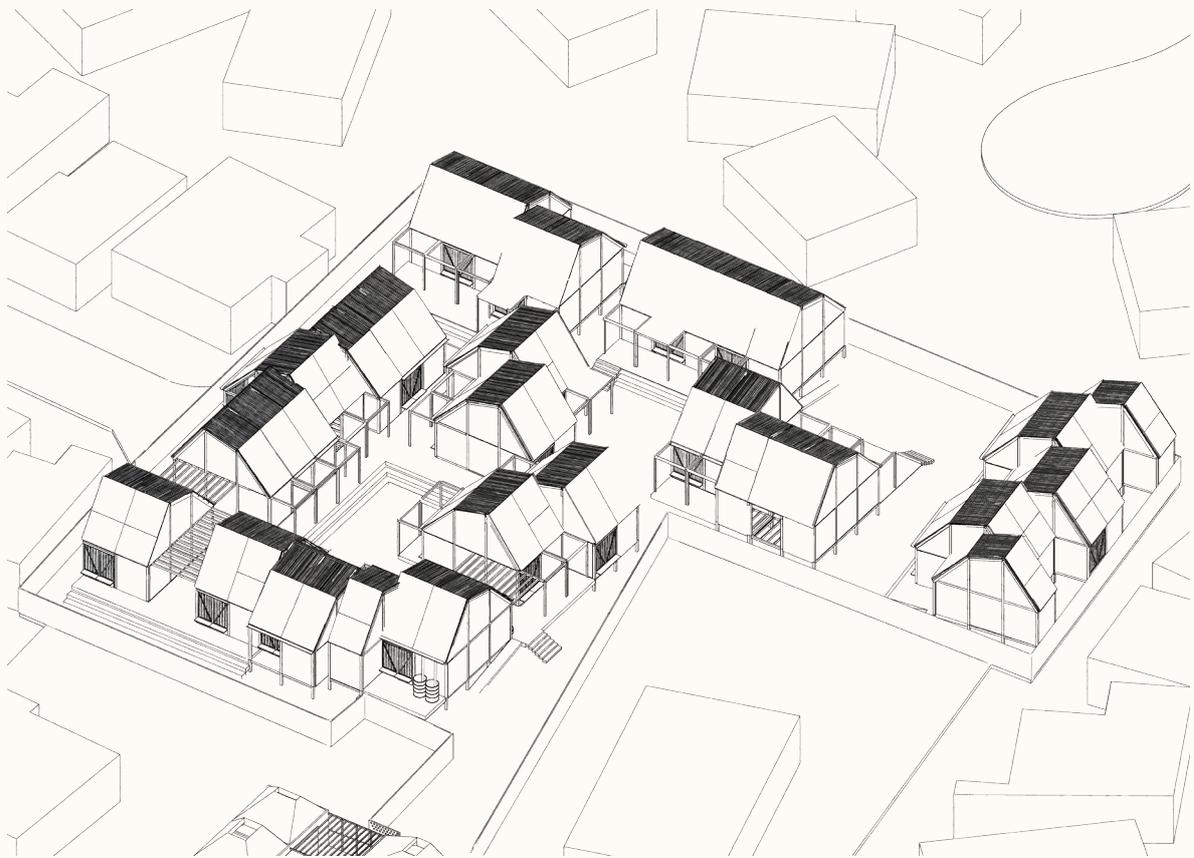


# Shelter from the Storm

Creating Disaster Response architecture in Puerto Rico

Sarah Neill

Shelter from the Storm



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Shelter from the storm

Sarah Neill

Examiner: Johnny Åstrand

Supervisor: Laura Liuke

**Abstract:**

Hurricane Maria hit Puerto Rico on the 20th of September 2017. It was a category four hurricane with winds of up to 175mph. It was the strongest hurricane to hit the island since Hurricane Mitch in 1998 and said to be the worst natural disaster ever to hit the Caribbean Islands. Officials stated that the hurricane killed 64 people; however, the death toll was later revealed to actually have been 2,975 by a study done by researchers at George Washington University (Barclay, 2018).

The hurricane created the largest blackout in US history and the second-largest globally, with 3.4 million citizens without electricity. In a country that already had poor infrastructure before Maria, 80% of the power lines were knocked down.

It took 328 days before power was restored to the whole island. The 44% of the Puerto Rican population living in poverty were hit the hardest. Remote and rural villages became utterly cut off from services for months as roads were destroyed by the storm.

**Acknowledgements:**

I dedicate this project to my grandmother Anna Neill, who sadly passed away while studying my Master's degree. You taught me to appreciate the little things in life, work hard and enjoy. This project is for you!

I would like to extend my greatest thanks to my supervisor Laura Liuke and my examiner Johnny Åstrand for all the guidance and advice throughout the project. I am also very grateful for the whole MArk, SUDES and Human shelter team at LTH for the past two years of teaching. I really feel like I have learned a lot here and the skills are invaluable to me.

I would like to thank my family for supporting me this far and encouraging me to follow my dreams. Also my good friends for their support, especially my friend Catarina who has always been there to listen and to help me.

Finally, I would like to thank my classmates who, even despite Covid19 restrictions, have made this experience so enjoyable and fun.

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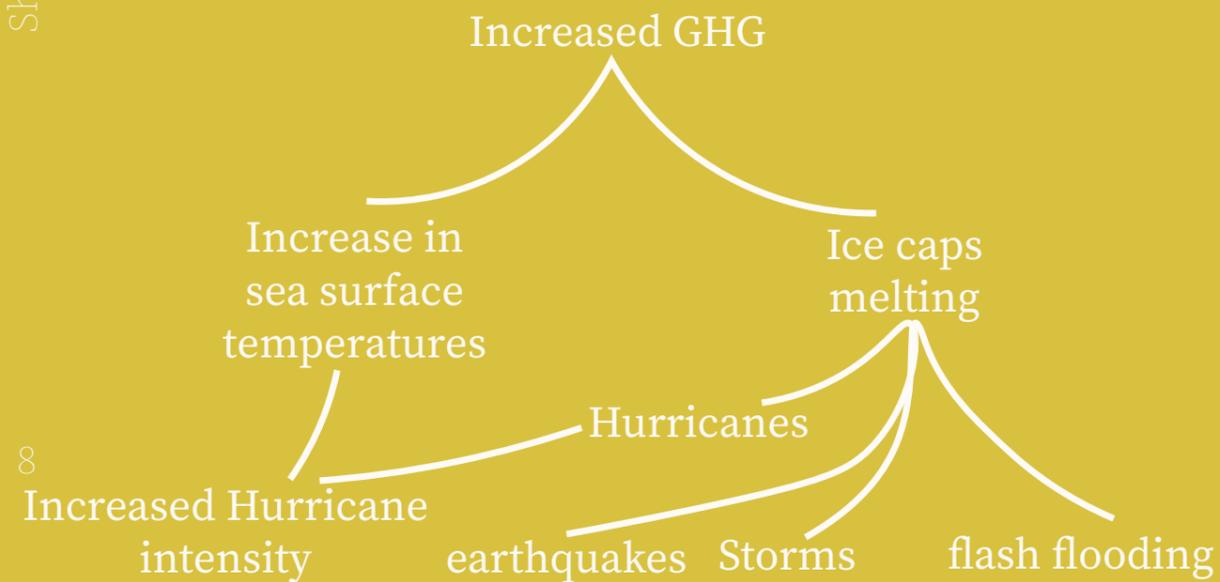
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1 - Research Question

**How can we adapt to become more resilient to future climate change issues with more effective and sustainable responses for vulnerable communities?**

In this project, I aim to explore the future of housing in vulnerable areas that will become more exposed to natural disasters due to climate change. Climate change will affect how we respond and deal with catastrophic events and how we need to become better prepared for the likelihood of such events. I will explore what can be improved with disaster response strategies to avoid catastrophic loss in the future.

I will home in on a specific area that will experience increasing problems to understand the importance of different needs in different areas. Climate change can not be held solely responsible but must be considered in the design process.



## 1 - Project overview

It has become apparent that global warming is going to be a significant problem in the future. The increase in surface temperatures will lead to more frequent droughts and more intense storms. This will put vulnerable people at risk. We need to have a plan of action to recover from these disasters and move forward with as little disruption to livelihoods as possible. A new strategy for disaster housing that works is needed.

There have been many examples of disaster housing solutions before that have been inadequate and unsustainable as they did not meet the users needs. The details of why this is the case will become apart later in my research. These projects highlight the importance of initial planning and future-proofing the disaster response house by making it site-specific.

Puerto Rico frequently experiences both hurricanes and earthquakes, putting it eligible for a project like this. The last devastating hurricane was Hurricane Maria in 2017, which is the most deadly storm to have ever hit the Caribbean islands. It caused 65 deaths. Many of these were indirect deaths in the aftermath of the storm. It is estimated to have caused \$ 90 000 000 of damage.

Statistically, women are most at risk after a natural disaster (S. Momtaz and M. Asaduzzaman, 2019). They are the most vulnerable group in society at this time, and their needs are often overlooked or simply not highlighted when designing disaster housing. A solution focused on women's needs could be especially beneficial in Puerto Rico as the island has a history of gender violence. Statistics currently show that, on average, one woman dies a week due to gender-based violence in Puerto Rico. On Sunday, the 24th of January 2021, Puerto Rico declared a state of emergency on gender-based violence. This displays a want for things to change and improve. An intervention that seeks to alleviate women after disasters and focuses on catering to their needs would be beneficial here. Even if there is not a natural disaster the housing could be used for women trying to escape domestic violence.



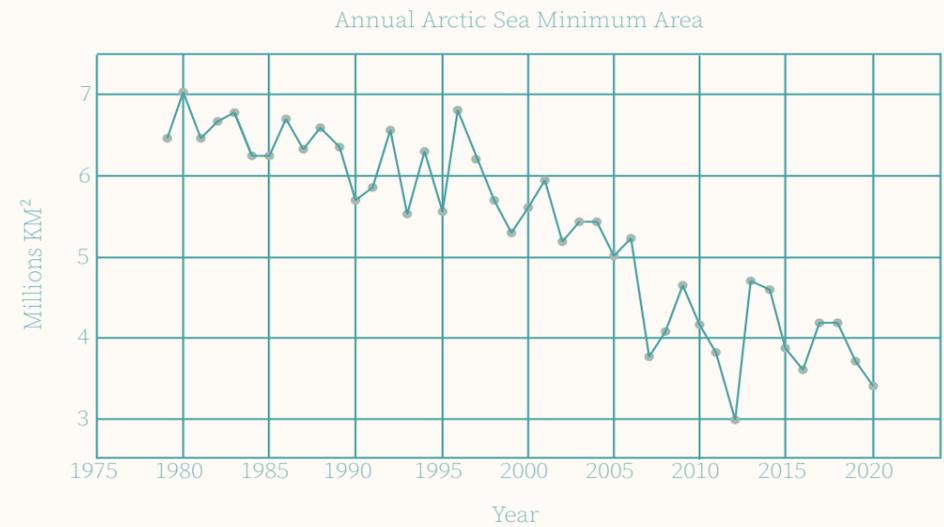
Rocky mountains 1909



2006

1 - The increase in Natural disasters

As our climate heats up, the number of natural disasters are increasing. The ice caps melting is causing more flash flooding, storms, hurricanes and even earthquakes. Hotter summers are increasing cases of drought and forest fires. According to the Intergovernmental Panel on Climate Change (IPCC 2014) (McConnell and Bertolin, 2019), it is likely that we will see an increase in the intensity of hurricanes due to a rise in sea surface temperatures from high greenhouse gas (GHG) concentrations. The sea levels will rise, causing changes in extreme coastal high-water levels and contributing to an upward trend in storm surge patterns. Climate or weather-related disasters have led to 22.5 million people losing their homes since 2008 (Hosseini, Pons and de la Fuente, 2019). The increase in disasters like this, plus the population increase, will put vulnerable people at risk, and there will be a greater need for disaster response housing. Global warming potential and energy demand magnitude is estimated to be between 5.5 and 27 times greater in areas of social vulnerability (McConnell and Bertolin, 2019). On top of this, the building sector accounts for 38% of the total GHG emissions globally (Recycle Rebuild, 2020). The industry uses many mined resources, and products are not recycled or reused at the end of their lifespan.





NASA Statistics on the Arctic sea and glaciers melting

### 1- A need for more sustainable solutions

We need to be more conscious of how we use materials as, every minute a truckload of trash enters the ocean. 90% of this waste comes from developing countries (Recycle Rebuild, 2020). According to the United Nations, there are 1.6 billion people who lack adequate housing, and only 7 percent of the world's population can afford to own a home under current financing structures (Logan, 2019). Natural disasters are causing severe stress issues on individuals whose homes have been damaged or destroyed (Bashawri, Garrity and Moodley, 2014).

### The issue

#### Effects of climate change on women

In many developing countries, the adverse effects of climate change are seen in extreme weather events, resulting in damage to crops, employment, livelihood and national wellbeing.

Two methods can be used to assess the vulnerability of a person, the Disaster Crunch Model (DCM) and the Panel on Climate Changes Livelihood Vulnerability Index (IPCC-LVI). The studies measure financial, social, physical and human aspects. These models have shown that women are most at risk after a disaster as their household assets, health, food security, education, sanitation, water sources and transportation systems are affected (Salim Momtaz and Muhammad Asaduzzaman, 2019). This is because often, womens' rights and social-economic status is not equal to men and more women die in disasters (Neumayer & Plümper, 2007). Discrimination, unequal power relationships, and fewer capabilities and opportunities to adjust play a part in this.

Particularly at risk are pregnant women, lactating mothers and differently-abled as it is difficult for them to move to safety before and after disasters hit (WEDO, 2008). Women are not always adequately warned, can not swim or leave the house alone (UNFCCC,2005).

According to the World Bank (World Bank, 2011b), designing for women can benefit sustainable design in three ways:

1. Whenever women's rights and socio-economic status is equal to men, women are not so disproportionately vulnerable to the effects of natural disasters.
2. Empowering women helps with climate resilience.
3. Low-emission pathways are more effective when designed with a gender-informed approach.

Introduction

## Most affected areas

Scientists believe that global warming will lead to an increase in temperatures at the poles leading to less variation in temperature between the poles and the equator will lead to a decrease in the number of storms but an increase in the intensity of storms still happening (Nasa.gov, 2005). If the CO2 concentrations in the atmosphere doubles, it will triple the number of category five storms (Anderson and Bausch 2006). For every one °C rise in global temperatures, the frequency of hurricane Katrina level magnitude Hurricanes will increase by between two and seven times (Thomas and Lopez, 2015). Some scientists believe that a warmer climate will spawn more hurricanes (Nasa.gov, 2005). However, this is widely debated, so it will not be a determining factor in site choice. One thing that can be seen is that category 4 and 5 hurricanes have almost doubled from 1975 to 2004, with category one decreasing (Thomas and Lopez, 2015).

The temperature rise will also lead to an increase in drought and forest fires and an increased drought flood cycle. So areas that already experience drought, heatwaves, monsoons, typhoons, hurricanes or tropical storms will be most affected in the future.

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## Most affected people

Not everyone is affected in the same way by natural disasters. Physical, behavioural and economic factors will influence how much a person is affected and their capacity to cope and adapt (Thomas and Lopez, 2015). People whose livelihoods, ecosystems, environmental services, resources, infrastructure, and economic, social, and cultural assets are more exposed are therefore more vulnerable. Weaker governments are also more affected by climate change. Often more females die in natural disasters, and children below ten and adults above forty are also in the most vulnerable groups (Birkmann, Fernando and Hettige 2007).

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## Finding a site

In order to evaluate correctly what the effects a catastrophic natural disaster can do to a place, an area that has recently experienced an uncharacteristically intense natural disaster must be chosen.

This led me to choose Puerto Rico as the aftermath of Hurricane Maria can be studied and learned from. The country also lies on the hurricane path and often experiences earthquakes, tsunamis, landslides, subsidence and flooding.

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## Vulnerability

“Social vulnerability refers to the potential negative effects on communities caused by external stresses on human health (www.atsdr.cdc.gov, 2020)”.

By reducing vulnerability, we can decrease human suffering and economic loss.

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2 - What will be researched

**What will be researched?**

In order to gain sufficient background knowledge of the subject, it is vital to research the pros and cons of previous disaster response methods in order to learn what aspects are important and what should be avoided. It is also essential to gain a little background on why housing is needed and how it can be used. What actions can be taken to ensure more sustainable housing in the future?

  
Background

## 2 - Vulnerability of women and the importance of livelihood strengthening

Women have different needs, knowledge and coping strategies towards climate change. Understanding social networks, cultural knowledge, legal rights, land, and physical resources are needed to improve the situation. Promoting self-reliance is the most sustainable option. This can be done through “livelihood strengthening” and “Livelihood diversification”.

“A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base” (Chambers & Conway, 1992).

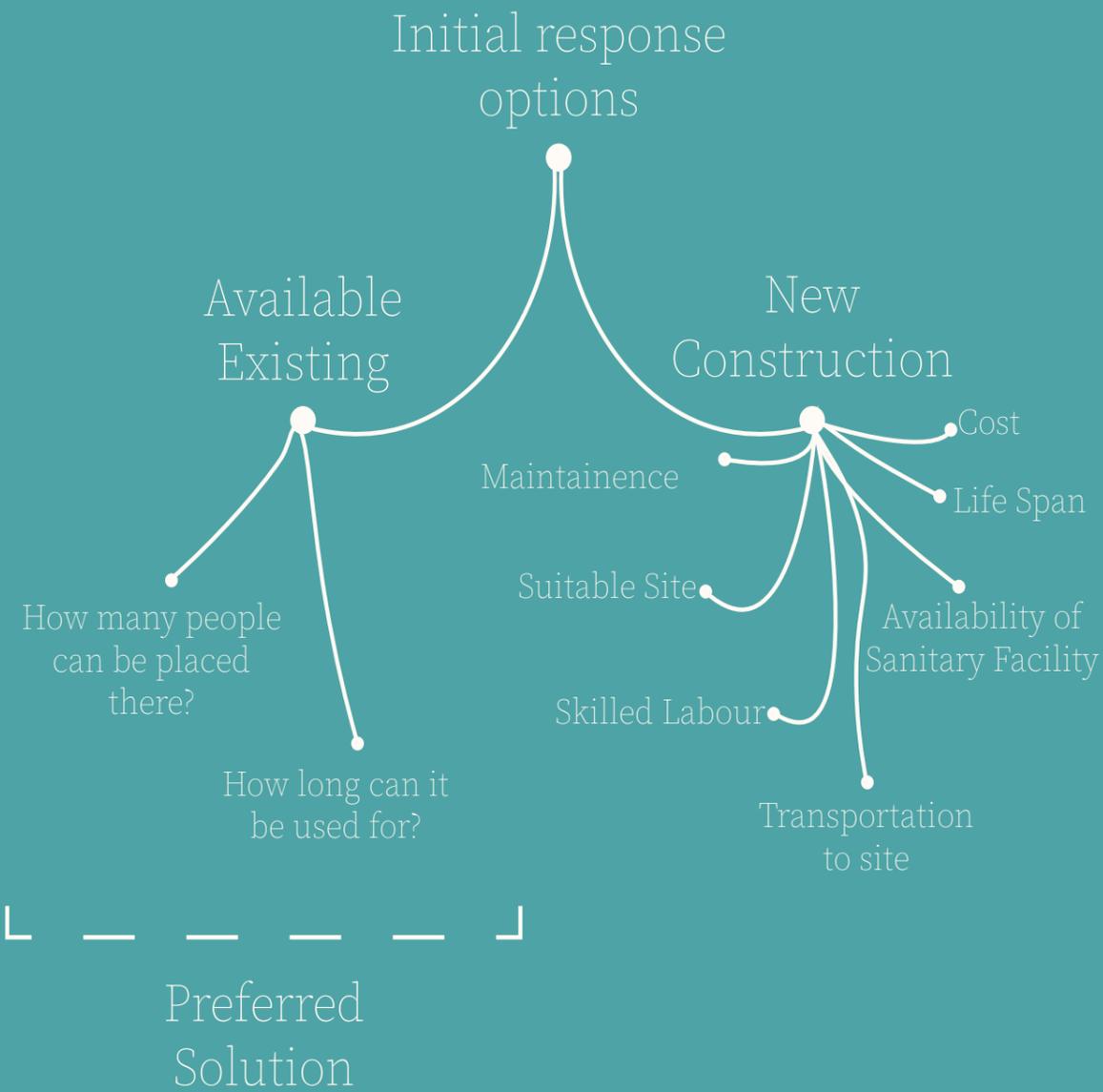
There is a need for Architecture to adapt now, both to reduce the consequences of global warming, help those most in need, and deal with future problems. This project will explore the possibility of improving temporary housing (TH) and making it more socially, environmentally and economically sustainable. How can we improve TH and minimise the negative social, economic and environmental impacts of TH?

### Women’s Vulnerability

#### Assessing Vulnerability



Background



2 - Temporary Housing Background

Rehoming citizens after a disaster usually takes a few years after extreme events (Johnson,2009) TH is the solution during this period. TH is often occupied by low-income families and the elderly (Elliot and Pais 2006; Johnson et al. 2006). If a poor standard of TH is not implemented correctly, it can adversely affect socially, environmentally and economically (Hosseini, Pons and de la Fuente, 2019).

Countries exposed to the greatest risk from natural disasters are not always adequately prepared for the situation. This is due to a lack of strategic planning before an event. Leading to critical decisions being made under pressure in the aftermath of a disaster. The decisions made during this time have a high probability of failing (Lizarralde & Davidson, 2006).

Furthermore, according to the Intergovernmental Panel on Climate Change (IPCC 2014), anticipating, evaluating and communicating disaster risks, probabilities and consequences will become more challenging due to climate change. Hence a resilience program implemented in anticipation of a disaster is critical.

Temporary housing can be divided into two categories:  
 available existing buildings  
 Something that needs to be constructed  
 (Hosseini, Pons and de la Fuente, 2019)

The best solution is usually considered to be the existing buildings, though constructed solutions can be a good solution if they are adequate. Constructed solutions encompass everything from tents to community-built housing.

Tents are easy and quick to erect; however, they do not contain facilities needed for the user to maintain their daily lives. For example, water, electricity and sanitation. With users typically being displaced for around a year, this solution would cause considerable disruption to people’s lives. Thus tents are usually only used during the initial disaster response phase, as the life cycle is not very sustainable.

More permanent solutions such as Self-help housing (SH) take longer to coordinate and implement and are not always appropriate depending on the conditions. For example, rural areas usually have a more skilled workforce and can implement SH housing easier than urban ones. This also highlights the importance of site selection and adaptation. SH housing can work well as a long term solution, but there is a need for something during the in-between phase.



## 2 - Modular Housing Solutions

**Opportunities** Modular construction has economic, social and environmental benefits. The materials used usually are cheaper and easier to transport and construct. Sustainable materials such as wood are often used as they can be easily transported.

Flatpack solutions are flexible, which is a significant bonus in disaster relief design. As there are so many variables, the design must be flexible. Though the dimensions are constrained to what would fit in a truck. Logan, (2019) claims that flat pack projects allow for up to 80% faster delivery of projects with added improved safety and quality control and higher environmental performance at a reduced risk.

Solutions can be constructed quickly, with less site work than traditional construction, and prefabrication allows for little disruption on site.

**Negative Aspects** According to experts, it can be up to three times more expensive to build a temporary house than rebuilding a permanent house (Johnson et al., 2006, Hadafi and Fallahi, 2010). This can be due to the cost of materials and transportation to the site. It is often much cheaper to buy materials in developing countries, as labour costs are a lot less there. Modular construction often calls for specialists to be brought over for the assembly, meaning that local labour is not used. Consequently, community-based construction is often considered better, though there are still many uncertainties regarding community requirements and reactions (Hosseini, Pons and de la Fuente, 2019).

There are also technical issues to consider, like lack of space for storing units and materials and units being illegally occupied after the disaster period has passed (Johnson,2007b)(Bashawri, Garrity and Moodley, 2014). Units that are not designed appropriately, i.e., too small, uncomfortable, and difficult to maintain and upgrade, will perform poorly (Arsalan and Cosgun, 2007; IRP and ISDR, 2011).

It costs a lot more to import skilled labour. Countries prone to a natural disaster often have an abundance of construction labourers, and it would be beneficial to use them to help with the local economy. Manufacture, site works, assembly, and transportation account for 50% of prefabricated design's total cost (Iwansson, 1993).

### Background



2 -Guidelines for Temporary Housing

We can design to keep these costs to a minimum, and using local labour and materials is an easy way of doing this.

Housing that is built to last can then be taken over by local personnel, and therefore TH should strive to be maintained without the aid of foreign helpers.

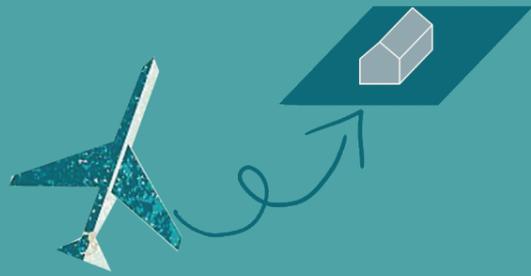
Guidelines for Temporary Housing Opportunities to elevate the local community lie in creating high standard TH. Local resources could be used to accelerate construction time and promote the local economy. The faster the local community can return to their daily lives, the faster the affected area is revived (Arslan and Cosgun, 2008).

Three aspects can determine the type of response needed:

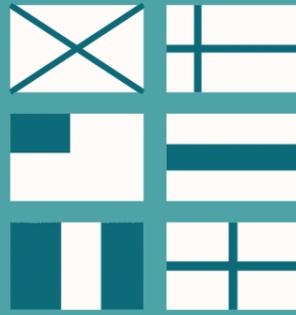
- Local conditions
  - Characteristics of the natural hazard
  - Characteristics of the TH
- (Hosseini et al., 2016)

An outline for how a country should respond can help with decision making in times of crisis, but there will always be many variables. Some standard variables include final decisions regarding financial power, local infrastructure, and existing buildings' availability before a hazard occurs (Hosseini, Pons and de la Fuente, 2019). Electricity, water and gas may not be available after a disaster creating limitations for modular housing and suggesting a need to incorporate a self sufficient design already into the TH (Park, Jeong and Cho, 2019). Features of the displaced people (DP) will also greatly impact the type of TH chosen.

Furthermore, the importance of a sustainable function for the houses and site will be vital in the future in order to lessen the effects on the environment. This can be done through analysing the utilisation period of the houses and minimising cost. Key considerations for the TH are sustainability, minimal fossil fuel consumption, flexible design and long term effects, along with also considering the recycling potential of houses, land and infrastructure. Reuse of TH, debris and waste management are areas that are often neglected or underestimated after a disaster (Arslan and Cosgun, 2008).



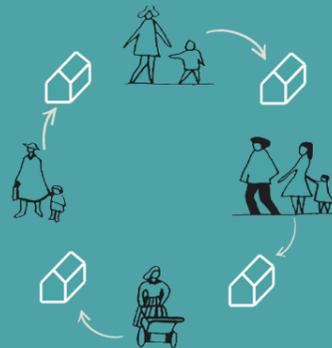
Delivery Time



Cultural Needs



Privacy/ Comfort / Safety



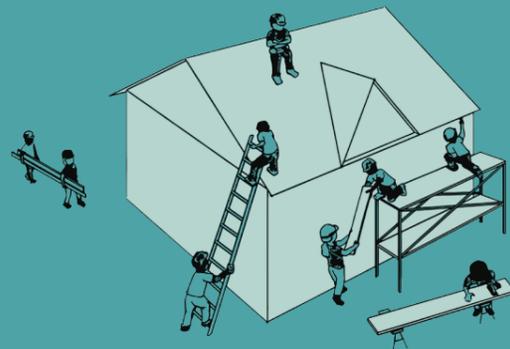
Reusability



Communication



Construction and Transformation



Participation

Design Considerations

2 - Factors needed for Successful Temporary Housing

1 Delivery time

A short delivery time is vital in order to reach those in need in time.

2 DP's culture/ needs

The cultural needs of the DPs will affect the needs of the area and the final design of the house. For example, in the Philippines, it is customary to have a wet/dirty kitchen outside the house, a feature that other cultures may not appreciate as much.

3 Privacy, comfort and safety conditions

Many DP's will have psychological trauma after experiencing a disaster, so it is vital that the users of the space feel that they have a safe, comfortable, private space where they can truly relax. Sometimes locks may also need to be provided on doors and windows.

4 Reusability

A reusable TH will help to improve the sustainability of the project. Also, it can be argued that upgrading temporary shelter is cheaper than moving from phase to phase.

5 DP's participation

DP participation can help strengthen the local economy after a disaster; however, the local skillset needs to be there. Participation can be during the manufacturing and production phase.

6 Suitable communication

Communication helps clarify the process and enables government officials to aid DP's appropriately.

7 Ease of construction and transformation

If the TH is easy to construct, it can be utilised faster in times of need and erected by anyone. A critical factor in achieving this is lightweight materials and fewer pieces. Something that can be transformed means that it can have a longer lifespan and continue to be used even after the DP's are rehomed. More complex designs take longer to construct and sometimes need training to make.



**“Adequate shelter has a significant impact on human survival in the initial stages of a disaster.”**

- Sphere Project, 2018

## 2 - Quality Control of a Temporary House

The Sphere project states that “adequate shelter has a significant impact on human survival in the initial stages of a disaster.” Adequate shelter is more than just a roof; it covers clothing, blankets, mattresses, stoves, fuel, and access to services such as water and sanitation.

### Needs

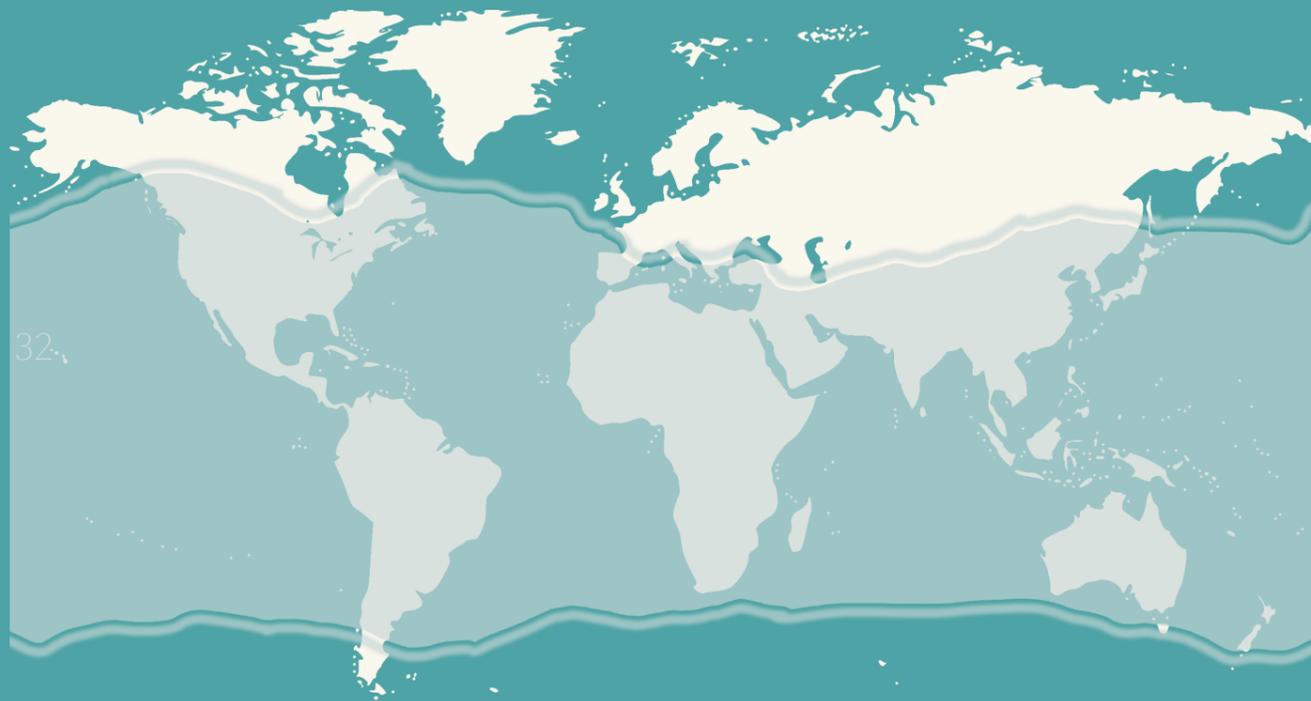
Sanitation facilities  
Local amenities  
Flexible for larger families  
Accessibility - elderly  
Accessibility - roads  
Site-specific - climate control - cultural adaptations  
Basic needs met - safety, comfort.

### Infrastructure Planning

When designing aid from abroad, it can be easy to ignore the recipient country’s national construction capacity (Iwansson, 1993). What local materials and machinery do they have access to, and is there a skilled workforce at disposal, even what are the infrastructure needs. For example, poor roads may make the construction process harder as it becomes difficult to transport materials to the site. Often prefabricated housing is built far from the site without consideration for the local context (Iwansson, 1993). After a storm, power cuts and disruption to the water supply are also highly likely. This must be considered as it is a necessity for the user.

### Comfort levels

A prefabricated home designed without consideration for the climate will affect comfort levels for the user. Certain site-specific requirements must be considered, such as ventilation and cooling. In this way, the orientation and positioning of windows must be considered and adapted to suit the site. Spaces for air conditioning must be considered as even if the house has been designed not to need it, the user will probably install it if possible to improve comfort levels. Ceiling height is also important for this reason that ceiling fans may be installed (Iwansson, 1993).



Termite Map

## 2 - Design Considerations

In a hot-humid climate, certain aspects that are more prevalent are mould, rot, humidity, termites and solar radiation (Larsson, 1989). These aspects can help to guide the design process. Projects should be designed to be low maintenance as often maintenance is neglected as locals do not know how to solve problems from construction techniques not commonly used in the recipient country, like moisture from air conditioners damaging multi-layer insulation. Mould can be reduced by ventilation.

### Climatic considerations

- Heat
- Rain
- Humidity
- Wind
- Termites
- Storms
- Earthquakes

### User considerations

- Comfort levels
- Social patterns
- Sanitation
- Cooking

Decision-makers must consider the TH's long-term effects so as not to hinder later reconstruction (Mossberg, Astrand and Jere, 1994).

### Termite design considerations

The diagram to the left shows where termites can be found. There are around 2000 species of termites found around the tropics. In Puerto Rico, Dampwood, Drywood, and subterranean termites can be found. It can take years before termites attack, but when they do, it results in rapid destruction. (Larsson, 1989)

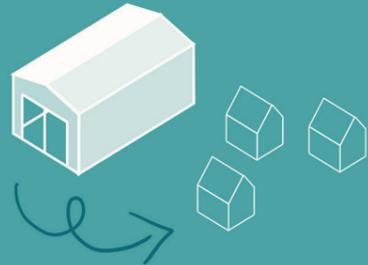
## 2 - Life Cycle Analysis: Why is it important?

Life cycle analysis is important for both environmental and budget reasons. Research conducted in Turkey (Arslan and Cosgun, 2008) revealed that temporary houses had a ratio of 10-15% of the entire reconstruction cost after a disaster. That is a large chunk of the budget for a short term solution.

By looking at every stage of the building process, we can find ways to cut costs and be more sustainable. More efficient ways of transport can be used. Building materials that are easy to process and transport can be used to cut costs. Designs can be made so that sizes allow for easy transportation and can be easily adapted to extend the life span of the building. They can be designed to have another use at the end of life.

With such a need for temporary housing now and such large amounts of GHG emissions coming from the built environment, we must analyse the sustainability of TH regarding supply and environmental impact (McConnell and Bertolin, 2019).

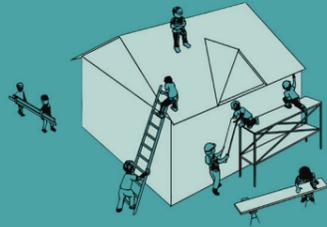
Using sustainable building techniques, energy consumption and resources can be minimised in planning, construction, use, renovation and demolition (Arslan and Cosgun, 2008). Furthermore, it is beneficial to design a well functioning unit from the beginning as the total material impact for modifications over a unit's lifespan is more than twice the erection costs (McConnell and Bertolin, 2019).



Set up and Storage

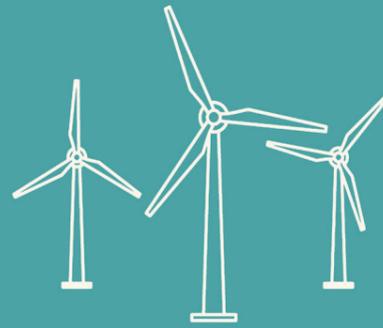


Materials and Workforce

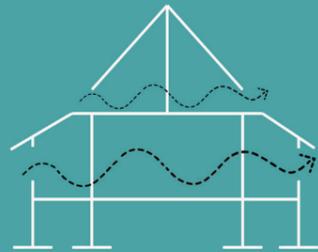


Participation

Construction and Adaptability



Climate Positive Design



Climatic Design



Life Cycle Analysis

Important factors for the Temporary house

2 - Life Cycle Analysis. How can it be used?

The TH could be continued to be used as a solution for housing after a disaster, but considerations must be made for what will happen to the unit after use. This must be accounted for in the design phase. In order to create a more sustainable TH, we must consider the following:

Set up and storage

It is important that the units can be stored locally in the region that they will be used in so that they can be deployed and used quickly during the time of need. This highlights the case for good initial planning.

Materials and workforce

Using local workers can both lower costs and help to get the economy started again. The ease of transportation and construction of materials also plays an important role.

Construction and adaptability

To help as many people as possible, a low budget must be kept. This can be achieved by minimising construction costs and lowering the energy demand during this phase (Arslan and Cosgun, 2008). The design must be adaptable to meet future needs. Family constellations will change, and the unit must be prepared for this.

Climate positive design

Sustainable practices that will actually give back to the environment should be considered.

Climatic design

Appropriate changes in the design must be made to suit the host country's climate. The unit should be designed for the climate that it will be placed in, so a unit in a warm, tropical climate should consider high ceilings and verandas, while colder climates should take care to reduce air gaps (Bashawri, Garrity and Moodley, 2014).

Assessment at every stage

The environmental impact should be assessed at every stage of the design. Materials that are "risk-free" (Arslan and Cosgun, 2008) or recyclable should be preferred, and consideration should be given both to how materials will be sourced and transported and what will happen to the unit at the end of its life.

Background

## 2 - Temporary Housing Critique

Throughout this section we have seen that many designs are often proposed as a temporary solution but always become permanent. If housing is designed in a temporary way then this is not always suitable for the inevitable long term usage. The results can be dangerous. Improper sanitation systems and overcrowding can lead to disease and incorrect architecture for the environment can cause dangerous cases of mould. If the structures happen to be hit by another kind of disaster, if they are designed in a temporary way, then they are unsafe and incapable of surviving the force.

Therefore I feel that it is a better solution to offer more long term housing. The design will be quick and easy to erect, but have permanent usage in consideration. It should be designed in a robust way, to survive future catastrophes and be adaptable for different needs and family sizes.

One problem with this is that it will cost more. A homeowner scheme can be set up which allows users to gradually pay off the design strategy. Making it more financially sustainable in the long run.

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3 - Why the case studies were chosen

**Why the case studies were chosen**

Previous disasters located in the same climatic region as the site have been chosen as similar learnings can be taken from them. Puerto Rico is also exposed to both earthquakes and hurricanes. It is a Caribbean island like Haiti, and it is a US commonwealth, making the response strategy after Hurricane Katrina relevant. Other proposals for temporary shelter have also been looked at to find inspiration and evaluate what would work well in the given context. Some examples of women's shelters have been studied to understand how to design for women, and community shelters have also been examined as the previous research has made it apparent that building a community within the shelter will help it to be successful for a longer period of time.

## Women's shelters

**1. Hollmén Reuter Sandman Architects**  
**Rufisque Senegal**  
**Women's Centre**

**Specification:**  
 NGO project through 'Tekniska Foreningen i Finland'  
 Completed over the period from 1996-2001  
 \$100,600 for 700 square meters  
 Cement and steel was donated from local factories, and local labour was used (predominantly the sons of the women using the centre)

**Reason for choice:**  
 The emphasis on designing for women and elevating their social security is something to learn from here. A good sense of community is created by the central courtyard and by how the boundary between public and private is clear yet flexible.

**Description:**  
 The project aims to create social security for women by providing a place to sell handicrafts. Recycled metal was used for concrete walls, roof, roof structure, and shutters. Recycled wheel hubs were used for ventilation and glass bottles as windows.

**2. Hollmén Reuter Sandman Architects**  
**Moshi Urban, Tanzania**  
**Eco-friendly shelter house**

**Specification:**  
 Completed in 2015  
 423 meters squares  
 Use of participatory planning and local labour.

**Reason for choice:**  
 In this area, violence against women is both socially and culturally. That is why this shelter house was created. The project respects local culture and spatial hierarchy.

**Description:**  
 Local materials and renewable energy were used, such as banana leaves and bamboo for ceilings and doors and low tech solar heaters for heating water. The shelter is located in the inner half of the plot so that the residents feel safe and protected. Covered outdoor spaces give room for outdoor seminars.

**3. Hollmén Reuter Sandman Architects**  
**Iringa region, Tanzania**  
**Secondary school girls hostel**

**Specification:**  
 First dormitory completed in 2018

**Reason for choice:**  
 An excellent example of how to design for the needs of women and create a community.

**Description:**  
 Education of women is one of the most effective ways to reduce poverty and develop community. The project is a girls hostel for secondary school girls. The project has a focus on sustainable, environmental and culturally appropriate architecture.

## 3 - Womens Shelters



## Community buildings

### 1. SchilderScholte Rajarhat, Bangladesh Community centre

Specification:  
910 meters squared  
Completed in 2014

Reason for choice:  
All materials are taken from a 15-mile radius of the site. Zero electricity or fossil fuels were used during the process. A high roof reduces heat build-up. Cross ventilation is used, and a pond added.

Description:  
Concept sharing was the process. Locally available materials were used, and the local weather played a significant role in the design. Local bamboo and mango wood were used along with reused steel, local mortar and recycled plastic.

### 2. Estudio flume Brazil Community centre renovation

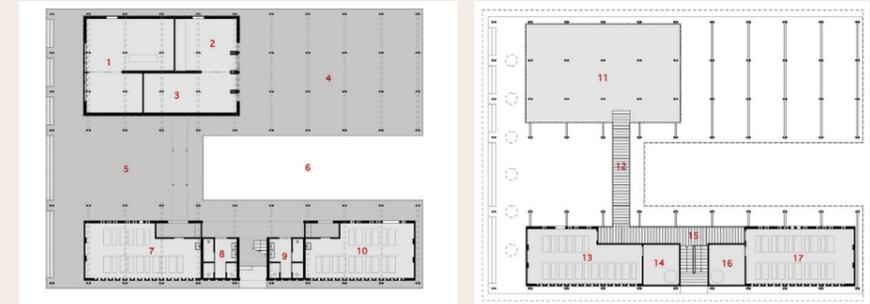
Specification:  
106 meters squared  
Completed in 2018

Reason for choice:  
The design is located in a similar context to the site in Puerto Rico. Traditional construction techniques and materials were used to create a community space.

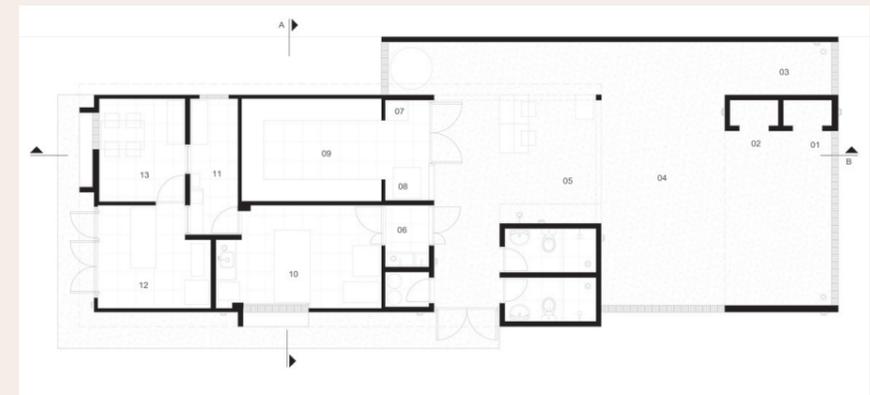
Description:  
A refurbishment and extension of a local house into a new headquarters for the coconut producers cooperative.

## 3 - Community Buildings

1.



2.



## Temporary housing

### 1. Othalo Temporary housing

Specification:  
Temporary housing made entirely from recycled plastic.

Reason for choice:  
Easy to set up and transport. It can be used anywhere. The design is flexible and can be adapted in many ways.

Description:  
Targeted at the developing world, OTHALO can create affordable housing, refugee shelters, camps, and temperature-controlled units to store food and medicine.

### 2. Barberio Colella ARC Nepal Temporary housing

Specification:  
Post-earthquake housing in Nepal

Reason for choice:  
An example of housing can be made simply without the use of many materials.

Description:  
A house that can be built quickly, is lightweight, durable, compact and economical. The shelter is designed using only bamboo, white juta, recycled wool and a waterproof membrane. Solar panels can be easily installed on the roof at a later stage.

### 3. Various architects, make it right housing New Orleans Housing

Specification:  
Completed in 2005

Reason for choice:  
An example of what not to do as many of the houses are now set to be torn down as they have been deemed unsafe.

Description:  
Many starchitects came together to produce new, innovative housing ideas to help rebuild housing after hurricane Katrina. The aim was to use the most sustainable materials available.

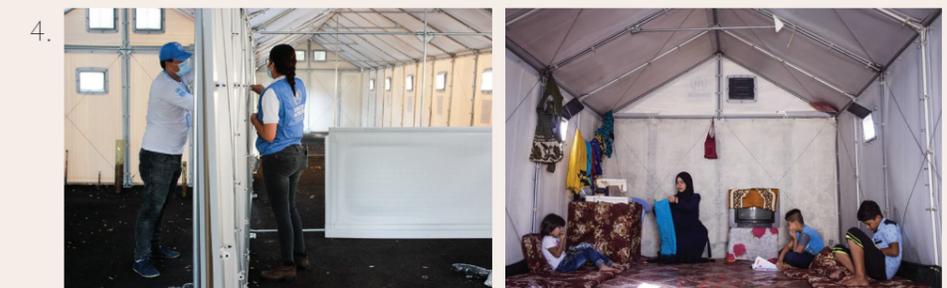
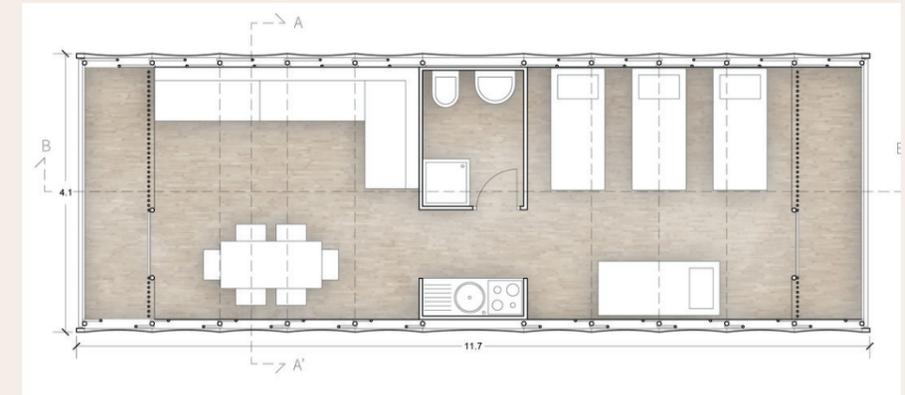
### 4. IKEA Better shelter Temporary housing

Specification:  
Over 60 000 shelters in 70 countries

Reason for choice:  
Simple flatpack design which is easy to install although they do not use local materials.

Description:  
The shelter focuses on being cost-effective and easy to construct.

## 3 - Temporary Housing



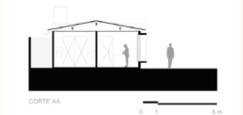
## Case Studies

Description	Building Type	Special Features	Positives	Negatives	Summary
<p>Organisation: UKUMBI</p> <p>Architect: Hollmén Reuter Sandman architects</p> <p>Year: 1995-2001</p>	 <p>Women's Shelter Location: Refusique, Senegal</p>	 <p>Wall provides security whilst not feeling enclosing and allowing for views.</p>	 <p>Communal courtyard external seating School Flexible</p>	 <p>Bright colour too obvious</p>	<p>The flexibility of this design and the communal aspect could be applied to my project.</p>

<p>Organisation: MEI, Rajarhat, Bangladesh</p> <p>Architect: SchilderScholte</p> <p>Year: 2014</p>	 <p>Community centre, RAJARHAT, BANGLADESH</p>	 <p>Children's play area</p>	 <p>Play area. School Orientation Use of electricity</p>	 <p>Implementation of materials</p>	<p>Zero electricity or fossil fuels used during construction, Materials used are inferior in this region and not sustainable.</p>
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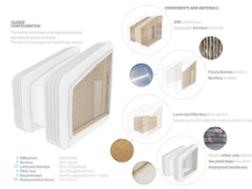
<p>Organisation: KWIECO</p> <p>Architects: Hollmén Reuter Sandman Architects</p> <p>Year: 2015</p>	 <p>Eco-friendly Shelter House Location: Moshi Urban, Tanzania</p>	 <p>Recycled materials Central courtyard Outdoor seating</p>	 <p>A safe and protected communal space sheltered from the heat</p>	 <p>Many different communal hubs allow for different types of activities.</p>	
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<p>Organisation: Lyra in Africa</p> <p>Architects: Hollmén Reuter Sandman Architects</p> <p>Year: 2017-19</p>	 <p>Secondary school girls hostel Location: Iringa region, Tanzania</p>	 <p>Communal corridor</p>	<p>Environmentally and culturally appropriate design</p> <p>community involved design</p>	<p>The design looks clean and easy to maintain.</p>	
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<p>Project: Castanhas de Caju Extension</p> <p>Architects: Estudio Flume</p> <p>Year: 2018</p>	 <p>Community centre Renovation Location: Brazil</p>	 <p>Integrated seating outdoor spaces local context</p>	 <p>Well connected outdoor and indoor spaces Biodigester septic tank and banana cycle for grey water</p>	 <p>This project is a good reference as the climate and culture is similar to that of my site.</p>	
--	---	--	---	---	--

Description	Building Type	Special Features	Positives	Negatives	Summary
<p>Architect: OTHALO</p> <p>year: 2019</p>	<p>Temporary housing</p>	<p>Made from Recycled plastic</p> 	<p>Low carbon footprint</p>	<p>Flamable Eaten by termites</p> 	<p>The flat pack design could be beneficial for my project</p>

<p>Architects: Hope on Water Sevince Bayrak, Oral Göktaş</p> <p>Year: 2019</p>	<p>Temporary Housing</p> <p>Location: Turkey</p>	<p>Responds to future disasters</p> 		<p>Not communal Expensive</p>	<p>This project is very site specific and I am not sure that people would want to change their lifestyle so radically for this.</p>
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<p>Architects: Barberio Colella ARC</p> <p>Year: 2015</p>	<p>Rapid response temporary housing</p> <p>Location: Nepal</p>	<p>Expandable</p> 	<p>Quickly assembled Low cost Adaptable</p>	<p>Designed far from the site Not adapted for monsoon season.</p>	<p>The adaptability of the design is impressive and how fast it can be erected but I fear that it does not respond to user needs.</p>
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<p>Organisation: Make it right project</p> <p>Architect: Various</p> <p>Year: 2007</p>	<p>Disaster response housing</p> <p>Location: New Orleans</p> 	<p>All innovative designs by famous architects</p> 		<p>Material failures problems with maintenance</p>	<p>This is a good example of why maintenance is important and simpler designs are better.</p>
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<p>Organisation: IKEA</p> <p>Architect: Better shelter</p>	<p>Temporary housing</p> 	<p>Quick to assemble</p>	<p>Not site specific designed far from site</p>	<p>The one size fits all model can be problematic when it comes to climate and user.</p>	
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Material Description and Potential

1 - Karuum  
Rattan is injected with various thickening agents and can then be used as veneers and boards. The renewable material is very light-weight and scratch resistant.

2 - Loam Construction Panel  
Can be used instead of plasterboard. Good thermal insulation and regulates moisture, protecting from fungi and air pollutants. Loam is not flammable. The panels use little energy to create and can be composed/recycled.

3 - Loam Textured Paint  
Loam is a mixture of sand, soil and clay. There is a lot of clay in Puerto Rico. It can be added to paint to give it texture and help to reduce noise. The material is renewable.

4 - Loam and hemp panels  
Hemp can be grown in Puerto Rico. made from Loam, clay, hemp and mineral binders. they can be easily cut and skrewed into place. This is a renewable material.

5 - Resysta  
Resysta is made from 60% rice husk, 22% salt and 18% mineral oil. It is very resistant to sun, rain, and salt water. It does not fluctuate in size due to moisture and could utilise the rice industry in Puerto Rico.

6 - Breathaboard  
Passively regulates moisture in the air through moisture buffering capillaries. Used like plasterboard only lighter. Breathaboard is biodegradable and nontoxic.

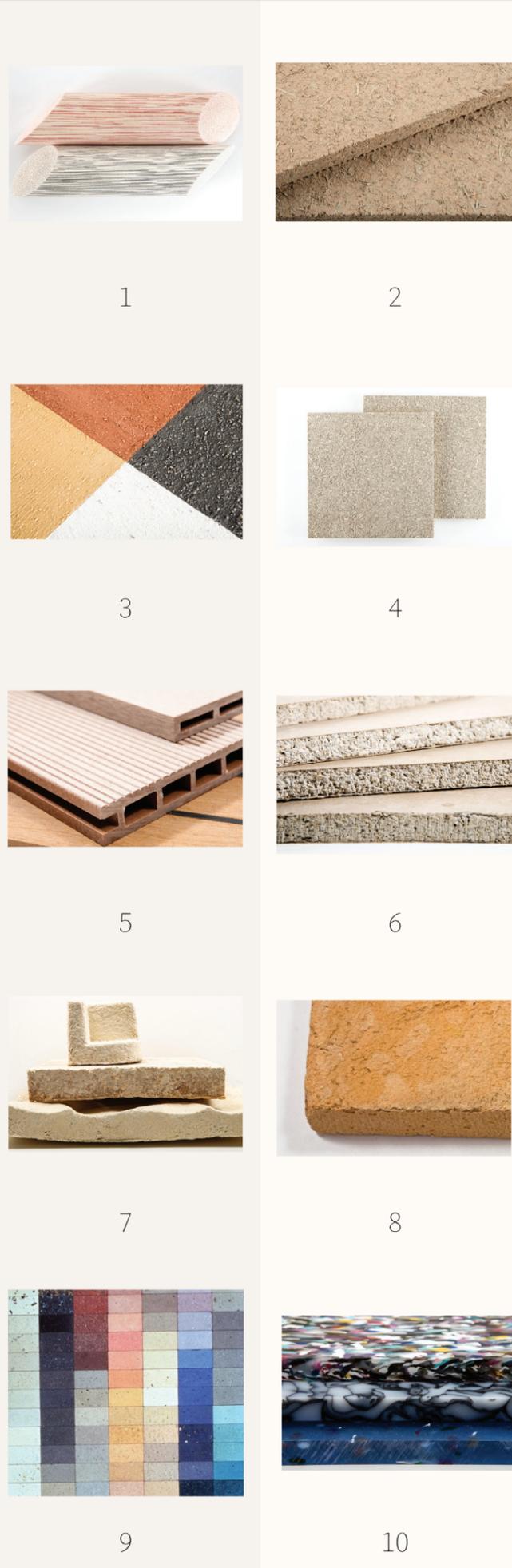
7 - Mycelium  
Made from mushroom roots, mycelium can act as a glue to bind biomass together. Food waste, mycelium and water are put into a mould and harden to be structurally stable after one week. It can be used as fertiliser at the end of it's cycle.

8 - Sandcrete  
Alternative to concrete made of desert sand with a carbon footprint of less than half of concrete. Can be reused and remoulded. Suitable for temporary constructions.

9. Syndecrete  
A sustainable, green, natural cement based product. half the weight and twice the compressive strength of concrete. It is fire resistant but not renewable.

10. Recycled Plastic  
Can be easily made with little machinery on site. However it is suseptable to termites and not renewable.

Materials



Materials



Material Description and Potential

Guanacaste - 11  
After hurricane Maria hundreds of thousands of trees were downed. Some species could be useful. Such as the hard wood Guanacaste, which is not suseptible to termites.

Mahogany - 12  
Mahogany is another tree species that was downed and that is not as suseptible to termites and could be used again in the construction industry.

Pine - 13  
Pine was also downed and is commonly used in the building industry. It is eaten by termites though and would have to be treated. Wood is very sustainable though.

Recycled Plastic Bricks - 14  
created by Precious Plastics, these blocks can be easily made and assembled by anyone.

Recycled Plastic Beams - 15  
Another product created by precious plastics. the beams can be made by anyone using one simple machine which could be installed in the host country.

Photovoltaic Panels - 16  
After a disaster electricy is usually not working. PV panels are a good solution to provide electricity after a storm. They are simple to install and run.

Textiles - 17  
Puerto Rico exports textiles. They could be used in the design to help get the industry running again after a storm.

Hemp concrete - 18  
A mixture of hemp fibers, natural glue and water. Very strong with great acoustic and insulation properties. It removes more carbon dioxide from the air than it adds.

Upcycled bricks - 19  
Made from at least 60% waste. suitable for external and internal use. Waste from demolished building is grinded and crushed to make new bricks.

Corrugated Sheet Metal - 20  
Commonly used as roofing in these situations. Corrugated metal sheets are a cheap solution which can easily be replaced and reflect heat.

## Materials - Processing



Guanacaste

Process:  
Salvaged in the aftermath of hurricane Maria.

Application:  
Can be used for furniture and framework if needed.



Recycled Plastic

Process:  
Recycled PP and HDPE are collected and processed.

Application  
Can be used for guttering, water collection and window panes.



Resysta

Process:  
A mixture of rice husk, salt and mineral oil is processed through an extrusion machine. The product is water moisture and UV-resistant.

Application  
Can be used as an alternative to wood for flooring and structural and facade design.

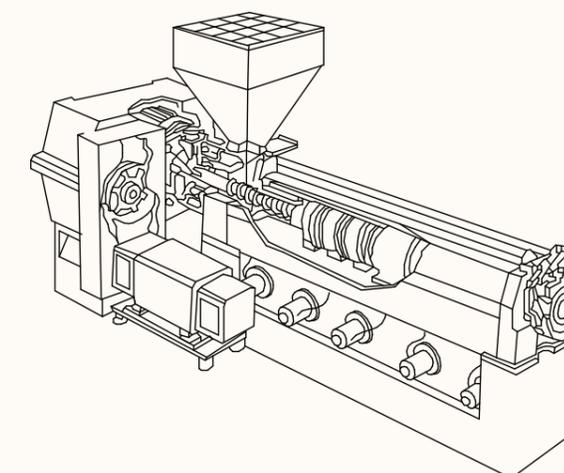
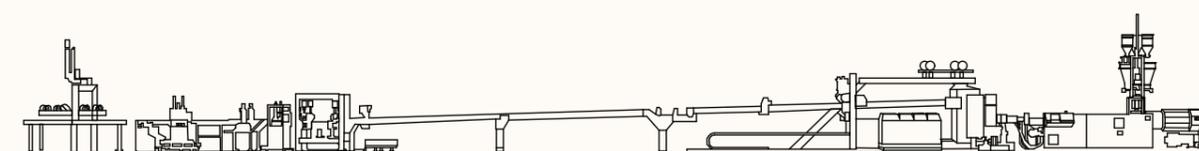
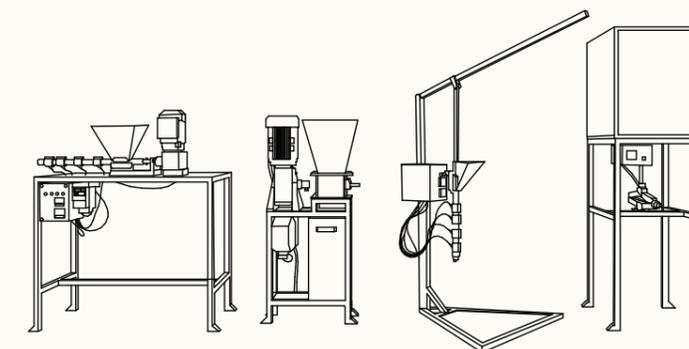
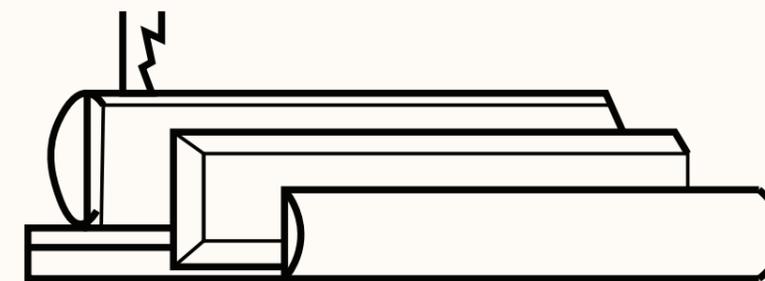


Karuun

Karuun  
Process  
Rattan is injected with a thickening agent to create panelling. The rattan is a climbing tree that grows faster than other woods and needs a biodiverse culture to survive.

Application  
Can be used for interior paneling and flooring.

## Materials - Processing



Solar panels

Process  
Imported from factory ahead of time

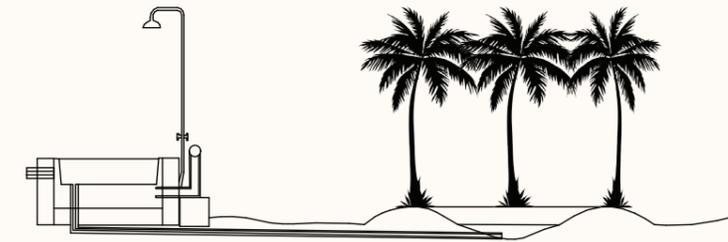
Application  
As hurricane Maria caused the largest blackout in US history it is very important that solar panels are available from the beginning of the design process.



Banana filtration

Process  
A natural way greywater can be treated as a close loop permaculture. Kitchen waste is thrown in a compost pit. The carbon from the compost treats the greywater. The pit is then surrounded by banana trees which absorb the nutrients in the soil from the water and compost.

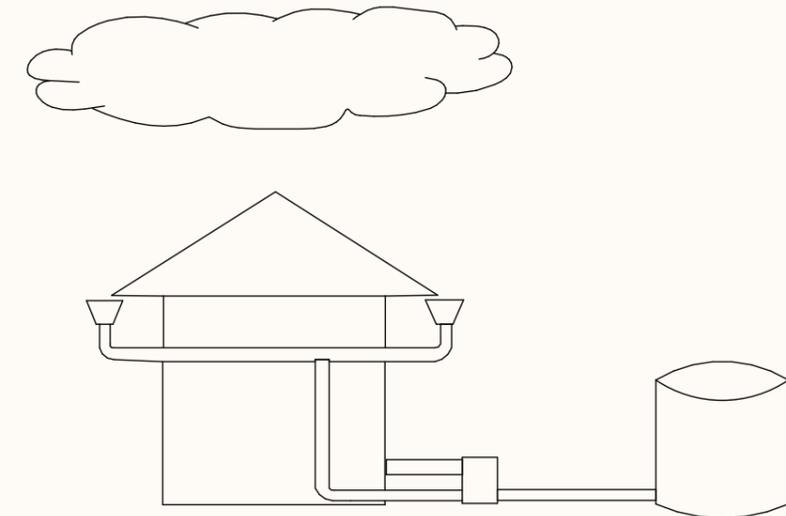
Application  
Treating greywater



Water collection

Process  
Collected in barrels incase of an emergency

Application  
Water supplies are often disrupted after a natural disaster and Puerto Rico often experiences drought. The last severe drought was in July 2020, which left 140 000 people without access to running water. Any water that can be collected and treated is helpful. Introducing bioswales, infiltration water trenches and aquadams can also be a way to help mitigate flooding. Encouraging other residents to implement these strategies to their homes would also help to lessen the impact of future disasters.





Images after Hurricane Katrina

## 3 - Hurricane Katrina, New Orleans

## Background

New Orleans is greatly exposed to hurricanes and extreme weather and faces certain characteristics that put it at greater risk. These being population growth, the area around the wetlands being mismanaged environmentally and a society rooted in racial and socio-economic divisions (Elliot and Pais 2006; Gotham and Campanella 2011, 2013; IPCC 2014).

When hurricane Katrina struck the Gulf coast, it proved to be one of the costliest and most deadly hurricanes ever to hit the US (Blake et al. 2011)(McConnell and Bertolin, 2019). Nearly 1 million people were displaced in Louisiana state, and over half a million were in New Orleans (Elliot and Pais 2006). In cases where families were predicted to be displaced for a period of longer than six months, TH was provided. However, other factors were later found to also contribute to vulnerability, such as level of dependency, being elderly, renting, having access to a vehicle and access to other people with assets (McConnell and Bertolin, 2019).

## Make it Right Housing

## Background

Hurricane Katrina completely submerged 80% of New Orleans. One of the areas most affected was the working class, predominantly African-American area called Lower Ninth ward. Two years after Hurricane Katrina hit New Orleans, actor Brad Pitt visited this area and was appalled by how little had been done to rebuild homes (Menza, 2019). With his power and wealth, he was able to set up the organisation “Make it right”. With the help of 21 world-renowned Architects, homeowners and community organisers, the project aimed to create environmentally friendly, affordable and attractive housing.

## Flaws

The project incorporated very experimental materials in order to keep everything cost-effective. This later backfired when the materials were found to be “defective”, and the housing had structural issues, electrical and plumbing issues and insufficient ventilation (Menza, 2019). Claiborne, a 67-year-old resident from a three-bedroom house whose husband had a stroke a few years ago, spoke of mould, safety, and electrical problems, “Our porch, the wood is rotten. We have a hole in the porch. The railing came apart. Right now we have problems with the light switches. It is just coming apart,” (Menza, 2019).



Global warming potential (kiloton CO<sub>2</sub>-eq)

Map of New Orleans

3 - Learnings - Make it Right foundation:

In interviews years later, Brad Pitt admitted that he was “incredibly naive” before the project. The designers thought of very extravagant solutions and lost sight of reality in the process. There is a reason why people build in a certain way in a certain place.

Overall Summary

Failures

There was a delay in providing temporary housing as authorities had to wait until after the area was pumped dry (Chandler, 2007)(Hosseini, Pons and de la Fuente, 2019). According to the US Federal Emergency Management Agency (FEMA), displacement periods were based solely on the Structural damage that occurred according to the US Federal Emergency Management Agency (FEMA). Low economy and high social vulnerability were proven to be factors that hindered recovery.

Learnings

Try to find sites with a lower risk of flooding. Highlight danger zones, i.e. population growth and environmental mismanagement, socio-economic or racial divisions. Expect displacement periods to be longer than the time taken to renovate housing.



Images after the Earthquake

### 3 - Earthquake in Haiti 2010

#### Background

Haiti has a warm, humid tropical climate with temperature lows of  $-25^{\circ}\text{C}$  in winter and highs of  $30^{\circ}\text{C}$  in Summer. This large temperature variation is due to such high elevation, with Kenscoff (1,430 m above sea level) at an average of  $16^{\circ}\text{C}$  and Port-au-Prince at  $26^{\circ}\text{C}$ .

Common dangers faced on the island are droughts, crop failure, famine and hurricanes on the southern peninsula, which also brings landslides and flooding.

The plains are densely populated, and 82% of the population is under 44 years old. Two-thirds of the working population work in agriculture, but there is a strong construction industry and a demand for housing.

After a series of Hurricanes in 2008, thousands of Haitians were displaced, and nearly 800 died. The country had to rely on international aid to recover, but a lack of governmental action inhibited this.

In January 2012, an earthquake hit Port-au-Prince. The death toll totalled nearly 316 000, and a further one million were left homeless. The earthquake affected one-third of the country's total population. Homes, schools, hospitals and almost all public buildings were destroyed. As a result, the government shut down during the early stages of the aftermath. (Ferguson, Girault and Macleod, 2019)

#### Failures

In mid-October of 2010, around 1.3 million people were still living in TH with basic sanitary facilities when an outbreak of cholera hit and killed thousands within several months. Recovery efforts were still ongoing in 2012 when Hurricane Sandy hit and caused further setbacks.

#### Learnings

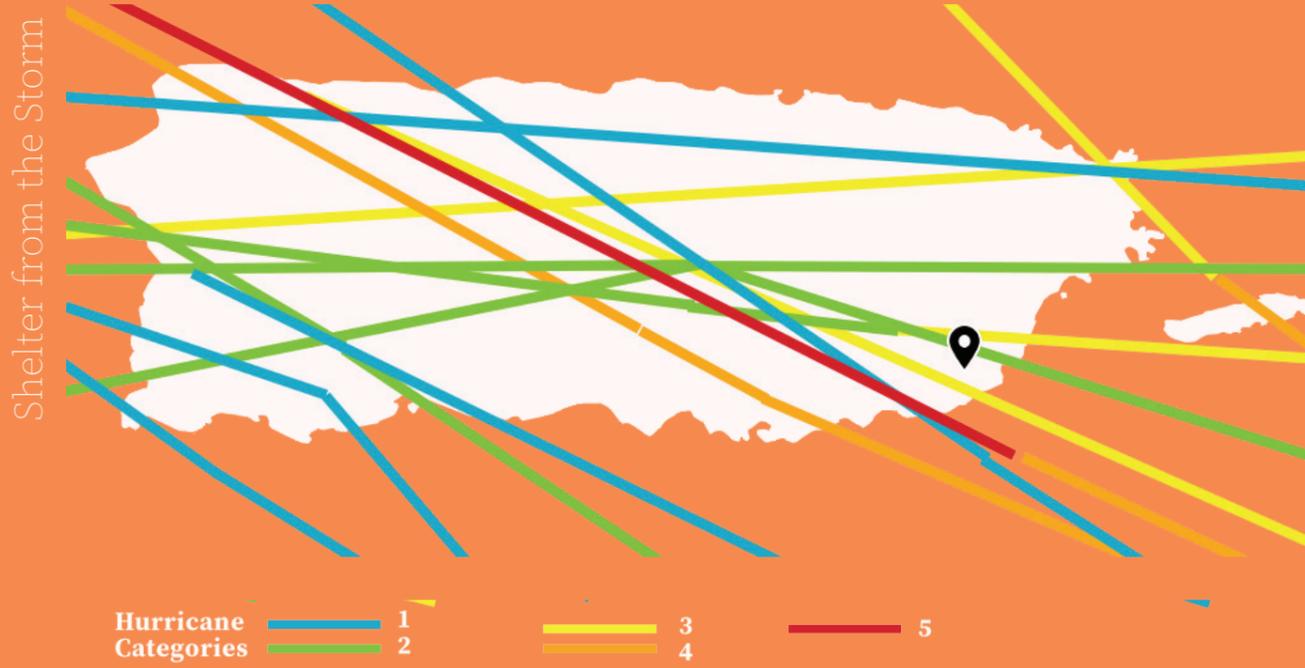
Important points to take up here are how easy disease can spread in overpopulated shelter areas and the importance of having adequate sanitation facilities due to the rise in disease, and the inevitability of the TH being used for longer than intended. In this case, the TH was also hit by another kind of disaster. We should be aware of this happening and try to design an option resilient to this.

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4 - Programming

**Why this context?**

This site was chosen for many reasons, some being that it lies on relatively flat ground, making it less exposed to landslides and because the location means that it will be close to local amenities. There are also many green spaces close by that can be used for the site if there is a greater need for housing and it must expand. Yabucoa is also an area that found it hardest to recover after Hurricane Maria and therefore in need of help. Learnings can be taken from the previous disaster and applied for future projects. The following is an example of a long term solution showing how housing could function both in a disaster and after to help people get back on their feet. Women are at the centre point of the design as they are the most vulnerable, and it is beneficial to Puerto Rico as a whole to elevate them.



Previous Hurricanes

64



Protected Areas

4 - Basic post disaster info on Puerto Rico:

Hurricane path

Hurricanes are the more highlighted and dominant hazard than earthquakes as they occur more frequently and cause greater loss. The typical hurricane paths can be seen in the map above. The site can be exposed to hurricanes, but that means that the displaced people will not have to travel too far for shelter. The design must be hurricane resilient.

Flooding

Flooding occurs mostly in riverines and in the tropical storm season of late summer to early winter and is often also due to clogged drains. After a Tsunami the sea can rise up to 11 feet and has been recorded to have travelled 1.2miles inland. Hurricanes can induce both coastal and riverine flooding so an ideal site would avoid these areas. A suitable site would therefore be located slightly inland. Considerations towards drainage and raising the design may also be beneficial in times of flooding.

Protected Land

Only between 11 and 15% of Puerto Rico's land is protected. These areas are one of the 35 global biodiversity hotspots, due to high species diversity and endemism (Castro, Quiñones and Gould, 2016). It is important to protect these endemic species as 912 of the 14, 526 native plants are at risk of extinction. Recently Puerto Rico's protected sites have been threatened by property developers seeking to build luxury apartments on their grounds. Much of the island has been exposed to monoculture which has in turn damaged soil.

Earthquake

Puerto Rico lies in one of the most earthquake prone zones in the world (Palm, Risa and Hodgson, 1993) The earthquake vulnerability is high because of the increased number of buildings and infrastructure in particularly hazardous earthquake zones (Palm, Risa and Hodgson, 1993). Tsunamis can also be an occurrence, triggered by the earthquakes. The most damage is caused when structures are on top of alluvium, a softer soil (Palm, Risa and Hodgson, 1993) This often occurs in San Juan.

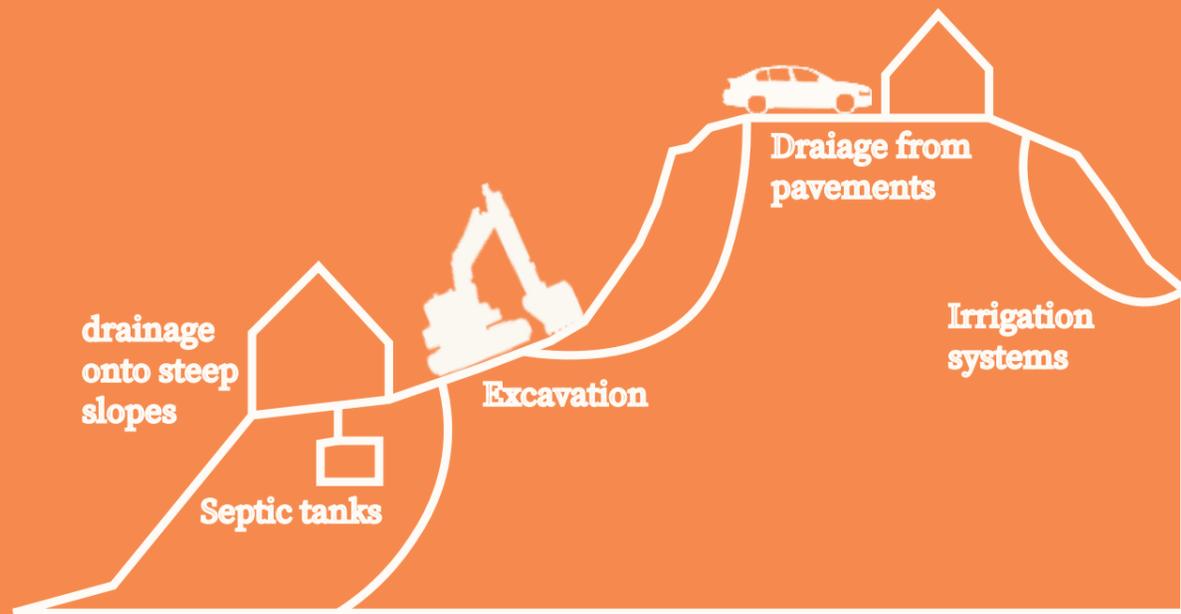
Context

65

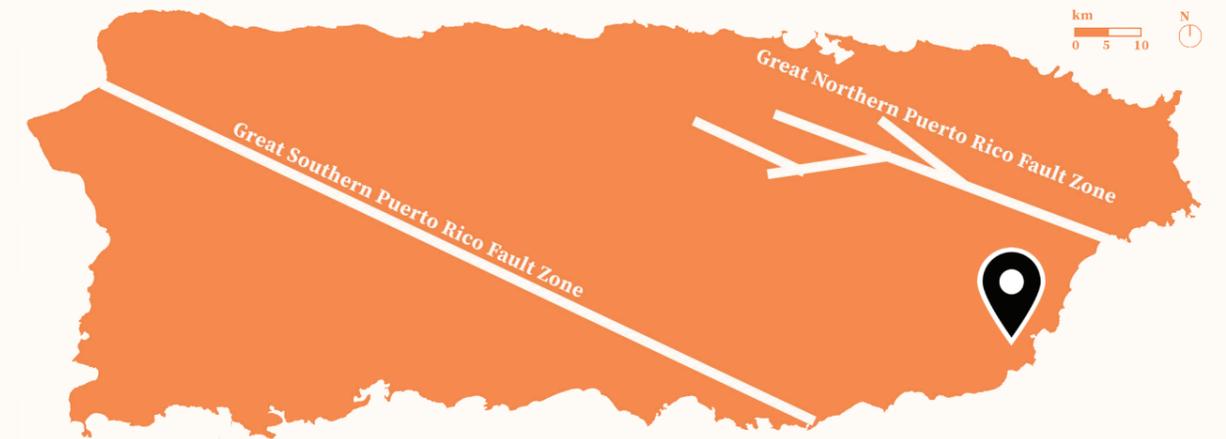


66 Landslides in Puerto Rico

### Human activities that contribute to landslide susceptibility

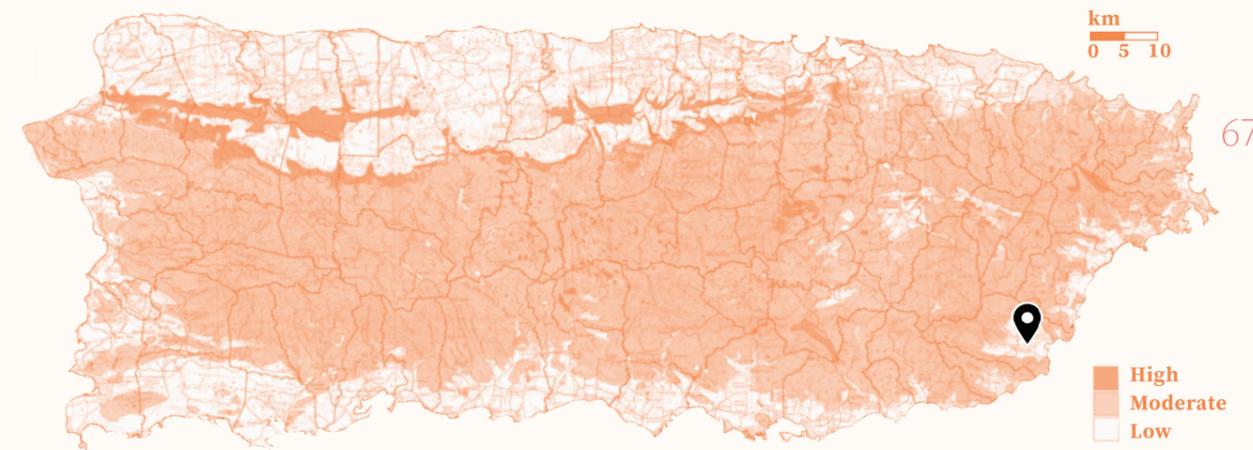


### 4 - Landslides



Earthquake zones

Landslides susceptibility



Landslides

Landslides are very common in Puerto Rico. Hurricane Maria resulted in 70 000 landslides (Blaine Erickson Brownell, 2010). The map above shows the most susceptible areas to landslides in Puerto Rico.

The landslides are often triggered by the natural phenomena of the island being particularly exposed to tropical storms and earthquakes, causing an increase in loose, slippery soil. Hence choosing a site that avoids areas prone to landslides and is not set on a slope is important. As is shown above Yabucoa is a safe area to build on as it is not susceptible to landslides.

Context



Map of south east Puerto Rico

4 - Yabucoa, Puerto Rico

I chose Yabucoa as it was a region that struggled the most to recover after hurricane Maria due to financial implications, which made me think that the people living here could benefit from an intervention. It is also on relatively safe ground as it is not exposed to landslides, or flooding. Relatively low levels of rainfall is set far enough away from the coast so does not experience tsunamis. There is no protected ground in the area also.

Context



Map of Typical Hurricane Pathways

#### 4 - The Site

The site is in Yabucoa, Puerto Rico and has been chosen due how hard it found it to recover after Maria. It is not overly exposed to earthquakes or flooding, so it should be safe for future inhabitants. The characteristics of the population put them at a higher probability to be negatively affected after a natural disaster than in other parts of Puerto Rico.

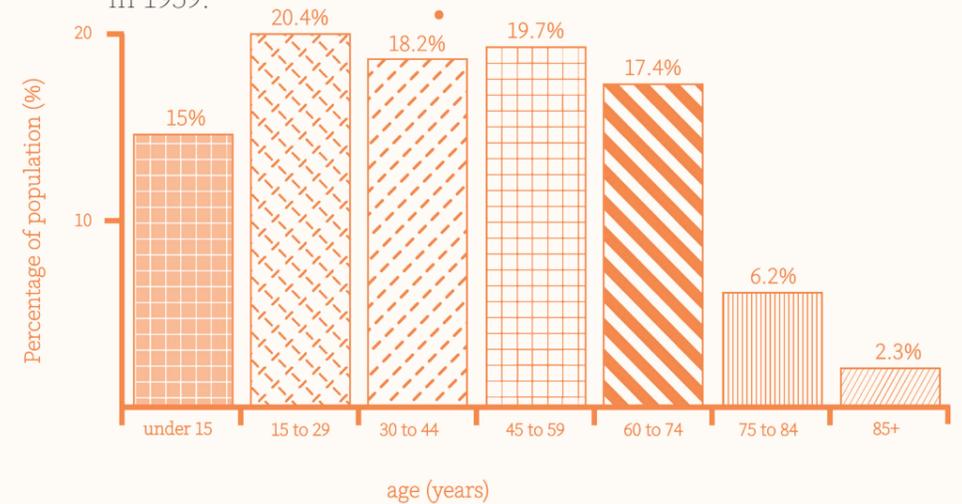
As it is impossible to preempt a natural disaster, the site will be used as a prototype. To portray which guidelines must be met and how they would be suitable in the likelihood that a disaster would happen here. The design could be placed in one of the surrounding islands, with alterations made to suit demographics and the site if needed. However, the units are specifically designed for this region and climate.

#### Demographics

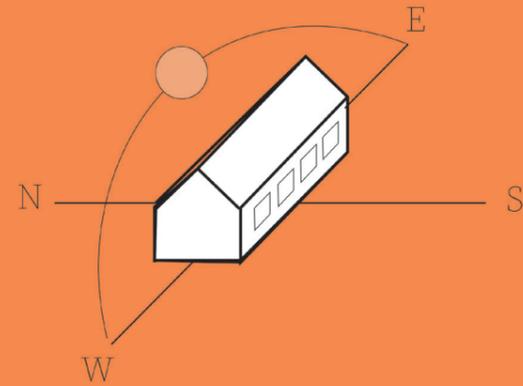
Before Hurricane Maria, 43.5% of Puerto Ricans lived in poverty, with the median wage on the island being \$19,350 (DURANA, 2017). Nine-tenths of the population live in cities or towns. Puerto Ricans have a mix of Spanish, Afro-Caribbean and US culture.

There is a high number of city dwellers. Cities are located along coastal areas due to plantations being predominantly around coastal towns with a few larger sugar farms in the centre.

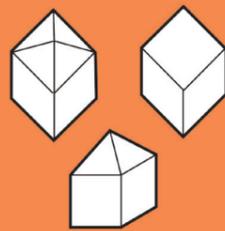
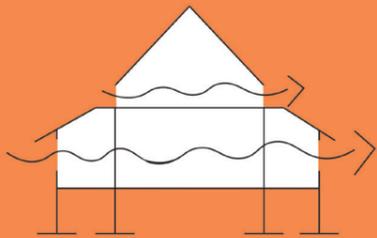
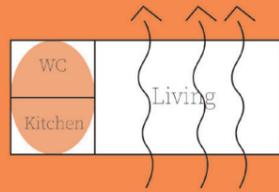
The indigenous people to the island are the Taino Indians, who were the only inhabitants until 1493 when Columbus arrived. There is said to have been between 20,000 to 50,000 of them. Spanish settlers brought African slaves, but the plantations were small compared to the other Caribbean islands. The island has experienced immigration from China, Scotland, Ireland, Italy, Corsica, Lebanon, Germany, and the USA, along with many immigrants from Cuba after Fidel Castro came to power in 1959.



Context



72



## 4 - Climate

## Designing in a warm, humid climate

Housing should have a North-South orientation, with the longer facade facing prevailing winds for natural ventilation. The plan should be spread out and provide generous shade. Materials should have a minimal heat storage time lag. Thermal radiation is only effective on surfaces with direct solar radiation. The outer walls should be as shaded as possible. Highly reflective roofs prevent excess solar gain in the house.

Cleaning methods, cooking and showers need special attention when designing because of the excess moisture.

Screwing metal sheeting is not recommended in the tropics as the heat warps the shape of the screws. Bellhead screws with plastic or rubber washers are driven through are a good alternative (Larsson, 1989). Roofs must be anchored to protect from the wind.

There is little climatic seasonal variation on the island. The north coast has heavy rainfall, and the south coast lies in a rain shadow. San Juan has an average rainfall of 1,525 mm, while Ponce (in the south) receives just 914 mm annually (Wagenheim et al., 2021). The months with the most rainfall are from May to December. Hurricane season is between June and November.

## Culture

The average temperature is 26°C with high humidity. Spanish and English are both official languages in Puerto Rico. Two-thirds of the population are roman catholic due to the Spanish colonial influence, but the USA brought many missionaries to the island. Unease with the catholic churches loyalty to Spain means that now and a quarter of Puerto Ricans are of a protestant denomination.

The US occupation led to an overall improvement in the population's health, and infant mortality dropped, which led to a rapid population increase that triggered unemployment and mass emigration.

## Agriculture and Industry

The manufacturing industry is the most profitable on the island. There is not much access to natural resources. Only clay, silica, sand and stone can be found in large quantities.

The mainly farmed products are; a dwindling sugarcane industry, textiles, small scale coffee, and corn.

The Northern Part of Puerto Rico has parts of tropical rainforest, though most of the country's natural vegetation was removed during the 20th-century plantation. New types of shrubs and trees were introduced and became dominant.

## Context

73



Town House, San Juan

#### 4 - Housing

##### Typical Puerto Rican Housing:

As the demographics of Puerto Rico are very mixed, so are the architectural styles. The main styles are plantation housing, agricultural housing, Spanish colonial, and pre-settlement housing.

##### Plantation and Agricultural housing (Spanish colonial)

They were built in the stone clay valleys where lots of hardwood could be found. The buildings were adapted to the environment by having open hallways to allow for ventilation and continuous verandas. High Hip roofs and half hip roofs were preferred. The hardwood structures lasted for years as they were made with fine craftsmanship. The houses have been nicknamed “Martillo” (meaning hammer) by the locals because of their L-shaped plan. A wooden arch marks the transition to the compact service spaces made up of Kitchens, storage and baths.

The agricultural houses were also wooden framed, had a central living space and were raised from the ground by at least 1m to prevent vermin and dust. This also caters to flooding after access rainfall.

##### African influences

Certain architectural elements were brought over from Africa, such as compact shapes and broad verandas for shade. With hip roofs added for the Puerto Rican climate.

##### Spanish colonial townhouses

###### San Juan

The housing in San Juan is unique in several ways. Ceilings are between 4m and 6m high to improve comfort levels; patios are used as ventilation shafts. The rooms are also always interconnected to help with ventilation. Walls were made of brick or local mamposteria made up of calcareous rock, broken bricks, mud, lime and other inorganic fillers. The walls are susceptible to erosion and need to be rendered with lime and sand. Walls are also designed to be breathable to help with cooling.

Windows are rarely seen to the exterior. Instead, a pair of doors is always used to allow for more ventilation. On upper floors, Juliet balconies are installed to allow for this.

Roofs were traditionally flat to increase the chances of catching water, as piped aqueduct water was not available until 1897.

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#### Context



Taino Housing

#### 4 - Housing

Detailing can be seen in the form of timber purlins and shuttered galleries with coloured glass.

The streets are colourful as the tall and narrow houses are painted in many vibrant colours. The paving is 19th-century slag cobbles imported from Britain.

#### Yauco town housing

The housing style is similar to San Juan, although some prominent features are the emergence of wine being made in the basement as housing has been lifted in consideration for floods after excessive rain. Large balconies opening up from a second living floor are common and a notable feature of the town. A lot of neoclassical architecture and revival architecture is present.

#### Pre settlement housing

The Taino people originally inhabited Puerto Rico. They were the largest of the indigenous groups of people on the Caribbean islands. The Taino who inhabited Puerto Rico were known as Borinquen. They were agricultural people though they did have town settlements with up to 3 000 people. After the settlement of Spanish colonists, the Taino nearly became extinct due to exposure to new diseases such as smallpox. Nevertheless, there are still many groups of people who identify as Taino and have a Taino heritage in Puerto Rico today.

The traditional housing of the Taino people were round, moveable huts called Bohio huts. The huts were wooden framed, clad with banana leaves and had a thatched roof.

The compact design responded to the climate very well, and the nature of fast, simple construction and use of local, renewable materials could work as good inspiration for disaster housing whilst also paying homage to the Islands history.



Puerto Rican home one year after Maria

#### 4 - Hurricane Maria

##### Background

On the 20th of September 2017, Hurricane Maria hit Puerto Rico. It was a category four hurricane with winds of up to 175mph. The strongest hurricane to hit the island since Hurricane Mitch in 1998 and said to be the worst natural disaster ever to hit the Caribbean Islands. Officials stated that the hurricane killed 64 people. However, the death toll was later revealed to have been 2,975 by a study done by researchers at George Washington University (Barclay, 2018).

The hurricane created the largest blackout in US history and the second-largest globally, with 3.4 million citizens without electricity. In a country that already had poor infrastructure before Maria, 80% of the power lines were knocked down. It took 328 days before power was restored to the whole island. The 44% of the Puerto Rican population living in poverty were hit the hardest. Remote and rural villages became utterly cut off from services for months as roads were destroyed by the storm.

##### Failures

According to the president at the time, Donald Trump, “we did a fantastic job with Puerto Rico... I think most of the people in Puerto Rico really appreciate what we have done” (Barclay, 2018).

The island did receive \$25 billion in aid, but the response to the disaster was slow, insufficient and lacking in transparency. Officials sent from FEMA to assess the situation did not even speak Spanish (www.amnesty.org, n.d.). FEMA also cancelled housing aid promised to hurricane survivors. The US government normally has a shipping regulation called the Jones Act imposed on Puerto Rico, which makes it very expensive to import goods. This act was dismissed after Maria to make it easier for Puerto Ricans to rebuild.

The blackout made heatwaves in Puerto Rico unbearable and caused food to spoil and medication to go bad. Hospitals crumbled under pressure. For months machines could not run, and an outbreak of Leptospirosis ensued.

---

##### Context

#### 4 - Hurricane Maria

Even more critical was the lack of clean, safe water as water pumps were shut off due to the storm. According to interviews performed by Oxfam all interviewees said that being without water was worse than being without power and women, who carried out the household tasks, were most affected by the lack of water. However Amnesty international confirmed satellite imagery of \$22 million worth of drinking water was left on tarmac without being distributed to families for months on end (www.amnesty.org, n.d.).

The repair of roofs has been extremely slow. One year after Maria 166, 000 homes were still being rebuilt/repared with thousands of families still living under blue tarps (www.amnesty.org, n.d.) . Even when warnings for the next hurricane, Hurricane Isaac, came 350 families were still living under blue tarps.

#### Opportunities

After the black out Puerto Ricans began to see an opportunity to rebuild the electricity grid with a focus on resilience and cleaner energy. The island currently has to rely on imported fuels, though entrepreneurs have taken the chance to introduce renewables into the power system. Hospitals and fire stations now generate their own electricity using solar panels (Barclay, 2018).

Community leaders in Puerto Rico self organised to carry out censuses after the hurricane so that they would be prepared with the correct information for FEMA for the next time a storm hit (www.amnesty.org, n.d.) .

#### Learnings

The importance of transparency and communication can really be seen here. The need for electricity generators and a clean water supply is vital in order to help the citizens recover. A need for a pre action plan and emergency supplies within the county before an event is crucial as many roads will be damaged due to the storm.



## 4 - Women in Puerto Rico

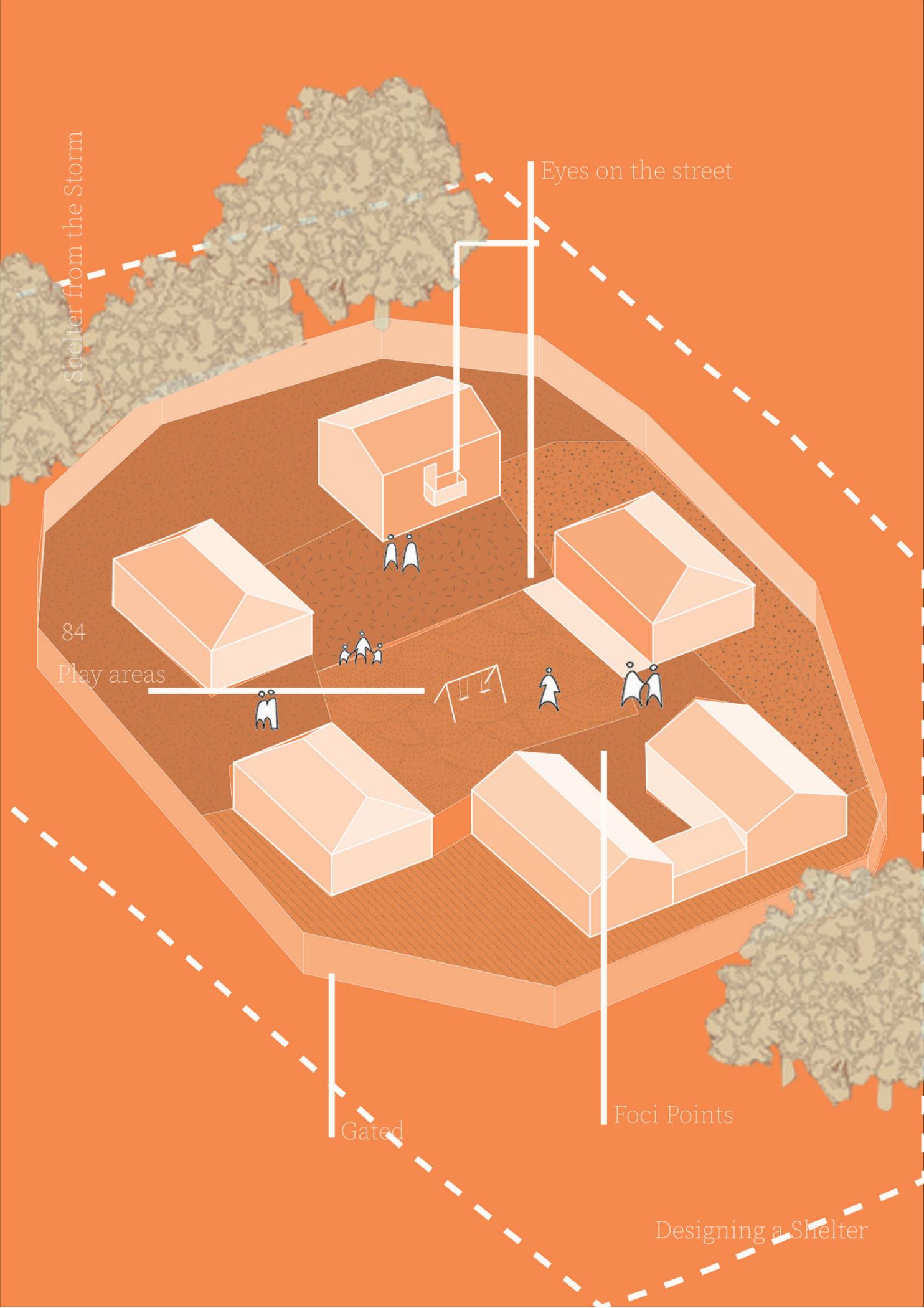
## Post disaster trends in Puerto Rico

Even before the hurricane, women in Puerto Rico were subject to gender inequality, and there were higher levels of women in poverty than men. The island also suffers from the highest levels of intimate partner violence in the world (Ravi, 2018). A lack of law enforcement leads to a reduction of accountability for abusers. Violence is often an accepted means of resolving conflicts in relationships, and there is a strong stereotype of the strong, powerful, controlling male “machismo” and a subordinate female.

“Women are more likely than men to have care responsibilities that will keep them out of the formal labour force. They are more likely to work in a flexible economy to accommodate care work.” According to a local woman, “The problem with having a stingy public welfare system, if you are trying to raise kids as a single mom or care for a relative with a disability and there is little federal money, [is] you cannot take time off from working,” (DURANA, 2017)

After the disaster, the inequalities became exacerbated, with women becoming more exposed to sexual and domestic violence and having limited access to reproductive healthcare and sanitary hygiene products (Ravi, 2018). In addition, in this culture, whenever disaster strikes, it is more likely that women are looked too, to step up and become caregivers for the children, elderly and disabled, making it harder for them to improve their situation. It hinders them from finding work or suitable shelter as they cannot spend extended periods away from home. It is difficult to find child care services after a disaster. Upon evacuation decisions, women are more likely to stay in unsafe areas because it would be too difficult to relocate too many people; they would rather sacrifice themselves. From 2010 to 2014, 148,642 Puerto Rican households were female lead, that is 42 percent of the population (Ravi, 2018).

Disasters increase the exposure of women to precarious situations. Overcrowded shelters and power outages can be extremely dangerous. Feelings of stress, fear and helplessness are increased after a disaster and lead to a greater desire for control and power (Ravi, 2018). These feelings can be instigators for violence (Stevens, 1973; Riquer et al., 1996). (Keyeux and Ramos, 2000)



#### 4 - Designing Shelter

When designing a shelter, the highest priority is to create a secure, home-like environment. Women should feel safe within the walls. A reception/counselling centre plays a vital role as a transitional safe space from the public to the private space. Communal spaces such as a “grand room” help bring the users together and are used for different activities or divided to create smaller spaces within. It can be good to create a foci point in the space like a courtyard or a fireplace. Porches and balconies can be a good asset as they increase neighbourhood connections. Play areas that allow small children to play and still be near their mother are essential. Spaces that allow for childcare, education and counselling are also appreciated. It is good to have access to local amenities nearby, such as stores. (Refuerzo and Verderber, 1993)

Post-disaster shelters usually have an open ground floor (for storm surges) with room to accommodate people on the top floors. 97% of women said that they felt vulnerable in these disaster shelters (World Bank, 2010).

It takes a long time to rebuild after a disaster, since most people’s livelihoods are lost, increasing their overall vulnerability. Help from NGOs is often needed.

#### Key Design Features

- Foci points
- Safe, gated area
- Communal spaces
- Balconies and porches
- Safe play spaces
- Childcare and education
- Local amenities close by

Context

Designing a Shelter

## 4 - Design Brief

From the research from previous chapters, we can see that many things are necessary for designing adequate shelter. That is why the brief will be split into stages.

The immediate response

Tools to rebuild

Permanent solutions

## Tools to rebuild

For the design to meet the immediate response needs, it will need to be easy to erect, produced on-site and self resilient. The design will also need to be suitable to be placed in different locations based on need and the number of people displaced. In this way, it needs to be adaptable to suit uneven ground conditions. Due to the research around women after disasters and gender violence being highlighted in Puerto Rico, it has become apparent that disaster housing designed to meet the needs of women improves the overall design for all and would be significantly beneficial for the design.

## The immediate response

To become part of tools to rebuild, the design will need to be easy for the user to create and adapt, reusable and suitable for Puerto Rico's people. The indoor climate should be comfortable, and people should not feel that they are missing anything.

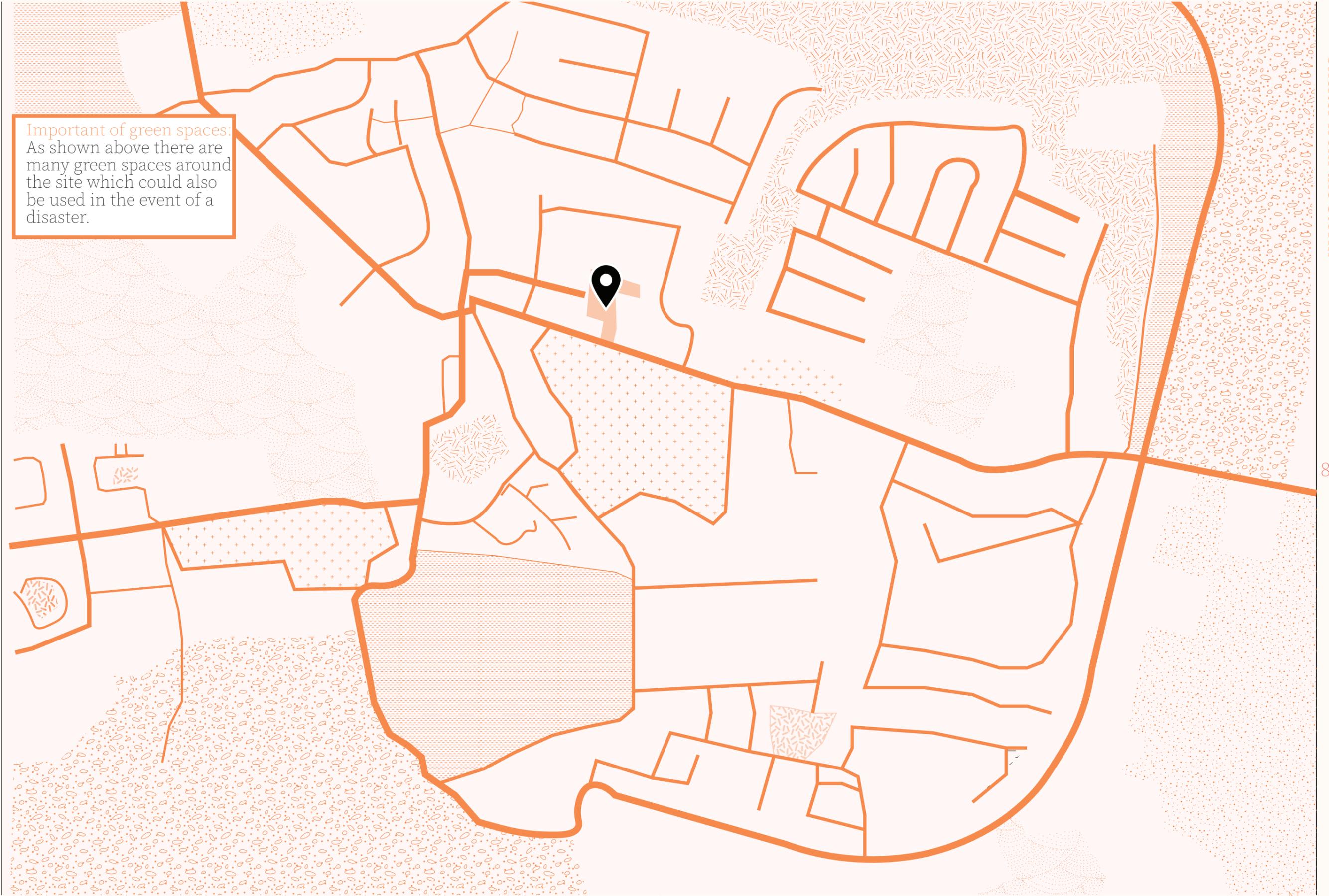
## Permanent solutions

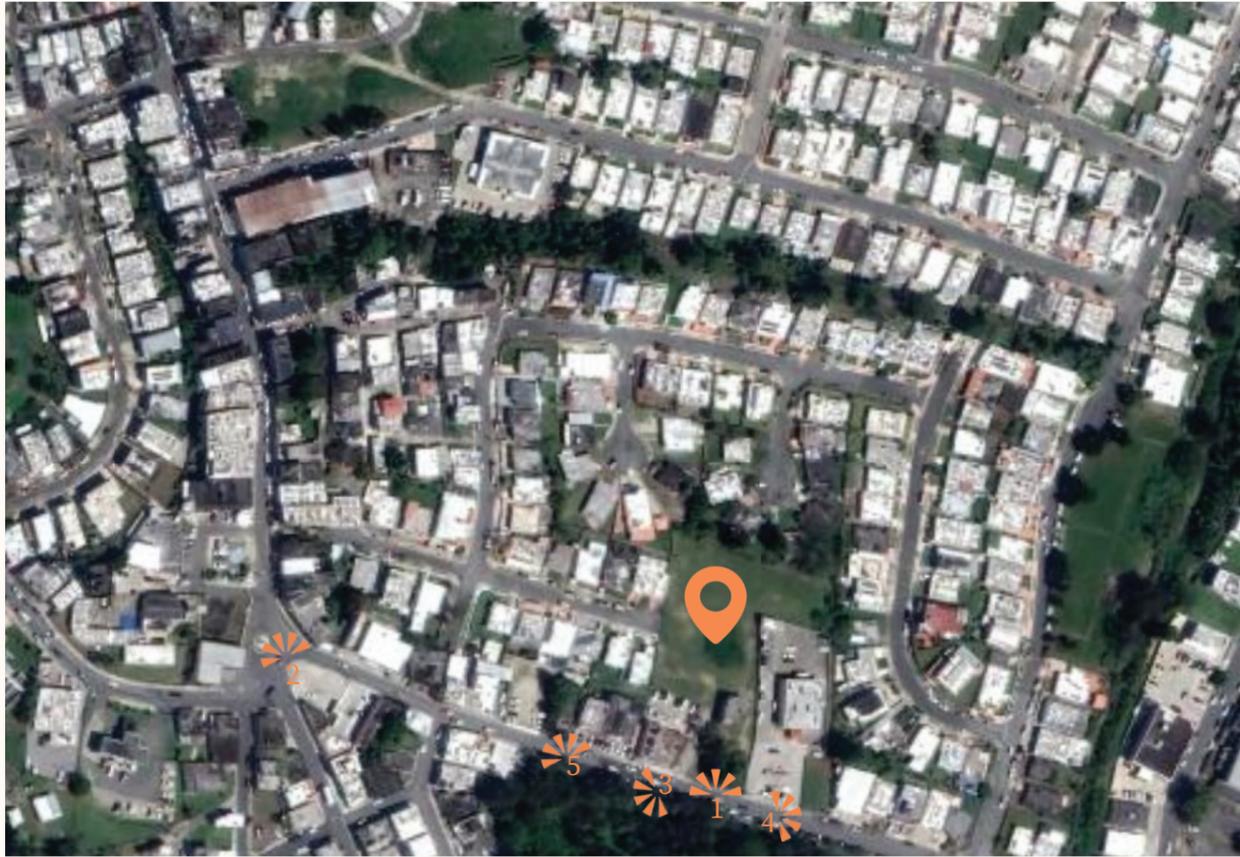
The housing should be of high enough quality that it would be considered as a permanent solution. Hence the permanent solution aspect of the design will show how the design could act as a women's shelter in Puerto Rico. This would be set up even if there has not been a natural disaster and used to test how well the idea works. Other shelters could be made after a disaster to give the housing a permanent use.

Important of green spaces:  
As shown above there are many green spaces around the site which could also be used in the event of a disaster.

88

89





3



4

90



1

91



5



2

-  The site
-  View points

**Notes on the site:**  
 The surrounding buildings are quite low in density and there is a lot of green space around the site. However the Yabucoa town centre is just west of the site and the hospital is directly opposite in case of emergencies.

**Context**

Routes to local amenities:  
As shown on the map above,  
local schools and churches  
can be reached easily and  
shops are located close to  
the site.

92

93



School  
Hospital



Shops  
Library



Sports Facilities  
Churches



Site



Context

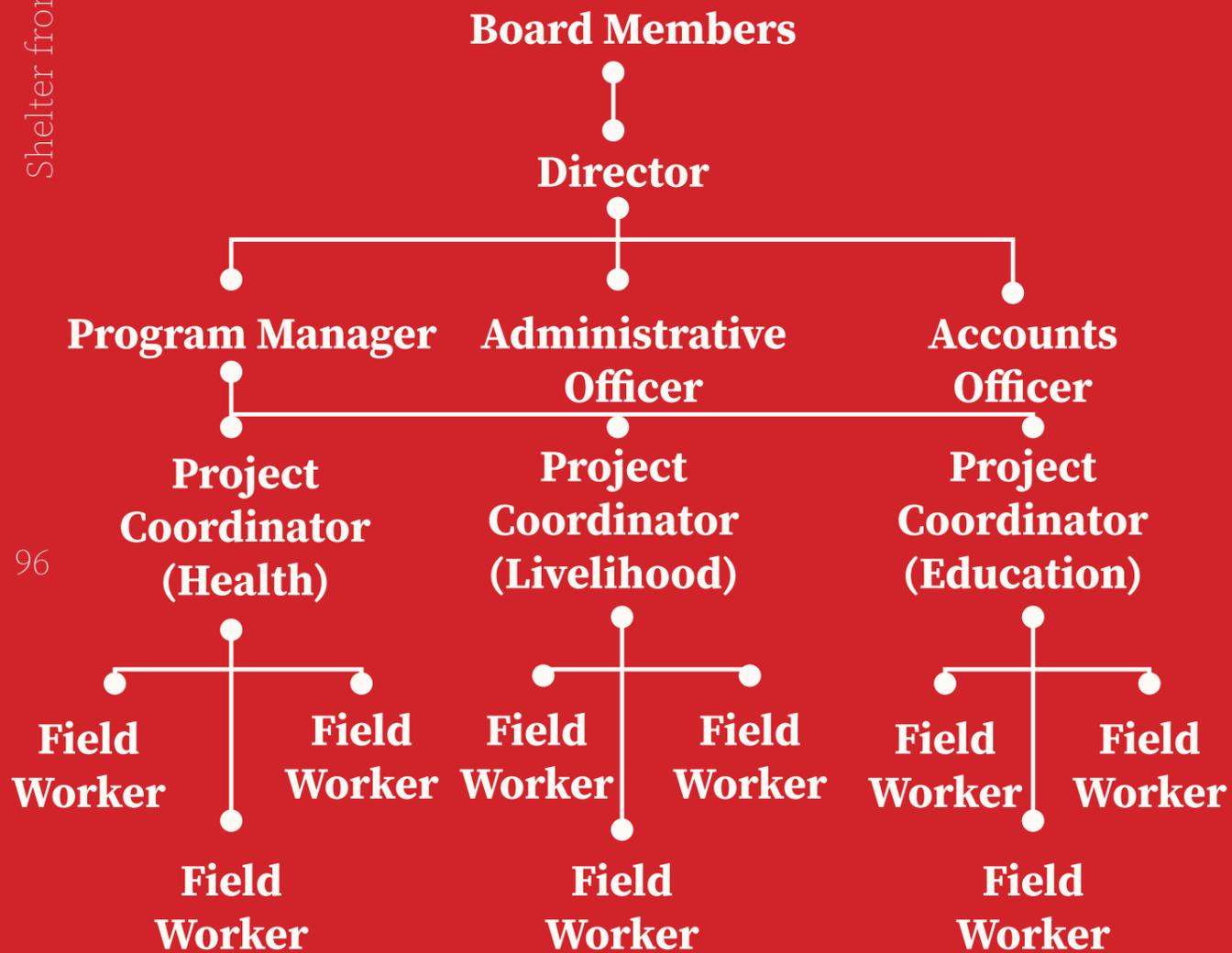
Local Amenities

D  
E  
S  
I  
G  
N

**An example of how the site can be programmed and how the concept will be shown**

In the following pages, I have drawn a scenario where a simple design can be manipulated and changed to be placed in many ways. I have shown how it would look on the chosen site and how it could be given the long term use of a women's shelter.

I have outlined how the structure would be built and how it could be adapted to meet different functions, lifting up the most essential aspects in the process.



5 - Possible Non governmental organisation Funding



**COHI**  
 The international NGO circle of health international has been working with the charity centroMAM to provide help to women after disasters. They currently have a women's health disaster fund which offers midwives and medicine to women and expecting mothers after disasters. They also have a relocation fund for expectant mothers and newborns. This project could be part of the relocation fund.

**CentroMAM**  
 CentroMAM is a local NGO working in Puerto Rico. They have a close relationship with the community there and would be a good partner to help implement the work in Puerto Rico.

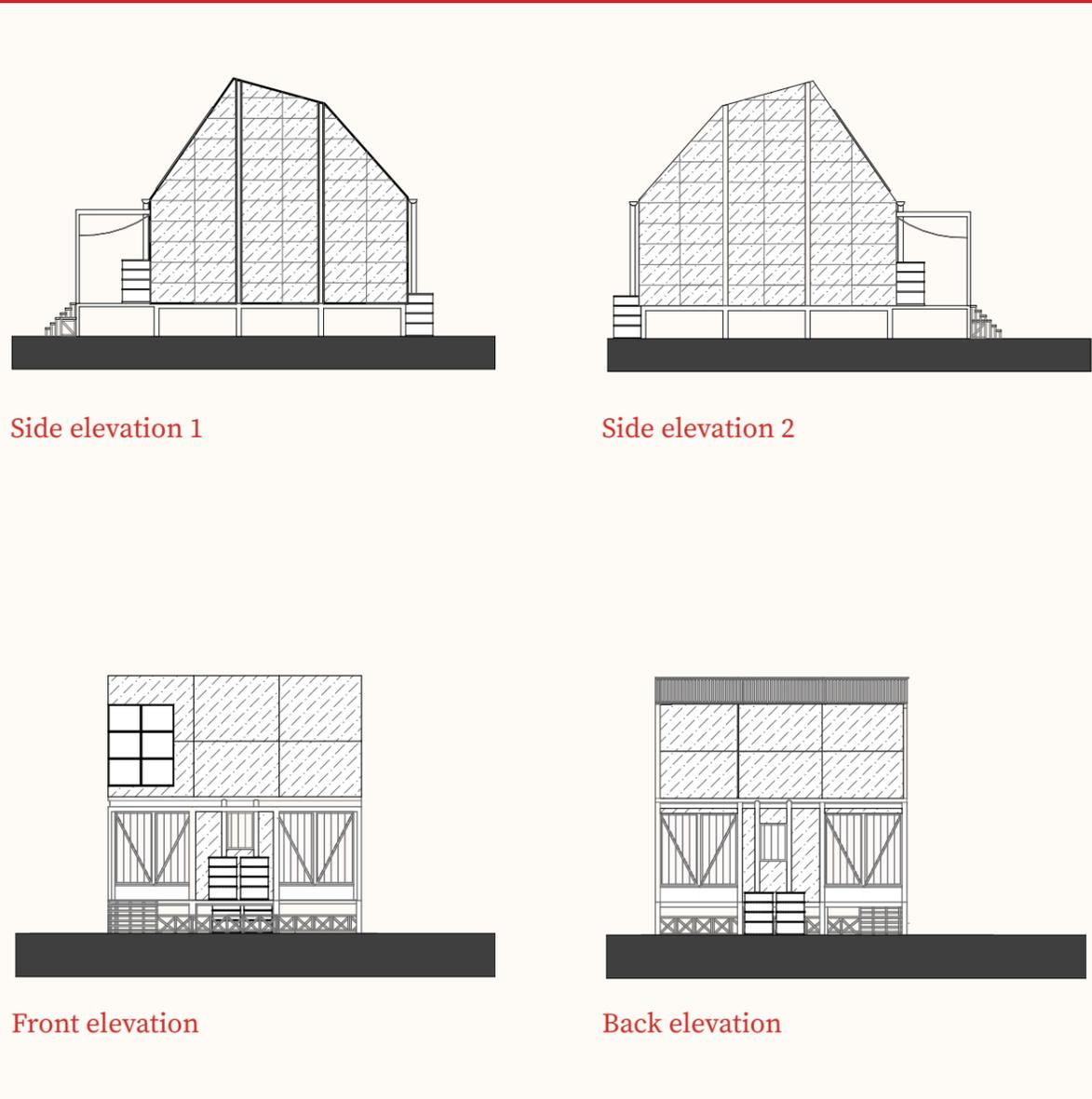


**FEMA**  
 I believe that the government should take some responsibility for the disaster response and should have a strategy for when events like this occur or in response to the gender violence emergency. In the case of Puerto Rico this is the Federal Emergency Management Agency. We have seen how they were unprepared to respond to Hurricane Maria. I think they could use this strategy to be ready for future disaster responses.



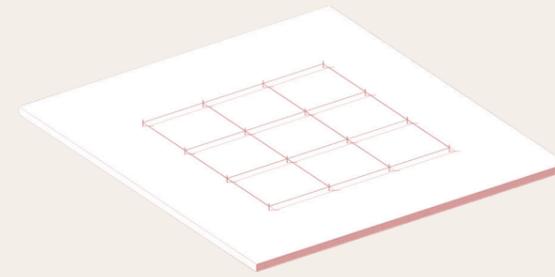
**Intercambios Puerto Rico**  
 The government is not always well trusted by the locals so it is important to look into what local charities can be used as they really know the people and their livelihoods. Intercambios Puerto Rico is a community based charity who are currently part of a program called Rebuilding a Safe Haven for Future Crisis. I believe that this project would fit into this initiative well.

**PARACa**  
 PARACa is the Program for the Empowerment and Retention of Agents of Change. They focus on social action and their members are college students and recent graduates.

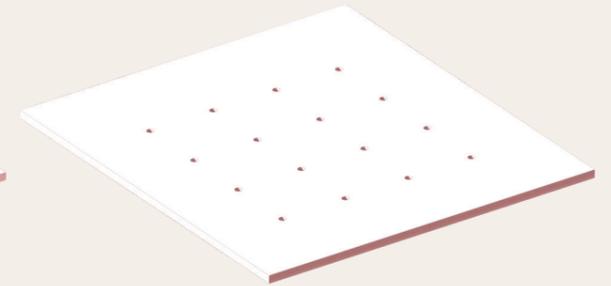


Standard unit elevations 1:200

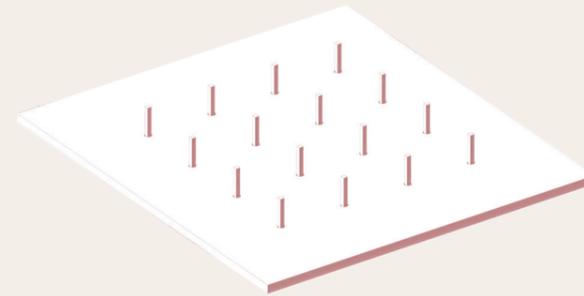
5 - Construction Steps



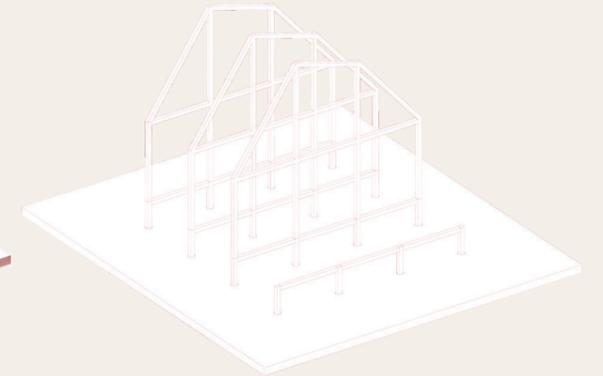
Mark out foundations



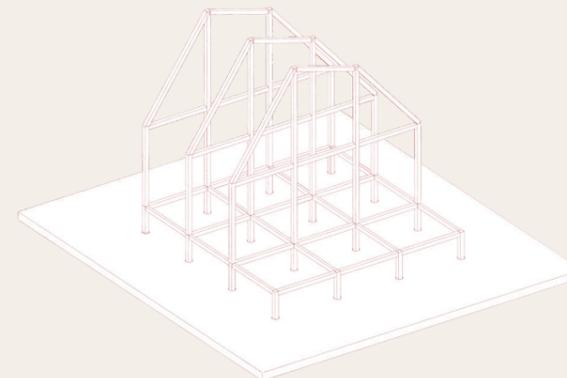
Dig the foundations



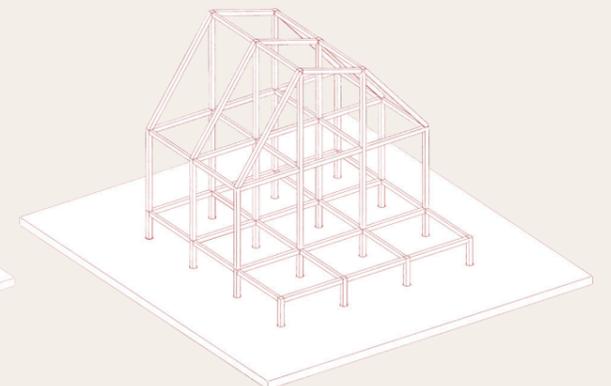
Insert pile foundations



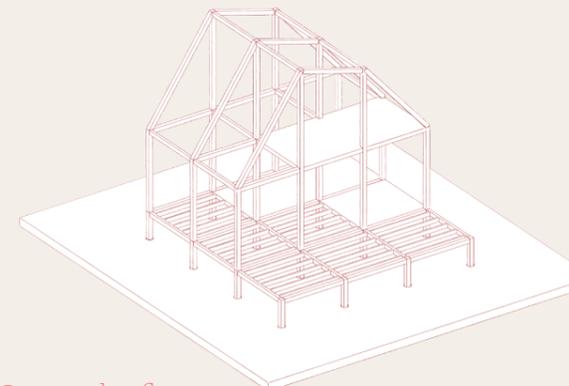
Insert Framework



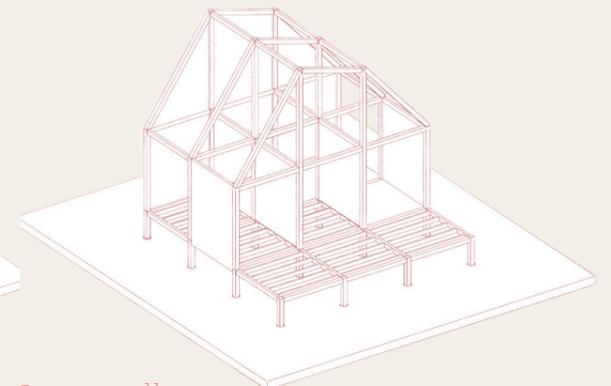
Connection Beams



Connection Beams



Insert the floor



Insert walls

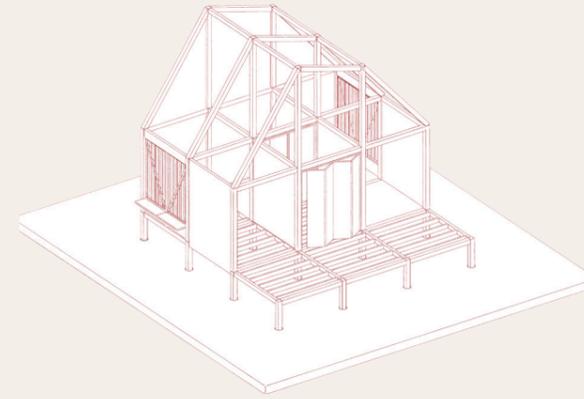


Design

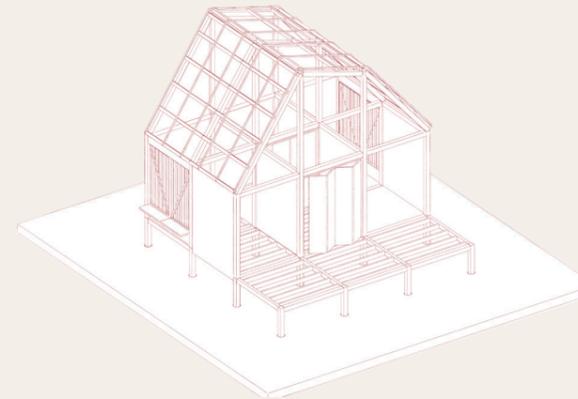


Single unit

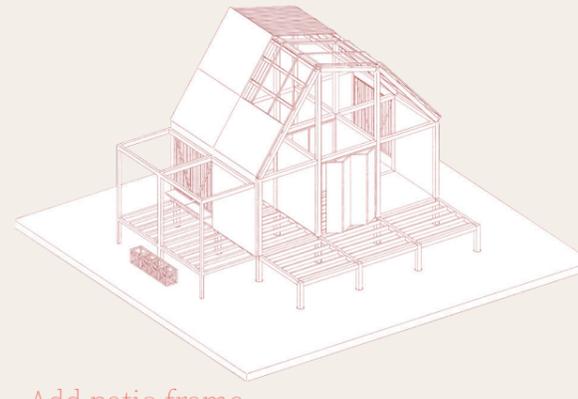
5 - Construction Steps



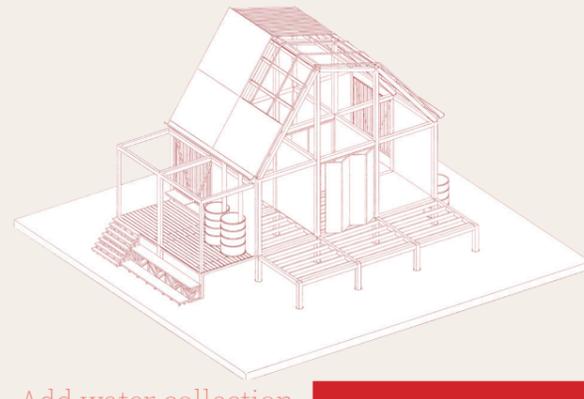
Insert doors



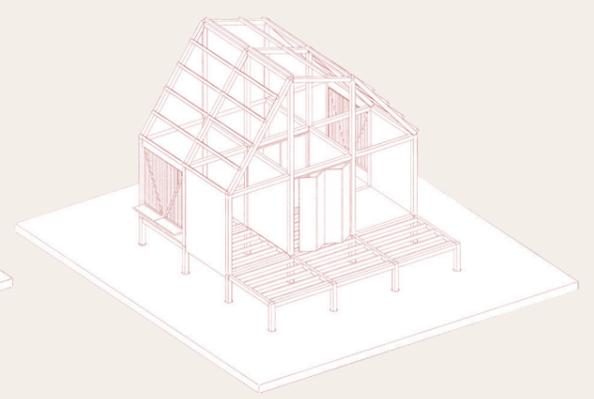
Insert cross battens



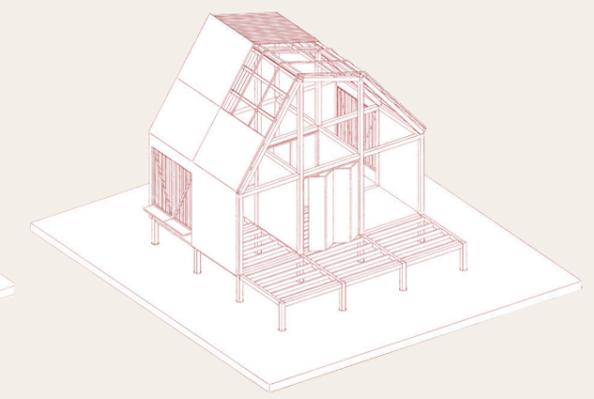
Add patio frame



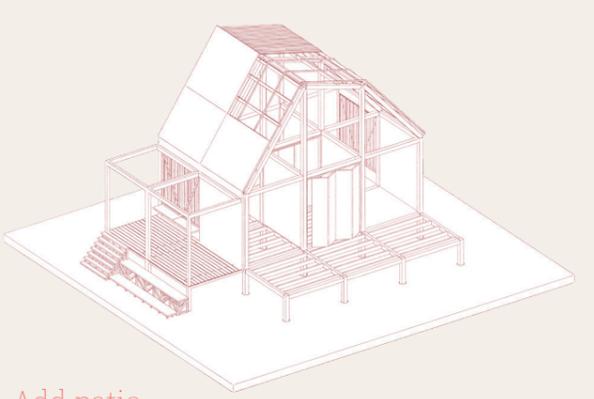
Add water collection



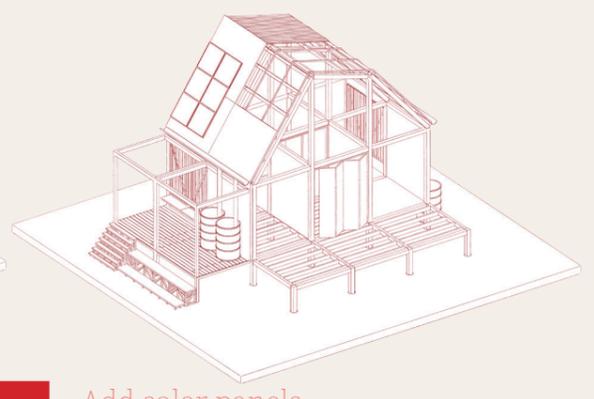
Insert purlins



Add roof panels

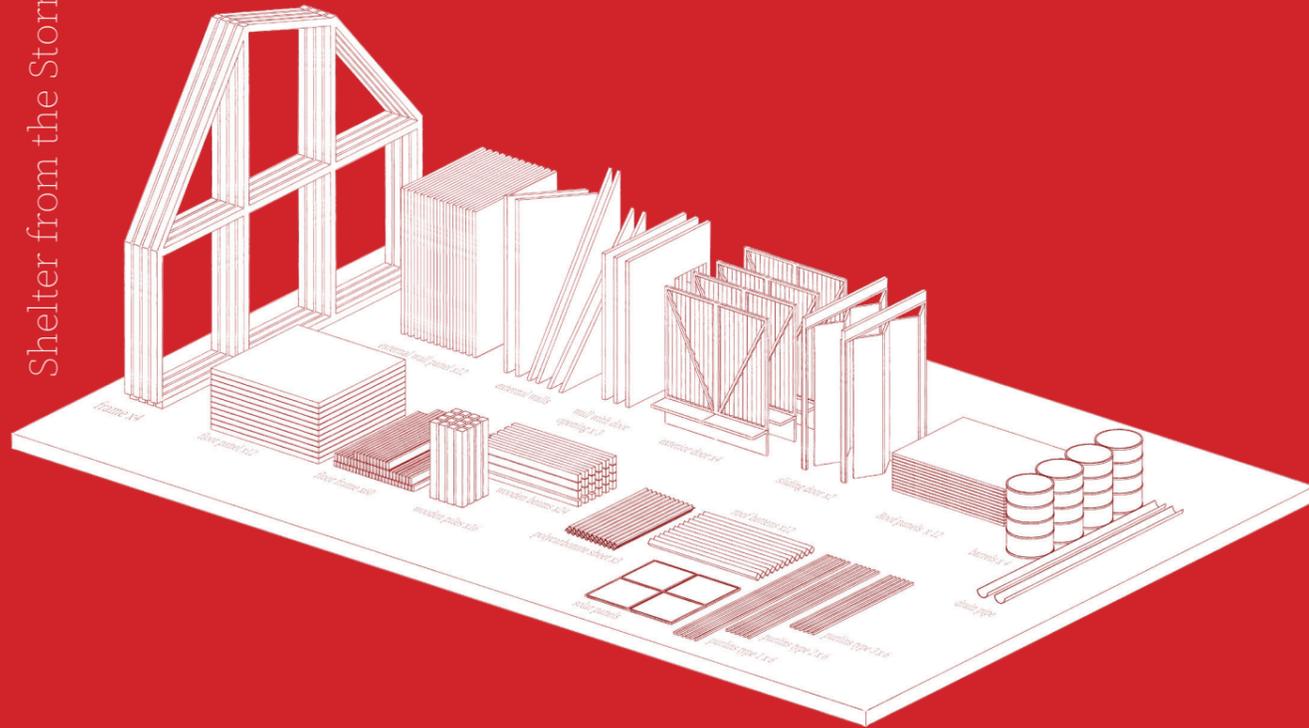


Add patio



Add solar panels

Design



**Standard Unit**

Hardwood frame x4

Resysta Floor panels x 12

Hardwood floor framework x 20

Wooden piles x16

Wooden beams x 24

Polycarbonate sheeting x3

Wooden roof battens x 12

Solar panels x 3

Steel barrels x 4

Recycled plastic drainpipe x 2

Loam roof panels x 12

Internal sliding doors x 2

Internal door x2

External door x 4

Wall with door opening x 3

External loam wall panel x 12

Special side panels x 6

5 - Unit Axonometric

Polycarbonate sheets

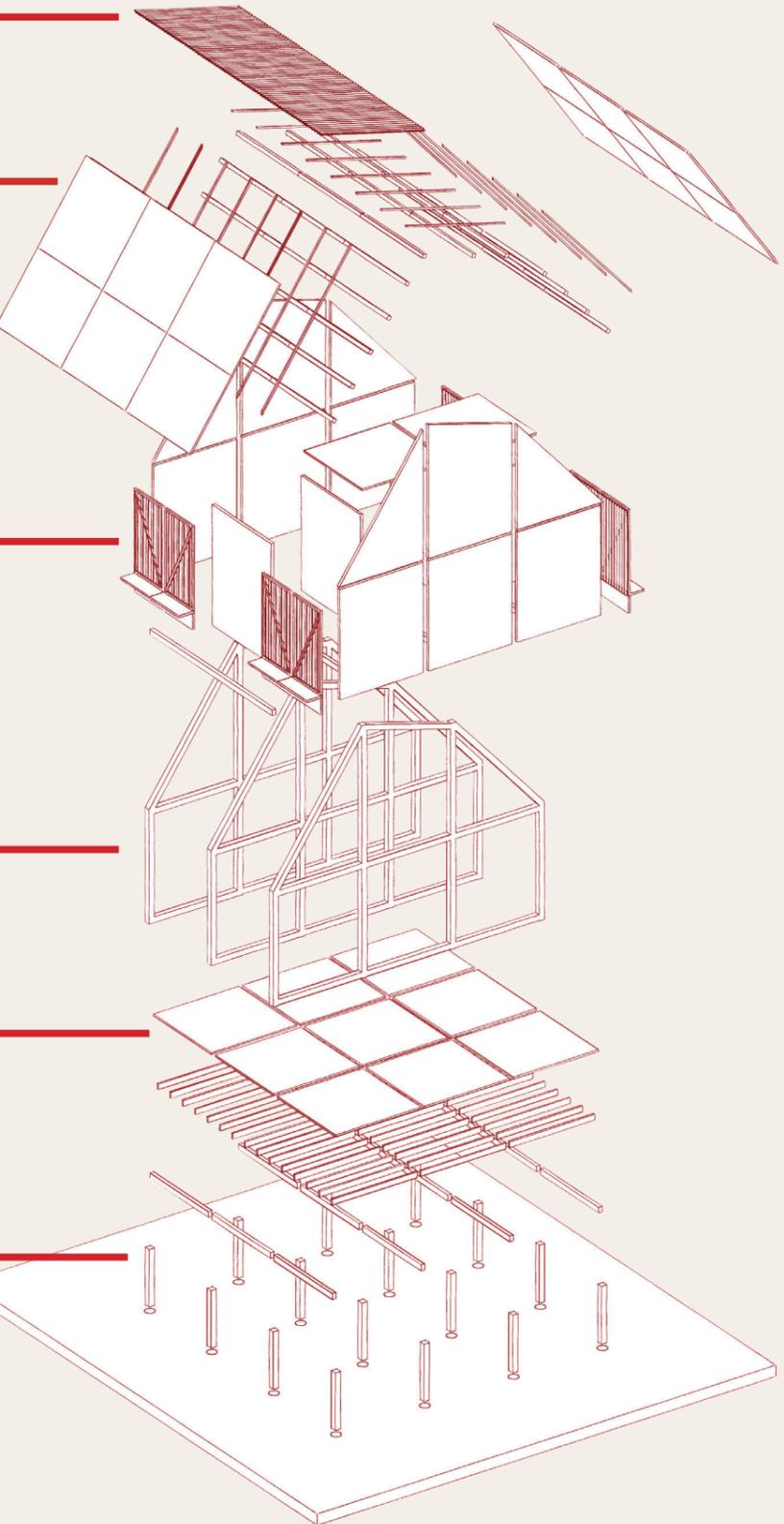
Loam panel cladding and roofing

Custom made doors

Hard wood frame

Resysta panel floor boards

Pile foundations

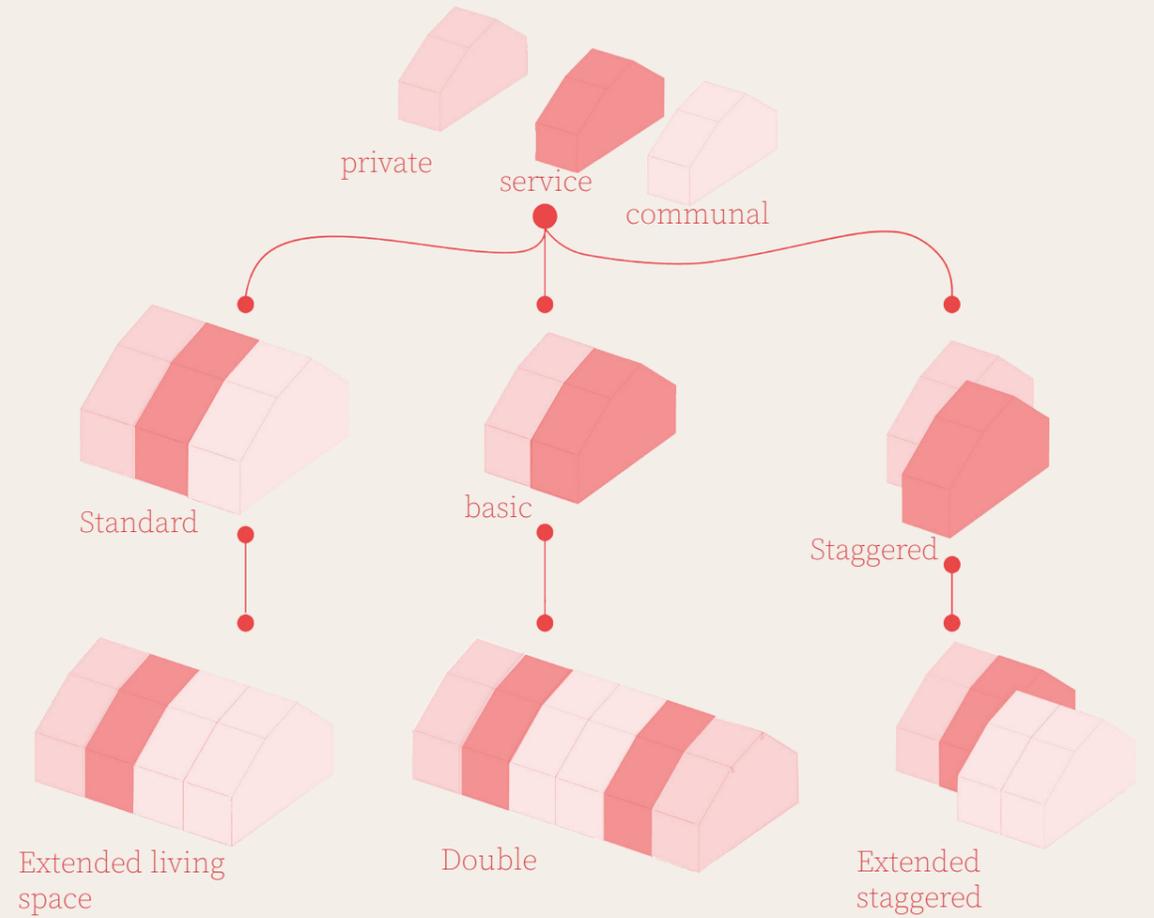




To be updated

Section through unit

### 5 - Unit Types



### Types of Housing

The housing is made up of three different elements:

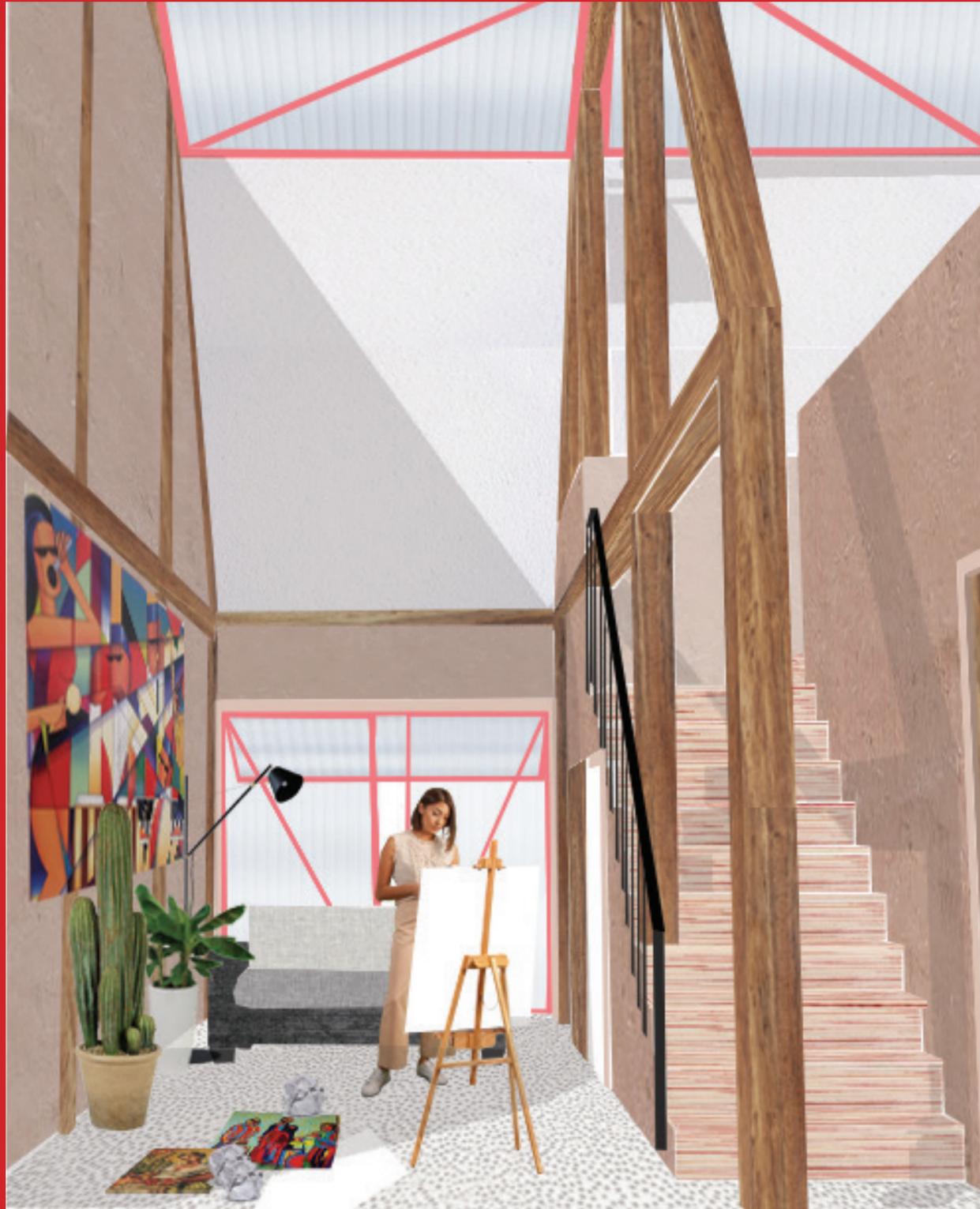
- A social unit
- A service unit
- A private unit

All of the units are the same size and structure but can be grouped in different ways to create different types of spaces.

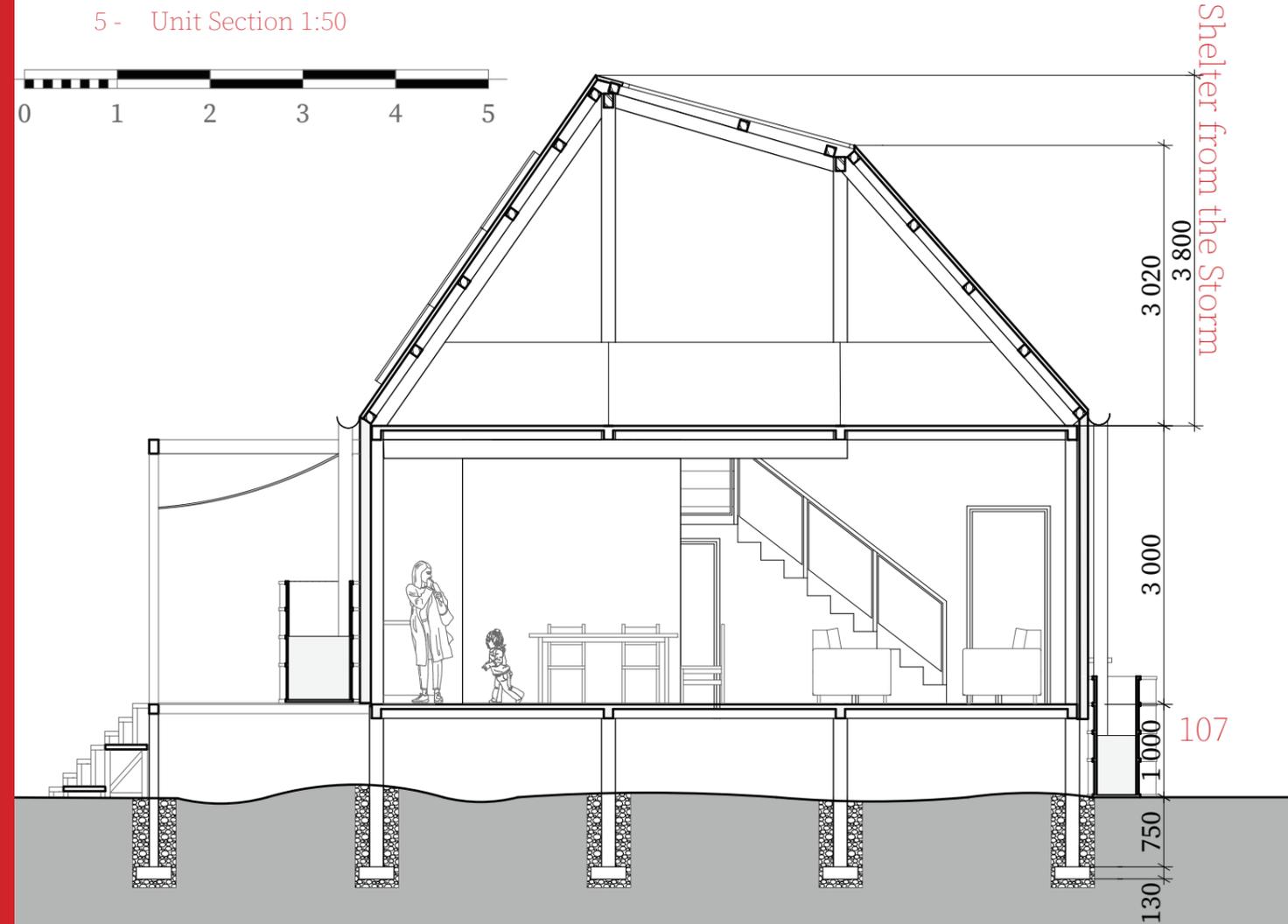
The minimum unit size is two units, and the recommended is three units.

Units can be offset to create interest in-between spaces and to fit into different sites.





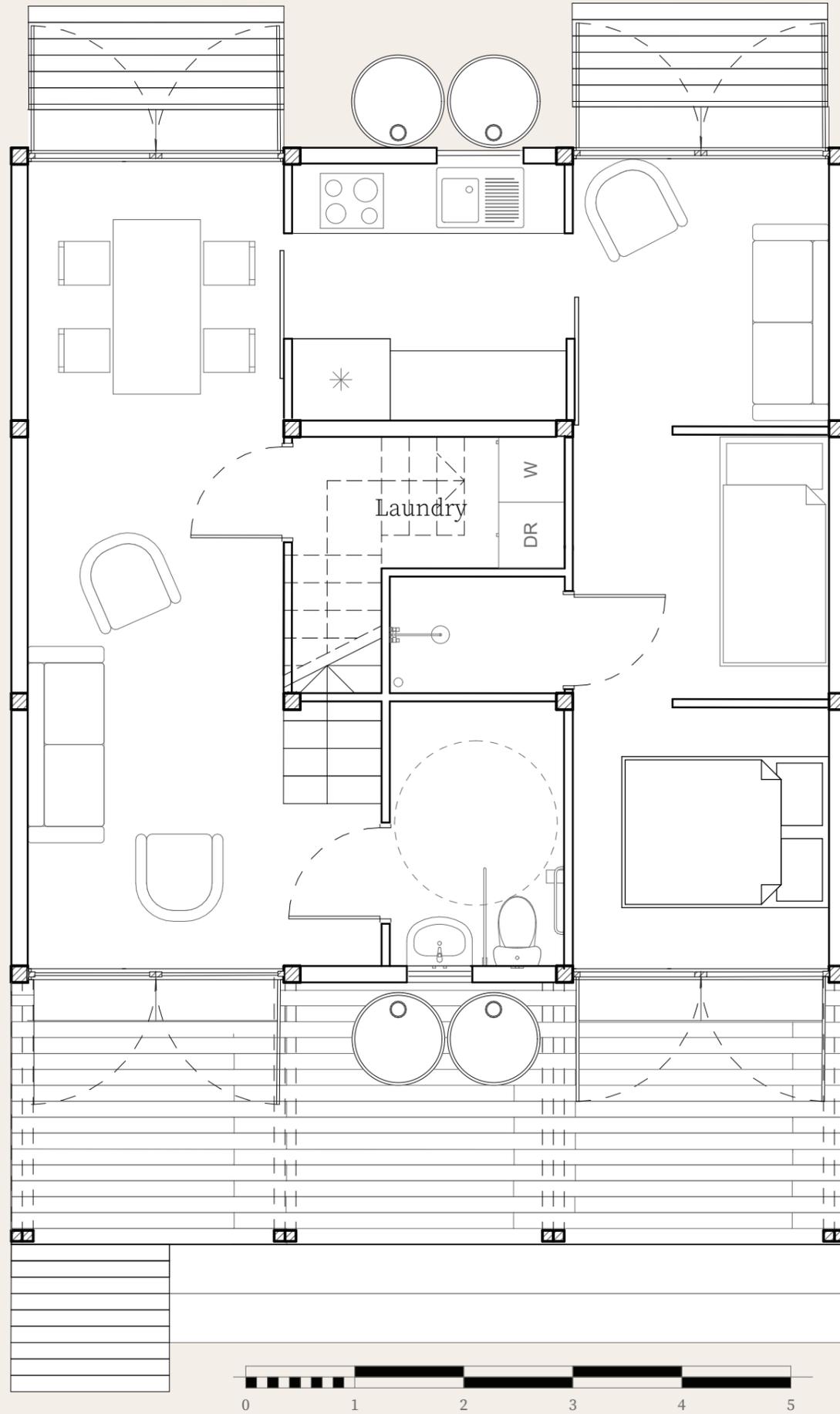
Interior perspective



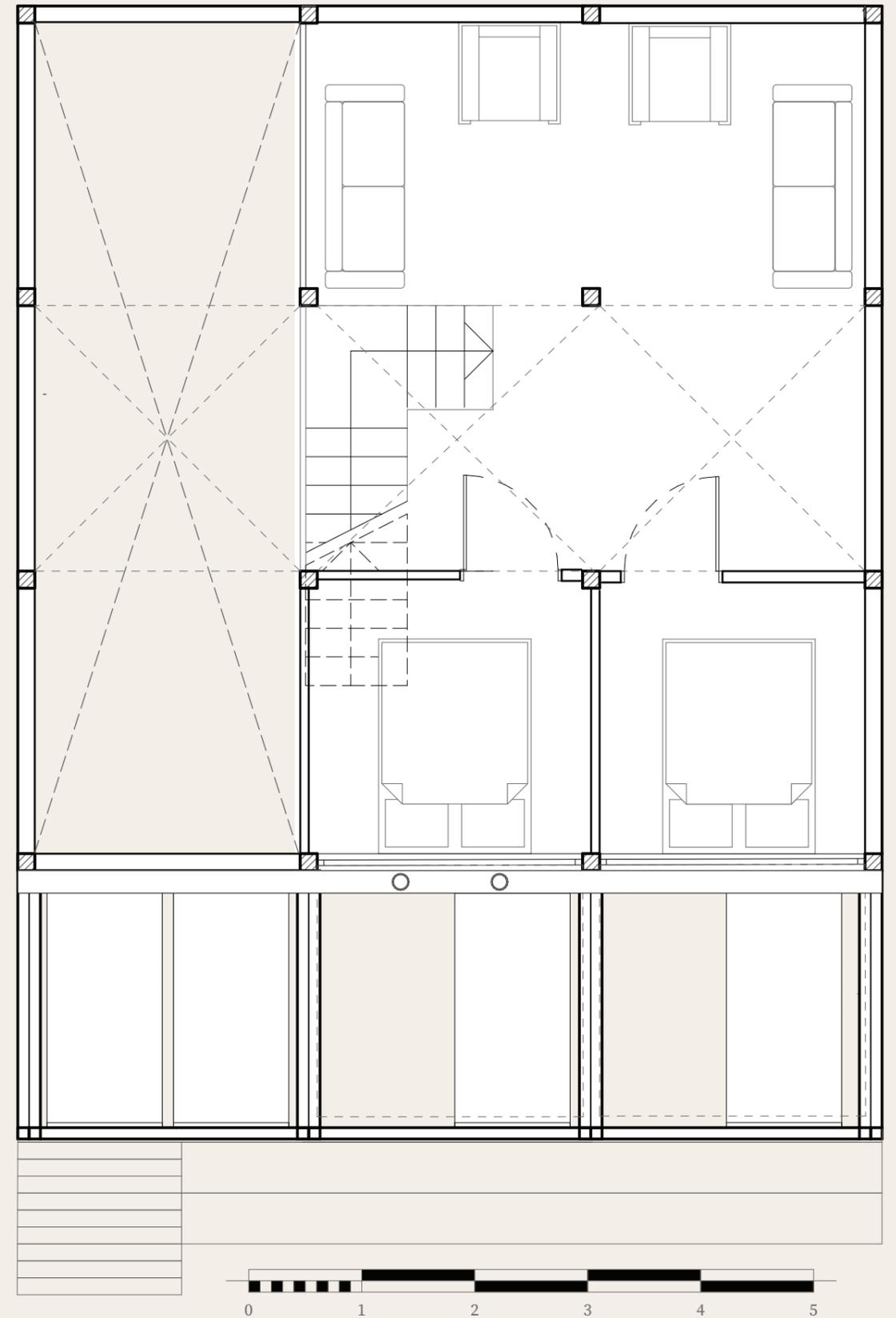
Design principles at a unit level

- Doors are chosen over windows as it is customary in Puerto Rico and allows for more ventilation
- A window on the ceiling is used to help with ventilation, and the social area is a double-height space.
- A framed, covered structure is placed to the front of the building to provide shading and encourage neighbours to socialise.
- Solar panels are added to each unit in case of a blackout.
- Rainwater is gathered in large tanks, and greywater is treated with banana filtration.
- A ground floor bedroom and an accessible toilet are always options for those who have experienced injuries.

Design



Ground floor 1:50



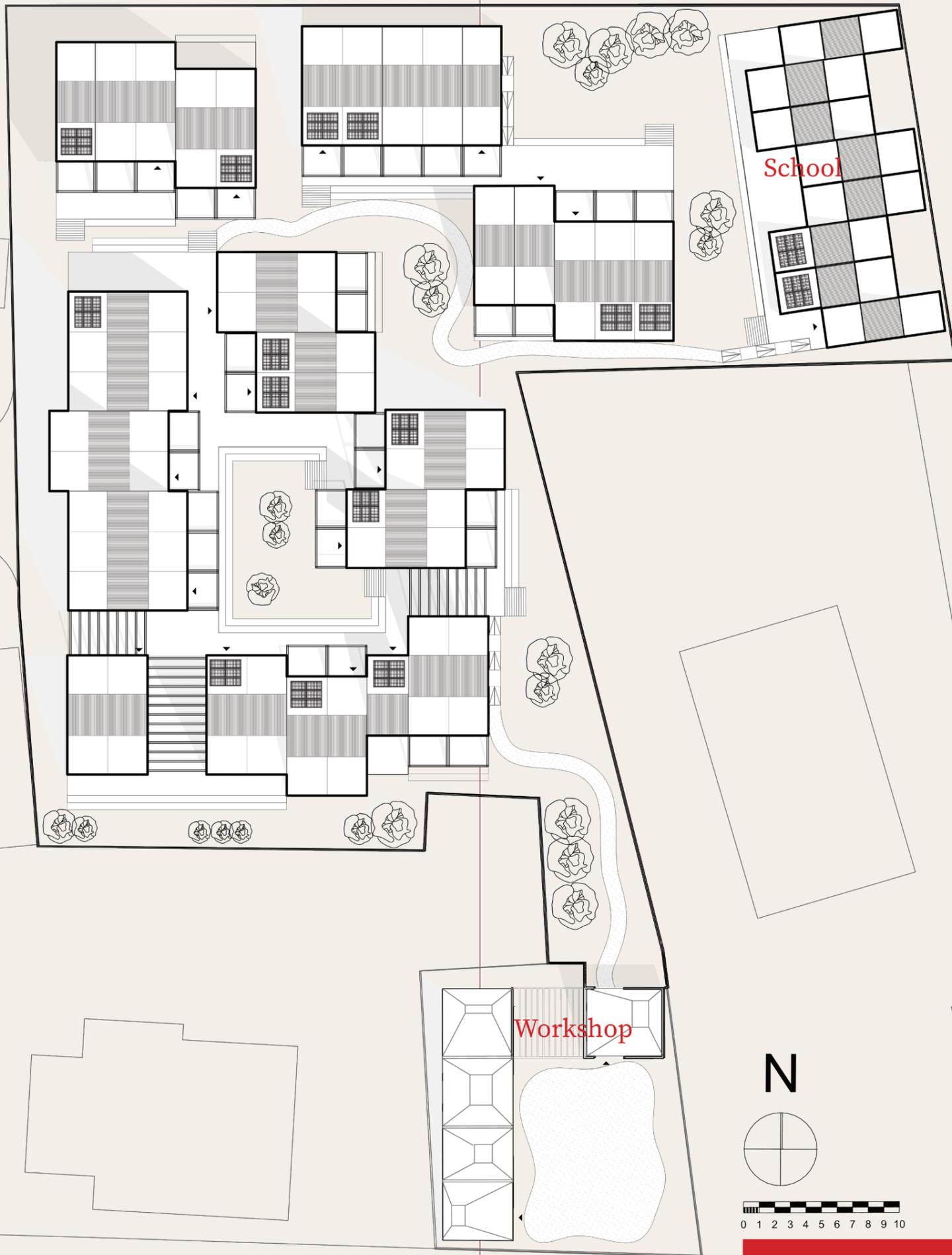
First floor 1:50

Shelter from the Storm

Shelter from the Storm

110

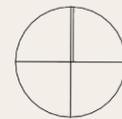
111



School

Workshop

N

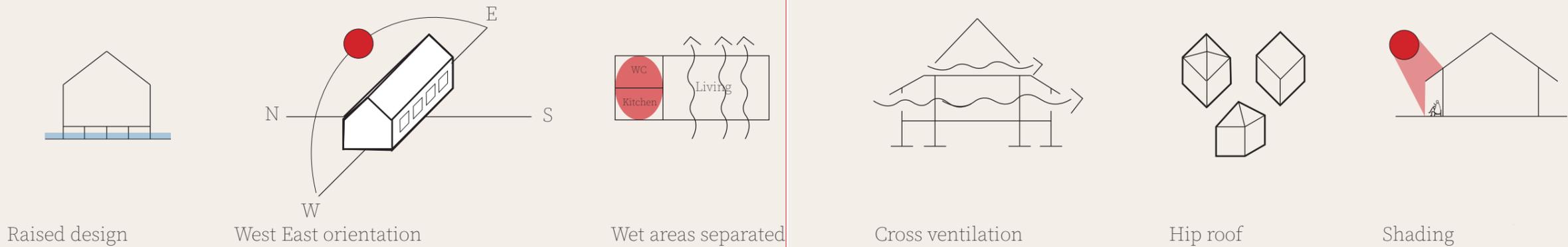
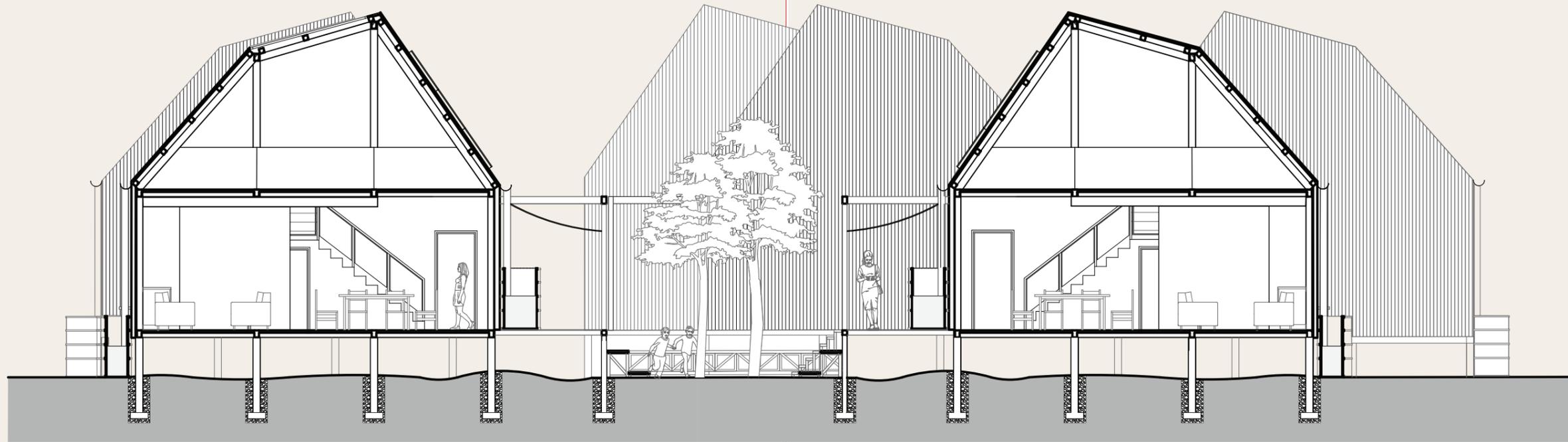


0 1 2 3 4 5 6 7 8 9 10

Site plan 1:300



5 - Community cross section and climatic design strategies



Community Cross section 1:100



116

Images of the community spaces

5 - Designing for women after a disaster



Outdoor lighting

Designing for women after a disaster

Some design features have been added to help women feel safe and be able to return to their daily lives. These features include:

- Walls for safety
- Outdoor lighting
- Daycare for children
- Outdoor social spaces like courtyards and patios
- Every space can be easily seen from the other units
- Ramps for injured people.
- Shaded spaces

Design



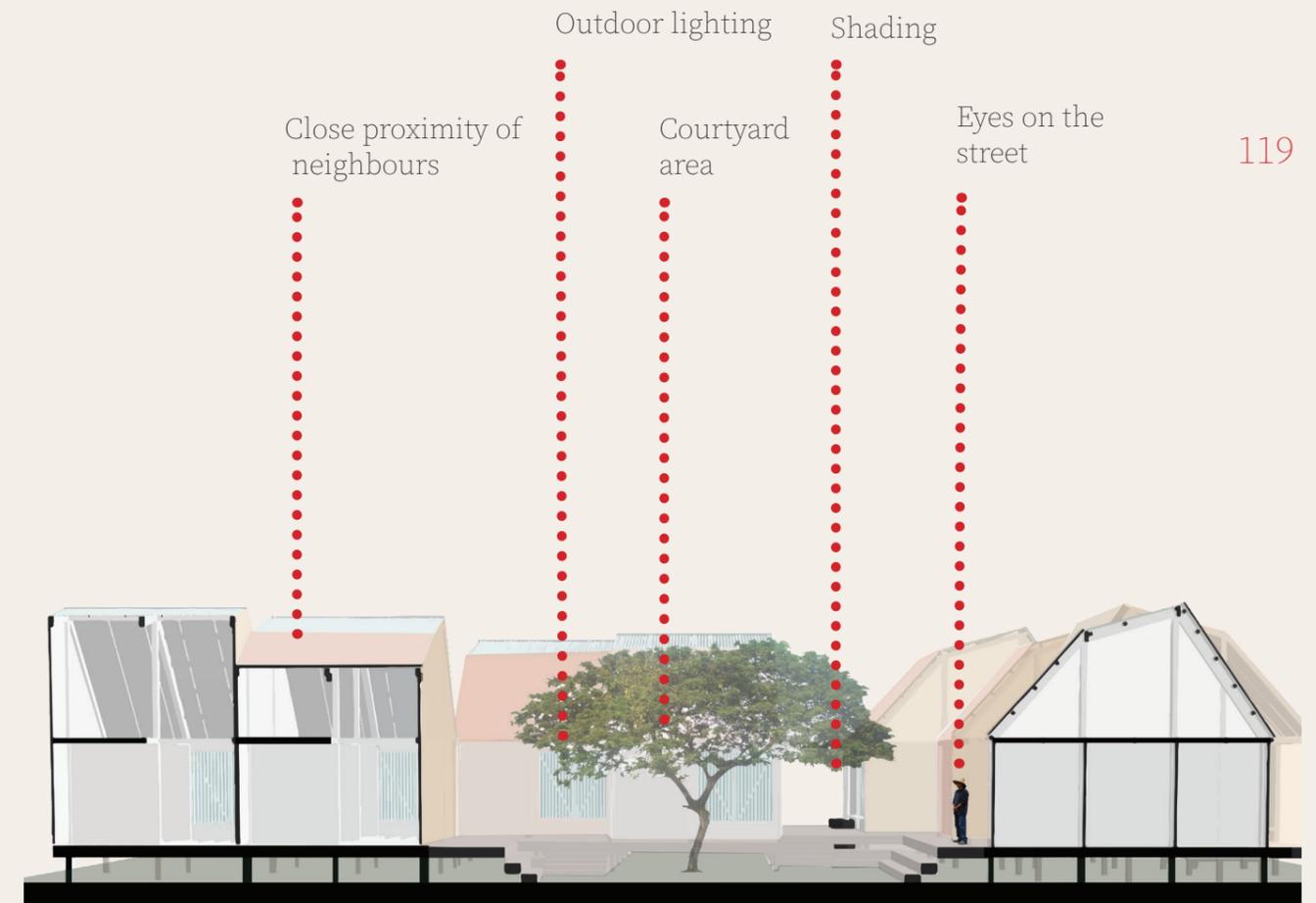
Entrance

### 5 - Community level design principles

The design features that I have tried to implement at a community level are, trying to always have eyes on the street to build a community for the people.

Creating pockets to add airflow and help keep the outdoor spaces breezy and inviting. Similarly to add shading so people can comfortably sit outside. This is done through trees and patios. Positioning buildings to increase the chances of interactions between neighbours.

Simple things like street lights are added for safety. Outdoor spaces are allowed for children to play in.



Community design section

Design



Workshop

### 5 - workshop design

A workshop has been added to the front of the site with the idea that it could make the design components ahead of time, and then they could be easily transported to the site or another site close by.

All materials are compact and can be transported by truck also if it is possible.

The workshop also makes the space behind more secluded, and users have to pass through the workshop to enter the site.

Materials that could be made in the workshop are processed wood, loam panels and recycled plastic elements.



Axonometric view

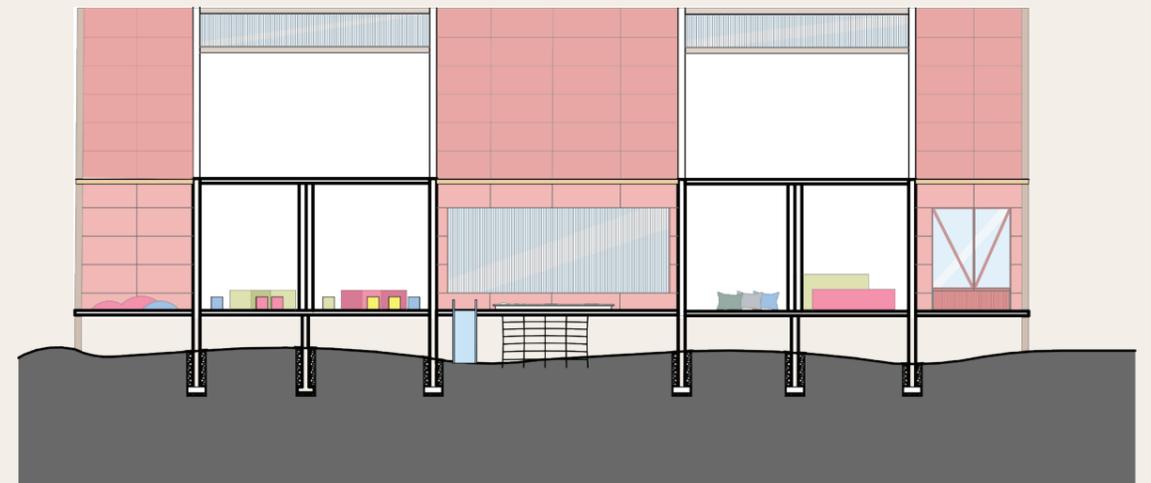
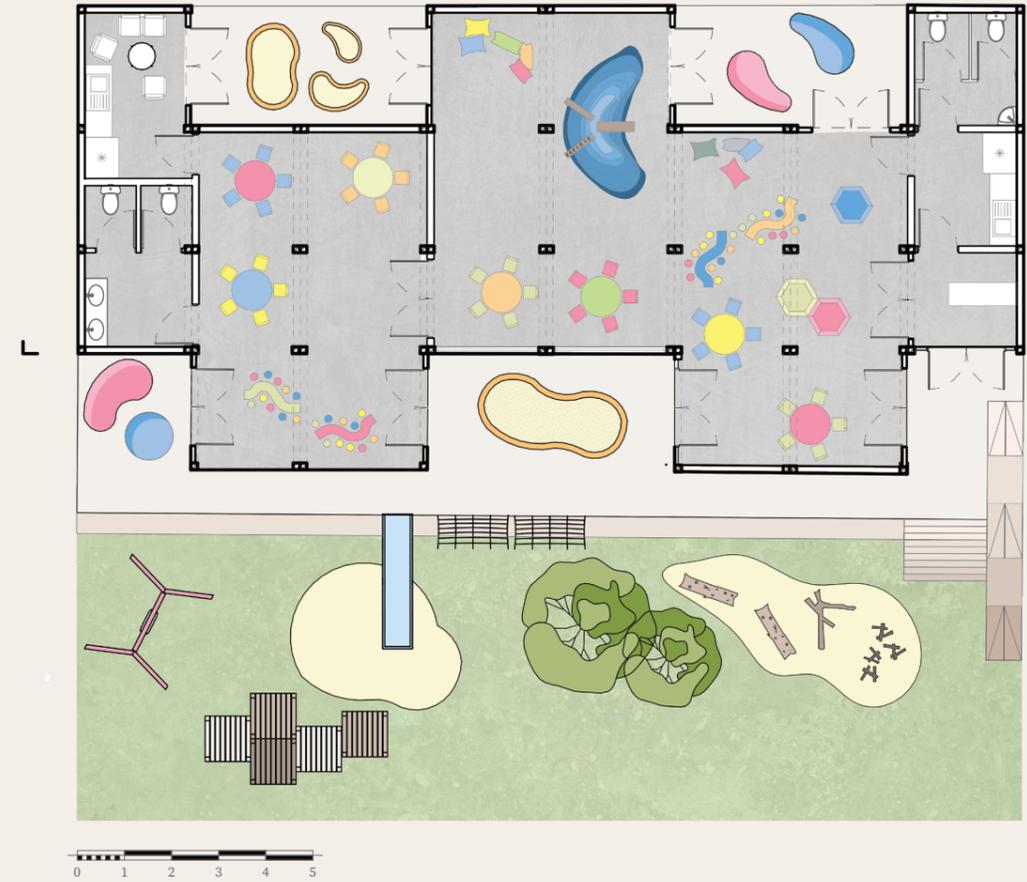
Design



School exterior

5 - School design

The units can also be combined and designed differently internally to create larger spaces. In this example, I have created a nursery school for young children using the structural grid.

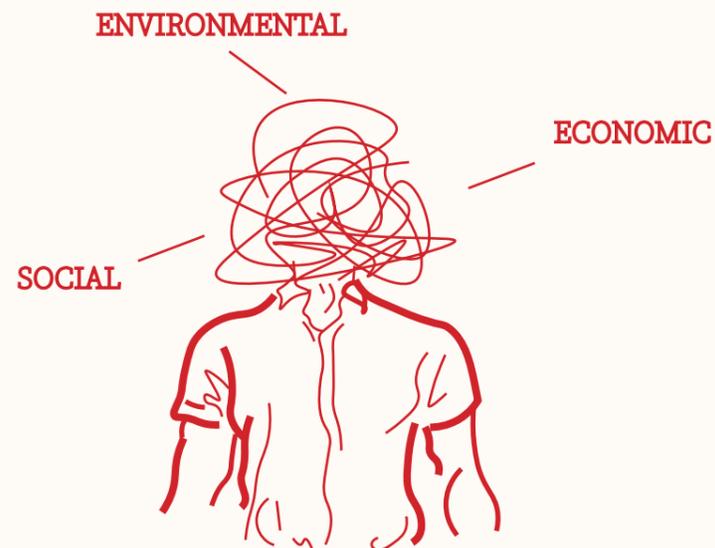


## Reflections

In the beginning of the process I wanted to investigate how temporary housing could be used to help people after disasters, how it could be improved and be more functional and efficient. However I quickly learnt that temporary housing has many problems and is not always the best answer. Yes, it has many advantages that can be used, such as prefabricated design and fast to build, though it usually becomes permanent and is not designed for such usage. Therefore it is important to design something with permanence in mind.

Another naivety that I initially had was the idea that something could be designed that would help in any post disaster scenario, anywhere in the world. I quickly realised that every location and every user has different needs and it is important to respond to them. I also feel that the project became much richer after I started looking at a specific place and figuring out what the needs were there.

I believe that it is vital to actually visit the site in order to get a true understanding of the context. As my project started with a very zoomed out approach and as travel was difficult during the time period because of covid19 restrictions I did not travel to the site. I think that to properly carry out this project a site visit would need to be made and alterations made accordingly.

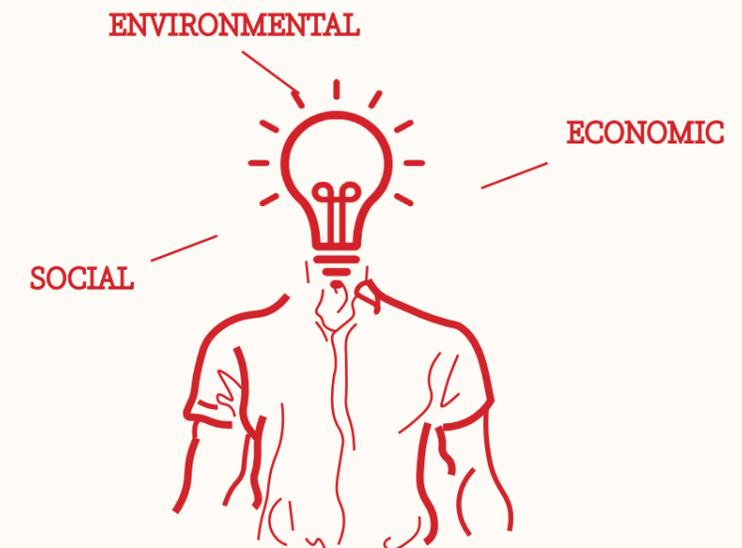


## Reflections

There are certain elements in the design that could be implemented in the future as sustainable practices. These elements could be materials used, as they are often renewable and sustainable and some systems used, such as banana filtration and solar panels.

When trying to create a sustainable design I encountered many challenges about how sustainable the project really is. I found that there are many factors to weigh up when considering sustainability, like if the design does not meet the user needs then it will not fulfill its purpose and is not sustainable. It is also not sustainable to use products that need to travel great distances to the site or to make a building that has so much embodied energy and a very short life span. Sometimes it is hard to determine how sustainable the design really is.

To summarise I still think that this topic is something that needs to be considered in the future of architecture, as the housing crisis is still very apparent and natural disasters are still occurring.



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## Abbreviations:

DCM          Disaster Crunch Model

DP            Displaced People

FEMA        US Federal Emergency Management Agency

GHG         Greenhouse gases

IPCC         Intergovernmental Panel on Climate Change

IPCC-LVI    Panel on Climate Changes Livelihood  
Vulnerability Index

TH:          Temporary Housing