REPORT
Sahel environmental impact study of the emergency shelter models

November 2022

croix-rouge luxembourgeoise
Mënschen hëllefen

LUXEMBOURG AID & DEVELOPMENT

Contents

Acknowledgements

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1. Definitions

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.[1]

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[2]

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)[3].

The Climate Risk Index (CRI) indicates a level of exposure and vulnerability to extreme events, which countries should understand as warnings in order to be prepared for more frequent and/or more severe events in the future[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].

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1 *European Parliament*
2 *Fast Company*
3 *Carbon Trust*
4 *Germanwatch*
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.

IDP (Internally Displaced person) is someone who is forced to leave their home but who remains within their country's borders.[14]

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[15].

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[16].

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 *UNHC*
15 *ISO*
16 *https://assembly.coe.int*

2. General information

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

Countries: Burkina Faso, Chad, Mali & Niger

Report date: November 2022

Type of operation: Remote consultancy

Requesting Organization: International Aid of the Luxembourg Red Cross

3. Context

The Aide Internationale de la Croix-Rouge Luxembourgeoise (AI-CRL) has been working for several years in the field of emergency shelter and sustainable housing in the Sahel region (Burkina Faso, Chad, Mali and Niger). AI-CRL collaborates closely and in partnership with the different National Society in each country; Nigeria Red Cross, Burkina Faso Red Cross, Chad Red Cross and Mali Red Cross.

Numerous research missions have made it possible to develop a total of eight different shelter models, that take into account the specificities of the contexts of the Sahel (climatic conditions and cultural aspects) and the availability of materials at the local level in each country; The “Diffa” model, “Tillaberi” model (built in Niger), “Sahel Shelter Type I”, “Sahel Shelter Type II” (built in Burkina Faso), “Sahel Shelter”, “Moundou Shelter” (built in Chad), “Case Végétale” (or Cases Peulh), and “Case en Milieu Humide” (built in Mali).

In 2015 in Niger 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. This emergency shelter has a total surface of 22m^2, is made of metal and PVC tubes, a dome-shaped geometry, covered with plastic sheeting, and doum palm mats. A total of 21,000 shelters have been built in Diffa and Maradi region. This shelter model has been implemented in other countries in the region.

In Burkina Faso two shelter models similar to “Diffa” were developed. The first model is the “Sahel Shelter Type I”, with a total surface of 21m^2. Built from 2018. Since 2021, a second shelter model, the “Sahel Shelter Type II”, has replaced Type I. It covers a smaller surface of 14m^2. A total of 4,700 shelters of both types have been installed in the country (62% Type I & 38% Type II), in the border areas with Mali and Niger: in the communes of Centre-North (58%), Sahel (37%) and Boucle de Mouhoun (5%).

In Chad, a similar shelter model as the ones develop in Niger and Burkina Faso was implemented, the “Sahel Shelter”. It was built in southern Chad in 2018 in a refugee camp (Belom camp, Maro department). The materials are similar to those of the previous model and a total surface of 21 m^2 .

In 2019 in order to provide a context-specific shelter solution, a variant of the Sahelian shelter model “Diffa” was developed in collaboration with beneficiaries and volunteers in the Tillaberi region (Niger). 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.

A second shelter model in Chad, the “Moundou Shelter”, has been tested in 2021 as part of the implementation of their emergency projects in the Lac province (Ngouboua Koura and Djourou Kapi, a total of 1262 were built. It is based on the traditional architecture of the intervention area. A dome-shape geometry of date palm stems, attached to the heads of the basswood posts. The roof is covered with plastic sheeting, and doum palm mats. And the wall are made of branches of stems of local straw, of a total surface of 18m^2

In Mali. The first model built is the “Case Végétale” (or Cases Peulh), of a total surface of 24m2, which can accommodate up to six people. It is made of metal tubes and a dome-shaped geometry covered with plastic sheeting, eucalyptus wood and palm doum mats. A total of 1000 shelters have been installed in Mali in the Tomboucto region by AI-CRL since 2018. The second shelter model is the “Case en Milieu Humide”, of a total surface of 20 m^2 which can accommodate up to five people. It has been adapted from a UNHCR model, is made of metal tubes, a double-sided roof (chevron) made of basswood timber and closures with plastic sheeting and fabric. A total of 163 shelters have been built in the Tombouctо region.

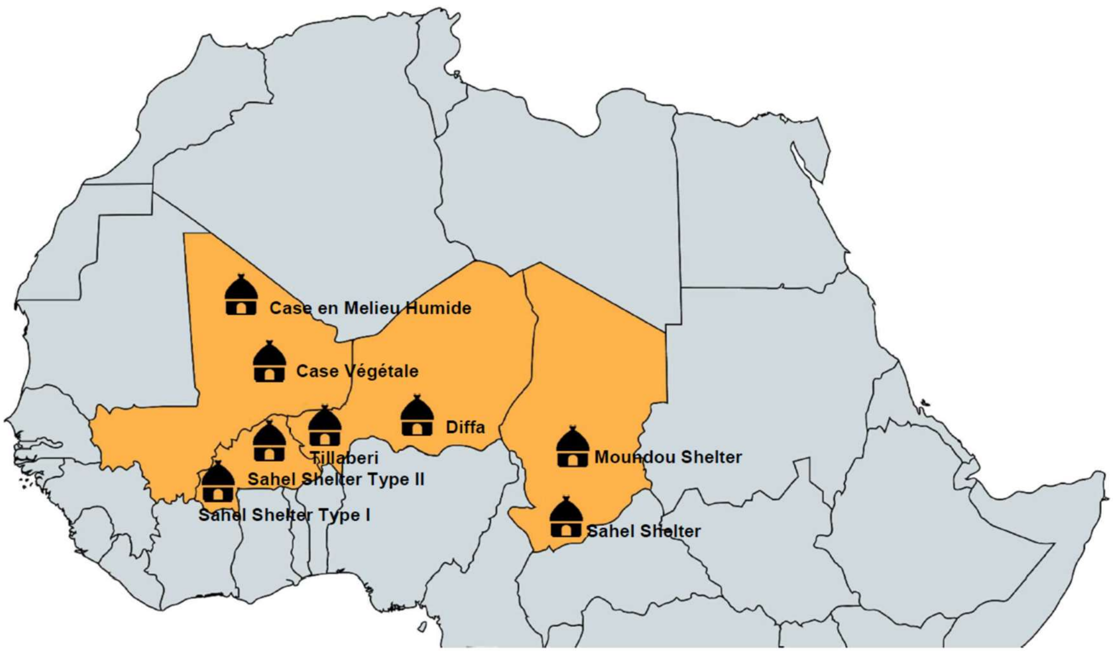
This experience gained in the field and the feedback collected from targeted populations has helped to evolve the shelter models designed by AI-CRL and adopted by all humanitarian actors in the different countries of the Sahel. However, one key factor has not been analysed in detail: the environmental impact of the shelter models. This is necessary in order to understand which option is best adapted to each local 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 as floods, droughts, desertification, fires, etc., are increasing due to climate change, and they are contributing to food insecurity, economic losses, population displacements, and are also drivers of conflict. People all over the world are facing the reality of climate change, and in many parts of the world this manifests as increased volatility of extreme weather events. Only between 2000 and 2019, over 475 000 people lost their lives worldwide[17] due to these. The 2021 edition of the Climate Risk Index clearly shows that signs of escalating climate change can no longer be ignored, on any continent or in any region. Impacts from extreme-weather events hit the poorest countries hardest as these are particularly vulnerable to the damaging effects of hazards, have a lower coping capacity and may need more time to rebuild and recover[18].

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 Sahel region is one of the most vulnerable to climate change (with most likely) the largest number of people disproportionately affected by global warming[19]. In 2020 the Sahel belt was pointed out as one of three ecological hotspots, which include regions with increased environmental stress that are more prone to collapse[20]. It is also one of the most environmentally degraded regions in the world, with temperature increases there projected to be 1.5 times higher than the global average, according to the UN[21]. In the Sahel, droughts are becoming more and more intense[22], and the frequency of heavy rainfall and storms has tripled in the Sahel since the 1980s[23]. The area of the Sahel desert has increased by 10% in the last 100 years[24]. The United Nations has also identified climate change as a driving force in creating conflicts in the region[25].

Good environmental practices from humanitarian agencies can help protect the local environment, contribute to improve the resilience of communities to natural disasters, and reduce their vulnerability, as well as reduce 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 on the environment. For instance, huge quantities of relief items have been brought into a country, local natural resources have been overused, and large amounts of unmanaged waste generated, 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 is a contribution to the growing body of work on the environmental impact of humanitarian assistance.

17 *Global Climate Risk Index 2021*
18 *Global Climate Risk Index 2021*
19 *UN: Sahel region one of the most vulnerable to climate change – Red Cross Red Crescent Climate Centre*
20 *2020 Ecological Threat Register*
21 *UN: Sahel region one of the most vulnerable to climate change – Red Cross Red Crescent Climate Centre*
22 *The Sahel in the midst of climate change. Solidarite International*
23 *World Meteorological Organization*
24 *University of Maryland*
25 *Impact of climate change on Africa's Sahel region (rte.ie)*



Map of the different shelters built in the region, by AI-CRL in partnership with the local Red Cross National Societies.

4. Outcome and Outputs[26]

Outcome
AI-CRL seeks to improve the quality of the shelter response in Burkina Faso, Chad, Niger and Mali, and minimise the environmental impact of its operations.

Outputs
- A comparative study of different shelter models in Burkina Faso, Chad, Niger and Mali.
- Recommendations to reduce the environmental impact of AI-CRL shelter interventions

Caveat on scope of this study
The scope of this study is limited to the environmental impact of the 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 programme evaluations of the AI-CRL shelter projects.

5. Methodology

26 *As included in the Terms of Reference for this study.*

These studies were conducted remotely, with the support of AI-CRL field staff (shelter, logistics, other); the Shelter Cluster in Burkina Faso, Chad, Mali and Niger; environmental experts from the shelter sector, and different local association, organisation, etc that specialises in ecological recycling and waste recovery in the region[27].

The methodology adopted is summarised by the graphic below.

Desk research and problem definition

- Literature review: programme documentation (including logistics/supply chain); environmental profile of the Sahel region 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)
- A rapid field assessment of shelters was considered, but was not seen as necessary after reviewing the documentation and interviewing the project teams.

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 shelter models according to the four criteria, analysing each material across its lifecycle from production to disposal.
- Overall (qualitative) comparison using a score card approach

Report writing, conclusions and recommendations

27 *Refer to Annex 1 to see the list of people and organisations contacted.*

6. Background information

6.1. Region profile

SAHEL

Location
Stretching 5000 kms from the Atlantic Ocean eastward through northern Senegal, southern Mauritania, the great bend of the Niger River in Mali, Burkina Faso, southern Niger, northeastern Nigeria, south-central Chad, and into Sudan. It forms a transitional zone between the arid Sahara (desert) to the north and the belt of humid savannas to the south[28].

Population
the Sahel is home to over 150 million people from ten countries.[29] Countries in the Sahel maintain some of the fastest growing populations in the world. Burkina Faso, Nigeria, Chad and Mali are all among the top twenty countries with the fastest projected population growth[30].

Economic situation
The countries of the Sahel are among the world's poorest. Niger is at the very bottom of the UN Human Development Index in 2018, and Chad, Burkina Faso and Mali rank just above. [31]

Conflict situation
Many of the world's poorest and insecure countries are found in the Sahel including Mali, Burkina Faso, Chad and Niger. In recent years, the region has become an epicentre for conflict. Especially with the expansion of several extremist groups within the region.[32] Ongoing clashes between armed forces and armed groups in the Sahel have forced millions of civilians to flee their homes in various countries within the Sahel region. Many of those who flee are farmers who can no longer till their land, thereby exacerbating an already existing food instability. Each conflict situation in the Sahel region is unique, with its own complex history and diversity in actors.[33]

Climate
The Sahel has a tropical semi-arid climate. The climate is typically hot, sunny, dry and somewhat windy all year long. The Sahel mainly receives a low to very low amount of precipitation annually. The steppe has a very long, prevailing dry season and a short rainy season. The precipitation is also extremely irregular, and varies considerably from season to season. Most of the rain usually falls during four to six months in the middle of the year, while the other months may remain absolutely dry. The Sahel is characterized by constant, intense heat, with an unvarying temperature. Rarely experiences cold temperatures. During the hottest period, the average high temperatures are generally between 36 & 42 °C[34]

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28 *Britannica*
29 *The Sahel: Challenges and opportunities | International Review of the Red Cross (icrc.org)*
30 *The Sahel Faces 3 Issues: Climate, Conflict & Overpopulation (visionofhumanity.org)*
31 *Sahel - The worlds most neglected and conflict-ridden region (nrc.no)*
32 *The Sahel Faces 3 Issues: Climate, Conflict & Overpopulation (visionofhumanity.org)*
33 *The Sahel: Challenges and opportunities | International Review of the Red Cross (icrc.org)*
34 *Wikipedia*

6.2. Sahel environmental Challenges

Environmental Challenges[35]

Climate change

The Sahel is one of the most vulnerable to climate change. It is also one of the most environmentally degraded regions in the world[36]

Increasing Temperature

Temperatures in the Sahel rise 1.5 times faster than the global average, with near surface temperatures increasing over the last 50 years. The Sahel is expected to warm by 3°C to 5°C by 2050[37].

Floods

Floods are a recurring natural hazard in the Sahel region, that are likely to become worse with climate change.[38]

Droughts

Over the past five decades, persistent droughts have contributed to recurring famines in the Sahel [39].

Desertification & Deforestation

Desertification in the Sahel region is a progressive threat. The Sahel Region has lost millions of hectares of easily accessible farming land to the desert[40]. 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[41].

Soil degradation & Wind erosion

Wind erosion is an important soil degradation process on agricultural fields in the Sahel and is strongly affected by the scattered woody vegetation.[42]

Solid waste

The national and local systems of waste collection, storage, treatment and disposal are not well functioning.

Water scarcity

Due to the drying up of the surface water table, traditional open-well type water supply systems are no longer viable in the region.[43]

Air Pollution

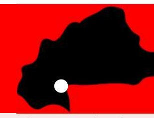
The air quality in most of the country in the Sahel region is considered unsafe. The data indicates the Sahelian countries' annual average concentration of $PM_{2.5}$ are higher[44] that the recommended maximum of 10 $\mu g/m^3$ according to the WHO.

35 *www.legit.ng*
36 *UN: Sahel region one of the most vulnerable to climate change - Burkina Faso | ReliefWeb*
37 *Climate Change, Food Security and migration in Chad: A Complex Nexus. American University, IOM Chad and the Chad Food Security Cluster*
38 *Climate Change Knowledge Portal*
39 *CHALLENGES IN THE SAHEL: OPPORTUNITIES FOR EUROPE - GeoPolitica*
40 *Desertification and Farming in the Sahel - The Borgen Project*
41 *Desertification in Niger - Studymode*
42 *Wind Erosion Reduction by Scattered Woody Vegetation in Farmers' Fields in Northern Burkina Faso. Jakolien K. Leenders,Geert Sterk, John H. van Boxel*
43 *The Sahel in the midst of climate change - Chad | ReliefWeb*
44 *CIA*

6.3. Sahel Shelter models

For further technical details for each shelter model refer to the annex 2

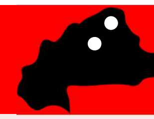
SAHEL SHELTER TYPE I



The Sahel Type I is designed as an emergency to transitional shelter solution, adapted to the Sahel region of the western Africa. Built from 2018 in Burkina Faso, in in the border areas with Mali and Niger: in the communes of Centre-North (Bourzanga, Bouroum, Tougourin, Kaya) and Sahel (Dori, Djibo).

It has a total surface of $21m^2$, is made of metal and PVC tubes, a dome-shaped geometry, covered with plastic sheeting, and doum palm mats.

SAHEL SHELTER TYPE II



This emergency shelter is designed as a variation adapted to the context on central Burkina Faso. Built from 2021, in the communes of Boucle du Mouhoun (Tougan), Centre-Nord (Bourzanga, Bouroum, Pensa), and Sahel (Sebba, Gorgadji).

It has a total surface of $14m^2$, is made of metal and PVC tubes, a dome-shaped geometry, covered with plastic sheeting, and doum palm mats.

SAHEL SHELTER

The Sahel Type is designed as an emergency to transitional shelter solution, adapted to the Sahel region of the western Africa. Built in southern Chad in a refugee camp (Belom camp, Maro department).

It has a total surface of $21m^2$, is made of metal and PVC tubes, a dome-shaped geometry, covered with plastic sheeting, and doum palm mats.

MOUNDOU SHELTER

This emergency shelter was developed as a basic emergency contextual shelter solution adapted to the Lake Province of Chad (Ngouboua Koura and Djourou Kapi).

A dome-shape geometry of date palm stems, attached to the heads of the basswood posts. The roof is covered with plastic sheeting, and doum palm mats. And the wall are made of branches of stems of local straw, of a total surface of $18m^2$.

CASE VÉGÉTALE

This emergency shelter is designed as a variation adapted to the context of Tombouctou, Mali.

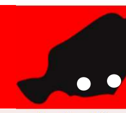
A total surface of 24m^2, which can accommodate up to six people. It is made of metal tubes and a dome-shaped geometry covered with plastic sheeting, eucalyptus wood and palm doum mats.

CASE EN MILIEU HUMIDE

UNHCR designed this emergency shelter in response to the needs of the displaced population in Mauritania. It was later implemented in Mali with some minor adaptations to the local market and Tombouctou context. In Mali

a total surface of 20 m$^{2.}$ It is made of metal tubes, a double-sided roof (chevron) made of basswood timber and closures with plastic sheeting and fabric.

DIFFA



The Sahel Type “Diffa” is designed as an emergency to transitional shelter solution, adapted to the Diffa and Maradi regions, in Niger.

It has a total surface of 22m^2, is made of metal and PVC tubes, a dome-shaped geometry, covered with plastic sheeting, and doum palm mats. A total of 21,000 shelters have been built in Diffa and Maradi region.

TILLABERI

The shelter type “Tillaberi” is inspired by the “Sahel Shelter” model, but adapted to the context of the Tillaberi region, in Niger.

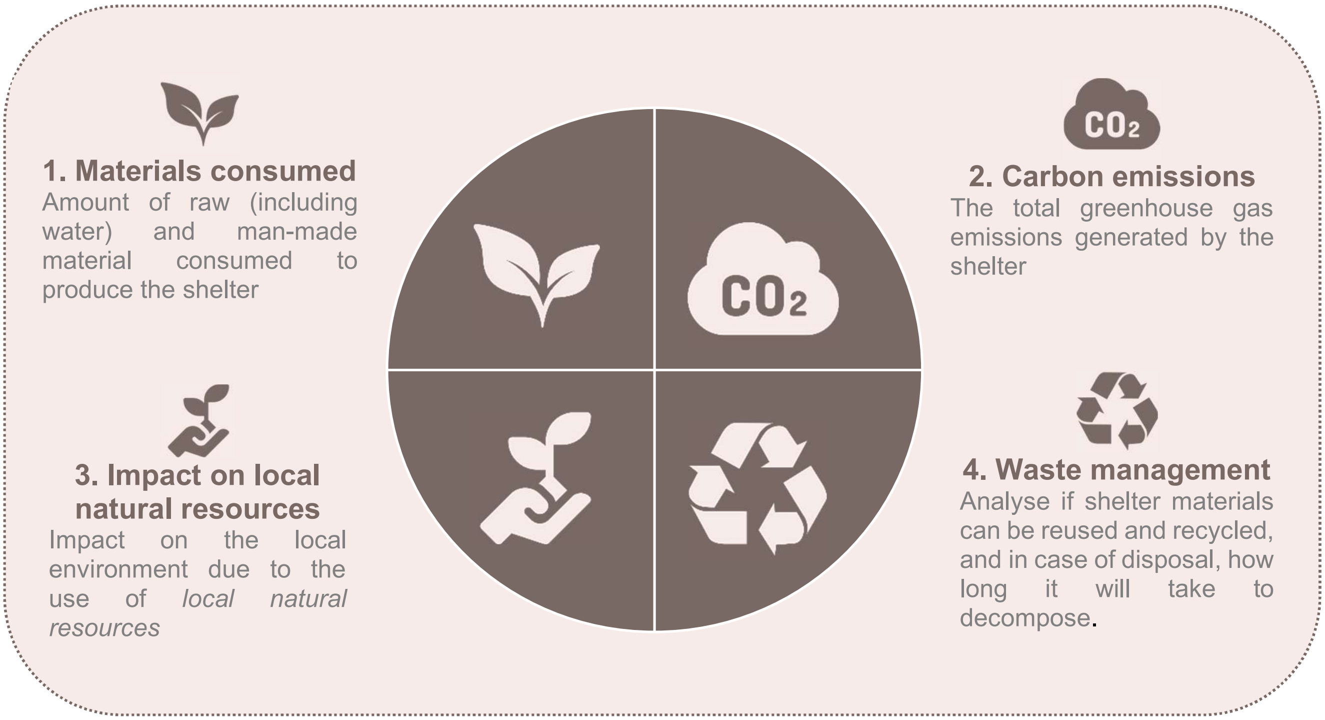
The structure it is made of eucalyptus timber covered with a cotton canvas sheet for the roof, and doum palm mats

7. Criteria used to analyse environmental impact

To do a comparative study of the environmental impact of the shelter models, each material must be analysed across its lifecycle, from production to end of life and disposal. 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 raw materials and 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 litres): 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, 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 the trees is not considered.

Any other raw materials which go into the production of the man-made materials are not considered – due to the complexity of this analysis, and since data is not readily available.

7.2. Criteria 2: *Carbon emissions*

Greenhouse gas emissions (GHS emissions), commonly called carbon dioxide (CO_2) emissions in the atmosphere warm the planet, and are the primary driver of global climate change. Human activities have raised the atmosphere's carbon dioxide content by 50% in less than 200 years[45]. It's widely recognised that to avoid the worst impacts of climate change, the world needs to urgently reduce emissions.

Therefore, it is important to assess the carbon footprint[46] generated by the shelters, and identify solutions to reduce these emissions. To do so, it is required to do a life cycle analysis (LCA)[47] .

Carbon calculator tool – SMAC tool

The carbon calculator tool used in the study is the new SMAC[48] (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 humanitarian shelter solutions in terms of their environmental impact over their entire life cycle.

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.

The SMAC allows for comparison of up to 4 different shelter types, in terms of their embodied CO_2 equivalent emissions from the following factors, or "*life-cycle stages*":

1. *"Production of the component materials"*
2. *"Packaging"*
3. *"Transport"*
4. *"End of Life"*[49]

Data required to use SMAC

In order to use the tool and calculate a CO_2 equivalent figure for the 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[50]

45 *NASA*
46 *A carbon footprint is the total greenhouse gas emissions caused by an individual, event, organization, service, place or product, expressed as carbon dioxide equivalent (CO2 equivalent).*
47 *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 carbon emissions, expressed as carbon dioxide equivalent (CO2 equivalent), 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.*
48 *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 second to use the SMAC tool, and feedback has been shared with the developers to improve it.
49 *SMAC uses assumptions about the level of recycling and CO2 eq. released at the 'end of life', meaning when the material has reached the end of its useful life, based on standard construction practices for each material. However, the actual portion of each material that is recycled at 'end of life' may be overestimated in the CO2 eq. calculation, according to the SMAC developers. This means that the carbon emissions calculated from 'end of life' are probably underestimated.*
50 *Refer to Annex 3 to find the information regarding shelter material and quantity in kilograms.*

- The type of packaging used for the materials[51] and 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 SMAC tool on this if accurate distances are not known)[52].

For some of the models the data on packaging was not available, therefore this source of emissions has been excluded from the study, in order to ensure consistency and to compare results across all the shelters.

Limitations of the SMAC carbon calculator tool

One of the limitations of the SMAC relates to the types of materials included in the database[53] 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, the user must choose a similar material when the precise material is not listed in SMAC's drop-down lists (for example, thatch was selected instead of doum palm trees). 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 publicly available data was used. However, the developers of the SMAC consider both of these limitations to be acceptable, and in line with what they term a "good enough approach".

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 environmental degradation. Another example is where using locally sourced straw or thatch 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, soil erosion, and degradation of water quality. A number of environmental organisations who specialise in the protection of forests and ecosystems in the Sahel, Regional Authorities etc[54] in each country were contacted for this study. Literature review[55], feedback from the project team and the perspective of the local organisations has formed the basis 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 should be to generate the minimum amount of waste and extract the maximum benefit from products, keeping them in use for as long as possible.
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 they will take to decompose.

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51 *Refer to Annex 3 to find the information regarding shelter packaging material and quantity in kilograms. Since for some of the models, this packaging data was not available, it has also been excluded from this study, in order to ensure consistency and to compare of results.*
52 *The average transport distances have been estimated and can be found in Annex 4.*
53 *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.*
54 *Refer to Annex 1 to see the list of people contacted.*
55 *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 created. 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[56]. The different options (in order of preference) are in the illustration.
The levels indicate the progressive order of actions to take to reduce waste. More efforts should be spent on the more significant layers at the top of the chart, like redesigning, reducing, and reusing. And to minimize the activities at the bottom, like residual management or landfill.

Some local private companies, start-ups, associations, “groupements d’intérêt économique” (GIE), etc [57] that specialise in ecological recycling and waste recovery in each of the countries, were contacted to enquire about *waste management*. Literature review[58], feedback from the specialists in ecological recycling and waste recovery, the project teams and environmental experts from the shelter sector[59] have been considered for this analysis.

7.5. Scorecard approach

A simple ‘scorecard’ approach is used to compare the shelter models across the four criteria.

The balanced nature of a scorecard means that no one environmental consideration takes precedence over the other considerations identified as significant. This recognises that *carbon emissions*, while being critical, are not the only environmental factor. While such a Humanitarian Environmental Scorecard is not an environmental impact assessment, it is at least a transparent process which goes beyond focusing on only one environmental consideration to make decisions on how to provide humanitarian assistance.

At its core, a balanced scorecard identifies environmental considerations of proposed actions (e.g., a package of shelter assistance), rates the possible environmental impacts for the proposed action and then combines these ratings into a single score.

A simple score card also recognises the challenge to apply any kind of numerical weighting for the four criteria in order to arrive at a calculated score per shelter. This would require too many assumptions on the relative weight of each criterion. Instead, a qualitative conclusion can be made based on the score card.

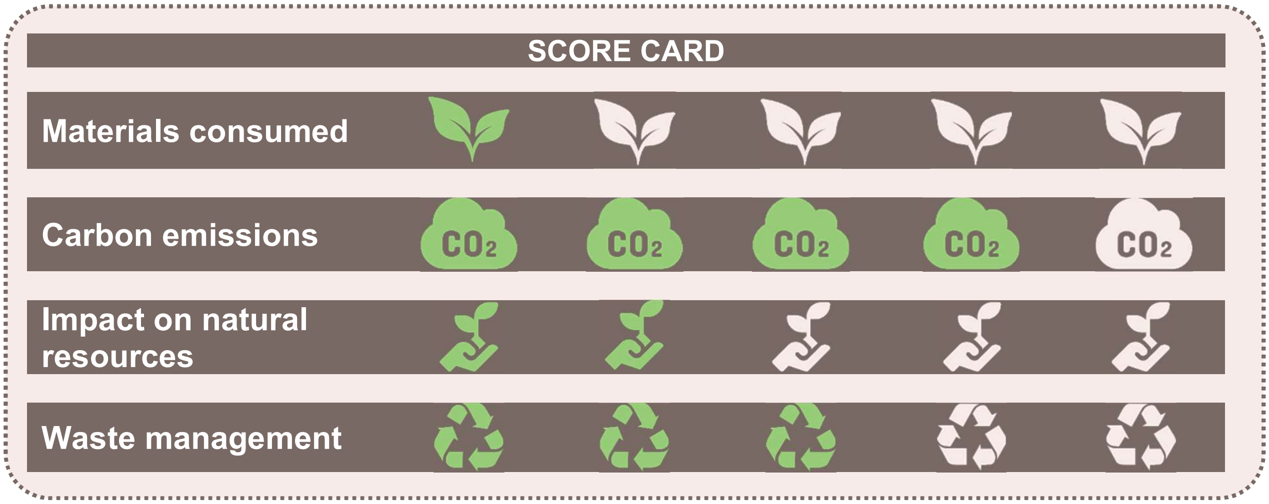
While acknowledging the methodological limitations of this approach, it is the only feasible option in the limited scope and time allotted to this study. A score card highlights in a simple way what the main environmental issues are for each shelter, thus identifying where mitigating solutions could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

Each shelter model is scored from 1 to 5 against each of the criteria, to enable comparison.

For this particular study, the scores on some criteria for certain shelter models have been modified with respect to the individual country studies, in order to better highlight the differences between the eight shelters analysed in this report.

56 *EU Commission, 2014*
57 *Africa Ecologie, KITA Entreprise, Soburec SARL, TECO*
58 *Refer to biography*
59 *Refer to Annex 1 to see the list of people contacted.*

An example of the score card (noting that a higher score is better, meaning lower environmental impact):



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

8. Environmental impact of the Sahel 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. [60] Half of all plastics ever manufactured have been made in the last 15 years. Only in 2020, 367 million tons were produced and this is expected to double by 2050.

Types of plastics used in the shelter model

Polyethylene; It was invented in 1932. Since it is such a versatile material, it became the most widely used type of plastic in the market, used to produce everything from shopping bags to plastic containers.

PVC; Polyvinyl Chloride plastic is the world's third most common plastic. 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 most environmentally damaging of all plastics. [61]

Nylon; Is composed of polyamides, it is a silk-like thermoplastic generally made from petroleum, that can be melt-processed into fibres, 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. [62]

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. [63]

Ocean contamination; 10 percent of this plastic ends up in the ocean, where it breaks down into microplastics. [64] 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. [65]

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. [66]

General environmental impacts[67]

60 *www.aquapakpolymers.com*
61 *www.greenpeace.org*
62 *https://goodonyou.eco*
63 *Center for International environmental law*
64 *Green Peace*
65 *Stopplastic.ca*
66 *The world counts*
67 *The world counts*

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[68]

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[69]

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[70]

Doum palm tree Hyphaene thebaica, with common name doum palm is a type of palm tree. Individuals can grow to 25 m. [71] It is a native to the Arabian Peninsula and also to the northern half and western part of Africa, [72] 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 especially the leaves to make woven mats for walls and roofs of housing.

General environmental impacts[73]

Soil fertility; Palm trees promote soil fertility.

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

Tree extinction; Commercial over-exploitation will lead to the disappearance of the tree

Date palm tree (Phoenix dactylifera). The species is widely cultivated across northern Africa, the Middle East, and South Asia, and is naturalized in many tropical and subtropical regions worldwide. [74] All parts of the date palm yield products of economic value. [75] It has been used as a source of food, for building houses, and landscaping. [76]

General environmental impacts

68 *The world counts*
69 *Stopplastic.ca*
70 *Stopplastic.ca*
71 *www.eol.org*
72 *World Check List of Selected Plant Families (WCSP). Kew Sciences.*
73 *Silviculture of eucalyptus plantings – Learning in the region. K.J. WHITE. FAO*
74 *Wikipedia*
75 *Date palm | Description, Uses, & Cultivation | Britannica*
76 *The Role of Date Palm Tree in Improvement of the Environment. Kadhim M. Ibrahim*

Preventing soil erosion: They have strong roots that hold well, even in sandy soil. This makes them useful in preventing soil erosion, especially in areas with poor soil quality. [77]

Improving soil properties: Date palm plantations have additional advantage in improving soil physical and chemical properties due to the large amounts of organic materials deposit to the soil after the tree pruning. [78]

Saves on water usage: They are drought resistant as they have been grown in dry areas. [79]

Reduces temperatures: The tree can decrease the atmospheric temperature of the surrounding air and may help cool down if enough trees are planted. [80]

Pollution control: Date palms are also great for removing harmful pollutants from the atmosphere, resulting from industrial activities. [81]

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[82]

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.

Basswood (Tilia americana) is a species of tree in the family Malvaceae, native to eastern North America but also now found in parts of Africa. It is a medium-sized to large deciduous tree reaching a height of 18 to 37 m, with a trunk diameter of 10-1.5 m at maturity. It grows faster than many North American hardwoods.[83] Basswood is an important commercial hardwood. Its wood is light, generally straight-grained and fine-textured. Its lumber is used for furniture, millwork, caskets, frames, toys and novelty products.[84]

General environmental impacts

The basswood provides food and shelter for many species of wildlife. Squirrels, chipmunks, mice, rabbits, upland game birds, songbirds, porcupines and foxes eat the seeds or bark of this tree. Trees become dens for many animals.[85]

77 *https://datepalmdubai.com*
78 *The Role of Date Palm Tree in Improvement of the Environment. Kadhim M. Ibrahim*
79 *https://datepalmdubai.com*
80 *The Role of Date Palm Tree in Improvement of the Environment. Kadhim M. Ibrahim*
81 *The Role of Date Palm Tree in Improvement of the Environment. Kadhim M. Ibrahim*
82 *Silviculture of eucalyptus plantings – Learning in the region. K.J. WHITE. FAO*
83 *Wikipedia*
84 *LE TILLEUL D'AMÉRIQUE (lrconline.com)*
85 *LE TILLEUL D'AMÉRIQUE (lrconline.com)*

Common Reed

Common Reed Genus Phragmites, is a broadly distributed wetland grass growing nearly 6 m tall.[86] It commonly forms extensive stands (known as reed beds), which may be as much as 1 km^2 or more in extent. Where conditions are suitable it can also spread at 5 m or more per year by horizontal runners, which put down roots at regular intervals. It can grow in damp ground, in standing water up to 1 m or so deep, or even as a floating mat. The erect stems grow to 2–4 m tall, growing in areas with hot summers and fertile growing conditions.[87] Reeds were and still are used locally in the construction of walls and roofs of houses.[88]

General environmental impacts

Mitigate environmental pollution: The Common reed has proven ability to mitigate the environmental pollution of its surroundings. It has been a most preferred unique plant system, especially in ecological engineering for improving the quality of wastewater.[89]

Invasive wetland plant: the common reed, is an aggressive, vigorous species which, in suitable habitats, will out-compete virtually all other species and form a totally dominant stand. Its invasive character has been particularly apparent in North America where it has become dominant in a range of wetland habitats replacing native species and biotypes. Bird, fish and insect populations can also be affected.[90]

Water

Water covers 70% of our planet, however, only 3% of the world's water is fresh water.[91] 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.[92]

Environmental impacts

Water shortage; Water shortages are likely to be the key environmental challenge of this century.[93] 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.[94]

Water pollution; comes from many sources including pesticides and fertilizers that wash away from farms, untreated human wastewater, and industrial waste.[95]

Climate change; is altering patterns of weather and water around the world, causing shortages and droughts in some areas and floods in others.[96]

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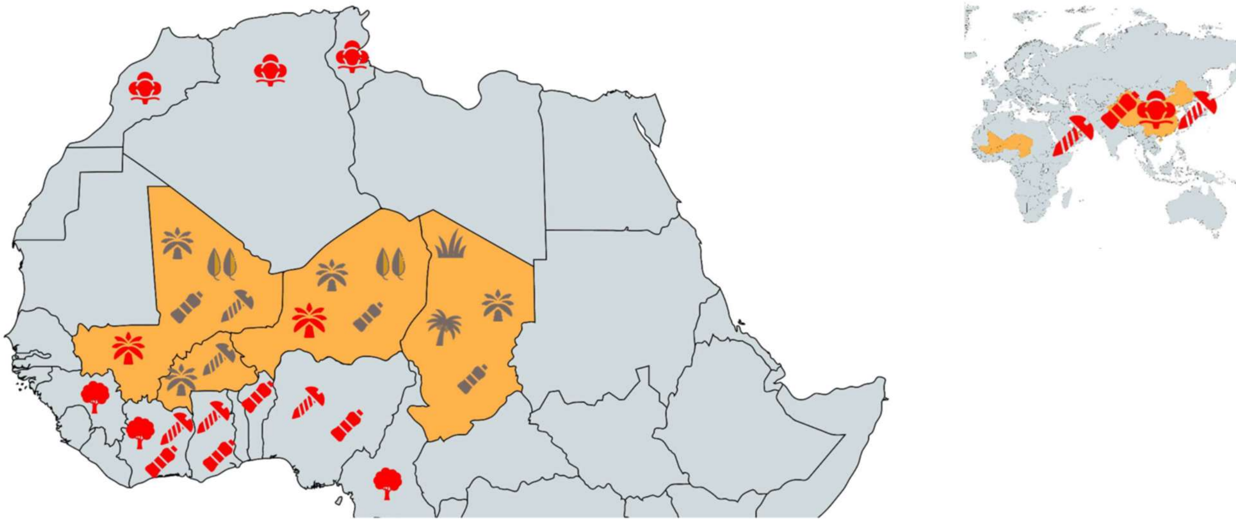
86 *The tall-statured grasses in the genus Phragmites are dominant vegetation in wetlands worldwide and thus play a vital role in ecosystem functioning. Expansive reed populations—alien invasion or disturbed wetlands? Kim Canavan. 2018*
87 *Wikipedia.*
88 *Daphné Durant, Anne Farruggia et Alexandre Tricheur, « Le roseau commun (Phragmites australis) : un capital naturel utilisé en litière pour le logement des vaches allaitantes »*
89 *Environmental perspectives of Phragmites australis (Cav.) Trin. Ex. Steudel. Jatin Srivastava, Swinder J. S. Kalra & Ram Naraian. 2013*
90 *Phragmites australis (common reed) (cabi.org)*
91 *WWF*
92 *www.un.org/waterforlifedecade*
93 *www.un.org/waterforlifedecade*
94 *NASA*
95 *University of Dundee*
96 *WWF*

8.1.2. Data and analysis of the materials in the shelters

The follow table 1 shows a simplified representation of the amount of raw and man-made materials used by each shelter. Please refer to Annex 5 to see the actual quantities of the materials used in each of the shelter models, by weight. The data was provided by the AI-CRL logistics teams in each country.

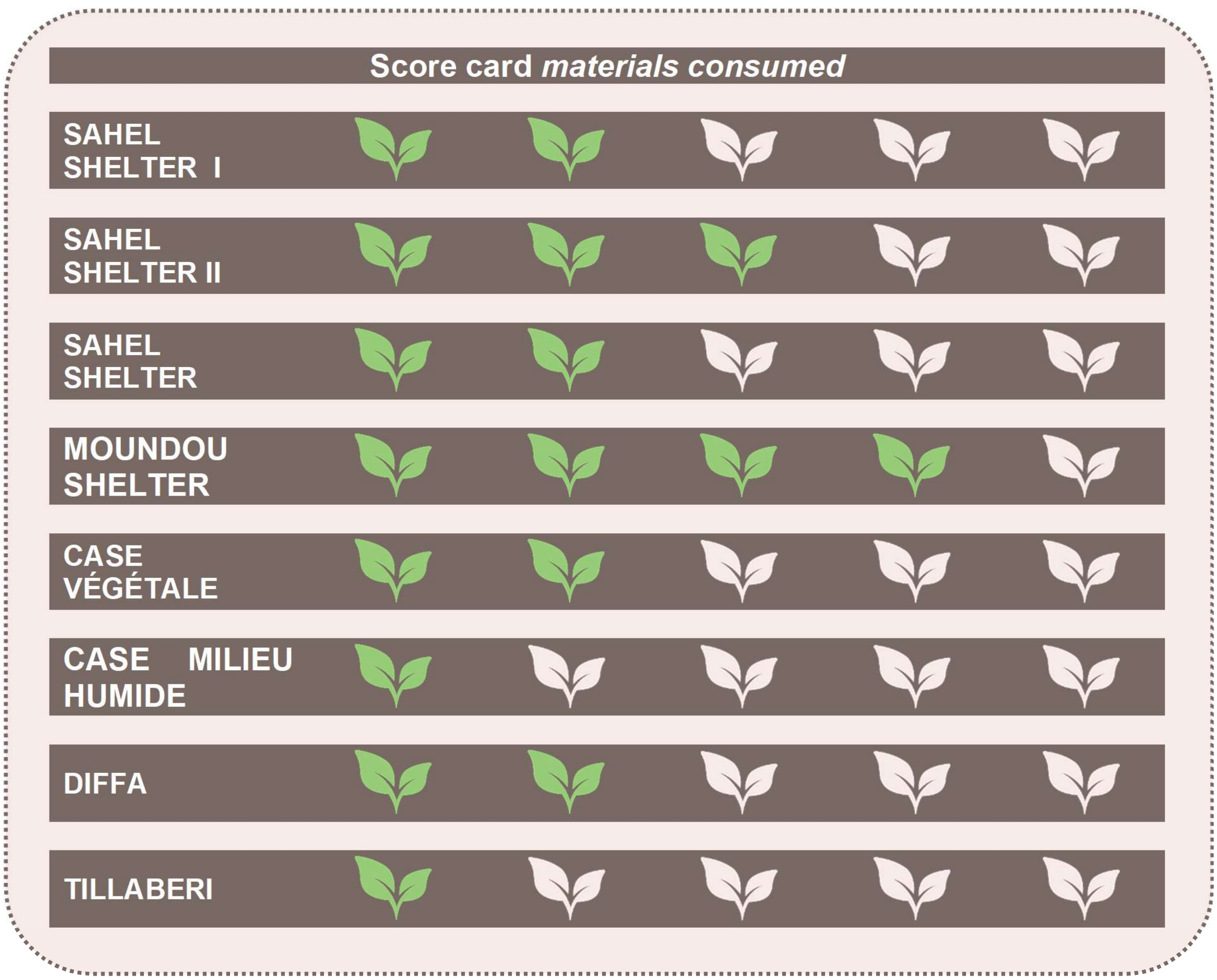
Table 1 – Amount of raw and man-made materials

Shelter model	Raw material	Man-made material
Sahel Shelter Type I		
Sahel Shelter Type II		
Sahel Shelter		
Moundou Shelter		
Case Végétale		
Case Milieu Humide		
Diffa		
Tillaberi		



Map showing where materials were procured from (brown = locally procured; red = imported). This does not reflect where materials were originally produced, since this information was not available.

8.1.3. Score card for *materials consumed*



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

"Moundou Shelter" model scored the highest of all (4 out of 5), while "Case en Milieu Humide" and "Tillaberi" have the lowest score (1 out of 5).

The reason why the "Moundou Shelter" has a high score is because it used mostly locally available raw materials and minimal amounts of man-made materials, meaning much less water consumed in the production process. Note that under this criteria the quantity of materials is considered, and not whether the extraction of local raw materials is environmentally harmful, which is considered under Criteria 3. Meanwhile "Case en Milieu Humide" and "Tillaberi" consumed a large amount of water. In the first case it is due to the production of cotton for the fabric which is used (30% cotton, 70% nylon), and in the second case it is due to the production of cotton for the canvas sheet. Also, the "Case en Milieu Humide" shelter used a high amount of man-made materials, especially steel.

"Sahel Shelter Type I", "Sahel Shelter Type II", "Sahel Shelter" and "Diffa" used a high amount of man-made material, especially steel and plastic, and also a considerable amount of water which goes into the production of those. However, "Sahel Shelter Type I" scored higher, 3 out of 5, because the total amount of materials is lower since the shelter is smaller compared to the others. The "Sahel Shelter Type I", "Sahel Shelter" and "Diffa" models scored 2 out 5. It is worth mentioning, that the "Sahel Shelter" used a considerable higher amount of palm doum mats, compared to the other shelters with the same design.

The "Case Végétale" model I used a high amount of raw material, specially eucalyptus wood and doum palm tree. As well as steel and plastic, so the score is also 3 out of 5.

How to improve the *materials consumed* score

For all the shelter models

By reducing the quantity of man-made materials used, especially plastic, steel and PVC, without compromising the functionality.

Sahel Shelter

By reducing the quantity of palm doum tree, without compromising the functionality.

Case Végétale

By reducing the amount of eucalyptus wood, used in the shelters, without compromising the functionality.

Case en Milieu Humide and Tillaberi

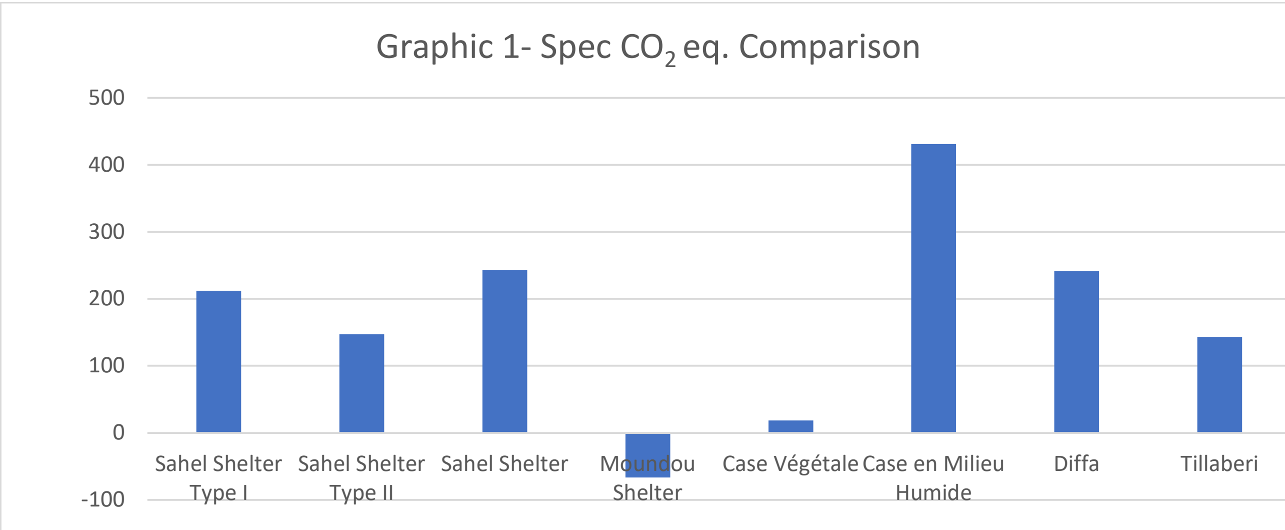
By using a different material for the fabric and canvas instead of cotton, or to decrease the amount in kilos by using a lighter fabric. However, another material may not perform as well, or be more costly. For instance, organic cotton, which consumes only 10% of the water that normal cotton does, costs around 20% to 30% more.

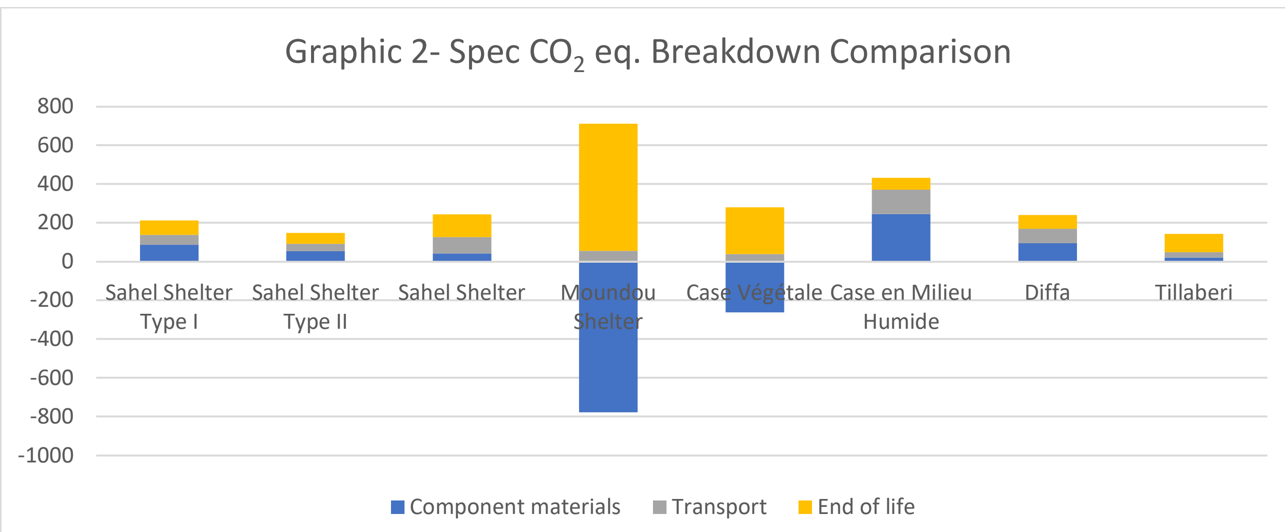
8.2. Criteria 2: *Carbon emissions*

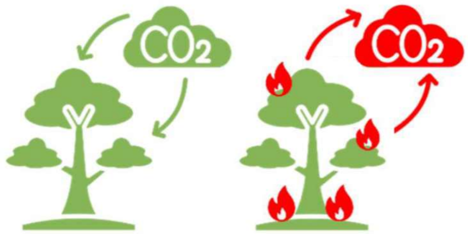
8.2.1. *Carbon emissions* of each shelter

Below are the total *carbon emissions* generated by each shelter model by country, in CO_2 equivalent. This is using the SMAC calculator and taking into account all the parameters and assumptions explained above in section 7.2. Please refer to Annex 6 to see the details of the carbon emission calculations per shelter.

The following Graphic 1 show the total carbon emission of each shelter, and Graphic 2 shows the breakdown of the *carbon emissions* per shelter.

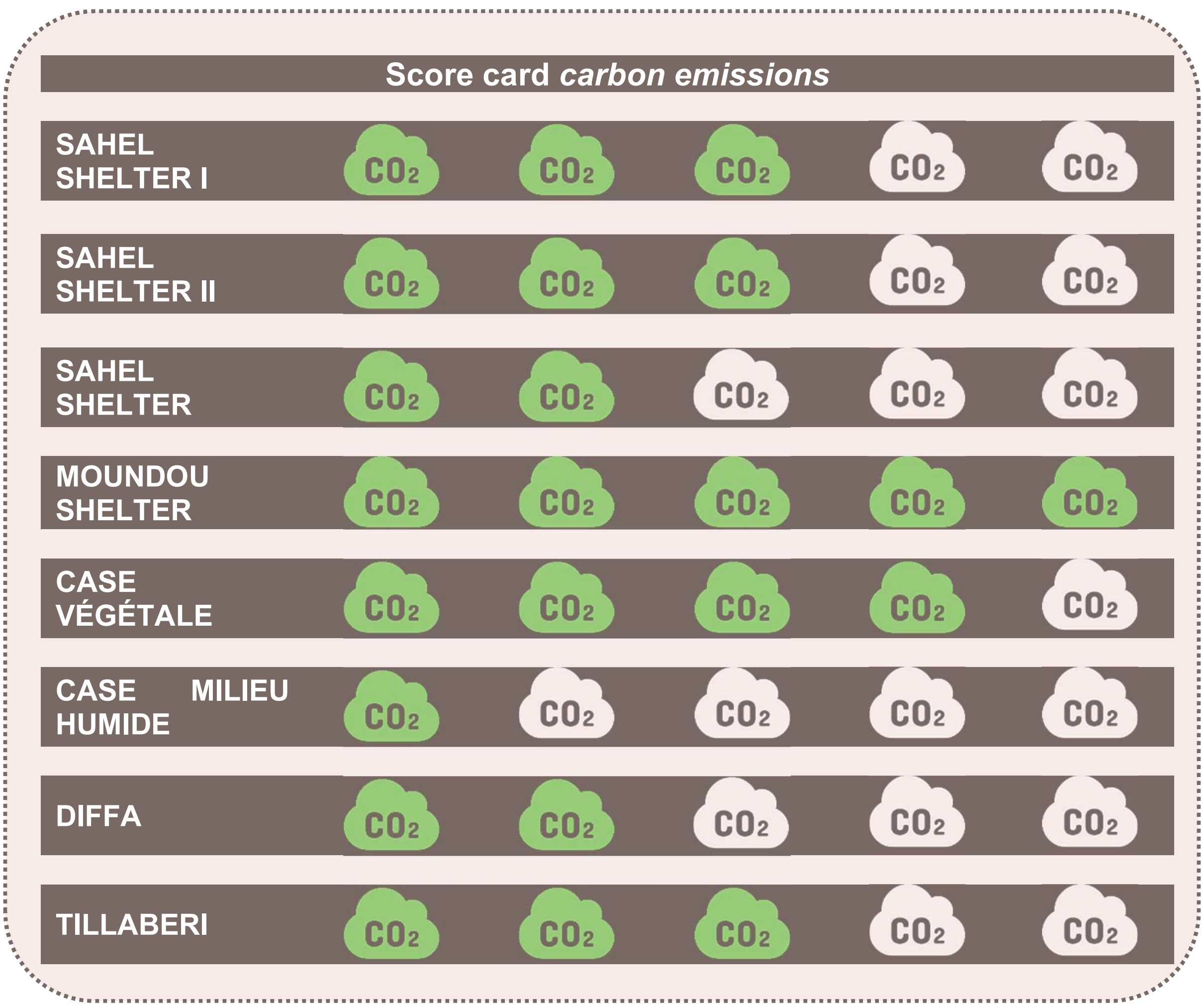






It is important to explain why there are significant *carbon emissions* generated from the "*end of life"* phase for models like "Moundou Shelter", which use a lot of natural materials. This is because the SMAC tool assumes that these materials are burnt at the end of their useful life, thus releasing the *carbon emissions* which were sequestered in the materials. If in fact these natural materials are left to decompose, or composted, these emissions would be eliminated and therefore the total emissions of that shelter model would be even lower.

8.2.2. Score card for *carbon emissions*



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

Please refer to Annex 6 to see the details of the *carbon emissions* calculations per shelter.

The comparison of overall *carbon emissions* is very clear, the “Moundou Shelter” model scored the best of all, 5 out 5, since it captures more *carbon emissions* that it releases during its life cycle. Followed by the “Case Végétale” model (4 out of 5). This is due to its reliance on natural materials like wood and palm tree products (in the first model), and eucalyptus and palm doum products (in the second model). Meanwhile the "Case en Milieu Humide" had the lowest score (1 out of 5). Most of its emissions are from the *“production of the components materials”* of the steel poles and fabric. *“Transport”* also adds substantial emissions from the steel poles.

As explained in more details in Annex 6 section 2.1, “Sahel Shelter Type I” and “Sahel Shelter Type II” overall *carbon emissions* should be less for both shelters. In this case the *carbon emissions* at *“end of life”* add a substantial amount, this is because the SMAC tool assumes that natural materials are burnt, so the level of CO_2 eq. released into the air is relatively high. However as explained, this is not the case in those models. According to the field team, the families do not burn the material at the end of its life. Instead, they dumped them in an open field. Therefore, the *carbon emissions* at the *“end of life”* should be zero, and the overall *carbon emissions* should be less for both shelters. However the SMAC tool does not allow this to be taken into consideration[97]. Taking this into consideration, both models score 3 out of 5. The biggest impact came from the “*production of the component materials*”, specially the PVC and metal tubes.

In the case of “Tillaberi” model, which scores 3 out 5, the biggest impact is from the production of the cotton canvas followed by the *“end-of-life*” of the eucalyptus timber and the palm doum mats.

The “Sahel Shelter” and “Diffa” model scored 2 out of 5, the second lowest. The overall *carbon emissions* are very similar, the difference is in the emissions generated in each life-cycle stage. Both shelters have the same design and are built with the same materials, the difference is in the quantity of these materials, especially the palm doum tree. The “Sahel Shelter” uses 109 kilos of palm doum tree compared to the “Diffa” model which use around 60 kilos. Also the origin of each material varies from one country to another, and it affects the amount of *carbon emissions* generated due to *“transport*”. Therefore the *carbon emissions* from the first model are higher at the *"end-of-life"* (as explained above, from assuming that the palm doum matts are burnt at the end of its useful life). However, the *carbon emissions* from *"production of the component materials"* is higher in the “Diffa” model, as they use less natural materials.

97 *The challenge with “end of life” is that it can be a very local process. As in this example, in one place the materials may be burned (e.g., when a site is abandoned), at another, used for compost (e.g., a well-established camp with a gardening program) and at a 3rd, just dumped in near-by unused land (as it is in this case study). As a result, only one process is considered in the SMAC tool. Therefore some local conditions could increase or decrease the carbon footprint. This is the reason why the SMAC tool cannot be seen as giving an exact answer, but as input into decision making. This is where a score card approach is important, since this can allow for a more explicit inclusion of local factors.*

How to improve the *carbon emissions* score

For all shelter models

To ensure that the natural materials are not burnt at the end of their useful life, and are composted instead.

To procure more locally produced materials if possible, to reduce emissions from transport

Sahel Shelter Type I & Sahel Shelter Type II

Considering to use different materials, especially replacing the PVC and metal tubes which have the highest embodied CO_2 emissions, or reducing the amount used without compromising the quality of the shelter.

To reduce the emissions from transport. The highest impact came from the doum palm mats, because most come from Mali and Niger. However this would be challenging, since the production of palm doum mats in Burkina Faso does not cover the current demand. Another way to reduce transport emissions is by procuring locally produced metal tubes and PVC, if possible.

Sahel Shelter

Consider to use different materials, especially replacing the PVC and metal tubes which have the highest embodied CO_2 emissions, or reducing the amount used without compromising the quality of the shelter.

To reduce the emissions from transport. The highest impact came from the doum palm mats, because of its heavy weight (109.2 kg per shelter). Since they are locally sourced, the only way to reduce overall emissions is by reducing the amount and weight of the mats, without compromising the quality of the shelter. However this can be challenging. Another way is by procuring locally produced

How to improve the *carbon emissions* score

Moundou Shelter

To reduce the emissions from transport from the imported basswood timber. However, it can be challenging to purchase timber more locally in Chad. The alternative could be carefully identifying a supplier that can source sustainable wood locally. If so, the wood should come from a sustainable plantation and it should be clear that over-extraction or other environmental damage does not happen.

Case Végétale

To consider to use different materials, especially replacing the metal tubes which have the highest embodied CO2 emissions

Case en Milieu Humide

To consider to use different materials, especially replacing the fabric and the steel poles which have the highest embodied CO_2 emissions, or reducing the amount used without compromising the quality of the shelter.

To reduce the emissions from transport. The highest impact came from the steel poles, since they come from China. Procuring locally produced metal tubes, if possible, should be considered.

Diffa

By reducing the amount of materials, especially PVC, which have the greatest emissions, but also the metal tubes, without compromising the functionality.

To reduce the emissions from transport, especially the PVC, steel tubes.

Tillaberi

To consider to use different materials, especially cotton, which have the greatest emissions.

8.3. Criteria 3: *Impact on local natural resources*

8.3.1. Overview of the *impact on local natural resources*

A common assumption is that the more natural a material it is, the better it is for the environment. However, when natural resources are harvested and processed, there are certain impacts on the local ecosystem 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 as part of project design.

Desertification, deforestation, soil degradation and loss of biodiversity are the major environmental problems in all the Sahelian countries. They have also been experiencing recurrent rainfall deficits for nearly three decades, which, combined with human activities that are not always respectful of the environment, have led to a degradation of natural resources[98]. Most of the communities depend on the exploitation of these natural resources, and forests play a strategic role, which in addition to wood energy provide food supplements, medicines, housing material, fodder for livestock and cash income.

Drivers of deforestation and forest degradation include agricultural expansion, overgrazing of livestock, bush fires, and demand for fuelwood and charcoal. For example, only in Burkina Faso, 80% of domestic energy needs in are met by firewood[99] and in Chad, wood energy remains the most used energy source. Also, wood for construction has exacerbated the problem[100]. In view of the generally expected population increase, higher demand will have a destructive effect and forest degradation will continue to grow, while the degradation is aggravated by the danger of desertification[101]. Tree mortality has also been linked to Sahelian droughts, which can further exacerbate climate change impacts by diminishing the ability of plants to uptake carbon dioxide[102]. Other factors like poor forest governance underlie these drivers[103].

Also climate change plays an important role on desertification. Rains are rare and when they occur, they wash away the soil exposed to erosion without vegetation cover.

The forestry sector plays an important role in the region, including economically, socially and culturally[104]. The consequences of land degradation are extremely serious, when most of the population's livelihood depends on agriculture and livestock. Land productivity declines. Rural communities have poorer and poorer harvests. Food insecurity and malnutrition are increased. Therefore the use of local forest resources in shelter construction needs to be carefully analysed.

In the context of climate change and pressure on *local natural resources*, it is important to analyse whether the shelter models contribute to this degradation of the environment. To do a proper study of potential harm done to the environment, it should really go beyond the *local natural resources* used, 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 and so analysis is restricted to the local materials used.

98 *Evaluation des ressources forestierese mondiales 2020. Rapport Tchad. FAO*
99 *Livelihoods Funds*
100 *Combating Desertification in Asia, Africa and the Middle East. G. Ali Heshmati, Victor R. Squires. 2013*
101 *FAO https://www.fao.org/3/AB579F/AB579F01.htm*
102 *Climate Change, Food Security and migration in Chad: A Complex Nexus. American University, IOM Chad and the Chad Food Security Cluster*
103 *Forest Carbon Partnership*
104 *FAO*

Attempts were made to contact several local environmental organisations, local Authorities in each of the countries.[105]

A quick overview about forests, why they are important to fight against climate change, and environmental issues

Forests play a key role in mitigating climate change[106] and increase the resilience of rural communities. They regulate ecosystems, protect biodiversity, play an integral part in the carbon cycle, support livelihoods, protect homes from major weather events, improve health and can help drive sustainable growth.[107]

Environmental issues[108]

- 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.
- Around 25% of global emissions come from the land sector. About half of these come from deforestation and forest degradation.
- The Sahel region has struggled with desertification, soil degradation, drought and loss of biodiversity for many years.
- A high population growth rate puts pressure of the few remaining forest lands.
- The Great Green Wall, is a major initiative to combat desertification in the Sahel region via reforestation and other interventions.

8.3.2. Overview of the local natural resources used in the shelter models

Doum palm tree in the shelter model

The doum palm tree are amongst the most useful plants across the continent. Most of its parts are used by local people. The 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[109].

Today, it is rated as one of the tree types at "the least concern" from extinction in Burkina Faso, Chad[110.,] Mali[111] and Niger[112..] 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,[113] if measures are not taken.

105 *Refer to Annex 1 to see the list of people contacted.*
106 *Forests and climate change. IUCN*
107 *Forests and climate change. IUCN*
108 *State of the World's Trees. Sept 2021. Botanic Gardens Conservation International*
109*Valoriser les produits du palmier doum pour gérer durablement le système agroforestier d'une vallée sahélienne du Niger et éviter sa désertification. Régis Peltier, Claudine Serre Duhem et Aboubacar Ichaou*
110. Botanic Gardens Conservation International. https://www.bgci.org/resources/bgci-databases/globaltree-portal/
111. Botanic Gardens Conservation International. https://www.bgci.org/resources/bgci-databases/globaltree-portal/
112. Botanic Gardens Conservation International
113Valoriser 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

Date palm tree used in the shelter models

Date palm is a component of the sub-Sahelian agriculture landscape and is present in different parts of the Sahel region. It adapted to the Sahel and its planting can contribute to combating desertification and, above all, contribute to the creation of microclimates favourable to the development of under-canopy crops such as other fruit trees, fodder, and market garden vegetables.[114]

Date palm is not listed in the Chad tree species list in the Botanic Gardens Conservation International, So the conservation status is unclear. However, at global level it is listed as not under threat of extinction.[115]

Common reed used in the shelter models[116]

The common reed It is a native species in Lake Chad[117]. It is a wild grass which grows only in water, mostly in the waters of Lake Chad, and is renewed every rainy season.

Common reed is not listed in the Chad tree species list in the Botanic Gardens Conservation International. So, it the conservation status is unclear. However, at global level it is listed as “least concern” on the IUCN Red list.[118]

Eucalyptus wood in the shelter models

The introduction of the eucalyptus was in the 1950s in African countries.[119] 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.[120]

The eucalyptus camaldulensis is not listed in the Mali and Niger tree species list in the Botanic Gardens Conservation International, So the conservation status is unclear. However, at global level it is listed as “Near Threatened” of extinction.[121]

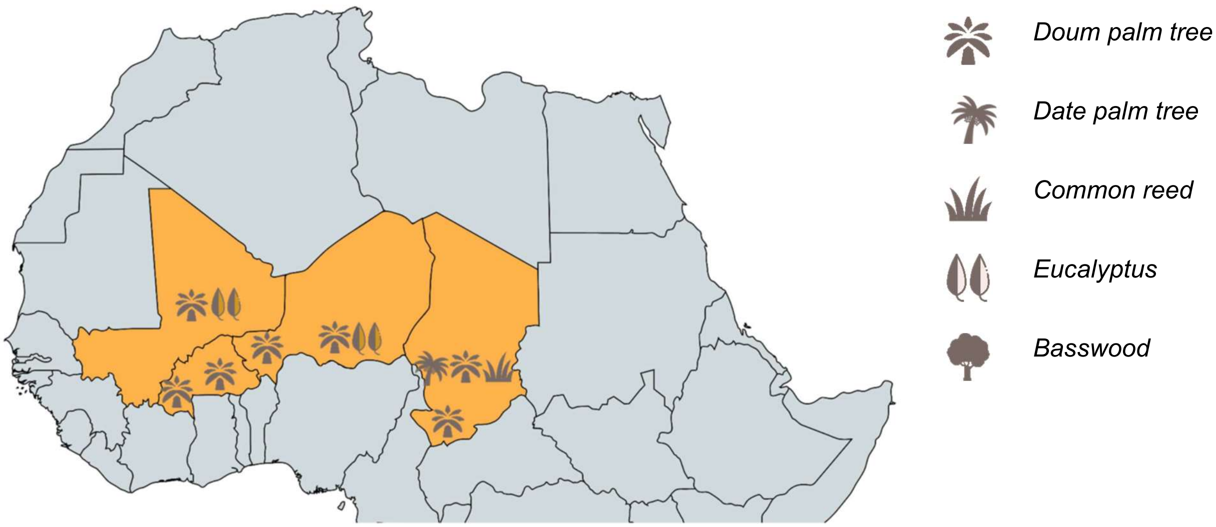
8.3.3. Quantity of the *local natural resources* in the shelters

The follow table 2 shows a simplified representation of the amount of *local natural resources* used by each shelter. Please refer to Annex 7 to see the actual quantities of the *local natural resources* used per shelter in kilograms. The data was provided by the AI-CRL logistics teams in each country.

114 *Date Palm Status and Perspective in Sub-Sahelian African Countries. Mohamed Ben Salah. 2015*
115 *https://www.bgci.org/resources/bgci-databases/globaltree-portal/species-search/?species=Phoenix+dactylifera*
116 *Little formal information has been found about the common reed in Chad. Most information has been sourced from the local team in the field*
117 *https://www.cabi.org/isc/datasheet/40514#REF-DDB-150742*
118 *https://tools.bgci.org/plant_details.php?plantID=3403*
119 *Expansion, research and development of the eucalyptus in Africa Wood production, livelihoods and environmental issues: an unlikely reconciliation. Dominique Louppe and Denis Depommier. 2010*
120. *Chaojun Chu, P.E. Mortimer, P.E. Mortimer, Hecong Wang, Yongfan Wang, Xubing Liu, Shixiao Yu. 2014*
121 *Species Search | Botanic Gardens Conservation International (bgci.org)*

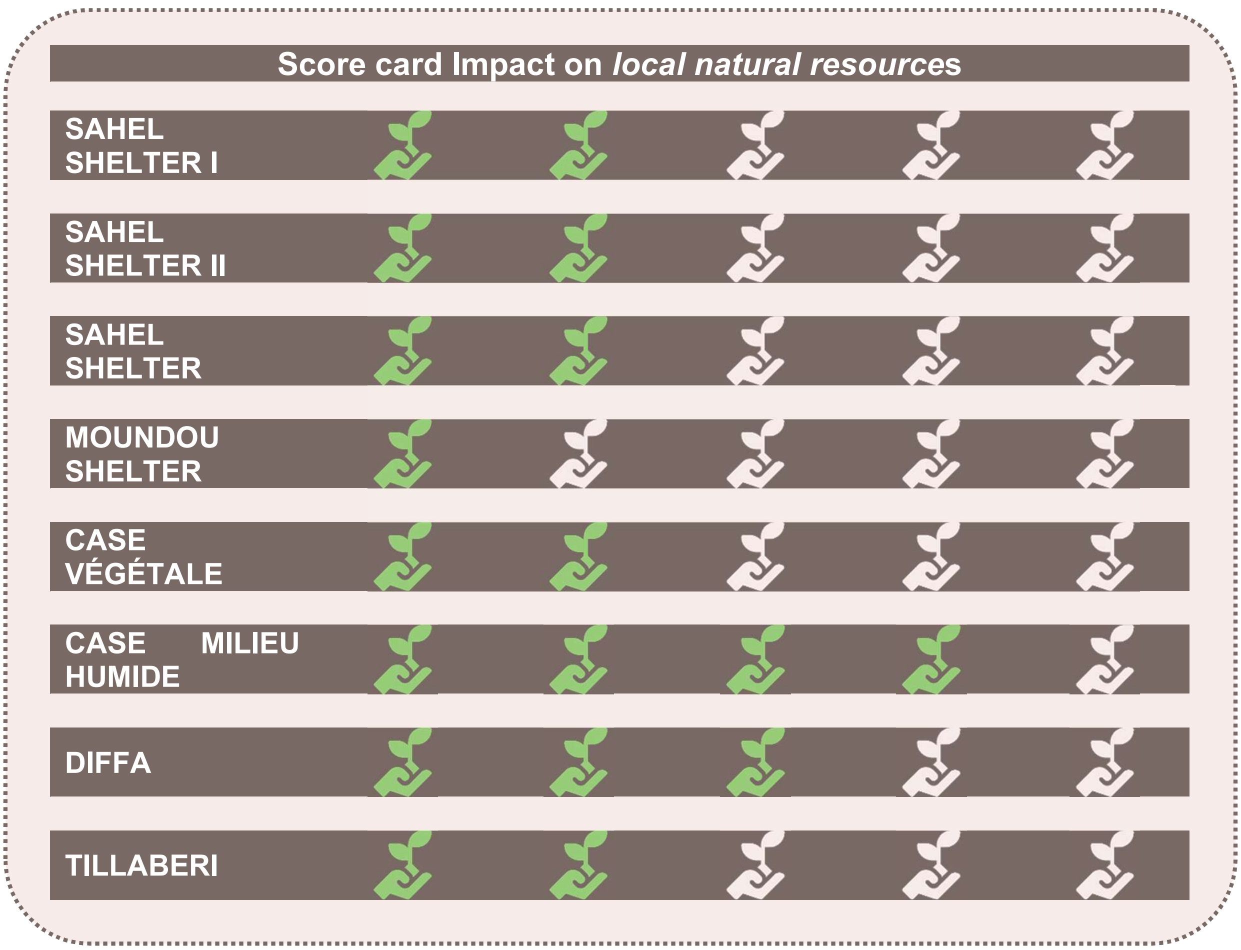
Table 2 - Amount of *local natural resources* used by each shelter.

Shelter model	Local natural resources	Amount
Sahel Shelter I	Doum Palm tree	
Sahel Shelter II	Doum Palm tree	
Sahel Shelter	Doum Palm tree	
Moundou Shelter	Doum Palm tree	
	Date palm tree	
	Common reed	
Case Végétale	Doum Palm tree	
	Eucalyptus	
Case Milieu Humide	*Does not use local natural materials, but use imported natural materials.*	
Diffa	Doum Palm tree	
Tillaberi	Doum Plam tree	
	Eucalyptus	



Map of the natural resources used in each country

8.3.4. Score card for impact on *local natural resources*



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

The use of natural materials in shelter has advantages. For example, the natural resources are used traditionally by the communities for many years, and the harvesting and preparation provides a source of income. But as it was pointed out by the Shelter Cluster in Chad, and the same can be said about the other countries of the region "*in principle, the use of construction materials that are being sourced locally from the natural environment is desirable. But in practice, the demand significantly outweighs the resources available. The number of shelters needed in comparison to the density of vegetation in the region, poses a high risk of environmental degradation and accelerated desertification. In and around the majority of IDP settlements, severe degradation of trees and plants is already occurring*".[122]

When asking different interviewees about the potential impact the natural resources used in the shelters could have on the local environment, the answers were mixed:

"Trees provide shade for nomadic herders and travellers. Without trees, there is no shade and it is difficult to make long journeys without resting on foot".
"*The use of date palm stalks and doum palm leaves is considered to be a good initiative because it is part of the development of the country's natural resources. However, a period of one year is needed for the uprooted stems to be able to renew themselves again on the same branch for both palms"*.
"The common reed that grows on Lake Chad, grows wild every year in the waters and therefore, even if they are cut, these renew themselves every rainy season, *they are used for construction of shelters and enclosures, and as the lake shrinks due to desertification, these common reeds are also disappearing"*.
"These *palm trees provide food for camels and dromedaries who eat the leaves, if there are no leaves, they will die".*

In the particular case of the "Case en Milieu Humide" model, it does not use *local natural resources* (from Mali, where this shelter model is built). However, this model uses basswood timber sourced from Ivory Coast and Guinea, which is why it has a score of 4 and not 5. Even if it does not directly affect the local natural habitat, it is advisable to ensure that the exploitation of any natural material does not affect the local environment of the country of origin.

The "Case Végétale" and "Tillaberi" used eucalyptus timber and mats from the palm doum tree. Both natural materials are locally produced, but while 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. The eucalyptus is an introduced species, requires irrigation techniques in countries with scarce water supplies, and has an impact on soil degradation and deforestation. Therefore the score is relative low, 2 out of 5.

In the case of the "Sahel Shelter Type I", "Sahel Shelter Type II" , the "Sahel Shelter" and "Diffa", they all only used doum palm mats. The difference is the total amount, the "Sahel Shelter" uses much more than the others. And also the origin of the mats. While in the Sahel model and "Diffa" the mats are locally produced, in the particular case of the "Sahel Shelter Type I" "Sahel Shelter Type II", only 15% of the doum palm mats used in the models come from Burkina Faso where the shelters models are built. The rest come from Niger (around 45%) and Mali (around 40%). *"The production of palm doum mats in Burkina Faso does not cover the current demand and humanitarian actors import the mats from other countries, with a consequent overpricing that makes mats an expensive item compared to the same type of shelter used in Niger by the AI-CRL"*[123]. Therefore, it would be advisable to look for local alternatives to this material, or, as a minimum, integrate some kind of replanting or forest protection initiatives as part of the shelter projects. Due to the above, the "Diffa" model has a better score (3 out 3) than the other three models (2 out of 5). Since it used less quantity of materials, but also these materials are locally produced.

122 *Shelter & Settlements. Environmental Impact Report. Shelter Cluster Chad. February 2021*
123 *Étude d'adaptation des abris de type « Sahel Shelter ». AI-CRL. 2019*

The “Moundou Shelter” model used more *local natural resources* compared to the rest of the shelters, doum and date palm trees, as well as the common lake reed from Lake Chad, therefore it has a lowest score, 1 out of 5. This shelter model also used uses basswood timber sourced from Cameroon.

What is clear is that these resources provide multiple benefits for communities, and over-harvesting is a potential problem. However a question remains unanswered for most of the shelters, whether the supply of each species could keep up with the demand of the shelters in the region, when considering thousands of shelters in crises that keep growing. Overexploitation and climate change could have a negative impact on production of the 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.

How to improve the *impact on local natural resources* score

All shelter models

Including a reforestation/replanting or 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 offset the overall *carbon emissions* generated, as well as ensuring protection of the local eco-system.

Sahel Shelter Type I & Sahel Shelter Type II

Considering to use a different local alternative to the doum palm tree as “Millet stalk mats (*nattes de tiges de mil)*”. However, further study on the impact on the environment, and mitigating strategies for identified impacts, should also be considered for these alternative materials.

Household Energy and fuel efficient cookstoves

The question of household energy and the use of wood biomass for cooking fuel is not an aspect of the shelter project being specifically considered in this study. However, it is closely linked to the household needs of the displaced and it is too important an environmental issue to ignore. On one hand, burning of the shelter wood products releases *carbon emissions* (meaning worse environmental impact from the shelter), but on the other, it also provides a source of fuel for households, avoiding more deforestation. If we want to advocate to not burn the wood from the shelter, to avoid emissions, and also to avoid further deforestation, then the household energy question (especially for cooking) needs to be considered.

Around 3 billion people globally still cook over an open fire, usually using some form of biomass (wood, charcoal etc.). In 2019 the Moving Energy Initiative (MEI) estimates that forcibly displaced families living in camps are burning 64,700 acres of forest (equivalent to 49,000 football pitches) each year.[124] As was mentioned above, in the region here is a high demand for fuelwood and charcoal. The predominant use of firewood directly accelerates the rate of deforestation and desertification already occurring in the region. Furthermore, the increasing scarcity of trees and wood can prompt an increase in inter-community clashes over resources.[125]

The question of household energy is a cross-cutting issue, often ignored by humanitarian agencies because it does not easily fit into one sector. There are the issues of health (indoor smoke pollution, harmful particulates in the air); environment (deforestation); protection (women and girls spending a lot of time collecting wood in insecure contexts); and also, the extensive time spent collecting wood and cooking on an open fire. However it is also closely linked to the shelter and settlements sector.

Where more sustainable fuels are not an option, fuel efficient cookstoves are a well-recognised solution to improve the sustainability of household energy. Affected populations generally have limited access to modern cooking solutions. Most either depend on insufficient humanitarian agency handouts of 'in-kind' firewood or have to travel long distances to collect firewood (in the latter case, exposing themselves to the risk of attack and/or sparking conflict with host communities). In many cases, host governments are recognising the environmental damage and are now pushing for change, banning in-kind firewood distribution or requesting humanitarian agency support to transition refugees to alternative more sustainable fuels.[126]

As well as considering the impact of use of wood and other plants for the construction of shelters, future projects should also consider the use of wood for cooking fuel by the displaced living in the shelters, the impact on local forests, and how it can be reduced. Even if initiatives to provide alternative fuels or fuel-efficient stoves are not integrated, partnerships with organisations who can do this could be promoted.

124 *Cooking in displacement Setting. Engaging the Private Sector in Non-wood-based Fuel Supply. Laura Patel and Katie Gross. January 2019*
125 *IDP Shelter & Settlements. Environmental Impact Report. Shelter Cluster Chad. March 2021*
126 *Cooking in displacement Setting. Engaging the Private Sector in Non-wood-based Fuel Supply. Laura Patel and Katie Gross. January 2019*

8.4. Criteria 4: *Waste Management*

8.4.1. Overview of *waste management*

When designing a shelter and choosing the construction materials, what happens to each material at the end of its useful life should be considered. Prolonging the life of each material by looking at the options for reusing or recycling contributes to reducing waste. The task is to find value in the waste, but unfortunately, once these materials are no longer used, most of them will end up discarded in open fields or unsafely burnt, contributing to pollution. In countries with very weak waste collection, storage and treatment systems, this is a major concern. 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* options in place should be a must for all programs. This should also extend to the packaging of materials and other items which are purchased. This is an obvious source of waste but also a relatively simple one to reduce, by reducing packaging, switching to biodegradable packaging, and eliminating all single-use plastics.

The analysis suggests that there is no *waste management* system covering IDP settlements. Even if many durable items are reused and recycled, much of the solid household waste is typically burnt, buried, or left scattered. Another challenge in IDP settlements, as pointed out by one of the interviewees, is that "*IDPs may have less direct concern for the impact of waste on the land as they don't perceive it as "their" land, but just a place where they are stopping before going back home".* This perspective can be a source of tension with the resident or 'host' population, adding conflict prevention to the *waste management* issue. As IDP settlements become more long-term, there should be more options to move toward sustainability and local ownership and responsibility.

8.4.2. Analysis of the waste generated by each shelter

The follow table 3 shows a simplified representation of how many *long-lasting* and *quickly degrading materials* each shelter used, and the shelter *life expectancy*.

Please refer to Annex 8 to see for each of the shelter materials their life expectancy, how long it takes for them to decompose and if they can be reused and recycled, based on potential in each country[127]. And to see the potential reuse and recycling options for each material, according to different associations that specialise in ecological recycling and waste recovery in each country, and ideas shared by some of the interviewees.

127 *Based on the feedback from the few local private companies, start-up, association, "groupements d'intérêt économique" (GIE), etc, that specialises in ecological recycling and waste recovery in each of the countries. Refer to Annex 1 to see the list of people contacted.*

Table 3 – Amount of long lasting & quickly degrading materials and shelter life expectancy

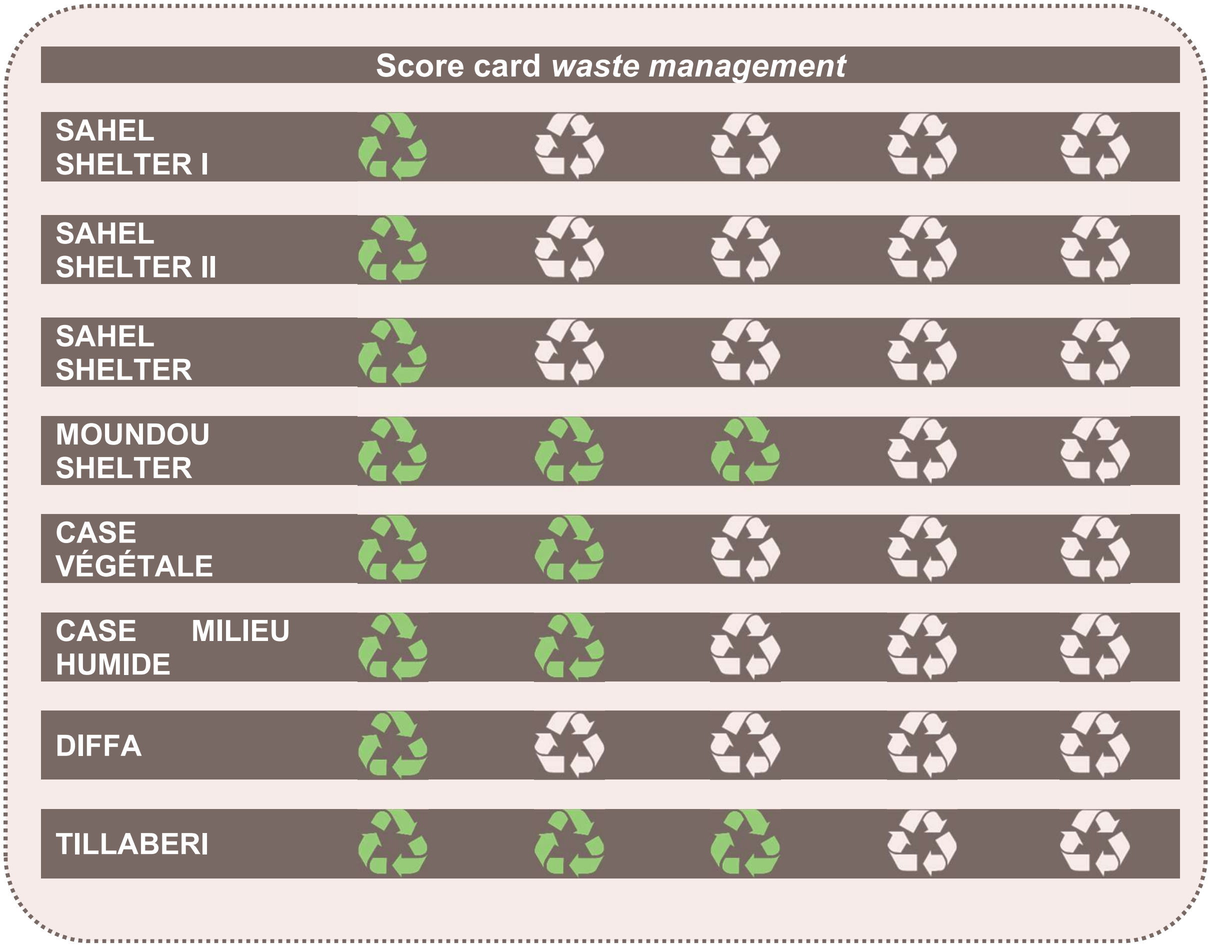
Shelter model	Long lasting materials	Quickly degrading materials	Shelter life expectancy
Sahel Shelter I	🗑🗑🗑🗑🗑	🌱🌱🌱	⌛⌛
Sahel Shelter II	🗑🗑🗑🗑🗑	🌱🌱	⌛⌛
Sahel Shelter	🗑🗑🗑🗑🗑	🌱🌱🌱	⌛⌛
Moundou Shelter	🗑🗑	🌱🌱🌱🌱🌱	⌛
Case Végétale	🗑🗑🗑	🌱🌱🌱🌱	⌛⌛
Case Milieu Humide	🗑🗑🗑🗑	🌱	⌛⌛⌛⌛
Diffa	🗑🗑🗑🗑🗑	🌱🌱🌱	⌛⌛
Tillaberi	🗑🗑	🌱🌱🌱	⌛

The *Global Joint Initiative on Sustainable Humanitarian Assistance Packaging Waste Management*[128] was also contacted for this study. One of the activities they are working on in partnership with the *Global Logistics Cluster* is to map out recycling and waste management infrastructures in countries with humanitarian contexts. At the moment only Niger is covered[129].

128 *Information can be found at https://eecentre.org/2019/07/15/https-www-eecentre-org-2019-07-15-sustainable-humanitarian-packaging-waste-management/*
129 *The information is then uploaded onto the Global Logistic Cluster LCA; https://dlca.logcluster.org/display/public/DLCA/LCA+Homepage.*

On the questions of packaging and single-use plastics, most of the countries in the region have new regulations[130] in place to either ban or discourage the use of single-use-plastics. However this not well enforced or not always applies for the whole country. The field teams confirmed some materials come packaged in single-use plastic[131]. Attempts could be made to eliminate this, in discussion with suppliers.

8.4.3. Score card for *waste management*



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

130 *Information can be found at Maps – plasticpollutioncoalition (plasticpollutioncoalitionresources.org)*
131 *Refer to Annex 3*

As can be seen in Annex 8, most of the materials have some local potential for reuse or recycling, and on top of this, all the 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 different models diverge.

From an environmental perspective, answering the question of how long it takes various types of waste to decompose is of great importance. The consumption of products that generate waste that takes a long time in landfill to completely decompose, should be reduced. From this perspective, one of the biggest concerns is plastic. Not only plastic sheeting, also the very polluting PVC, and the steel tubes, which also take long time to decompose. And the “Sahel Shelter Type I”, “Sahel Shelter Type II”, “Sahel Shelter”, “Diffa” and “Case en Milieu Humide” use more compared to the “Case Végétale”, and a lot more compared to “Moundou Shelter”, and “Tillaberi”. These models used more natural materials (especially the two last models) for which the time of decomposition is much less of a concern.[132]

Also, good quality materials and construction practices are important. Both affect the durability of the shelter, and therefore the materials, by increasing their life expectancy. As the Chad Shelter Cluster notes, “*This gap in construction and maintenance knowledge significantly impacts the durability of the shelters. Poor construction not only poses safety risks but increases the material turnover period, further compounding the environmental impact of shelter construction”.*[133] So promoting this is a must in every programme. The life expectancy of the Moundou and “Tillaberi shelter’s materials are short, and the Case Milieu Humide shelter’s materials last the longest.

Taking this into account, together what happens with the materials at the end of their useful life, gives a low score for the “Sahel Shelter Type I”, “Sahel Shelter Type II”, “Sahel Shelter” and “Diffa”: 1 out of 5. These used long-lasting materials, but also the life expectancy of the overall shelter is short.

In the case of the “Moundou Shelter”, and “Tillaberi” models, which have more natural materials that will decompose sooner, however the life expectancy is short, the score is 3 out of 5. While the "Case en Milieu Humide" used more long-lasting materials, however, the life expectancy is the longest compare to the rest (up to 3 years). Therefore the score is 2 out of 5. The “Case Végétale” model used long-lasting materials, as well as natural materials, but the life expectancy is relative low, 1 year, so the score is also 2 out of 5.

132 *However, most of these natural materials end up being burnt or used as firewood. By doing this, it releases the carbon that they captured during their growth into the atmosphere, thus reversing much of the ‘positive’ benefit. Special attention should be focused on avoiding this, however it must be acknowledged that this is be challenging, since affected families depend on firewood for cooking energy. In the other hand if this materials are burned for cooking or heating then there is an offset against other combustibles not used.*

133 *IDP Shelter & Settlements. Environmental Impact Report. Shelter Cluster Chad. March 2021*

How to improve the *waste management* score

All shelter models

Promoting different waste collection and recycling projects in the camps and communities.

Link communities to private waste companies to collect materials which are not reused, or helping them putting a system in place. It will not only improve the *waste management* situation, it can also create income generating opportunities for the communities.

Reducing packaging, switching to biodegradable packaging, and eliminating single-use plastic packaging, relatively simple changes which should be made.

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.

Promoting the composting of the organic materials, or re-using them for various purposes, would make a big difference, instead of burning them. As seen under Criterion Two (*carbon emissions*), that would avoid the release of sequestered *carbon emissions* from the timber and plant materials. But this would require parallel efforts to decrease the dependency of families on firewood for cooking, by promoting cleaner fuels or more fuel-efficient cookstoves.

8.5. Summary for the Shelters

Below are summaries of;

- Materials used in each shelter.
- Advantages and disadvantages of each material.
- The scorecard for each shelter.
- Results for each model.

Conclusions are drawn in section 9.

8.5.1. Summary of materials used in each shelters

The following Table 4, is a summary of materials used in each shelters.

Table 4 - Materials used in each shelter

Materials	Sahel Shelter I	Sahel Shelter II	Sahel Shelter	Moundou shelter	Case végétale	Case en milieu humide	Diffa	Tillaberi
Steel	✓	✓	✓		✓	✓	✓	
PVC	✓	✓	✓				✓	
Plastic	✓	✓	✓	✓	✓	✓	✓	✓
Cotton						✓		✓
Nylon	✓	✓	✓	✓	✓	✓	✓	✓
Iron	✓	✓	✓	✓		✓	✓	✓
Palm doum tree	✓	✓	✓	✓	✓		✓	✓
Date palm tree				✓				
Common reed				✓				
Eucalyptus					✓			✓
Basswood				✓		✓		

8.5.2. Summary of the advantages and disadvantages of each material

The following Table 5, shows the summary of the advantages and disadvantages of each material, from an environmental point of view, analysed in this study.

Table 5 – Advantage and Disadvantage of the materials

Materials	Advantage	Disadvantage
Steel	• Can be reused and recycled • "life expectancy" is relative hight.	• Production of steel is the most energy-consuming in the world. • The production of the steel, generated a high amount of *carbon emissions*. • Long-lasting material, which take long time to decompose.
PVC	• Can be reused and recycled.	• The most polluted material. • The production of the PVC, generated a high amount of *carbon emissions*. • Long-lasting materials, which take long time to decompose.
Polyethylene plastic	• Can be reused and recycled.	• The production of the plastic, generated a high amount of *carbon emissions*. • Long-lasting materials, which take long time to decompose.
Cotton	• Doesn't take long time to decompose.	• The most dramatic negative impact is on water availability. It takes 10,000 liters of water to produce one kilogram of cotton. • The production of the cotton generated a high amount of *carbon emissions*. • "Life expectancy" is short.
Nylon	• Can be reused and recycled	• The production of nylon, generated a high amount of *carbon emissions*.
Iron	• Can be reused and recycled • life expectancy" is relative hight.	• Long-lasting materials, which also take long time to decompose. • The production of iron, generated a high amount of *carbon emissions*.
Doum and date palm tree /Common reed / Basswood	• It "captures carbon" (and other greenhouses gases) during their growth. • Doesn't take long time to decompose.	• If the material is burnt at the end of its useful life, it released a high amount of CO_2 eq. into the atmosphere. • "Life expectancy" is short.
Eucalyptus	• It "captures carbon" (and other greenhouses gases) during their growth. • Doesn't take long time to decompose.	• Growing eucalyptus in low rainfall areas may cause adverse environmental impacts due to competition for water with other species. • "Life expectancy" is short, if not well treated. • If the material is burnt at the end of its useful life, it released a hight amount of CO_2 eq. into the atmosphere.

8.5.3. Summary of scores across each criteria

Table 6 – Scores summary

Shelter models	Material consumed	Carbon emissions	Impact on local natural resources	Waste management
SAHEL SHELTER I	2	3	2	1
SAHEL SHELTER II	3	3	2	1
SAHEL SHELTER	2	2	2	1
MOUNDOU SHELTER	4	5	1	3
CASE VÉGÉTALE	2	4	2	2
CASE MILIEU HUMIDE	1	1	4	2
DIFFA	2	2	3	1
TILLABERI	1	3	2	3

1 poor · *2 average* · *3 medium* · *4 good* · *5 very good*

8.5.4. Summary of the results for each model

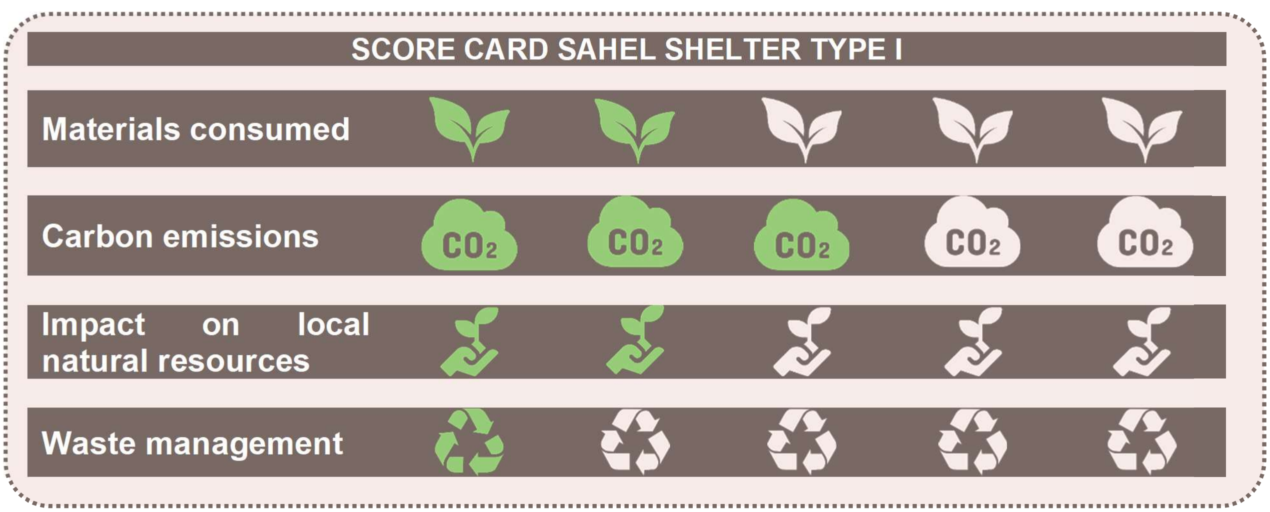
SAHEL SHELTER TYPE I

"Sahel Shelter Type I" uses a high amount of man-made material, especially steel and plastic, and also a considerable amount of water which goes into the production of these.

Most of the *carbon emissions* are from the *"production of the component materials*. The biggest impact is from the metal tubes and PVC tubes. The biggest emissions from *"transport"* come from the palm doum mats, since 85% of the total are imported and are transported by road.

"Sahel Shelter Type I" uses doum palm mats. However production of palm doum mats in Burkina Faso (where this shelter model is built) does not cover the current demand, and humanitarian actors import the mats from other countries.

Most of the materials of the "Sahel Shelter Type I" have the potential for reuse or recycling, and on top of this, the shelter has been designed to be easily dismantled and transported. However the shelter uses long lasting materials sauch as plastic, the very polluting PVC, and the steel tubes, which also take long time to decompose. Also the time expectancy is relatively low (1 year), increasing the material turnover period.



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

SAHEL SHELTER TYPE II

"Sahel Shelter Type II" uses a high amount of man-made material, especially steel and plastic. Since the shelter is smaller compared to the others, it uses lower quantities. Also the amount of water is lower compared to the other models.

Most of the *carbon emissions* are from the *"production of the component materials"*. The biggest impact is from the metal tubes and PVC tubes. The biggest emissions from *"transport"* comes from the palm doum mats, since 85% of the total are imported and are transported by road.

"Sahel Shelter Type II" uses doum palm mats. However production of palm doum mats in Burkina Faso (where this shelter model is built) does not cover the current demand, and humanitarian actors import the mats from other countries.

Most of the materials of the "Sahel Shelter Type II" have the potential for reuse or recycling, and on top of this, the shelter has been designed to be easily dismantled and transported. However the shelter uses long lasting materials as plastic, the very polluting PVC, and the steel tubes, which also take long time to decompose. Also the time expectancy is relatively low (1 year), increasing the material turnover period.

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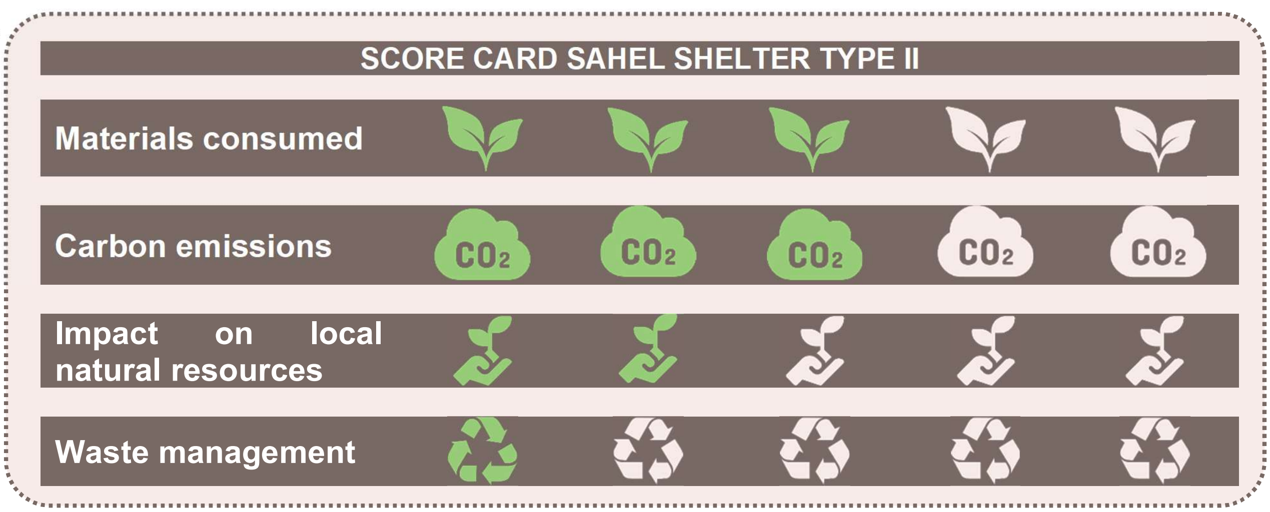


1 poor, 2 average, 3 medium, 4 good, 5 very good

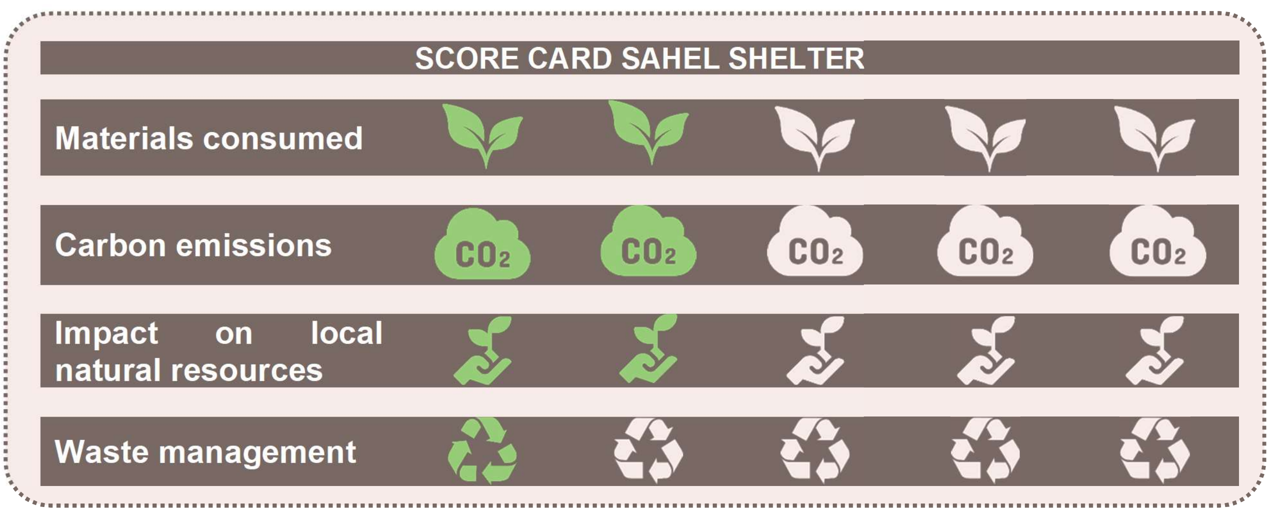
SAHEL SHELTER

The “Sahel Shelter” uses a high amount of man-made material, especially steel and plastic, and also a considerable amount of water which goes into the production of those.

Most of the *carbon emissions* are from the *“end of life”* due to the emissions released from the burning of the palm mats. Also, PVC is the one that has the biggest emissions, followed by metal tubes and wire, from the *"production of the component materials"*.

The “Sahel Shelter” uses doum palm mats locally produced. Over-harvesting is a potential problem.

Most of the materials of the “Sahel Shelter” have the potential for reuse or recycling, and on top of this, the shelter has been designed to be easily dismantled and transported. However, the shelter uses long lasting materials as plastic, the very polluting PVC, and the steel tubes, which also take long time to decompose. Also the time expectancy is relatively low (1 year), increasing the material turnover period.



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

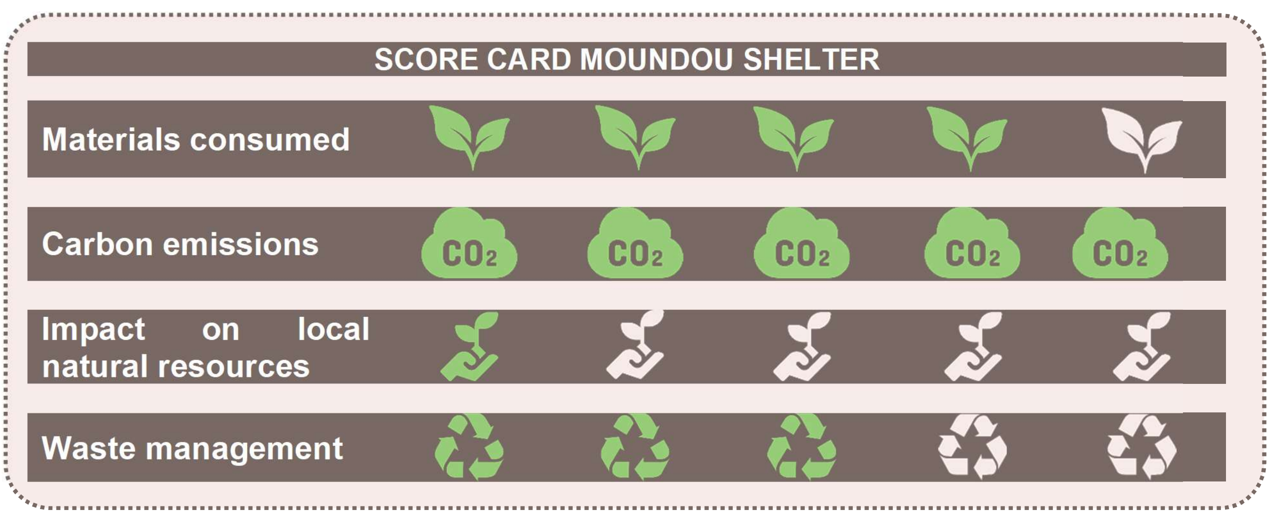
MOUNDOU SHELTER

The "Moundou Shelter" uses mostly locally available raw materials and minimal amounts of man-made materials, meaning much less water consumed in the production process.

Overall the "Moundou Shelter" generates no *carbon emissions*, due to its reliance on natural materials like wood, palm and reed mats. The plastic sheeting is the only material which generates any significant emissions from *"the production of the components materials"*, but these are offset by the "carbon captured" during the growth of the natural materials.

The "Moundou Shelter" model uses more *local natural resources* compare to the rest of the shelters, doum and date palm trees, the common reed from Lake Chad, over-harvesting is a potential problem. It also uses basswood timber sourced from Cameroon. Even if it does not directly affect the local natural habitat, it is advisable to ensure that the exploitation of any natural material does not affect the local environment of the country of origin. However, this is beyond the scope of work of this study.

Most of the materials of the "Moundou Shelter" have the potential for reuse or recycling, and on top of this, the shelter model has been designed to be easily dismantled and transported. The shelter uses more natural materials (doum & date palm tree, basswood timber and common reed) for which the time of decomposition is much less of a concern. Also uses long-lasting materials (plastic and wire) but in less quantity in comparison to the other shelters. However the life expectancy is short (6 months to 1 year), increasing the material turnover period.



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

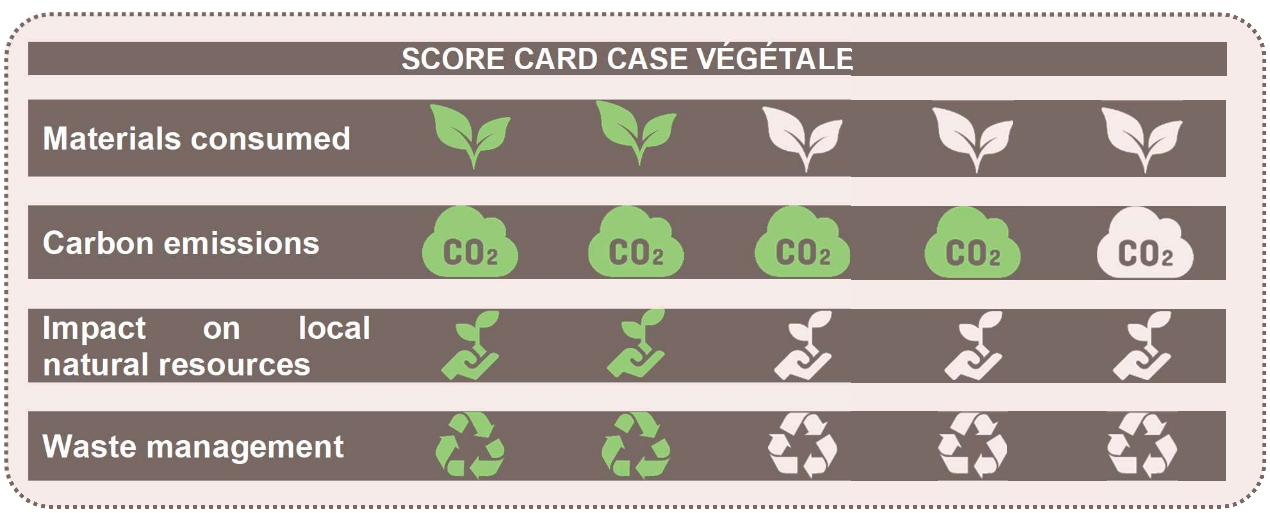
CASE VÉGÉTALE

The “Case Végétale” model uses a high amount of raw material, especially eucalyptus wood and doum palm tree. It also uses steel and plastic.

Overall all, the “Case Végétale” model generates little *carbon emissions*, due to the amount of natural materials it used like eucalyptus wood and palm doum. Steel poles are the only material which generates any significant emissions from *“the production of the components materials”,* follow by plastic sheeting, but these are offset by the “carbon captured” during the growth of the natural materials.

The “Case Végétale” uses eucalyptus timber and the palm doum tree. Both natural materials are locally produced, but while 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. The eucalyptus is an introduced species, requires irrigation techniques in countries with scarce water supplies, and has an impact on soil degradation and deforestation.

Most of the materials from the “Case Végétale” model, have the potential for reuse or recycling, and on top of this, the shelter has been designed to be easily dismantled and transported. However, the model used long-lasting materials (steel, plastic) as well as natural materials (eucalyptus wood & doum palm tree) for which the time of decomposition is much less of a concern. Also the life expectancy is relatively low (1 -2 years), increasing the material turnover period



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

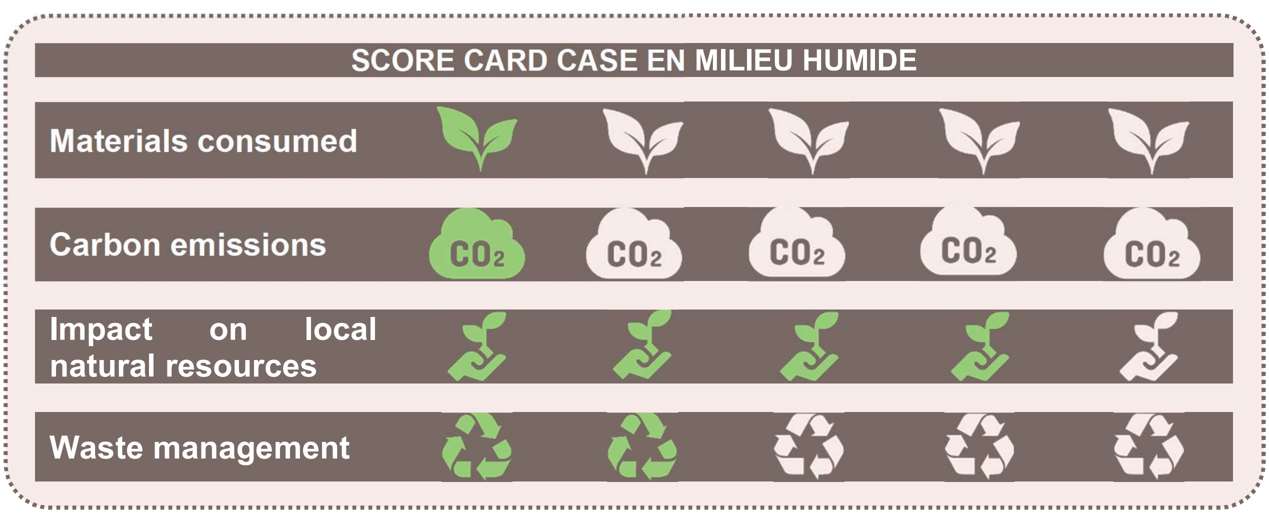
CASE EN MILIEU HUMIDE

"Case en Milieu Humide" consumed a large amount of water 107,108 litres due to the production of cotton for the fabric which is used (30% cotton, 70% nylon). Also used a high amount of man-made material, especially steel.

Most of the *carbon emissions* for this shelter are from the *"production of the component materials".* Steel poles and fabric are the ones that have the biggest emissions, followed by the screws and iron (CGI). Also the *"transport"* of the steel poles, since they come from China, adds substantial emissions.

The "Case en Milieu Humide" model does not use Mali's *local natural resources*, However, this model uses basswood timber sourced from Ivory Coast and Guinea. Even if it does not directly affect the local natural habitat, it is advisable to ensure that the exploitation of any natural material does not affect the local environment of the country of origin. However, this is beyond the scope of work of this study.

Most of the materials of the "Case en Milieu Humide" have the potential for reuse or recycling, and on top of this, the shelter has been designed to be easily dismantled and transported. However, the model uses long-lasting materials (steel, plastic, CGI) as well as natural materials (basswood timber) for which the time of decomposition is much less of a concern. However, the life expectancy is relative higher compared to the other shelters (2 to 3 years), decreasing the material turnover period.



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

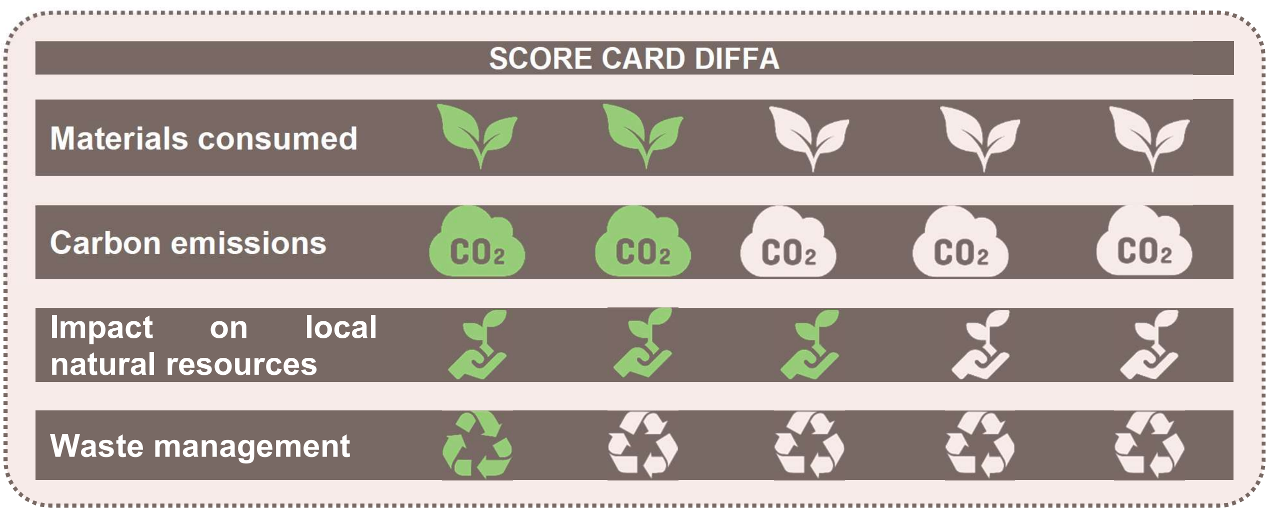
DIFFA

The "Diffa" model uses a high amount of man-made material, especially steel and plastic, and also a considerable amount of water which goes into the production of those.

Most of the *carbon emissions* are from the *"production of the component materials"*. The biggest impact is from the PVC tubes and metal tubes. Also *"end of life"* adds substantial emissions, due to the emissions released from the burning of the palm mats.

"Diffa" uses doum palm mats locally produced. Over-harvesting is a potential problem.

Most of the materials of the "Diffa" have the potential for reuse or recycling, and on top of this, the shelter has been designed to be easily dismantled and transported. However, the shelter uses long lasting materials as plastic, the very polluting PVC, and the steel tubes, which also take long time to decompose. Also the time expectancy is relatively low (6 months), increasing the material turnover period.



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

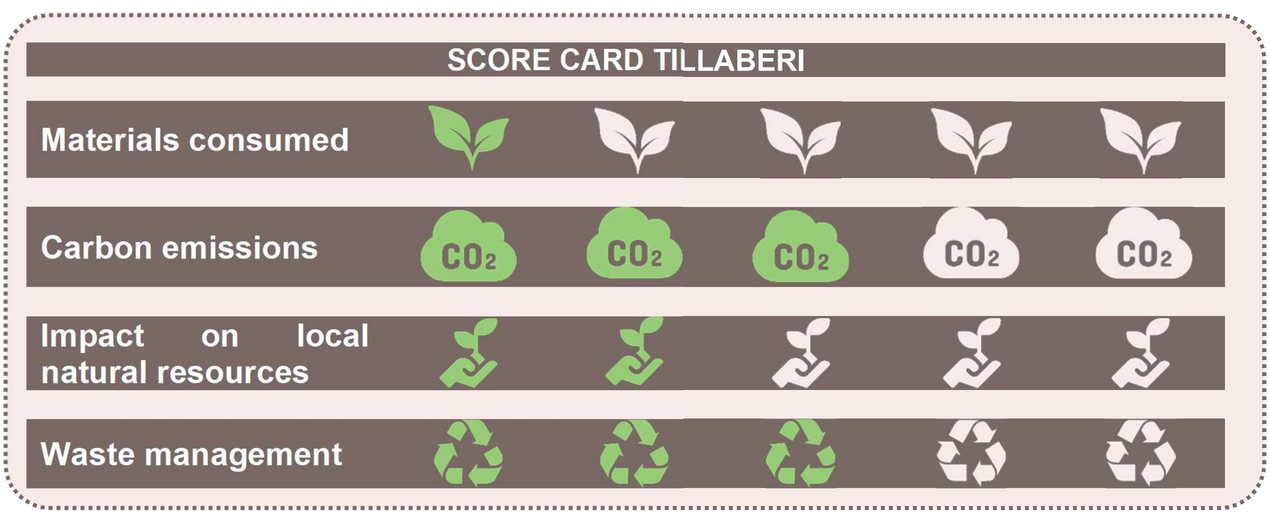
TILLABERI

The "Tillaberi" model consumes a large amount of water, 136,264 litres, due to the production of cotton for the canvas sheet.

The biggest *carbon emissions* are from the cotton canvas, due mostly to the *"production of the component materials"* and *"transport"*. Followed by the *"end of life"* of the eucalyptus timber and the palm doum mats, due to the emissions released from the burning of these materials.

"Tillaberi" used eucalyptus timber and the palm doum tree. Both natural materials are locally produced, but while 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. The eucalyptus is an introduced species, requires irrigation techniques in countries with scarce water supplies, and has an impact on soil degradation and deforestation.

Most of the materials from "Tillaberi" have the potential for reuse or recycling, and on top of this, the shelter has been designed to be easily dismantled and transported. the shelter natural materials (palm doum tree and eucalyptus timber), as well as the cotton canvas, have a time of decomposition that is much less of a concern, However, the model also uses long-lasting materials (plastic and wire). Also, the life expectancy is low (6 months), increasing the material turnover period



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

9. Conclusion

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 the need to reduce *carbon emissions* is critical and increasingly well acknowledged today, it is also clear 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 different 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 in the countries of this study, does not allow for a quantitative weighting for each criteria, leading to a numerical score. An overall qualitative comparison is all that is feasible, which is done through the scorecard.

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, cultural aspects, etc. Between the different options the “least harmful solution” should be adopted.

So, while one solution complies better with some of these factors, another is better according to other factors. The same can be said about the criteria analysed. For example, the “Moundou Shelter” has much lower *carbon emissions* (a higher score in the score card), however its impact on the local environment due to the amount of natural resources used is worse (a lower score for this criteria). This is one of the benefits of using the score card approach, to highlight which shelter complies better with which criteria, as well as to help identify mitigating solutions.

When looking at the materials that the shelters are made of, what it is clear is that the *local natural resources* have some advantages; they not only can provide a source of income for communities, also they capture carbon (and other greenhouses gases) during their growth, and once these materials are no longer used, they decompose in a short time. However, over-harvesting is a potential problem. The question whether the supply of each species could keep up with the demand of the shelters in the region, remains unanswered for most of the shelters. Therefore, promoting reforestation and replanting projects could be included as part of the shelter programmes. Also most of the natural resources end up being burnt or used as firewood. By doing this, it releases the carbon that was previously captured into the atmosphere, thus reversing much of the ‘positive’ benefit. Special attention should be focused on avoiding this, however it must be acknowledged that this is challenging, since affected families depend on firewood for cooking energy. on the other hand, if these materials are burned for cooking or heating then there is a potential offset against other biomass combustibles not used, which could reduce potential deforestation. And finally, these natural resources, if not well treated, have a relative short life expectancy , increasing the material turn-over period. All shelters use natural materials, however, “Moundou Shelter” uses the most, followed by “Case Végétale” and “Tillaberi”.

When thinking on the other materials, attention should be focussed on steel, plastic and the very polluting PVC. They not only generate a large amount of *carbon emissions*. They also take very long time to decompose. This is extremely important, especially in countries which do not have a well-functioning *waste management* system in place, as is the case in these countries. It could be considered to use different materials, or reduce the amount of them, although admittedly this may not always be practical. Otherwise, a project component for reusing, repurposing or recycling (R3) the materials once the shelter gets to the state it has to be replaced, could be set up. All the shelter models use plastic, “Case Végétale” and "Case en Milieu Humide" also use steel and “Sahel Shelter”, “Sahel Shelter Type I”, “Sahel Shelter Type II” and “Diffa” use PVC as well.

Another material which should carefully been considered is cotton. This material does not only take a very large amount of water during its production. It also generates a high amount of *carbon emissions*. However, it does not take long time to decompose, but its life expectancy is relative short. This applies to “Tillaberi” model, that uses cotton canvas for roofing, and "Case en Milieu Humide" that uses fabric made of a cotton-nylon mix. It could be considered to use a different natural material instead of cotton, or to decrease the amount in kilos (ex; 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.

It is important to recognise that the longer a shelter lasts, the more efficient and cost effective it is[134]. 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, all the models have been designed for this purpose. However, the "Case en Milieu Humide" model, has the longest life expectancy in comparison to the rest (2-3 years), but also has the long-lasting material that will take time to disappear. At the other end, “Tillaberi” and “Moundou Shelter” have the shortest life expectancy (6 months – 1 year), however their benefit is that once the materials will reach the end of the useful live, they will decompose relatively fast.

This study does not make a definitive recommendation of one shelter over the others. The final verdict rests on the available options to mitigate some of the worst concerns, 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 or at least environmental screening using a tool such as the NEAT+[135], and following that identification of mitigation strategies, should accompany the design of all shelter and site planning activities.

134 *In the Shelter & Settlements Environmental Impact Report, Shelter Cluster Chad. February 2021, graph Cost vs Durability*
135 *https://neatplus.org/*

10. Recommendations

Shelter-specific recommendations

Avoid or decrease the amount of certain materials, if possible, like plastic, cotton, metal and PVC. Especially PVC since it is one of the most polluting materials and which has the highest embodied CO_2 emissions. Also cotton, since that comes with a heavy environmental footprint. However these changes should not compromise the quality and durability of the shelter.

Analyse further the risks of overexploitation of natural materials used such as doum palm, and if necessary explore other alternative materials. As an example, a local alternative is mats made from millet stalks.

Examinate the sustainability issues with the suppliers for the sourced timber to ensure over-extraction or other environmental damage is not happening. The wood should come from a sustainable plantation and it should also ensure over-extraction or other damage won't happen.

Reduce the packaging for all material, and eliminate any single-use plastic, or support the reuse of packaging for other purposes.

Promote composting the natural materials, consider to use the compost in urban gardens or household kitchen gardens, or transform them into green charcoal[136] instead of burning them at their end of life. This could be difficult to implement, since families often rely on burning organic matter for cooking fuel. This can be partially addressed by integrating clean household energy into the shelter project. See point below.

Procure more locally produced materials when possible, to reduce the *carbon emissions* from *"transport"*. As an example the highest impact in the "Case en Milieu Humide" shelter model came from the steel poles, since they come from China. Procuring more locally produced metal tubes, if possible, is advisable.

General programme recommendations

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.

Raising awareness of environmental sanitation and the pollution generated by the disposal of the materials, though the programme (link to WASH), or through advocacy in partnership with other organisations.

136 *The associations "Africa Ecologie" produced "green charcoal". However some considerations should be taken into account. Practicality, acceptability and cost. Here is a guidance of producing "green carbon" https://fscluster.org/sites/default/files/documents/fuel_efficiency_strategy.pdf*

Set up a reuse/recycling/repurposing site to sort and process the waste. A bit away from the main camp, preferably with a water supply or water storage.

Encourage people to brainstorm what can be done with the items at the end of the useful life, through community engagement. Defining how to turn waste into value. Materials can be collected and reused as raw materials in other products, especially those materials that take a long time to decompose, like plastic sheeting or steel tubes. This can easily be linked with livelihoods or education programmes. For example, plastic sheeting can be transformed into bags, coats, etc.[137].

Link communities to private waste companies to collect materials which are not reused, for recycling. There is also the possibility to generate income for communities from this.

Consider to provide families with access to cooking stoves that do not rely on organic materials, and rely more on solar power or alternative fuels; or at least are more fuel-efficient if they have to burn wood fuel or other biomass. It will reduce the dependency on firewood and take pressure off of forest resources.

Advocate and work with the Shelter Cluster working group and other partners in each country and the region, to pass key environmental messages.

Consider to do an environmental impact assessment or at least environmental screening using a tool such as the NEAT+[138], during the design of all shelter and site planning activities.

Carbon offsetting: Another way to pursue carbon neutrality is to offset emissions generated by reducing them somewhere else, or by purchasing carbon credits[139] from a project that has been accredited by a recognised standard[140].

137 *recycling_reuse_and_disposal_of_plastic_sheeting.pdf (sheltercluster.org)*
138 *https://neatplus.org/*
139 *One potentially interesting case study in Chad that might be of use as an example of how the provision of stoves can impact refugee settings is the CooKit Solar Cooker, which utilised carbon credits from saving CO2 emissions to facilitate expansion of the programme https://www.fairclimatefund.nl/en/projects/chad-solar-cookers-for-refugee-families*
140 *European Parliament*

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12. Annexed documents

- Annex 1 - Informants
- Annex 2 - Shelter models technical information
- Annex 3 - Shelter components material, packaging, quantity and country of origin
- Annex 4 - Transport distance
- Annex 5 - Materials used in each of the shelter models
- Annex 6 - Carbon emissions calculation per shelter
- Annex 7 - Local natural resources used per shelter
- Annex 8 - Protentional reuse option and recycling options
- Annex 9 - Comparative study of the environmental impact of Niger emergency shelter models
- Annex 10 - Comparative study of the environmental impact of Chad emergency shelter models
- Annex 11 - Comparative study of the environmental impact of Burkina Faso emergency shelter models
- Annex 12 - Comparative study of the environmental impact of Burkina Faso emergency shelter models

ANNEX 1 - Informants

International Aid of Luxemburg Red Cross

- Haphane Serge CISSE, Chef des projets Urgences /Croix-Rouge Burkinabè
- Karim SANKARA, Suivi-Evaluateur et Reporting des Projets Urgences/Croix-Rouge Burkinabè
- Dr. LIGBAN Raymond, Chef de Mission Burkina Faso - Aide Internationale de la Croix-Rouge Luxembourgeoise
- Leandro FERNANDEZ-JARDON, Délégué Régional Habitat Humanitaire
- DIALLO Harouna, Logisticien du projet Burkina Faso
- Issa TRAORE, point focal de l'évaluation environnementale au Mali.
- Leandro FERNANDEZ-JARDON, Délégué Régional Habitat Humanitaire
- Luc AHANHANZO , Chef de misión Mali
- Oumar Ag IDBALY, Chef de projet urgence abris Tombouctou
- Éric Pegdwindé BAMBARA, Chef de misión Chad
- Olivier Djimadoum DJIMRAMADJI, Chef de projet Chad
- Daniel LEDESMA, Research officer
- Prosper ZOMBRE, Chef de Mission Niger
- Ismael OUSMANE, Chef de projet Niger
- Abdoulaye MAMANSAN, asistente de Project, Niger

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

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

Shelter Cluster Burkina Faso

- ABDELSADICK Youssouf Ahmat, Associate Shelter Cluster Coordination Officer
- Brice DEGLA, Coordonnateur du Cluster Abri au Burkina Faso

Groupe de Travail Abris & Biens Non Alimentaire TChad

- Pierre Claver NYANDWI, coordinateur du cluster Abris/AME et mouvement de population

Cluster Abris et BNA Mali

- Anicet Adjahossou, Senior Shelter & NFI Cluster Coordination Officer

Groupe de Travail Abris & Biens Non Alimentaire Niger

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

Global Shelter Cluster

- Madelaine MARARA, Global Shelter Cluster Environmental Focal Point.
- Mandy GEORGE, Senior Environmental Advisor

From the Red Cross Sustainable Supply Chain Alliance

- Patrick OGER, *ICRC*

Other organisation contacted in Chad:

- LEAD, DAFNA, NAFIR
- ANADER- Abakar Mahata KAILA- Directeur technique (DT) de la délégation de l'ANADER dans la province du Lac.

Other person contacted:

- Samantha brangeon. Consultant- JI Sustainable Humanitarian Packaging Waste Management
- Pauline MAGUIER, Emergency Coordinator, IOM Chad
- Eve ZORAWSKA, Shelter Officer UNHCR Chad
- Victor ALLANDIGUIBAYE, Assistant Environment Officer, UNHCR Chad

- Orlane Claire Charlotte MATHIEU-MAINCENT – IOM Niger
- Oumarou SEYNI – IOM Niger

Other organisation contacted in Burkina Faso:

- Africa Ecologie: Azize Diloma HEMA. Association is a waste sorting and recovery centre with other partner associations
- KITA Entreprise
- Soburec SARL
- TECO[2]

GIE's contacted in Mali:

- GIE Alahidou
- GIE Nouveau visage de Tombouctou
- GIE Nouveau visage de Tombouctou

Regional Authorities contacted in Mali :

- Direction Régionale de l'Assainissement et du Contrôle des Pollutions Nuisance Tombouctou
- Direction Régionale de la Conservation de la Nature Tombouctou
- Direction Régionale de Génie Rurale Tombouctou

Other person contacted in Niger:

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

Other organisation contacted in Niger:

- JVE Niger
- African Forest Forum

UNEP-Africa

ANNEX 2 - Shelter Models Technical Information

SAHEL SHELTER TYPE I

The "Sahel Shelter Type I" is designed as an emergency to transitional shelter solution, adapted to the Sahel region of the western Africa. Built from 2018, in in the border areas with Mali and Niger: in the communes of Centre-North (Bourzanga, Bouroum, Tougourin, Kaya) and Sahel (Dori, Djibo).

Total area
21 m²

Occupancy
6 persons

Construction time
6 hours/3 persons

Cost
287 euros

Durability
12 months

Total # Built
2944

To Build
2540

Dimensions
6.50m x 3.50m

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=2 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.

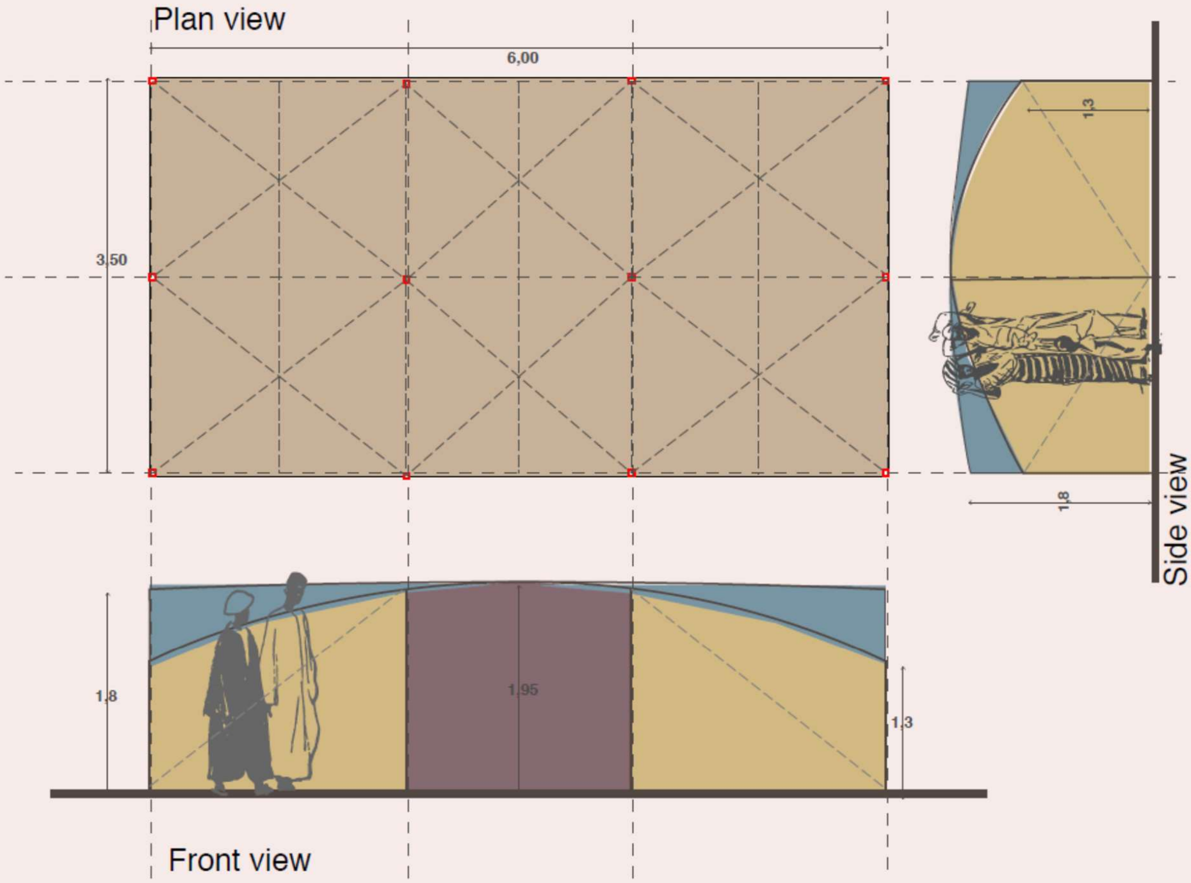
Cladding walls
The walls are made of 14 woven mats of 1x2m from the doum palm tree, directly sewn to the shelter structure.

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 RCRC Movement standards plastic sheets (tarpaulins) of 4x6m.

Openings
The doors are made of 4 plastic mats of 2x1.2m, sewn together.

SAHEL SHELTER
Type I

Graphics



SAHEL SHELTER TYPE II

This emergency shelter is designed as a variation adapted to the context on central Burkina Faso. Built from 2021, in the communes of Boucle du Mouhoun (Tougan), Centre-Nord (Bourzanga, Bouroum, Pensa), and Sahel (Sebba, Gorgadji).

Total area
$14m^2$

Occupancy
4 persons

Construction time
4 hours / 3 persons

Cost
268 euros

Durability
12 months

Total # Built
1777

To Build
1064

Dimensions
4.00m x 3.50m.

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.

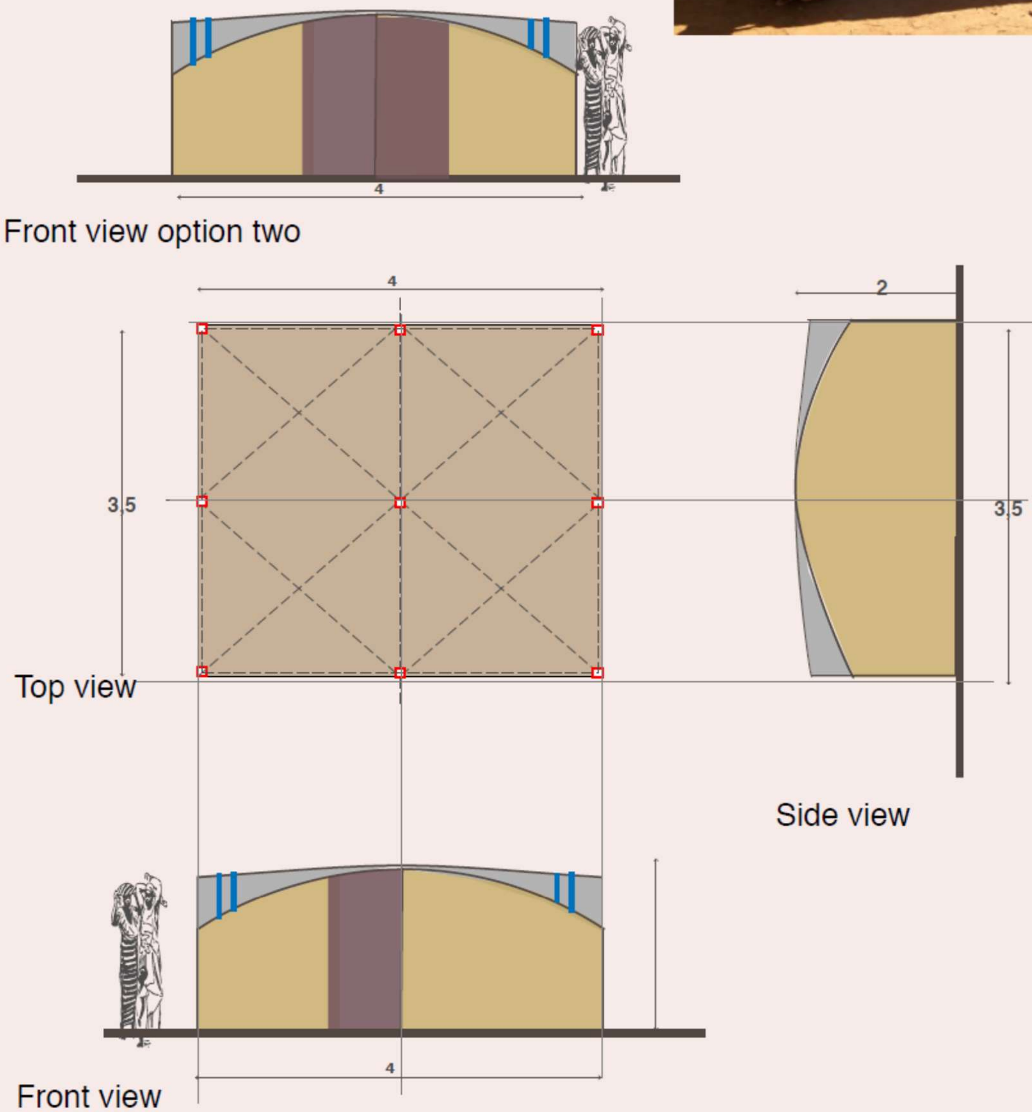
Structure (wall/roof)
The roof geometry is a dome shape created using arches fixed above the column heads. 9 steel tube columns with a minimum section of 30x30mm, e=2 mm.
Additional use of triangulations in the walls to complete the structural system. The material used is semi-rigid PVC with d=32mm and e=2m.

Cladding walls
The walls are made of 11 doum palm mats of 1x2m directly sewn to the shelter structure.

Roof covering
The inner layer consists of 11 doum palm mats of 1x2m, sewn together, which cover the entire dome structure. The second layer consists of 1 RCRC Movement standards plastic sheets (tarpaulins) of 4x6m.

Openings
The doors are made of 1 plastic mat of 2x1.2m, sewn together

SAHEL SHELTER
Type II



SAHEL SHELTER

The Sahel Type is designed as an emergency to transitional shelter solution, adapted to the Sahel region of the western Africa. Built in southern Chad in a refugee camp (Belom camp, Maro department).

Total area
21 m²

Occupancy
6 persons

Construction time
48 hours

Cost
200 euros

Durability
12 to 24 months

Total # Built
505

Dimensions
6.50m x 3.50m

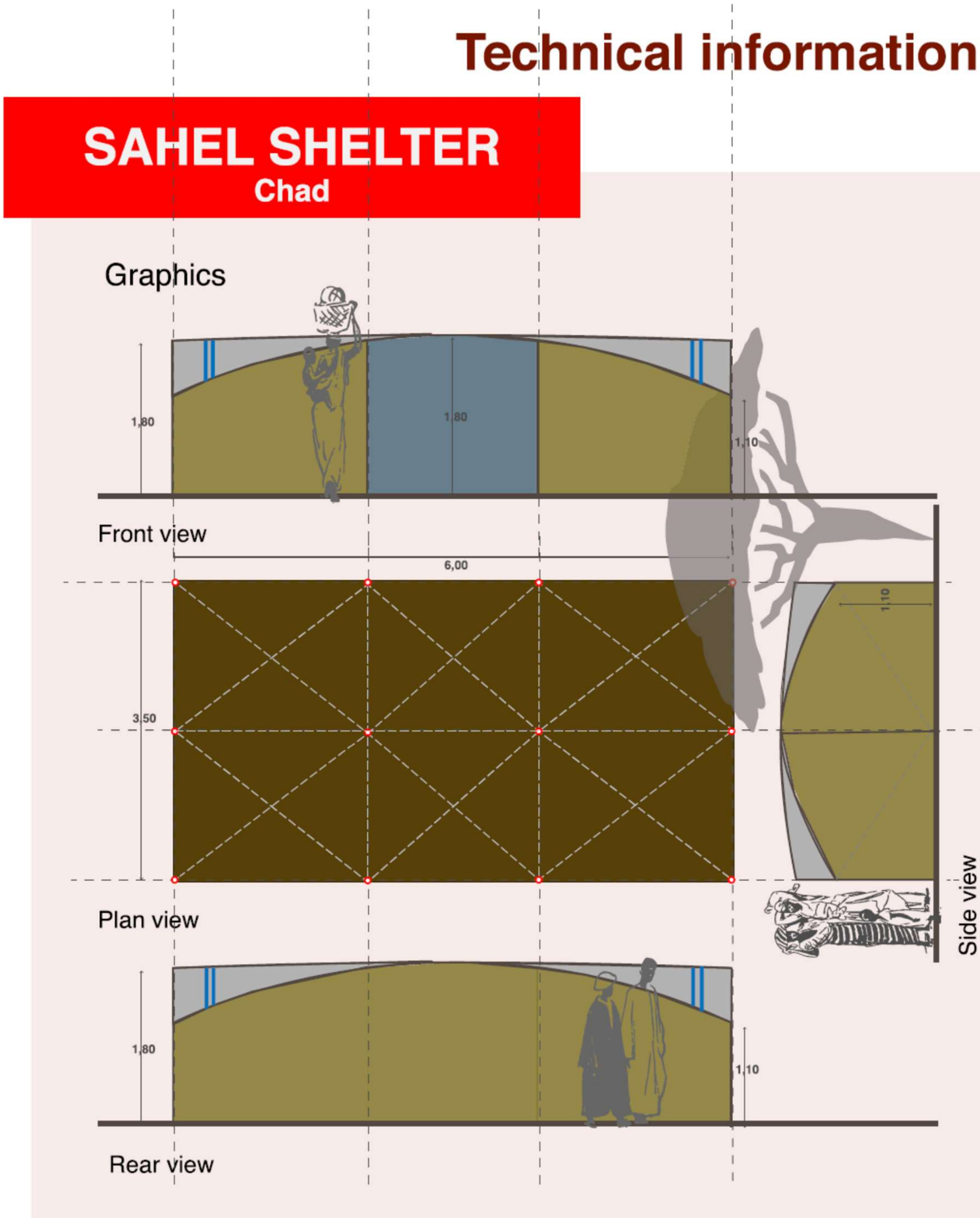
Depth of excavation
Depending on the soil context, with a minimum of 25cm depth to a maximum of 40cm for each pillar.

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=2 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 woven mats of 1x2m from the doum palm tree, 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 RCRC Movement standards plastic sheets (tarpaulins) of 4x6m.

Openings
The doors are made of 2 plastic mats sewn together


Technical information
SAHEL SHELTER
Chad
Graphics
1,80
1,80
1,10
Front view
6,00
3,50
1,10
Plan view
Side view
1,80
1,10
Rear view

MOUNDOU SHELTER

This emergency shelter was developed as a basic emergency contextual shelter solution adapted to the Lake Province of Chad (Ngouboua Koura and Djourou Kapi).

Total area
17.65m

Occupancy
5 persons

Construction time
72 hours

Cost
258 euros

Durability
6 to 12 months

Total # Built
1261

To Build
348

Dimensions
4.90m x 3.60m.

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.

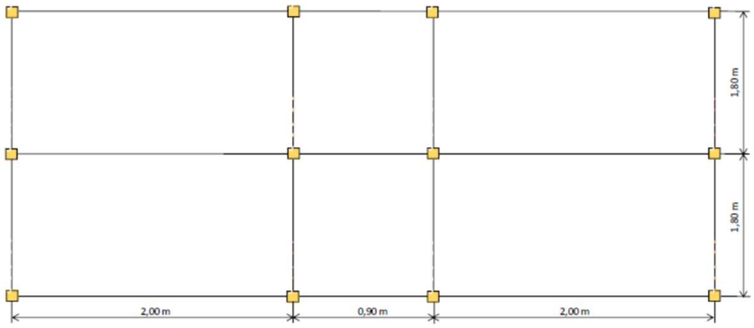
Structure (wall/roof)
There are twelve basswood timber posts consisting of 4 posts of 2.7 m fixed to the central axis and 8 posts of 2.2 m fixed to the ends.
The geometry of the roof is a dome shape created by arches attached to the heads of the posts. The material used is date palm stems (branches) of a varying dimension depending on the season (d = 25-32 mm and e = 2.5 m). The columns are also interconnected transversally by the date palm stems.

Cladding walls
The walls are made of a layer of around 80 branches of 80-85 stems of local straw (common reed), and 1 doum palm woven mat of 1x2m sewn directly onto the shelter structure.

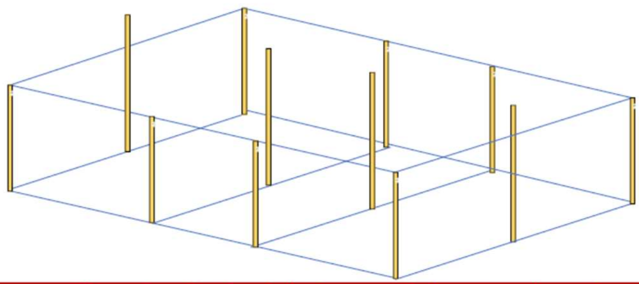
Roof covering
The inner layer consists of 14 doum palm mats of 1x2m, sewn together, which cover the entire dome structure. The second layer consists of 2 RCRC Movement standards plastic sheets (tarpaulins) of 4x6m.

Openings
The door is made of date palm stems sewn together and attached to one side of the poles. The width of the door is 0.90 m and the height varies according to the families.

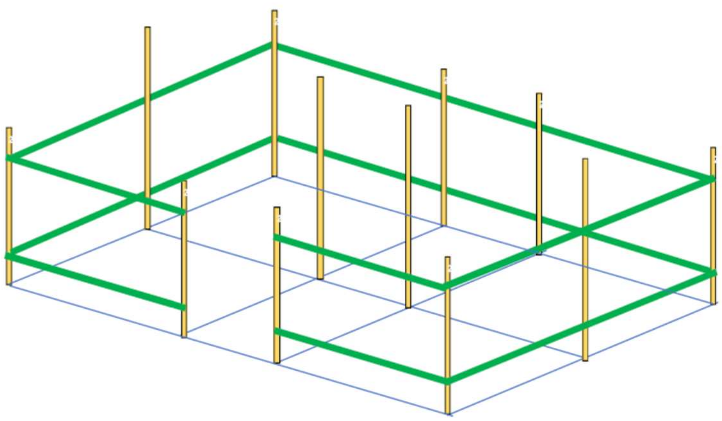
I. Implantation



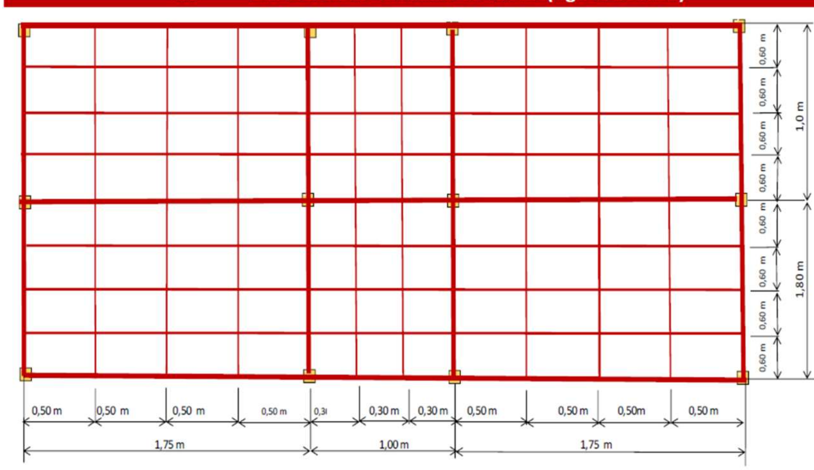
II. Fixation des poteaux



III. Pose des tiges de dattier pour relier les poteaux (en vert)



IV. Vue de toiture en forme de voûte (tige de dattier)



CASE VÉGÉTALE

This emergency shelter is designed as a variation adapted to the context of Tombouctou. In Mali.

Total area
24m²

Occupancy
6 persons

Construction time
1 day

Cost
197 euros

Durability
1 to 2 years

Total # Built
1000

Dimensions
4 x 6 m.

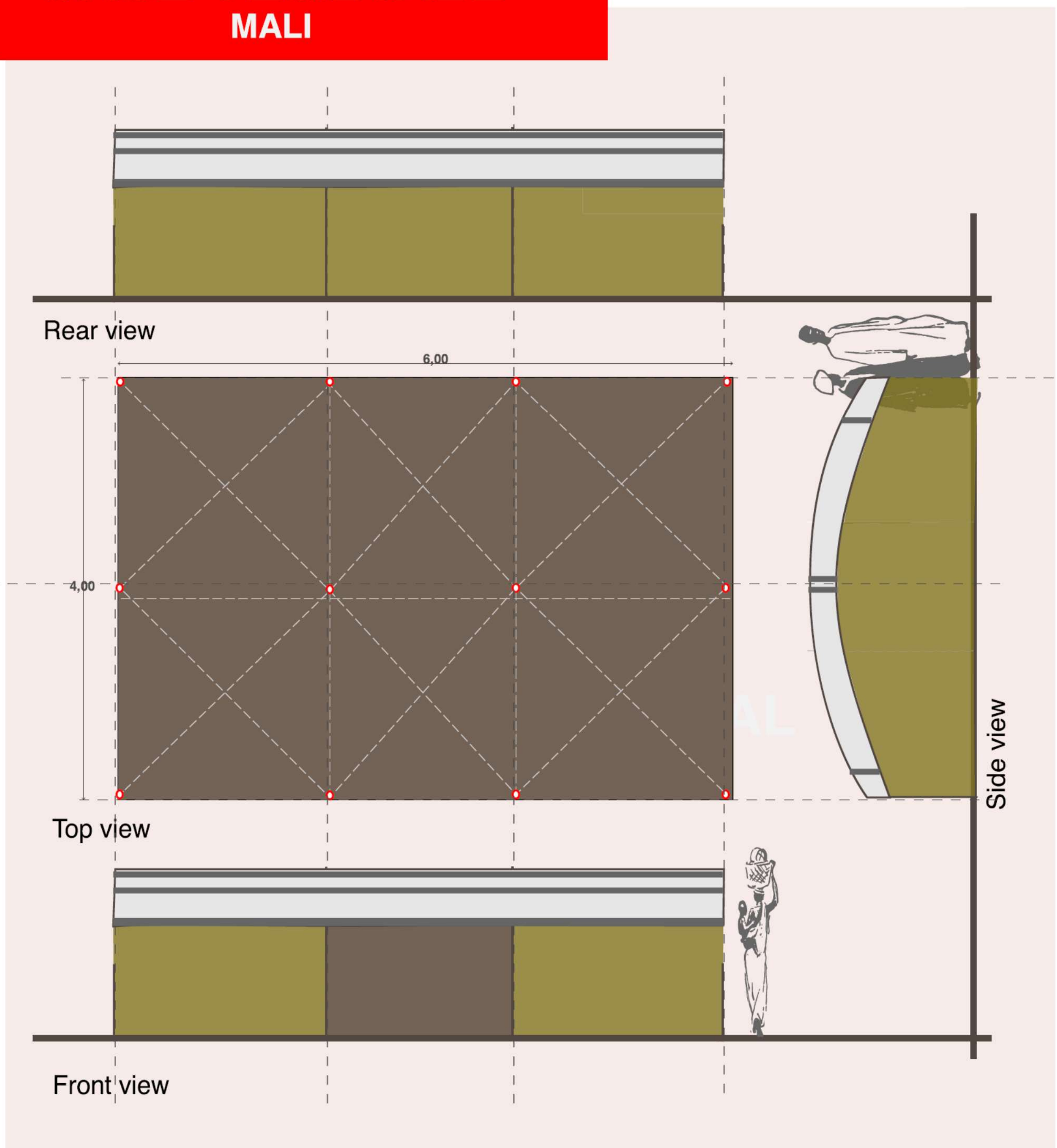
Depth of excavation
The depth of the excavation will be according to the soil context, with a minimum depth of 25 cm for each pillar.

Structure (wall/roof)
10 steel columns with a minimum section of 40x40mm, e=1.5 mm.
The roof geometry is a dome shape created using arches fixed above the column heads. The material used is eucalyptus with a cross-section of 3 to 8 cm, e 1.5 mm

Cladding walls
The walls are made of 10 doum palm mats of 1x2m directly sewn to the shelter structure.

Roof covering
The inner layer consists of 24 doum palm mats of 4x2m, sewn together, which cover the entire dome structure. The second layer consists of two plastic sheeting of 4x4m.

CASE VEGETALE
MALI



CASE EN MILIEU HUMIDE

UNHCR designed this emergency shelter in response to the needs of the displaced population in Mauritania. It was later implemented in Mali with some minor adaptations to the local market and Tombouctou context. In Mali

Total area
20 m²

Occupancy
5 persons

Construction time
1 day

Cost
746 euros

Durability
2 to 3 years

Total # Built
163

Dimensions
5m x 4m

Depth of excavation
Depending on the soil context, with a minimum of 25cm depth to a maximum of 50cm for each pillar.

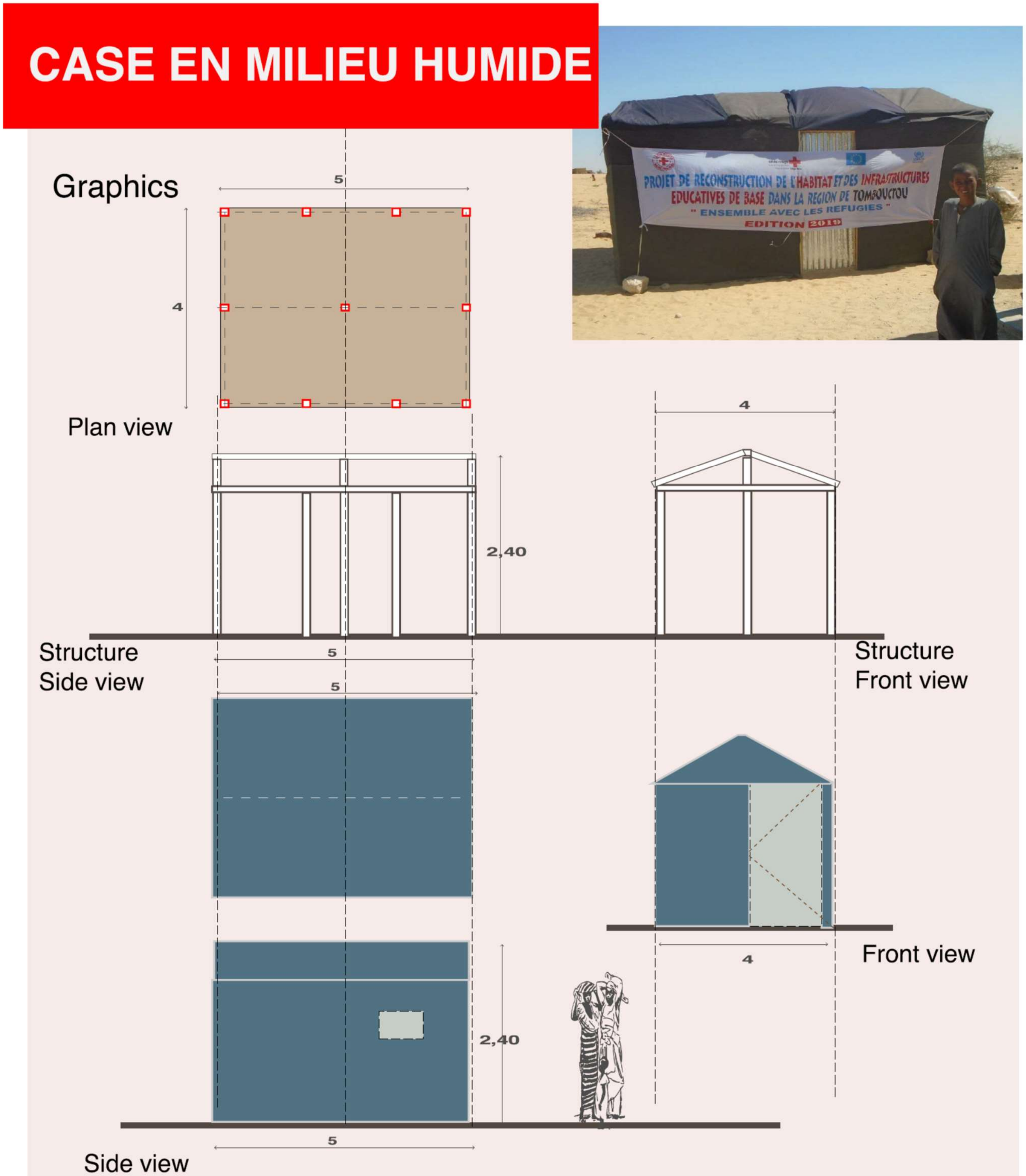
Structure (wall/roof)

11 galvanized steel poles of a diameter of 40 mm. The roof geometry is a gable shape created with lumber rafters attached in a lintel ring over the pole's heads.
The material used is 6 lumber pieces of baswood with 80 x 80 mm section and length between 4 and 5 meters.

Cladding walls
The walls are made of two layers of fabrics stitched together.

Roof covering
The inner layer consists of two layers of fabrics stitched together. The second layer consists of 1 RCRC Movement standards plastic sheets (tarpaulins) of 4x5m.

Openings
The doors and windows are made of Corrugate Galvanised Iron (CGI) sheets over a wooden framework


CASE EN MILIEU HUMIDE
PROJET DE RECONSTRUCTION DE L'HABITAT ET DES INFRASTRUCTURES EDUCATIVES DE BASE DANS LA REGION DE TOMBOUCTOU
" ENSEMBLE AVEC LES REFUGIES "
Graphics
5
4
Plan view
4
2,40
Structure
Side view
5
5
Structure
Front view
Front view
4
2,40
5
Side view

DIFFA

The Sahel Type "Diffa" is designed as an emergency to transitional shelter solution, adapted to the Diffa and Maradi regions[141].

Total area
22.10m

Occupancy
6 persons

Construction 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.

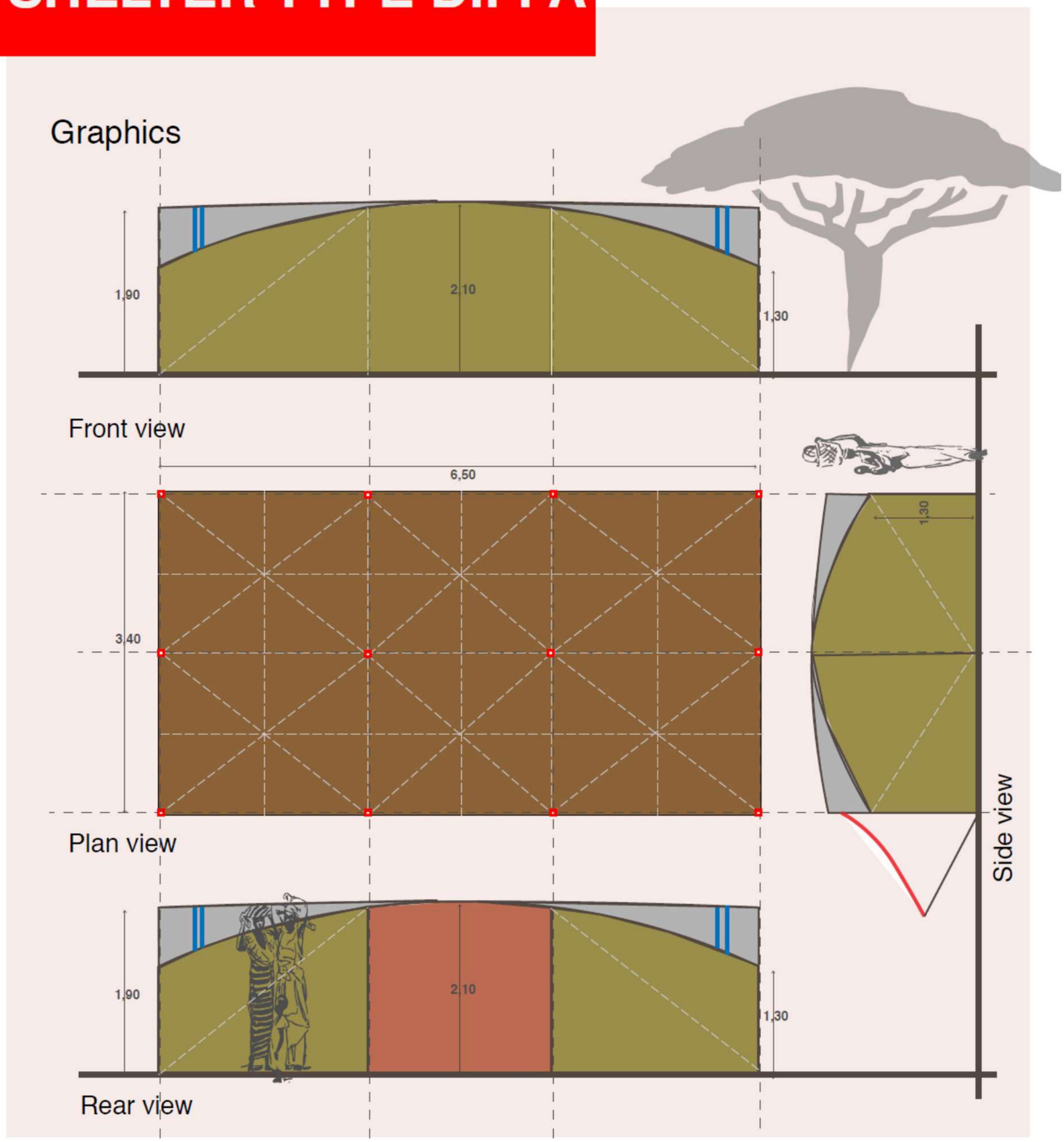
Roof covering
The inner layer consists of 14 doum palm mats of 1x2m, sewn together, which cover the entire dome structure. The second layer consists of 2 RCRC Movement standards plastic sheets (tarpaulins) of 4x6m.

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

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

Technical information

SHELTER TYPE DIFFA



TILLABERI

The shelter type "Tillaberi" is inspired by the "Sahel Shelter" model, but adapted to the context of the Tillaberi region[142].

Total area
17.60m

Occupancy
5 persons

Construction 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 12 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.

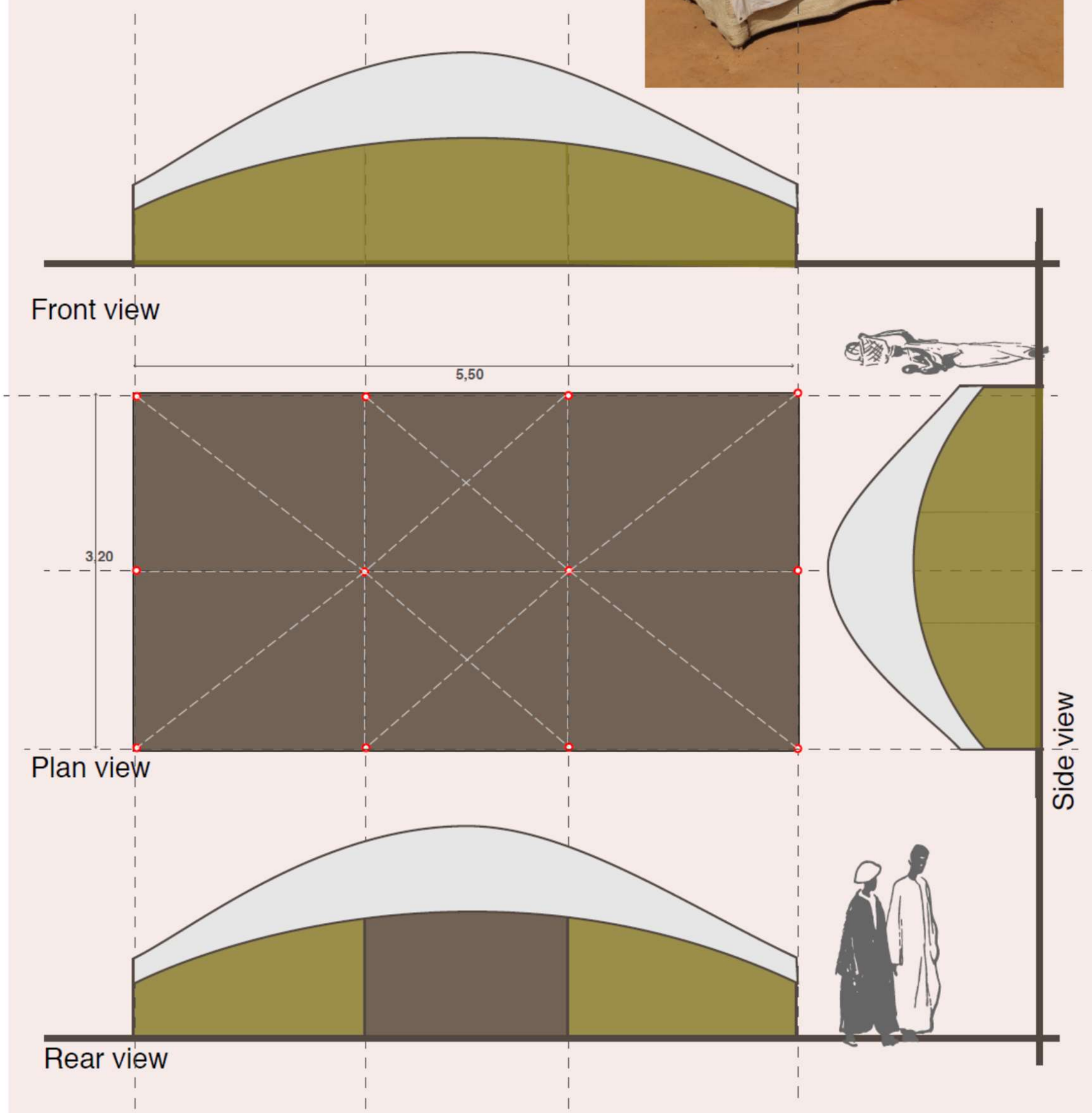
Roof covering
The roof layer covering the dome structure is a waterproof cotton canvas sheet, 4x6m.

Openings
The door is made of 2 plastic matts according to the preferences of the families.

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

Technical information

SHELTER TYPE TILLABERI



ANNEX 3 - Shelter components material, packaging, quantity and country of origin

All the information below was provided by the AI-CRL team in-country. Since for some of the models, the packaging data was not available, it has been excluded from this study, in order to ensure consistency and to compare of results.

Table 1 - Sahel Shelter Type I[143]

Name	Raw material	Quantity/ Kg	Country of origin	Packeting
Steel poles	Steel	26.4	Ghana	None
PVC poles	PVC	33	Ivory Coast	Polyethylene
Plant mats	Palm doum	63	Burkina Faso (15%) Mali (40%) Niger (45%)	Polyethylene
Plastic sheeting	Polyethylene	9	China	Polyethylene
Plastic mats	Polyethylene	7.2	Ivory Coast	Polyethylene
Synthetic rope	Nylon	0.8	China	Polyethylene
Wire	Iron	3	Burkina Faso	Polyethylene
Sewing thread	Cotton	0.45	China	Polyethylene

Table 2 - Sahel Shelter Type II

Name	Raw material	Quantity/ Kg	Country of origin	Packeting
Steel poles	Steel	22.05	Ghana	None
PVC poles	PVC	22.5	Ivory Coast	Polyethylene
Plant mats	Palm doum	49.5	Burkina Faso (15%) Mali (40%) Niger (45%)	Polyethylene
Plastic sheeting	Polyethylene	4.5	China	Polyethylene
Plastic mats	Polyethylene	1.8	Ivory Coast	Polyethylene
Synthetic rope	Nylon	0.8	China	Polyethylene
Wire	Iron	1.5	Burkina Faso	Polyethylene
Sewing thread	Cotton	0.45	China	Polyethylene

143 *All this information was provided by the AICRL team in country*

Table 3 - Sahel Shelter[144]

Name	Raw material	Quantity/ Kg	Country of origin	Packeting
Steel poles	Steel	22.5	Nigeria (Lagos)	*Information not provided*
PVC poles	PVC	36.4	Chad (N'Djamena)	*Information not provided*
Plant mats	Palm doum	109.2	Chad (Ngouri)	*Information not provided*
Plastic sheeting	Polyethylene	9	China (China)	Polyethylene bag
Plastic mats	Polyethylene	2	Chad (N'Djamena)	*Information not provided*
Synthetic rope	Nylon	0.5	Nigeria (Lagos)	*Information not provided*
Wire	Iron	6	Nigeria (Lagos)	*Information not provided*

Table 4 - Moundou Shelter

Name	Raw material	Quantity/ Kg	Country of origin	Packeting
Timber Wood	Tila Americana (Basswood)	92.3	Cameroon (Garoua)	No packeting
Palm stems	Date-palm	143.75	Chad (Mao, Bol, Moussoro)	No packeting
Plant mats	Doum palm	58	Chad (Bol, Bagasola)	No packeting
Straw brunches	Common Reed	402.5	Chad (Bagasola, Ngouboua)	No packeting
Plastic mats	Polyethylene	9	China (China)	Polyethylene bag
Synthetic rope	Nylon	0.25	Nigeria (Etat de Borno)	No packeting
Wire	Iron	0.5	Dubai	No packeting
Plant Rope	Doum palm	9	Chad (Bol, Bagsola)	No packeting

Table 5 - Case Végétale[145]

Name	Raw material	Quantity/ Kg	Country of origin	Packeting
Steel poles	Steel	25	China	No packeting
Fabric	Nylon	1	Mali (Bamako)	Polyethylene
Plastic sheeting	Polyethylene	8	China (China)	Polyethylene
Timber	Eucalyptus wood	188	Mali (around Tombouctou & Diré)	Rope (palm doum)
Plant mats	Palm doum	68	Mali (around Tombouctou & Niafunfé)	Rope (palm doum)
Rope	Palm doum	0.5	Mali (around Diré & Niafunfé)	Rope (palm doum)

144 *All this information was provided by the AI-CRL team in country, except the quantity in kilos of the packaging for the "Sahel shelter" model, which was not known, so this data has not been included in the calculation for both shelters.*
145 *All this information was provided by the AI-CRL team in country*

Table 6 - Case en Milieu Humide

Name	Raw material	Quantity/ Kg	Country of origin	Packeting
Steel poles	Steel	75	China	No packeting
Fabric	70% Nylon & 30% Cotton	15	China	Polyethylene
Plastic mats	Polyethylene	4	China	Polyethylene
Corrugate Galvanised Iron sheets (CGI)	Iron	7	Mali (Bamako)	No packeting
Timber Wood	Tila Americana (Basswood)	41.2	60% Guinea (Conakry) & 40% Ivory Coast (Abidjan)	Polyethylene
Screw	Steel	5	China	Polyethylene

Table 7 - Diffa

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 Beni	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

Table 8 - Tillaberi

Name	Raw material	Quantity/ Kg	Country of origin	Packeting
Timber	Eucalyptus	61	Niger (Dosso)	No packaging
Plant matt	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 4 - Transport distances

When calculating the CO_2 equivalent, one of the key factors 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 neighbouring 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 kilometres 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)

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. The following assumptions have been made:

- The tool and the analysis here do 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.
- When one material could come from different locations, the average distance is calculated according to a weighting determined by the proportion of material coming from each location.
- When calculating the average distance from the warehouse to the construction site, the distance has been calculated based on the proportion of shelters that have been built in each location.
- The distances in kilometres have been calculated using Google Maps, when they have not been provided by the field team.
- A few materials have been manufactured in China and transported by boat[146].
- 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 kilometres.
- Other sea distances were calculated[147] in nautical miles and converted to kilometres for entry into the tool.
- Since it is not known exactly what happens with disposal, transportation from the site of construction of the shelters for disposal is not included.

BURKINA FASO – Sahel Shelter Type I & II

Country of origin to point of arrival in country

Distance by boat

Departing point	Arrival point	Distance
China	Ivory Coast - Port Abidjan	19,000 km[148]

Distance by road

Departing point	Arrival point	Distance
Ivory Coast (Abidjan)	Ouagadougou	1154 km
Ghana	Ouagadougou	996 km
Mali	Ouagadougou	900 km
Niger	Ouagadougou	513 km

146 *Refer to Annex 4 for further information*
147 *http://ports.com/sea-route/Ports.com*
148 *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.*

Origin to Warehouse (km)

Area	Location warehouse	Distance
Dédougou	Ouagadougou	233 km
Léo	Ouagadougou	168 km

ICRC warehouse to AI- CRL warehouse (km)

Area	Location warehouse	Distance
Ouagadougou (Warehouse ICRC)	Ouagadougou (Warehouse IALRC)	7 km

Point of Arrival (Warehouse) to Construction Site (km)

Departing point	Arrival point	Distance
Ouagadougou	Bouroum	188 km
Ouagadougou	Pensa	161 km
Ouagadougou	Barao	233 km
Ouagadougou	Tougouri	168 km
Ouagadougou	Bourzanga	157 km
Ouagadougou	Kaya	105 km
Ouagadougou	Djibo	210 km
Ouagadougou	Gorgadji	326 km
Ouagadougou	Dori	268 km
Ouagadougou	Sebba	363 km
Ouagadougou	Tougan	236 km
Ouagadougou	Ouaihigouya	236 km
Ouagadougou	Silmagué	233 km

CHAD – Sahel Shelter & Moundou Shelter

Country of origin to point of arrival in country

Distance by boat

Departing point	Arrival point	Distance
China	Ivory Coast - Port Abidjan	19000 km[149]
Port Abidjan	Cameron- Port Douala	1626 km[150]
Port Dubai	Cameron- Port Douala	14847 km[151]

Distance by road

Departing point	Arrival point	Distance
Nigeria (Lagos)	N'Djamena	1892 km
Nigeria (Maiduguri / Etat de Borno)	Baga Sola	767 km
Cameroon (Port Douala)	N'Djamena	1824 km
Cameroon (Garoua)	N'Djamena	446 km

149 *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.*
150 *Sea distance were calculated in nautical miles (http://ports.com/sea-route/Ports.com) and converted to kilometres for entry into the tool*
151 *Sea distance were calculated in nautical miles (http://ports.com/sea-route/Ports.com) and converted to kilometres for entry into the tool*

Point of Arrival to Warehouse / Store

Departing point	Arrival point	Distance
Ngouri	N'Djamena	231 km
N'Djamena	Maro (site de Belom)	880 km[152]
N'Djamena	Baga Sola	374 km
Mao	Baga Sola	394 km
Moussoro	Baga Sola	412 km
Bol	Baga Sola	71 km

Warehouse to Construction Site (km)

Area	Location warehouse	Distance
Bagasola	Ngouboua Koura	32 km[153]
Maro	Site de Belom	*Information not provided*

MALI – Case Végétal & Case en Milieu Humide

Country of origin to point of arrival in country

Distance by boat

Departing point	Arrival point	Distance
China	Senegal (Dakar)	19000 km[154]

Distance by road

Departing point	Arrival point	Distance
Senegal (Dakar)	Bamako	1360 km
Ivory Coast (Abidjan)	Bamako	1157 km
Guinea (Conacry)	Bamako	974 km

Point of Arrival to Warehouse / Store

Departing point	Arrival point	Distance
Bamako	Tombouctou	1015 km

Warehouse to Construction Site (km)

Departing point	Arrival point	Distance
Warehouse (Tombouctou)	Tombouctou	5 km
Warehouse (Tombouctou)	Goudam	91 km
Warehouse (Tombouctou)	Niafunke	163 km
Warehouse (Tombouctou)	Gourma Rharous	121 km
Warehouse (Tombouctou)	Around Diré; *Niafunké, Koumaira, Sarafére, N´gorkou & Banikane*	120 km

152 *Distance provided by the field team*
153 *Distance provided by the field team*
154 *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.*

Warehouse (Tombouctou)	Around Niafunfé; *Kourmaira, Saraféré, N´gorkou & Banikane*	163 km
Warehouse (Tombouctou)	Around Tombouctou; *Toya, Daye, Hondoubormo & Bourem Inaly*	60 km
Warehouse (Tombouctou)	Around Diré; *Kirchamba, Dangha & Garbakoira Koiratao*	120 km

NIGER – Diffa & Tillaberi

Country of origin to point of arrival in country

Departing point	Arrival point	Distance
Nigeria (Lagos)	Niamey	1029 km
Côte d'Ivoire (Abidjan)	Niamey	1691 km
Ghana (Accra)	Niamey	1240 km
Benin (Porto- Novo)	Niamey	982 km
Tunisia (Tunis)	Niamey	4162 km
Algeria (Algiers)	Niamey	3754 km
Morocco (Marrakesh)	Niamey	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 5 - Materials used in each of the shelter models

Below are the tables showing the materials used in each of the shelter models, by weight (kilograms). The data was provided by the AI-CRL logistics teams in each country.

Water consumption is calculated for all the man-made materials used to build the shelters. The water consumed by natural growth of the natural materials is not considered. To calculate the water in litres, the following baseline assumptions have been used:

- Production of 1 kg of plastic requires 17 litres of water[155]
- Production of 1 kg of steel requires 705 litres of water[156]
- 1 kilo of cotton requires 10,000 litres of water[157]

Table 1 - SAHEL SHELTER Type I

Raw material	
Doum palm tree	63 kilos
Water consumption	21,010 litres
Man-made material	
Steel	29.4 kilos
PVC	33 kilos
Plastic	16.65 kilos
Nylon	0.8 kilos

Table 2 - SAHEL SHELTER Type II

Raw material	
Doum palm tree	49.5 kilos
Water consumption	16,753 litres
Man-made material	
Steel	23.6 kilos
PVC	22.5 kilos
Plastic	6.8 kilos
Nylon	0.8 kilos

Table 3 - SAHEL SHELTER

Raw material	
Doum palm tree	109.2 kilos
Water consumption	20,898 litres
Man-made material	
Steel	28.5 kilos
PVC	36.4 kilos
Plastic	11 kilos
Nylon	0.5 kilos

Table 4 - MOUNDOU SHELTER

Raw material	
Doum palm tree	67 kilos
Date palm tree	143.75 kilos
Common reed	402.5 kilos
Basswood	92.3 kilos
Water consumption	505.5 litres
Man-made material	
Steel	0.5 kilos
Plastic	9 kilos
Nylon	0.25 kilos

Table 5 - CASE VÉGÉTALE

Raw material	
Doum palm tree	68.5 kilos
Eucalyptus wood	188 kilos
Water consumption	17,761 litres
Man-made material	
Steel	25 kilos
Plastic	8 kilos
Nylon	1 kilos

Table 6 - CASE EN MILIEU HUMIDE

Raw material	
Basswood	41.2 kilos
Cotton fabric	4.5 kilos
Water consumption	107,108 litres
Man-made material	
Steel	81 kilos
Iron	7 kilos
Plastic	4 kilos
Nylon	10.5 kilos

155 *Shelter and Sustainability, UNHCR, 2021*
156 *Shelter and Sustainability, UNHCR, 2021*
157 *www.theworldcounts.org*

Table 7 - DIFFA

Raw material	
Doum palm tree	60 kilos
Water consuption	20,898 litres
Manmade material	
Steel	22.5 kilos
PVC	36.4 kilos
Plastic	11 kilos
Nylon	0.5 kilo
Wire	6 kilos
Thread	0.04 kilos

Table 8 - TILLABERI

Raw material	
Doum palm tree	20 kilos
Ecualyptus wood	61 kilos
Water consuption	136,264 litres
Manmade material	
Cotton	13.2 kilos
Plastic	2 kilos
Nylon	0.5 kilo
Wire	6 kilos
Thread	0.04 kilos

ANNEX 6 - *Carbon emissions* calculations per shelter

Below are the total *carbon emissions* generated by each shelter model, in CO_2 equivalent. This is using the SMAC calculator and taking into account all the parameters and assumptions explained in section 7.2.

Table 1 – SAHEL SHELTER Type I

Impact	Carbon emissions Kg CO_2 eq
Production of the component materials	86
Packaging	*Data not considered*
Transport	51
End of life	75
Total	**212**

Table 2 – SAHEL SHELTER Type II

Impact	Carbon emissions Kg CO_2 eq
Production of the component materials	54
Packaging	*Data not considered*
Transport	37
End of life	56
Total	**147**

Table 3 – SAHEL SHELTER

Impact	Carbon emissions Kg CO_2 eq
Production of the component materials	41
Packaging	*Data not available*
Transport	85
End of life	117
Total	**243**

Table 4 – MOUNDOU SHELTER

Impact	Carbon emissions Kg CO_2 eq
Production of the component materials	-778
Packaging	*Data not available*
Transport	55
End of life	656
Total	**-67**

Table 5 - CASE VÉGÉTALE

Impact	Carbon emissions Kg CO_2 eq
Production of the component materials	-263
Packaging	*Data not considered*
Transport	39
End of life	241
Total	**18**

Table 6 - CASE EN MILIEU HUMIDE

Impact	Carbon emissions Kg CO_2 eq
Production of the component materials	245
Packaging	*Data not considered*
Transport	126
End of life	60
Total	**431**

Table 7 - DIFFA

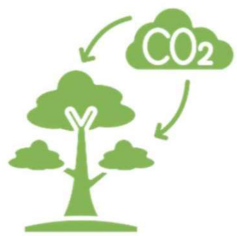
Impact	Carbon emissions Kg CO_2 eq
Production of the component materials	95
Packaging	*Data not available*
Transport	74
End of life	71
Total	**241**

Table 8 - TILLABERI

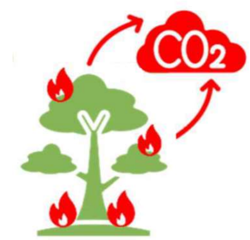
Impact	Carbon emissions Kg CO_2 eq
Production of the component materials	95
Packaging	*Data not available*
Transport	74
End of life	71
Total	**241**

Emissions from “packaging\” are not included in this study, as previously mentioned in section 7.2.1, in some shelter this packaging data was not available. Therefore it has been excluded from this study, in order to ensure consistency and to compare of results.

It is important to explain why there are significant carbon emissions generated from the *“end of life*” phase. This is because the SMAC tool assumes that these materials are burnt at the end of their useful life, thus releasing the carbon emissions which were sequestered in the materials. If in fact these natural materials are left to decompose, or composted, these emissions would be eliminated and therefore the overall emissions of that shelter model would be even lower.



Natural material “captures carbon” when they are growing



When burnt, the carbon is relisted

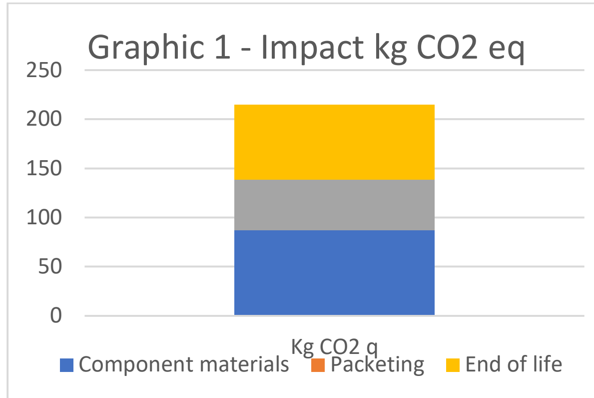
Below are the details of the *carbon emissions* calculations per shelter.

1. SAHEL SHELTER TYPE I

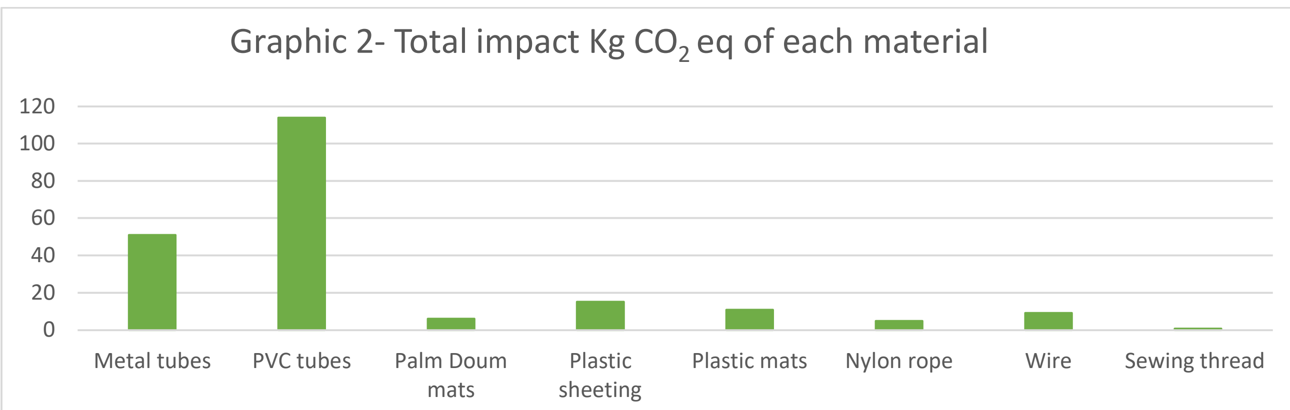
The following Table 1 and Graphic 1 show the breakdown of the *carbon emissions*, in terms of Kg CO_2 eq. of the shelter unit per "*life-cycle stages*": *"production of the component materials"*. *"transport"* and *"end of life"*.

Table 1 – SAHEL SHELTER TYPE I

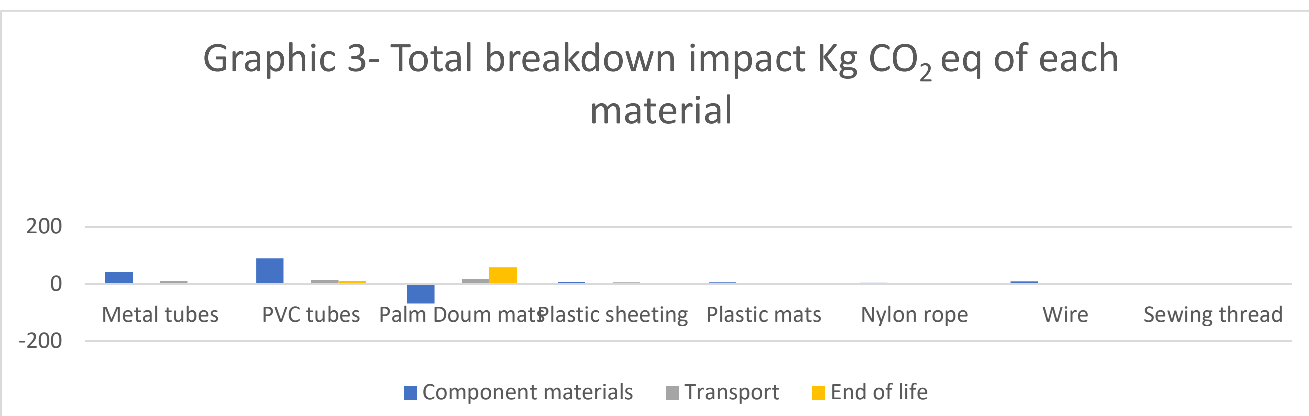
Impact	Carbon emissions Kg CO_2 eq.
Production of the component materials	86
Packaging	*Data not considered*
Transport	51
End of life	75
Total	**212**



The follow Graphic 2 shows the total Kg CO_2 eq. impact of each material.



The follow Graphic 3 shows the total Kg CO_2 eq. emissions of each material, broken down into the emissions generated by "*production of the component materials*", *"transport"* and *"end of life"*.



1.1. Interpretation of the result for "Sahel Shelter Type I"

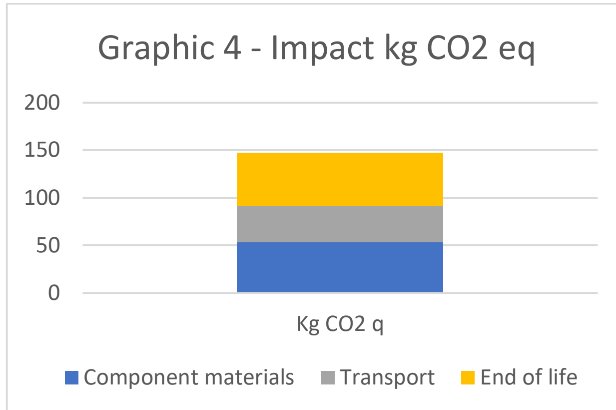
Since "Sahel Shelter Type I" and "Sahel Shelter Type II" are composed by exactly same materials, the only difference being the total amount of the materials used, the interpretation of the results are the same for both models. The difference remains in the total *carbon emissions* generated. Therefore, the interpretation of the result for both types will be done below, in section 2.

2. SAHEL SHELTER TYPE II

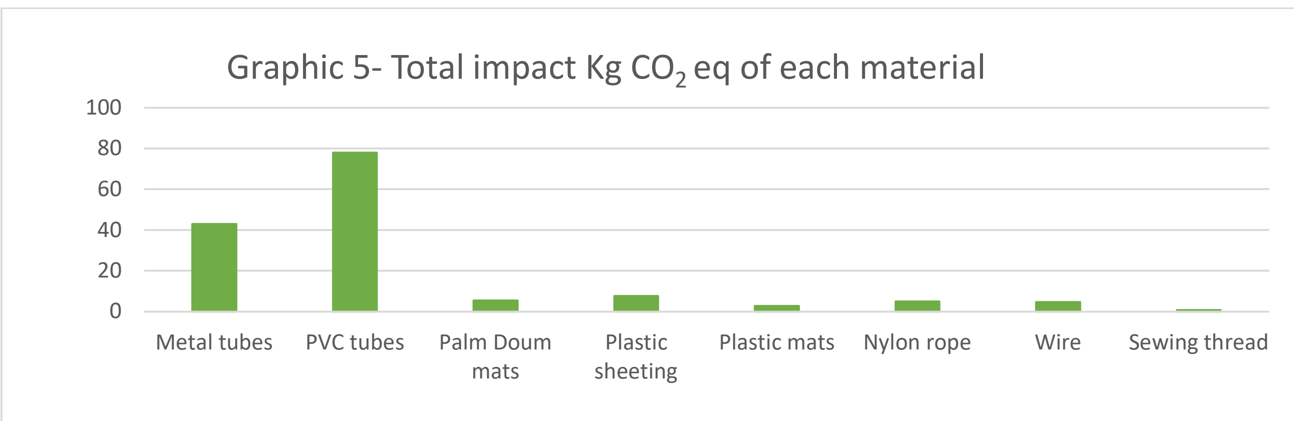
The following Tables 2 and Graphic 4 show the breakdown of the *carbon emissions* generated, in terms of Kg CO_2 eq. of the shelter unit per "*life-cycle stages*": *"production of the component materials"*, *"transport"* and *"end of life"*.

Table 2 – SAHEL SHELTER II

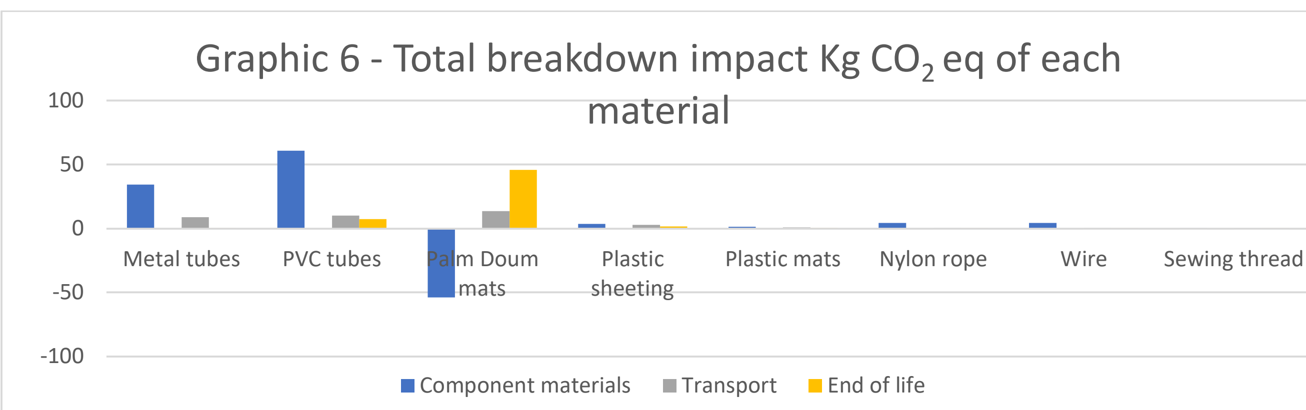
Impact	Carbon emissions Kg CO_2 eq.
Production of the component materials	54
Packaging	*Data not considered*
Transport	37
End of life	56
Total	**147**



The follow Graphic 5 shows the total Kg CO2 eq. impact of each material.



The follow Graphic 6 shows the total Kg CO_2 eq. emissions of each material, broken down into the emissions generated by "*production of the component materials*", *"transport"* and *"end of life"*.



2.1. Interpretation of the results for both shelters

The overall *carbon emissions* for the "Sahel Shelter Type II" are lower than the "Sahel Shelter Type I" model. This is obvious, because it uses less materials.

As per Graphic 1 ("Sahel Shelter Type I") and Graphic 4 ("Sahel Shelter Type II") most of the *carbon emissions* for both shelters are from the *"production of the component materials"* and the *"end of life*" of the component materials used, with *"transport"* contributing less. However, in this particular case, the *"end of life" carbon emissions* are somewhat misleading, and the real carbon footprint should be less as is explained below.

When looking into each of the materials, Graphic 2 ("Sahel Shelter Type I") and Graphic 5 ("Sahel Shelter Type II"), PVC is the one that has the biggest emissions, followed by metal tubes and plastic sheeting. As per Graphic 3 ("Sahel Shelter Type I") and Graphic 6 ("Sahel Shelter Type II"), most of the emissions from the PVC and metal tubes come from the *"production of the component materials"*. According to the results, the third biggest contribution to the *carbon emissions* is from the *"end of life* of the palm doum mats. But as mentioned above, in this particular case the *"end of life"* should be less.

When looking into the palm doum mats, Graphic 3 ("Sahel Shelter Type I") and Graphic 6 ("Sahel Shelter Type II") , the *"production of the component materials"* generates negative *carbon emissions*. This is because natural materials capture carbon (and other greenhouse gases) during their growth. It is important to understand this well since it is not intuitive for many. Using such local natural materials produces 'negative' emissions – they do not require any energy to produce (unlike the other materials), and in fact they reduce *carbon emissions*. However, at *"end of life"*, they are generally assumed to be burned (The SMAC tool assumes that these type of plant materials and wood are burnt at the end of their useful life, as this is usually the case in these humanitarian contexts), and thus release much of that carbon into the air.

However, this is not the real case for these models. When the materials are burnt, the level of CO_2 eq. released into the air is relatively high. Therefore, *carbon emissions* are released at the *"end of life"* as per Graphic 3 (Sahel Shelter Type I") and Graphic 6 ("Sahel Shelter Type II") , where palm doum mats seem to make a big contribution to emissions . But if the material is allowed to decompose, is composted, or is just buried, little or no CO_2 eq. would be released into the environment. This is what happens in this specific case in Burkina Faso. According to the field team, the families do not burn the material at the end of its life. Instead, they dumped them in an open field. Therefore, the *carbon emissions* at the *"end of life"* should be zero, and the overall *carbon emissions* should be less for both shelters. However the SMAC tool does not allow this to be taken into consideration.

The challenge with *"end of life"* is that it can be a very local process. As in this example, in one place the materials may be burned (e.g., when a site is abandoned), at another, used for compost (e.g., a well-established camp with a gardening program) and at a 3rd, just dumped in near-by unused land (as it is in this case study). As a result, only one process is considered in the SMAC tool. Therefore some local conditions could increase or decrease the carbon footprint. This is the reason why the SMAC tool cannot be seen as giving an exact answer, but as input into decision making. This is where a score card approach is important, since this can allow for a more explicit inclusion of local factors.

However, in the case where some families burnt the palm doum mats, then the estimation of the *carbon emissions* by the SMAC tool would be more accurate.

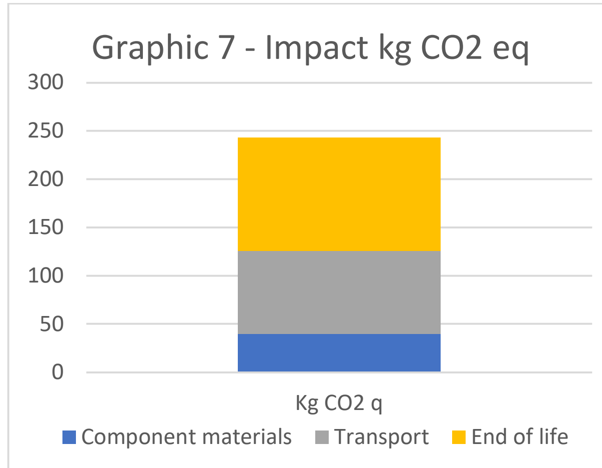
Overall, it is clear that the metal and PVC tubes are driving most of the *carbon emissions*; however, for the entire shelter the emissions from *"production of the component materials"*. appear lower due to the 'carbon capture' effect of the palm doum mats; similarly the emissions from *"end of life"* appear much higher due to the emissions released from considering the burning of the palm mats, acknowledging that this is not actually the case for these models in this context. So the total *carbon emissions* should be less. The biggest impact on *"transport"* comes from the palm doum mats, since 85% of the total are imported and are transported by road.

3. SAHEL SHELTER

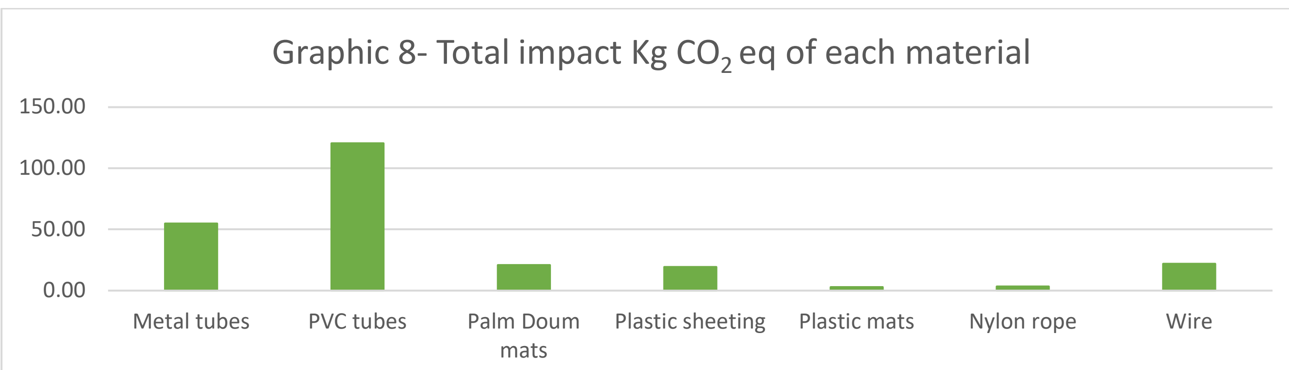
The follow Table 3 & and Graphic 7 show the breakdown of the *carbon emissions*, in terms of Kg CO_2 eq of the shelter unit per "*life-cycle stages*": *"production of the component materials"*, *"transport"* and *"end of life".*

Table 3 – SAHEL SHELTER

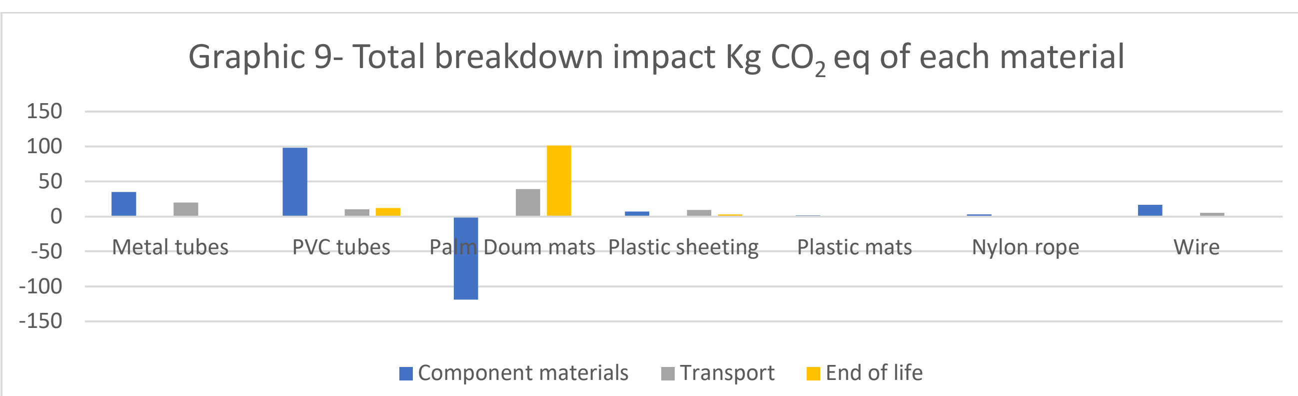
Impact	Carbon emissions Kg CO_2 eq
Production of the component materials	41
Packaging	*Data not available*
Transport	85
End of life	117
Total	**243**



The follow Graphic 8 shows the total Kg CO2 eq impact of each material.



The follow Graphic 9 shows the total impact Kg CO_2 eq emissions of each material, broken down into the emissions generated by "*production of the component materials*", "*transport*" and *"end of life*".



3.1. Interpretation of the result for "Sahel Shelter" model

As per Graphic 7 most of the *carbon emissions* for this shelter are from the *"end of life"* of the component materials used, with *"transport"* and "*production of the component materials"'* making a smaller contribution. However, as will be explained, this overall picture is slightly misleading, because the use of the natural palm doum mats has the effect of offsetting many of the emissions from the metal and PVC tubes.

When looking into each of the materials, Graphic 8, PVC is the one that has the biggest emissions, followed by metal tubes and wire. As per Graphic 9, most of the emissions from the PVC and metal tubes come from the *"production of the component materials"*. *"transport"* also adds substantial emissions.

When looking into the palm doum mats, Graphic 9, the '*"production of the component materials"* actually generates negative *carbon emissions*, because of the captured carbon (and other greenhouse gases) during their growth of the natural material. However, this captured carbon is released at the *"end of life"*, Graphic 9, where palm doum mats have the biggest impact on emissions.

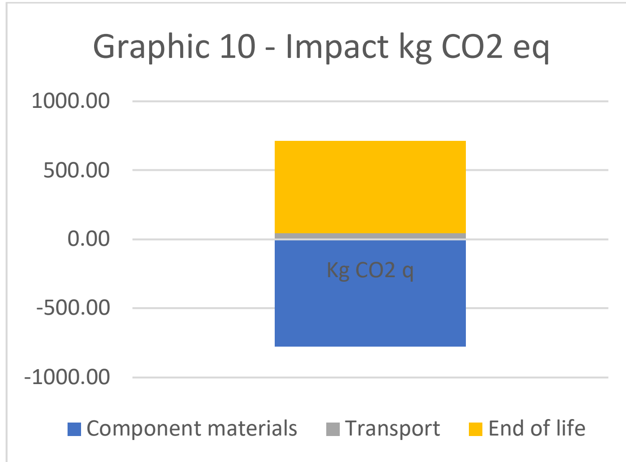
Overall, it is clear that the metal and PVC tubes are driving most of the *carbon emissions*; however, for the entire shelter the emissions from production appear lower due to the 'carbon capture' effect of the palm doum mats; similarly the emissions from *"end of life"* appear much higher due to the emissions released from the burning of the palm mats.

4. MOUNDOU SHELTER

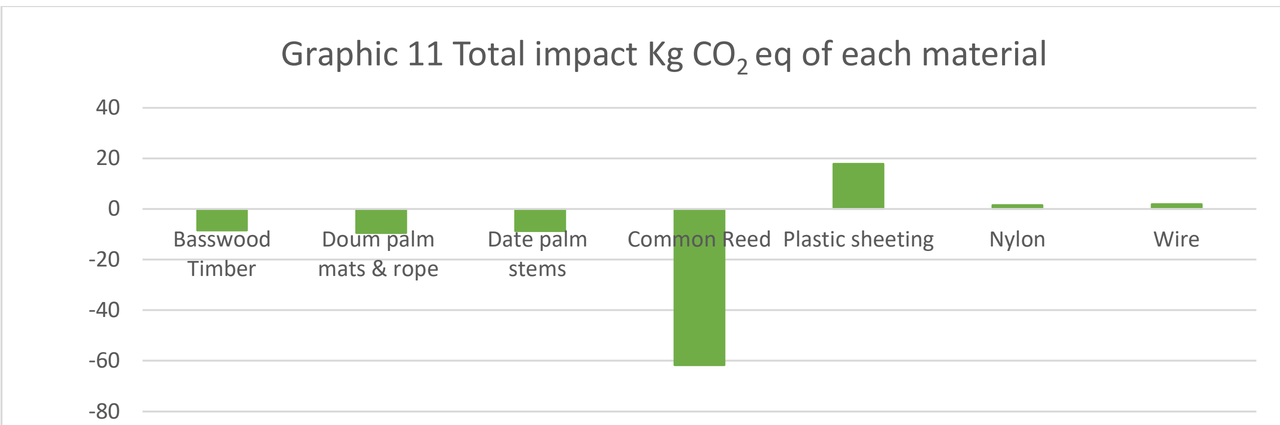
The follow Tables 4 and Graphic 10 show the breakdown of the *carbon emissions* generated, in terms of Kg CO_2 eq of the shelter unit per "*life-cycle stages*": *"production of the component materials"*, *"transport"* and *"end of life"*.

Table 4 – MOUNDOU SHELTER

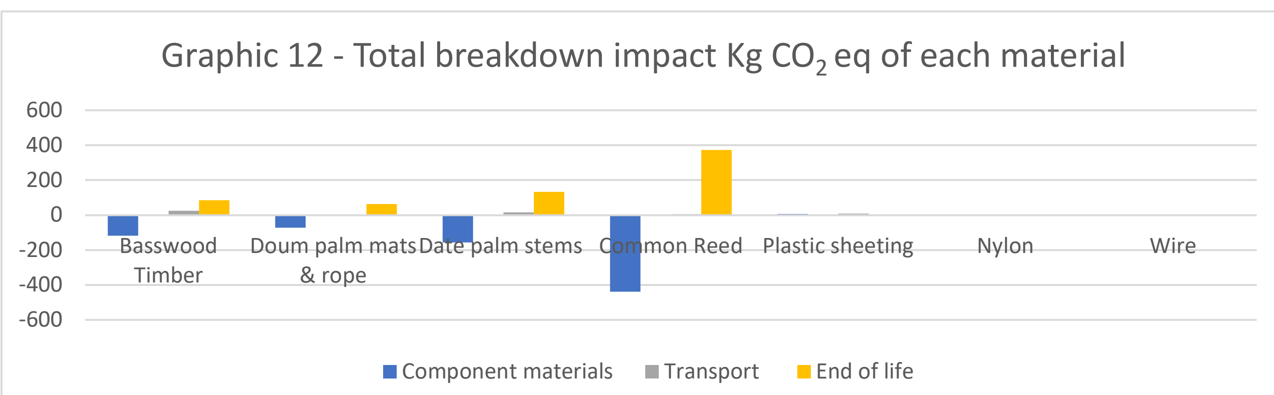
Impact	Carbon emissions Kg CO_2 eq
Production of the component materials	-778
Packaging	*Data not available*
Transport	55
End of life	656
Total	**-67**



The follow Graphic 11 shows the total Kg CO2 eq impact of each material.



The follow Graphic 12 shows the total Kg CO_2 eq emissions of each material, broken down into the emissions generated by "*production of the component materials*", "*transport*" and "*end of life".*



4.1. Interpretation of the result for Moundou Shelter model

Overall the “Moundou Shelter” generates no *carbon emissions*, due to its reliance on natural materials like wood, palm and reed mats. The plastic sheeting is the only material which generates any significant emissions, but these are offset by the “carbon captured” during the growth of the natural materials.

Considering the total impact of each of the materials used in the shelter, Graphic 11, the biggest impact is the plastic sheeting followed by wire and nylon. The emissions generated by the plastic sheeting are due mostly to the *“transport”*, Graphic 12.

As per Table 4 and Graphic 10 the biggest impact on *carbon emissions* is due to the *“end of life”*, followed by *“transport”*. However, this is slightly misleading because of the “carbon captured” (negative emissions generated) by the natural materials during production, and the large emissions released when these materials are burnt at the end of their useful life.

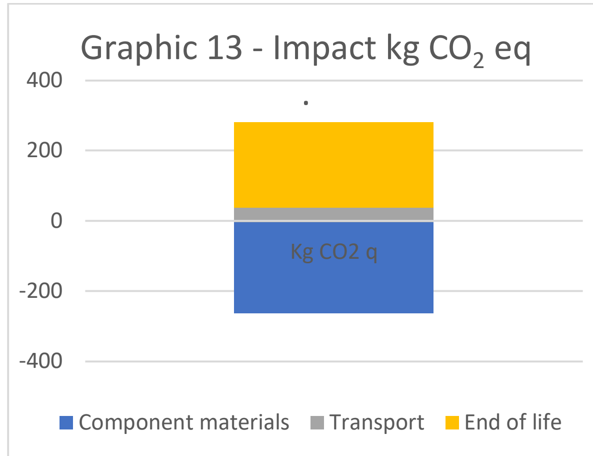
Overall the “Moundou Shelter” captures more *carbon emissions* that it releases during its life cycle. This is because all the natural materials capture carbon during their growth (as per Table 4 and Graphic 10). However, this number is almost balanced out when considering what happens at the *“end of life”* of the materials, when “carbon captured” is released (656 Kg CO_2 eq as per Table 11 and Graphic 10). If the material is allowed to decompose, or is just buried, little or no CO_2 eq would be released into the environment. This would further Increase the ’positive’ impact on emissions of the “carbon captured” by the natural materials used.

5. CASE VÉGÉTALE

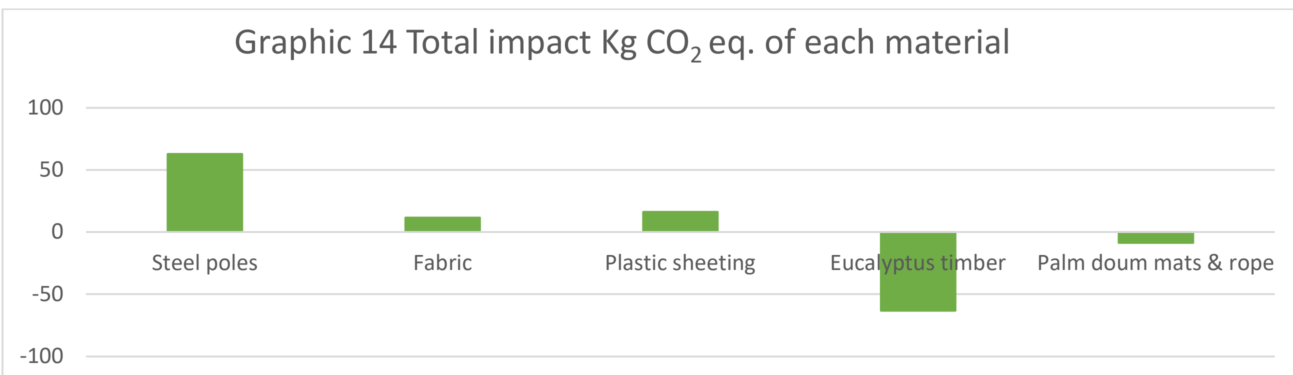
The follow Table 5 & and Graphic 13 show the breakdown of the *carbon emissions*, in terms of Kg CO_2 eq. of the shelter unit per "*life-cycle stages*": *"production of the component materials"*, *"transport"* and *"end of life".*

Table 5 - CASE VÉGÉTALE

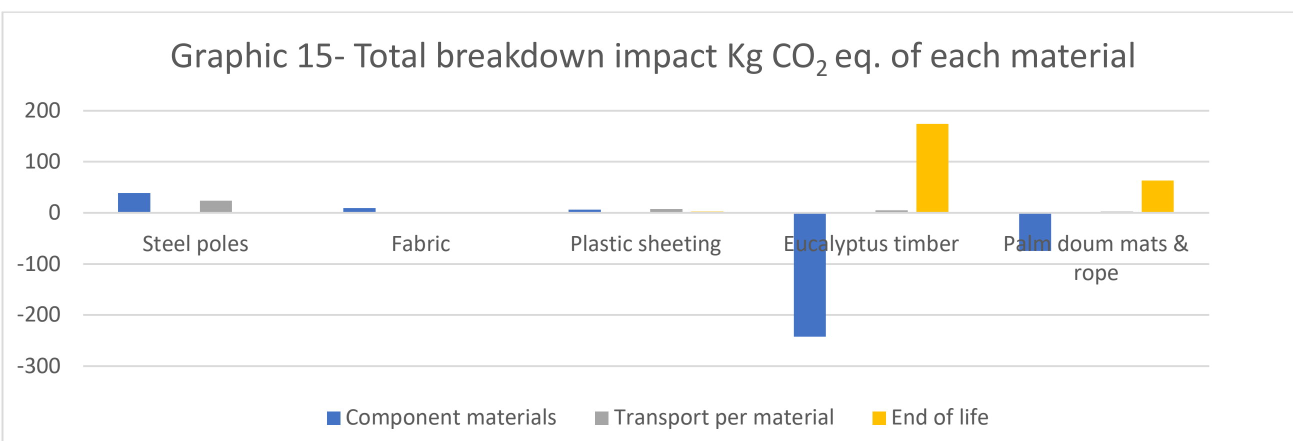
Impact	Carbon emissions Kg CO_2 eq.
Production of the component materials	-263
Packaging	*Data not considered*
Transport	39
End of life	241
Total	**18**



The follow Graphic 14 shows the total Kg CO_2 eq. impact of each material.



The follow Graphic 15 shows the total Kg CO_2 eq. emissions of each material, broken down into the emissions generated by "*production of the component materials*", "*transport*" and "*end of life".*



5.1. Interpretation of the result for “Case Végétale” model

Overall all, the “Case Végétale” model generates little *carbon emissions*, due to the amount of natural materials it used like eucalyptus wood and palm doum. Steel poles are the only material which generates any significant emissions, but these are offset by the “carbon captured” during the growth of the natural materials.
Considering the total impact of each of the materials used in the shelter (Graphic 14), the biggest impact is the steel poles, followed by plastic sheeting and fabric. The emissions generated by the steel poles are due mostly to the *“production of the component materials”* (Graphic 15).

As per Table 5 & Graphic 13 most of the *carbon emissions* for this shelter are from the *“end of life”* of the component materials used, with *“transport”* making a smaller contribution and *“production of the component materials”* actually generates negative *carbon emissions*. However, this overall picture is slightly misleading, because the use of the natural materials, as eucalyptus timber and palm doum mats has the effect of offsetting many of the emissions from the other materials like steel poles or plastic sheeting.

When looking into the eucalyptus timber and palm doum mats & rope (Graphic 15), the *“production of the component materials”* actually generates negative *carbon emissions*. However, this captured carbon is released at the *“end of life”* (Graphic 15), where the eucalyptus timber has the biggest impact on emissions, follow by the palm doum mats & rope. If the material is allowed to decompose, is composted, or is just buried, little or no CO_2 eq. would be released into the environment.

So, initially, the CO_2 eq. number for eucalyptus wood and palm doum mats may be negative as producing the material takes less CO_2 eq. than for instance, plastic sheeting. But these negative emissions are ‘balanced out’ when considering what happens at the end of life of the material, when carbon is emitted, and also due to the emissions from transportation.

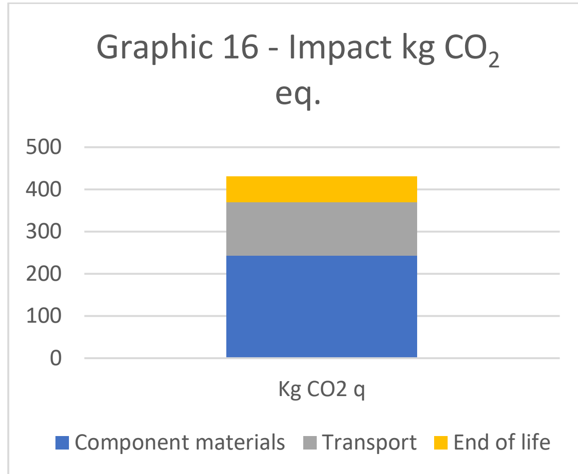
Overall, it is clear that the steel poles, and also the plastic sheeting, are driving most of the *carbon emissions*; however, for the entire shelter the emissions from production appear lower due to the ‘carbon capture’ effect of the natural materials; similarly the emissions from *“end of life”* appear high due to the emissions released from the burning them.

6. CASE EN MILIEU HUMIDE

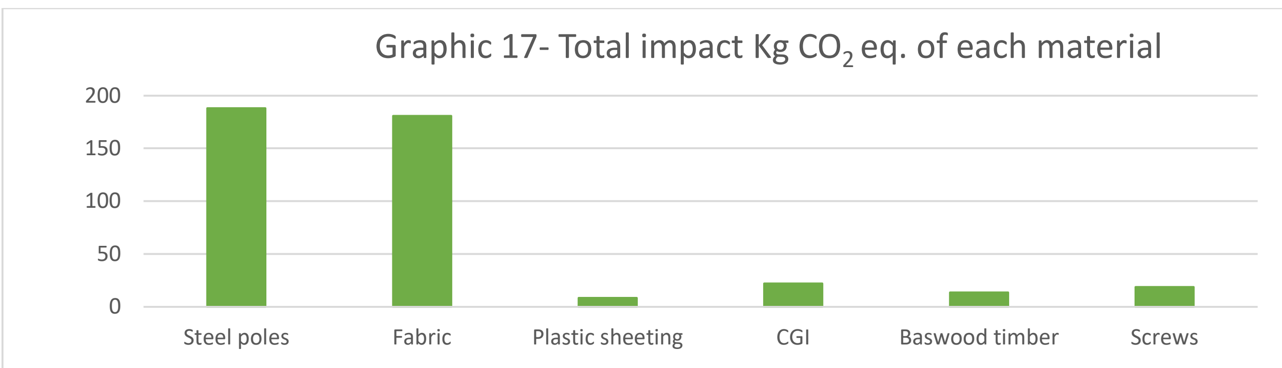
The follow Table 6 and Graphic 16 show the breakdown of the *carbon emissions* generated, in terms of Kg CO_2 eq. of the shelter unit "*life-cycle stages*": *"production of the component materials"*, *"transport"* and *"end of life"*.

Table 6 – CASE EN MILIEU HUMIDE

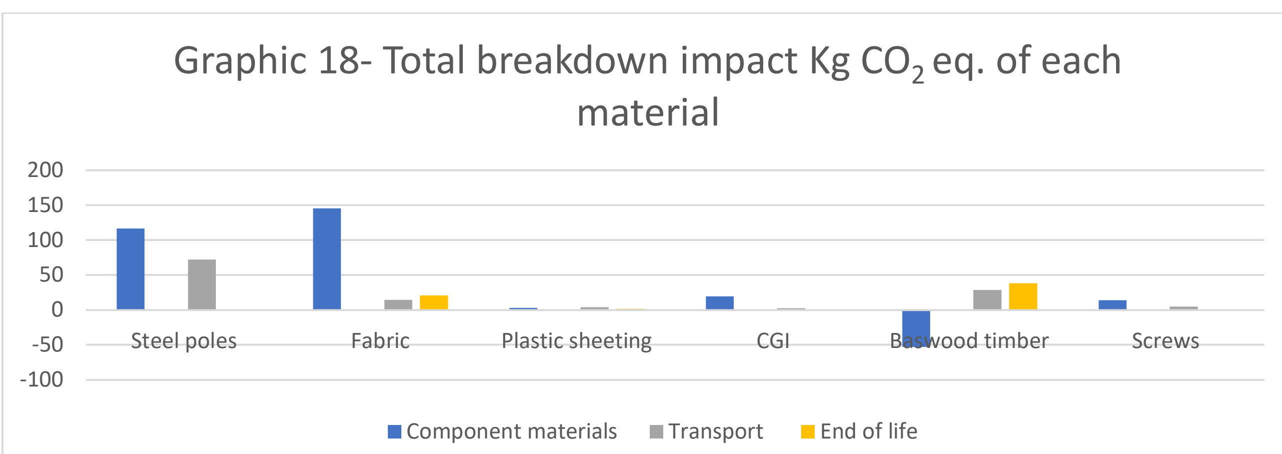
Impact	Carbon emissions Kg CO_2 eq.
Production of the component materials	245
Packaging	*Data not considered*
Transport	126
End of life	60
Total	**431**



The follow Graphic 17 shows the total Kg CO_2 eq. impact of each material.



The follow Graphic 18 shows the total Kg CO_2 eq. emissions of each material, broken down into the emissions generated by "*production of the component materials*", *"transport*" and "*end of life*".



6.1. Interpretation of the result for Case en Milieu Humide

As per table 6 & Graphic 16 most of the *carbon emissions* for this shelter are from the *"production of the component materials*" followed by *"transport*", with *"end of life"* making the least contribution.

When looking into each of the materials, Graphic 17, steel poles and fabric are the ones that have the biggest emissions, followed by the screws and CGI (Corrugate Galvanised Iron sheets). As per Graphic 18 most of the emissions from the steel poles and fabric are from the "*production of the component materials*". *"Transport*" also adds substantial emissions from the steel poles.

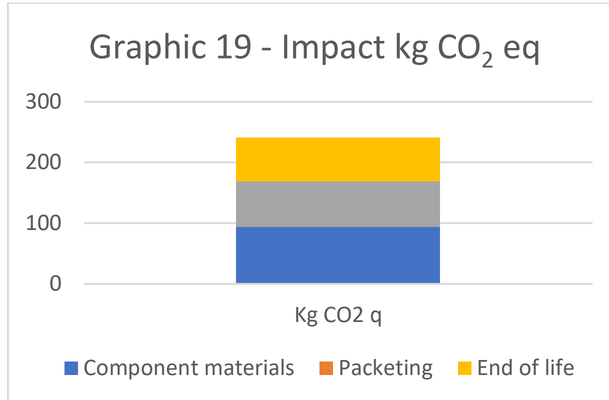
Regarding basswood timber, Graphic 18, it "captures carbon" during the *"production of the component materials".* However, this number is almost balanced out when considering what happens at the *"end of life"* of the materials, when "carbon captured" is released (Graphic 18).

7. DIFFA

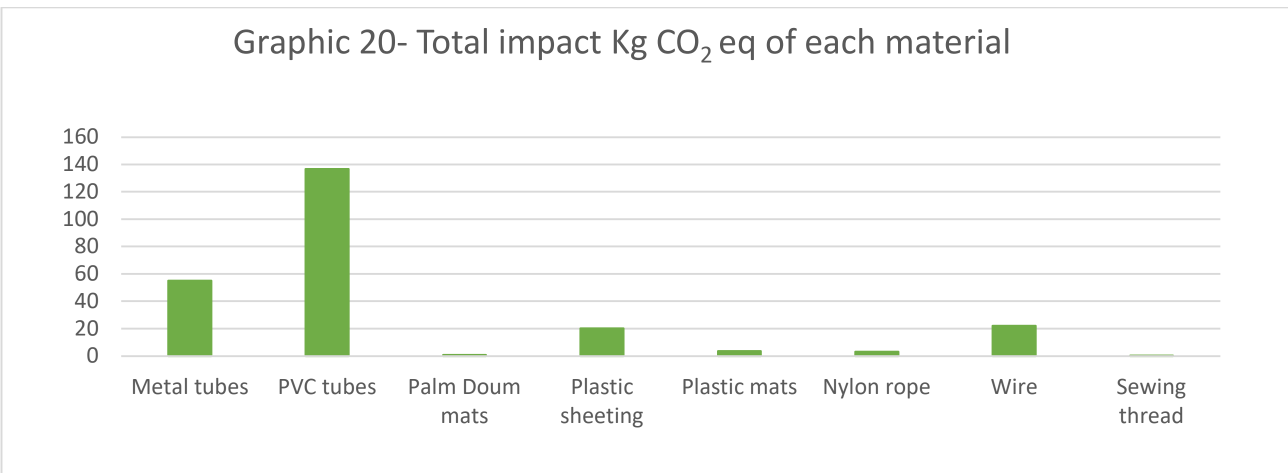
The follow Table 7 and Graphic 19 show the breakdown of the *carbon emissions* generated, in terms of Kg CO_2 eq. of the shelter unit per "*life-cycle stages*": *"production of the component materials"*, *"transport"* and *"end of life"*.

Table 7 – DIFFA

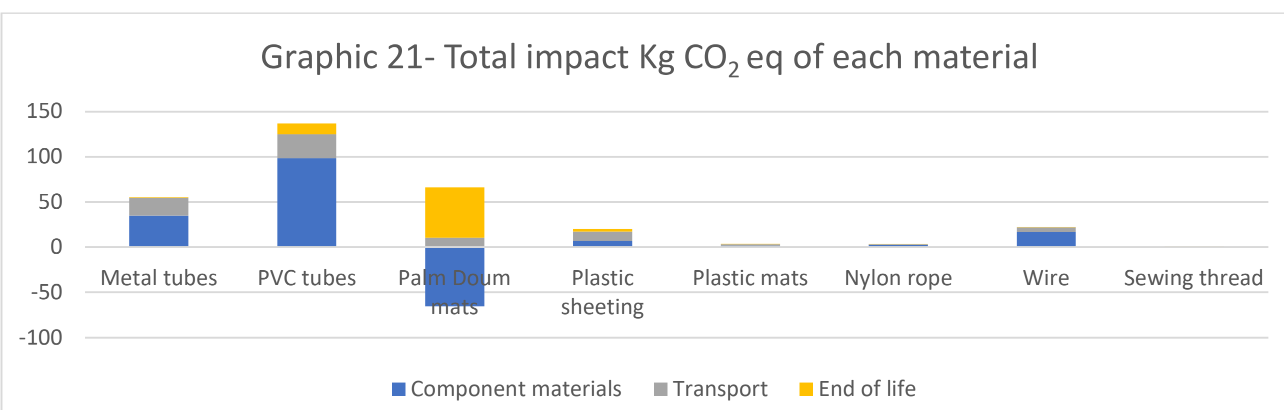
Impact	Carbon emissions Kg CO_2 eq
Production of the component materials	95
Packeting	*Data not available*
Transport	74
End of life	71
Total	**241**



The follow Graphic 20 shows the total Kg CO_2 eq. impact of each material.



The follow Graphic 21 shows the total Kg CO_2 eq. emissions of each material, broken down into the emissions generated by "*production of the component materials*", *"transport"* and "*end of life*".



7.1. Interpretation of the result for Diffa model

As per Table 7 and Graphic 19, 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 20) we can see that the PVC is the one that has the biggest impact followed by metal tubes.

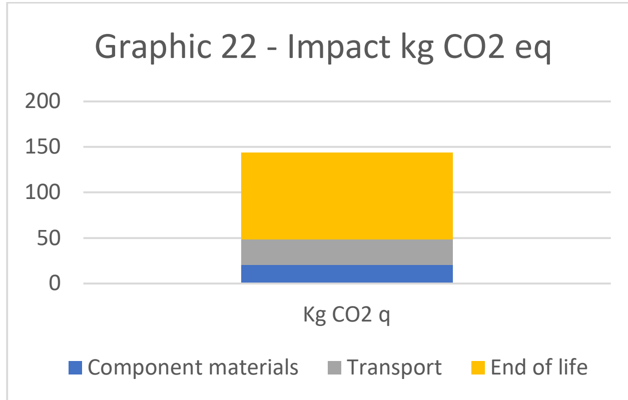
As per graphic 21, most of the emissions from the PVC come from the "*production of the component materials"* and *"transport".* However, when looking into the palm doum mats, the "*production of the component materials"* has the lowest impact. However, this captured carbon is released at the *"end of life"* (graphic 21), where palm doum mats have the biggest impact.

8. TILLABERI

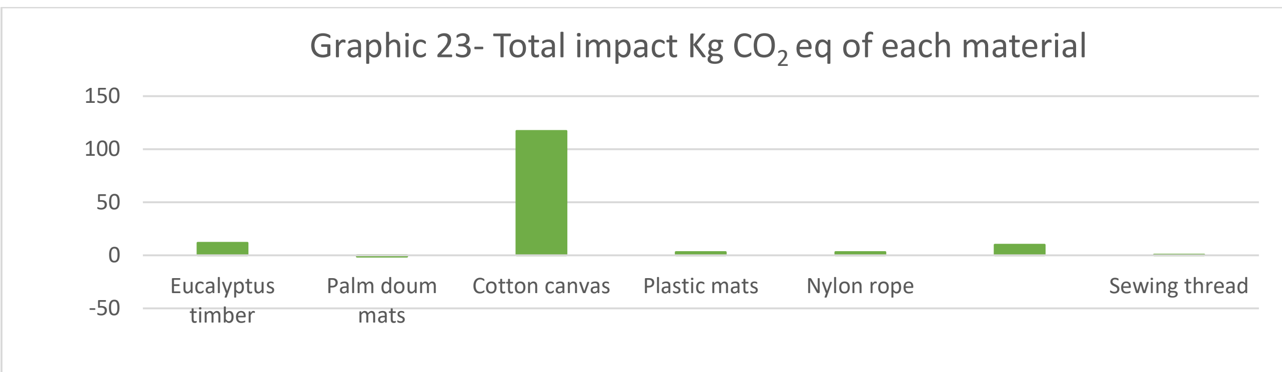
The follow Table 8 and Graphic 22 show the breakdown of the *carbon emissions* generated, in terms of Kg CO_2 eq. of the shelter unit per "*life-cycle stages*": "*production of the component materials*", "*transport*" and "*end of life*".

Table 8 - TILLABERI

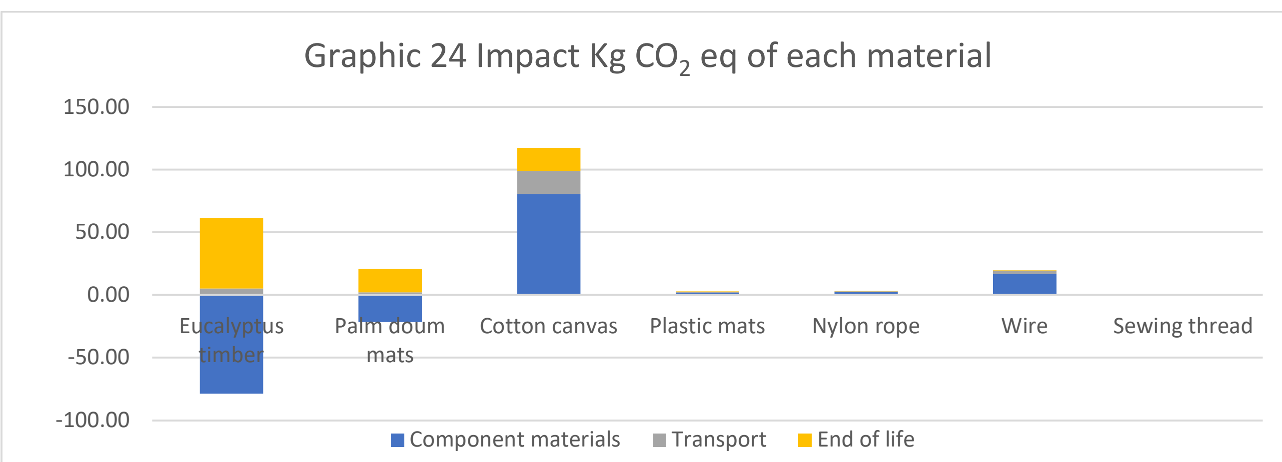
Impact	Carbon emissions Kg CO_2 eq
Production of the component materials	21
Packeting	*Data not available*
Transport	28
End of life	94
Total	**143**



The follow Graphic 23 shows the total Kg CO_2 eq. emissions of each material, broken down into the emissions generated by "*production of the component materials*", "*transport*" and "*end of life*".



The follow Graphic 24 shows the total Kg CO_2 eq. emissions of each material, broken down into the emissions generated by "*production of the component materials*", "*transport*" and "*end of life*".



8.1. Interpretation of the result for Tillaberi model

As per Table 8 and Graphic 22 the biggest impact on *carbon emissions* is due to the *"end-of-life",* followed by "*transport*". The *carbon emissions* generated by *"production of the 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 23), 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*s", followed by the "*transport*" (Graphic 24).

When looking into the eucalyptus timber and the palm doum mats, the "*production of the component materials*" has the lowest impacts (Graphic 24). However, this captured carbon is released at the *"end of life"* (Graphic 24), where, together with the cotton canvas, they have the biggest impact.

ANNEX 7 - *Local natural resources* used per shelter

Total amount of doum palm mats used in the models

- **"Sahel Shelter Type I"**: Around 63 kilos for the wall and roofing. *Only around 15% of the doum palm mats used in the models come from Burkina Faso. The rest come from Niger (around 45%) and Mali (around 40%)*
- **"Sahel Shelter Type II"**: Around 50 kilos for the wall and roofing. *Only around 15% of the doum palm mats used in the models come from Burkina Faso. The rest come from Niger (around 45%) and Mali (around 40%)*
- **"Sahel Shelter" model:** Around 109 kilos for the wall and roofing
- **"Moundou Shelter" model:** Around 67 kilos for the walls, roofing and rope.
- **"Case Végétale" model:** Around 69 kilos for the wall and roofing
- **"Diffa" model:** Around 60 kilos for the wall and roofing
- **"Tillaberi" model**: Around 20 kilos for the walls.

Total amount of date palm tree used in the shelter models

- **"Moundou Shelter" model**: Around 144 kilos for the structure.

Total amount of common reed used in the shelter models

- **"Moundou Shelter" model:** Around 403 kilos for the wall.

Total amount of eucalyptus timber used in the shelter models

- **"Case Végétale" model:** Around 188 kilos for the structure
- **"Tillaberi" model**: Around 61 kilos for the structure

ANNEX 8 - Protentional reuse option and recycling options

The tables below examine for each of the shelter materials their life expectancy, how long it takes for them to decompose and if they can be reused and recycled, based on potential in each country[158]. It is important to note that the rate of decomposition can depend upon disposal or landfill conditions.

Table 1 - Sahel Shelter Type I & Type II

Material	Life expectancy[159]	Time to decompose	Reuse	Recycling
Steel poles	*Information not provided*	200 to 500 years[160]	Yes	Yes
PVC	Minimum 1 years	450 years[161]	Yes	Yes
Plastic sheeting	1-2 years	500 to 1000 years	Yes	Yes
Plastic mats	1-2 years	500 to 1000 years	Yes	Yes
Nylon	More than 1 years	40 years[162]	Yes	Yes
Wire	2-3 years	200 to 500 years	Yes	Yes
Doum palm mats	1-2 years	Yes 100%	Yes	No

According to the field team, most of the materials are discarded once they are no longer used or reach an advanced state of deterioration. Including the palm doum mats.

Table 2 - Sahel Shelter model

Material	Life expectancy[163]	Time to decompose	Reuse	Recycling
Steel poles	1 year[164]	200 to 500 years[165]	Yes	Yes
PVC	1 years[166]	450 years[167]	Yes	Yes[168]
Plastic mats	6- 12 months[169]	500 to 1000 years	Yes	Yes
Plastic sheeting	1 year[170]	500 to 1000 years	Yes	Yes
Nylon	3 years	40 years[171]	Yes	Yes
Wire	2 years[172]	200 to 500 years	Yes	Yes
Doum palm mats	1 year[173]	Yes 100%	Yes	No

According to the field team, most of the materials are discarded once they are no longer used or reach an advanced state of deterioration (wire, doum palm mats, plastic sheeting, plastic mats), or used as firewood (doum palm mats) or directly burnt (plastic sheeting). Which contributes to air pollution.

158 *Based on the feedback from the few local private companies, start-up, association, "groupements d'intérêt économique" (GIE), etc, that specialises in ecological recycling and waste recovery in each of the countries. Refer to Annex 1 to see the list of people contacted.*
159 *Information provided by the field team through direct observation on the field.*
160 *How long does it take for metal to degrade - Riba Farré (ribafarre.com)*
161 *https://expandusceramicsquestions.com/qa/how-long-does-pvc-take-to-decompose.html*
162 https://www.dnr.sc.gov/up2u/decompose.html
163 *Information provided by the field team through direct observation on the field.*
164 *According to the field team; first damage (oxidations) appears from the 7th / 8th to12th months, depending on the quality of the rust inhibitor applied by the manufacture.*
165 *How long does it take for metal to degrade - Riba Farré (ribafarre.com)*
166 *According to the field team; under normal circumstances, if the beneficiary does not hang objects on the roof, the PVC can last up to 12 months before deforming. This also depends on the cladding, PVC tubes that are well installed last longer.*
167 *https://expandusceramicsquestions.com/qa/how-long-does-pvc-take-to-decompose.html*
168 *However, PVC products cannot easily be separated for recycling, which makes breaking vinyl products down into their original components nearly impossible.*
169 *According to the field team; it depends on the context and exposure to the sun. First damages can appear 3 months after the construction, if it has been exposed to the sun, and 12 if they have been protected from the it.*
170 *According to the field team; the time when the first damage appears vary, and it depends when the shelter was constructed. It happens faster during the dry season, where the shelter is exposed to strong winds and high temperature, that sometimes exceeds 45°C*
171 https://www.dnr.sc.gov/up2u/decompose.html
172 *This usually rusts*
173 *According to the field team; the mats can last 1 year or more, if they are sheltered from strong winds, rain and domestic animals. However, the first damage can appear during the raining season, if they are exposed to the water, so they start deteriorating.*

Table 3 - Moundou Shelter Model

Material	Life expectancy[174]	Time to decompose	Reuse	Recycling
Plastic mats	6- 12 months[175]	500 to 1000 years	Yes	Yes
Wire	2 years[176]	200 to 500 years	Yes	Yes
Nylon	3 years	40 years[177]	Yes	Yes
Doum palm mats and rope	1 year[178]	Yes 100%	Yes	No
Date palm stems	More than 5 years	Yes 100%	Yes	No
Common reed brunches[179]	6-12 months	Yes 100%	Yes	No
Basswood timber	4 years[180]	Yes 100%	Yes	No

According to the field team, most of the materials are discarded once they are no longer used or reach an advanced state of deterioration (wire, doum palm mats, plastic sheeting, plastic mats and doum palm rope), or used as firewood (date palm stems, doum palm mats, common reed branches and basswood timber) or directly burnt (plastic sheeting). Which contributes to air pollution.

Table 4 - Case Végétale Model

Material	Life expectancy[181]	Time to decompose	Reuse	Recycling
Steel poles	1-2 years	200 to 500 years[182]	Yes	Yes
Nylon fabric	1-2 years	30-40 years[183]	Yes	Yes
Plastic sheeting	1-2 years	500 to 1000 years	Yes	Yes
Eucalyptus wood	6 months -1 year	Yes 100%	Yes	No
Doum palm mats and rope	1 year	Yes 100%	Yes	No

According to the field team, most of the materials are discarded once they are no longer used or reach an advanced state of deterioration (plastic sheeting, , fabrics), used as firewood (eucalyptus timber) or directly burnt (palm doum mats and ropes). Such burning contributes to air pollution.

Table 5 - Case en Milieu Humide Model

Material	Life expectancy[184]	Time to decompose	Reuse	Recycling
Steel poles	1-2 years	200 to 500 years[185]	Yes	Yes
Nylon & cotton fabric	2-3 years	Over 100 years[186]	Yes	Yes
Plastic sheeting	1-2 years	500 to 1000 years	Yes	Yes
CGI	1 year	200 to 500 years	Yes	Yes
Screw	3-5 years	200 to 500 years[187]	No	Yes
Basswood timber	3-5 years	Yes 100%	Yes	No

According to the field team, most of the materials are discarded once they are no longer used or reach an advanced state of deterioration (plastic sheeting, CGI, screws, fabrics), used as firewood (basswood timber). Such burning contributes to air pollution.

174 *Information provided by the field team through direct observation on the field.*
175 *According to the field team; it depends on the context and exposure to the sun. First damages can appear 3 months after the construction, if it has been exposed to the sun, and 12 if they have been protected from the it.*
176 *This usually rusts*
177 https://www.dnr.sc.gov/up2u/decompose.html
178 *According to the field team; the mats can last 1 year or more, if they are sheltered from strong winds, rain and domestic animals. However, the first damage can appear during the raining season, if they are exposed to the water, so they start deteriorating.*
179 *According to the field team; common reeds brunches are vulnerable to termites and pets rubbing. Also, rain reduces their resistance to high winds.*
180 *According to the field team; basswood timber can be used for a long time if they are protected against termites. However, in the lake area in Chad termites are rare.*
181 *Information provided by the field team through direct observation on the field.*
182 *How long does it take for metal to degrade - Riba Farré (ribafarre.com)*
183 *How Long It Takes 50 Common Items to Decompose | Stacker*
184 *Information provided by the field team through direct observation on the field.*
185 *How long does it take for metal to degrade - Riba Farré (ribafarre.com)*
186 *How Long It Takes 50 Common Items to Decompose | Stacker*
187 *How long does it take for metal to degrade - Riba Farré (ribafarre.com)*

Table 6 – Diffa model

Material	Life expectancy[188]	Time to decompose	Reuse	Recycling
Steel pools	After 1 year[189]	200 to 500 years[190]	Yes	Yes
PVC[191]	2 years[192]	450 years	Yes	Yes[193]
Plastic sheeting	2 years	500 to 1000 years	Yes	Yes
Plastic mats	12 months	500 to 1000 years	Yes	Yes
Nylon	*Information not available*	40 years[194]	Yes	Yes
Wire	*Information not available*	200 to 500 years	Yes	Yes
Sewing thread	*Information not available*	3–4 months[195]	Yes	No[196]
Doum palm mats	12 months	Yes 100%	Yes	No

Table 7- Tillaberi model

Material	Life expectancy[197]	Time to decompose	Reuse	Recycling
Cotton Canvas	4 to 6 months	1 year[198]	Yes	Yes[199]
Plastic mats	12 months	500 to 1000 years	Yes	Yes
Nylon	*Information not available*	40 years[200]	Yes	Yes
Wire	*Information not available*	200 to 500 years	Yes	Yes
Sewing thread	*Information not available*	3–4 months[201]	Yes	No[202]
Eucalyptus[203] timber	3 months	Yes 100%	Yes	No
Doum palm mats	12 months	Yes 100%	Yes	No

188 *Information provided by the field team through direct observation on the field.*
189 *According to the file team, the steel beams start to oxidates after the winters, and never before one year from installation.*
190 How long does it take for metal to degrade - Riba Farré (ribafarre.com)
191 *https://expandusceramicsquestions.com/qa/how-long-does-pvc-take-to-decompose.html*
192 *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.*
193 *However, PVC products cannot easily be separated for recycling, which makes breaking vinyl products down into their original components nearly impossible.*
194 https://www.dnr.sc.gov/up2u/decompose.html
195 *https://www.dnr.sc.gov/up2u/decompose.html*
196 *In theory yes, as is cotton. However, in practice, it would be difficult to separate it from the fabric.*
197 *Information provided by the field team through direct observation on the field.*
198 *How Long it Takes 50 Common Items to Decompose | Stacker . However, in dry environments, it will probably take more to decompose naturally.*
199 *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.*
200 https://www.dnr.sc.gov/up2u/decompose.html
201 *https://www.dnr.sc.gov/up2u/decompose.html*
202 *In theory yes, as is cotton. However, in practice, it would be difficult to separate it from the fabric.*
203 *Thinking Sustainably*

The tables below examine the potential reuse and recycling options for each material, based on potential from different associations that specialise in ecological recycling and waste recovery in each country, and ideas shared by some of the interviewees.

Table 8 - Potential options in Burkina Faso – Sahel Shelter Type I & II

Material	Potential Reuse option[204]	Potential Recycling options[205]
Plastic sheeting	• To reuse for auxiliary construction (e.g.: roofing for showers or shelters, smaller sun shades, walling) • Interior floor mats, covering exterior cooking areas. • As lining for rainwater runoff collection, to be used for watering of community kitchen gardens and/or as drinking water for herds. • Privacy screens around latrine pits.	• Recyclable through the production of latrine slabs, paving stones, school tables and benches
Plastic mats	• To reuse for auxiliary construction (e.g.: roofing for showers or shelter) • Sleeping mats.	• Recyclable through the production of latrine slabs, paving stones, school tables and benches • Biofuel
PVC[206]	• To reuse for auxiliary construction • Handicrafts (earrings, home decorations/accessories, etc.) • Made into various functions; can be cut and glued together	• Ground into granules
Steel poles	• To reuse for auxiliary construction	• Made into various functions if welding is available. Like school tables and benches
Wire	• To reuse for auxiliary construction • Handicrafts (earrings, home decorations/accessories, etc.) • Used for various functions – can be used for attachments of reused mats, etc	• Made into various functions if welding is available.
Nylon[207]	• To reuse for auxiliary construction • Re-use as rope	• Input for making bags, baskets, satchels, etc.
Doum palm mats	• To reuse for auxiliary construction	• Green charcoal

204 *Information provided by the field team through direct field observations, and from the Global Shelter Cluster community of practice.*
205 *Based on potential from other neighbouring countries (Niger) or ideas shared by some of the interviewees*
206 *https://expandusceramicsquestions.com/qa/how-long-does-pvc-take-to-decompose.html*
207 *https://www.dnr.sc.gov/up2u/decompose.html*

Table 9 - Potential options in Chad – Sahel Shelter & Moundou Shelter

Material	Potential Reuse option[208]	Potential Recycling options[209]
Plastic sheeting	• To reuse for auxiliary construction (e.g.: roofing for showers or shelters, smaller sun shades, walling) • Interior floor mats, covering exterior cooking areas[210]. • As lining for rainwater runoff collection, to be used for watering of community kitchen gardens and/or as drinking water for herds. • Privacy screens around latrine pits[211].	• Production of latrine slabs, paving stones, racks and gutters
Plastic mats	• To reuse for auxiliary construction (ex; roofing for showers or shelter) • Sleeping mats.	• Recyclable through the production of latrine slabs, paving stones, racks and gutters
PVC[212]	• Handicrafts (earrings, home decorations/accessories, etc.) • Made into various functions; can be cut and glued together	• Crushing and export
Steel poles	• Information not provided	• Made into various functions if welding is available. Collect and take to N'Djamena for recycling. • Compacting and export
Wire	• Handicrafts (earrings, home decorations/accessories, etc.) • Used for various functions – can be used for attachments of reused mats, etc	• Collect and take to N'Djamena for recycling. • Compacting and export
Nylon[213]	• Re-use as rope	• Input for making bags, baskets, satchels, etc.
Doum palm mats	• They are not reused	• Not relevant
Date palm stems	• To reuse for auxiliary construction (construction of new shelters or latrines) • Combustible wood • Resell at the local market	• Information not provided
Common reed brunches	• Combustible wood	• Information not provided
Basswood timber	• Combustible wood • Resell at the market	• Information not provided
Doum palm rope	• They are not reused	• Not relevant

208 *Information provided by the field team through direct field observations, and from the Global Shelter Cluster community of practice.*
209 *Based on potential from other neighbouring countries (Niger) or ideas shared by some of the interviewees*
210 *IDP Shelter & Settlements. Environmental Impact Report. Shelter Cluster Chad. March 2021*
211 *IDP Shelter & Settlements. Environmental Impact Report. Shelter Cluster Chad. March 20211*
212 *https://expandusceramicsquestions.com/qa/how-long-does-pvc-take-to-decompose.html*
213 *https://www.dnr.sc.gov/up2u/decompose.html*

Table 10 - Potential options in Mali – Case végétal & Case en Milieu Humide Model

Material	Potential Reuse option[214]	Potential Recycling options[215]
Steel poles	• To reuse for auxiliary construction (e.g.: animal pens)	• Production of carts; wheelbarrows, keys, shovels; pickaxes; hoes; machetes, chair, etc
CGI	• To reuse for auxiliary construction (e.g.: animal pens) • Handicrafts (earrings, home decorations/accessories, etc.)	• Production of carts; wheelbarrows, keys, shovels; pickaxes; hoes; machetes, chair, etc
Plastic sheeting	• To reuse for auxiliary construction (e.g.: roofing for showers or shelters, smaller sun shades, walling) • Interior floor mats, covering exterior cooking areas[216]. • As lining for rainwater runoff collection, to be used for watering of community kitchen gardens and/or as drinking water for herds. • Privacy screens around latrine pits[217]. •	• Production of paving stones
Doum palm mats and rope	• They are not reused	• Organic fertiliser.
Eucalyptus timber	• To reuse for auxiliary construction • Combustible wood	• Art objects
Basswood timber	• To reuse for auxiliary construction • Combustible wood • Art objects	• Art objects
Screw	• They are not reused	• Production of carts; wheelbarrows, keys, shovels; pickaxes; hoes; machetes, chair, etc
Nylon Fabric	• Re-use as rope	• Production of paving stones • Input for making bags, baskets, satchels, etc.
Nylon and cotton fabric	• Re-use as rope	• Production of paving stones • Input for making bags, baskets, satchels, etc.

214 *Information provided by the field team through direct field observations, and from the Global Shelter Cluster community of practice.*
215 *Based on potential from other neighbouring countries (Niger) or ideas shared by some of the interviewees*
216 *Shelter & Settlements Environmental Impact Report_Shelter Cluster Chad February 2021*
217 *Shelter & Settlements Environmental Impact Report_Shelter Cluster Chad February 2021*

Table 11 - Potential options in Niger[218] - Diffa & Tillaberi

Material	Potential Reuse option	Potential Recycling options
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[219]	• 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[220]	• 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[221] 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

218 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.
219 https://expandusceramicsquestions.com/qa/how-long-does-pvc-take-to-decompose.html
220 https://www.dnr.sc.gov/up2u/decompose.html
221 Is Wood Biodegradable? Here Are The Facts - Thinking Sustainably