# REPORT
# DRC Environmental Impact Study of House Model "Maison Adobe Type Uvira"

November 2023

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].

**Decomposition** 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:** DRC Environmental Impact Study of House Model "Maison Adobe Type Uvira"

**Countries**: Democratic Republic of the Congo (DRC)

**Report date:** November 2023

**Type of operation:** Remote consultancy

**Requesting Organization**: International Aid of the Luxembourg Red Cross

# 3. Context

The Aide Internationale de la Croix-Rouge Luxembourgeoise (AICRL) has been working for several years in the field of emergency shelter and sustainable housing in Africa. It relies on its Shelter Research Unit (AICRL-SRU) to develop models of humanitarian architectural solutions tailored to the climatic conditions and cultural contexts of each region. Numerous research missions have led to the development of shelter models that take into account local specificities and the availability of materials. AICRL collaborates closely and in partnership with the different National Society in each country.

Since 2021, the Luxembourg Red Cross has conducted several studies to assess the environmental impact of emergency constructions in the various countries where it collaborates. To date, these studies have been carried out for their shelter model in Niger, Burkina Faso, Chad, and Mali[17]. The same methodology used in the previous studies will be applied to conduct this study. Additionally, the housing models in Burundi and Madagascar, will also be included in this ongoing research.

In the DRC, AICRL has been actively engaged since 2019. It is involved in several emergency reconstruction projects in collaboration with local partners, as well as risk reduction projects. In 2021 AICRL, in collaboration with the South Kivu branch of the Red Cross of the Democratic Republic of Congo (CRRDC), have identified an emergency project that involves providing emergency shelter support through the distribution of tarpaulins to 400 households and more durable housing solutions to 150 households affected by floods in the city of Uvira, located in the South Kivu province.

This durable housing solution, which is the focus of this study, is based on traditional local architecture and has a total area of 33.64 m$^2$. It is constructed using adobe bricks made by the families. The mortar is made of soil, and the coating is done with lime and cement. The roof has a dual slope covered with metal sheets and a structure made of eucalyptus wood. However, one key factor has not been analysed in detail: the environmental impact of the house 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.

Global warming has accelerated the change in weather patterns over the past century, leading to an increase in natural disasters like floods, droughts, desertification, and fires. These climate change-driven events contribute to food insecurity, economic losses, population displacements, and conflicts. Between 2000 and 2019, over 475,000 lives were lost worldwide due to extreme weather events, highlighting the urgent reality of climate change[18]. The 2021

17 *Each country report and a compilation report for the Sahel region are available in both English and French on the Global Shelter Cluster website, under. Environment Community of Practice - Documents | Shelter Cluster*
18 *Global Climate Risk Index 2021*

Climate Risk Index[19] indicates that no continent or region can ignore the escalating signs of climate change. Poor countries are hit hardest as they are vulnerable, have lower coping capacities, and require more time to recover[20].

Africa is already one of the continents most affected by climate change, even if is responsible for only 4 percentage of the world's greenhouse gas emissions. However it is disproportionately affected by its consequences, which have profound impacts on lives, livelihoods, and economies. DRC is the 4th most vulnerable country to the impacts of climate change, ranking 182th out of 185 countries classified on the Notre Dame Global Adaptation Index (ND-GAIN Index in 2021)[21]. Climate change is exacerbating the complex challenges and humanitarian crisis faced by the country, including a protracted civil war, weak governance, and deep-rooted poverty and inequality[22]. DRC’s major environmental challenges are floods and droughts, deforestation, the threat to wildlife from poaching, water, air and soil pollution, from the impacts of mining activities among other factors. Rising temperatures may extend dry periods, especially in the southern regions. Some of these environmental events will increase in frequency and severity due to climate change, droughts, frequent floods and deforestation will aggravate land degradation and soil erosion, and could result in reduced crop yields and worsen food insecurity.

The nation's future holds global significance due to its extensive Congo-basin rainforest, which plays a vital role in absorbing carbon and preserving biodiversity [23] .However the country has witnessed a dramatic increase in deforestation since 2010, resulting in the world's second-highest deforestation rate by 2020[24], only behind Brazil.

The country's recurring political instability and poverty will exacerbate these challenges, potentially escalating the violence and conflict[25]. Worsening the already delicate situation of population displacement. At the end of 2022, some 5.5 million people were displaced within the country, and over a million had crossed borders to seek asylum[26].

Therefore, humanitarian agencies adopting responsible environmental practices can help protect local ecosystems, strengthen community resilience to natural disasters, and reduce vulnerability while minimising further contributions to climate change. Historically, some humanitarian responses overlooked environmental impacts, leading to issues like importing excessive relief items, overexploiting local resources, and generating significant unmanaged waste. To avoid further degradation of the essential natural resources communities depend on, humanitarian agencies must actively work to mitigate climate change and adhere to a 'do no harm' approach regarding the environment. This study of the environment impact of DRC house model is a contribution to the growing body of work on the environmental impact of humanitarian assistance.

19 *The Climate Risk Index (CRI) is a tool used to assess and rank countries or regions based on their vulnerability to the impacts of climate change. Global Climate Risk Index 2021_1.pdf*

20 *Global Climate Risk Index 2021*

21 *The ND-GAIN, or the Notre Dame Global Adaptation Initiative, is a research project and index developed by the University of Notre Dame's Global Adaptation Initiative. It is designed to assess and rank countries' vulnerability to climate change and their readiness and ability to adapt to its impacts. ND-GAIN provides valuable data and insights to help policymakers, businesses, and organizations understand the climate risks faced by different countries and make informed decisions on adaptation strategies and investments. The index considers various factors, including environmental, social, and economic indicators, to evaluate a country's overall climate readiness and vulnerability. ND-GAIN aims to promote climate resilience and adaptation efforts worldwide by providing a comprehensive assessment of each country's preparedness. Rankings // Notre Dame Global Adaptation Initiative // University of Notre Dame (nd.edu)*

22 *Climate and Environmental Security in the Democratic Republic of Congo | DGAP*

23 *Congo Rainforest and Basin | Places | WWF (worldwildlife.org)*

24 *What Happened to Global Forests in 2020? | Global Forest Watch Blog*

25 *Climate Risk Profile: Congo, Democratic Republic (2021): The World Bank Group.*

26 *Democratic Republic of the Congo regional refugee response plan 2023 | Global Focus (unhcr.org)*


*Map showing the location of the "Maison adobe type Uvira" built in DRC, by AICRL in partnership with the DRC Red Cross*

# 4. Outcome and Outputs

**Outcome**
With the support of the SRU, AICRL seeks to improve the quality of the shelter response in DRC, and minimise the environmental impact of its operations.

**Outputs**
- A study of the environmental impact of the house model in DRC
- Recommendations to reduce the environmental impact of AICRL shelter interventions

**Caveat on scope of this study**
The scope of this study is limited to the environmental impact of the house model. It does not include aspects relating to the preparation 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 AICRL shelter projects.

# 5. Methodology

These studies were conducted remotely, with the support of AICRL field staff (shelter, logistics, other); environmental experts from the shelter sector, and different local associations, organisations, etc that specialise in ecological recycling and waste recovery in the region[27].

The methodology adopted is summarised by the graphic below. This follows the same approach as in the previous studies conducted for the Sahel shelter models in Niger, Burkina Faso, Chad, and Mali. Additionally, this research will extend to include the housing models in the Burundi and Madagascar, each detailed in a separate country report[28].

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

28 *Each country report and a compilation report for the Sahel region are available in both English and French on the Global Shelter Cluster website, under. Environment Community of Practice - Documents | Shelter Cluster*

**Desk research and problem definition**

- Literature review: programme documentation (including logistics/supply chain); environmental profile of DRC 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 the houess was considered, but was not seen as necessary after reviewing the documentation and interviewing the project teams.

**SMAC tool**

- Use the SMAC, the carbon footprint calculation tool for the shelter sector.
- 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) Local natural resource environmental impact
  - (4) Waste management
- Scorecard Approach

**Analysis**

- Evironmental impact of the house model according to the four criteria, analysing each material across its lifecycle from production to disposal.
- Overall (qualitative) comparison using a scorecard approach

**Report writing, conclusions and recommendations**

# 6. Background information

## 6.1. Region profile

## DRC

### Location

DRC is a country located in central sub-Saharan Africa. By land area, the DRC is the second largest country in Africa. It borders Angola and Zambia in the south, Tanzania, Burundi, Rwanda and Uganda in the east, Sudan and the Central African Republic in the north, the Republic of Congo (Congo-Brazzaville) in the west and the South Atlantic Ocean.

### Population

DRC, with a current population of approximately 90 million, experiences one of the world's highest population growth rates at 3.19 percentage. It is expected to exceed 100 million by 2024 and double its population by 2047[29].

### Economic and social situation

DRC 's Human Development Index[30] (HDI) score was 0.479 in 2021, which categorizes the country as having a low level of human development. It ranked 179th out of 191 countries[31]. It is among the five poorest nations in the world[32].

### Crisis overview

DRC is facing a multifaceted crisis characterised by political instability, ongoing armed conflicts in the eastern regions, economic difficulties, violence related to resource exploitation, and limited access to essential services[33]. This multifaceted situation is further exacerbated by a history of political unrest and disputed elections, resulting in frequent displacement of millions of people, (as of November 2022, some 5.5 million people were displaced within the country and over a million had crossed borders to seek asylum)[34], poor living conditions, and a fragile economy[35]. Additionally, DRC has faced health crises such as cholera, measles, and ebola outbreaks, while international interventions, including peacekeeping missions, seek to address the complex challenges facing the country[36].

### Climate

DRC has a tropical climate with heavy rain and high temperatures and humidity. The Equator runs just north of Liranga. In the north, it's dry from November to March and rainy from April to October, while in the south, it's the opposite. But both sides of the Equator have two dry and two wet seasons. There's a lot of rain throughout the year. Temperatures don't change much between seasons but vary between day and night, with about a 15 °C difference between highs and lows. In most of the country, the yearly average temperatures range from the high 25 °C to low 20°C. In the south, the Benguela Current can make it cooler, with temperatures as low as 10 °C. The humidity is usually around 80 percent[37].

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*29 Dr Congo Population 2023 (Live) (worldpopulationreview.com)*
*30 The Human Development Index (HDI) is a composite measure used to assess a country's overall human development, considering factors such as life expectancy, education, and per capita income. It is calculated and published by the United Nations Development Programme (UNDP)*
*31 Specific country data | Human Development Reports (undp.org)*
*32 Democratic Republic of Congo Overview: Development news, research, data | World Bank*
*33 Democratic Republic of Congo Overview: Development news, research, data | World Bank*
*34 Democratic Republic of the Congo: 2023 Regional Refugee Response Plan | Global Focus (unhcr.org)*
*35 Democratic Republic of Congo Overview: Development news, research, data | World Bank*
*36 Democratic Republic of Congo Overview: Development news, research, data | World Bank*
*37 Republic of the Congo - Tropical, Rainforest, Humid | Britannica*

## 6.2. DRC environmental challenges

# Environmental challenges

**Climate change**
The DRC is amongst the countries most vulnerable to climate change in the world, and is the fourth least ready country in the world to address its impacts. Ranking 182th out of 185 countries classified on the ND-GAIN Index in 2021[38]. Some of the climate change impacts are rising temperatures, changed rainfall patterns, and frequent extreme weather events, land degradation and soil erosion.

**Increasing Temperature**
Annual temperatures in DRC are projected to increase, between +1.7°C to +4.5°C by end of the century. This will lead to more frequent and extended heat waves. Rising temperatures may also prolong dry periods, particularly in the vulnerable southern regions. Notably, the higher temperatures and increased drought risk will have adverse effects on water storage capacity, potentially resulting in substantial economic losses, damage to agricultural areas and infrastructure[39].

**Floods**
In the DRC, the risk and severity of floods are expected to rise due to increase of heavy rainfall events. Mountainous regions, in particular, are at greater risk of mudslides and landslides. With intensified rainfall, there's also a heightened potential for soil erosion and waterlogging in fields, which could lead to reduced crop yields and exacerbate food insecurity[40].

**Deforestation**
Deforestation in the DRC has surged since 2010, making it the second-highest deforestation rate globally after Brazil in 2020[41]. Projections suggest that the country may lose 40 percentage of its forests by 2050, according to Greenpeace[42]. This is a major global concern, since DRCs forests represent one of the largest carbon sinks on the planet.

**Land degradation and soil erosion**
Land degradation and soil erosion, is exacerbated by deforestation and recurrent floods, adversely impact agricultural production, disproportionately affecting the livelihoods of the rural poor.

**Solid waste**
DRC faces solid waste management challenges due to limited collection services, inadequate disposal facilities, and a lack of recycling programs. This leads to littering, environmental pollution, and health risks.

**Water pollution**
Water pollution is a pressing issue in the DRC, posing substantial public health risks. The primary sources of this pollution stem from agricultural and mining activities, coupled with inadequate land and wastewater management[43].

38 *The ND-GAIN, or the Notre Dame Global Adaptation Initiative, is a research project and index developed by the University of Notre Dame's Global Adaptation Initiative. It is designed to assess and rank countries' vulnerability to climate change and their readiness and ability to adapt to its impacts. ND-GAIN provides valuable data and insights to help policymakers, businesses, and organizations understand the climate risks faced by different countries and make informed decisions on adaptation strategies and investments. The index considers various factors, including environmental, social, and economic indicators, to evaluate a country's overall climate readiness and vulnerability. ND-GAIN aims to promote climate resilience and adaptation efforts worldwide by providing a comprehensive assessment of each country's preparedness. Rankings // Notre Dame Global Adaptation Initiative // University of Notre Dame (nd.edu)*
39 *Climate Risk Profile: Congo, Democratic Republic (2021): The World Bank Group.*
40 *Climate Risk Profile: Congo, Democratic Republic (2021): The World Bank Group.*
41 *What Happened to Global Forests in 2020? | Global Forest Watch Blog*
42 *Forest / Democratic Republic of the Congo | Interactive Country Fiches (unepgrid.ch)*
43 *Pollution / Democratic Republic of the Congo | Interactive Country Fiches (unepgrid.ch)*

**Air Pollution**
In DRC, outdoor $PM_{2.5}$ levels often exceed the World Health Organization's Air Quality Guideline, particularly in urban areas like the city of Kinshasa, where over 11 million people reside. Additionally, a significant portion of the DRC's population faces frequent exposure to harmful indoor air pollution because over 90 percentage of the population relies on wood biomass for cooking. This dual challenge of outdoor and indoor air pollution contributes to an estimated 32,000 annual deaths in the DRC[44].

## 6.3. House model

For further technical details of the house model refer to Annex 2.

### MAISON ADOBE TYPE UVIRA

The "Maison Adobe type Uvira" is designed as a sustainable housing solution, with the assistance of the Sud-Kivu branch of the Red Cross of the Democratic Republic of Congo (CRRDC). 150 houses have been built from 2022, in the city of Uvira, located in the Sud-Kivu province.

This model has a total area of 33.64 m$^2$ and is constructed using adobe bricks made by the families. The mortar is made of soil, and the coating is done with lime and cement. The roof has a dual slope covered with sheet metal and a structure made of eucalyptus wood. The foundation consists of a continuous strip footing with a rubble stone base bonded with cement mortar, and a base made of rubble stone.

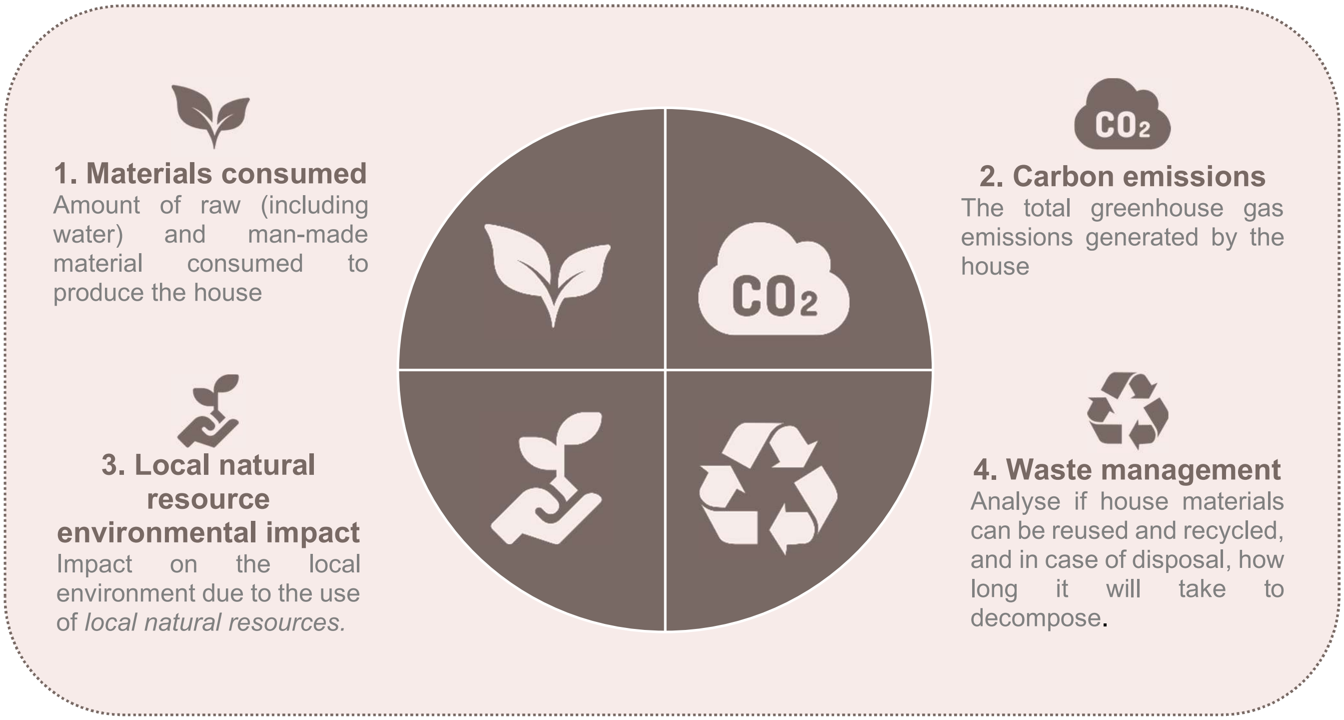
44 *Pollution / Democratic Republic of the Congo | Interactive Country Fiches (unepgrid.ch)*

# 7. Criteria used to analyse environmental impact

To do a comparative study of the environmental impact of the house model, 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. *Environmental effects of local natural resource use*
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 house. It does not reflect the materials / resources used for the preparation, and maintenance of the sites where the houses 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 for all the materials used to build a house. To calculate the embody water in litres, the UNHCR shelter and sustainability tool baseline[45] have been used.

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.

45 *UNHCR-TSS (epfl.ch)*

## 7.2. Criteria 2: *Carbon emissions*

Greenhouse gas emissions (GHS emissions), commonly called carbon emissions (they are measured as $CO_2$ equivalent) 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 percentage in less than 200 years[46]. 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[47] generated by the houses, and identify solutions to reduce these emissions. To do so, it is required to do a life cycle analysis (LCA)[48].

### Carbon calculator tool – SMAC tool

The carbon calculator tool used in the study is the SMAC[49] (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 four 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"*[50]

### 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 house components and materials
- The amount of each material used (in kg) for each house[51]
- The type of packaging used for the materials[52] and the amount of each packaging material used (in kg) for each house.

46 *NASA*
47 *A carbon footprint is the total greenhouse gas emissions caused by an individual, event, organization, service, place or product, expressed as carbon dioxide equivalent ($CO_2$ equivalent).*
48 *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.*
49 *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.*
50 *SMAC uses assumptions about the level of recycling and $CO_2$ equivalent. 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 $CO_2$ equivalent. calculation, according to the SMAC developers. This means that the carbon emissions calculated from 'end of life' are probably underestimated.*
51 *Refer to Annex 3 to find the information regarding house material and quantity in kilograms.*
52 *Refer to Annex 3 to find the information regarding house 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.*

- 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)[53].

For this models the data on packaging was not available, therefore this source of emissions has been excluded from the study.

**Limitations of the SMAC carbon calculator tool**

One of the limitations of the SMAC relates to the types of materials included in the database[54] 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. 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: *Local natural resource environmental impact*

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, extraction 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 soil to make adobe bricks for a single house might not pose an environmental concern. However, producing 300,000 bricks to construct 150 houses could place significant stress on the local ecosystem and potentially cause major issues in the area.

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

A few environmental organisations that specialise in the protection of forests and ecosystems in the DRC were contacted for this study, but without success[55]. Literature review[56] and feedback from the project team 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.

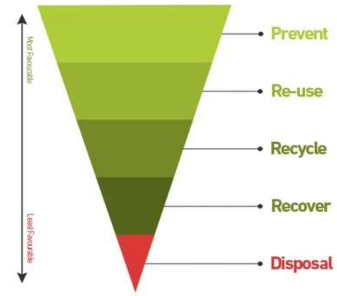
This section studies if the life cycle of the house materials can be prolonged by reusing and recycling, and in case of disposal, how long they will take to decompose.

53 *The average transport distances have been estimated and can be found in Annex 4.*
54 *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.*
55 *Refer to Annex 1 to see the list of people contacted.*
56 *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[57]. 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.




Local private companies that specialise in ecological recycling and waste recovery in the country were attempted to be contacted without success, to enquire about *waste management*[58]. Literature review[59], feedback from a specialist in agroecology[60], the project teams and environmental experts from the shelter sector[61] have been considered for this analysis.

## 7.5. Scorecard approach

A simple "scorecard approach" is used to compare the house model 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.

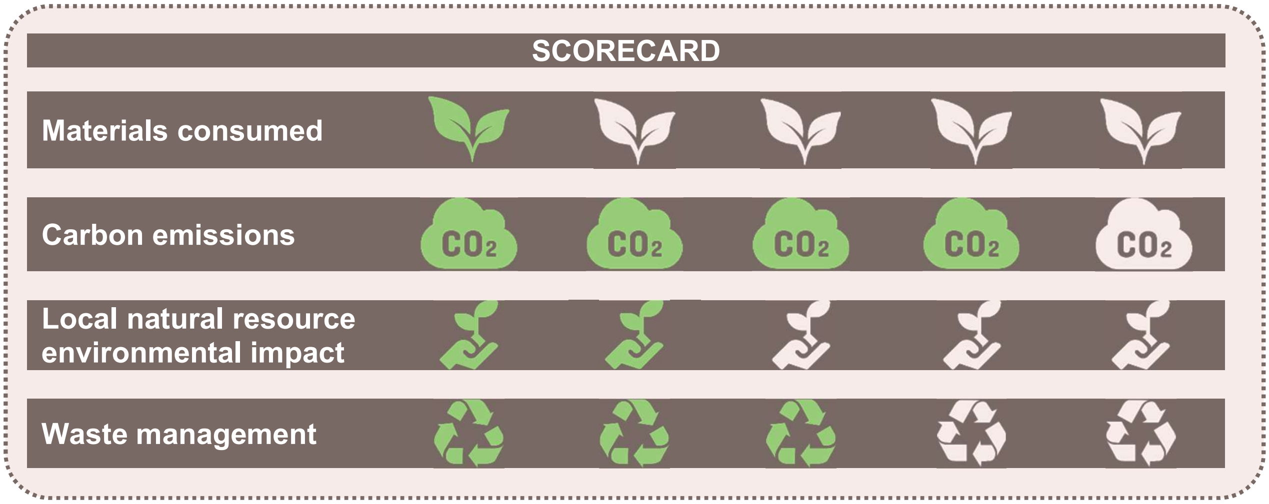
A simple scorecard also recognises the challenge to apply any kind of numerical weighting for the four criteria in order to arrive at a calculated score per house. This would require too many assumptions on the relative weight of each criterion. Instead, a qualitative conclusion can be made based on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

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 scorecard highlights in a simple way what the main environmental issues are for each house, thus identifying where mitigating solutions could help to improve the overall environmental impact of the house model.

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

57 *EU Commission, 2014*
58 *Refer to Annex 1 to see the list of people contacted*
59 *Refer to biography*
60 *Refer to Annex 1 to see the list of people contacted*
61 *Refer to Annex 1 to see the list of people contacted*

An example of the scorecard (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 house model

## 8.1. Criteria 1: *Materials consumed*

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

**RAW MATERIALS**

**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**[62]

**Carbon sequestration:** It is a sustainable material because of the carbon sequestration and helps to offset carbon when use to make any products made with Eucalyptus.

**Soil erosion:** Unsustainable or inappropriate forest timber extraction can cause forest destruction, soil erosion, landslides, land degradation, habitat destruction, and can increase flood risk. When is grown as a short rotation crop for high biomass production and removal, soil nutrients are exhausted rapidly.

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

**Pollution;** Due to the use of fertilizers, weedicides and pesticides, and fire hazards. Additionally, transporting of woods/logs can damage forests and rural roads.

**Soil** is a natural resource resulting from rock weathering and organic matter decomposition over time, comprising minerals, organics, water, air, and microorganisms. It's crucial for plant growth, supporting agriculture, forestry, and ecosystem functions. Soil can be used to make bricks, and the specific type of soil used for this purpose is often referred to as "brick clay" or "brick earth”. Adobe bricks are made from a mixture of clay-rich soil, sand, straw, and sometimes other organic materials.

**General environmental impacts**

**Soil extraction** may cause natural habitat destruction, pollutes water bodies, creates ponds where disease vectors can breed, alters local hydrological regime, and may cause soil erosion[63].

**Rubble** consists of large stones mined from rivers, quarries or open-pit mines, often used in construction, landscaping, and architecture. Available in various types, sizes, and colours, these stones vary based on the geological traits of their quarrying location.

**General environmental impacts**

62 *Silviculture of eucalyptus plantings – Learning in the region. K.J. WHITE. FAO*
63 *Hettiarachchi M., Dwivedi V., Miller W.M, Carr S.H, Dunn J.B., McMahon M.M and Van Breda A. Building Material Selection and Use: An Environmental Guide, 2nd Ed. World Wildlife Fund, Washington DC and Northwestern University, Evanston IL.*

**Quarried material extraction** can lead to habitat and farmland loss, water pollution, and the creation of disease-vector breeding ponds, while also changing local hydrology and causing soil erosion. This erosion then alters riverbeds and banks, making them steeper and changing their shape, leading to riverbank collapse, land or structure loss, and changes in sediment patterns, damaging river habitats[64].

## Gravel

**Gravel** is a loose, coarse collection of rock fragments that vary in size, used in construction for concrete, roads, drainage, and landscaping. Size and composition depend on the application.

### General environmental impacts[65]

**Quarried material extraction** may cause natural habitat and farmland destruction, it pollutes water bodies, creates ponds where disease vectors can breed, alters local hydrological regime, and may cause soil erosion.

## Sand

**Sand** consists of tiny granules of various rocks and minerals, including quartz, feldspar, and mica, resulting from natural weathering processes. It is one of the most abundant resources on Earth.

### General environmental impacts[66]

**Quarried material extraction** may cause natural habitat and farmland destruction, it pollutes water bodies, creates ponds where disease vectors can breed, alters local hydrological regime, and may cause soil erosion.

## Water

**Water** covers 70 percentage of our planet, however, only 3 percentage is fresh water[67]. with billions lacking access. Water is crucial for sustainable development, socio-economic progress, healthy ecosystems, and human survival[68].

### Environmental impacts

**Water shortage;** Water shortages are likely to be the key environmental challenge of this century[69]. 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 percentage of the world's accessible freshwater, and wastes 60 percentage of it, much of that through inefficiencies due to leaky irrigation systems, inefficient application methods as well as the cultivation of crops[70].

**Water pollution;** comes from many sources including pesticides and fertilizers that wash away from farms, untreated human wastewater, and industrial waste[71].

**Climate change;** is altering patterns of weather and water around the world, causing shortages and droughts in some areas and floods in others[72].

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64 *Hettiarachchi M., Dwivedi V., Miller W.M, Carr S.H, Dunn J.B., McMahon M.M and Van Breda A. Building Material Selection and Use: An Environmental Guide, 2nd Ed. World Wildlife Fund, Washington DC and Northwestern University, Evanston IL.*
65 *Hettiarachchi M., Dwivedi V., Miller W.M, Carr S.H, Dunn J.B., McMahon M.M and Van Breda A. Building Material Selection and Use: An Environmental Guide, 2nd Ed. World Wildlife Fund, Washington DC and Northwestern University, Evanston IL.*
66 *Hettiarachchi M., Dwivedi V., Miller W.M, Carr S.H, Dunn J.B., McMahon M.M and Van Breda A. Building Material Selection and Use: An Environmental Guide, 2nd Ed. World Wildlife Fund, Washington DC and Northwestern University, Evanston IL.*
67 *WWF*
68 *www.un.org/waterforlifedecade*
69 *www.un.org/waterforlifedecade*
70 *NASA*
71 *University of Dundee*
72 *WWF*

## MAN MADE MATERIALS

**Cement** is a binding material used in construction to bond and harden other materials, such as sand and gravel, to create mortar or concrete. It plays a crucial role in building structures. Concrete is the most widely used material in existence and is behind only water as the planet's most-consumed resource. Cement is manufactured using limestone and other minerals extracted from quarries or mines.

### General environmental impacts[73]

**Greenhouse effect:** It accounts for about 5 percentage of global $CO_2$ emissions due to its large-scale energy intensive production[74].

**Pollution:** Cement production is energy-intensive, leading to carbon emissions and severe air pollution, including dust. The process generates waste that poses respiratory and pollution health risks, while transportation of cement contributes to noise pollution and road damage in rural areas.

**Extractions** Uses limestone and other minerals extracted from quarries or mines in manufacturing, which can cause severe mining impacts.

**Steel** is an alloy (a metal combined with two or more metallic elements) made up of iron and a percent of carbon. 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.[75]

### General environmental impacts[76]

**Energy consuming;** Production of steel is the most energy consuming industrial process 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.[77] It accounts for about 7-9 percentage of global $CO_2$ emissions.

**Lime** is a mineral composed primarily of calcium oxides and hydroxides, and it has been a fundamental component of construction and engineering materials for centuries. Lime-based materials continue to be used extensively in construction and engineering applications, including the production of limestone products, cement, concrete, and mortar. Local lime exists in areas such as North Kivu.

### General environmental impacts

Its **overall** environmental impact is much lower than that of cement. Furthermore, the production of lime can be significantly improved through the use of specific kilns and control over the amount of water used after its burning.[78]

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73 *Hettiarachchi M., Dwivedi V., Miller W.M, Carr S.H, Dunn J.B., McMahon M.M and Van Breda A. Building Material Selection and Use: An Environmental Guide, 2nd Ed. World Wildlife Fund, Washington DC and Northwestern University, Evanston IL.*
74 *Shelter and sustainability overview-UNHCR.pdf*
75 *The world counts*
76 *The world counts*
77 *The world counts*
78 *17514_fiche_reponse_rdc.pdf (sheltercluster.s3.eu-central-1.amazonaws.com)*

**Greenhouse effect:** Lime used in construction doesn't emit carbon dioxide itself. Nevertheless, the production of quicklime does release $CO_2$ into the atmosphere, though it results in fewer greenhouse gas emissions per unit weight when compared to the production of Portland cement.[79]

**Energy Intensive Productions:** The productions of binders from limestone requires considerable energy input. [80]

**Extractions** Uses limestone and other minerals extracted from quarries or mines in manufacturing, which can cause severe mining impacts.

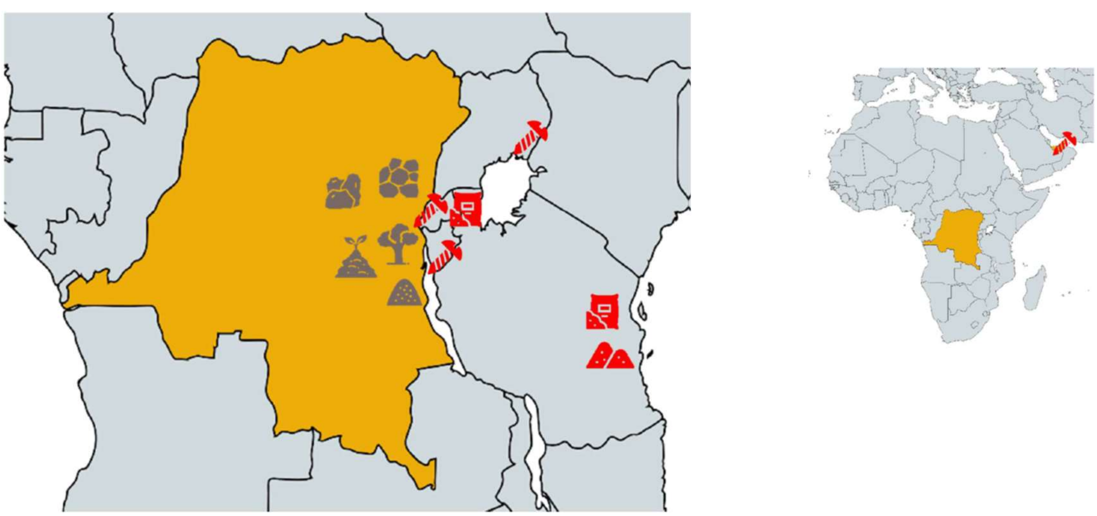
### 8.1.2. Data and analysis of the materials in the house

Table 1 below shows a simplified representation of the quantities of each material used in the house. It offers a comparative view of the consumption of each material, rated on a scale from 1 to 10. In this assignment, the material used in the maximum quantity (water) is scored at 10 points, while the material used in the least quantity (eucalyptus tree) receives a score of 1 point. Scores for other materials are assigned relative to these maximum and minimum values, indicating their usage in the construction. For a detailed breakdown of the actual weights of materials used, please refer to Annex 5.

79 *The Environmental Benefits Of Using Lime Mortar (theyorkshirelime.company)*
80 *The Environmental Benefits Of Using Lime Mortar (theyorkshirelime.company)*

**Table 1 - Amount of materials used by the house model**

| House model | *Materials* | Amount |
|---|---|---|
| Maison adobe type Uvira | Water |  |
| | Timber |  |
| | Soil |  |
| | Rubble |  |
| | Gravel |  |
| | Sand |  |
| | Cement |  |
| | Lime |  |
| | Steel |  |



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

### 8.1.3. Scorecard for *materials consumed*

**Scorecard *materials consumed***

**MAISON ADOBE TYPE UVIRA**

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

The house model scored 4 out of 5, with its positive rating primarily attributed to the extensive use of locally available raw materials and the limited reliance on synthetic materials. However, it's important to note that the materials used in the house result in a relatively high amount of embodied water. This score is based on the quantity of materials used and does not consider whether the extraction of these local raw materials has any adverse environmental effects, which would fall under Criteria 3.

In terms of the materials used, aside from water, soil and rubble are the most significant in quantity, and both are considered sustainable and environmentally friendly building materials. The soil is used to make the adobe bricks and mortar, and they are eco-friendly because they are composed of natural materials like soil, sand, straw, and water. Similarly, rubble is a sustainable choice for construction as it is locally sourced.

Even though the house model uses a small quantity of materials like cement and steel compared to soil and stones, it's crucial to minimise their environmental impact. This can be achieved by considering sustainable alternatives, such as using recycled or low-impact materials like local plant-based roofing, such as “makongo” leaves, optimising construction techniques to reduce material usage. Also being aware that steel has a high level of embodied water per kilogram compared to the other materials used.

## How to improve the *materials consumed* score

Consider using recycled or low-impact materials instead of CGI or using other alternative materials, such as a green roof made of plants, such as such as makongo leaves. If this option is chosen, other considerations must also be taken into account, such the impact of local environment of harvesting the natural material.

Making sure the amount of cement is kept to a minimum without compromising the house.

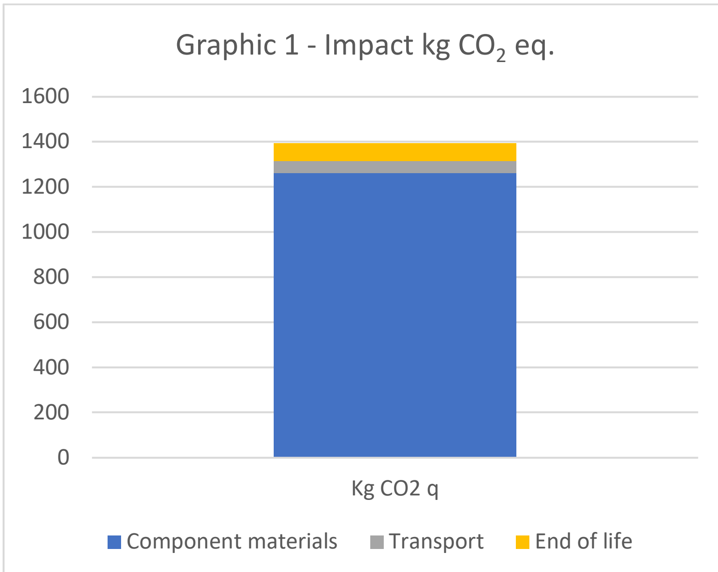
Ensure that the quantity of adobe brick and stones used is minimised without affecting the structural integrity of the house.

## 8.2. Criteria 2: *Carbon emissions*

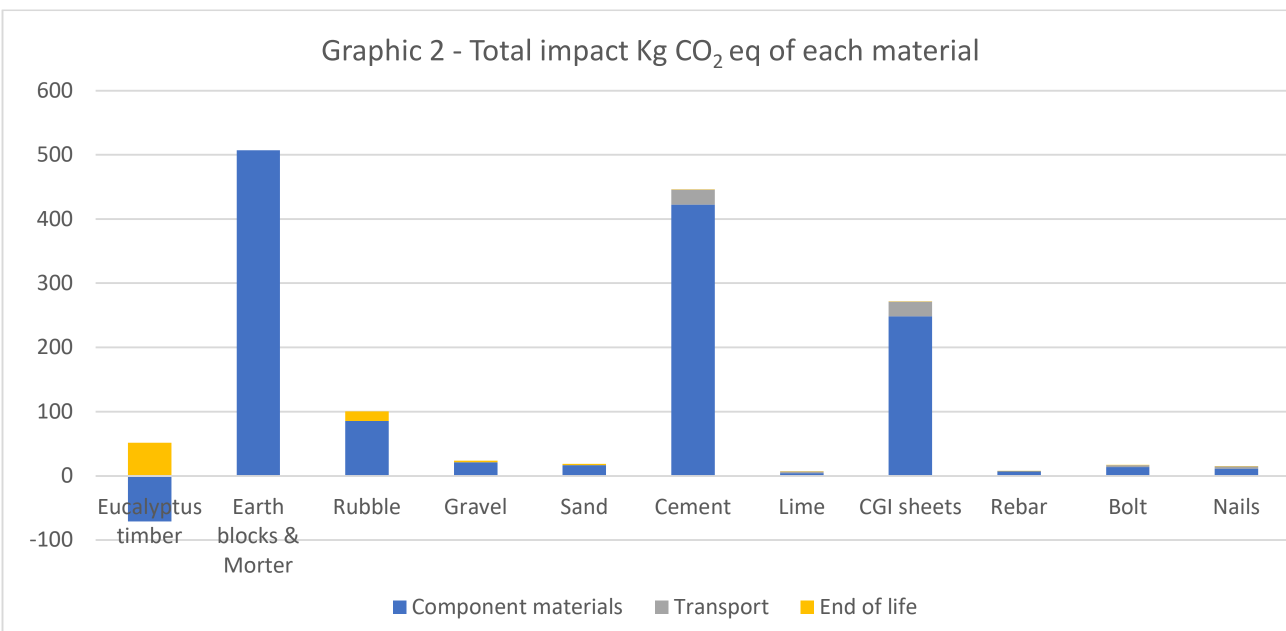
### 8.2.1. *Carbon emissions* of the house model

Below are the total *carbon emissions* generated by the house model, 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 for the house.

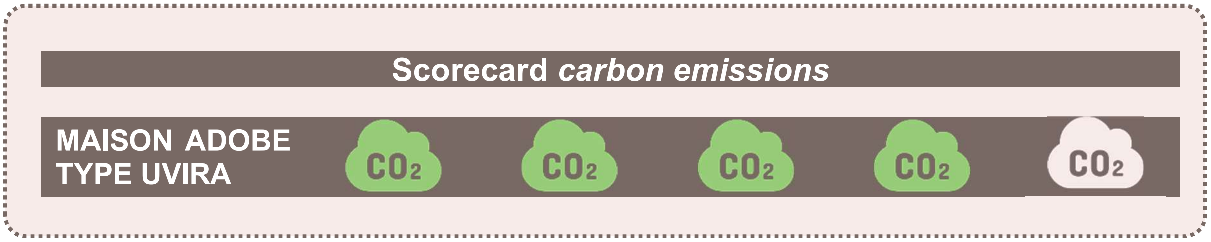
The following Graphic 1 show the breakdown of the *carbon emissions*.




The following Graphic 2 show the breakdown of the *carbon emissions* of each material



### 8.2.2. Scorecard 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 house *carbon emissions* calculations.

The house model scored 4 out of 5. In this case, carbon emissions at the *"component material*" phase are significant compared to the *“end of life”* and *“transport”* phases, primarily due to the extensive use of adobe bricks. While the embodied carbon emissions of adobe brick is very low, the high quantity used results in a significantly higher overall impact. Nevertheless, choosing adobe bricks is still a favourable option; using alternative materials such as Compressed Earth Block (CEB)[81] or clay bricks would have led to substantially higher embodied carbon emissions.[82] Additionally, cement and CGI sheets contribute significantly to emissions, even though the total material quantity used is relatively small, as their embodied carbon emissions are higher, especially for steel.

The *“end of life*” and *“transport”* phases do not generate a substantial amount of emissions. Regarding *“transport”,* even though a few materials are not purchased locally and come from neighbouring countries, the distances involved are relatively short, and the amount of material is not very high, minimising their environmental impact. The materials that generate the most carbon emissions in this phase are cement and CGI sheets, primarily due to the quantity of these materials compared to others. The only material that comes from further away are the bolts, sourced from Dubai, but their impact is not very significant due to the very small quantity used.

When considering the *“end of life”* phase, eucalyptus wood is the material that produces the most emissions. This is because the SMAC tool assumes that natural materials like wood are burned at the end of their useful life, which is reportedly the case here, resulting in relatively high $CO_2$ equivalent emissions released into the air. However, if these materials were disposed, such as in an open field, or composted, the carbon emissions at the "end of life" phase could be reduced to zero, leading to a lower overall carbon footprint.

81 *Compressed earth blocks are a type of building material made by compressing a mixture of raw earth and a stabilizing agent like cement or lime*
82 *Guide de Reference ABRIS-ANA Burundi. 2019. Croix-Rouge luxembourgeoise*

## How to improve the *carbon emissions* score

Consider the possibility of using recycled or low-impact materials as an alternative to CGI, given its high embodied carbon per kilogram.

Make sure the amount of cement is kept to a minimum without compromising the house. Cement is a material with a high embodied carbon.

Ensure that the use of adobe is optimised, keeping quantities to a minimum without compromising the structural integrity of the house.

Continue sourcing materials locally as much as possible to minimise transport-related emissions.

## 8.3. Criteria 3: *Local natural resource environmental impact*

### 8.3.1. Overview of the *local natural resource environmental impact*

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.

The DRC's forests are part of the greater Congo Basin, which makes up 18 percentage of the world's tropical forests. The second-largest tropical rainforest area in the world, covering 59 percentage of its territory and storing 8 percentage of global forest carbon. These forests play a crucial role as a source of products (timber, charcoal, palm oil), habitat for wildlife, and providers of essential ecosystem services like carbon sequestration, erosion control, and water regulation[83].

However, deforestation in the DRC has been on the rise since 2010, experiencing a considerable increase. By 2020, the DRC ranked second in terms of the highest deforestation rate, only after Brazil[84]. The main drivers of deforestation and forest degradation in the country are subsistence agriculture (the agricultural sector contributes 40 percentage to the national GDP, provides employment for 70 percentage of the country's population, and serves as the main income source for most people)[85], fuelwood production (around 95 percentage of the country's energy needs are currently met by biomass sources), logging (a significant and expanding portion of the Congo Basin is allocated for logging and mining operations by various companies)[86], as well as road and urban infrastructure[87]. Greenhouses gas emission from deforestation and forest degradation are the main source of emissions in the country[88].

Additionally, deforestation within the Congo Basin has been linked to climate change impacts: a potential drying over the basin, as well as changes in precipitation over the Sahel, Ethiopian highlands and Guinean coast. Poverty is also a contributing factor to deforestation in the DRC. There is a growing issue of unsustainable activities within the country's protected areas, including hunting, palm wine production, snail hunting, and the harvesting of traditional medicinal plants by healers[89].

Moreover, deforestation exacerbates global climate change by releasing carbon dioxide into the atmosphere. Forests act as carbon sinks, and their destruction contributes to greenhouse gas emissions, further intensifying climate-related challenges such as irregular rainfall patterns and extreme weather events.

In addition to deforestation, the extraction of materials like soil, sand, or gravel for construction purposes can have detrimental effects on the environment. It may contribute to soil erosion, disrupt local ecosystems, and negatively impact agricultural productivity, exacerbating existing problems. To address these concerns, it's crucial to implement sustainable sourcing practices that minimise adverse environmental impacts.

Given the severe consequences of deforestation and land degradation in DRC, there are several government initiatives and policies in place to address these challenges. However, the effective implementation of these measures remains highly challenging[90]. Therefore, to mitigate deforestation and its impacted, the use of local natural resources in construction needs to be carefully analysed, ensuring that it does not contribute to the worsening of the situation.

83 *Climate Risk Profile: Congo, Democratic Republic (2021): The World Bank Group.*
84 *Climate Risk Profile: Congo, Democratic Republic (2021): The World Bank Group.*
85 *https://www.climatelinks.org/resources/climate-risk-profile-democratic-republic-congo*
86 *Congo Rainforest and Basin | Places | WWF (worldwildlife.org)*
87 *https://dicf.unepgrid.ch/democratic-republic-congo/forest#section-pressures*
88 *Climate Risk Profile: Congo, Democratic Republic (2021): The World Bank Group.*
89 *https://dicf.unepgrid.ch/democratic-republic-congo/forest#section-pressures*
90 *https://dicf.unepgrid.ch/democratic-republic-congo/forest#section-pressures*

In the context of climate change and pressure on *local natural resources*, it is important to analyse whether the house model contributes 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.

Attempts to contact local environmental organisations in the country were unsuccessful[91].

## 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[92] 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[93].

### Environmental issues[94]

- 30 percentage of global tree species are threatened with extinction. And over the past 300 years, the global forest area has decreased by about 40 percentage.
- 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 percentage of global emissions come from the land sector. About half of these come from deforestation and forest degradation.
- In DRC Greenhouse Gas Emissions resulting from deforestation and forest degradation are the primary contributors to emissions in the country[95].
- The DRC ranks among the top ten countries worldwide in terms of forest loss, with an estimated deforestation rate exceeding 350,000 hectares per year (0.3 percentage) from 2000 to 2010.
- By 2020, the DRC ranked second in terms of the highest deforestation rate, only after Brazil[96].

#### 8.3.2. Overview of the local natural resources used in the house model

While most of the entries below highlight the potential negative environmental impacts associated with using local natural resources, it is crucial to note that these impacts largely depend on the scale or quantity used. When used in small quantities, the environmental repercussions might be minimal and more manageable to mitigate. However, as the quantity or scale increases, the negative impacts can intensify, becoming less easy to mitigate or absorb by local ecosystems.

91 *Refer to Annex 1 to see the list of people contacted.*
92 *Forests and climate change. IUCN*
93 *Forests and climate change. IUCN*
94 *State of the World's Trees. Sept 2021. Botanic Gardens Conservation International*
95 *Climate Risk Profile: Congo, Democratic Republic (2021): The World Bank Group.*
96 *Climate Risk Profile: Congo, Democratic Republic (2021): The World Bank Group.*

**Eucalyptus timber** is used in the house model as the structure for the roofing.
In DRC, eucalyptus is a species that is cultivated quite extensively in the eastern part of the country. Its potential for rapid exploitation as wood for construction is highly profitable. This tree has been planted extensively and it has been proven to be a threat in terms of soil conservation, and its durability is not always very good without treatment[97].

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[98]. The use of eucalyptus wood in DRC can lead to environmental concerns including deforestation, habitat loss, and biodiversity reduction. Eucalyptus trees consume large amounts of water, affecting local water availability and soil nutrients. If not native, they might displace local plant species, impacting biodiversity negatively. The demand for eucalyptus wood can also affect the livelihoods of local communities and may lead to unsustainable exploitation if not properly managed.

**Soil** is used in the house model to make home bricks and mortars.
In the DRC, adobe bricks are widely used across all provinces, both in rural and remote urban areas. When implemented correctly, these architectural solutions offer comparable quality in terms of maintenance and lifespan to other available options in the country. The durability of this technique relies on a solid foundation and base (such as stone, baked bricks, or cement blocks) and a well-designed roof with adequate overhang. Adobe walls often serve as load-bearing elements for the roof. Block formats vary based on soil quality. This technique is economically accessible as the raw materials are readily available on-site[99].

Soil to made adobe bricks are an eco-friendly choice, as it is a natural material, locally sourced, and has low energy consumption. However, there are environmental considerations. Their production can lead to land degradation, energy consumption, and significant water use.

**Rubble** is used in the house model as part of the foundation. Since is it a very rocky terrain, is it taken directly from the site to be used in the construction.

In DRC stone is a traditionally used material in areas where this resource is available, for example, in the mountains of the eastern part of the country. In these areas, volcanic stone rubble is used for foundations and base walls of earthen buildings (adobe or wattle and daub), and even for the entire walls[100].

Directly extracting rubble from a construction site saves costs and reduces environmental impacts by reducing the need for external resources. However, it carries risks like quality variations, structural integrity issues, and potential environmental disruption, including soil erosion and habitat alteration, due to careless extraction practices.

97 17514_fiche_reponse_rdc.pdf (sheltercluster.s3.eu-central-1.amazonaws.com)
98. Chaojun Chu, P.E. Mortimer, P.E. Mortimer, Hecong Wang, Yongfan Wang, Xubing Liu, Shixiao Yu. 2014
99 17514_fiche_reponse_rdc.pdf (sheltercluster.s3.eu-central-1.amazonaws.com)
100 17514_fiche_reponse_rdc.pdf (sheltercluster.s3.eu-central-1.amazonaws.com)

**Sand and gravel.** Gravel is utilised for the foundation, while sand is employed for plastering the house. Both of these materials are sourced by extracting them from nearby rivers.

Extracting sand and gravel from rivers could leads to habitat disruption, biodiversity loss, and altered riverbeds and water flow, which can negatively affect aquatic life and water quality. The process also increases erosion risks, potentially harming riverbanks and coastal areas. Socioeconomic impacts include threatened livelihoods for communities reliant on rivers and potential conflicts over resource competition.

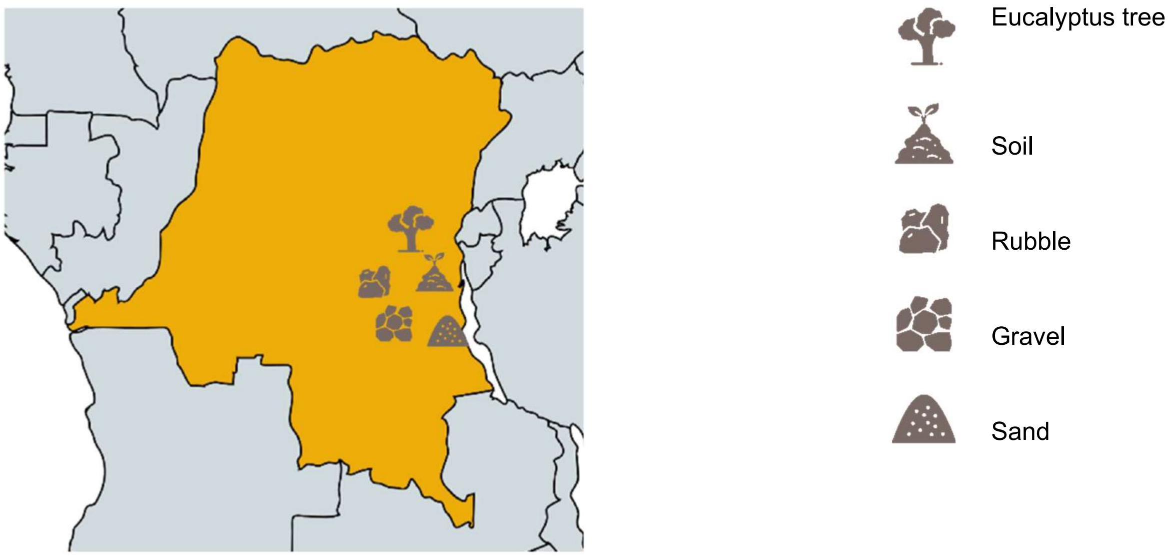
### 8.3.3. Quantity of the *local natural resources* in the house model

The follow Table 2 shows a simplified representation of the amount of *local natural resources* used by the house. It offers a comparative view of the consumption of each natural material, rated on a scale from 1 to 10. This assignment gives the maximum amount (soil) a score of 10 points and the minimum amount (sand) a score of 1 point, with scores for the other materials falling in between based on their amounts relative to the maximum and minimum.

Please refer to Annex 7 to see the actual quantities of the *local natural resources* used per house in kilograms.

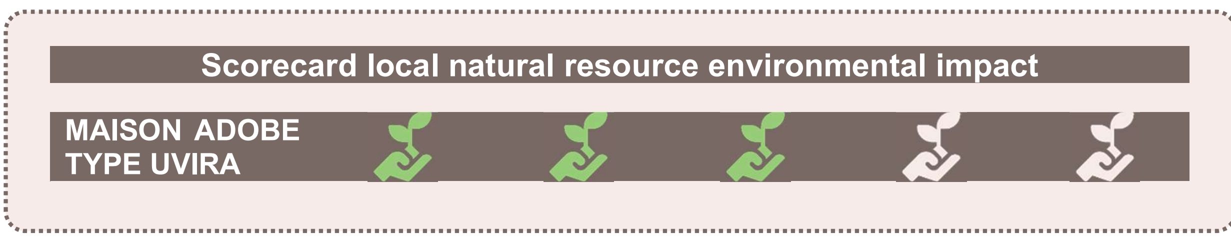
**Table 2 - Amount of *local natural resources* used by the house model**

| House model | *Local natural resources* | Amount |
|---|---|---|
| Maison adobe type Uvira | Eucalyptus tree |  |
| | Soil |  |
| | Ruble |  |
| | Gravel |  |
| | Sand |  |




*Map of the source of the natural resources used*

### 8.3.4. Scorecard for *local natural resource environmental impact*




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

The house model scores 3 out of 5, primarily due to the substantial use of natural materials in the model and the impact they could have on the local environment. On one hand, the use of locally available natural resources is beneficial, as one of their advantages lies in their local availability and they are also considered renewable as they return to the environment after their useful life - this point will be further analysed in the Criteria 4. However, their use could lead to environmental problems if extraction is not properly managed, and the study suggests that it is not always the case. It is important to note that in the project, the extraction of these materials is carried out manually, not mechanically, thus reducing overall environmental damage.

The most abundant natural material used in the model is soil. Using soil offers several advantages for the local environment, as it is locally available and requires minimal transportation, resulting in low environmental pollution. However, the production of soil-based construction materials may have environmental impacts, including potential land degradation and significant water use. It's crucial to implement sustainable practices, such as erosion control, proper site selection, and soil conservation.

The second-largest material in terms of quantity used in the model is rubble. Again, the rubble comes from nearby, so there is no need for transportation. However, extensive rock extraction can result in land degradation and changes in the landscape, which can have long-term effects on the environment and local communities. Measures to mitigate habitat disruption, erosion, pollution, and land degradation should be incorporated into construction and quarrying processes to minimise their impact on the local environment.

Other materials used, albeit in smaller quantities, are gravel and sand. In the DRC, the production of gravel is often artisanal, resulting in inconsistent quality and size limitations, making it unsuitable for reinforced concrete structures[101]. Therefore, a thorough analysis of gravel usage is essential for this project. Additionally, sand extraction frequently occurs informally and without proper control from riverbeds. While transportation is not an issue since it comes from a nearby river, it's crucial to ensure that the extraction processes are sustainable and do not overexploit riverbed resources. Implementing responsible extraction techniques is vital to minimise ecological damage in these areas, and the same principles apply to gravel extraction.

The house model employs eucalyptus as its primary hardwood timber, ensuring the avoidance of tropical wood and sourcing only from official providers. Eucalyptus offers specific benefits but also has associated environmental concerns. Its cultivation is prevalent in the eastern regions of the country, making it a potentially profitable construction material due to its widespread availability[102]. The local team notes that the eucalyptus used is sourced from private plantations, with sustainability practices in place. These practices include harvesting methods that allow the trees to regrow more substantially over time and a commitment to replanting after a designated period. Despite the high-water consumption associated with eucalyptus trees, the DRC benefits from extensive surface and groundwater reserves and a rainy season that spans nine months of the year, according to the team. However, the Shelter Cluster in DRC has raised concerns about the extensive planting of eucalyptus for soil drying purposes, which poses threats to soil conservation, and its sustainability isn't always guaranteed without the right treatment[103].

Exploring eco-friendlier alternatives like bamboo is recommended. The government is actively promoting bamboo through the "National Bamboo Program in DRC" (PNBC), according to the Shelter Cluster in DRC[104] However, an interviewee highlighted that upon suggesting bamboo for construction, a local engineer informed of governmental restrictions on its use. This is due to bamboo's significance as a habitat for gorillas, an endangered species. This aspect needs further exploration.

It is important to emphasise the deforestation of the land where the houses have been constructed. This has led to one of the major problems, which is exposure to strong winds that sometimes damage houses, including roofs. Although eucalyptus may be an invasive plant, it has the potential to contribute to environmental protection if used selectively to shield against the winds and prevent further soil erosion. According to one of the interviewees, there are organisations that have implemented such programmes with eucalyptus. Therefore, it is recommended that a comprehensive study be undertaken to assess the advantages and disadvantages of using eucalyptus trees for wind mitigation and soil erosion prevention. Additionally, it is essential to explore the feasibility of alternative plant/tree options to effectively address these specific tasks.

What is clear is that these resources offer various benefits to communities, but the risk of over-harvesting and exploitation is evident without proper measures. Overexploitation and climate change may harm plant production and soil quality. Therefore, effective planning, environmental assessments, and mitigation are essential to ensure sustainable construction practices.

101 17514_fiche_reponse_rdc.pdf (sheltercluster.s3.eu-central-1.amazonaws.com)
102 17514_fiche_reponse_rdc.pdf (sheltercluster.s3.eu-central-1.amazonaws.com)
103 17514_fiche_reponse_rdc.pdf (sheltercluster.s3.eu-central-1.amazonaws.com)
104 17514_fiche_reponse_rdc.pdf (sheltercluster.s3.eu-central-1.amazonaws.com)

## How to improve the local natural resource environmental impact

Promote sustainable soil sourcing practices by ensuring that soil extraction rates do not exceed the natural soil formation rates, preventing soil depletion.

Ensure that the extraction of rubble, gravel and sand is done sustainably, develop an extraction management plan for surround resource source area. Also, take steps to prevent problems like overusing resources from riverbeds, habitat disruption, erosion, pollution, and land damage.

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. If necessary, explore other alternative materials. As an example, a local alternative it could be bamboo. However, further study on the quality of the material and impact on the environment, and mitigating strategies for identified impacts, should also be considered.

Ensure that the use of eucalyptus wood does not lead to the loss of native forests in DRC.

Including a reforestation or forest protection project, continue replanting trees with the local national society 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.

To study further the use of eucalyptus trees for wind mitigation and soil erosion prevention, or to explore the feasibility of alternative plant/tree options to address these tasks.

## 8.4. Criteria 4: *Waste management*

### 8.4.1. Overview of *waste management*

When designing a housing solution 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 the region. Even if some durable items are reused and recycled, much of the solid household waste is typically burnt, buried, or left scattered.

### 8.4.2. Analysis of the waste generated by the house model

The following Table 3 shows a simplified representation of how many *long-lasting* and *quickly degrading materials* the house used, and the house *life expectancy*.

Please refer to Annex 8 to see for each of the house materials their life expectancy, how long it takes for them to decompose and if they can be reused and recycled, based on potential in DRC[105], according to an association specialised in agroecology, and ideas shared by some of the interviewees.

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

| House model | Long lasting materials | Quickly degrading materials | House life expectancy |
|---|---|---|---|
| Maison adobe type Uvira |  |  |  |

The *Global Joint Initiative on Sustainable Humanitarian Assistance Packaging Waste Management*[106] 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. DRC is one of the countries covered[107].

105 *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.*
106 *Information can be found at https://eecentre.org/2019/07/15/https-www-eecentre-org-2019-07-15-sustainable-humanitarian-packaging-waste-management/*
107 *The information is then uploaded onto the Global Logistic Cluster LCA at DRC Waste management and recycling assessment | Logistics Cluster Website (logcluster.org)*

On the questions of packaging and single-use plastics, DRC implemented a law in 2012 that bans the production, import, and sale of non-biodegradable packaging[108]. However this not well enforced. The field teams confirmed some materials come packaged in single-use plastic[109]. Attempts could be made to eliminate this, in discussion with suppliers.

### 8.4.3. Scorecard for *waste management*


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

Managing disposal in DRC presents a challenge due to the absence of efficient waste management systems. So from an environmental perspective, answering the question of how long it takes various types of waste to decompose is of great importance. Products that produce long-lasting waste should either be limited in consumption or alternative waste management solutions should be devised to mitigate the environmental impact.

As can be seen in Annex 8, most of the materials possess some local potential for reuse or recycling. Moreover, the house models have primarily been designed using materials that will decompose and won't pollute. Meaning that there is no need to introduce additional energy in this process. For instance, adobe bricks, being the most extensively used material, can be 100 percentage recycled and are biodegradable, when they are not painted, chemically treated, or mixed with cement, as is the case here. Old adobe bricks can be crumbled and returned to the earth or repurposed in the creation of new bricks. However, certain materials in the houses, even in minor quantities, such as cement and steel, will take many years to decompose.

Also, good quality materials and construction practices are important. Both affect the durability of the house, and therefore the materials, by increasing their life expectancy. Poor construction not only poses safety risks but increases the material turnover period, further compounding the environmental impact of house construction. So promoting this is a must in every programme. While the current life expectancy of the house is reasonably satisfactory, 10 years according to the local team, measures to enhance its durability should be actively promoted. Therefore, advocating for superior construction standards is essential in every programme.

Several products, like cement, CGI, bolts, rebar, and screws, come in single-use plastic packaging. It's essential to minimise this practice wherever possible.

Taking all these into account, together what happens with some of the materials at the end of their useful life, the house scores 4 out of 5.

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

## How to improve the *waste management* score

Continue encouraging best construction methods, emphasising the "build back safer" approach, and advocating for extending the lifespan of materials through proper care and maintenance. This will reduce the need for frequent material replacements.

Promote to reduce packaging, switch to biodegradable packaging, and eliminate single-use plastic packaging, relatively simple changes which should be made. Efforts could be undertaken to address this issue by engaging in discussions with suppliers.

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

Link communities to private waste companies to collect materials which are not reused, like the steel, 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.

## 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 and it is too important an environmental issue to ignore. On one hand, burning of the house 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 house, 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[110].

In 2020, only 3.7 percentage of the population in the DRC had access to clean cooking fuels and technologies, with rural areas having an even lower rate at nearly 0.5 percentage[111]. Around 95 percentage of the country's energy needs are currently met by biomass sources. The absence of alternatives to wood fuel not only leads to labour-intensive cooking practices and health issues linked to air pollution but also contributes to the gradual deterioration of the DRC's forests, posing a threat to the preservation of the world's second-largest rainforest.

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[112].

As well as considering the impact of use of wood and other plants for the construction of houses, future projects should also consider the use of wood for cooking fuel by the displaced living in the shelter solutions, 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.

110 *Cooking in displacement Setting. Engaging the Private Sector in Non-wood-based Fuel Supply. Laura Patel and Katie Gross. January 2019*
111 *https://www.worldbank.org/en/news/feature/2022/11/15/in-the-democratic-republic-of-congo-people-centered-solutions-to-forest-degradation*
112 *Cooking in displacement Setting. Engaging the Private Sector in Non-wood-based Fuel Supply. Laura Patel and Katie Gross. January 2019*

## 8.5. Summary of the results


The house model predominantly uses natural raw materials, especially soil and rubble, in greater quantities than man-made materials, offering an environmental advantage due to their lower impact. These materials are more sustainable, locally sourced, and renewable, requiring less energy for production compared to synthetic options. However, it is important to note that the model also has a significantly high embodied water level.

Overall, the house model has a relatively low carbon emission, mainly due to the use of adobe bricks, which, despite their volume, have a lower embodied carbon than other materials. Following adobe bricks in terms of emission contributions are cement and corrugated galvanized iron (CGI) sheets, also due to their transportation since they are imported. Additionally, the use of eucalyptus timber in the house leads to a high emissions at the end of its life cycle, as burning the timber releases carbon into the atmosphere.

The model primarily utilises local natural resources such as soil, stones, sand, and eucalyptus trees. However, the impact on the local ecosystem hasn't been adequately addressed. The team should ensure that the extraction of these local resources does not damage the environment.

The house is constructed predominantly from materials like soil, rock, sand, and timber (if not burned) that won't cause pollution at the end of their life cycle. Despite the lack of waste management systems in place, most of these materials have the potential for reuse or recycling. However, the inclusion of durable materials such as steel and cement, which have extended decomposition times, should be taken into account. The expected lifespan of the house is satisfactory, 10 years according to the local team, however it could range from one-to-many years, provided it's well-maintained. This extends the period before materials need to be replaced.

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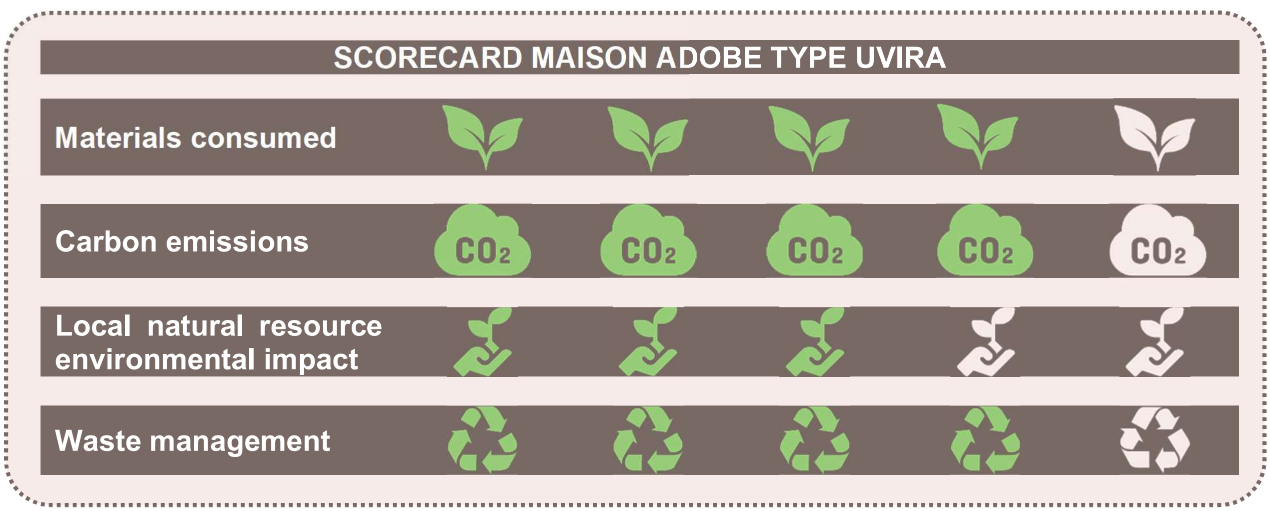


*1 poor, 2 average, 3 medium, 4 good, 5 very good*

# 9. Conclusion

The significance of analysing the complete life cycle of the house and its materials, from their production to their disposal, has been highlighted throughout this research. The evaluation considers not only carbon emissions but also aspects such as the utilisation of local natural resources and waste management. While reducing carbon emissions is crucial and widely recognised, it's equally important to think about the effects of using natural resources on the local environment. Moreover, waste is a hidden challenge in the humanitarian world, it is usually ignored during project design, and rarely discussed at more strategic levels.

To assess the environmental impact of the house model requires us to balance relative sources of environmental harm across the different criteria. The scope of this remote 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 benefit of using the scorecard approach is to highlight which solution complies better with which criteria, as well as to help identify mitigating solutions. For example, when there is damage to the environment due to our actions, such as deforestation due to harvesting eucalyptus, mitigation measures should be adopted, like reforestation or replanting projects, and ensuring that the timber source is managed sustainably. It is recommended that a simple environmental impact assessment or at least environmental screening using a tool such as the NEAT+[113], and following that identification of mitigation strategies, should accompany the design of all shelter and site planning activities.

The house model examined in this study is evidently designed with environmental sustainability in mind, primarily due to its use of locally available natural resources, with adobe bricks as the main component. Using local natural resources presents certain benefits, like lower carbon emissions and less waste management issues; however it has also its challenges.

Soil to make adobe is locally available, dried using sunlight, which saves energy, and it creates income opportunities for communities who produce the blocks. Furthermore, when these materials reach the end of their lifecycle, they are entirely recyclable and biodegradable, when not mixed with stabilisers like cement, ensuring zero waste and pollution. Moreover, it aligns with traditional local architecture, is energy-efficient due to their low embodied energy and therefore carbon emissions, high thermal mass, compatibility with passive solar design strategies, and the sustainable nature of their production process. Moreover it provides added safety in earthquake-prone areas.

However, concerns arise regarding the exploitation of soil in their production. On one hand, the manual extraction of these materials avoids greater environmental damage compared to mechanical means. Yet, there is a lack of regulation concerning soil extraction, leading to potential environmental issues such as soil erosion.

Additionally, while adobe bricks minimise carbon emissions typically associated with transport, as families are responsible for the transportation, normally on foot, this not only involves them in the construction process but also creates income opportunities through "cash for work" initiatives. However, concerns have been raised about the human aspect of transportation. The labour can be physically demanding for those involved, something even including minors, especially when they are tasked with carrying these heavy blocks, particularly in challenging uphill terrains. It's crucial to ensure that vulnerable individuals aren't burdened with such tasks. One solution could be to avoid construction in areas with difficult access. However, this presents another challenge, as local governments often allocate non-prime land for such purposes. Advocacy is recommended to address these concerns. Since this could be very challenging, another solution could be to conduct preliminary studies of topography and transport viability to assist families in the process. As an example, there is currently a plan to build a staircase to assist in this process. This concept can also be extended to the transportation of the rest of the materials.

The local sourcing of rock and sand, while eco-friendly, poses issues. Uncontrolled extraction harms ecosystems and the environment, and there are doubts about material quality and availability. To combat this, it's essential to ensure sustainable extraction. This involves creating a management plan for resource extraction and implementing measures

113 *https://neatplus.org/*

to avoid issues like riverbed over-extraction, habitat disturbance, and erosion. However this task can be challenging for the local team; hence seeking expert opinion from environmental organisations or universities is advisable. Such collaboration ensures awareness of potential risks, facilitating a well-informed analysis of the proposed raw material sourcing strategies.

As for timber, particularly eucalyptus, there are notable benefits as well. For instance, this deters the use of tropical woods often linked with deforestation, it captures carbon during growth, also, once these materials are no longer used, they decompose in a short time and don’t generate any pollution (assuming they are not burnt). Furthermore, other organizations in the region have employed eucalyptus for purposes such as wind mitigation and soil erosion prevention.

However, concerns arise from the widespread cultivation of eucalyptus, which can threaten soil conservation. Questions remain about whether plantations are harming local species or causing deforestation. The team should verify the suppliers' sustainability to prevent over-extraction or additional environmental damage. Wood should be sustainably sourced; the project already conducts reforestation projects, and this should continue. Additionally, consider forest protection projects, or alternative materials like bamboo. Further studies on material quality, environmental impact, and mitigation strategies are essential.

Regarding the potential use of timber as firewood, as pointed out by the local team, it's important to note that burning it releases the stored carbon back into the atmosphere, negating some of its environmental benefits. While it's crucial to prevent this, affected families rely on firewood for cooking, making it a complex issue. Burning these materials for heat or cooking might reduce the need for other woods, possibly decreasing deforestation. To address this, introducing non-organic material cooking stoves is worth considering. Additionally, incorporating reforestation and replanting initiatives into shelter programmes is beneficial.

The house incorporates lime sourced from local environments for its plastering needs, marking it as a sustainable choice over other materials such as cement. This is due to its carbon-neutral qualities that enable $CO_2$ reabsorption during the curing process. Lime also boasts lower emissions during manufacturing, promotes material reusability and biodegradability, and is cost-effective. Additionally, its breathability is vital for natural buildings, and its flexibility allows for 'self-healing' properties that prevent damage, making it an environmentally friendly choice.

Focus should be on materials like steel and cement due to their carbon emissions and extremely long decomposition time. Even if their quantities are small compared to other materials, this should not be disregarded. This concern is heightened in countries like DRC, where waste management systems are inadequate. While considering alternative materials is vital, it's not without difficulties. Efforts to introduce natural roofing, such as the “makongo” leaves, encountered resistance from the local families due to the high maintenance they require, while reducing the amount of steel and cement used might not be feasible. Otherwise, a project component for reusing, repurposing or recycling (R3) the materials once the house gets to the state it has to be replaced, could be set up.

Although local procurement is encouraged, it poses challenges in DRC. The frequent import of shelter materials to meet quality standards hinders the promotion of local production of materials. The DRC's logistical challenges further complicate humanitarian interventions, many of the most vulnerable populations reside in extremely remote locations, often isolated or with limited access. An alternative, as suggested by the Shelter Cluster, could be collaborating with shelter and NFI manufacturers in East Africa to enhance quality standards to meet humanitarian needs. Sourcing from this region could potentially reduce the environmental impact from transportation and speed up delivery.

Also, improper treatment of materials, such as inadequate handling, preparation, and application during construction, maintenance, and repair processes, can compromise the integrity and durability of the house, leading to a reduced lifespan and frequent need for material replacements. The durability of a house is not only cost-effective but also environmentally efficient. For instance, for structures like adobe houses, their life expectancy varies, influenced by several factors such as soil quality, climate, and construction and maintenance techniques. It can range from a brief period to many years. Proper maintenance techniques, such as applying protective plaster layers like mud or lime plaster (like is the case here), can safeguard the bricks against weathering, thus potentially extending the life expectancy of the house, which is currently estimated at 10 years by the local team. Maintenance and good construction techniques, plays a crucial role in extending this lifespan. Since training programs on house maintenance and construction improvement already exist, it's important to continue and reinforce these initiatives. Additionally, considering other long-lasting alternative materials, such as the use of Compressed Earth Blocks (CEB) should be explored.

In conclusion, the house model in this study is centered on environmental sustainability, using local materials like adobe bricks, which offer ecological and economic benefits. Yet, it faces challenges like soil exploitation and the labour-intensive transport of materials. Managing the sustainable extraction of resources like rock, sand, and timber is also crucial to prevent environmental degradation. The use of eucalyptus timber, in place of tropical hardwoods, offers environmental benefits but poses potential risks. The reliance on timber for fuel also complicates matters, as it releases stored carbon dioxide. Introducing alternative cooking methods and promoting reforestation could mitigate this. Despite the smaller quantities used, the environmental impact of materials like steel and cement should not be underestimated, especially in areas with poor waste management. Collaborating with East African manufacturers may improve local material standards and reduce environmental impacts from the supply chain. Finally, durability and proper maintenance of housing are key to environmental efficiency, underlining the importance of ongoing training in construction techniques.

It is important to clarify that this study does not make a definitive recommendation. 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 house. This study essentially 'captures a snapshot' of the current situation, as a baseline. If the study is repeated in the future for the same house model, it can indeed create a timeline that illustrates how the environmental impact has evolved over time. This can help track the effectiveness of mitigation measures, identify trends, and assess whether the environmental situation is improving or deteriorating.

It's worth noting that implementing some of the recommendations might be challenging, and their feasibility should be verified, as the scope of this work didn't allow for in-depth verification. Many suggestions involve behavioural changes, which can be time-consuming. However, initiating discussions on these topics is already a step in the right direction.

In closing, the notion of an ideal housing solution that meets every requirement is not realistic. As well as the environment, there are multiple other considerations, such as technical efficiency, longevity, habitability, cost-effectiveness, and cultural relevance, to name a few. While these elements haven't been the focus of this study, they play a crucial role in comprehending the entirety of the house context. No shelter solution is perfect; it's about finding the one which is most suitable, feasible, and least harmful to the environment.

# 10. Recommendations

## House-specific recommendations

Consult and collaborate with experts, environmental organisations, or universities to ensure that the extraction of rubble, sand, and gravel is done sustainably, preventing problems like overusing resources from riverbeds, habitat disruption, erosion, pollution, and land damage.

Promote sustainable soil sourcing practices by ensuring that soil extraction rates do not exceed the natural soil formation rates, preventing soil depletion.

Examine 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. If necessary, explore other alternative materials. As an example, a local alternative it could be bamboo. However, further study on the quality of the material and impact on the environment, and mitigating strategies for identified impacts, should also be considered. Another way to consider reducing the use of wood is to use masonry arches as lintels. However, it's important to conduct further studies to assess the environmental impact of these alternatives options.

Consider the possibility of using recycled or low-impact materials as an alternative to CGI, given its high embodied carbon and water content per kilogram, and prolonged decomposition time. Alternatives such as green roofs made of local available plants, like “makongo” leaves, could also be explored. However, this can be challenging, especially if families are resistant to such changes. If this alternative is chosen, it's also essential to consider the impact on the local environment when harvesting the natural materials for roofing.

Make sure the amount of cement is kept to a minimum without compromising the house. Cement is a material with a high embodied carbon, also will take long time to decompose.

Ensure that the quantity of adobe brick and stones used is minimised without affecting the structural integrity of the house. While adobe bricks are among the most environmentally friendly materials, extracting soil for their production can lead to environmental damage. It's also worthwhile to explore other long-lasting alternative materials, like the use of Compressed Earth Blocks (CEB). However, it's important to conduct further studies to assess the environmental impact of these alternatives.

Reduce the packaging for all materials, and eliminate any single-use plastic, or support the reuse of packaging for other purposes.[114] Efforts could be undertaken to address this issue by engaging in discussions with suppliers.

114 See Guidelines-for-Packaging-Waste-Management-in-Humanitarian-Operations-compressed.pdf

## General programme recommendations

Continue sourcing materials locally as much as possible to minimise transport-related emissions. Alternatively, work with potential shelter and NFI manufacturers in East Africa to raise standards to levels which meet humanitarian standards and permit procurement within this region. This would likely reduce the environmental footprint of assistance and shorten delivery times. This effort would best be done in cooperation with humanitarian shelter and NFI assistance providers working in East Africa, including UNHCR, IOM, IFRC, ICRC and others.

Include a reforestation or forest protection project, continue replanting trees with the local national society 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.

To study further the use of eucalyptus trees for wind mitigation and soil erosion prevention or to explore the feasibility of alternative plant/tree options to address these tasks.

Continue to improve skill development by providing targeted training of the best practices for sustainable adobe construction and upkeep to community members and workers involved in construction and house maintenance. This will significantly contribute to increasing the longevity of houses and reducing the need for material replacement.

Continue raising awareness of environmental sanitation and the pollution generated by the disposal of the materials, though the programme, or through advocacy in partnership with other organisations.

Link communities to private waste companies to collect materials, especially steel, one it has reached the end of its useful life, 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.

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. This can also prevent the burning of eucalyptus timber, which keeps the carbon it has stored over the years from getting into the atmosphere, as pointed out in the section about carbon emissions.

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

Conduct preliminary studies of topography and transport viability to assist families in the process of material transportation.

Lobby the local government to refrain from allocating housing in areas with challenging access.

Consider doing a simple environmental impact assessment or at least environmental screening using a tool such as the NEAT+[115], 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[116] from a project that has been accredited by a recognised standard.[117]

115 *https://neatplus.org/*
116 *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 $CO_2$ emissions to facilitate expansion of the programme https://www.fairclimatefund.nl/en/projects/chad-solar-cookers-for-refugee-families*
117 *European Parliament*

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- Rapport de l’enquête Post Distribution Monitoring (PDM) dans les communes de Bouroum, Pensa et Gorgadji. CRBK. 2021
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- Reducing environmental impact in humanitarian response, Sphere, 2019
- Roadmap for research- A collaborative Research Framework for Humanitarian Shelter and Settlements Assistance.
- Shelter and Sustainability, UNHCR, 2021
- Silviculture of eucalyptus planting- learning in the region. K.J. WHITE. FAO
- State of the World's Trees. Sept 2021. Botanic Gardens Conservation International
- www.flaticon.com

# 12. Annexed documents

- Annex 1 - Informants
- Annex 2 - House model technical information
- Annex 3 - House components material, packaging, quantity and country of origin
- Annex 4 - Transport distance
- Annex 5 - Materials used in the house model
- Annex 6 - Carbon emissions calculation of the house
- Annex 7 - Local natural resources used per house
- Annex 8 - Protentional reuse option and recycling options
- Annex 9 - Advantages, impacts and best practice of each material

# ANNEX 1 - Informants

International Aid of Luxemburg Red Cross
- ANZARA, alphonse ; Chef de Mission DRC
- BROW BIRABÉN, María : Point focal Construction en terre
- DE LA VEGA MERONO, Isabel
- FEZEU, Cedric R; Coordinateur Technique
- LEDESMA, Daniel LEDESMA, Research officer
- MAHAMAN OUSMANE, Ismael, Chef de projet DRC
- THEISEN, Claudine: DESK DRC and Burundi

Shelter Cluster DRC
- Laschoni SOKI, Coordinator

Global Shelter Cluster
- Madelaine MARARA, Global Shelter Cluster Environnemental Focal Point.
- Mandy GEORGE, Senior Environmental Advisor
- Charles KELLY, Co-Chair, Environment Community of Practice, Global Shelter Cluster

Waste management organisation contacted in DRC
- AFRIQUE SOLIDARITE (AFRISL-RDC) specialist in agroecology
- BRIQUETTE DU KIVU

Environmental organisation contacted in DRC
- SOCEARUCO

Others
- Samantha Brangeon. Consultant- JI Sustainable Humanitarian Packaging Waste Management

## ANNEX 2 - House Model Technical Information

### MAISON ADOBE TYPE UVIRA

The "Maison Adobe type Uvira" is designed as a sustainable housing solution, with the assistance of the Sud-Kivu branch of the CRRDC. 150 houses have been built from 2022, in the city of Uvira, located in the Sud-Kivu province.

Total area
33.64 $m^2$

Occupancy
6 persons

Construction time
21 days

Cost
663 euros

Durability
10 years

Total # Built
150

To Build
0

**Dimensions**
5.8m x 5.8m

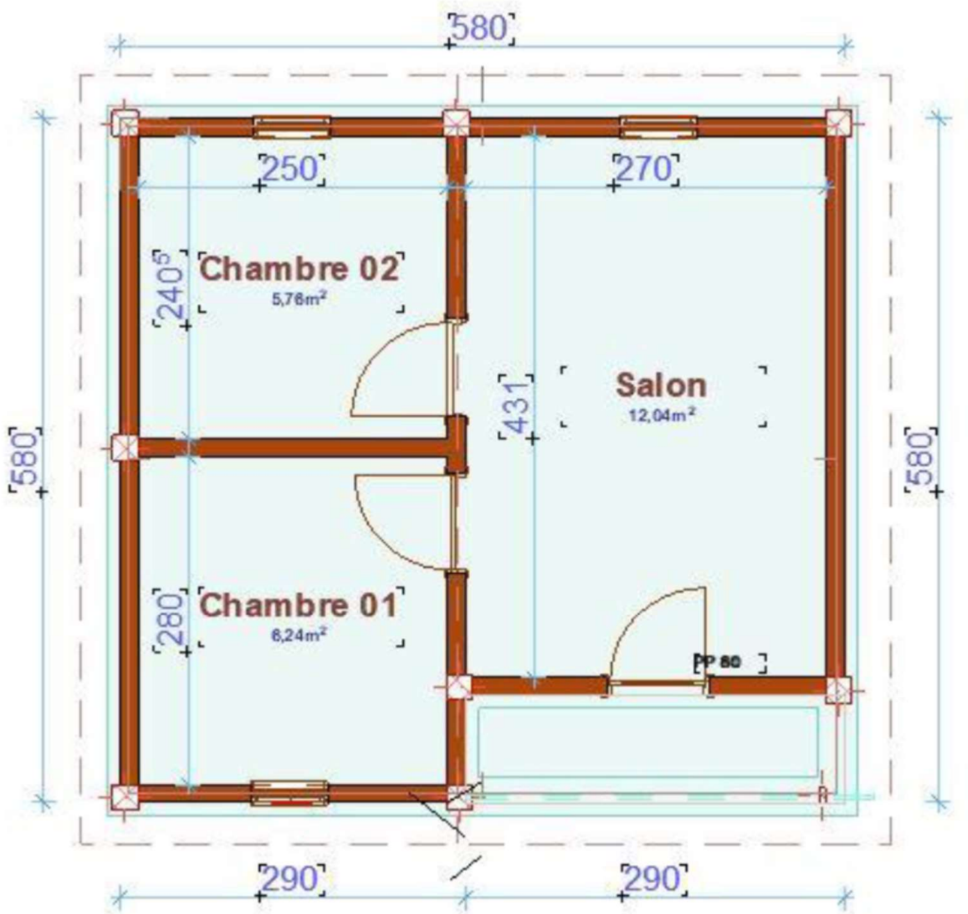
**Foundation**
The foundation has a depth of 40 cm approximately and 40 cm wide and 40 cm width, a layer of 5cm concrete, and a 40cm sub-foundation wall made of rubble stones with cement mortar joints.

**Walls**
The walls are built of adobe bricks (32 x 20 x 12 cm), and earth mortar, requiring an estimation of 1,500 bricks. The bricks are made by the families, the CRRDC volunteers, and other community members.

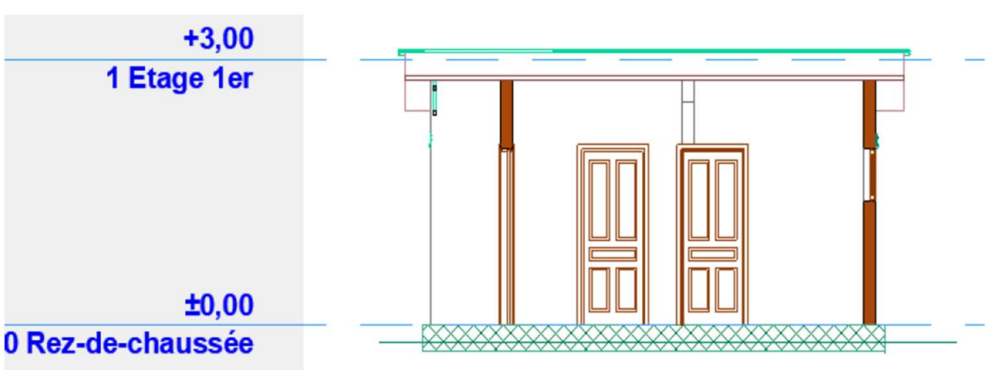
**Wall cladding**
The wall cladding is composed of lime, cement, and water.

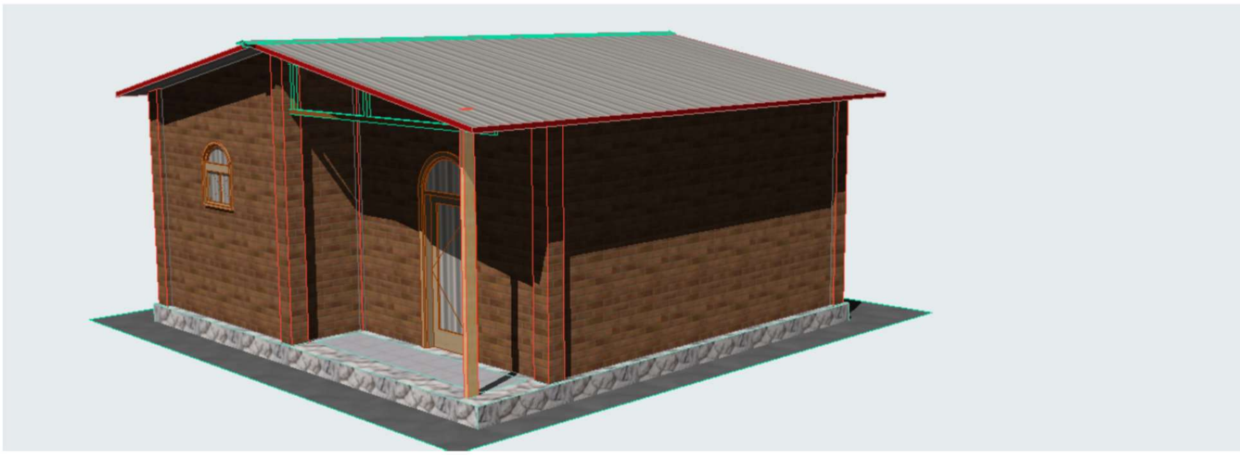
**Roof covering**
The roof has two slopes with a 20 percentage grade, covered with metal roofing, and has a structure made of eucalyptus wood.

**Openings**
3 doors and 3 windows made of eucalyptus wood.


580
250
270
Chambre 02
5,76m²
240⁵
Salon
12,04m²
431
580
580
Chambre 01
6,24m²
280
PP 80
290
290

**COUPE CC**


+3,00
1 Etage 1er
±0,00
0 Rez-de-chaussée



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

All the information below was provided by the AICRL team in-country.

Below is the table showing the materials used in the house model, by weight (kilograms) and the corresponding total embodied water in litres produced by each material. The data in kilograms was provided by the AICRL logistics teams in the country, except for the gravel and sand, the total amount was calculated based on the cubic meters ($m^3$) they used in the Bill of Quantities (BoQ).

### Table 1 - Maison en Adobe de type Uvira

| Name | Raw material | Quantity/ Kg | Country of origin | Packeting | Quantity/ Kg |
|---|---|---|---|---|---|
| **Timber** | Eucalyptus wood | 55 kg | RDC | None | None |
| **Adobe brick** | Soil | 23,250 kg | RDC | None | None |
| **Mortar** | Soil | 2,100 kg | RDC | None | None |
| **Rubble** | Stone | 15,000 kg | RDC | None | None |
| **Gravel** | Sand | 2,800 kg | RDC | None | None |
| **Sand** | Sand | 2,200 kg | | | |
| **Cement** | Cement | 325 kg | 5% Tanzania<br>80% Rwanda<br>15% RDC | Polypropylene | *Information not provided* |
| **Lime** | Lime | 150 kg | Tanzania | Polypropylene | *Information not provided* |
| **Corrugate Galvanised Iron Sheets (CGI)** | Steel covered in zinc | 90 kg | 20% Burundi<br>80% Uganda | Polyethylene strapping | *Information not provided* |
| **Rebar** | Steel | 3.5 kg | Burundi | Polyethylene strapping | *Information not provided* |
| **Bolt** | Steel | 5 kg | United Arab Emirates | recycled cardboard | *Information not provided* |
| **Ordinary nails** | Steel | 14 kg | 20% Burundi<br>80% Uganda | Polypropylene | *Information not provided* |

# 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 houses that have been built in each location.
- The distances in kilometres have been provided by the field team.
- The suggested approximate distance baseline provided by the SMAC guidelines from MENA to East Africa has been used.
- Since it is not known exactly what happens with disposal, transportation from the site of construction of the house for disposal is not included.

**Country of origin to point of arrival in country**

*Distance by boat*

| Departing point | Arrival point | Distance |
|---|---|---|
| Uniated Arab Emirates (Dubai) | Tanzania – Dar-es-Salam | 4500[118] |

*Distance by road*

| Departing point | Arrival point | Distance |
|---|---|---|
| Burundi (Bunjumbura) | Uvira | 26 km |
| Rwanda (Bugarama) | Uvira | 81 km |
| Tanzania (Dar es Salaam) | Uvira | 1542 km |
| Uganda (Tororo) | Uvira | 951 km |

**Warehouse to Construction Site (km)**

| Departing point | Arrival point | Distance |
|---|---|---|
| Kalemi | Uvira | 386 km |
| Uvira | Construction site | 25 km |

118 *The suggested approximate distance baseline provided by the SMAC guidelines from MENA to East Africa has been used.*

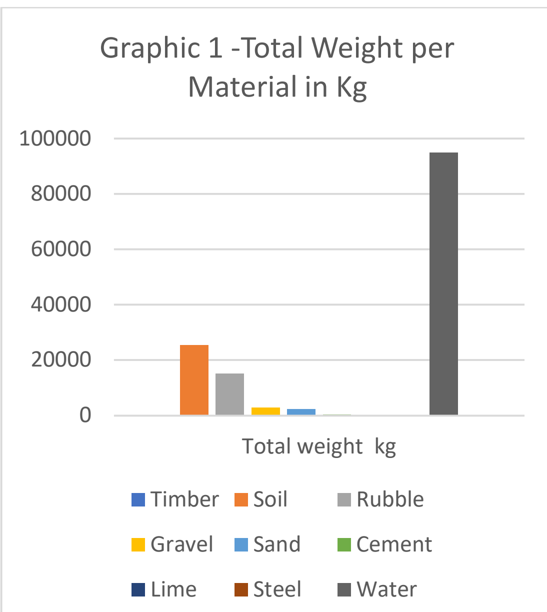
## ANNEX 5 - Materials used in house model

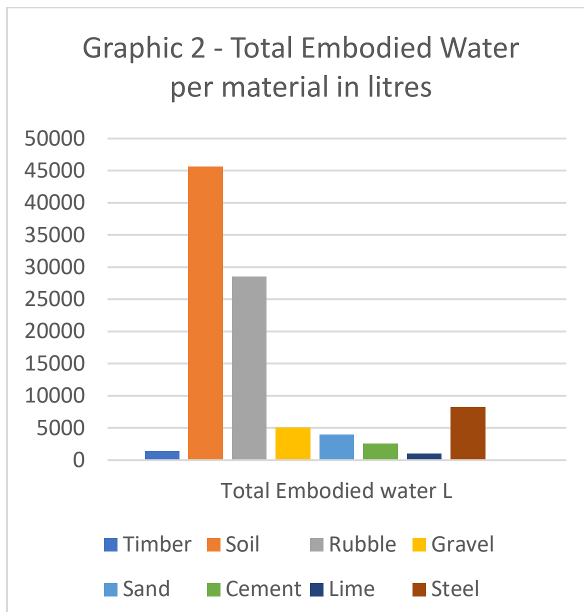
Below is the table showing the materials used in the house model, by weight (kilograms) and the corresponding total embodied water in litres produced by each material. The data in kilograms was provided by the AICRL logistics teams in the country, except for the gravel and sand, the total amount was calculated based on the cubic meters ($m^3$) they used in the Bill of Quantities (BoQ). To calculate the embody water in litres, the UNHC Shelter and Sustainability Tool baseline[119] have been used.

**Table 1 – MAISON ADOBE TYPE UVIRA**

| Raw material | Quantity / Kg | Embodied water (L) |
|---|---|---|
| Timber | 55 Kg | 1,460 L |
| Soil | 25,350 Kg | 45,630 L |
| Rubble | 15,000 Kg | 28,500 L |
| Gravel | 2,800 Kg | 5,040 L |
| Sand | 2,200 Kg | 3,960 L |
| Total Embodied water | 96,335 L | - |
| **Man-made material** | **Quantity / Kg** | **Embodied water (L)** |
| Cement | 112.50 Kg | 2,535 L |
| Lime | 325 Kg | 975 L |
| Steel | 150 Kg | 8,235 L |

The follow Graphic 1 shows the total weight in kilograms of each material, and Graphic 2 shows the total embodied water in litres produced by each material




119 *UNHCR-TSS (epfl.ch)*

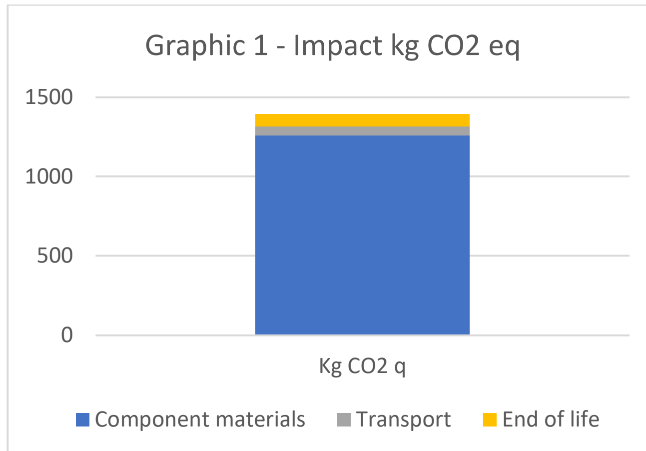
# ANNEX 6 - Carbon emissions calculations

Emissions from "packaging" are not included in this study, since the packaging data was not available, as previously mentioned in section 7.2.1.

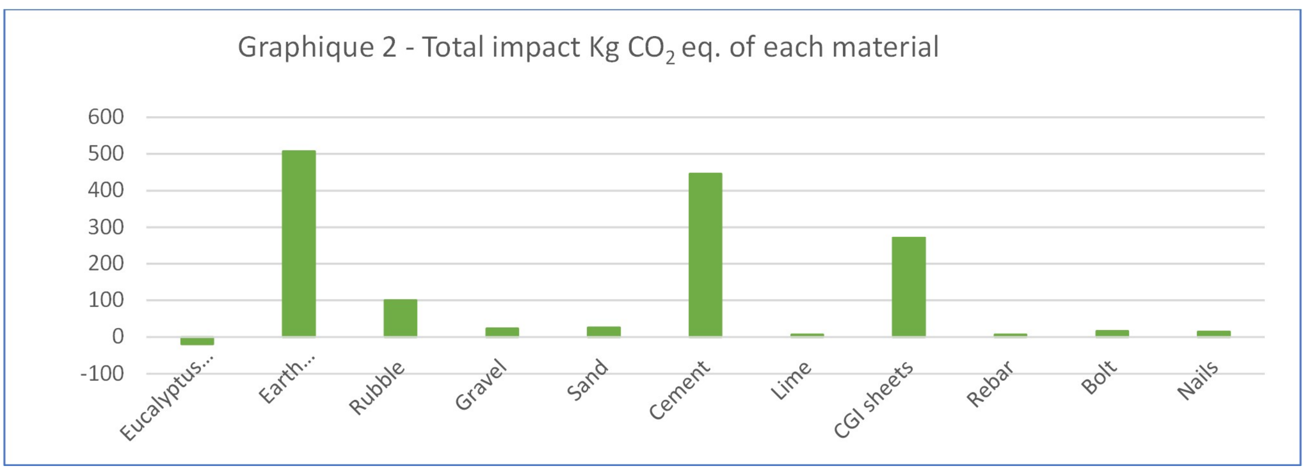
Below are the total *carbon emissions* generated by the house model, in $CO_2$ equivalent. This is using the SMAC calculator and taking into account all the parameters and assumptions explained in section 7.2. The follow Table 1 & and Graphic 1 show the breakdown of the *carbon emissions*, in terms of Kg $CO_2$ eq. of the house unit per "*life-cycle stages*": *"production of the component materials"*, *"transport"* and *"end of life"*.

**Table 1**

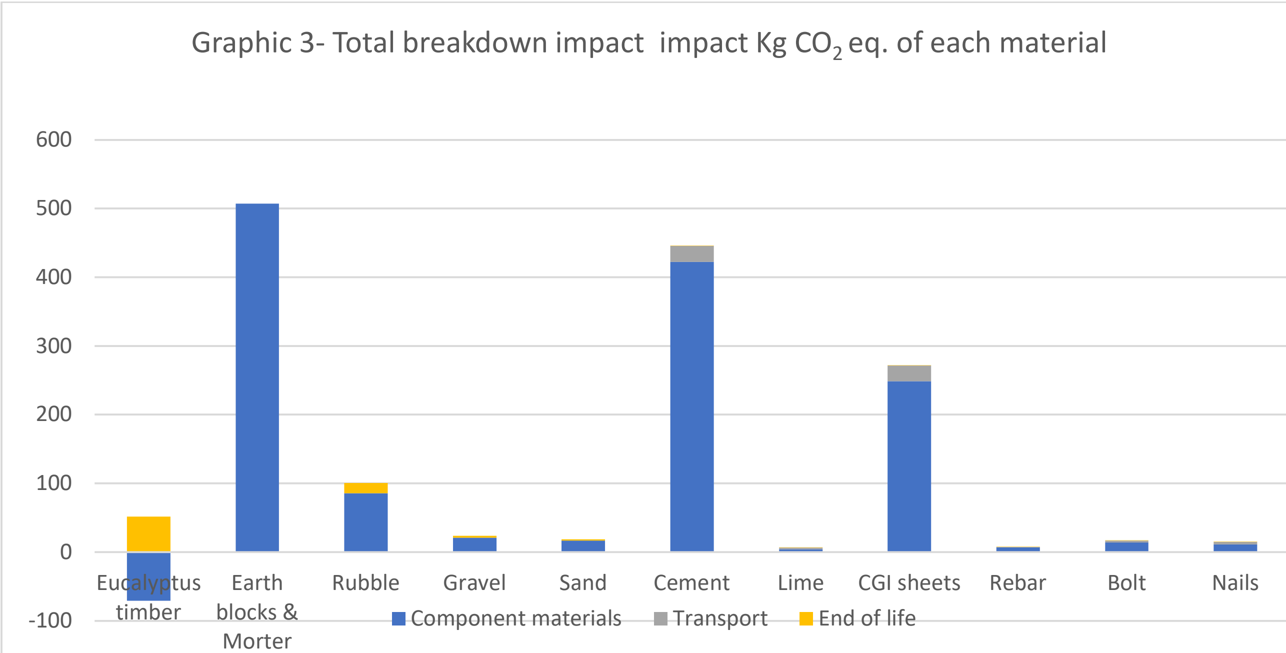
| Impact | Carbon emissions Kg $CO_2$ eq. |
|---|---|
| Production of the component materials | 1265 |
| Packaging | *Data not considered* |
| Transport | 55 |
| End of life | 71 |
| Total | **1392** |




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”.*



## ANNEX 7 - Local natural resources used

**Total amount of eucalyptus tree used in the house model**

- Approximately 55 kilos for the roofing structure

**Total amount of soil used in the house model**

- Approximately 25350 kilos to build adobe bricks and mortar

**Total amount of rubble used in the house model**

- Approximately 15000 kilos as part of the foundation wall

**Total amount of gravel used in the house model**

- Approximately 2800 kilos as part of the foundation wall

**Total amount of sand used in the house model**

- Approximately 2200 kilos as part of the foundation wall

# ANNEX 8 - Protentional reuse option and recycling options

The Table 1 below examine the life expectancy, decomposition time, and potential for reuse and recycling of each material used in the house, based on possibilities within the country[120]. It's important to note that the rate of decomposition can vary based on disposal or landfill conditions.

**Table 1 – Maison adobe type Uvira**

| Material | Life expectancy[121] | Time to decompose | Reuse | Recycling |
|---|---|---|---|---|
| Wood[122] | 2 to 10 years[123] | 10–15 years[124] | Yes | Yes |
| Soil | 2 to 100 years[125] | *Not relevant* | Yes | Yes |
| Ruble, sand and gravel | *Information not provided* | *Not relevant* | Yes | *Not relevant* |
| Cement | 100 years | *Around 50 years[126]* | No[127] | No[128] |
| Lime | 10 years | *Around 50 years[129]* | Yes | No |
| CGI | *Information not provided* | 200 to 500 years | Yes | Yes |
| Rebar | *3 years* | 200 to 500 years[130] | No | Yes |
| Screw /Bolt | 30 years | 200 to 500 years[131] | No | Yes |

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

120 *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.*
121 *Information provided by the field team through direct observation on the field.*
122 *The time it takes for wood to decompose depends on various factors, including the type of wood, environmental conditions, and whether it is exposed to microorganisms that facilitate decomposition. In natural environments, such as forests, it can take several years to decades for wood to decompose fully. In more controlled conditions, such as composting or decomposition in landfills, the process can be accelerated, typically taking months to a few years for wood to break down. Hardwoods like oak may decompose more slowly than softwoods like pine due to differences in wood density and composition.*
123 *Depending on the weather conditions and drying before use*
124 *How Long It Takes 50 Common Items to Decompose | Stacker*
125 *Depending on the construction technique and the weather conditions*
126 *How Long Does Concrete Take to Decompose? (concreterecruiters.com)*
127 *Reusing cement in its original form as a binding powder is difficult once it has been mixed with water and cured, as it undergoes a chemical reaction that changes its properties. However, there are methods and contexts in which materials associated with cement can be reused and recycled.*
128 *Reusing cement in its original form as a binding powder is difficult once it has been mixed with water and cured, as it undergoes a chemical reaction that changes its properties. However, there are methods and contexts in which materials associated with cement can be reused and recycled.*
129 *How Long Does Concrete Take to Decompose? (concreterecruiters.com)*
130 *How long does it take for metal to degrade - Riba Farré (ribafarre.com)*
131 *How long does it take for metal to degrade - Riba Farré (ribafarre.com)*

The Table 2 below examines the potential reuse and recycling options for each material. This is based on what is feasibly possible in the country, insights from interviewees, and findings from a desk review.

**Table 2 - Potential options in DRC**

| Materials | Potential reuse options | Potential recycling options |
|---|---|---|
| **Soil mortar and adobe brick** | • Recovered soil from waste of old adobe bricks, can be reused in other to achieve other elements of this kinds. The physical and mechanical performance of adobe-bricks, newly manufactured, are not negative affected by using recycled soil material[132]. | • Disintegrating adobe brick can be added to the house’s garden and became fertilizer for the grass[133]. |
| **Timber** | • To reuse for auxiliary construction (like stable)<br>• Combustible wood<br>• Art objects | • Art objects |
| **Cement** | Reusing cement in its original form as a binding powder is difficult once it has been mixed with water and cured, as it undergoes a chemical reaction that changes its properties. However, there are methods and contexts in which materials associated with cement can be reused.<br>• Pieces made of cement can be reused in different constructions. For example, larger chunks can be used in creating retaining walls, riprap revetments, or as a fill material.<br>• Recycled Aggregate: Concrete, once it has been broken and crushed, can serve as an aggregate in the production of new concrete, though this can sometimes affect the new concrete’s properties.<br>• Crushed concrete can be used as a subbase for roads and driveways, providing a method to reuse concrete from old pavements and structures.<br>• To reuse for auxiliary construction (stable or chicken coop) | Cement itself as a powder cannot be recycled once it has hydrated and cured, but concrete, which is made by combining cement with sand, gravel, and water, can be recycled to some extent.<br>• Gravel, aggregate and paving materials can be used. |
| **Lime** | • Concrete or mortar made with cement and lime can be crushed and reused as aggregate in new concrete mixes or as a base layer for roads. | • Once cement and lime have reacted with water and cured (hardened), they cannot be "recycled" in the sense that they can't be returned to their original powdered form |
| **Steel** | • To reuse for auxiliary construction<br>• Handicrafts (earrings, home decorations/accessories, etc.)<br>Used for various functions – can be used for attachments of reused mats, etc | • It can be taken as scrap metal and sold to a metallurgical company from Uganda that comes to buy the scrap metal in Bukavu. |

132 *Experimental Research on the Recyclability of the Clay Material used in the Fabrication of Adobe Bricks Type Masonry Units*
133 *Adobe: The Most Sustainable Recyclable Building Material | ArchDaily*

## ANNEX 9 - Advantages, impacts and best practice of each material

Table 1 below shows the advantages, impacts and best practices of each material analysed in this study from an environmental point of view.

**Table 1 –Advantage, impacts and best practice of the materials**

| MATERIALS | ADVANTAGES | IMPACTS | BEST PRACTICES |
|---|---|---|---|
| Soil | • Used for millennia in the DRC<br>• Local material that does not require transportation.<br>• Soil does not create pollution and waste.<br>• It is recyclable if not stabilised (with cement).<br>• A wide variety of solutions allowing a high level of comfort if the bioclimatic conditions of each site are taken into account.<br>• An efficient regulator of humidity in indoor spaces, increasing comfort. | • Their production can lead to land degradation, energy consumption, and significant water use. | • Use local knowledge and building cultures.<br>• The extracted soil can be useful for creating canals, retention basins, dikes, etc.<br>• Improve the strength of walls with inert materials for foundations (stone, cement blocks, baked bricks).<br>• Avoid building earth walls in flood-prone areas.<br>• Support local livelihoods / industries.<br>• Extract earth in areas where it cannot cause danger or environmental impact.<br>• Enhance surface strength by applying an earth coating annually |
| Eucalyptus wood | • It “captures carbon” (and other greenhouses gases) during their growth.<br>• Doesn’t take long time to decompose.<br>• It is a renewable resource when managed well.<br>• Forestry is a priority for the government of the DRC, both commercially and environmentally. Mitigating the effects of climate change is particularly important in areas such as the former Katanga province, where deforestation worsens the effects of floods and promotes erosion of the arable layer. | • “Life expectancy” is short, if not well treated.<br>• If the material is burnt at the end of its useful life, it released a hight amount of $CO_2$ eq. into the atmosphere.<br>• Growing eucalyptus in low rainfall areas may cause adverse environmental impacts due to competition for water with other species.<br>• Extraction can lead to deforestation, landslides, soil degradation, habitat destruction, as well as risks of flooding, flash floods, droughts, and a growing cycle of difficulties.<br>• Transporting wood can further damage forests and rural roads.<br>• Where processing is carried out, poorly managed factories | • Whenever possible, avoid oversizing or specifying too many requirements. Carry out appropriate structural design and calculate wood requirements accordingly.<br>• Minimise wood cuts.<br>• Treat wood properly to ensure its long-term durability. There are certainly several wood treatment recipes that can vary locally depending on product availability.<br>• Minimize the use of wood for formwork (if applicable), prefer reusable modular formwork.<br>• Encourage wood reuse (e.g., door and window frames, structural elements). |

| | | | |
|---|---|---|---|
| | | cause pollution from solid waste, noise, and air.<br>• The use of toxic chemicals for treatment purposes poses risks to the environment and health. | • Cuts of chemically treated wood must be considered hazardous and should never be used as firewood. |
| **Rubble** | • Local stone requires no transportation and doesn't create pollution or waste.<br>• It is a recyclable material.<br>• “Life expectancy” can be very long | • Unplanned rock extraction can lead to landslides and hydrogeological impacts. Without planning or protection, blasting poses occupational risks.<br>• Transporting rocks can affect rural roads.<br>• Extraction can leave large pits that may pose health risks.<br>• Stone construction in earthquake-prone areas must be carried out with seismic design. | • Design and construct properly to ensure long-term durability.<br>• Use stone only in areas where it can be extracted without causing danger or environmental impact.<br>• Employ good storage and loading practices during transportation.<br>• Implement measures to mitigate the negative impacts of extraction, such as erosion control, sedimentation ponds, and proper disposal of waste materials. |
| **Sand and Gravel** | • Sand and gravel are locally available resources in many parts of the DRC, reducing the need for long-distance transportation and associated costs.<br>• Utilising locally sourced sand and gravel can reduce the environmental impact associated with long-distance transportation and extraction from fragile ecosystems. | • Gravel and sand are often illegally extracted from rivers, contributing to erosion and bank displacement, increasing bank slopes, leading to changes in river morphology. Moreover, this can cause riverbank collapses, loss of land and/or adjacent structures, downstream changes in deposition patterns, and destruction of riparian habitats.<br>• Unplanned extraction of gravel and sand can trigger landslides and hydrogeological impacts. | • Before commencing extraction, perform an assessment of potential environmental impacts to understand consequences and implement necessary mitigation measures. |
| **Cement** | • Cement can replace wood as a primary construction material, reducing the demand for timber and helping to combat deforestation.<br>• Cement structures can be less susceptible to soil erosion compared to traditional mud or earth-based construction, which can help prevent land degradation.<br>• Cement structures often have a longer lifespan, reducing the | • $CO_2$ production and impacts on climate change. The cement industry is one of the most polluting sectors. The use of these construction solutions.<br>• Cement production requires substantial amounts of water, and improper water management can lead to local water shortages and environmental degradation. | • Use alternatives to concrete and cement-based products, such as earthen wall if possible.<br>• Use cement efficiently in construction to minimise waste and maximize its benefits.<br>• Never dispose of concrete or cement-based products in the environment. This can be: |

| | | | |
|---|---|---|---|
| | frequency of construction and its associated environmental impacts. | • Cement production requires significant quantities of raw materials, including limestone, clay, and shale, which can lead to resource depletion if not managed sustainably | Reused on-site/off-site for construction purposes (e.g., filling);<br>Safely transported to a construction material recycling space,<br>Safely transported to a controlled landfill site. |
| **Lime** | • Lime production typically generates fewer greenhouse gas emissions compared to cement production, reducing the carbon footprint of construction.<br>• Lime production can be less energy-intensive than cement production, contributing to energy conservation.<br>• Lime can be recycled or repurposed, reducing waste generation.<br>• In some regions of the DRC, lime is readily available, reducing the need for long-distance transportation. | • Excessive lime extraction can deplete local limestone resources, affecting the environment and communities dependent on these resources.<br>• Unregulated lime extraction may lead to habitat destruction, water pollution, and soil erosion.<br>• Improper handling of lime can pose health risks to workers and nearby communities. | • Implement responsible mining practices to mitigate habitat destruction and protect water sources.<br>• Use lime efficiently in construction to minimise waste and maximize its benefits.<br>• Conduct an environmental assessments to understand the impact of lime extraction and construction activities and take appropriate mitigation measures. |
| **Steel** | • Production of steel is the most energy-consuming in the world.<br>• The production of the steel, generated a high amount of *carbon emissions*.<br>• Long-lasting material, which take long time to decompose. | • Can be reused and recycled<br>• "life expectancy" is relative hight. | • Procure steel from reputable suppliers who adhere to sustainable and ethical sourcing practices. Ensure that steel is not linked to illegal mining or deforestation.<br>• Implement stringent quality control measures to verify the quality and strength of the steel used in construction,<br>• Optimise the design to minimise the amount of steel required.<br>• Consider alternative materials or designs that use less steel while maintaining structural integrity.<br>• Encourage recycling and proper disposal practices. |