REPORT

Niger environmental impact study of the emergency shelter models

October 2021

croix-rouge luxembourgeoise
Mënschen hëllefen

LUXEMBOURG AID & DEVELOPMENT

Contents

Acknowledgements

This study was commissioned by International Aid of Luxemburg Red Cross, and authored by Alicia Gimeno Blanco, independent consultant.

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1. Definitions

Allelopathy refers to a negative or positive effect on one type of plant by a chemical produced by another type of plant. When growing in harsh conditions, plants and trees have to compete for resources. In order to survive, sometimes the best defense is offence. Many trees and plants have evolved a defensive mechanism known as allelopathy, where they release inhibitory chemicals to suppress the development and growth of neighboring plants[1].

Carbon neutral means that any greenhouse gases (including but not limited to carbon dioxide) that are released into the atmosphere are balanced by an equivalent amount of greenhouse gases being removed.

Carbon offsetting a way to reduce emissions and to pursue carbon neutrality is to offset emissions made in one sector by reducing them somewhere else.[2]

Carbon positive means that an activity goes beyond achieving zero carbon emissions to create an environmental benefit by removing additional carbon dioxide from the atmosphere[3]

Carbon footprint is a term commonly used which refers to the total greenhouse gas emissions caused by an individual, event, organization, service, place or product, expressed as carbon dioxide equivalent (CO_2 equivalent)[4].

Climate change is a long-term shift in global or regional weather patterns. Usually, the term climate change refers specifically to the increase in global temperatures from the mid-20th century to the present[5].

CO_2 equivalent A carbon dioxide equivalent or CO_2 equivalent (a.k.a. CO_2 eq) is a metric measure used to compare the emissions from various greenhouse gases (GHGs) on the basis of their global-warming potential (GWP), by converting amounts of other gases to the equivalent amount of carbon dioxide with the same GWP[6].

Decompose is the process by which dead organic substances are broken down into simpler organic or inorganic matter such as carbon dioxide, water, simple sugars and mineral salts.[7]

Embodied carbon comes from the embodied energy consumed to extract, refine, process, transport and fabricate a material or product (including buildings). It is often measured from cradle to (factory) gate, cradle to site (of use), or cradle to grave (end of life). The embodied carbon footprint is therefore the amount of carbon (CO_2 or CO_2 emissions) which is generated in order to produce a material[8].

Environment refers to the physical, chemical, and biological surroundings in which communities live and develop their livelihoods. It provides the natural resources that sustain individuals and determines the quality of the surroundings in which they live[9].

Environmental Impact is defined as any change to the environment, whether adverse or beneficial[10], caused by a project, a process, an organism(s) and a product(s), from its conception to its end of life.

Environmental Performance Index (EPI) is a method of quantifying and numerically marking the environmental performance of a state's policies[11].

Environmental sustainability: A state in which the demands placed on the environment can be met without reducing its capacity to allow all people to live well, now and in the future. While environmental sustainability is broader than climate action, limiting climate and environmental impacts can both contribute to mitigating climate change, for instance by reducing emissions and greening practices, and to strengthening people's resilience to climate change[12].

1 *Deep Green Permaculture*
2 *European Parliament*
3 *Fast Company*
4 *Carbon Trust*
5 *National Geographic*
6 *Energy Manager Canada*
7 *Lynch, Michael D. J.; Neufeld, Josh D. (2015). "Ecology and exploration of the rare biosphere"*
8 *Circular Ecology*
9 *NSW Government*
10 *University of Calgary*
11 *Yale Center for Environmental Law & Policy, and Center for International Earth Science Information Network at Columbia University.*
12 *IFRC*

Global warming is the unusually rapid increase in Earth's average surface temperature over the past century primarily due to the greenhouse gas effect. Global warming is often described as the most recent example of climate change[13].

Greenhouse gas effect a natural phenomenon that causes a rise in the surface temperature of our planet.

Life cycle refers to the consecutive and interlinked stages of a product or service, from raw material acquisition or generation from natural resource, to design, production, transportation / delivery, use, end-of-life treatment and final disposal[14].

Life cycle assessment (LCA) is a method of evaluating the environmental impact associated with all stages of a product's life, i.e. from the extraction of raw materials, through materials processing, manufacturing, distribution, use, repair and maintenance, to disposal or recycling.

Waste any residue from a production, transformation or use process, any substance, material, product or, more generally, any movable asset disposed of or intended for disposal by its holder[15].

Waste management A set of operations involving the sorting, pre-collection, collection, transport, storage, recycling and disposal of waste, including the monitoring of disposal sites.

13 *NASA*
14 *ISO*
15 *https://assembly.coe.int*

2. General information

Project/mission title: Niger environmental impact study of the emergency shelter models

Country: Niger

Report date: October 2021

Type of operation: Remote consultancy

Requesting Organization: International Aid of the Luxembourg Red Cross

3. Context

Niger is one of the largest West African countries, 80% of its land lies in the Sahel dessert. It faces a complex humanitarian emergency marked by continued insecurity and violence against civilians perpetrated by armed groups, endemic poverty and the effects of extreme changes in weather patterns.

The Aide Internationale de la Croix-Rouge luxembourgeoise (AICRL) has been working for several years in the field of emergency shelter and sustainable housing in Niger, providing assistance to the population affected by the protracted crisis in the regions of Diffa, Marandi and Tillaberi.

AICRL collaborates closely with the IFRC Shelter Research Unit (IFRC-SRU) in the development of shelter models adapted to the climatic conditions and cultural contexts of the Sahel. Numerous research missions have made it possible to develop shelter models that take into account the specificities of the contexts and the availability of materials at the local level. In 2015 a storable shelter model, Diffa, was developed in order to be able to maintain contingency stocks for a faster response capacity, but also to strengthen the shelter response capacity in Niger.

In order to provide a context-specific shelter solution, in 2019 a variant of the Sahelian shelter model Diffa was developed in collaboration with beneficiaries and volunteers in the Tillaberi region. This variant is called the Tillaberi shelter and is characterised by the use of a cotton canvas sheet for the roof, instead of a plastic tarpaulin. The Nigerian Red Cross in partnership with the IFRC-SRU of the AI-CRL organised participatory workshops in 2017, 2019 and 2021 to improve and adapt these existing shelter solutions. This experience gained in the field and the feedback collected from targeted populations has helped to evolve the shelter models designed by AICRL and adopted by all humanitarian actors in Niger. However, one key factor has not been analysed in detail: the comparative environmental impact of the two shelter models (Diffa and Tillaberi). This is necessary in order to understand which option is best adapted to the Niger context, and is in line with the current global trend to improve the environmental sustainability of humanitarian assistance.

The change in weather patterns caused by global warming has happened faster over the past century. Natural disasters, such a floods, droughts, desertification, fires, etc, are increasing due to climate change, and they are contributing to food insecurity, economic losses, population displacements, and conflicts. Africa is already one of the continents most affected by climate change, even if is responsible for only 4% of the world's greenhouse gas emissions The frequency of heavy rainfall and storms has tripled in the Sahel since the 1980s[16]. The area of the Sahel desert has increased by 10% in the last 100 years[17].

Niger is considered one of the countries most at risk from further climate change, which exacerbates an already pronounced vulnerability. The region is continuously exposed to challenges related to recurrent seasonal floods, drought, water scarcity, desertification, rising temperatures, violent and dusty winds, destruction of thin vegetation cover, etc. These climatic changes have consequences including: land drying, loss of biodiversity, food insecurity, migration, flooding (loss of crops and animal species), silting of waterways, soil degradation, and erosion.

16 *World Meteorological Organization*
17 *University of Maryland*

Good environmental practices from humanitarian agencies can contribute to improve the resilience of communities to natural disasters, and reduce their vulnerability, as well as reducing the contribution made to further climate change. However, in the past a lack of consideration for the environment has led to humanitarian responses having a negative impact of the environment. For instance, huge quantities of relief items have been brought into a country, and local natural resources have been overused, without considering the consequences for the environment. Humanitarian agencies should not contribute to the degradation of the natural resources that affected communities rely on, and should take steps to mitigate climate change. The concept of 'do no harm' should also be extended to the environment. This comparative study of the environment impact of the Sahel Shelter models implemented in Niger is a contribution to the growing body of work on the environmental impact of humanitarian assistance.

4. Outcome and Outputs[18]

Outcome
With the support of the IFRC-SRU, AI-CRL seeks to improve the quality of the shelter response in Niger, and minimise the environmental impact of its operations.

Outputs
A comparative study of the Diffa and Tillaberi shelter models to assess the environmental impact of each model.
A comparative study between plastic and cotton tarpaulins from an environmental point of view.

The scope of this study is limited to the comparative environmental impact of the two shelter models. It does not include aspects relating to the preparation, construction and maintenance of the sites where the shelters were constructed, nor does it include factors relating to cost, functionality, and satisfaction of targeted populations etc. These have been well covered by previous evaluations of the Niger shelter projects.

5. Methodology

This study was conducted remotely, with the support of AICRL field staff (shelter, logistics, other); the Shelter and Non-Food Assets Working Group (SNAG) in Niger; environmental experts from the shelter and logistics sector: and a private waste management and recovery company in Niger[19].

The methodology adopted is summarized by the graphic below:

18 *As included in the Terms of Reference for this study.*
19 *Refer to Annex 2 to see the list of people and organisations contacted.*

Desk research and problem definition

- Literature review: programme documentation (including logistics/supply chain); environmental profile of Niger, etc. *(Refer to biblography).*
- Review of emerging best practice in life-cycle analysis / carbon footprinting tools for the Shelter sector.

Data collection

- Key informant interviews (semi-structured): Refer to Annex 2 to see the list of people and organisations contacted.
- A rapid field assessment of shelters was considered, but was not seen as necessary after reviewing the documentation and interviewing the project team.

Review SMAC tool

- Review the SMAC, a new carbon footprint calculation tool for the shelter sector.
- This study is one of the first to use the SMAC, and feedback has been shared with the developers of the tool to improve it.
- Extended engagement with the focal point for the Shelter Cluster Environmental Community of Practice, regarding using the SMAC.

Set Criteria

- Set criteria to compare the environmental impact of the shelter models:
  - (1) Materials consumed
  - (2) Carbon emissions (using the SMAC tool)
  - (3) Impact on local natural resources
  - (4) Waste management
- Score Card Approach

Analysis

- Comparison of the environmental impact of the two shelter models according to the four criteria, analysing each material across its lifecycle from production to disposal.
- Additional analysis comparing the two types of tarpaulins, plastic sheeting and cotton canvas, as standalone materials.
- Overall (qualitative) comparison using a score card approach

Report writing, conclusions and recommendations

6. Background information

6.1. Country profile[20]

NIGER

Location
The Republic of Niger is situated in West Africa, with parts of its 1,267,000 km^2 located within the Sahel and Sahara. Three-quarters of its terrain is desert.

Geography
Niger is bordered by Algeria and Libya to the north, Chad to the east, Nigeria and Benin to the south, while Burkina Faso and Mali are its western neighbors.

Population
24 million inhabitants (2020 data). The majority are concentrated in the southern part of the country, where the climate is more favorable for agricultural and pastoral activities.

Income
Classified as extremely low income, more than 10 million people live in extreme poverty, some 42.9% (2020) of the population.

Political situation
The country has been prone to political instability and security crises in recent years in the areas bordering Nigeria, Burkina Faso and Mali, where armed groups carry out attacks against the security forces and civilians.

Climate
Niger is one of the hottest regions of the world. The northern two-thirds of its territory lies in dry tropical desert. In the southern part of the country the climate is of the type known as Sahelian, which is a hot semi-arid climate. Temperatures rise from February to May and drop during the "winter" rainy season, rising again somewhat before falling to their annual minimum averages in December or January. In January and February the winds, known as the harmattan, blows southwestward from the Sahara toward the equator. The rains last from one to four months (June to September) according to the latitude; August is the rainy month everywhere except in the far north, where the rainfall is unpredictable[21].

Natural disaster
Niger is also prone to natural disasters such as droughts, floods, and locust infestations, all of which contribute to chronic food insecurity, conflict and population displacement.

20 *World Bank*
21 *Niger* | *Encyclopedia.com*

6.2. Environmental Challenges in Niger

Environmental Challenges[22]

Climate change
Niger is one of the countries in the world most affected by climate change. It is ranked 179 out of 180 countries in terms of environment challenges.[23]

Floods
Heavy rainfall has serious negative impact on agricultural productivity, loss of lives, and it is responsible for massive population displacement every year.

Desertification
Desertification in Niger is a progressive threat, 200,000 hectares are being lost each year. Around 65% of total land is affected by desertification. This is mainly caused by climatic variations and human activities, such as deforestation, extensive cultivation, overgrazing, cultivation of marginal land, bush burning, fuel wood extraction, faulty irrigation system and urbanization[24].

Deforestation
The high rate of urbanization, the industrial development, and agricultural processes led to deforestation and extinction of animals living in the forest.

Soil degradation
Pesticides and chemicals used by people for different purposes are degrading the soil.

Wind erosion
In the northern part of Nigeria, the land is constantly being eroded by the wind, due to little remaining vegetation cover.

Solid waste
The system of waste collection, storage, treatment and disposal is not well functioning.

Water pollution
Nigeria has a deficit of drinking water, and often the potable water available is polluted by industrial chemicals, like oxidizable nitrogen and bacteria from lack of sanitation facilities. Fecal pollution increases after the rainy season.

Air Pollution
The air quality in Niger is considered unsafe, Contributors to poor air quality in Niger include mining, petroleum, cement, and brick industries, Sahara Desert dust, and vehicle emissions.

Oil spills
Oil activities have led to poor water quality in the Niger Delta, negatively impacting on the mangrove ecosystem with extensive depletion of fish stocks in the region. Oil is found in the soil, even as deep as five meters from the surface.

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22 *www.legit.ng*
23 *According to the Environmental Performance Index (EPI) of Yale University*
24 *Desertification in Niger - Studymode*

6.3. Niger Shelter models

DIFFA

The Sahel Type Diffa is designed as an emergency to transitional shelter solution, adapted to the Diffa and Maradi regions[25].

Total area
22.10m

Occupancy
6 persons

Constructio
n time
4 hours

Cost
220 euros

Durability
12 months

Total Built
21,059

Dimensions
6.50m x 3.40m

Depth of excavation
Depending on the soil context with a minimum of 25cm depth to a maximum of 40cm for each pillar.

Structure (wall/roof)
The roof geometry is a dome shape created using arches fixed above the column heads. 12 steel tube columns with a minimum section of 30x30mm, e=1,3 mm. Additional use of triangulations in the walls to complete the structural system. The material used is semi-rigid PVC with d=32mm and e=2m.

Cladding walls
The walls are made of 14 palm doum mats of 1x2m directly sewn to the shelter structure.

Roof covering
The inner layer consists of 14 doum palm mats of 1x2m, sewn together, which cover the entire dome structure. The second layer consists of 2 IFRC tarpaulins of 4x6m.

Openings
The doors are made of 2 plastic mats sewn together.

25 *Please refer to Annex 3 to see the graphics of the shelter.*

TILLABERI

The shelter type Tillaberi is inspired by the Sahel shelter model, but adapted to the context of the Tillaberi region[26].

Total area
17.60m

Occupancy
5 persons

Constructio
n time
4 hours

Cost
135 euros

Durability
6 months

Total Built
1461

Dimensions
5.50m x 3.20m.

Depth of excavation
The depth of the excavation will be according to the soil context with a minimum depth of 25 cm for each pillar.

Structure (wall/roof)
There are twelve eucalyptus posts with a section of 6-8 cm.
The geometry of the roof is a dome shape created by arches attached to the heads of the posts. The material used is eucalyptus with a cross-section of 4 to 6 cm.

Cladding walls
The walls are made of 10 palm doum mats of 1x2 me, sewn directly onto the shelter structure.

Roof covering
The roof layer covering the dome structure is a waterproof cotton canvas sheet, 4x6m.

Openings
The door is made of two plastic matts according to the preferences of the beneficiaries.

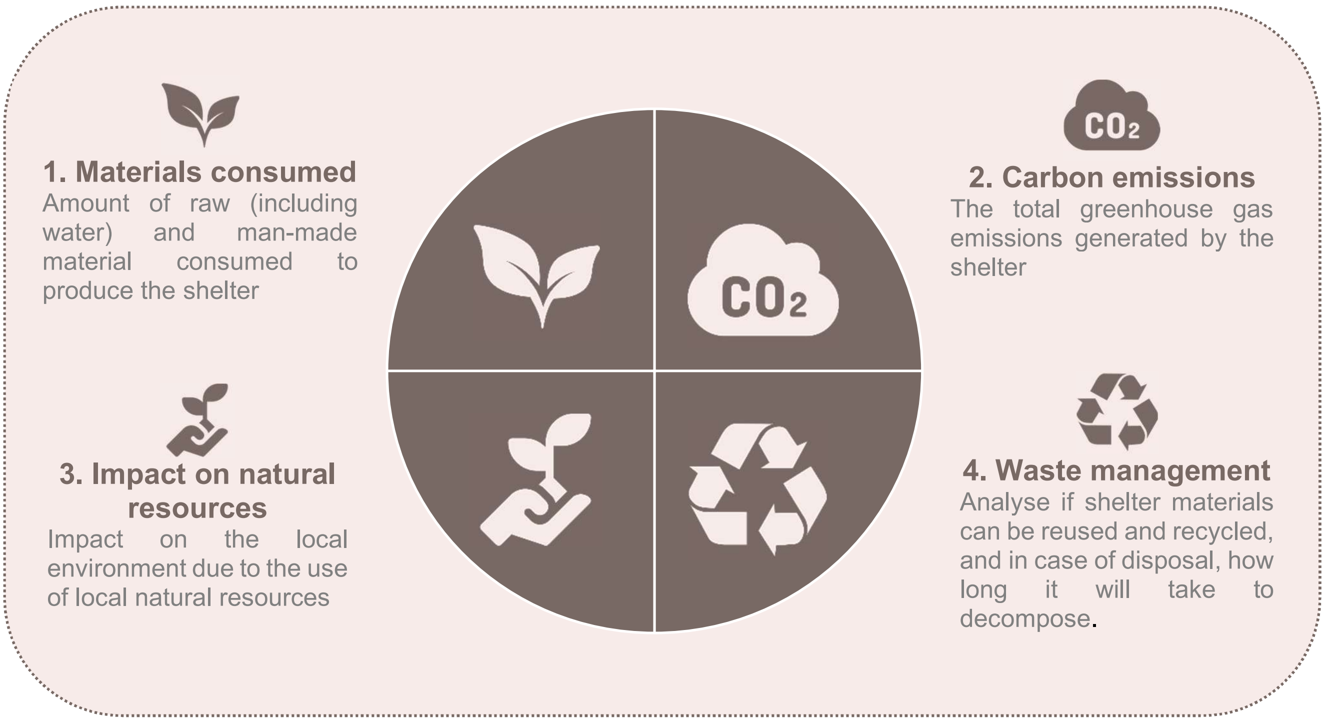
26 *Please refer to Annex 3 to see the graphics of the shelter.*

7. Criteria used to analyse environmental impact

To do the comparative study of the environmental impact of the two shelter models, each material must be analysed across its lifecycle, from production to disposal and end of life. The following criteria were selected to structure this analysis:

1. Materials consumed
2. Carbon emissions
3. Impact on local natural resources
4. Waste management

Each of these is explained in detail below.



7.1. Criteria 1; Materials consumed

The consumption of materials is calculated by taking into consideration the materials / resources needed to build one shelter. It does not reflect the materials / resources used for the preparation, construction and maintenance of the sites where the shelters were constructed. This includes two main groups of materials:

- Natural materials used (in kilograms or liters): any naturally sourced product or physical matter (water, timber, etc.).
- Man-made materials (in kilograms): any product or physical matter that goes through rigorous processing (steel, plastic, cotton canvas etc.).

Water consumption is calculated as an input for all the man-made materials used to build the shelter. The water consumed by the natural growth of trees (for eucalyptus wood) and vegetation (palm doum) is not considered.

Any other raw materials witch goes into the production of the man-made materials is not considered – since it is too complex and the data is not readily available.

7.2. Criteria 2; Carbon emissions

What is a carbon footprint?

A carbon footprint is the total greenhouse gas emissions caused by an individual, event, organization, service, place or product, expressed as carbon dioxide equivalent (CO_2 equivalent).

Life cycle analysis (LCA)

LCA is a commonly adopted methodology for quantifying carbon emissions and can be used to help compare shelter options. This 'cradle to grave' assessment evaluates the environmental impact of the shelter from extraction of raw materials to the end of its life. It is a good starting proxy for a quantitative approach to measuring the environmental footprint of the different shelter options.

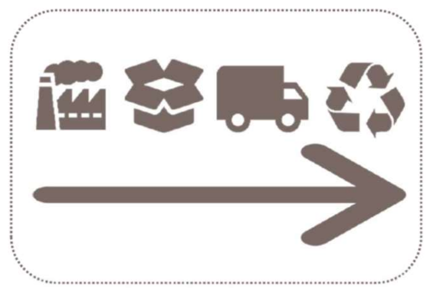
Using CO_2 equivalent doesn't cover the entirety of the complex issue of environmental impact, as there can be other more local impacts related to humanitarian shelter and settlement practices, but it provides a useful metric that can inform decision making.

Carbon calculator tool

The carbon calculator tool used in the study is the new SMAC[27] (Shelter Methodology for the Assessment of Carbon) tool. It calculates the CO_2 equivalent for most shelter designs and allows for the comparison of different shelter solutions in terms of their environmental impact for their entire life cycle.

SMAC allows for comparison of up to 4 different shelter types in terms of their embodied carbon equivalent emissions on the following criteria:

1. Production of the component materials
2. Packaging
3. Transport
4. End of Life



7.2.1. Data required to use SMAC

In order to use the tool and calculate a kg CO_2 equivalent figure for the two shelter options, the following data has been compiled:

- A list of the shelter components and materials
- The amount of each material used (in kg) for each shelter
- The type of packaging used for the materials
- The amount of each packaging material used (in kg) for each shelter
- The transportation distances and modes from point of source of materials to point of use and disposal (there is further guidance in the tool on this if accurate distances are not known).

i) Shelter components and packaging materials

The amount (in kgs) of each raw material used in every shelter component is required.

Refer to Annex 4 to find the information regarding shelter material and quantity in kilos, packaging components, and origin of the material used in the calculation. All this information was provided by the AICRL team in country, except the quantity in kilos of the packaging which was not known, so this data is not included in the calculation.

27. *SMAC It is a simplified LCA methodology, developed by BRE Trust, the Global Shelter Cluster Environment Community of Practice, and WWF, based on components of shelter options that use CO_2 equivalent emissions as a metric for assessment. Information on SMAC can be found at https://www.sheltercluster.org/community-of-practice/environment*
This study is one of the first to use the SMAC tool, and feedback has been shared with the developers to improve it.

ii) Transportation

When calculating the CO^2 equivalent, one of the key factors it is the origin of the materials, since transportation can make a big contribution to carbon emissions. Whether a material has been purchased locally or imported, transported from a neighboring country by road, or produced in a distant country and transported by sea or air, will have a material impact on total carbon emissions.

To calculate the transportation distance, the following distances in kilometers for each product are required.

- Country of origin to point of arrival in country
- Point of arrival to warehouse / store
- Warehouse to construction site
- Construction site to disposal site
- Type of transport used for each phase (truck/road, train, sea or air)

Calculating transport distances

The origin of certain products used in the shelters varies depending on availability and the cost. For instance, one supplier would source one material from three different factories based in three different countries depending on availability and price at the time of purchasing.

For the purpose of this study, since the exact travel distance and the exact location of each factory are not known, average transport distances have been estimated and can be found in Annex 5 The following assumptions have been made:

- The tool and the analysis here does not include any transportation that may have occurred earlier in the supply chain, for example if part of a product is manufactured in one country and then shipped to another country where production is completed, from where the programme purchases it. The data is not available to include this, and the complexity of such analysis is beyond the scope of the SMAC tool.
- For each of the countries where supplies were purchased, the capital city was used as a departure point, acknowledging that materials could have come from other locations.
- When one material could come from different countries or locations, the average distance has been used.
- All the imported material goes first to Niamey before being delivered to the respective warehouse elsewhere in Niger. Acknowledging that some materials are delivered directly to the warehouse, but the exact information is not available.
- The distances in kilometers have been calculated using Google Maps.
- Regarding the Diffa model, since the shelter type has been built in two different locations (Diffa and Maradi), the total distance has been calculated considering that 95% of the total shelters have been built at Diffa and 5% in Maradi.
- All materials have been transported by road (as per information provided by the suppliers), except the plastic sheeting that came by boat from China to Cote d'Ivore and then by road to Niger, as per information from ICRCs logistics team.
- Since the exact location of the Chinese factory wasn't available, the suggested approximate distance baseline provided by the SMAC guidelines from Asia to West Africa has been used: 19,000 kilometers.
- Since we don't know exactly what happens with disposal, transportation from the site of construction of the shelters for disposal is not included.

Regarding the comparison between the two types of tarpaulins:

- Since the objective is to compare both as standalone materials, and not as used in the two shelter models, the same construction locations for both, Tillaberi, have been assumed. Even though one material is used only in Diffa and Maradi, and the other in Tillaberi.
- In the cotton canvas calculation only the country of manufacturing (Morocco, Algeria and Tunisia) is included, and not the production location, since this information was not available.

iii) End of life

SMAC uses assumptions about the level of recycling and CO^2 eq release at end of life based on standard construction practices.

7.2.2. Limitations of the SMAC carbon calculator tool

One of the limitations of the SMAC relates to the types of materials included in the database [28] used by the tool. It was not possible to find Environmental Product Declarations (EPD) for all possible shelter materials that are used in humanitarian operations. As a result, it uses similar materials when the precise material it was not listed in SMAC's drop-down lists (for example, thatch was selected instead of palm doum tree actually used in Niger). Similarly, assumptions are made in the SMAC relating to end of life (recycling options and level of CO^2 released from disposal), where the best data available was used. However, the developers of the SMAC consider both of these limitations to be acceptable, in line with what they term a "good enough approach".

Also, the SMAC tool uses approximate, best fit, materials for the CO^2 eq numbers. So, CO^2 eq numbers developed directly for a specific material produced in a specific location would generate more accurate results. However, this still not likely to change the overall broad result.

7.3. Criteria 3; Impact on local natural resources

Going beyond the carbon emissions measured by CO^2 equivalent, which is only one measure of environmental impact, this section looks at impacts on the local environment due to the use of local natural resources. It is important to analyse whether the production or harvesting of natural resources could be causing environmental harm.

For instance, while carbon emissions analysis may indicate that importing wood generates greater emissions than procurement of locally available wood, this local procurement could result in excessive local tree cutting and damage to the environment. Another example is where using locally sourced straw to roof one house is not an environmental issue, however 1,000 houses may pose some stress on the local eco-system, while roofing 10,000 houses every year could create a major issue in the local area.

The following factors are considered: Deforestation and vegetation removal, aletophyte effects, soil erosion, and degradation of water quality.

Two environmental organizations[29] who specialize in the protection of forests and ecosystems in Niger and the region were contacted without success. So literature review[30] and feedback from the project team has been considered for this analysis.

7.4. Criteria 4; Waste Management

One of the challenges of humanitarian action is that more end-to-end thinking about waste isn't common in the largely 'truck and chuck' humanitarian reality. All through the project cycle, any organisation that imports, produces, transports, or generates waste in some way, must think of the waste management implications. The ultimate goal is to generate the minimum amount of waste and extract the maximum benefit from products.
This section studies if the life cycle of the shelter materials can be prolonged by reusing and recycling, and in case of disposal, how long it will take to decompose.

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28 The data from the tool has been taken from the Inventory of Carbon and Energy (ICE database), as well as from various environmental product declarations (EPD, such as those found in Eco Platform and Greenbooklive). The ICE database is a collation of aggregated and EPDs. Where data did not exist in ICE, and one EPD was available, that data point was used. Where several EPDs were available, an average was used. All data sources have been referenced within the tool. Data for packaging, end of life and recycled content have been sourced from BRE.
29 Refer to Annex 2
30 Refer to biography

Waste hierarchy

Reduce, Reuse, Recycle: Commonly referred to as the "3 R's" of the waste hierarchy. Reduce means to minimise the amount of waste we create. Reuse refers to using items more than once. Recycle means putting a product to a new use instead of throwing it away. The full waste hierarchy is usually characterised as: Reduce/Prevent; Reuse; Recycle; Recover; Disposal[31]. The different options (in order of preference) are in the illustration.

The levels indicate the progressive order of actions to take to reduce waste. We should spend more energy on the more significant layers at the top of the chart, like redesigning, reducing, and reusing. And we want to minimize the activities at the bottom, like residual management or landfill.

A local private startup that specialises in ecological recycling and waste recovery, and a private waste management and recovery company in Niger, GVD Afrique, were contacted to enquire about waste management in the country.

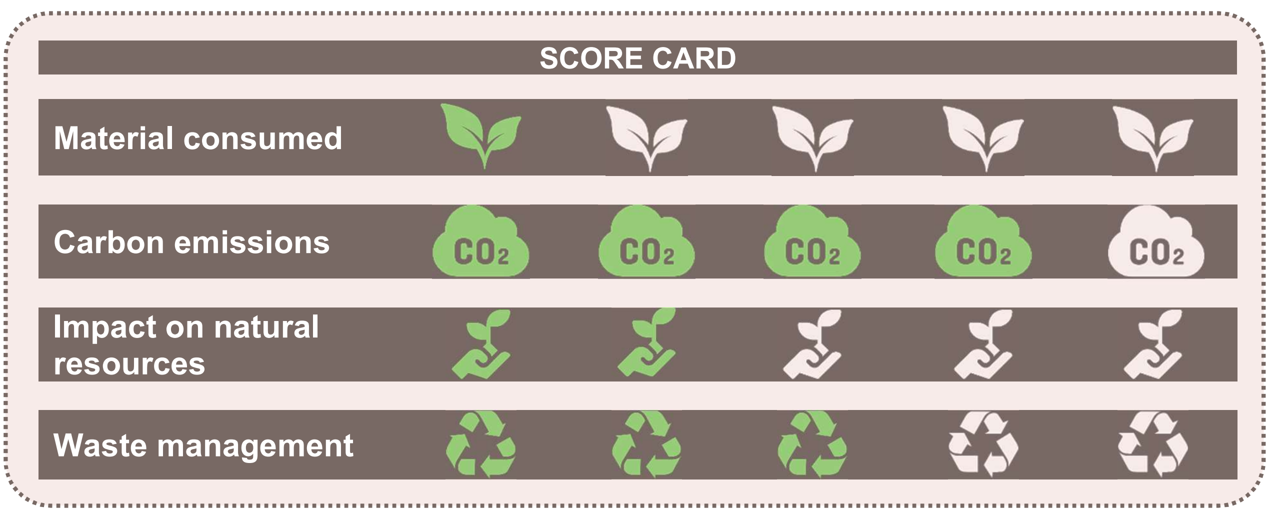
7.5. Score card approach

A simple 'score card' approach is used to compare the two shelter models across the four criteria. This recognises that carbon emissions, while being critical, are not the only factor. A score card also recognises the challenge in applying any kind of numerical weighting for the four categories in order to arrive at a calculated score. This would require too many assumptions on the relative weight of each category. Instead, a qualitative conclusion will be made based on the score card.

While acknowledging the methodological limitations of this approach, it is the only feasible option in the limited scope and time allotted to this study. A score card highlights in a simple way what the main environmental issues are for each shelter, thus identifying where mitigating solutions could help to improve the overall environmental impact of the shelter models.

Both shelter models, and both types of tarpaulins, will be scored from 1 to 5 against each of the criteria, to enable comparison.

Example of the score card (noting that a higher score means less environmental impact):



1 poor, 2 average, 3 medium, 4 good, 5 very good

31 *EU Commission, 2014*

8. Comparison of environmental impact of the shelter models

8.1. Criteria 1: Materials consumed

8.1.1. Overview of the materials used and their general impact on the environment

Plastic Is the term commonly used to describe a wide range of synthetic or semi-synthetic materials that are used in a huge and growing range of applications[32]. Half of all plastics ever manufactured have been made in the last 15 years. Only in 2020, 367 million tons were produced and is expected to double by 2050.

Types of plastics used in the shelter model

Polyethylene; The poly tarpaulin was invented in 1932. Because polyethylene is such a versatile material, it became the most widely used type of plastic in the market, almost everything from shopping bags to plastic containers is made from it.

PVC[33] ; Polyvinyl Chloride plastic is the world's third most common plastic. As it is inexpensive, durable, strong, and chemically and biologically resistant, as well as easy to install and replace. It is widely used in packaging, home furnishings, children's toys, building materials, etc. It is the single most environmentally damaging of all plastics.

Nylon[34] ; Is composed of polyamides, it is a silk-like thermoplastic generally made from petroleum, that can be melt-processed into fibers, films, or shapes. It was the first fabric made entirely in a laboratory. It became widely available to the general public around the time of World War II, thanks to its strength and durability.

General environmental impacts

Greenhouse effect; the use of fossil fuels and other chemicals in the production of these products is a key contributor to the global warming crisis. Plastic production and incineration currently account for 3.8% of carbon emissions and is estimated to be responsible for 13% by 2050. In 2019 alone 850 million metric tons of carbon dioxide equivalent was released into the atmosphere due to plastic[35].

Ocean contamination; 10 percent of this plastic ends up in the ocean[36]. By 2050, the world's oceans will contain more plastic than fish (by weight) if current trends continue.

Harm to wildlife; Plastics harm fish, plants, wildlife and the natural environment by leaching toxins into soil, water and air. They poison, injure and kill wildlife[37].

32 *www.aquapakpolymers.com*
33 *www.greenpeace.org*
34 *https://goodonyou.eco*
35 *Center for International environmental law.*
36 *Green Peace*
37 *Stopplastic.ca*

Steel is an alloy (a metal combined with two or more metallic elements) made up of iron and a percent of carbon, to improve its strength and fracture resistance. Other elements may be present or added. Iron is the world's third most produced commodity by volume - after crude oil and coal. Over 2,000 million tons of iron is mined a year - about 95 percent is used by the steel industry[38].

General environmental impacts[39]

Energy consuming; Production of steel is the most energy-consuming in the world.

Pollution; Steel production requires large inputs of coke (a type of coal) which is extremely damaging to the environment. Coke ovens emit air pollution highly toxic and can cause cancer. Wastewater from the coking process is also highly toxic and contains a number of carcinogenic organic compounds.

Greenhouse effect; Steel production is responsible for the emission of 3,3 million tons of CO_2 annually[40]

Cotton is a natural plant fiber which grows around the seed of the cotton plant. Cotton fibers are the starting point of the production chain for the textile industry.

General environmental impacts[40]

Water consumption; Cotton's most dramatic negative impact is on water availability. It takes 10,000 liters of water to produce one kilogram of cotton. Global cotton production requires over 250 billion tons of water annually.

Chemical pollution; Cotton is the crop most heavily sprayed with chemicals in the world. Hazardous pesticides commonly used for cotton production are often found in nearby water resources.

Soil degradation; Cotton cultivation also causes soil degradation and erosion as well as loss of forest area and other habitat.

Greenhouse effect; Cotton production is responsible for the emission of 220 million tons of CO_2 annually[40].

38 *The world counts*
39 *The world counts*
40 *The world counts*

Doum palm tree Hyphaene thebaica, with common name doum palm is a type of palm tree, Individuals can grow to 25 m[41]. It is a native to the Arabian Peninsula and also to the northern half and western part of Africa[42] where it is widely distributed and tends to grow in places where groundwater is present. Most of its parts are used by local people, but specially the leaves to make mats for walls and roofs of housing.

General environmental impacts[43]

Soil fertility; Palm trees promote soil fertility.

Wind erosion; Palm trees fight against wind erosion and the desertification

Eucalyptus is an ever-green tree native to Australia. It is widely planted in different parts of the world, integrated into various farming systems. It is commonly cultivated as a monocultural crop in short rotations of 3 years for biomass crops and 6 or more for timber use. It is a highly profitable forestry crop.

General environmental impacts[44]

Water consumption; Growing eucalyptus in low rainfall areas may cause adverse environmental impacts due to competition for water with other species.

Soil erosion; Short rotations and intensive management practices, result in soil compaction, soil erosion, and other adverse effects.

Pollution; Due to the use of fertilizers, weedicides and pesticides, and fire hazards.

Soil nutrient; When is grown as a short rotation crop for high biomass production and removal, soil nutrients are exhausted rapidly.

41 *www.eol.org*
42 *World Check List of Selected Plant Families (WCSP). Kew Sciences.*
43 *Valoriser les produits du palmier doum pour gérer durablement le système agroforestier d'une vallée sahélienne du Niger et éviter sa desertification. Régis Peltier, Claudine Serre Duhem et Aboubacar Ichaou*
44 *Silviculture of eucalyptus plantings – Learning in the region. K.J. WHITE. FAO*

Water covers 70% of our planet, however, only 3% of the world's water is fresh water[45]. Billions of people worldwide lack access to water. Water is at the core of sustainable development and is critical for socio-economic development, healthy ecosystems and for human survival itself[46].

Environmental impacts

Water shortage; Water shortages are likely to be the key environmental challenge of this century [47]. More than half the world's wetlands have disappeared. Many of the water systems that keep ecosystems thriving and feed a growing human population have become stressed. Rivers, lakes and aquifers are drying up.

Agriculture; consumes more water than any other source, 70% of the world's accessible freshwater, and wastes 60% of it, much of that through inefficiencies due to leaky irrigation systems, inefficient application methods as well as the cultivation of crops that are too thirsty for the environment in which they are grown[48].

Water pollution; comes from many sources including pesticides and fertilizers that wash away from farms, untreated human wastewater, and industrial waste[49].

Climate change; is altering patterns of weather and water around the world, causing shortages and droughts in some areas and floods in others[49].

8.1.2. Data and analysis of the materials in the shelters

Below are the tables of each of the materials used in each of the shelter model, by wieght (kilograms). These numbers have been provided by the AI-CRL logistics team in Niger.

Water consumption is calculated for all the man-made materials used to build the shelter. The water consumed by natural growth of the eucalyptus and the palm doum is not considered. To calculate the water in liters, the following baseline data have been used:

- Production of 1 kilo of plastic requires 17 liters of water[50]
- 1 kilo of steel takes 705 liter of water[51]
- 1 kilo of cotton takes 10,000 liter of water[52]

DIFFA- Table 1

Raw material	
Doum palm tree	60 kilos
Water consuption	20,898 liters

Manmade material	
Steel pole	22.5 kilos
PVC pole	36.4 kilos

TILLABERI – Table 2

Raw material	
Doum palm tree	20 kilos
Ecualyptus wood	61 kilos
Water consuption	136,264 liters

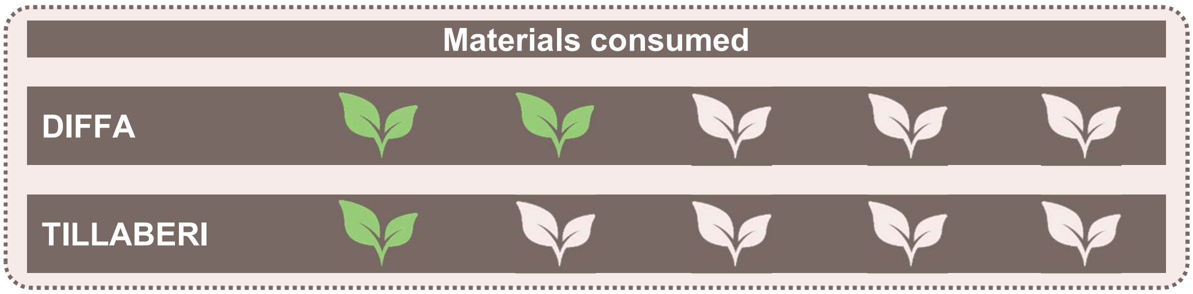
Manmade material	
Cotton canvas	13.2 kilos
Plastic mats	2 kilos

45 *WWF*
46 *www.un.org/waterforlifedecade*
47 *NASA*
48 *University of Dundee*
49 *WWF*
50 *Shelter and Sustainability, UNHCR, 2021*
51 *Shelter and Sustainability, UNHCR, 2021*
52 *www.theworldcounts.org*

Plastic sheeting	9 kilos
Plastic mats	2 kilos
Nylon rope	0.5 kilos
Wire	6 kilos
Thread	0.04 kilos

Nylon rope	0.5 kilos
Wire	6 kilos
Thread	0.04 kilos

8.1.1. Interpretation of the results
In the score card, Diffa model scores 2 out of 5, and Tillaberi 1 out of 5.



1 poor, 2 average, 3 medium, 4 good, 5 very good

The Diffa model used higher amount of manmade material, especially steel and plastic. However, Tillaberi model consumed a large amount of water compared to Diffa, the difference is significant, 20,898 liters vs 136,264 liters, and is due to the production of cotton for the canvas sheet.

Both scores could be improved by reducing the amount of materials, especially plastic, steel and PVC, without compromising the functionality. In the case of Tillaberi, it could be improved in the future by using a different natural material for the canvas instead of cotton, or to decrease the amount in kilos by using a lighter cotton canvas However, another natural material could be more costly. For instance, organic cotton, which consumes only 10% of the water that normal cotton does, costs around 20% to 30% more.

8.2. Criteria 2; Carbon emissions
Below are the total carbon emissions for each shelter model, in CO_2 equivalent, using the SMAC calculator and taking into account all the parameters explained above in section 7.2.

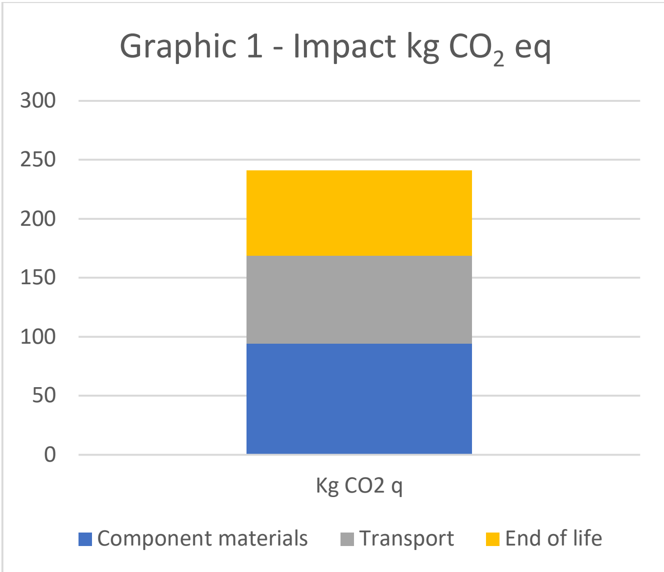
8.2.1. Diffa Model
The follow tables (3 & 4) and graphics (1 & 2) show the breakdown of the carbon emissions, in terms of Kg CO_2 eq and relative % CO_2 eq, of the shelter unit per life cycle stage (production of the component material, transport and end of life, packaging is not included as information was not available).

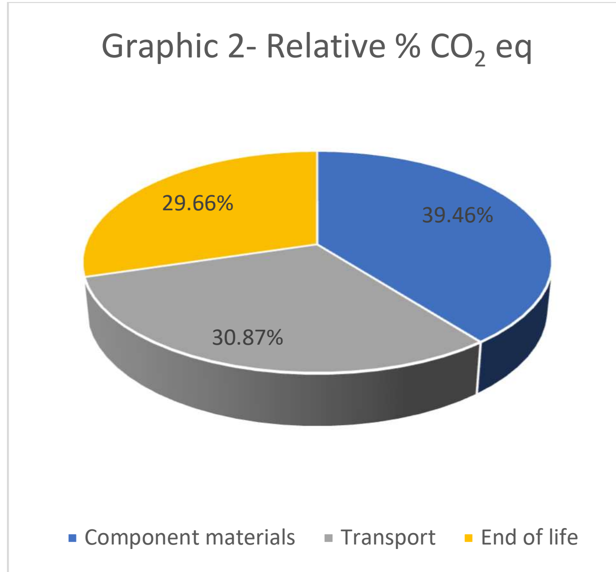
Table 3

Impact	Carbon Emissions Kg CO_2 eq
Production of component material	95.09
Packeting	*Data not available*
Transport	74.39
End of life	71.48
Total	**240.96**

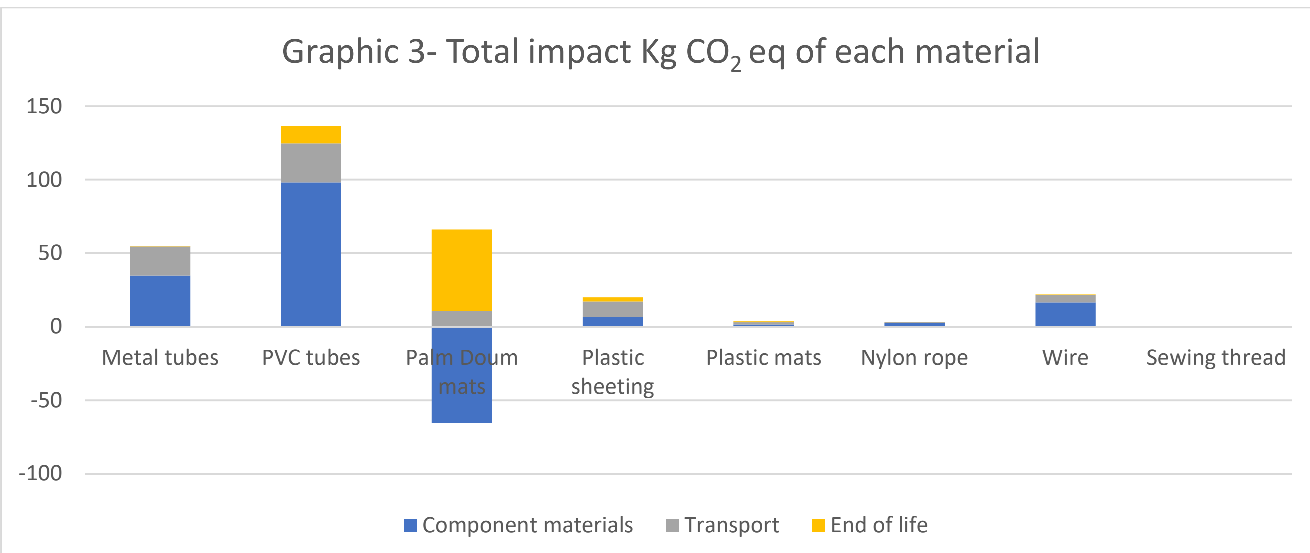
Table 4

Impact	Relative % CO_2 eq
Production of component material	39.49%
Packeting	*Data not available*
Transport	30.87%
End of life	29.66%
Total	**100%**

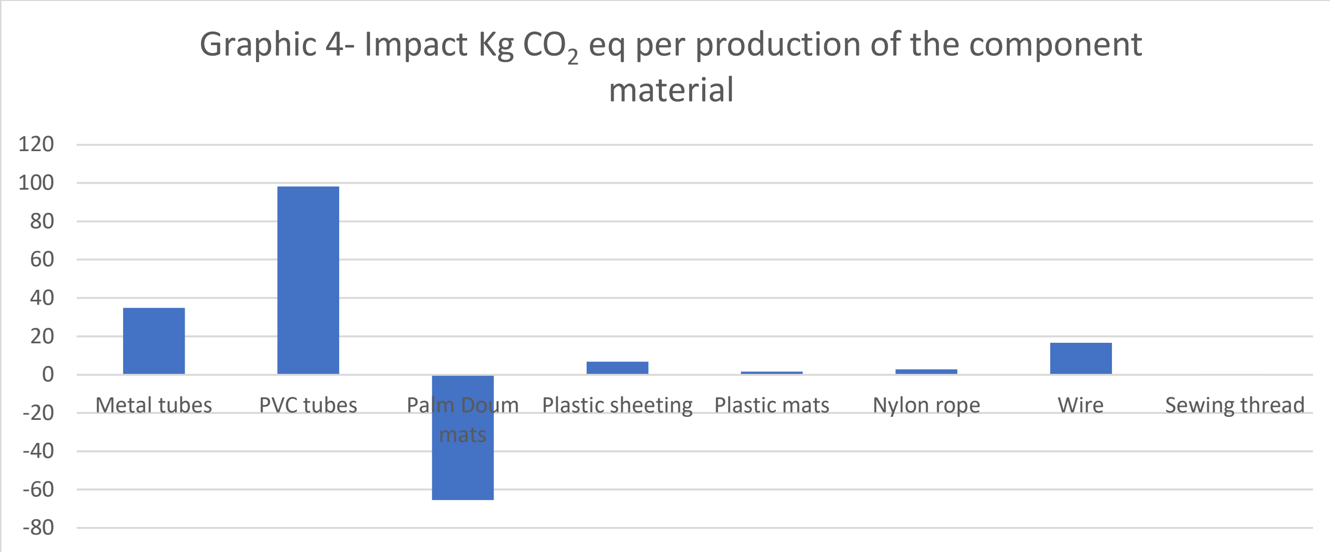


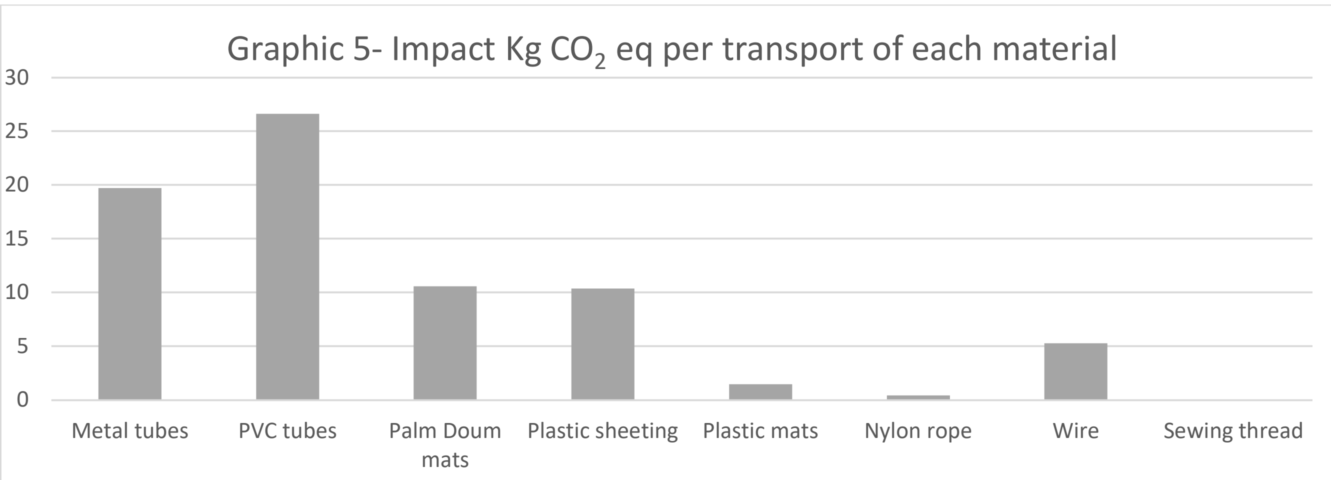


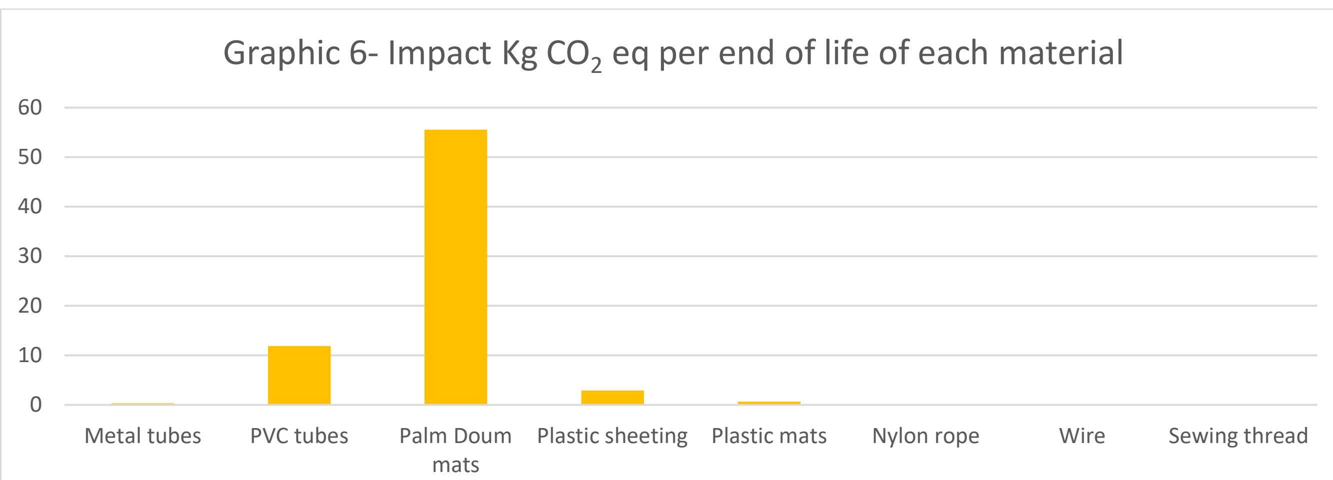
The follow graphic 3 show the total Kg CO_2 eq impact of each material, broken down into the emissions generated by production of the component materials, transport and end of life.



The following graphics 4, 5, and 6 show the Kg CO_2 eq emissions for each material, first for the production of the component materials, then for transport, and finally for end of life. This additional analysis helps to see, for each material, at which stage of the life cycle most emissions come from.


Graphic 4- Impact Kg CO_2 eq per production of the component material
120
100
80
60
40
20
0
-20
-40
-60
-80
Metal tubes
PVC tubes
Palm Doum mats
Plastic sheeting
Plastic mats
Nylon rope
Wire
Sewing thread


Graphic 5- Impact Kg CO_2 eq per transport of each material
30
25
20
15
10
5
0
Metal tubes
PVC tubes
Palm Doum mats
Plastic sheeting
Plastic mats
Nylon rope
Wire
Sewing thread


Graphic 6- Impact Kg CO_2 eq per end of life of each material
60
50
40
30
20
10
0
Metal tubes
PVC tubes
Palm Doum mats
Plastic sheeting
Plastic mats
Nylon rope
Wire
Sewing thread

8.2.2. Interpretation of the result for Diffa model

As per graphics 1 & 2, the biggest impact on carbon emissions is due to the production of the component materials used, followed by transport and end of life, however, the difference between the last two is relatively small.

When looking into each of the materials, (graphic 3) we can see that the PVC is the one that has the biggest impact followed by palm doum mats and steel tubes.

As per graphic 4, 5 & 6, most of the emissions from the PVC come from the production of the component material and transport. However, when looking into the palm doum mats, the production of the component material has the lowest impact (-65.4 kg CO_2 eq), because natural materials like palm doum and raw timber, capture carbon (and other greenhouses gases) during their growth. However, this captured carbon is released at the end of life (graphic 6), where palm doum mats have the biggest impact. This is because these materials are usually burned (which the SMAC tool assumes), therefore the level of CO_2 eq released into the air is relatively high. If the material is allowed to decompose, or is just buried, little or no CO_2 eq is released into the environment over the near term. So, initially, the CO_2 eq number for palm doum mats may be negative as processing the material takes less CO_2 eq to make available for use than, for instance, plastic sheeting. But this number is "balanced out" when considering what happens at the "end of life" of the commodity, when carbon is emitted.

8.2.3. Tillaberi Model

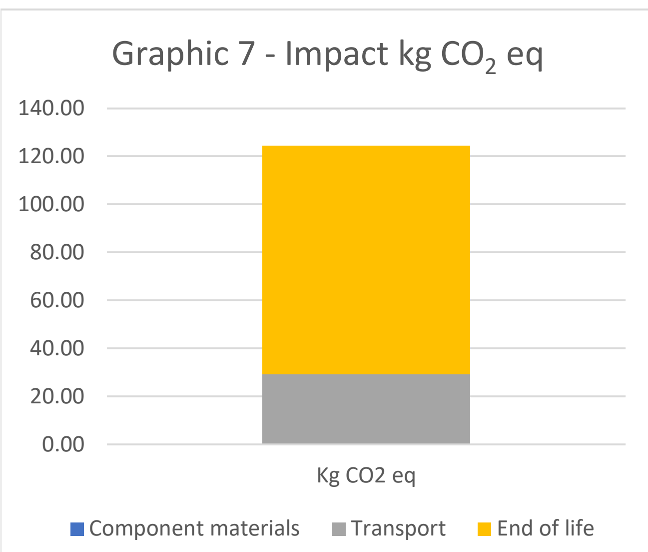
The follow tables (5 & 6) and graphics (7 & 8) show the breakdown of the impact, in terms of Kg CO_2 eq and relative % CO^2 eq, of the shelter unit per life cycle stage (production of the component material, packaging, transport and end of life).

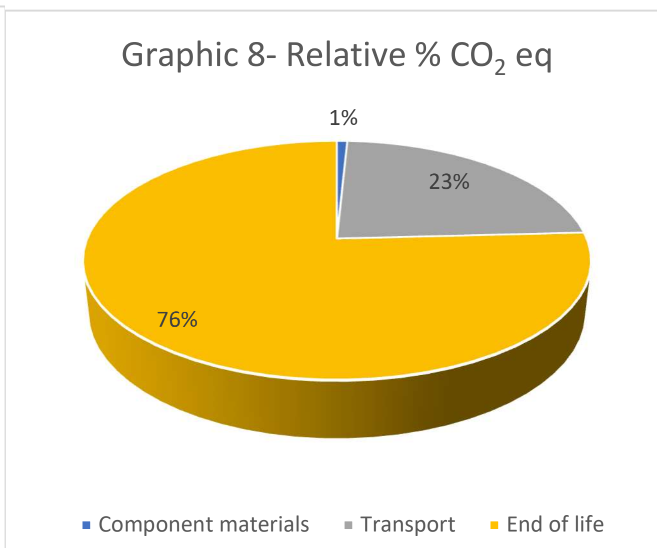
Table 5

Impact	Carbon Emissions Kg CO_2 eq
Production of the component material	0.98
Packeting	*Data not available*
Transport	29.05
End of life	94.24
Total	**124.27**

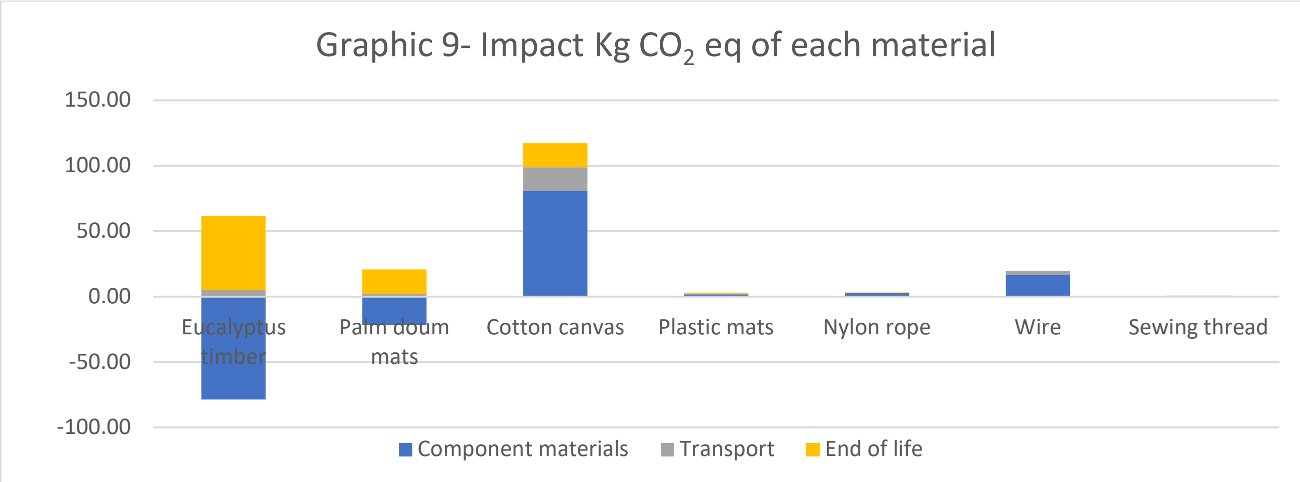
Table 6

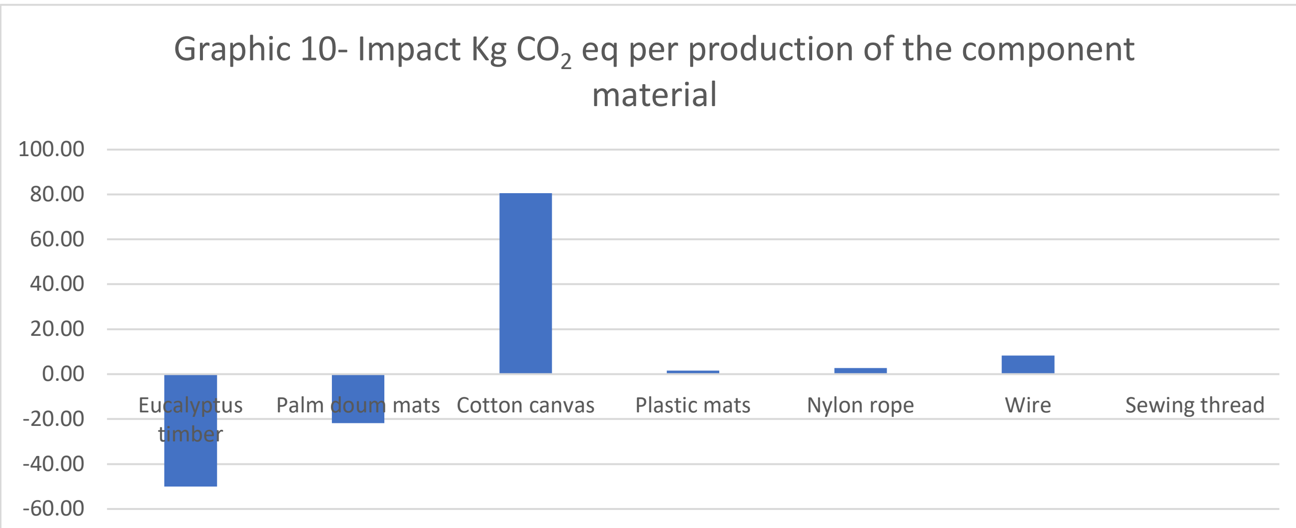
Impact	Relative % CO_2 eq
Production of the component material	1%
Packeting	*Data not available*
Transport	23%
End of life	76%
Total	**100%**

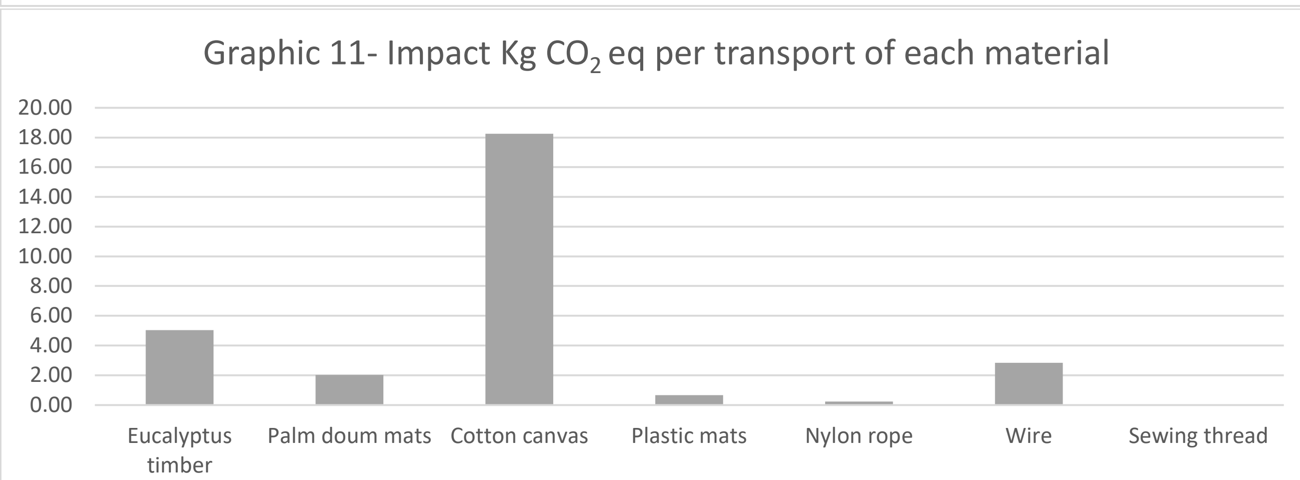


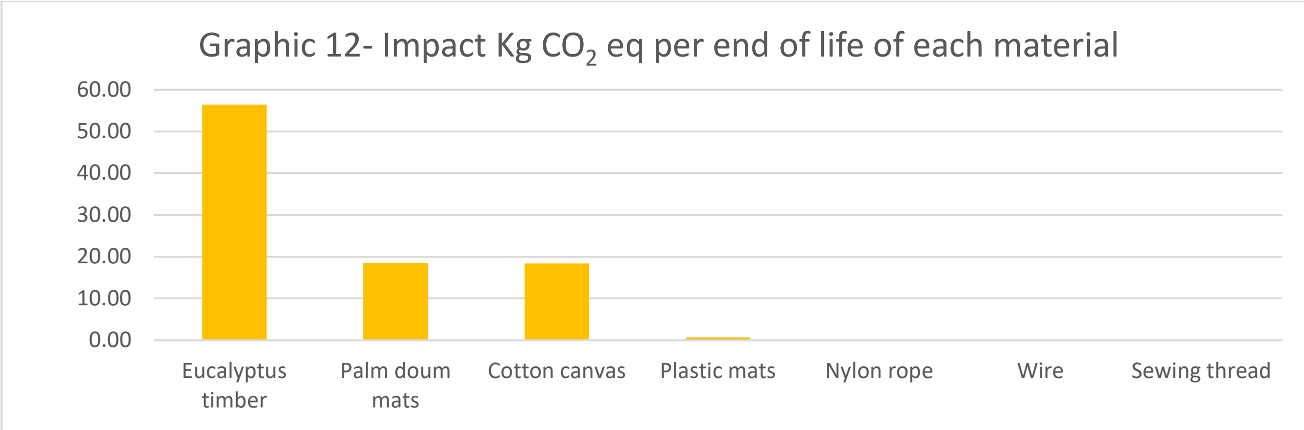


The following graphics 9, 10, and 12 show the Kg CO_2 eq emissions for each material, first for the production of the component materials, then for transport, and finally for end of life. This additional analysis helps to see, for each material, at which stage of the life cycle most emissions come from.


Graphic 9- Impact Kg CO2 eq of each material
150.00
100.00
50.00
0.00
-50.00
-100.00
Eucalyptus timber
Palm doum mats
Cotton canvas
Plastic mats
Nylon rope
Wire
Sewing thread
Component materials
Transport
End of life


Graphic 10- Impact Kg CO2 eq per production of the component material
100.00
80.00
60.00
40.00
20.00
0.00
-20.00
-40.00
-60.00
Eucalyptus timber
Palm doum mats
Cotton canvas
Plastic mats
Nylon rope
Wire
Sewing thread


Graphic 11- Impact Kg CO2 eq per transport of each material
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Eucalyptus timber
Palm doum mats
Cotton canvas
Plastic mats
Nylon rope
Wire
Sewing thread



8.2.4. Interpretation of the result for Tillaberi model

As per graphic 7 & 8 the biggest impact on carbon emissions is due to the end of life, followed by transport. The carbon emissions generated by production of component materials is very low; however, this is because the embodied carbon emissions of the cotton canvas is offset by the carbon captured by the timber and palm doum during the growing process.

Considering the total impact of each of the materials used in the shelter (graphic 9), the biggest impact is the cotton canvas followed by the eucalyptus timber and the palm doum mats.

The emissions generated by the cotton canvas is due mostly to the production of the component material, followed by the transport (graphic 9).

When looking into the eucalyptus timber and the palm doum mats, as per comments above, the production of the component materials has the lowest impacts (-50.02 & -21.80 Kg CO_2 eq) graphic 10, because natural materials capture carbon (and other greenhouses gases) during their growth. However, this captured carbon is released at the end of life (graphic 12), where, together with the cotton canvas, they have the biggest impact, as per the calculation and assumption explained in section 8.2.2

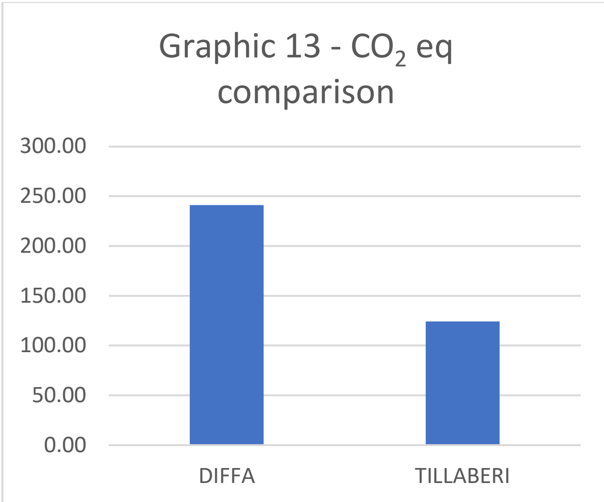
8.2.5. Comparing the result for both models

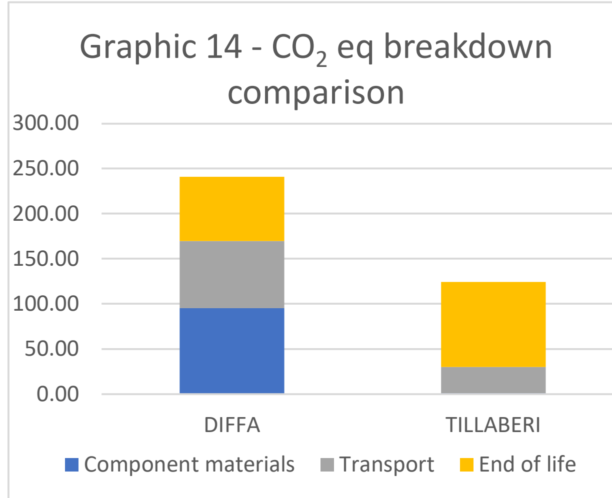
Table 3

Impact	Carbon Emissions Kg CO_2 eq
Production of the component material	95.09
Packeting	*Data not available*
Transport	74.39
End of life	71.48
Total	**240.96**

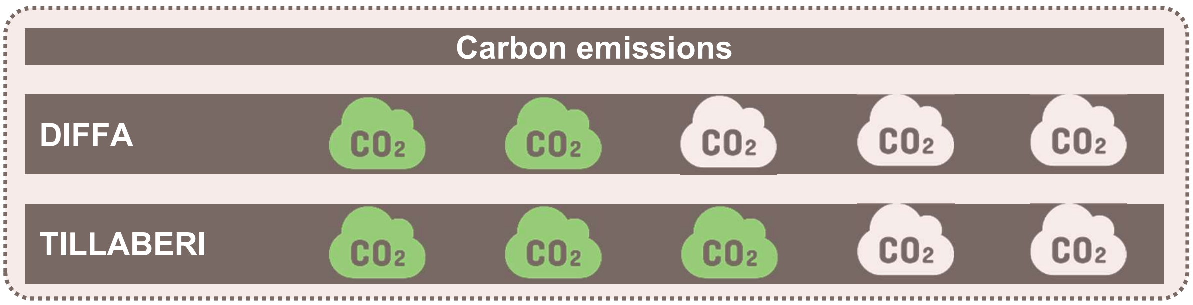
Table 5

Impact	Carbon Emissions Kg CO_2 eq
Production of the component material	0.98
Packeting	*Data not available*
Transport	29.05
End of life	94.24
Total	**124.27**





In the score card, Diffa model scores 2 out of 5, and Tillaberi 3 out of 5.



1 poor, 2 average, 3 medium, 4 good, 5 very good

Diffa model has greater carbon emissions compared to Tillaberi (240.96 vs 124.27 Kg CO_2 eq). As per the comments above, the biggest impact on the Diffa model is from the production of the component materials, followed by transport and end of life. However, most of Tillaberi's emissions are due to the end of life.

In terms of emissions from the production of the component materials, Diffa has a much bigger impact (95.08 vs 0.98 Kg CO_2 eq) as per tables 3 & 5 respectively. As can been seen in graphics 4 & 10, materials like PVC have high embodied carbon, while materials like palm doum and eucalyptus timber are initially net carbon positive as little or no carbon is emitted in harvesting (they absorb more CO_2 and other greenhouse gases from the atmosphere during their growth than the CO_2 equivalent they release during their production). This factor reduces the CO_2 eq emissions of Tillaberi greatly.

In terms of emissions from transport Diffa model has a larger impact as well (74.39 vs 29.05 Kg CO_2 eq) as shown in tables 3 & 5. This is because the Diffa model "travels" around 19,000 kilometers by road, and another 19.000 kilometers by boat, before installation. As graphic 5 shows, the material which has the biggest impact in terms of transport are the PVC tubes followed by steel tubes. The Tillaberi model "travels" around 10,000 kilometers by road, before installation. As per graphic 11, the material which has a biggest impact in terms of transport is the cotton canvas (coming from Morocco, Tunisia and Algeria). The cotton canvas alone travels around 4200 kilometers before installation.

In terms of emissions from end of life, Tillaberi model has the highest carbon emissions (94.24 vs 71.48 Kg CO_2 eq) as per tables 5 & 3 respectively. As explained above, this is because in the SMAC tool, the materials that have a biggest impact are the palm doum tree and eucalyptus timber, as they are considered to be burned at the end of their life, releasing gas into the atmosphere.

The score card for both shelter models could be improved by reducing the amount of materials, especially PVC and cotton, which have the greatest emissions, but without compromising the functionality. Also, Diffa model could consider to use different type of material for their structure, since PVC and Steel has a higher embodied CO_2. And for Tillaberi model, the impact can be reduced by ensuring that palm doum mats and eucalyptus timber are not burnt at the end of their useful life, or replanting is encouraged. Another option for both shelters is to procure more of the materials locally, to reduce the emissions from transport, especially the PVC, steel tubes, and cotton canvas.

8.3. Impact on local natural resources

A common assumption is that the more natural a material it is, the better is for the environment. However, when selecting a natural resource, there are certain impacts on the local eco-system that need to be considered, such as deforestation and vegetation removal, soil erosion, degradation of water quality, pollution etc. Where possible, options to mitigate these effects should be considered.

In Niger, like in the rest of the Sahel, populations depend heavily on the exploitation of natural resources: extensive pastoralism, rain-fed food crops, collection of Non-Timber Forest Products (NTFPs), etc. Forests play a strategic role, which in addition to wood energy, provide food supplements, medicines, housing material, fodder for livestock and cash income.

However, these natural resources are subject to strong biophysical pressures: low and erratic rains, high temperatures, high aridity, often poor and easily degradable soils, etc. These pressures are exacerbated by anthropogenic pressures: demographic boom, climate change, insecurity and weak governance.[53] "Soil erosion, desertification and land degradation are some of the challenges faced by the people in Niger as a result of indiscriminate felling of trees"[54]. Forest and woodland protection in the Sahel have become a priority because there has been over-exploitation of these resources.

In the context of climate change and pressure on the natural resources, it is important to analyse whether the shelter models contribute to this degradation and deterioration of the environmental conditions. To do a proper study of potential harm done to the environment, it should really go beyond the local natural resources used, in this case the doum palm tree for the walls and roofing, and eucalyptus timber for the structure, and look into the overall sheltering strategy and implementation (site selection, access, infrastructure and services, environmental protection, etc.). However, this is beyond the scope of this study.

A quick overview about forests, why they are important to fight against climate change, and forest situation in Niger

Forests play a key role in mitigating climate change[55] and increase the resilience of rural communities. They regulate ecosystems, protect biodiversity, play an integral part in the carbon cycle, support livelihoods, protects homes from major weather events, improves world health and can help drive sustainable growth[56].

Environmental issues[57]

- 30 % of global tree species are threatened with extinction. And over the past 300 years, the global forest area has decreased by about 40%.
- The main threats to tree species are forest clearance and other forms of habitat loss, direct exploitation for timber and other products. Climate change, like fire, extreme weather and sea level rise, is also having a clearly measurable impact.

53. *FAO*
54. *This was stated by the Secretary to the state government Alhaji Ibrahim Matane in a statement to Voice of Nigeria on September 2021*
55. *Forests and climate change. IUCN*
56. *Forests and climate change. IUCN*
57 *State of the World's Trees. Sept 2021. Botanic Gardens Conservation International*

- Around 25% of global emissions come from the land sector. About half of these come from deforestation and forest degradation.

Niger Forest Information and Data[58]

- Niger has struggled with desertification, soil degradation, drought and loss of biodiversity for many years.
- The Sahara Desert, which covers two-thirds of the country, is expanding at a rate of 200,000 hectares annually.
- 1 % (1,104,000 ha[59]) of Niger is forested[60]. Of this 18.3% (220,000 ha) is classified as primary forest, the most biodiverse and carbon-dense form of forest. Niger has 148,000 ha of planted forest.
- Between 1990 and 2010, Niger lost an average of 37,050 ha or 1.90% of its forest cover per year. In total, between 1990 and 2010, Niger lost 38.1% of its forest cover, or around 741,000 ha.
- Niger's forests contain 25.61 million metric tons of carbon in living forest biomass[61].
- A high population growth rate puts pressure of the few remaining forest lands.
- As of 2003, about 8 percent of Niger's land area was protected, but poaching and habitat loss are taking a heavy toll on the country's wildlife.

8.3.1. Overview of the two natural resources

Doum Palm Tree in the shelter model

The palm flora of continental Africa, are amongst the most useful plants across the continent. The small-sized palm-tree, the doum, (Hyphaene thebaica), is a very common palm species in Niger. It has significant local and regional economic, social and ecological value[62].

Most of its parts are used by local people. The trunk is used as timber. The pulp of its fruit is eaten, dried palm cores produce flour, several parts are used as fuel, palm trees have a favorable influence on associated crops or pastures and above all the leaves are used for numerous craft products. These leaves are normally purchased by craftswomen to make mats, commonly used in these semi-arid regions, which serve to sit on and to make the walls and roofs of housing. Other different uses are basketry and ropes[63].

Harvesting

Leaf harvesting is very intensive throughout the country, but collecting practices differ from one region to another. The mats are made after cutting the leaves of the doum or dwarf palm tree, which are left to dry in the open air for three or four days. It is usually done during the rainy season. Professional artisans, usually women, weave the fibers into strips of about ten centimeters wide and two meters long. In general, twelve strips are needed to make a mat the size of two people[64].

Labor productivity is low: on average, it can take one person more than a day to make a rectangular mat, to which must be added cutting, drying, transporting and processing of the necessary palms. There is no industrial production of these mats.

Environmental impacts

58. Mongabay
59 UN data 2018
60 FAO
61 UN data 2018
62 Low extinction risk for an important plant resource: Conservation assessments of continental African palms (Arecaceae/Palmae). April 2018
63 Valoriser les produits du palmier doum pour gérer durablement le système agroforestier d'une vallée sahélienne du Niger et éviter sa désertificationRégis Peltier, Claudine Serre Duhem et Aboubacar Ichaou
64 Low extinction risk for an important plant resource: Conservation assessments of continental African palms (Arecaceae/Palmae). April 2018

- Palm trees promote soil fertility. In cultivated fields, farmers have found that the soil is more fertile inside doum patches than outside.
- In the dry season, the leaf traps the fine elements transported by the wind. This contributes effectively to the fight against wind erosion and the desertification of certain fields.[65]
- Today, the Hyphaene thebaica is rated as one of the tree types at "the least concern" from extinction in Niger[66]. However, the general degradation of the Sahelian environment and its desertification, on account of climate uncertainties and the commercial exploitation of the doum palm-tree, will lead to the disappearance of adult seed trees, then to sprout exhaustion and disappearance of young seedlings[67], if measures are not taken.

Total amount of palm doum matts in the models

- Diffa model: 60 kilos for the wall and roofing
- Tillaberi model: 20 kilos for the walls.

Eucalyptus wood in the shelter models

The introduction of the eucalyptus was in the 1950s in African countries, more specifically in 1963 in Niger. Soon after this introductory phase and selection of species, the most promising Eucalyptus species were put in place. In Niger, 101 species including 11 hybrids of eucalyptus were tested, most without success, and the rest with variable results according to whether they were irrigated or not[68].

Eucalyptus plantations are easily established and fast growing, and can be highly profitable, even in areas that are traditionally poor in timber production. However, there are also negative environmental impacts in planting eucalyptus.[69]

Harvesting

Timber cutting usually starts after 4 years of hedge planting (i.e., eucalyptus)[70]. Pruning is carried out at the end of each rainy season to allow the plants to develop properly.

Environmental impacts

- Growing Eucalyptus in low rainfall areas may cause adverse environmental impacts due to competition for water with other species and an increased incidence of allelopathy (is a survival mechanism that allows certain plants to compete with and often destroy nearby plants by inhibiting seed sprouting, root development, or nutrient uptake). The harmful effect on the environment is that it uses a lot of nutrients which leads to soil exhaustion and reduction of crop yields, secretion of allelochemical and decreasing crop production[71].
- However, these plantations in Niger also help for land delimitation, crop protection against animals and erosion (defensive hedges) as well as the production of timber, etc.
- The environmental impact is also in terms of changes in land use and transport distances between a production site and the sites where the wood is used. Local production of wood close to where it is used reduces costs and environmental impacts (pollution, road construction, etc.) while promoting local employment. This is a factor in favor of the existence of dedicated plots near processing sites.

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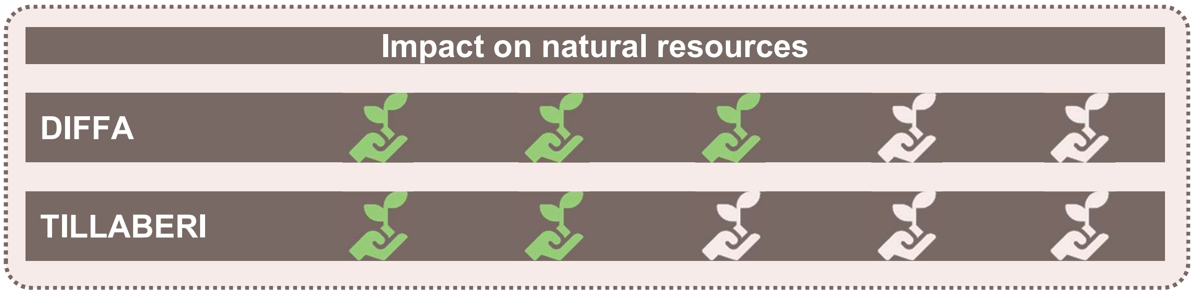
65 Valoriser les produits du palmier doum pour gérer durablement le système agroforestier d'une vallée sahélienne du Niger et éviter sa desertification. Régis Peltier, Claudine Serre Duhem et Aboubacar Ichaou
66. Botanic Gardens Conservation International
67 Valoriser les produits du palmier doum pour gérer durablement le système agroforestier d'une vallée sahélienne du Niger et éviter sa desertification. Régis Peltier, Claudine Serre Duhem et Aboubacar Ichaou
68 Expansion, research and development of the eucalyptus in Africa Wood production, livelihoods and environmental issues: an unlikely reconciliation. Dominique Louppe and Denis Depommier. 2010
69. Chaojun Chu, P.E. Mortimer, P.E. Mortimer, Hecong Wang, Yongfan Wang, Xubing Liu, Shixiao Yu. 2014
70. National Network of Chambers of Agriculture in Niger. June 2019
71 BIO-PHYSICAL AND ENVIRONMENTAL IMPACTS OF EUCALYPTUS PLANTATIONS. FAO

Eucalyptus timber in the models
In this specific case, the eucalyptus wood (Eucalyptus camaldulensis) that supplies the Tillaberi shelters come from Dosso region, so the total travel distance by land is 253 kilometers.
The Tillaberi model uses around 61 kilos of eucalyptus.
Some of the challenges that the team has faced is that the branches of eucalyptus timber needed for the structure of the shelter, have to be green before the construction, to help with the dome form. However, some of the timbers were already dry by the time they reached the construction site, so they couldn't be used for construction purposes. This means some additional waste, but it was not possible to quantify this.

8.3.2. Interpretation of the results
In the score card, Diffa model scored 3 out of 5, and Tillaberi 2 out of 5



1 poor, 2 average, 3 medium, 4 good, 5 very good

Since the negative impact on the environment by the eucalyptus timber it is higher, the Tillaberi model scores lower. On one hand, Diffa used more palm doum mats, 60 kilos vs 20 kilos. However, Tillaberi used 61 kilos of eucalyptus timber. Both are locally produced, but while eucalyptus is an introduced species, requires irrigation techniques in a country with scarce water supplies, and has an impact on soil degradation and deforestation, the palm doum tree is an endemic species, well mastered by the communities for years, and appears to help to fight against wind erosion and fertilises the soil.

However, a question remains unanswered for both, whether the supply of both species could keep up with the demand of the shelters in Niger, when considering thousands of shelters in a crisis that keep growing. Overexploitation and climate change could have a negative impact on production of both plants. While the quantities used for the shelters already built are unlikely to exhaust supply, it is difficult to estimate what the implication of many more shelters might be.

The score can be improved in the future by promoting mitigation strategies for some of these negative impacts, like including a reforestation and forest protection project, or advocating for such a project or partnering with a suitable local organisation who can make this happen in the relevant area. Note that this would also reduce the overall carbon emissions generated, as well as ensuring protection of the local eco-system.

8.4. Criteria 4; Waste Management
When designing a shelter and choosing the construction materials, we should consider what happens to each material at the end of its useful life. Prolonging the life of each material by looking at the options for reusing or recycling definitely contributes to reducing waste. But unfortunately, once these materials are no longer used, most of them will end up in open fields contributing to pollution, particular in countries with a lack of waste management system in place such as Niger. This is especially relevant for those materials which take many years to decompose, potentially harming the environment for years to come. Thinking in advance of all the different waste management systems and options in place should be a must for all programs. This is not easy in countries like Niger, where cities and towns lack an efficient waste

collection, storage and treatment system[72]. However, there are many new waste management initiatives already happening, and it is important to be aware of those and see how they could be integrated into planning.

The new government in Niger has just established a department for' waste management and improvement of the quality of life' *(direction de gestion de déchets et d'amélioration du cadre de vie.).* The Department is supporting, through the mobilisation of funds, the implementation of various new programmes and waste management initiatives in some urban communes, planning to expand them on a national scale[73]. While this can take a long time to be fully implemented, there are other private waste management and recovery companies already collecting waste for recycling. A collecting system through the communities could be organised, proving an opportunity to earn income from selling the waste.

In the two tables below, we examine for each of the shelter materials how long they take to decompose, if they can be reused and recycled, and what the options are. It is important to note that the rate of decomposition can depend upon landfill conditions.

Table 7

Material	Life expectancy	Time to decompose	Reuse	Recycling
Plastic sheeting	2 years	500 to 1000 years	Yes	Yes
Plastic mats	12 months	500 to 1000 years		Yes
PVC[74]	2 years[75]	450 years	Yes	Yes. However, PVC products cannot easily be separated for recycling, which makes breaking vinyl products down into their original components nearly impossible.
Steel beams	After 1 year[76]	200 to 500 years[77]		Yes
Wire	*Information not available*	200 to 500 years	Yes	Yes
Nylon[78]	*Information not available*	40 years	Yes	Yes
Cotton Canvas	4 to 6 months	1 year[79] *However, in dry environments, it will probably take more to decompose naturally*	Yes	Yes. However, recycled cotton has its place for certain end-uses, but the challenges with strength and quality reduction can cause issues during production and after the consumer takes the product home. Once garments are recycled, they cannot continue to be recycled due to the fiber separation process that weakens the fibers. Recycled materials cannot be recycled infinitely.

72 *Studio Kanlangou 2020*
73 *GBV Africa*
74 https://expandusceramicsquestions.com/qa/how-long-does-pvc-take-to-decompose.html
75 According to the field team, this depends on its exposure to the sun and the effects of the weather. However, normally PVC only deforms to fit the shape given.
76 According to the file team, the steel beams start to oxidates after the winters, and never before one year from installation.
77 How long does it take for metal to degrade - Riba Farré (ribafarre.com)
78 https://www.dnr.sc.gov/up2u/decompose.html
79 How Long it Takes 50 Common Items to Decompose | Stacker

Sewing thread	*Information not available*	3–4 months[80]	Yes	In theory yes, as is cotton. However, in practice, it would be difficult to separate it from the fabric.
Eucalyptus[81] timber	3 months	Yes 100%	Yes	Not
Palm Doum mats	12 months	Yes 100%	Yes	Not

Table 8[82]

Material	Reuse option in Niger	Recycling options in Niger
Plastic sheeting	• To reuse for auxiliary construction	• Production of latrine slabs, paving stones, racks and gutters
Plastic mats	• To reuse for auxiliary construction. • Sleeping mats.	• Recyclable through the production of latrine slabs, paving stones, racks and gutters
PVC[83]	• To reuse for auxiliary construction • Structure for a courtyard • Simple shade structures • Door structure	• Crushing and export
Steel poles	• To reuse for auxiliary construction • Structure for a courtyard • Simple shade structure	• Compacting and export
Wire	• To reuse for auxiliary construction	• Compacting and export
Nylon[84]	• To reuse for auxiliary construction	• Input for making bags, baskets, satchels, etc.
Cotton Canvas	• To reuse for another shelter or building • households use them for a variety of purposes: some use them to shore up their shelters, others use them to fence their yards.	• Crushing and application of pouffe, mattress, cushion
Sewing thread	• Can't be reused	• Can't be recycled
Eucalyptus[85] timber	• To reuse for auxiliary construction • Combustible wood	• Not relevant
Palm Doum mats	• To reuse for auxiliary construction • Simple shade structures • Door • Mattress	• Not relevant

80 https://www.dnr.sc.gov/up2u/decompose.html
81 Thinking Sustainably
82 Regarding the recycling, these questions were addressed directly to GVD Afrique. Regarding the reuse options, the team provide the information through direct observation on the field. To see some photos of how these materials have been used, please refer to annex 6
83 https://expandusceramicsquestions.com/qa/how-long-does-pvc-take-to-decompose.html
84 https://www.dnr.sc.gov/up2u/decompose.html
85 Is Wood Biodegradable? Here Are The Facts - Thinking Sustainably

It is also worth mentioning that Niger has banned the production, import, marketing, use and storage of low-density flexible plastic bags and packaging. (*Loi 2014-63 du 05 Novembre 2014).* But the reality is that this has been very challenging to implement. Certain items of the shelters are packed in plastic, like the plastic sheeting, the wire, the nylon rope or the thread. Alternative options should be considered, like eliminating this single-use plastic from packaging, in discussion with suppliers.

8.4.1. Interpretation of the result

In the score card, Diffa model scored 1 out 5 and Tillaberi scored 3 out 5.

1 poor, 2 average, 3 medium, 4 good, 5 very good

As we can see from the two tables, most of the materials can be reused or recycled, and on top of this, both shelter models have been designed to be easily dismantled and transported, enabling the material to be easily reused, recycled or even sold. But when thinking about disposal options, it became more challenging, and this is where the two models diverge and the reason why Diffa scores less in comparison to Tillaberi.

From an environmental perspective, answering the question of how long it takes various types of waste to decompose is one of great importance. We should reduce consumption of products that generate waste materials that take a long time in landfill to completely decompose. From this perspective, one of the biggest concerns is plastic and Diffa used a lot more compared to Tillaberi. Not only plastic sheeting, also the very polluting PVC, and the steel tubes, which also take long time to decompose. While Tillaberi uses timber and cotton canvas, for which the time of decomposition is much less of a concern.

Whilst many of the materials do have possibilities for reuse and even recycling, the reality is that while reuse is already happening, given the Niger waste management context, recycling is unlikely to take place unless proactive steps are taken. The score card can be improved in the future by promoting different waste collection and recycling projects. Connecting communities to recycling companies, like GVD-Africa and helping them putting a system in place, will not only improve the waste management situation, can also create income generating opportunities for the communities.

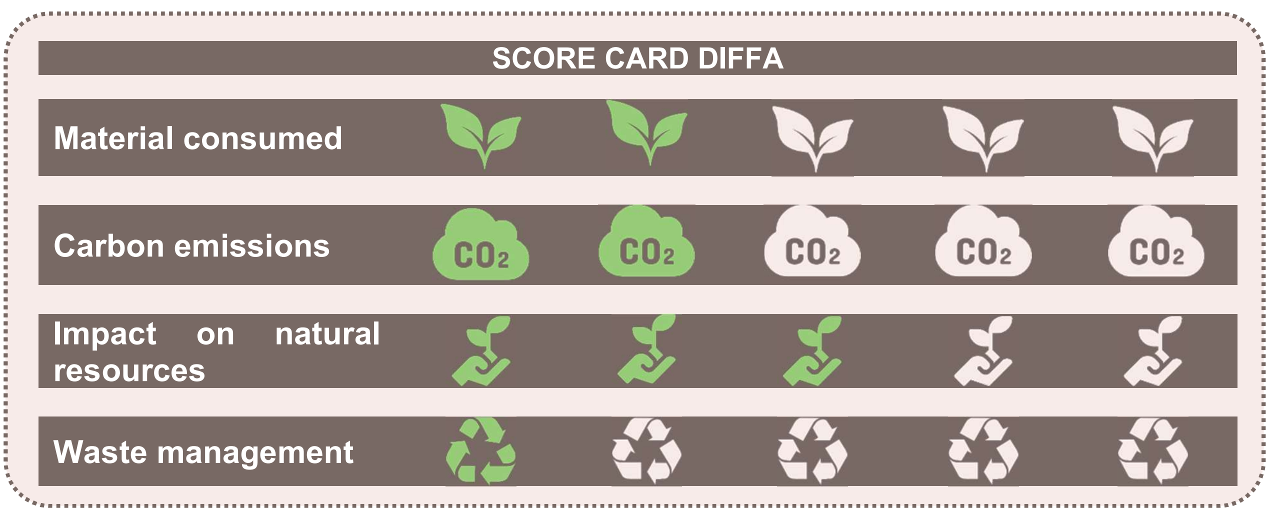
Raising awareness of the pollution generated by the disposal of the products, though advocacy with communities, or projects in partnerships with other organisations, would also be a way of mitigating the waste impact.

8.5. Summary: Diffa vs Tillaberi Shelter Models

Summary of the results for each model, conclusions are drawn in section 10.

DIFFA MODEL

Summary of the enviromental impact DIFFA		
Raw material used	Doum Palm tree Water comsuption	60 kg 20,898 liters
Manmade material used in kg	Steel pole PVC pole Plastic sheeting Plastic mats Nylon rope Wire Sewing thread	22.5 kg 36.4 kg 9 kg 2 kg 0.5 kg 6 kg 0.04 kg
Carbon emissions in kg CO_2 eq	Production of material Packaging Transport End of life Total for shelter Per year	95.09 *Data not available* 74.39 71.48 240.96 240.96[86]
Impact on natural resources	Deforestation and erosion due to the harvesting of natural or farmed vegetation (palm)	
Waste managment	Almost all the materials can be reused or recycled. The biggest concern is the time that most of the materials take to decompose.	

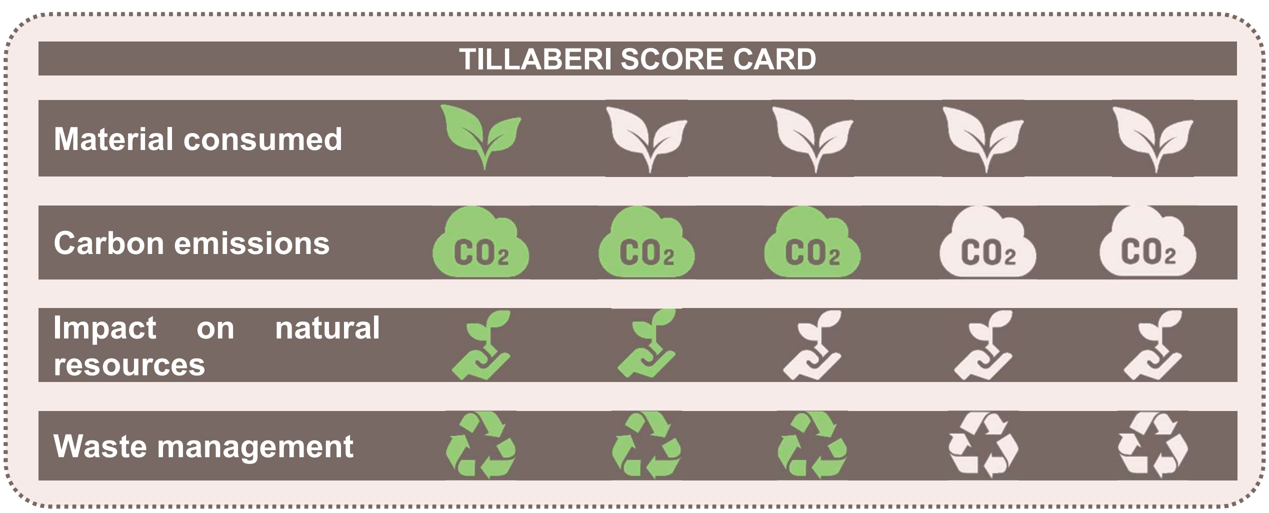


1 poor, 2 average, 3 medium, 4 good, 5 very good

86 *Considering that Tillaberi model last 6 months, and without taking into consideration that certain of its materials could last longer that that.*

TILLABERI MODEL

Summary of the enviromental impact TILLABERI		
Raw material used	Doum Palm tree Ecualyptus wood Water comsuption	20 kilos 61 kilos 136,264 liters
Manmade material used in kilos	Cotton canvas Plastic mats Nylon rope Ware Sewing thread	13.2 2 0.5 6 0.04
Carbon emissions in kg CO_2 eq	Production of material Packaging Transport End of life Total for shelter Per year	0.98 *Data not available* 29.05 94.24 124.27 248.54[87]
Impact on natural resources	Deforestation and erosion due to the harvesting of natural or farmed vegetation (palm) and the plantation of eculayptus, which also has a high demand of water, strong absorption of nutrients, allelopathy effects, and desertification of the area.	
Waste managment	Almost all the materials can be reused or recycled. The shelter uses materials that are easy to decompose (palm doum tree, eucalytus). However, the wire, plastic mats and nylon take a long time to decompose, but are used in small quantities.	



1 poor, 2 average, 3 medium, 4 good, 5 very good

87 *Considering that Tillaberi model last 6 months, and without taking into consideration that certain of its materials could last longer that that.*

9. Environmental impact comparison between tarpaulin options: plastic sheeting and cotton canvas

Additional analysis comparing the two types of tarpaulins, plastic sheeting and cotton canvas, as standalone materials in isolation from the shelter models, was seen as important. This was a specific request in the Terms of Reference for this study, as it is of interest to the shelter partners in Niger, mostly because cotton has been seen as a good alternative to plastic sheeting.

The methodology for this analysis follows the same principles as for the comparison of the two shelter models. The only criteria that has not been assessed is the damage or the impact on local natural resources, since it is not relevant. So the following criteria have been analysed:

1. Materials consumed
2. Carbon emissions
3. Waste management

Below is an overview and comparison of both materials, before going into the analysis.

9.1. Plastic sheeting vs cotton canvas used in the project

9.1.1. Plastic sheeting

The plastic sheeting used in the shelters is the standard multi-purpose sheeting (tarpaulin) that is procured by both the IFRC and International Committee of the Red Cross (ICRC). It is manufactured in China and shipped to Cote d´Ivore before being transported to Niamey in Niger. The technical specifications of the plastic sheeting can be found as annex 7.

The product was developed through an inter-organisational research project, and its specifications adapted to humanitarian use in regards to durability, waterproofness, sheltering capacity, versatility and recyclability. This multi-purpose sheeting is widely used in the humanitarian sector and is a standard item procured by 46 of the larger agencies in the shelter sector, and used in many countries.[88]

Another advantage regarding the plastic sheeting is the durability. Plastic sheeting can last at least 2 years if not more.

9.1.2. Cotton canvas

The cotton canvas used in the shelter was procured locally, and it is manufactured in the continent (Morocco, Niger and Algeria) as per information provided by the AIC-CRL team.

Cotton canvas is one of the most used canvas fabrics due to its versatility and ease of production[89]. However, the experience of the team in the field, and according to the results of the shelter project Impact Study,[90] its performance and degree of acceptance by beneficiaries was not as good as expected.

Some of the problems they are facing are as follows, all this information has been gathered through different interviews with the team members:

Permeability: the appearance of fungus after the first rains affects the quality of the tarp and causes rot, so water starts coming through.

88 *Carbon footprint of humanitarian shelter: A case study of relief and construction materials used in Haiti, Selina Chan, 2014*
89 *Totebagfactory*
90 *Impact study of the emergency shelter response of AI-CRL in Niger between 2017 and 2020*

It is **not as breathable** as expected, the internal temperature measurements are the same or even higher than those of plastic sheeting during the hot season. according to one of the interviews, a reason could be because more light can penetrate, in comparison with the plastic sheeting which is opaque. This heats the interior of the shelter, creating a greenhouse effect and increasing the indoor temperature.
UV degradation affected the cotton tarp rapidly, degrading it.
It has a shorter **life expectancy** of 6 months, or even less according to the team; if the canvas is installed during the rainy season, the canvas can last up to only 4 months.
It needs a **higher quality control** during construction. If the tarp is not perfectly installed and wrinkles remain, the water will stagnate and fungus will appear from the first rain, decreasing its performance

It would be necessary to consider a different quality of cotton canvas, as any of these performance issues could be improved. However, one of the key informants, who has been involved for a long time in logistics and materials selection in the humanitarian sector, and is one of the first promoters of the plastic sheeting design, noted that when cotton tents were designed and used in the 1990s in the Congo crisis, they had similar results. The problem with cotton is that as soon as there is humidity, it rots and the life expectancy is reduced dramatically. So, this may indicate that cotton is not the most appropriate material for this environment. Future programmes should take this into consideration.

Advantages and Disadvantages of both materials[91]

Table 9

Material	Advantage	Disadvantage
Polyethylene	Lightweight, cheap, quick to dry, low maintenance. Long lifespan The production of plastic sheeting has much lower carbon emissions than cotton canvas (0.76 CO_2 equivalent per kg) [92]	Poor insulator, UV unstable, offers low level of privacy, condensation can build up, noisy and not stable in winds
Canvas (cotton)	Good insulation, breathable, quiet, UV stable	Heavy and bulky to transport and erect, slow to dry, costly, tears easily, low water resistance Higher carbon emissions from production (6.10 CO_2 equivalent per kg) [93]

9.2. Criteria 1; Material consumed

To have an overview of both raw materials, plastic and cotton refer to section 8.1.1.

The total number of kilos per material per shelter, has been provided by the logistics team in country
To calculate the water consuption in liters the following baseline data have been used:

- To produce 1 kilo of plastic, it requires 17 liters of water[94]
- 1 kilo of cotton takes 10,000 liter of water[95]

Table 10 Plastic sheeting

Raw material	
Water consumption	153 liters

Manmade material	
Plastic sheeting	9 kilos

Table 11 Cotton canvas

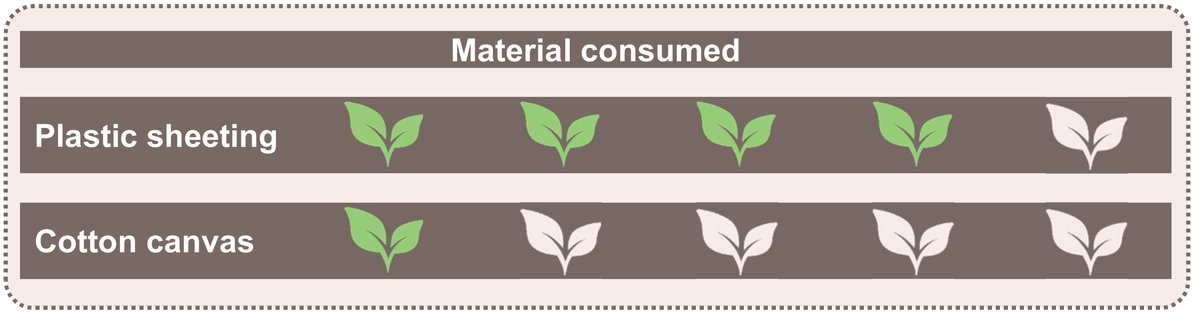
Raw material	
Water consumption	132,000 liters

Manmade material	
Cotton canvas	13.2 kilos

91. Carbon footprint of humanitarian shelter: A case study of relief and construction materials used in Haiti, Selina Chan, 2014
92. According to SMAC tool.
93. According to SMAC tool.
94. Shelter and Sustainability, UNHCR, 2021.
95. www.thewolrdcounts.

9.2.1. Interpretation of the results

In the score card, Diffa model scored 4 out of 5, and Tillaberi 1 out of 5



1 poor, 2 average, 3 medium, 4 good, 5 very good

Even if it is hard to pin down exact data, what is clear is that there is a significant difference in water used, 153 liters vs 132,000 liters (Diffa vs Tillaberi). Considering the cotton is produced in Africa in countries that do not have an abundance of water resources, this is a concern.

The score card can be improved in the future by using a different natural material for the canvas, or decreasing the amount in kilos by using a lighter cotton canvas. However, to use another natural material is not that affordable. For instance, organic cotton, which consumes only 10% of the water that normal cotton does, costs around 20% to 30% more.

9.3. Criteria 2; Carbon emissions

This examines which material results in more CO_2 equivalent emissions in the manufacturing process and transportation, using the SMAC tool.

This follows the same transport distance assumptions as per section 6.2.

As mentioned before, since the objective is to compare both materials, and not the shelter model, the same construction locations for both are used, Tillaberi.

9.3.1. Plastic sheeting

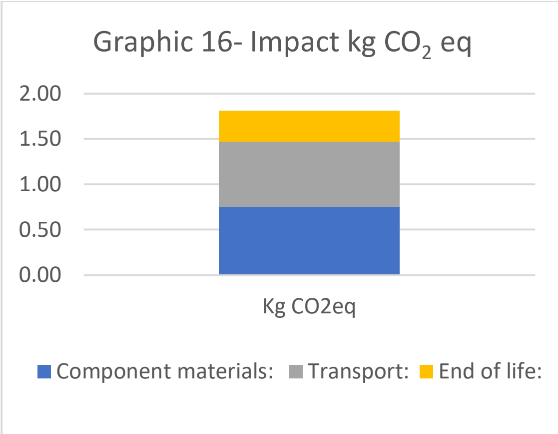
The following tables 12 & 13 and graphics 16 & 17 are a breakdown of the impact, in terms of Kg CO_2 eq and relative % CO_2 eq, of the material per life cycle stage (production of the component material, transport, and end of life. Packeting has not been considered, as data was not available).

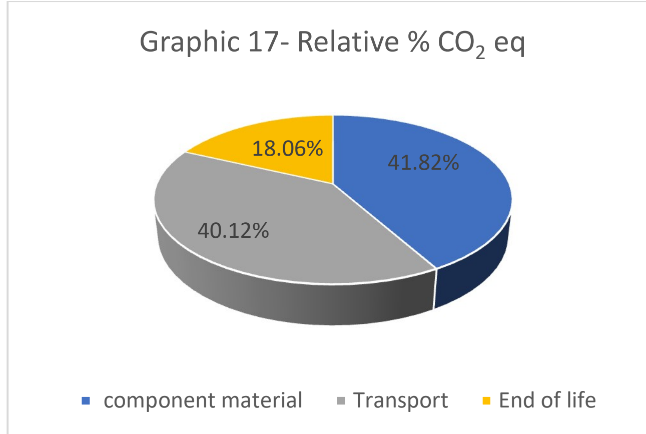
Table 12

Impact	Carbon Emissions Kg CO_2 eq
Production of the component material	6.80
Packeting	*Data not available*
Transport	6.52
End of life	2.93
Total	**16.25**

Table 13

Impact	Relative % CO_2 eq
Production of the component material	41.82%
Packeting	*Data not available*
Transport	40.12%
End of life	18.06%
Total	**100%**





9.3.2. Cotton canvas

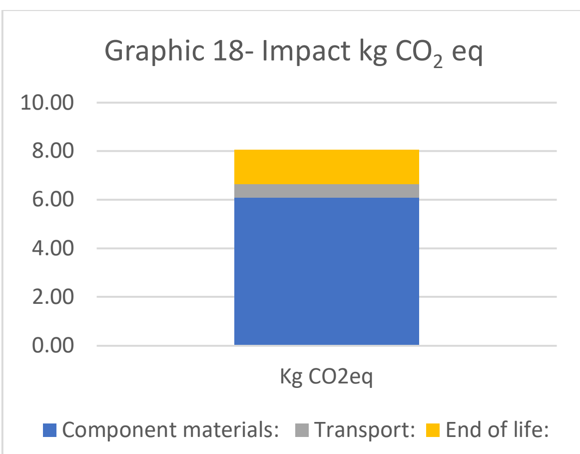
The follow tables 14 & 15 and graphics 18 & 19 are a breakdown of the impact, in terms of Kg CO_2 eq and relative % CO_2 eq, of the material per life cycle stage (production of the component material, transport, and end of life. Packeting has not been considered, as data was not available).

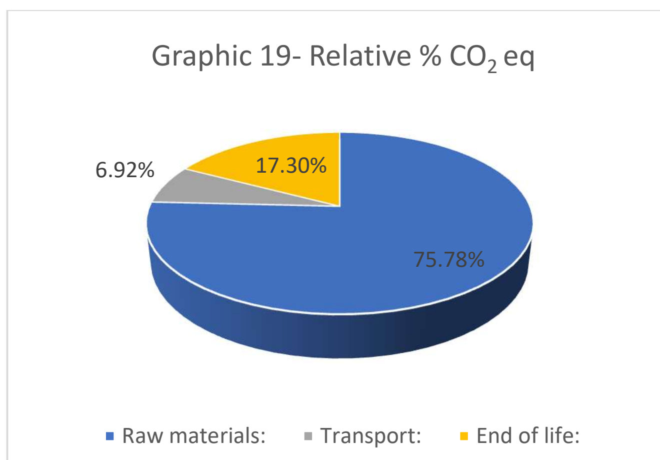
Table 14

Impact	Carbon Emissions Kg CO_2 eq
Production of the component material	80.52
Packeting	*Data not available*
Transport	7.35
End of life	18.38
Total	**106.25**

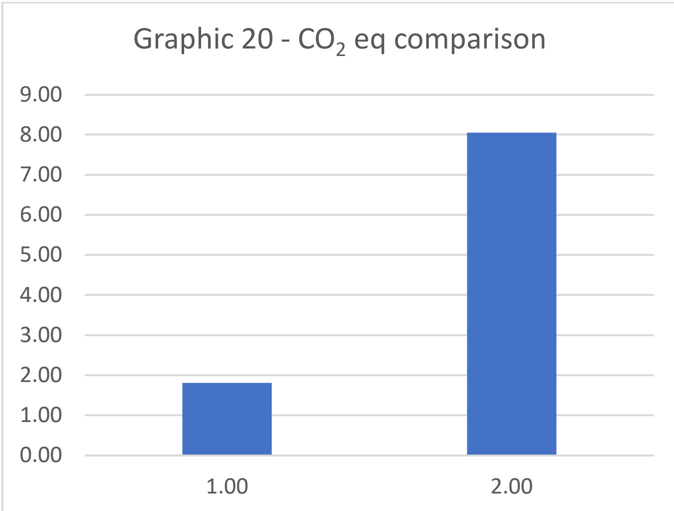
Table 15

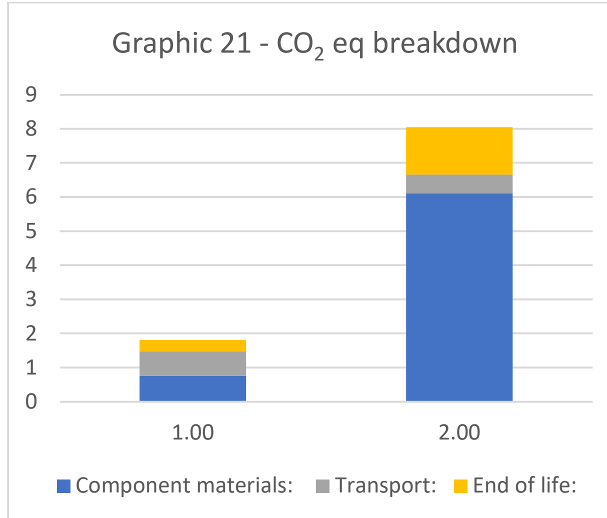
Impact	Relative % CO_2 eq
Production of the component material	75.78%
Packeting	*Data not available*
Transport	6.92%
End of life	17.30%
Total	**100%**





9.3.3. Comparison between both materials

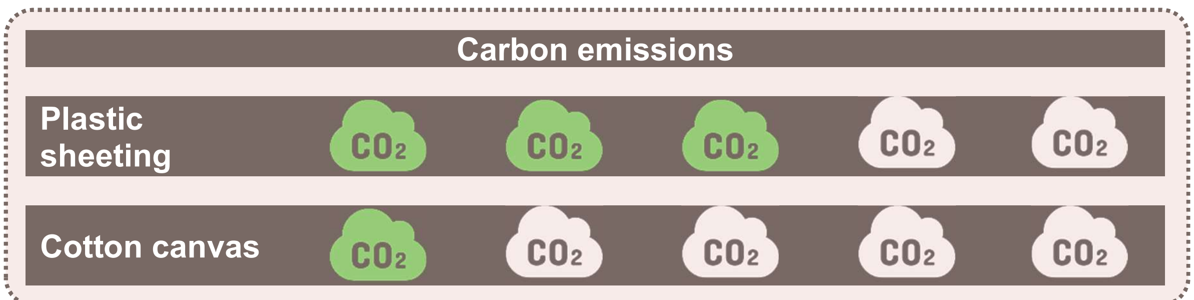




Number 1 refers to plastic sheeting, number 2 refers to cotton canvas.

9.3.4. Interpretation of the results

In the score card, plastic sheeting scores 3 out of 5, and cotton canvas 1 out of 5.



1 poor, 2 average, 3 medium, 4 good, 5 very good

The carbon emissions of the cotton canvas are much higher than the plastic sheeting (106.25 vs 16.25 Kg CO_2 eq) as per tables 12 & 14. Also, plastic sheeting lasts much longer than the cotton, around 2 years vs 6 months. When looking only at the production of the material, the difference remains big (6.80 vs 80.52 Kg CO_2 eq). The explanation behind is that making cotton takes more CO_2 eq when you consider what goes into producing the seed, treating the seed, planting and treating the crop, processing the cotton into cloth and, particularly, the water involved in the process. This is an example of how the calculation of CO_2 eq isn't just the product, but the process that went into the product.

Transporting the cotton canvas releases a little more CO_2 equivalent (6.73 vs 7.35 Kg CO_2 eq) than the plastic sheeting. The cotton canvas is manufactured and transported by road from three different countries: Morocco, Tunisia and Algeria (this is without considering where the cotton has been harvested). This is an average of 4200 kilometers from country of origin to point of arrival in country (Niamey). In comparison, plastic sheeting is shipped from China to Cote d'Ivore by boat (19,000 kilometers) and then transferred to Niamey by road (1691 kilometers). It is important to mention than ocean shipping is more environmentally efficient than road transportation by truck, and a lot more than by air.

Regarding the plastic sheeting there is little that can be done to improve the score card, only by reducing the emissions from transport, but this seems quite difficult to do since it is already being shipped by sea.
Regarding the cotton canvas, emissions could be reduced by procuring more locally, although it is not clear if this is possible; and reducing the quantity of cotton used without compromising the functionality of the canvas.

9.4. Criteria 3; Waste management

In the two tables below, we examine for each of the two materials how long they take to decompose, if they can be reused and recycled, and what the options are.

Table 16

Material	Life expectancy	Time to decompose	Reuse	Recycling
Plastic sheeting	2 years	500 to 1000 years	Yes	Yes
Cotton canvas	4-6 months	1 year *However, in dry environments, it will probably take more to decompose naturally*	Yes	Recycled cotton has its place for certain end-uses, but the challenges with strength and quality reduction can cause issues during production and after the consumer takes the product home. Once garments are recycled, they cannot continue to be recycled due to the fiber separation process that weakens the fibers—recycled materials cannot be recycled infinitely.

Table 17

Material	Reuse options in Niger	Recycling options in Niger
Plastic sheeting	• To reuse for auxiliary construction	• Production of latrine slabs, paving stones, racks and gutters
Cotton canvas	• To reuse for auxiliary construction • Households use them for a variety of purposes: some use them to shore up their shelters, others use them to fence their yards.	• Crushing and use in pouffe, mattress, cushions

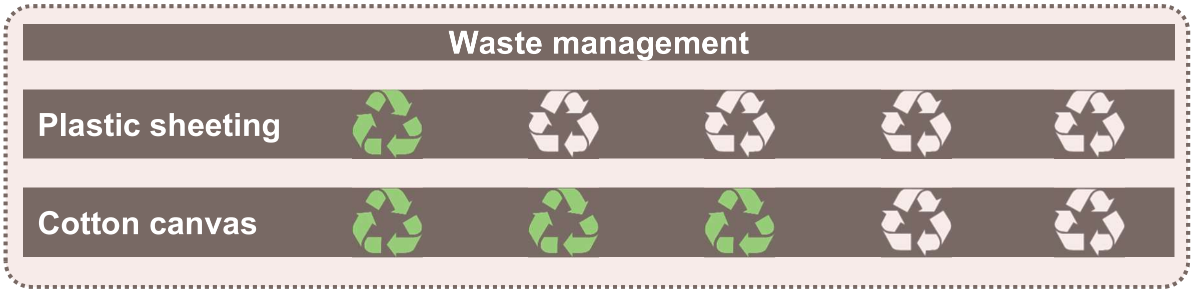
The Red Cross plastic sheeting (tarpaulin) was designed to minimise the impact on the environment: the life cycle of the material is long lasting and it can be used as second-hand raw material for other products. Many re-use examples have been observed in different countries, such as bags for recycled waste collection, car tarpaulins, raincoats, personal bags, etc. The plastic sheets can also be recycled as the raw plastic is made of one single type of plastic, Polythene. This Polythene does not contain fire retardant such as bromide compound, which reduces both the chemical hazard during its use and its recycling possibilities. The tarpaulins are not individually packed avoiding hundreds of thousands of plastic bags[96]. However, despite all of this, recycling does not usually happen, especially in Niger, and the plastic will eventually take many years to degrade, once the material is no longer used.

Cotton canvas can also be reused but has a much shorter useful life, however it is used, but has the benefit of decomposing very quickly.

9.4.1. Interpretation of the results

In the score card, plastic sheeting score 1 out 5 and cotton canvas 3 out 5.

96 Carbon footprint of humanitarian shelter: A case study of relief and construction materials used in Haiti, Selina Chan, 2014



1 poor, 2 average, 3 medium, 4 good, 5 very good

While both materials can be reused and recycled, the biggest concern is the plastic, which takes a very long time to decompose, while the cotton used will disappear much sooner. However, the biggest risk of the cotton canvas would be if it was burned at the end of its useful life, releasing gas into the atmosphere.

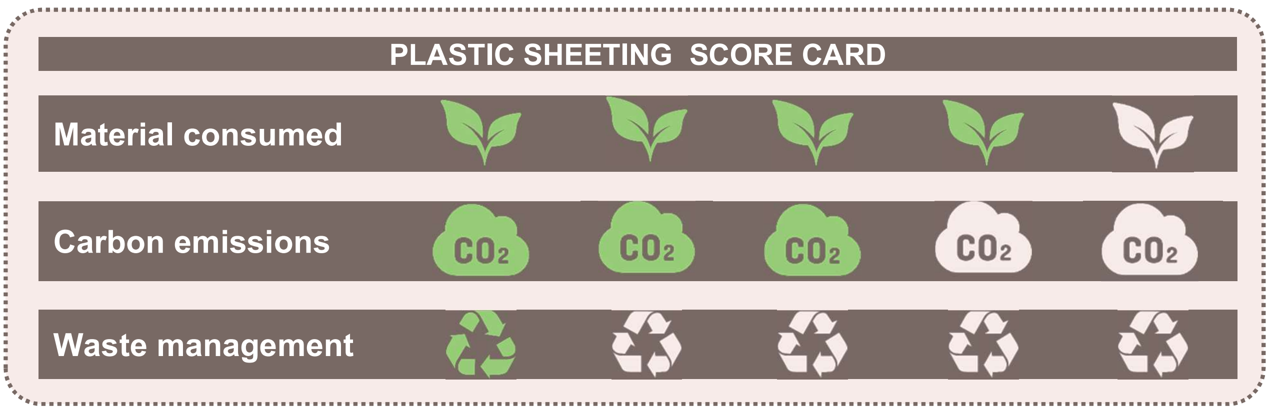
The score card can be improved in the future by promoting different waste collection and recycling projects. Connecting communities to recycling companies, like GVD-Africa and helping them putting a system in place, not only deals with the waste better buy can also generate small livelihoods opportunities for communities. Raising awareness of the pollution generated by the disposal of the products with communities, or though advocacy projects in partnerships with other organisations, is another step which can be taken.

9.5. Summary: Plastic Sheeting vs Cotton Canvas

Summary of the results for each material, conclusions are drawn in section 10.

PLASTIC SHEETING

Summary of the enviromental impact : plastic sheeting		
Raw material used	Water consumption	153 liters
Manmade material used	Plastic sheeting	9 kilos
Carbon emissions in kg CO_2 eq	production of material packaging transport end of life Total for product Per year	6.80 *Data not available* 6.52 2.93 16.25[97] 8.13
Waste managment	Plastic sheeting can be reused and recycled. The biggest concern is the time that plastic will take to decompose.	

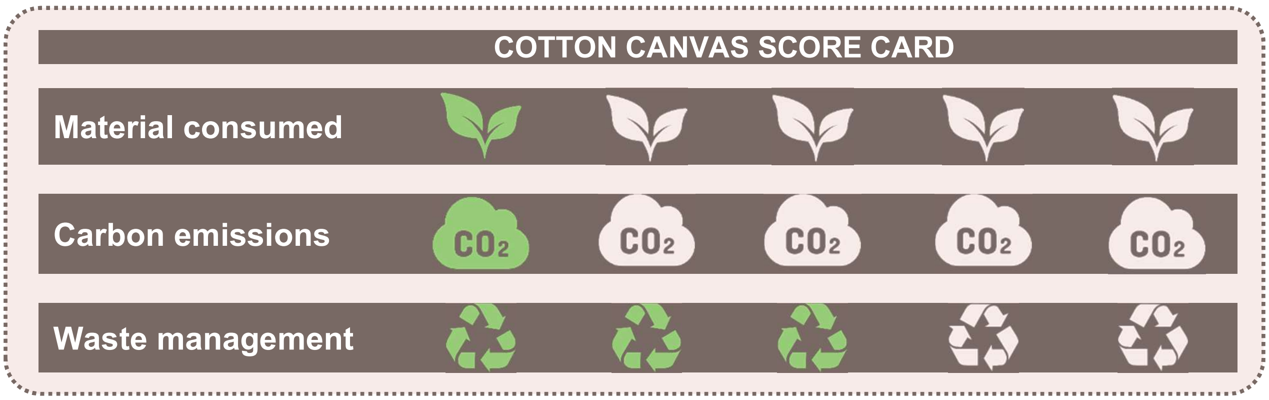


1 poor, 2 average, 3 medium, 4 good, 5 very good

97 Considering a life expectancy of 2 years

COTTON CANVAS

Summary of the enviromental impact cotton canvas		
Raw material used	Water consumption	132,000 liters
Manmade material used	Cotton canvas	13.2 kilos
Carbon emissions in kg CO_2 eq	production of material packaging transport end of life total for product Per year	80.52 *Data not available* 7.35 18.38 106.25 212.25[98]
Waste managment	Cotton canvas can be reused and recycled. The biggest advantage is that cotton will decompose fast.	



1 poor, 2 average, 3 medium, 4 good, 5 very good

98 Considering a life expectancy of 6 months

10. Conclusion

Diffa shelter model vs Tillaberi shelter model
The importance of examining in detail the entire life cycle of each shelter and each material, from production through to end of life, has been emphasised throughout this study. The criteria consider not only carbon emissions, but other factors, like use of local natural resources and waste management. While reducing carbon emissions is critical and well acknowledged today, it is clear is that waste is one of the hidden problems of the humanitarian world. It is usually ignored during project design, and rarely discussed at more strategic levels.

Comparing the two shelter models requires us to balance relative sources of environmental harm across the different criteria. The scope of this remote study and the limited access to environmental information from Niger and from suppliers does not allow for a quantitative weighting for each criteria, leading to a numerical score. An overall qualitative comparison is all that is feasible.

Between the different options the “least harmful solution” should be adopted. The idea that there is a perfect shelter solution that ticks all the boxes is not realistic. Not only regarding the environment, but also the other factors that need to be considered: technical performance, durability, habitability, affordability, etc. While one solution complies better with some of these factors, another is better for others.

One benefit of using the score card approach is to help identify mitigating solutions. The final verdict rests on the available options to mitigate some of the environmental impacts, which if adopted in future could reduce the overall environmental impact of the shelters. When there is damage to the environment due to our actions, for example deforestation or over-harvesting of the palm doum, mitigation measures should be adopted, like reforestation or replanting projects. It is recommended that an environmental impact assessment, and identification of mitigation strategies, should accompany the design of all shelter and site planning activities.

Overall, the Diffa model scores better regarding the materials consumed in production and the impact on local natural resources, while the Tillaberi model scores better on carbon emissions and waste management. Diffa uses more long-lasting materials that are unlikely to be recycled, and will take a very long time to decompose, polluting the environment for years to come, but on the other hand making the shelter more resistant with a longer life span. The biggest problem with the Tillaberi model is the amount of water that the cotton canvas uses, as well as the impact that the use of locally harvested natural materials can have on the already fragile environment on Niger. But its biggest benefit is that once the materials are no longer needed, most of them will decompose very fast.

Based on the analysis above, in the case of the Tillaberi model, the project should consider some of the following mitigating actions which could significantly reduce the environmental impacts of Tillaberi:

(1) Promoting with communities to avoid burning the natural materials once they are no longer needed, due to the amount of CO_2 eq that is released during this process. It is better the wood is reused, and the palm doum mats allowed to decompose.
(2) Set up a project component for reusing, repurposing or recycling (R3) the materials, especially the cotton canvas, once it gets to the state it has to be replaced. The R3 process can be a livelihoods generator as well
(3) Promoting reforestation and replanting projects, to ensure that the wood and palm supplies are not over-exploited. Small-scale projects could be included as part of the shelter programme, such as supporting communities to replant palm doum. Larger scale efforts could be in partnership with specialist organisations.
(4) Carefully examining sustainability issues with the suppliers for the locally sourced wood, to ensure over-extraction or other damage is not happening
(5) Invest in purchasing carbon off-sets for the CO_2 eq produced (following one of the many internationally recognised certification standards)

However, it is important to recognize that the longer a shelter lasts, the more efficient it is. This semi-permanence may not be initially acceptable as it implies that the reasons for displacement will continue beyond tomorrow. But it makes sense when the designs are such that they can be deconstructed and become movable assets for their owners. In this sense, both models have been designed for this purpose. However, the Diffa model has a longer life span than Tillaberi. Keeping this in mind, as well as noting that it uses long-lasting materials that will take a very long time to decompose, mitigating actions can be taken to reduce the worst environmental impacts of Diffa as follows:

(1) Set up a project component for reusing, repurposing or recycling (R3) the materials once the shelter gets to the state it has to be replaced. The R3 process can be a livelihoods generator as well. This is especially for

the plastics sheeting, PVC, and plastic mats, because we can assume the metal poles have a good likelihood of continual reuse.
(2) Invest in purchasing carbon off-sets for the CO_2 eq produced (following one of the many internationally recognised certification standards). The offsetting cost would be lower than for the cotton canvas (less CO_2 eq produced).
(3) Promoting reforestation projects, to ensure that the wood supplies are not over-exploited in the local area. Small-scale projects could be included as part of the shelter programme, while larger scale efforts could be in partnership with specialist organisations.
(4) Carefully examining sustainability issues with the suppliers for the locally sourced wood, to ensure over-extraction or other damage is not happening.

Plastic sheeting vs Cotton canvas
Regarding the environmental comparison of the two materials as standalone materials, plastic sheeting has a better score for materials consumed in production and carbon emissions, while cotton canvas scores much better in waste management. As we have seen, cotton wastes thousands of liters of water and pesticide during its production, manufacturing cotton canvas has a greater CO_2 equivalent, and is a less “durable” solution, meaning that the cotton canvas needs to be replaced more often increasing the environmental effects even more. However, the greater benefit of cotton is that will degrade in the environment, while plastic will not. On top of this, plastic sheeting will break into small pieces, having a negative impact on the environment for years to come. This is even more so in a country like Niger, with an inefficient waste management system.

When using cotton canvas, the project should take the following mitigating actions:
(1) set up a project component for reusing, repurposing or recycling (R3) the cotton canvas once it gets to the state it has to be replaced. The R3 process can be a livelihoods generator as well.
(2) invest in purchasing carbon off-sets for the CO_2 eq produced (following one of the many internationally recognised certification standards).

Taking these steps means that cotton could still be used from an environmental point of view, but at a somewhat higher cost, particularly for the cost of carbon offsets.

It should be noted that the performance of the cotton hasn’t been considered in this report, since it is not part of the environmental criteria and outside of the scope of work, however, it should not be disregarded. Cotton canvas may better for the environment, but if its performance is not good in a climate like in Niger, and is also less cost efficient, then another alternative should be considered, or a different cotton canvas tried that will have a better performance. Further research into this should be done.

When considering other factors like durability and efficiency, plastic sheeting may be better. Even if plastic sheeting is not the perfect fit, especially due to the environmental impact at the end of its life, at this stage it seems the best solution due to durability, waterproofness, sheltering capacity, versatility, many reuse possibilities, and has the possibility to be recycled. At the time of this study, there is an ongoing project that is part of the Red Cross Sustainable Supply Chain Alliance, involving ICRC, IFRC and UNHCR to improve the sustainability of plastic sheeting, and this will hopefully reduce some of the biggest concerns. Compared to the cotton canvas, plastic sheeting does not consume much water in its production, and generates lower carbon emissions, but generates more waste. The following mitigating actions could be considered when using plastic sheeting:
(1) Set up a project component for reusing, repurposing or recycling (R3) the plastic sheeting once it gets to the state it has to be replaced. The R3 reuse or recycling process can be a livelihoods generator as well.
(2) Invest in purchasing carbon off-sets for the CO_2 eq produced (following one of the many internationally recognised certification standards).

The offsetting cost for plastic sheeting would be lower than for cotton canvas (less CO_2 eq produced) and the problem with plastic not decomposing in any reasonable period would be addressed by the R3.

11. Recommendations

Based on the analysis and findings of this study, these are the recommendations to improve the environmental impact of the project:

Recommendations from the environmental analysis

Materials

- Further study on the impact on the habitat of the eucalyptus in Niger, determining with suppliers if its harvesting can be regarded as sustainable, and explore other alternatives if necessary.
- Further study on the risks of overexploitation of the palm doum and explore other alternatives if necessary. Sorghum?
- Include reforestation or replanting projects within the shelter programme. Either directly with communities, or if on a bigger scale through partnerships with other specialist organisations.
- Consider to avoid using PVC, since it is one of the most polluting materials.
- Further study if by using a different cotton canvas, its performance and durability could be improved.
- Consider to source the cotton canvas from a nearby country instead of from North Africa.
- Using other materials instead of cotton could also be considered, the issue with organic cotton is its price. Other material like hemp, linen, etc.

Reduce carbon emissions

- Promoting with communities to avoid burning the natural materials once they are no longer needed, due to the amount of CO_2 eq that is released during this process.
- Carbon offsetting: Another way to reduce emissions and to pursue carbon neutrality is to offset emissions generated by reducing them somewhere else, or by purchasing carbon credits from a project that has been accredited by a recognised standard[99].
- To procure more "locally", especially the cotton canvas, PVC and steel tubes, thus reducing emissions from transportation.

Waste management practices

- Raising awareness of the pollution generated by the disposal of the materials, though the programme, or through advocacy in partnership with other organisations. This could be difficult to implement in a country like Niger, where families often rely on burning organic matter for cooking fuel. However, a project could consider to distribute to families cooking stoves that do not rely on these organic materials, and rely more on solar power or alternative fuels.
- Materials can be collected and used as second-hand raw materials in other products, especially those materials that takes long time to decompose, like plastic sheeting or steel tubes. It can easily be linked with livelihood or education programmes. For example, plastic sheeting can be transformed to be bags, coats, etc. while cotton canvas could be used for making clothes[100].
- Link communities to private waste companies to collect materials which are not reused, for recycling, like GVD Afrique. There is also the possibility to generate income from this.
- Reduce the packaging for all material, or support the reuse of this for other purposes.

Others

- Advocate to and involve the shelter cluster working group and other partners in the Country to pass key environment messages, including some of the findings from this study.
- Promoting reforestation programs more broadly, to help with Niger's environmental context.

99 *European Parliament*
100 *recycling_reuse_and_disposal_of_plastic_sheeting.pdf (sheltercluster.org)*

General recommendations to consider for future programmes

Design

- Design a shelter that allows the materials to be easily dismantled and transported if relocation occurs, to enable reuse
- Incorporating vegetation on the site can promote water retention and reduce flooding. This can be done by promoting replanting projects.

Materials

- Prioritise locally available shelter materials, provided they do not negatively impact the local environment significantly. This does require some research on the ground.
- Use long lasting products and materials, to minimize the replacement and allow a second life through reuse.
- No single-use plastic wrapping for material, work with suppliers to eliminate this

Reduce carbon emissions

- Procurement choices:
    - Select manufacturing companies that produce 'green' products or from countries that have demonstrated results in terms of lower carbon emissions through good governance and investment in clean energies.
    - Ensure that acquired products were manufactured under acceptable conditions in terms of environmental compliance.
    - Use locally produced and purchased shelter materials, if acceptable quality can be guaranteed.
- Transportation routes.
    - Optimize the logistics supply chain to reduce the carbon footprint from transport.
    - Reduce weight and volume
    - Take into account that transportation by road, sea and air can also lead to a significantly different emission. In the African case, ocean shipping is better than long distances by road, while of course air transportation is the worst.
- Manufacturing phase: There are fewer opportunities to reduce CO_2 equivalent at the manufacturing phase, but influence can be exerted by:
    - Try to support wood suppliers with FSC certification, which can reduce carbon emissions indirectly as plantations growing trees sustainably means that felled tree are replaced with new trees. The carbon emitted by the felled trees will be sequestered by the growing trees, hence use of sustainably sourced timber can potentially be carbon neutral or even carbon negative (D'Arrigo et al. 1987). Or by favouring manufacturing processes that facilitate pollution control.
- Carbon offsetting: purchasing carbon credits from a project that also delivers benefits to local communities, and has accreditation from a recognised international standard.

Waste management practices

- Waste management practices should be taken into consideration, ideally, they should be considered early on in the planning phase. This means selecting materials with high probability of reuse, and investigating how communities can be linked to private sector recycling firms.
- Promote composting of biodegradable material when possible, such as wood, plant products etc. But avoid burning them.

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13. Annexed documents

ANNEX 1 – Term of Reference

CONTEXT AND JUSTIFICATION

The Aide Internationale de la Croix-Rouge luxembourgeoise (AICRL) has been working for several years in the field of emergency shelter and sustainable housing in Niger. It works closely with the IFRC Shelter Research Unit (IFRC-SRU) in the development of shelter models adapted to the climatic conditions and cultural contexts of the Sahel. Numerous research missions have made it possible to develop shelter models that take into account the specificities (contexts) and the availability of materials at the local level. In 2017, a storable shelter model was developed in order to be able to set up contingency stocks for a faster response capacity but also to strengthen the national society's shelter capacities.

In order to provide a context-specific shelter solution, in 2019 a variant of the Sahelian shelter model was developed in collaboration with beneficiaries and volunteers in the Tillaberi region. This variant is called the Tillaberi shelter and is characterised by the use of a cotton sheet to curve the dome.

With this in mind, the Nigerian Red Cross in partnership with the Luxembourg Red Cross organised participatory workshops in 2017, 2019 and 2021 to improve and adapt existing shelter solutions.

Based on the experience gained in the field and the feedback from beneficiaries collected by the project teams and trained volunteers, AICRL wishes to capitalise on these experiences and the beneficiaries' feedback on the models designed by AICRL and adopted by all humanitarian actors in Niger. However, one key factor has not been analysed in detail, the comparative environmental impact of the two shelter models (Diffa and Tillaberi). This is necessary in order to understand which option is really the best adapted to the Nigerien context and in line with the current global trend to improve the environmental sustainability of humanitarian aid.

Outcome and Output

Outcome

With the support of the IFRC-SRU, AI-CRL seeks to improve the quality of the shelter response in Niger, and minimise the environmental impact of its operations.

Outputs

- A comparative study of the Diffa and Tillaberi shelter models to assess the environmental impact of each model.
- A comparative study between plastic and cotton tarpaulins from an environmental point of view.

Product and delivery format

- Study report
- Predefined format
- Size A4
- French language

Approche méthodologique

The following is an initial proposal for the methodology. It may be adjusted as the consultation progresses, in discussion with the CRL technical officer, according to the information found, the time available and any constraints related to working remotely.

Literature search and problem definition

- Literature review: programme documentation (including logistics/supply chain); environmental profile of Niger, etc.

Data collection and analysis

- Key informant interviews (semi-structured): with AICRL staff (shelter, logistics, other); other shelter agencies/shelter cluster Niger (or the Shelter and Non-Food Assets Working Group (SNAG) in Niger); local actors/government (if necessary).
- Brief review of emerging best practice in life-cycle analysis / carbon footprinting tools.
- Discuss and prepare with the field team for light monitoring of the shelters in the field (in particular to determine the useful life of the Tillaberi shelter; also reuse of materials). Assume that this is not quantitative
- Calculations of carbon emissions from both shelters.
- Analysis of other environmental factors of both shelter models.
  - Sustainability of the sources of the natural resources used
  - Disposal and/or reuse options at the end of the materials' life (waste management perspective).
- Analysis of cotton versus plastic sheeting (tarp)
  - Consideration of manufacturing process, natural resources used, carbon emissions, biodegradability, useful life, etc.
- Write the report and share it with the AICRL technical officer.

Conclusions and report

- Comment on and validate the report.
- Presentation of results to AICRL and GTABNA staff; follow-up meetings
- Final drafting

Detailed field monitoring, surveys, etc. are not foreseen and are outside the scope of this study.

Field team support

Operation

- Be available for semi-structured interviews.
- Filling in forms if necessary after the literature review and preparation of the working tools.
- Be available to discuss and prepare a rapid assessment with the field team
- Refer to or put in contact with key actors in the field that the team considers necessary for the study (GTABNA in Niger); local actors / government (if necessary) etc.

Human Resources

- Availability of a field team to carry out a rapid assessment. No more than one day is expected. Details will be worked out once the consultant and the field team have exchanged ideas.
-

Logistics

- Prepare all documentation necessary for the environmental study.
- Be available for semi-structured interviews.
- Refer to or put in contact with key stakeholders in the field that the team considers necessary for the study (suppliers, etc).

Documentation

- Provide all detailed and accessible information on the materials used in both types of shelters (BoQ, suppliers, supply chain, packaging, etc.),
- Provide any reports that the team deems necessary for this study (Impact study, etc.).
- If available, recommend or provide more secondary data sources (environmental profile of Niger, etc.).

ANNEX 2 – Informants

International Aid of Luxemburg Red Cross

- Daniel LEDESMA
- Prosper ZOMBRE
- Ismael OUSMANE
- Abdoulaye MAMANSAN

Technical support in the use of SMAC for the report was provided by:

- C. KELLY, Co-Chair, Environment Community of Practice, Global Shelter Cluster.
- Stephen ALEXANDRE, BRE
- Flavie Lowres, Independent Consultant.

From the Red Cross Sustainable Supply Chain Alliance

- Patrick OGER, *ICRC*

Groupe de Travail Abris & Biens Non Alimentaire

- Ben ODUWA WOTSHU - *Coordonnateur Groupe de Travail Abris & Biens Non Alimentaire – GT ABNA*

IOM

- Orlane Claire Charlotte MATHIEU-MAINCENT
- Oumarou SEYNI

Other person contacted:

- Ali MOUSA DOGO – Directeur GVD Afrique
- Amina ISSA ADO – RE 'AGIS

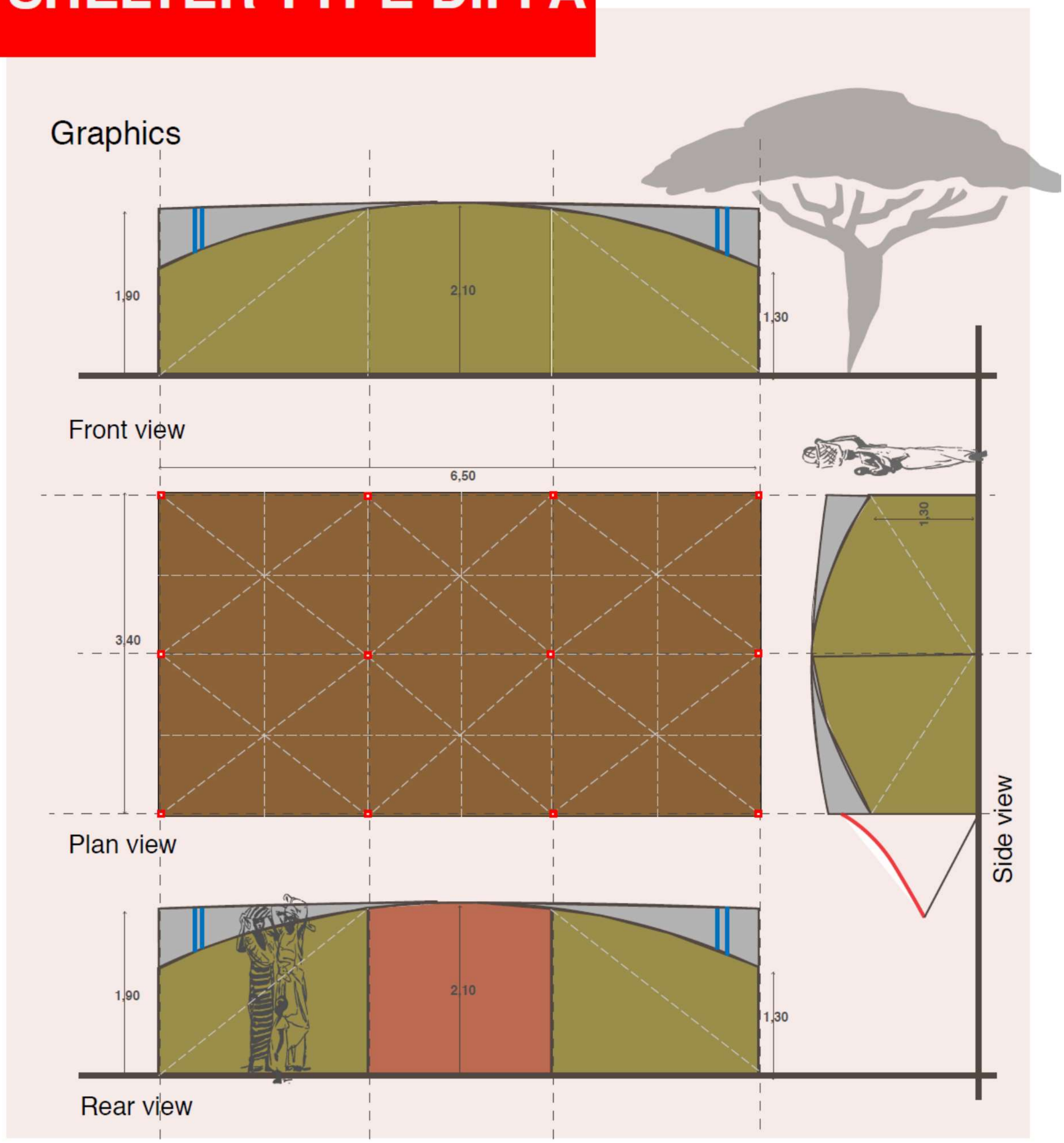
Other organisation contacted:

- JVE Niger
- African Forest Forum

ANNEX 3 – Shelter Models Technical Information

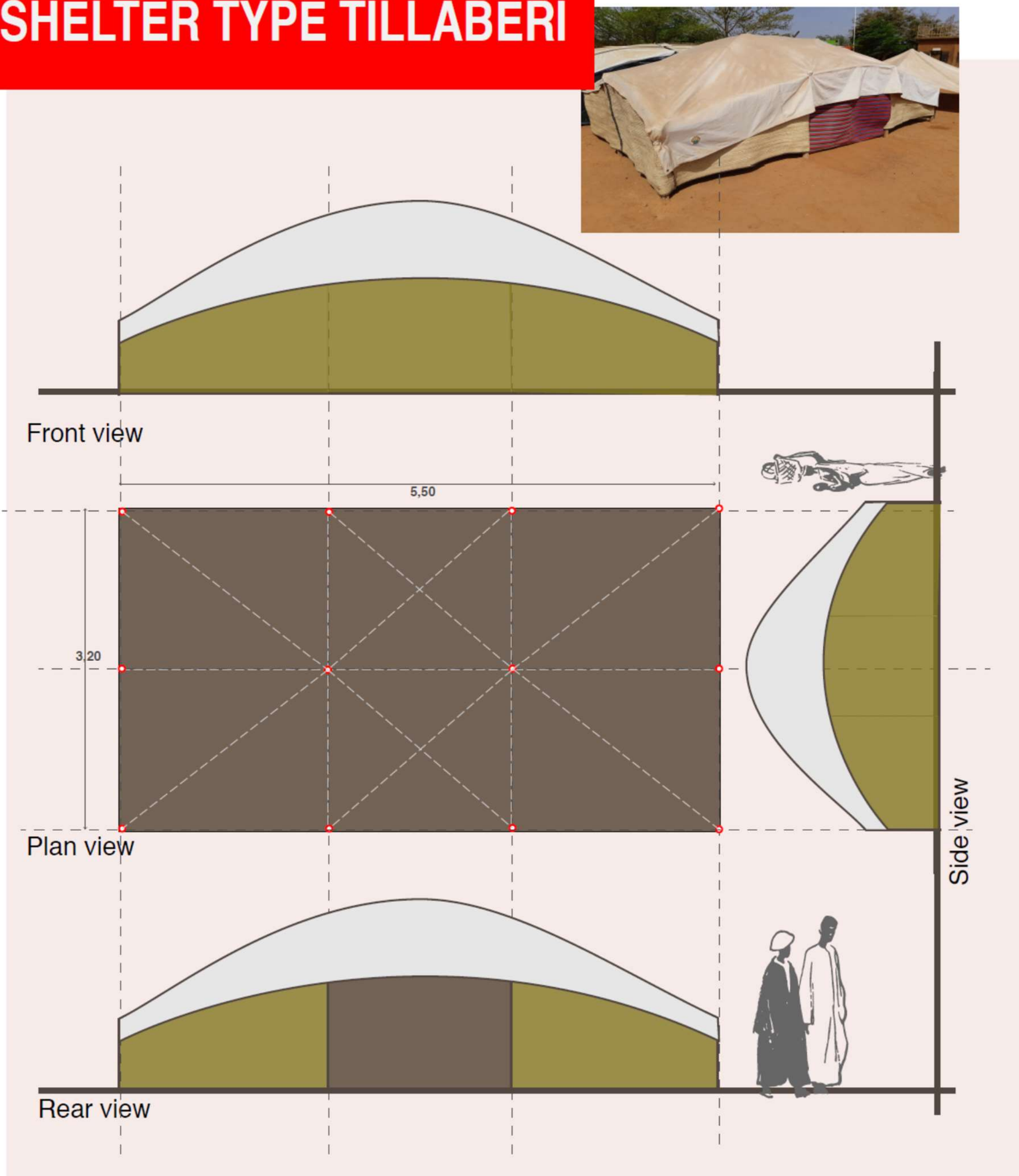
Technical information

SHELTER TYPE DIFFA



Technical information

SHELTER TYPE TILLABERI



ANNEX 4- Shelter components material, packaging, quantity and country of origin

Diffa model

Name	Raw material	Quantity/ Kg	Country of origin	Packeting
Steel poles	Steel	22.5	Nigeria Côte d'Ivoire	No packaging
PVC poles	PVC	36.4	Niger Nigeria Côte d'Ivoire	No packaging
Plant matts	Palm doum	60	Niger (Dosso, Tillaberi, Zinder, Diffa, Maradi, Tahoua)	No packaging
Plastic sheeting	Polyethylene	9	Chine	5 tarpaulins attached in one tarpaulin
Plastic matts	Polyethylene	2	Niger, Côte d'Ivoire Benin,	Tied with strings, 40 pieces per set
Synthetic rope	Nylon	0.5	Nigeria Côte d'Ivoire Ghana	Polyethylene bag
Wire	Iron	6	Nigeria Côte d'Ivoire	Polyethylene bag
Sewing thread	Cotton	0.04	Nigeria Côte d'Ivoire	Polyethylene bag

Tillaberi Model

Name	Raw material	Quantity/ Kg	Country of origin	Packeting
Timber	Eucalyptus	61	Niger (Dosso)	No packaging
Plant matts	Palm doum	20	Niger (Dosso, Tillaberi, Zinder, Diffa, Maradi, Tahoua)	No packaging
Cotton canvas	Cotton	13.2	Morocco Algeria Tunisia	Cotton bag
Plastic matts	Polyethylene	2	Niger, Côte d'Ivoire Benin,	Tied with strings, 40 pieces per set
Synthetic rope	Nylon	0.5	Nigeria Côte d'Ivoire Ghana	Polyethylene bag
Wire	Iron	6	Nigeria Côte d'Ivoire	Polyethylene bag
Sewing thread	Cotton	0.04	Nigeria Côte d'Ivoire	Polyethylene bag

ANNEX 5 - Transport distances

Country of origin to point of arrival in country

Country	Capital	Distance to Niamey
Nigeria	Lagos	1029 km
Côte d'Ivoire	Abidjan	1691 km
Ghana	Accra	1240 km
Benin	Porto-Novo	982 km
Tunisia	Tunis	4162 km
Algeria	Algiers	3754 km
Morocco	Marrakesh	4684 km

Plastic Sheeting: China to Abidjan (Cote d'Ivore) by boat 19,000 kilometers

Point of Arrival to Warehouse / Store

Departing point	Arrival point	Distance
Niamey	Diffa	1365 Km
Niamey	Marandi	661 Km
Niamey	Tillaberi	115 Km
Dosso	Diffa	1228 Km
Dosso	Maradi	524 Km
Dosso	Tillaberi	253 Km
Zinder	Diffa	475 Km
Zinder	Maradi	235 Km
Zinder	Tillaberi	1005 Km
Tahoua	Diffa	1052 Km
Tahoua	Maradi	710 Km
Tahoua	Tillaberi	679 Km

Warehouse to Construction Site (km)

Area	Location warehouse	Distance
Diffa	Awardi:	5 Km
	Djori Koulo	3 Km
	Bagara	2Km
	Hypodraume	2 Km
	Maine Soroa	70 Km
	Bosso	105 Km
	N'Guigmi	130 Km
Marandi		100 Km
Tillabéri	Niamey	115 Km

ANNEX 6 - Examples of materials reused

Materials reused for a courtyard

PVC and palm doum mats

Layout of a courdtyard with plastic sheeting ties

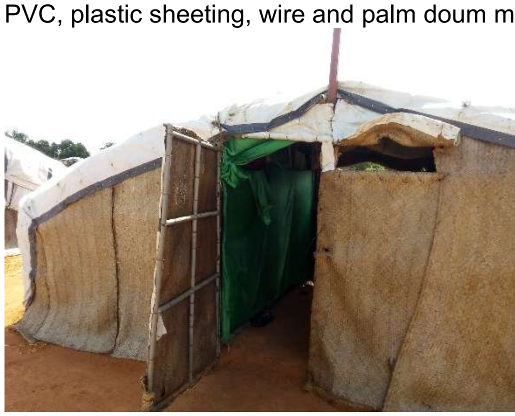
Materials reused as a door

PVC, palm doum mats and wire

Plastic sheeting

PVC and palm doum mats

PVC, plastic sheeting, wire and palm doum mats



Shade structures

PVC and steel pole

PVC

PVC and palm doum mats

PVC and palm doum mats

Other examples

PVC and eucalytus wood, used to build a Mosque

Reinforced shelter with palm doum matt ties

ANNEX 7- Plastic Sheeting specifications

Plastic Tarpaulins 6x4m with pre-punched reinforcement bands

Material	
Material for the plain sheet	Woven high-density polyethylene (HDPE) black fibres fabric laminated on both sides with white low-density polyethylene (LDPE) coating.
Material for the reinforced attachment points	6 bands of 75mm +/-3% width made of woven black HDPE fibres fabric and coated with grey LDPE on the outside. Pre-punched 8mm holes on the 2 side bands at 0.1m +/-10% intervals, positioned in the centre of the bands (only the reinforcement bands are pre-punched, not the tarpaulin itself). Position of the 6 bands and pre-punched holes as per drawing below. Side bands can be positioned at maximum 10mm from the edge. Dimension tolerance on the distance between two bands: +/-10mm
Strength at state of origin and after UV exposure	
Tear strength in plain sheet at state of origin	Minimum 100N under ISO 4674-1B 2003, with a test piece of 200x200mm as described in ISO 4674 annex B, in plain sheet.
Tensile strength in plain sheet at state of origin	Minimum 500N and 15% to 35% elongation in warp and weft in plain sheet under ISO 1421-1.
UV resistance of the plain sheet, measured as remaining tensile strength after UV exposure	The tarpaulin tensile strength under ISO 1421-1 after 1500 hours UV under ASTM G53/94 (UVB 313 nm peak) must be: Minimum 80% of the original value of the actual product, <u>AND</u> not less than 475N. To be tested in the plain sheet.
Tensile strength in the reinforcement bands at state of origin	Minimum 700N inside the reinforcement bands as per ISO 1421-1, pulling lengthwise in a pre-punched hole of 8mm with a hook of 8mm wire diameter. To test in 2 holes in each side bands
UV resistance of the reinforcement bands measured as remaining tensile strength after UV exposure	The reinforcement bands tensile strength under ISO 1421-1 after 1500 hours UV under ASTM G53/94 (UVB 313 nm peak) must be: Minimum 80% of the original value of the actual product, <u>AND</u> not less than 665N. To be tested inside the reinforcement bands as described above.
Welding number and strength at state of origin	Only one welding allowed, in the middle of the sheet, length wise. The tarpaulin tensile strength crossways at the place of the welding under ISO 1421-1 must be: Minimum 50% of the original value of the actual product, <u>AND</u> not less than 400N.
Size, weight, colour, fire resistance	
Width	4 m ± 1% net width
Length	6m minimum net length
Weight, plain sheet only, excluding the bands weight	190g/m² ± 20g under ISO 3801 (equivalent to 170g/m² minimum to 210g/m² maximum)
Weight, complete sheet including bands weight.	Plain sheet specific weight plus 10% additional weight for the reinforcement bands under ISO 3801.

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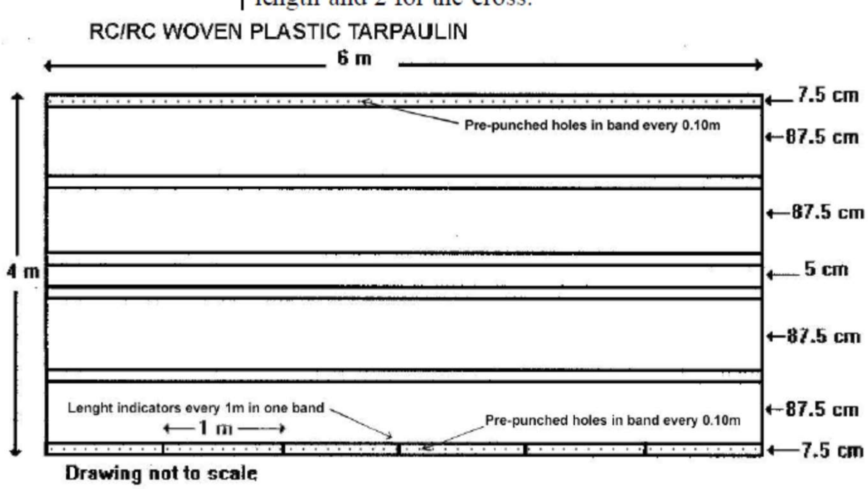
	Total weight from 187g/m² minimum and 231g/m² maximum Specific weight of the bands from 150g/ m² minimum and 200g/m² maximum
Flame retardant EN13823+A1	Minimum class D, s2, d2. Minimum time to reach large wing external edge: 4minutes (LFS)
Colour	White sun reflective on both sides of the sheet. Grey coating on the outside of the bands. Inner black fibres to ensure opacity. **White Coating colour definition:** L.a.b Coordinates under ISO 105J01 Minimum L: 82 "a" value between -1.7 and +1.5 "b" value between -4.5 and 0
Opacity measured as minimum reflection and maximum transmission, in the range of visible light and near infrareds.	Measured under ISO 13468-1. Values should be measured respectively from 350 to 750nm, and from 750 to 2500nm wavelength. The final result is the average of the averages in each range. Minimum total reflection: 35% Maximum total reflexion: 50% Maximum total transmission: 5%
Marking, packing, and accessories	
Printing	Continuous indelible printing in white colour on grey, or in black colour on white, of the manufacturer name, the month and year of production (Letters of 2.5cm high +/10%). Length indicator marks every meter. Customer logo on request.
Bale dimensions	Length: 600mm; Width: 400mm; Height: 180mm (all +/-20%) There must be 5 tarpaulins per bale
Bale marking	As per indicated in contract.
Bale protection	The bale must be wrapped with a piece of similar material as the one of the tarpaulins. The wrapping must be properly folded, closely tight to the bale content, making a well-shaped cubic bale. Inside the bales the tarpaulins are not individually wrapped.
Bales strapping	The bale must be strapped with 2 heat-sealed plastic straps for the length and 2 for the cross.



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