXIS- ROTATION 85º

Year 2013, tstep=100, RadModel=Perez, Options: optimized xsun longwsky longwave

Thermal zone	Sum/Mean	1 (31 days)	2 (28 days)	3 (31 days)	4 (30 days)	5 (31 days)	6 (30 days)	7 (31 days)	8 (31 days)	9 (30 days)	10 (31 days)	11 (30 days)	12 (30 days)
qHeating	0	0	0	0	0	0	0	0	0	0	0	0	0
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-462.44	-40.6	-36.13	-38.93	-37.05	-38.55	-36.58	-37.06	-37.71	-38.36	-40.78	-41.37	-39.32
qVenting	-1036.05	-88.9	-81.84	-91.8	-89.26	-88.14	-87.33	-92.14	-89.23	-82.01	-84.05	-75.58	-85.76
qSunRad	0	0	0	0	0	0	0	0	0	0	0	0	0
qPeople	1178.45	100.36	90.65	100.36	97.12	100.36	97.12	100.36	100.36	97.12	100.36	97.12	97.12
qEquipment	1496.77	127.47	115.14	127.47	123.36	127.47	123.36	127.47	127.47	123.36	127.47	123.36	123.36
qLighting	0	0	0	0	0	0	0	0	0	0	0	0	0
qTransmission	-1176.73	-98.33	-87.82	-97.1	-94.17	-101.14	-96.57	-98.63	-100.9	-100.12	-103	-103.53	-95.4
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mea	26.2	14	16.7	20.3	25.9	32.1	35.2	36.2	36.4	33	27.6	21.6	15.1
tOp mean	54.1	41.4	43.9	47.2	52.9	60	63	63.6	64.5	61.9	56.6	51.4	42.7
AirChange/h	1.7	1.6	1.6	1.7	1.7	1.7	1.7	1.8	1.7	1.6	1.6	1.4	1.6
Rel. Moisture	11.5	18.7	15.6	13.8	10.7	7.8	6.6	6.9	8.2	7.8	9.5	11.6	21.1
Co2(ppm)	1385.9	1454	1418.9	1375.1	1332.8	1350.8	1312	1269.7	1297.1	1393.4	1437.4	1545.2	1444.5
PAQ	-0.7	-0.5	-0.6	-0.7	-0.9	-0.9	-0.9	-0.6	-0.4	-0.9	-1	-0.9	-0.7
Hours > 20	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Hours > 24	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Hours > 26	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Hours < 20	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

TEMPERATURES TOO HIGHT. HEAT CAN NOT GO OUT

CO2 ALSO HIGHER THAN ALLOWED

EXTREME SITUATION EXAMPLE

CASE 2 - SIMULATION 2 - 30CMM INSULATION SAUDI ARABIA- NO OPENING EAST/WEST AXIS- ROTATION 85º

Year 2013, tstep=100, RadModel=Perez, Options: optimized xsun longwsky longwave

Thermal zone	Sum/Mean	1 (31 days)	2 (28 days)	3 (31 days)	4 (30 days)	5 (31 days)	6 (30 days)	7 (31 days)	8 (31 days)	9 (30 days)	10 (31 days)	11 (30 days)	12 (30 days)
qHeating	0	0	0	0	0	0	0	0	0	0	0	0	0
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-490.35	-43.34	-38.46	-41.41	-39.33	-40.65	-38.75	-39.41	-39.93	-40.43	-43.15	-43.54	-41.94
qVenting	-906.3	-76.7	-71.5	-80.28	-78.42	-77.37	-77.08	-81.32	-78.82	-71.94	-73.51	-65.32	-74.04
qSunRad	0	0	0	0	0	0	0	0	0	0	0	0	0
qPeople	1178.45	100.36	90.65	100.36	97.12	100.36	97.12	100.36	100.36	97.12	100.36	97.12	97.12
qEquipment	1496.77	127.47	115.14	127.47	123.36	127.47	123.36	127.47	127.47	123.36	127.47	123.36	123.36
qLighting	0	0	0	0	0	0	0	0	0	0	0	0	0
qTransmission	-1278.57	-107.79	-95.83	-106.15	-102.73	-109.81	-104.65	-107.11	-109.08	-108.12	-111.17	-111.63	-104.5
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mea	26.2	14	16.7	20.3	25.9	32.1	35.2	36.2	36.4	33	27.6	21.6	15.1
tOp mean	43.2	30.9	33.4	36.8	42.4	49	52.2	53	53.5	50.6	45.3	39.6	32
AirChange/h	1.4	1.4	1.4	1.5	1.5	1.5	1.5	1.6	1.5	1.4	1.4	1.3	1.4
Rel. Moisture(	15.6	26.8	22	19.2	14.8	10.2	8.5	6.9	7.8	10.3	13.4	16.5	31.1
Co2(ppm)	1080.7	1137.7	1107.9	1075.3	1043.6	1052.2	1023.5	996.7	1015.8	1080.4	1113	1190.4	1131.6
PAQ	-40.00%	0.00%	-10.00%	-20.00%	-40.00%	-60.00%	-70.00%	-60.00%	-70.00%	-70.00%	-50.00%	-30.00%	-20.00%
Hours > 20	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Hours > 24	98.90%	93.50%	99.70%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	93.10%
Hours > 26	96.30%	79.40%	93.90%	99.10%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	82.90%
Hours < 20	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

CASE 2 - SIMULATION 2 - 20CMM INSULATION SAUDI ARABIA- NO OPENING EAST/WEST AXIS- ROTATION 85º

Year 2013, tstep=100, RadModel=Perez, Options: optimized xsun longwsky longwave

Thermal zone	Sum/Mean	1 (31 days)	2 (28 days)	3 (31 days)	4 (30 days)	5 (31 days)	6 (30 days)	7 (31 days)	8 (31 days)	9 (30 days)	10 (31 days)	11 (30 days)	12 (30 days)
qHeating	0	0	0	0	0	0	0	0	0	0	0	0	0
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-464.21	-41.41	-36.72	-39.47	-37.37	-38.33	-36.64	-37.3	-37.66	-37.97	-40.67	-40.8	-39.86
qVenting	-747.28	-61.96	-58.39	-66.35	-65.01	-64.04	-64.67	-68.03	-65.56	-59.66	-60.59	-53.15	-59.87
qSunRad	0	0	0	0	0	0	0	0	0	0	0	0	0
qPeople	1178.45	100.36	90.65	100.36	97.12	100.36	97.12	100.36	100.36	97.12	100.36	97.12	97.12
qEquipment	1496.77	127.47	115.14	127.47	123.36	127.47	123.36	127.47	127.47	123.36	127.47	123.36	123.36
qLighting	0	0	0	0	0	0	0	0	0	0	0	0	0
qTransmission	-1463.72	-124.47	-110.68	-122.01	-118.1	-125.47	-119.17	-122.5	-124.61	-122.85	-126.58	-126.54	-120.75
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mea	26.2	14	16.7	20.3	25.9	32.1	35.2	36.2	36.4	33	27.6	21.6	15.1
tOp mean	38.9	26.7	29.2	32.7	38.3	44.7	47.9	48.7	49.1	46	40.7	34.9	27.8
AirChange/h	1.3	1.3	1.3	1.4	1.4	1.3	1.4	1.5	1.4	1.3	1.3	1.2	1.3
Rel. Moisture(	18.9	32.8	26.7	23.1	17.8	12.1	10	8.1	9.2	12.4	16.3	20.3	38.2
Co2(ppm)	1001.9	1065.2	1035.2	998.6	967.8	972.3	946.3	923.4	939.8	996.3	1026.5	1096	1055.5
PAQ	-0.2	0.2	0.1	0	-0.2	-0.4	-0.5	-0.5	-0.6	-0.5	-0.3	-0.1	0
Hours > 20	98.90%	93.80%	98.70%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	94.30%
Hours > 24	92.60%	63.40%	81.80%	96.60%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	99.30%	69.40%
Hours > 26	87.90%	43.30%	67.60%	91.30%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	97.80%	53.20%
Hours < 20	1.10%	6.20%	1.30%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5.70%

CASE 2 - SIMULATION 2 - 25CMM INSULATION denmark- NO OPENING EAST/WEST AXIS- ROTATION 85º

Year 2013, tstep=100, RadModel=Perez, Options: optimized xsun longwsky longwave

Thermal zone	**Sum/Mean**	1 (31 days)	2 (28 days)	3 (31 days)	4 (30 days)	5 (31 days)	6 (30 days)	7 (31 days)	8 (31 days)	9 (30 days)	10 (31 days)	11 (30 days)	12 (30 days)
qHeating	0	0	0	0	0	0	0	0	0	0	0	0	0
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-494.33	-40.44	-39.14	-41.56	-42.61	-43.41	-41.25	-42.04	-42.55	-40.43	-40.14	-40.32	-40.45
qVenting	-958.37	-86.25	-70.45	-85.04	-74.92	-79.05	-78.23	-81.98	-79.03	-78.7	-86.95	-78.49	-79.28
qSunRad	0	0	0	0	0	0	0	0	0	0	0	0	0
qPeople	1178.45	100.36	90.65	100.36	97.12	100.36	97.12	100.36	100.36	97.12	100.36	97.12	97.12
qEquipment	1496.77	127.47	115.14	127.47	123.36	127.47	123.36	127.47	127.47	123.36	127.47	123.36	123.36
qLighting	0	0	0	0	0	0	0	0	0	0	0	0	0
qTransmission	-1222.52	-101.15	-96.2	-101.24	-102.96	-105.38	-101	-103.82	-106.25	-101.35	-100.75	-101.68	-100.76
qMixing	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
qVentilation	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sum	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
tOutdoor me	830.00%	150.00%	20.00%	290.00%	620.00%	1150.00%	1470.00%	1660.00%	1690.00%	1230.00%	970.00%	510.00%	150.00%
tOp mean	21.6	14	13.5	15.8	20	25.3	28.4	30.2	30.8	25.7	22.4	18.2	14.3
AirChange/h	1.5	1.6	1.4	1.5	1.4	1.4	1.5	1.5	1.4	1.5	1.6	1.5	1.5
Rel. Moisture(	51.9	61.4	64.9	54	50.8	45	41.5	41.3	45.7	48.6	50.4	56.3	62.6
Co2(ppm)	1077.5	1045.3	1133.6	1066.6	1134	1101	1067.7	1049.7	1071.2	1062.4	1026.3	1081.5	1091.1
PAQ	0.3	0.7	0.7	0.6	0.4	0.1	-0.1	-0.2	-0.4	0	0.2	0.5	0.7
Hours > 20	54.30%	9.40%	9.40%	10.20%	36.50%	91.90%	100.00%	100.00%	100.00%	91.40%	61.80%	23.20%	12.60%
Hours > 24	38.50%	7.90%	7.90%	8.20%	11.50%	48.90%	80.30%	97.40%	98.40%	57.60%	23.00%	9.30%	8.10%
Hours > 26	29.30%	6.90%	6.50%	8.10%	9.20%	26.50%	61.50%	84.30%	85.30%	30.60%	14.80%	8.90%	6.50%
Hours < 20	45.70%	90.60%	90.60%	89.80%	63.50%	8.10%	0.00%	0.00%	0.00%	8.60%	38.20%	76.80%	87.40%

H< 20ºC SAO MUITAS HORAS.

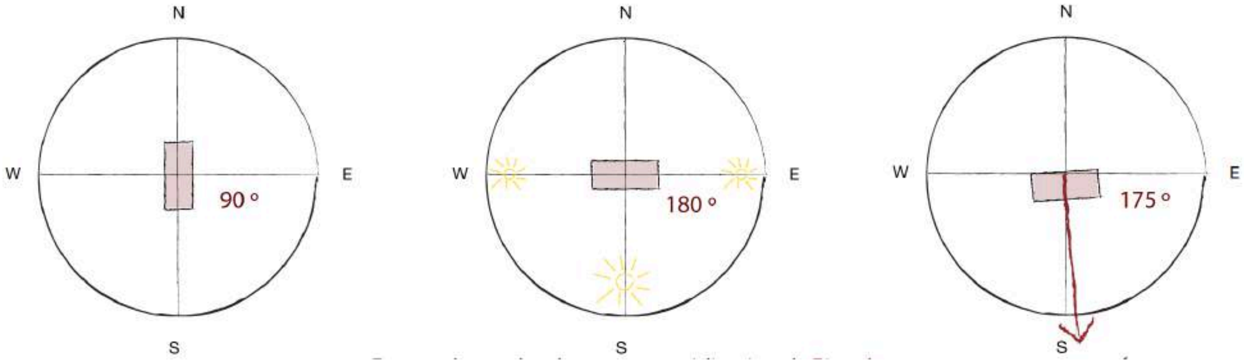
CASE 2 - SIMULATION 3 - WALL 30CMM+ ROOF 40 CM INSULATION denmark- NO OPENING EAST/WEST AXIS- ROTATION 85º

Year 2013, tstep=100, RadModel=Perez, Options: optimized xsun longwsky longwave

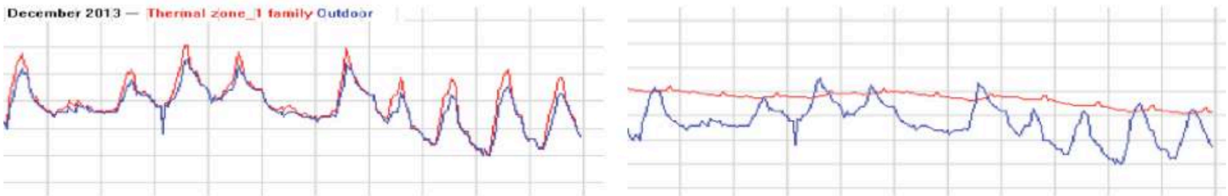
Thermal zone	Sum/Mean	1 (31 days)	2 (28 days)	3 (31 days)	4 (30 days)	5 (31 days)	6 (30 days)	7 (31 days)	8 (31 days)	9 (30 days)	10 (31 days)	11 (30 days)	12 (30 days)
qHeating	0	0	0	0	0	0	0	0	0	0	0	0	0
qCooling	0	0	0	0	0	0	0	0	0	0	0	0	0
qInfiltration	-495.95	-41.37	-40.06	-42.37	-42.93	-42.71	-40.55	-41.51	-42.14	-39.92	-40.02	-40.97	-41.4
qVenting	-1030.54	-90.12	-73.68	-88.78	-80.07	-87.46	-86.33	-89.84	-86.76	-87	-94.15	-83.28	-83.08
qSunRad	0	0	0	0	0	0	0	0	0	0	0	0	0
qPeople	1178.45	100.36	90.65	100.36	97.12	100.36	97.12	100.36	100.36	97.12	100.36	97.12	97.12
qEquipment	1496.77	127.47	115.14	127.47	123.36	127.47	123.36	127.47	127.47	123.36	127.47	123.36	123.36
qLighting	0	0	0	0	0	0	0	0	0	0	0	0	0
qTransmission	-1148.73	-96.35	-92.05	-96.69	-97.49	-97.67	-93.6	-96.49	-98.94	-93.57	-93.67	-96.23	-96
qMixing	0	0	0	0	0	0	0	0	0	0	0	0	0
qVentilation	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	0	0	0	0	0	0	0	0	0	0	0	0	0
tOutdoor mea	8.3	1.5	0.2	2.9	6.2	11.5	14.7	16.6	16.9	12.3	9.7	5.1	1.5
tOp mean	24	16.6	16.4	18.5	22.6	27.5	30.7	32.5	33.2	27.9	24.6	20.8	17.1
AirChange/h	1.5	1.6	1.4	1.5	1.4	1.5	1.6	1.6	1.6	1.6	1.7	1.5	1.5
Rel. Moisture(	46.8	55.5	58.4	49	45.7	40.5	37.5	37.2	41	43.8	45.7	50.6	56.5
Co2(ppm)	1159.2	1149.2	1250.3	1173	1231.4	1154.9	1119.8	1107.4	1131.9	1116.2	1095.5	1179.7	1200.9
PAQ	0.2	0.6	0.6	0.5	0.3	0	-0.2	-0.3	-0.5	-0.1	0.1	0.3	0.5
Hours > 20	65.60%	17.90%	16.40%	23.90%	68.30%	100.00%	100.00%	100.00%	100.00%	98.60%	87.10%	47.80%	22.90%
Hours > 24	47.40%	8.70%	8.50%	9.10%	24.30%	74.90%	95.00%	100.00%	100.00%	79.40%	39.10%	16.00%	9.00%
Hours > 26	38.80%	8.10%	8.20%	8.20%	13.10%	49.60%	80.60%	97.20%	98.80%	56.10%	24.50%	9.90%	8.20%
Hours < 20	34.40%	82.10%	83.60%	76.10%	31.70%	0.00%	0.00%	0.00%	0.00%	1.40%	12.90%	52.20%	77.10%

ANNEX 9- STEP BY STEP DESIGN PROCESS: SAUDI ARABIA

A. ORIENTATION / LOCATION



B. INSULATION



	Copenhagen, Denmark	Riyadh, Saudi Arabia
External wall	qTransmission (mean)	qTransmission (mean)
Only steel container	- 2507,55	- 2517,05
Steel + inside wrapping (50 cm insulation)	- 1014,44	- 1176,73

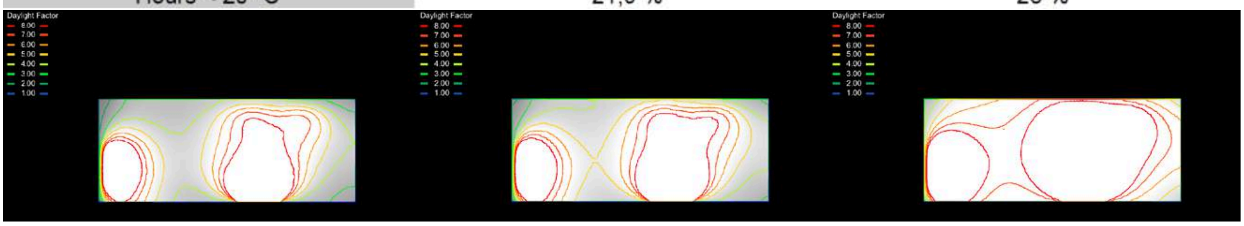
Thermal zone	Steel	Steel + 50cm insulation	Steel + 10cm insulation	Steel +2cm ins.	Steel + 2/10 cm insul. (Wall and floor/ roof)	Steel + 2/10/none cm insul. (Wall/roof/floor
Rel. Moisture (%)	32,8	11,5	23,7	30,1	29,8	31,4
CO2 (ppm)	848,1	1385,9	935,1	861,8	875,9	874,3
Hours > 20 °C	72,7 %	100,0 %	90,7 %	78,5 %	79,1 %	76,6 %
Hours > 24 °C	61,6 %	100,0 %	80,4 %	66,6 %	67,0 %	64,5 %
Hours > 26 °C	55,8 %	100,0 %	74,3 %	61,2 %	61,7 %	59,0 %
Hours < 20 °C	27,3 %	0,0 %	9,3 %	21,5 %	20,9 %	23,4 %

C. GENERAL CONSIDERATIONS ON THERMAL MASS AND GOOD INERTIA

	2/10 cm ins. + 20 concrete (wall/roof) no floor ins.	None /10 cm ins. + 20 concrete (wall/roof) no floor ins.	holow brick 1200 + air 3 cm + hollow brick 1200	Lime brick + 3cm air + lime brick	Hollow brick 1000+ 3cm air+ 2cm ins.+ hollow brick 1000
Rel. Moisture(%)	32.2	34.4	32.5	33.2	31
Co2(ppm)	1047	1060.1	1100.3	1103.5	1019
Hours > 20	78.20%	76.20%	79.80%	65.10%	80.50%
Hours > 24	64.70%	61.90%	66.70%	59.10%	67.30%
Hours > 26	59.10%	55.90%	60.10%	21.20%	60.20%
Hours < 20	21.80%	23.80%	20.20%	1103.5	19.50%

D.BUILDING AND SURROUNDING COLOR

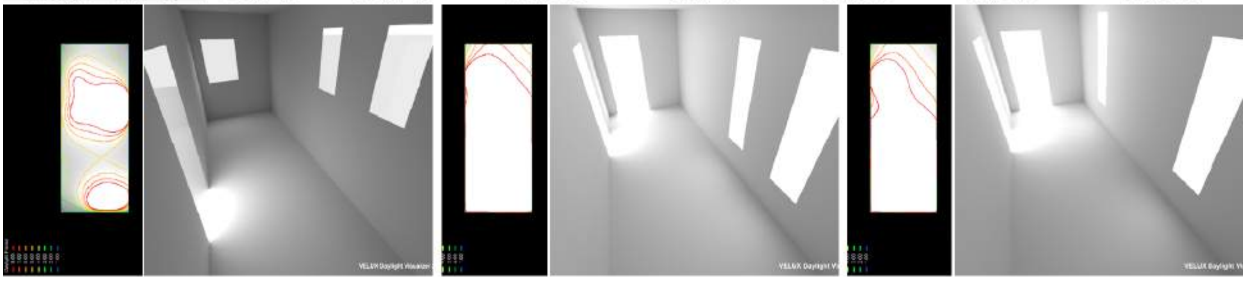
	Medium color	Reflective bright color
Hours > 26 °C	53,9 %	51,1 %
Hours < 20 °C	21,9 %	23 %

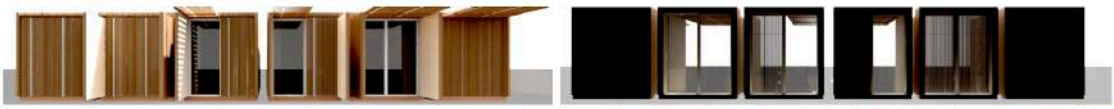


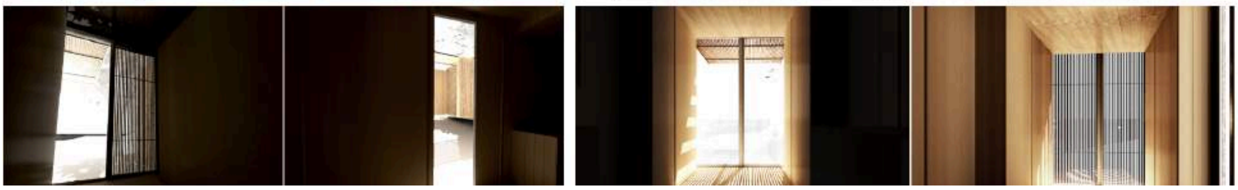
E. OPENINGS AND SHADING

	No windows	Big size windows E / S/ O	Smaller windows	Smaller, higher and shaded	Smaller, higher and shaded
Hours > 20	80.50%	100.00%	80.90%	80.10%	79.10%
Hours > 24	67.30%	99.80%	68.00%	66.80%	65.40%
Hours > 26	60.20%	99.10%	60.80%	59.60%	56.60%
Hours < 20	19.50%	0.00%	19.10%	19.90%	20.90%

Shading device / Out "Comfort range"	No shading	Horiz.shad (overhang)	Vert. shad. (Shutters)	Horiz. and vert. shad. (flexible)	Extra: roof overhang	Extra: Neighboor	Extra: Covered alley (courtyard)
Hours > 26 °C	61,9 %	60,2 %	59,6 %	58,2 %	56,1 %	55,2 %	53,9 %
Hours < 20 °C	20,0 %	20,4 %	20,6 %	20,7 %	21,6 %	21,6 %	21,8 %

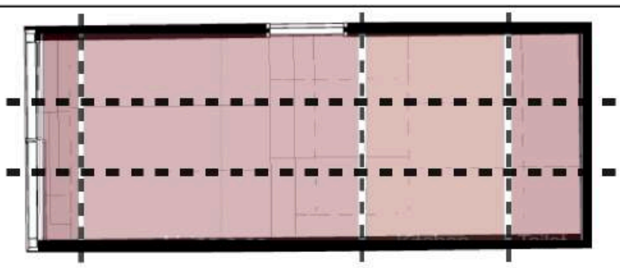


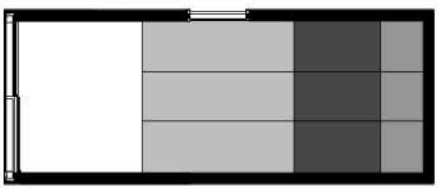


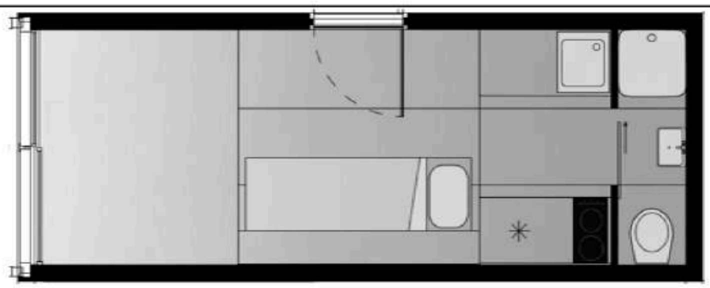


F. INSIDE PLAN DVISION AND PUZZLE PIECES

Container board	1x B	2 x B	B / 2	B / 4
Measurements (mm)	1220 x 2144	2440 x 2144	610 x 2144	205 x 2144
Area (House's function of the piece)	Kitchen	Living Area	Toilet	Extension (free area)

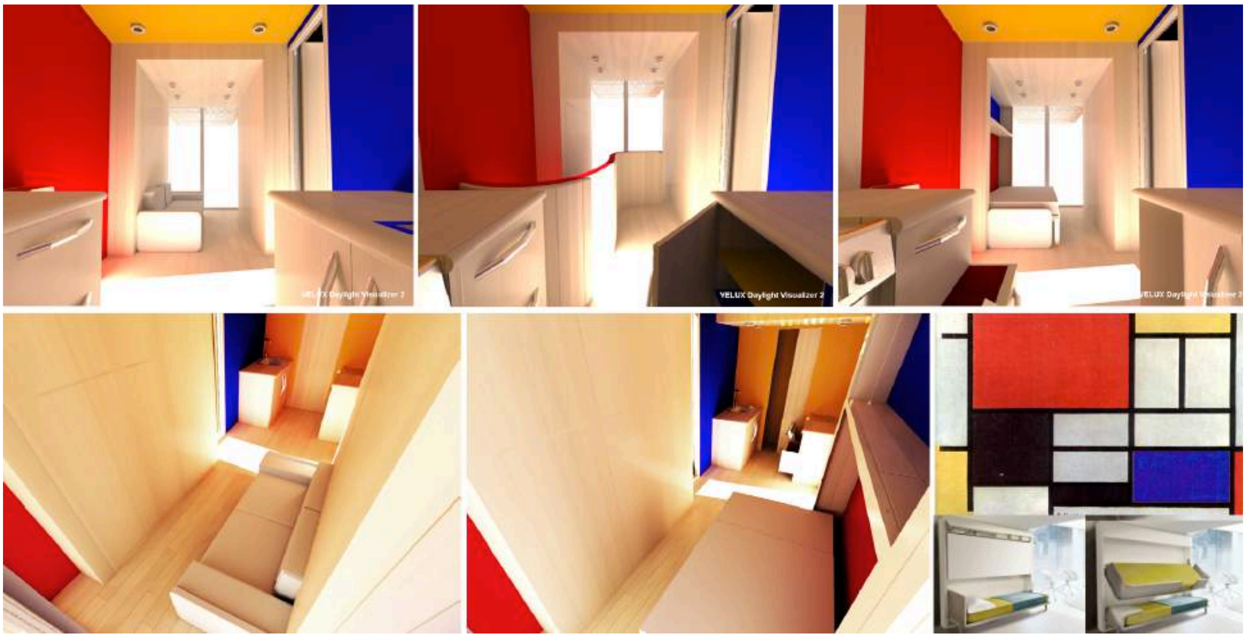






G. INSIDE ATMOSPHERES AND STORAGE SPACES: USAGE OF M3

H. INSIDE COLOR AND FLEXIBLE FURNITURE : THE MAGIC BASIC BOX



H. OUTSIDE POSSIBLE SOLUTIONS

Figure 27- Step by step from organisation and location on site to the second outside skin.

ANNEX 10 -CASE 1 AND 2: SHADING DEVICES, VISUALISATIONS

Figure 28- Ligth and daylight, details and windows

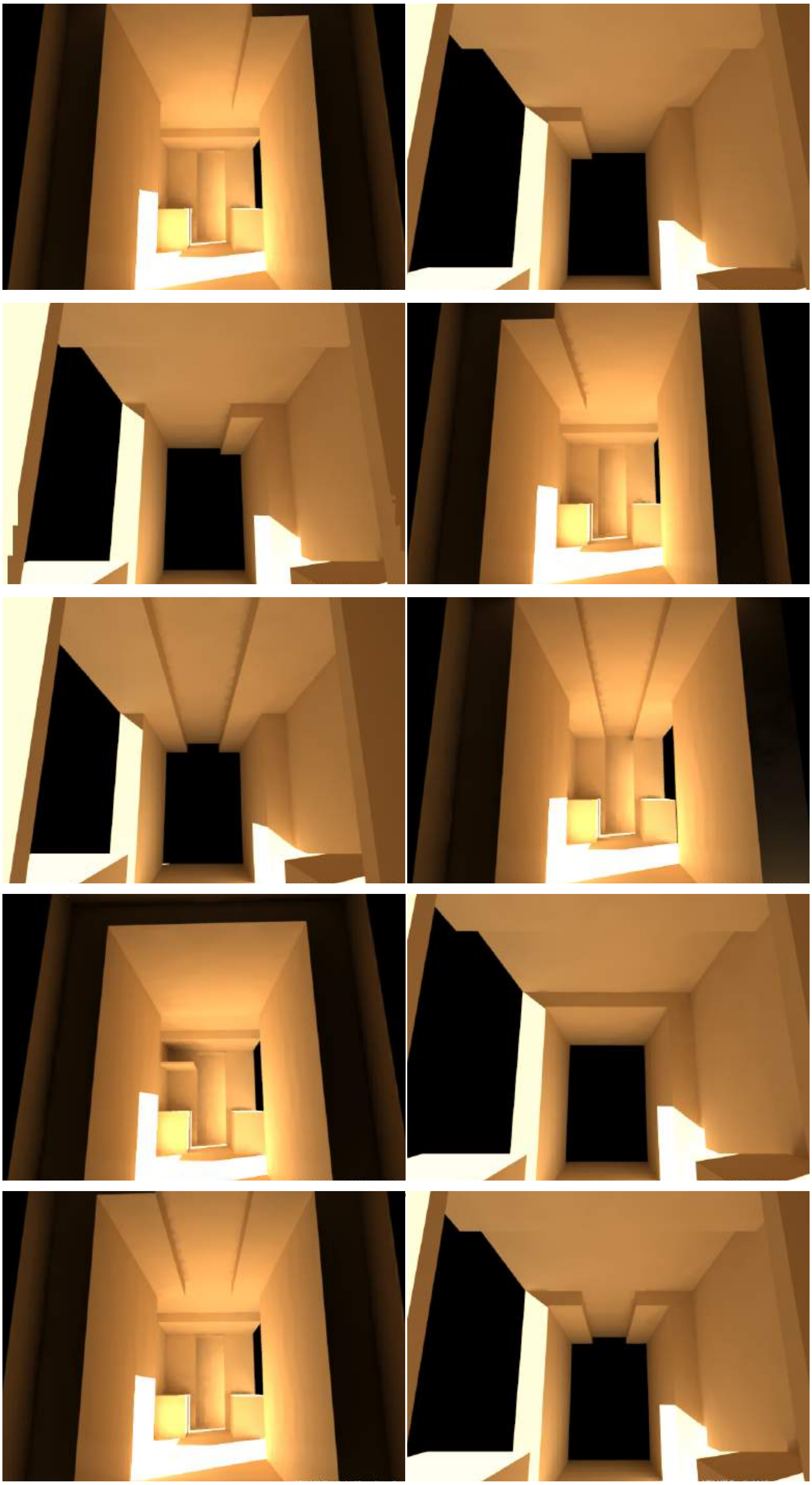


Figure 29 -Inside organisation volume: Storage areas and atmospheres

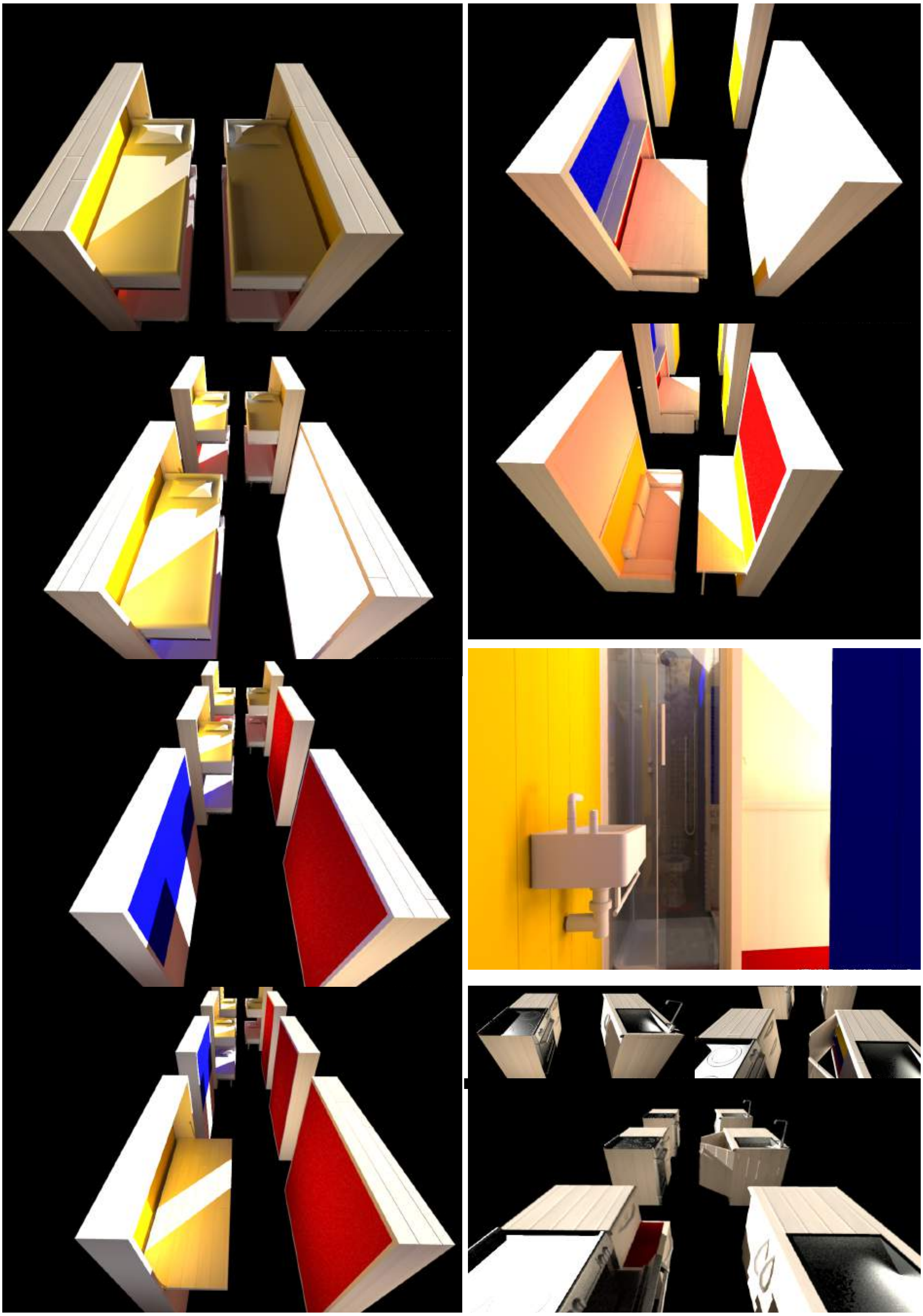
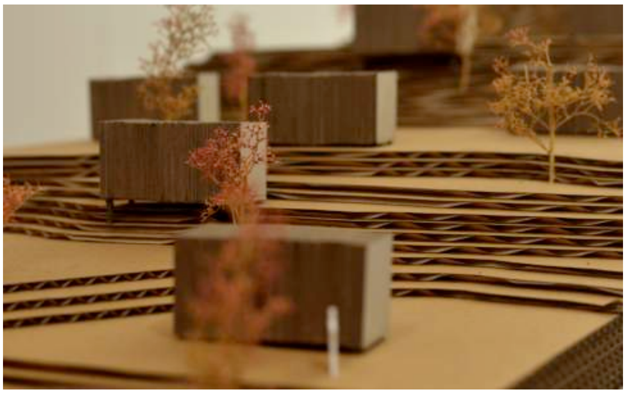
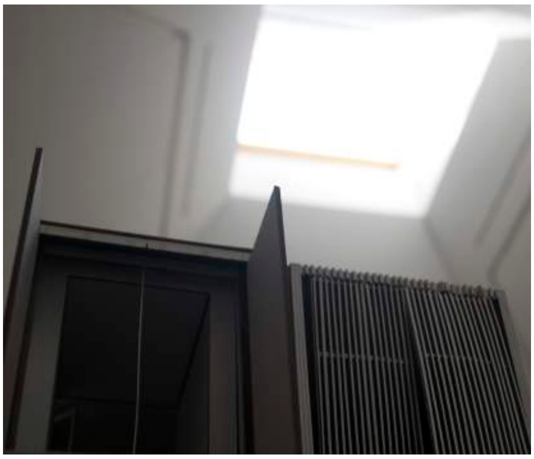


Figure 30- Flexible Furniture







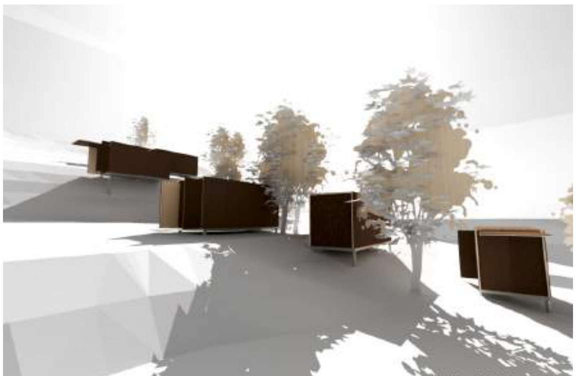





Figure 31- 3D visualisations to show possible shading devives in both contexts: Above) Visualizations for a cold climate; (Bellow) Visualizations for hot climate

DETAILING

These apartments are all designed to provide an unmeasureable quality of living with a care of detailing using the spatial and use of materials qualities. The walls are thick to obtain a high quality of indoor climate. These walls create an opportunity to let the windows become a place to sit, integrated furniture. To create a connection between the interior and exterior the brick walls turned to the terraces are continued inside. The grey brick walls are creating a contrast to the white painted concrete walls. The terraces warm wood flooring is continued inside. The windows framings , doors, kitchens, tables, and facades cladding are all being applied with the same warm wood material. This will create an overall connection between the uses of materials.

ANNEX 11 – EXTRA ELEMENTS ON FLEXIBILITY

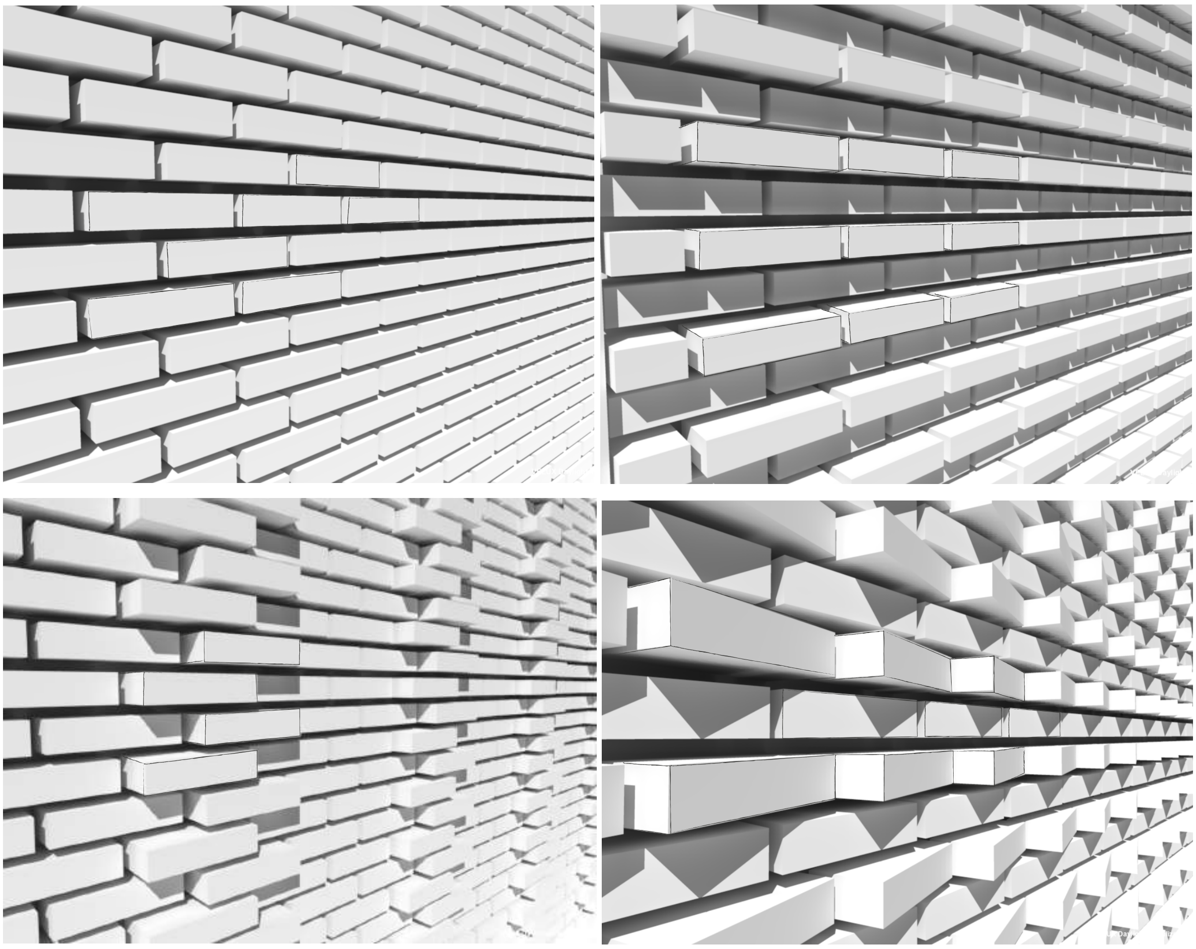


Figure 32 - Ideas on how to show that “LESS is MORE” (Mies van der Rohe). (not BORE, by Robert Venturi) Sustainable economic- materials long lasting from site; Sustainable Environmental and social and architectural value- flexible material and aesthetically interesting.

Figure 33 - Shading device used in different occasions and different ways and additions to the module, as people get more money or have other needs. A deck also helps access to the house and space to sit outside when the ground is not flat or the module needs to be set on columns.

ANNEX 12 – COST AND SCHEDULING BREAKDOWN

1. COST

A. SOME EXAMPLES ALREADY BUILT AND THEIR REAL COST:

-EXAMPLE 1: Container Homes, 15 m2 20 ft. container house price: 12 500 $. (= 10 054 €)

Includes following: Durable Heavy Duty Steel Shipping Container. (ISO standard), Fully finished 1.5" insulated walls and ceiling, Basic Plumbing and fixtures for one bathroom and kitchen, Basic Electricity and fixtures throughout the unit. (110v/220v electrical system), Two ceiling lights and four wall plug receptacles per 20ft unit, 1M x 1M Windows (2 per 20ft unit), Built-in Shelves in kitchen and living space, Standard front door (re-use of the cutout material), Kitchen (sink, faucet, shelves, ceramic counter top), Bathroom (sink, shower, toilet). Ceramic floor only, Outside shell painted, Finished Floor, Ceramic or Bamboo; All labor and taxes.

Source:http://containerhomes.net/products/designs-shipping-container-homes-costa-rica.html

-EXAMPLE 2: SG-Blocks, offer container homes (not complete done house, structural core of house only), 13 m2, 50.000 kr (=6 720 €).

Includes following: Steel reinforcements and paint job; Cutting opening for doors and windows; Delivered to building site. Electricity, plumbing fixtures, kitchen etc. are not included in price.

Source:http://www.tincribs.com/container-home-costs-prices.htm;http://www.sgblocks.com/sgblocks-key-services-and-deliverables.html

-EXAMPLE 3- BASIC QUICK HOUSE:

Table 13- Based on: http://www.quik-build.com/quikHouse/QH_howMuch.htm

General	Description (includes)	COST
Shipping (based on destination)		Aprox. $ 3 000
Finishing Costs for Basic Quik House	- 6 modified shipping containers - all the glass necessary to enclose the Quik House - basic electrical and plumbing (also fixtures) - walls ready to receive your local inspection	$119 000
SUBTOTAL A	The Quick House	$119 000
Quik House Assembly		$2 500
Site Preparation	- excavation	$2 000
	- foundation and slab	$6 000
	- in slab radiant heat	$6 000
Infrastructure	glass installation	$4 000
	- HVAC	$7 000
	- plumbing	$7 000
	- electrical	$7 000
	- insulation	$5 500
	- wall finish and painting	$6 000
	- flooring	$5 000
	- built in shelves and closets	$2 000
	- interior doors and hardware	$2 000
	- roofing	$3 000
SUBTOTAL B	Cost to Finish the Quik House	$65 000
Total Estimate		**$184 000**

Depending on which package you buy, the Quik House will cost between $150 000 and $175 000 finished plus taxes. This translates into a per square foot cost of between $73 and $90, about half the cost of a conventional house. You may arrange for one of our construction foremen to work with you or your contractor on site during any phase of the process. The cost will be $500/day plus expenses.

(Based on: http://www.quik-build.com/quikHouse/QH_howMuch.htm) This options counts with 6 containers, making the price go up: container themselves and all the cost associated with infrastructure and insides are 6 times higher. Could be almost concluded- without big precision- that if the final cost is 184 000 dollars for a 6 container design, then if the design would only be with one container, it would be around 184 000 / 6 = 30 666 $ = 24 664 €

-EXAMPLE 4- LUXURY EXPENSIVE SOLUTIONS

-SU-SI KFN systems: Mobile flexible home. Around 36 876 € (Pre FAB, Allison Arieff, p. 101).

-Micro Compact Home, Lee Architects. Around 50 107€ (Great spaces Flexible Homes, Mostaedi, p. 174)

SHIPPING COST for any distances and Shippings (depends on good, type of container, etc…) based on http://www.freight-calculator.com/ex_apxocean_cal.asp. Based on a website available to make shipping cost estimates.

Table 14- Shipping prices

Description	VALUE	RATE ($)	QTY.	AMOUNT ($)
Freight (FURNITURE)	20' Container	1 577,00	1	1 577,0
Bunker Adjustment Factor [BAF Charges]	20' Container	120,00	1	120,0
Warfage	0.1 MT	2,90		2,90
Bill Of Lading				50,00
Charges for High Security Seal				15,00
Surcharge for Personal Effects (with or without Cars)				250,00
Drayage to Loading Area (1 - 10 Miles)		285,00	1	285,00
Fuel Surcharge				42,75
Customs Brokerage Fee				320,00
Delivery Charges (1 - 10 Miles)		295,00	1	295,00
Total				2 957,65
Drayage to Loading Area (601 - 700 Miles)		1 495,00	1	1 495,00
Fuel Surcharge				224,25
Delivery Charges (501 - 600 Miles)		2 398,00	1	2 398,00
Total				6,452.15

Based n http://www.freight-calculator.com/ex_apxocean_cal.asp

C. COST BASED ON ALL TASKS, MATERIALS AND OTHER:

RS MEANS to estimate the whole design based on cost – approximated values (estimates)

Table 15- Project cost estimate

Items	Quantity	Unit	Unit cost ($)	Total cost ($)
Factory fit out: common items				
20ft shipping container	1	EA	1 300,0	1 300,0
Painting (treat container exterior)	1	EA	450,0	450,0
Window cutouts , torch cutting	3	LF	0,97	2,91
Windows, aluminum, single hung, standard glass	3	EA	350,0	1050,0
Door cut out, torch cutting	1	LF	0,97	0,97
Very resistant door	1	EA	244,0	244,0
Plywood 19/32 in.	764,24	SF	0,64	489,1
Roof, wall and floor insulation	764,24	SF	0,30	229.3
Wall / Ceiling / Floor Painting (primer and 2 coats)	764,24	SF	0,79	603.7
Electrical Rough- in	1	EA	1000,0	1 000,0
Pumbling Rough- in	1	EA	8000,0	8 000,0
Factory fit out: custom items				
20 7/8" x 18" Sinks	2	EA	82,0	164,0
22.4 CF Refrigerator	1	EA	900,0	900,0
D0430" Freestanding Range, 4.4 CF Oven	1	EA	600,0	600,0
Standard Wood 24’’ long Cabinets (4m long aprox)	1	EA	394,0	394,0

Bed / Table / Couch (transforming furniture)	2	EA	300,0	600,0
11.4' x 5' bench seats	2	EA	56,0	112,0
Water closet (toilet)	1	EA	349,96	349,96
Shower stalls, curtains ands rods	1	EA	140,0	140,0
Mirror (32''x22'')	1	EA	70,0	70,0
Tower rack	1	EA	11,9	11,9
Paper and soap dispenser	1	EA	35,3	35,3
On site fit out				
Pumbling Hook up	1	EA	160,0	160,0
Electrical Hook up	1	EA	120,0	120,0
Foundation posts	4	EA	50,0	200,0
Tent to cover the whole structure and poles (folding canopy shelter)	2	EA	97,0	194,0
Entry stairs (if necessary)	3	EA	50,0	150,0
TOTAL				**17 571,14**

The example two does not include as many things as the first, but it does include the transport to the site, so it gets more expensive. Nevertheless, the price is very low when considered that the core, the structure – container- is included in the money estimate.

The calculations presented in C are not 100% trustworthy because they are more theoretical, they are estimates. Cost will mostly depend on the container availability and prices, transport and also experts. Furthermore, some of the furniture used is not exactly the one proposed: in most cases, the furniture solutions given here are more expensive than the ones that would be used- low energy and low cost. In some cases, innovative and green ideas would be incorporated (such as the solar oven etc)

In this case, the inside materials are substantially better than very cheap solutions- wood- but not extremely expensive: plywood. The estimated cost -without the transportation of the container before and after renovation to the factory and to the site, respectively- costs 17 571,14 dollars, meaning 14,133.17 € approximately.

If 867,23 € from long distance shipping – added 2 times to consider going back and forward from the factory to the site in the housing unit life cycle- the final cost would be 14 133,17+ 1 734,46 summing up 15 867,63 € for the project.

D. PRICE ESTIMATE IN SOME TRADITIONAL HOUSING Old house from the 1900th in Denmark: Just under 134 409€ (28 m2) http://home.dk/bolignyt/flere-artikler/april-2013/28-kvadratmeter-solgt-paa-24-dage. Statistically, small houses has an initial price of 2 284€. Pr. m2. If a house is 13 m2, this gives about 29 692€. http://bolignyheder.boligsiden.dk/2013/06/sma-huse-er-nemmest-at-saelge/

Estimate of price for 13 m2 place around Lisbon: 32570€. http://www.portugalvirtual.pt/real-estate/prices-how-to-finance.php#.U6dvqfkZOCk.

The next pictures show examples of some very precarious housing under 12 m2 , far from the city center and still more expensive than the container solution estimated in point C. (Here 18 400 and 20 000€)

GMI013/794: Quintinha do Corterrador
Price: 20.000€
Property Type: Quintinha
Nearest Town: Góis
Location: Corterredor
House area: 10m2
Land: 15.000m2

GMI010/441: Quinta da Vara Selvagem
Price: 18.400€
Property Type: Xisto cottage with land
Nearest Town: Coja
Location: Dreia
House area: 12m2
Land: 3000m2

2. SCHEDULING

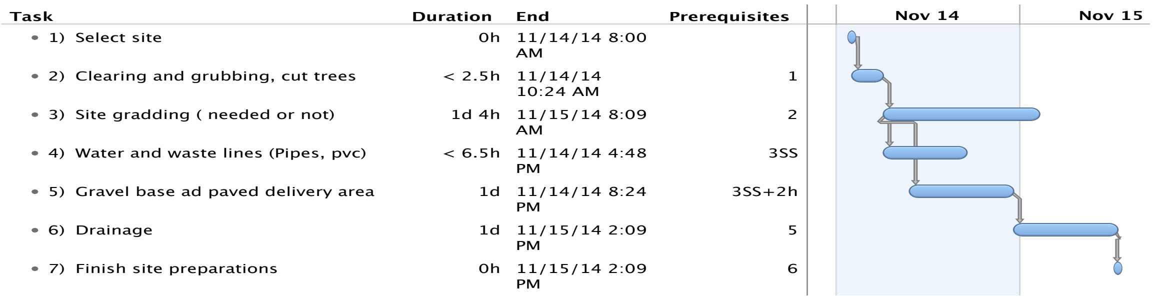
The total duration of each activity was found by dividing the total quantity of the specific item by the daily output of a specified number of crews. The majority of activity durations were taken from RS Means 2010

Unit Cost Assembly and Modifications Data; all crew abbreviations refer to those contained within RS Means. Before factory modifications take place, the containers must be purchased, loaded on trucks, and shipped to a storage yard; the duration of this activity is dependent both on the location of the container distributor and the location of the factory. During the factory modification stage, it is assumed that the containers would be prepared in an assembly line type operation, similar to that of a modular housing factory. Furthermore it was take for granted that each activity could proceed for at least one day until the next sequential activity could begin; for example, if insulation installation had been taking place for one day, enough containers would be completed to begin the installation of the horizontal furring strips. After common and custom factory modifications are completed, the containers must be shipped to a storage area from the factory; this duration will depend on the specific location of the storage facility and the location of the factory. The containers will remain at such a storage area until needed, at which point the units then must be again loaded onto trucks and shipped to the particular location.

Upon arrival to the site, the containers must be placed on the precast concrete foundation posts with the aid of a crane, or other possible foundation (concrete was used when planning) .

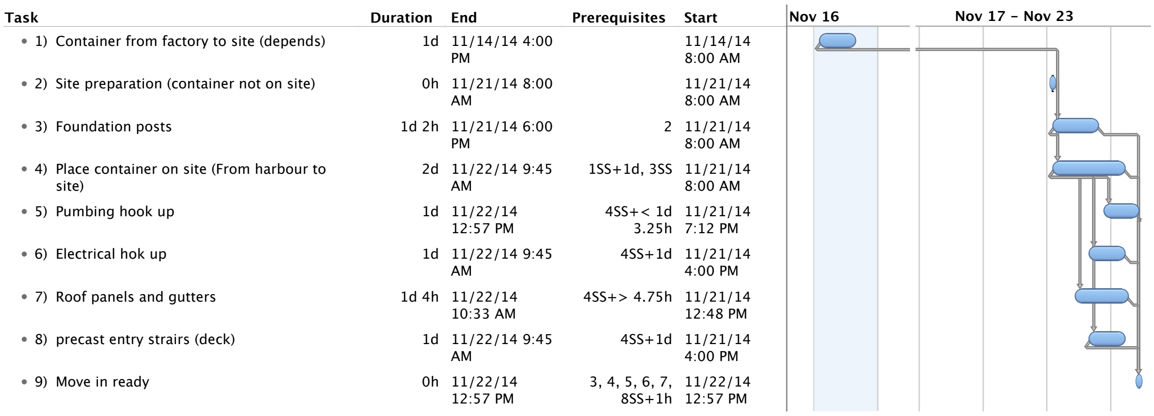
Based on RS Means book , using the RS Means online tools and then adding the information in the software Omniplan for the scheduling and duration of each bigger phase. This first phase can be taking place without the container being ready, so it does not really matter when the dates are, due to the fact this is not the phase that takes longer.

This report suggests that all factory modifications, which are the most time consuming, be conducted prior to the occurrence of a disastrous event and that the site work begin as soon as possible. The site preparation and on site fit out duration of three days would necessitate that the containers are shipped immediately after the site has been chosen. In a best case scenario, the container development would be ready within three days of beginning the site preparation. However, as previously mentioned differing site conditions and locations may affect the time necessary for site preparation.



Task	Duration	End	Prerequisites
1) Select site	0h	11/14/14 8:00 AM	
2) Clearing and grubbing, cut trees	< 2.5h	11/14/14 10:24 AM	1
3) Site gradding (needed or not)	1d 4h	11/15/14 8:09 AM	2
4) Water and waste lines (Pipes, pvc)	< 6.5h	11/14/14 4:48 PM	3SS
5) Gravel base ad paved delivery area	1d	11/14/14 8:24 PM	3SS+2h
6) Drainage	1d	11/15/14 2:09 PM	5
7) Finish site preparations	0h	11/15/14 2:09 PM	6

Figure 30- Site Work Schedule (at the same time the off site is being done)



Task	Duration	End	Prerequisites	Start
1) Container from factory to site (depends)	1d	11/14/14 4:00 PM		11/14/14 8:00 AM
2) Site preparation (container not on site)	0h	11/21/14 8:00 AM		11/21/14 8:00 AM
3) Foundation posts	1d 2h	11/21/14 6:00 PM	2	11/21/14 8:00 AM
4) Place container on site (From harbour to site)	2d	11/22/14 9:45 AM	1SS+1d, 3SS	11/21/14 8:00 AM
5) Pumbing hook up	1d	11/22/14 12:57 PM	4SS+< 1d 3.25h	11/21/14 7:12 PM
6) Electrical hok up	1d	11/22/14 9:45 AM	4SS+1d	11/21/14 4:00 PM
7) Roof panels and gutters	1d 4h	11/22/14 10:33 AM	4SS+> 4.75h	11/21/14 12:48 PM
8) precast entry strairs (deck)	1d	11/22/14 9:45 AM	4SS+1d	11/21/14 4:00 PM
9) Move in ready	0h	11/22/14 12:57 PM	3, 4, 5, 6, 7, 8SS+1h	11/22/14 12:57 PM

Figure 34- On Site Modifications Schedule

Task	Duration	End	Prerequisites
1) 20 ft Container	0h	11/14/14 8:00 AM	
2) Window cut out , torch cutting	5h	11/14/14 1:00 PM	1
3) Door cut out, torch cutting	2h	11/14/14 10:00 AM	1
4) Painting and treatment exterior /interior	2d	11/15/14 5:45 PM	2SS+> 1d
5) Insulation (roof and walls)	7h	11/15/14 4:45 PM	4SS+1d
6) Insulation (floor)	2.25h	11/15/14 8:00 PM	4SS+1d, 5SS+1d
7) Furring strip installation	< 6.5h	11/16/14 5:54 PM	6SS+1d
8) Electrical rough -in another phase (whole house)	7.5h	11/17/14 12:45 PM	7SS+1d
9) Plumbing rough-in (wet areas)	< 6.5h	11/16/14 5:54 PM	6SS+1d
10) Plywood inside - wallboard and celing	1d	11/17/14 8:45 PM	6, 8, 9
11) Flooring	1d	11/17/14 1:15 PM	6SS+1d, 8SS, 9SS
12) Wall/ ceiling paiting and treatment (primer and 2 coats)	2d 3h	11/19/14 11:15 AM	10SS+1d, 11
13) Door instalation	3h	11/18/14 5:30 PM	3SS+1d, 12SS +1d
14) Window installation	1d	11/19/14 8:15 AM	2SS+1d, 12SS +1d
15) Finish item fit out	0h	11/19/14 11:15 AM	14, 13, 12
16) Wall inside partition and door (for bathroom area)	5h	11/19/14 4:15 PM	15
17) Bed and bedframe / table (1-4)	1d	11/19/14 8:15 PM	16SS+1h
18) Dresser / storage (whole house)	2h	11/19/14 2:15 PM	17SS
19) Bench seats (dinning/ free area)	1h	11/19/14 12:15 PM	15
20) Wood cabinets (bathroom/ kitchen)	5h	11/19/14 4:15 PM	15
21) Countertops (kitchen)	6h	11/20/14 11:00 AM	20SS+1d
22) Sink (kitchen) and toilet	< 6.5h	11/20/14 11:24 AM	20SS+1d
23) Oven (kitchen)	4h	11/20/14 5:00 PM	22SS+1d
24) Refrigerator (kitchen)	< 1h	11/20/14 1:54 PM	21SS+1d
25) Water closet and shower (bathroom)	4h	11/19/14 3:15 PM	15
26) Sinks (bathroom)	< 0.25h	11/19/14 11:27 AM	15
27) Shower rods (bathroom)	> 0.25h	11/19/14 3:33 PM	25
28) Shower curtain (bathroom)	> 0h	11/19/14 3:20 PM	25
29) Towel rack (bathroom)	< 0.25h	11/19/14 3:25 PM	25
30) Mirror (bathroom)	> 0h	11/20/14 11:29 AM	22
31) Soap and toilet paper dispenser	0.5h	11/20/14 11:54 AM	15, 22
32) Finish custom items fitout	1d	11/20/14 7:54 PM	30, 31

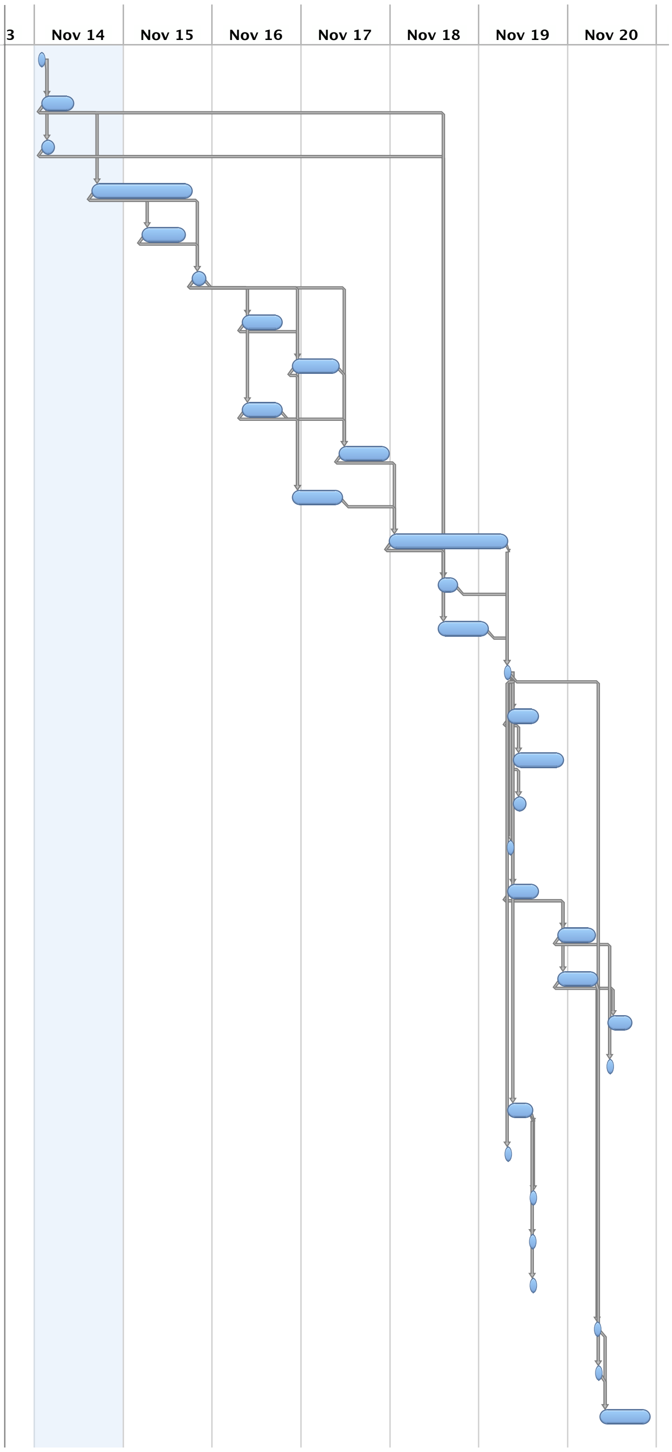


Figure 35- Site Work Schedule (at the same time the off site is being done)