REPORT

Burundi Environmental Impact Study of the House Model “Maison Adobe Type Muyinga”

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: Burundi Environmental Impact Study of the House Model “Maison Adobe Type Muyinga”

Countries: Burundi

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 DRC and Madagascar, will also be included in this ongoing research.

Since 2009, AICRL has been working in Burundi, in partnership with the Burundi Red Cross (CRB). They have been particularly committed to build sustainable homes in Muyinga for returning refugees from Tanzania and Rwanda. This project, accumulating substantial technical knowledge through various research and training missions, has resulted in the creation of the "Maison Adobe Type Muyinga." Developed with the Muyinga branch of the CRB since 2017. A total of 965 houses have been built in Gietrang and Gashoho. Each 44.8m² house is constructed with family-made adobe bricks and soil mortar, featuring a two-sloped metal roof supported by eucalyptus wood, all set on a foundation of adobe bricks, cement, sand and stones.

Field experience and feedback have allowed AICRL to refine their housing models. However, a detailed analysis of the environmental impact of these models is still pending. This analysis is crucial to identify the model best suited for each local context, aligning with global efforts to enhance the environmental sustainability of humanitarian aid.

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] And in the last decade, events tied to weather conditions have led to an annual average of 21.5 million new displacements, this is over double the number caused by conflicts and violent incidents.[19] The 2021 Climate Risk Index[20] indicates

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*
19 *Displaced on the frontlines of the climate emergency (arcgis.com)*
20 *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*

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.[21]

Though Africa only contributes 4 percent of global greenhouse gas emissions, it is significantly affected by climate change, impacting lives, livelihoods, and economies across the continent. Burundi, despite contributing less than 0.02 percent of global emissions,[22] is highly vulnerable to climate change, ranking 169th out of 185 countries on the Notre Dame Global Adaptation (ND-GAIN) Index in 2021.[23]

Burundi, classified as Least Developed Country[24], and one of the most densely populated nations in Africa, faces significant challenges. This includes extreme poverty (affecting approximately 75 percent of its 11.6 million residents) and reliance on subsistence farming (86 percent of the population). The country's economy heavily relies on natural resources and sectors susceptible to climate influences.[25] Less than 20% of its population resides in urban areas, with the majority living in traditional rural setups. Housing is mostly dispersed, isolated on the hills called as “*collines*”, each of which constitutes a traditional social and administrative unit.

While Burundi has experienced historical displacements due to conflict, climate-related hazards, like torrential rains, floods, and landslides, are now the primary reasons for internal displacement,[26] affecting vulnerable groups such as children, women, the elderly, internally displaced persons (IDPs), refugees, and individuals with disabilities. As of May 2023, 89 percent of IDPs fled due to disasters, as reported by the International Organization for Migration (IOM).[27]

Institutions in Burundi struggle to manage the new environmental and climate risks due to high poverty levels and reliance on agriculture, making the country extremely vulnerable. With climate change exacerbating existing problems through increased rainfall and temperature variations, the frequency of floods, landslides, and soil erosion is expected to rise, adversely affecting lives and exacerbating poverty in the nation.[28]

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 Burundi house model is a contribution to the growing body of work on the environmental impact of humanitarian assistance.

21 *Global Climate Risk Index 2021*
22 *Burundi | Climate Promise (undp.org)*
23 *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)*
24 *Human Development Index | Human Development Reports (undp.org)*
25 *Tackling Climate Change, Land Degradation and Fragility: Diagnosing Drivers of Climate and Environmental Fragility in Burundi’s Colline Landscapes: Towards a Multi-Sector Investment Plan to Scale up Climate Resilience World Bank Advisory Services and Analytics (ASA) Final Report World Bank Document*
26 *Tackling Climate Change, Land Degradation and Fragility: Diagnosing Drivers of Climate and Environmental Fragility in Burundi’s Colline Landscapes: Towards a Multi-Sector Investment Plan to Scale up Climate Resilience World Bank Advisory Services and Analytics (ASA) Final Report World Bank Document*
27 *IOM Burundi Internal Displacement Dashboard - May 2023*
28 *World Bank scales up climate change investments in Burundi | World Economic Forum (weforum.org)*

Map showing the location of the “Maison adobe type Muyinga” built in Burundi, by AICRL in partnership with Burundi Red Cross

4. Outcome and Outputs

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

Outputs
- A study of the environmental impact of the house model “Maison Adobe Type Muyinga” in Burundi.
- 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.

5. Methodology

These studies were conducted remotely, with the support of AICRL field staff; environmental experts from the shelter sector. A local association, organisation, etc that specialises in ecological recycling and waste recovery in the region and an environmental organisation that specialise in the protection of forests and ecosystems in Burundi,[29] were contacted for this study, but without success.

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 DRC and Madagascar, each detailed in a separate country report. [30]

29 *Refer to Annex 1 to see the list of people and organisations contacted.*
30 *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 Burundi 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 houses 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.
- Extended engagement with the focal point for the Shelter Cluster Environmental Community of Practice, regarding using the SMAC.

Set Criteria

- Set criteria to compare the environmental impact of the shelter models:
  - (1) Materials consumed
  - (2) Carbon emissions (using the SMAC tool)
  - (3) Local natural resource environmental impact
  - (4) Waste management
- Scorecard Approach

Analysis

- Environmental 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

BURUNDI

Location

A landlocked country in East Africa. Located in the Great Lakes region, it is surrounded by Rwanda to the north, Tanzania to the east, the Democratic Republic of the Congo to the west, and bordered by Lake Tanganyika to the southwest.[31]

Population

Burundi has an estimated population of 12.5 million people.[32] It is one of the most densely populated countries in the world. It is currently growing at a rate of 2.87% per year.[33]

Economic and social situation

Burundi's Human Development Index[34] (HDI) score was 0.426 in 2021, which categorizes the country as having a low level of human development. It ranks 187th out of 191 countries.[35]

Crisis overview

While the humanitarian situation in Burundi remains concerning, there has been a slight improvement over the past year. The number of people in need decreased by 21%, dropping from 2.3 million in 2021 to 1.8 million in 2022. However, various factors such as natural disasters, inflation, and the socioeconomic impacts of the COVID-19 pandemic continue to leave the population vulnerable. Additionally, a significant portion of IDPs and returning citizens lack access to essential services and receive limited assistance, increasing their susceptibility to exploitation and gender-based violence. The absence of long-lasting solutions also hinders efforts to prevent future displacements. Since gaining independence in 1962, Burundi has grappled with periods of instability and conflict.[36]

Climate

The climate of Burundi is equatorial in nature, and is marked by high mean annual temperatures, small temperature ranges, and rainfall throughout the year. The country’s generally high elevation produces relatively cool temperatures, which average only about 21°C throughout the year in the central plateau area and usually drop to below 15°C at night. At lower elevations the annual average is only slightly higher. Annual precipitation, which averages 1,500 to 1,800 mm in the highest-lying areas, is only about 1,000 mm on the shores of Lake Tanganyika. There is a short dry season from May to August.[37]

31 *World Bank*
32 *Population, total - Burundi | Data (worldbank.org)*
33 *Burundi Population 2023 (Live) (worldpopulationreview.com)*
34 *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)*
35 *Specific country data | Human Development Reports (undp.org)*
36 *European Commission. Burundi (europa.eu)*
37 *Burundi | History, Geography, & Culture | Britannica*

6.2. Burundi environmental challenges

Environmental Challenges

Climate change
Burundi faces severe climate change impacts, including rising temperatures, changed rainfall patterns, and frequent extreme weather events. These effects lead to population displacements and worsen food insecurity due to high population density.

Increasing Temperature
Between 1979 and 2018, Burundi's average temperature increased by 0.31°C per decade. Hot days have become more intense, and cold nights have moderated. Future climate projections suggest that Burundi may be 0.5–1.0°C warmer, on average, between 2040 and 2060.[38] This aligns with global climate change trends.

Floods
Burundi has naturally variable rainfall, but extreme precipitation appears to be occurring more frequently according to recent research. The substantial risks of flooding, attributed to intense rainfall and the overflow of lakes and rivers, have far-reaching consequences for individuals, infrastructure, and land erosion. [39]

Land degradation and soil erosion
Burundi experiences an annual soil loss of nearly 38 million tonnes. Between 2017 and 2020, over 33,000 hectares of land, about 1.2% of the country's total land area, suffered severe degradation, including 10,800 hectares of productive land (1% of the total area). Soil erosion is worsening, and if present trends continue, sediment loss could rise by 69% by 2030 and potentially double by 2050 compared to 2020 levels. [40]

Deforestation
Burundi witnessed extensive deforestation during the years of conflict, and the ongoing transformation of land for agricultural purposes, demand for firewood, population pressure, has resulted in the country having less than 10 percent of its land covered by forests.[41]

Solid waste
Burundi 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 supply
Pollution of freshwater sources is a significant concern. It results from agricultural runoff, inadequate sanitation facilities, and industrial activities. This pollution has adverse effects on aquatic ecosystems and public health.

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38 *Tackling Climate Change, Land Degradation and Fragility: Diagnosing Drivers of Climate and Environmental Fragility in Burundi’s Colline Landscapes: Towards a Multi-Sector Investment Plan to Scale up Climate Resilience World Bank Advisory Services and Analytics (ASA) Final ReporWorld Bank Document*
39 *Tackling Climate Change, Land Degradation and Fragility: Diagnosing Drivers of Climate and Environmental Fragility in Burundi’s Colline Landscapes: Towards a Multi-Sector Investment Plan to Scale up Climate Resilience World Bank Advisory Services and Analytics (ASA) Final ReporWorld Bank Document*
40 *Tackling Climate Change, Land Degradation and Fragility: Diagnosing Drivers of Climate and Environmental Fragility in Burundi’s Colline Landscapes: Towards a Multi-Sector Investment Plan to Scale up Climate Resilience World Bank Advisory Services and Analytics (ASA) Final ReporWorld Bank Document*
41 *Tackling Climate Change, Land Degradation and Fragility: Diagnosing Drivers of Climate and Environmental Fragility in Burundi’s Colline Landscapes: Towards a Multi-Sector Investment Plan to Scale up Climate Resilience World Bank Advisory Services and Analytics (ASA) Final ReporWorld Bank Document*

Air Pollution
In accordance with the World Health Organization's (WHO) guidelines, the air quality in Burundi is considered unsafe. The most recent data indicates the country's annual mean concentration of PM2.5 exceeds the recommended maximum of 10 µg/m3[42]. Contributors to poor air quality in Burundi include the use of biomass (e.g. wood, crops, straw) for energy in households, industrial pollution, household and agricultural waste burning.

6.3. Burundi house model

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

MAISON ADOBE TYPE MUYINGA

The "Maison Adobe Type Muyinga" is designed as a sustainable housing solution, with the assistance of the Muyinga branch of the Burundi Red Cross. Built since 2017 in the Muyinga region.

This model has a total surface area of 44.8 m^2 and is constructed from adobe bricks made by families. The mortar is made from soil. The roof has two slopes covered with metal roofing and has a structure made of eucalyptus wood. The foundation is composed of adobe bricks and a sub-base made of cement, sand and stones.

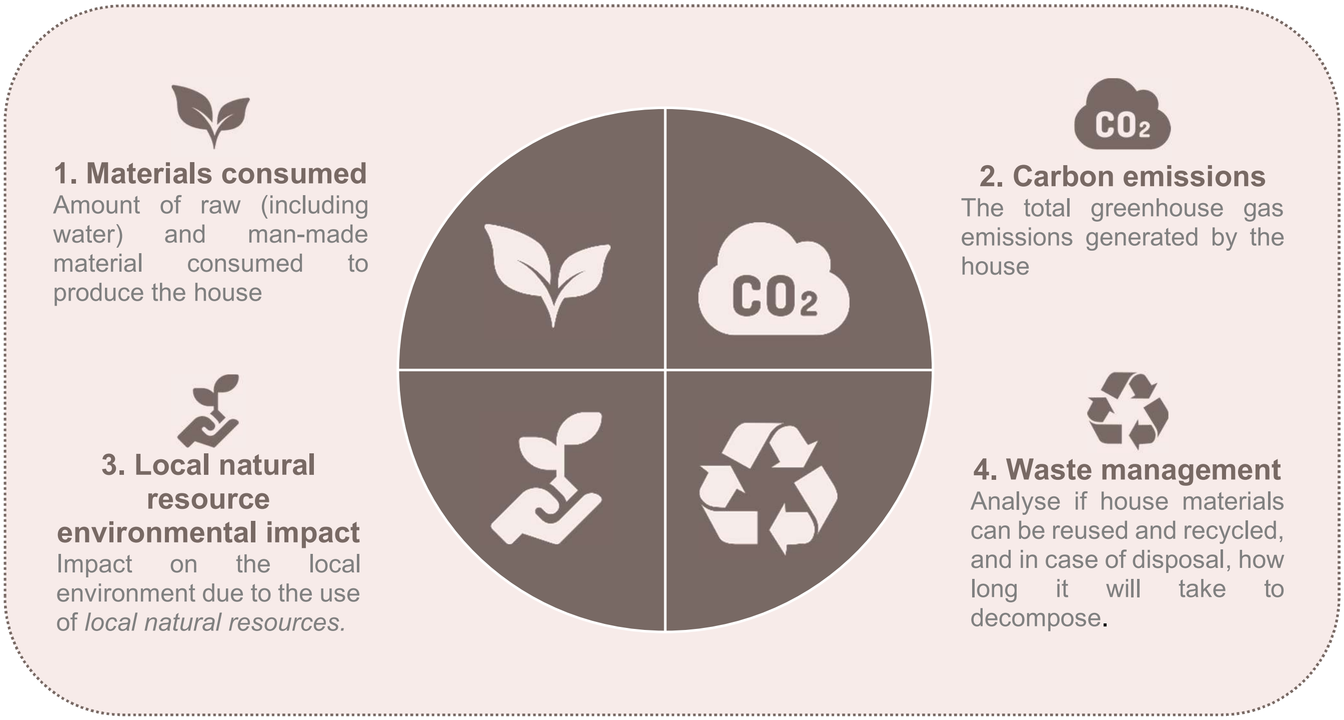
42 *WHO ambient air quality database, 2022 update: status report*

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. *Local natural resources environmental impact*
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[43] 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.

43 *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 percent in less than 200 years.[44] 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[45] generated by the houses, and identify solutions to reduce these emissions. To do so, it is required to do a life cycle analysis (LCA).[46]

Carbon calculator tool – SMAC tool

The carbon calculator tool used in the study is the SMAC[47] (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”*[48]

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[49]
- The type of packaging used for the materials[50] and the amount of each packaging material used (in kg) for each house.

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44 *NASA*
45 *A carbon footprint is the total greenhouse gas emissions caused by an individual, event, organization, service, place or product, expressed as carbon dioxide equivalent (CO2 equivalent).*
46 *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.*
47 *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.
48 *SMAC uses assumptions about the level of recycling and CO2 eq. released at the ‘end of life’, meaning when the material has reached the end of its useful life, based on standard construction practices for each material. However, the actual portion of each material that is recycled at ‘end of life’ may be overestimated in the CO2 eq. calculation, according to the SMAC developers. This means that the carbon emissions calculated from ‘end of life’ are probably underestimated.*
49 *Refer to Annex 3 to find the information regarding house material and quantity in kilograms.*
50 *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)[51].

For this model 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[52] 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.

An environmental organisation that specialises in the protection of forests and ecosystems in the Burundi was contacted for this study, but without success. [53] Literature review[54] 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.

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51 *The average transport distances have been estimated and can be found in Annex 4.*
52 *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.*
53 *Refer to Annex 1 to see the list of people contacted.*
54 *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[55]. 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.

Efforts to contact local private companies specialising in ecological recycling and waste recovery within the country,[56] were not successful. Literature review[57], feedback from the project teams and environmental experts from the shelter sector[58] 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.

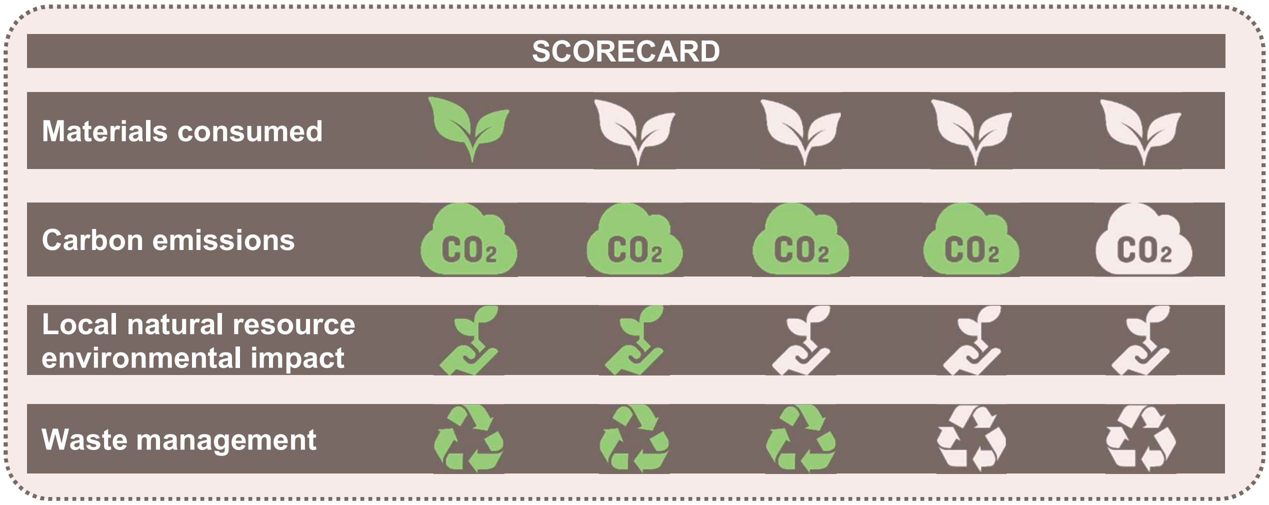
A simple scorecard also recognises the challenge to apply any kind of numerical weighting for the four criteria in order to arrive at a calculated score per house. This would require too many assumptions on the relative weight of each criterion. Instead, a qualitative conclusion can be made based on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

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

55 *EU Commission, 2014*
56 *Refer to Annex 1 to see the list of people contacted.*
57 *Refer to biography*
58 *Refer to Annex 1 to see the list of people contacted.*



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[59]

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.

Grevillea trees, native to Australia and found in New Guinea and parts of Indonesia, are evergreen flowering plants used for landscaping, timber, erosion control, fuel, and agroforestry, etc due to their versatility.

General environmental impacts

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 Grevillea.

Habitat and Biodiversity: Grevillea trees can provide habitats for wildlife. Grevilleas are good bird-attracting plants. They are also used as food plants by some insects.

Soil erosion and deforestation: 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.

Invasive Species: In some cases, Grevillea species introduced to new areas may become invasive and outcompete native vegetation, leading to ecological imbalances. Like in South Africa and USA.[60]

59 *Silviculture of eucalyptus plantings – Learning in the region. K.J. WHITE. FAO*
60 *GISD (iucngisd.org)*

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.[61]

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

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.[62]

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[63]

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 covers 70% of our planet, however, only 3% is fresh water. [64] with billions lacking access. Water is crucial for sustainable development, socio-economic progress, healthy ecosystems, and human survival. [65]

Environmental impacts

Water shortage; Water shortages are likely to be the key environmental challenge of this century.[66] 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.

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61 *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.*
62 *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.*
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.*
64 *WWF*
65 *www.un.org/waterforlifedecade*
66 *www.un.org/waterforlifedecade*

Agriculture; consumes more water than any other source, 70% of the world’s accessible freshwater, and wastes 60% of it, much of that through inefficiencies due to leaky irrigation systems, inefficient application methods as well as the cultivation of crops. [67]

Water pollution; comes from many sources including pesticides and fertilizers that wash away from farms, untreated human wastewater, and industrial waste.[68]

Climate change; is altering patterns of weather and water around the world, causing shortages and droughts in some areas and floods in others. [69]

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[70]

Greenhouse effect: It accounts for about 5% of global CO_2 emissions due to its large-scale energy intensive production.[71]

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.[72]

General environmental impacts[73]

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

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

Greenhouse effect; Steel production is responsible for the emission of 3,3 million tons of CO_2 annually.[74] Steel production is responsible for the emission of 3,3 million tons of CO_2 annually.[75] It accounts for about 7-9% of global CO_2 emissions.

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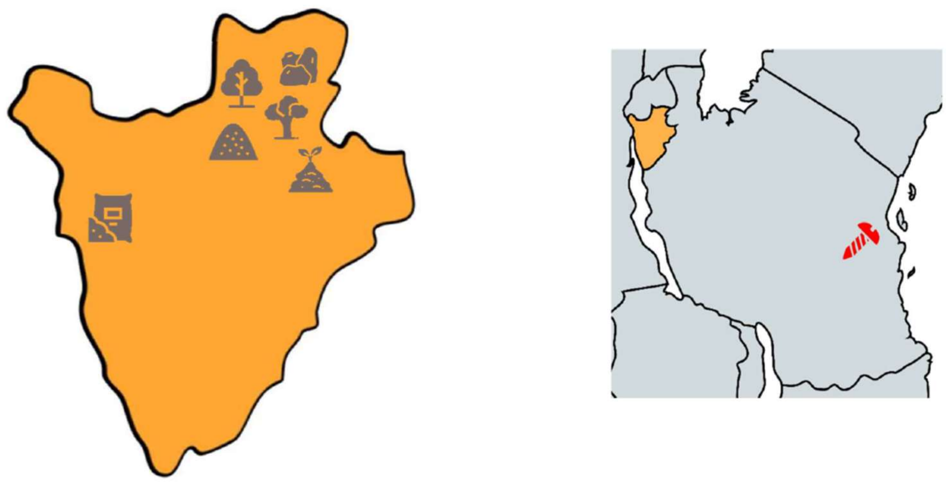
67 *NASA*
68 *University of Dundee*
69 *WWF*
70 *Hettiarachchi M., Dwivedi V., Miller W.M, Carr S.H, Dunn J.B., McMahon M.M and Van Breda A. Building Material Selection and Use: An Environmental Guide, 2nd Ed. World Wildlife Fund, Washington DC and Northwestern University, Evanston IL.*
71 *shelter and sustainability overview-UNHCR.pdf*
72 *The world counts*
73 *The world counts*
74 *The world counts*
75 *The world counts*

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 (cement) 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.

Table 1 - Amount of materials used by the house model

House model	*Materials*	Amount
Maison adobe type Muyinga	Water	
	Timber	
	Soil	
	Rubble	
	Sand	
	Cement	
	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*

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 is the most significant in quantity, follow by timber, 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.

Even though the house model uses a small quantity of materials like cement and steel compared to soil and timber, it's crucial to minimise their environmental impact. Also, steel has a high level of embodied water per kilogram compared to the other materials used. This could be achieved by considering sustainable alternatives, such as using recycled or low-impact materials like plant-based roofing, such as fibres, grass straw, or banana leaves, which are commonly used for thatching and is widely available and popular in use[76]. However, this encounters challenges. According to the local team, grass and banana leaves are scarce due to diminishing cultivable land caused by rapid population growth. Moreover, banana plants are at risk due to various phytosanitary[77] challenges.

76 *Rapport de mission Burundi. Amélioration de la résilience des populations vulnérables aux aléas naturels et sociaux économiques. 2019. CRA terre*
77 *Phytosanitary refers to the measures and practices related to plant health and the prevention of the spread of pests, diseases, and pathogens that affect plants*

Additionally, the government's policy advocates for modern housing without thatch, further complicating the adoption of alternative roofing materials. Another alternative is to optimise construction techniques to reduce material usage.

How to improve the *materials consumed* score

Consider using recycled or low-impact materials instead of CGI and optimise construction techniques to reduce material usage.

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

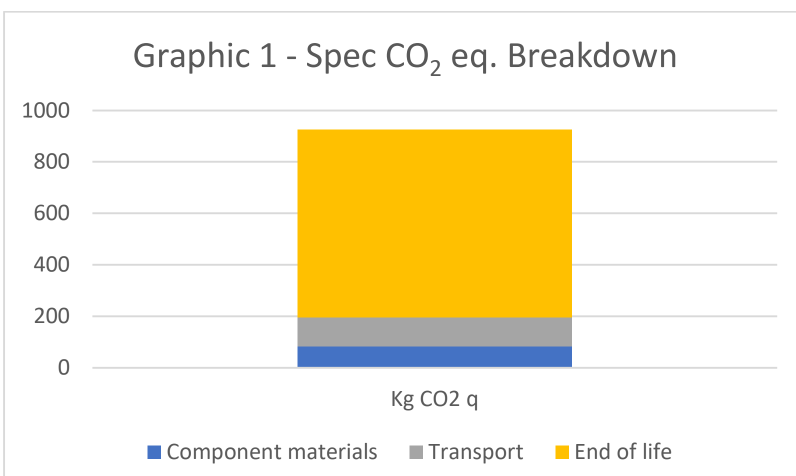
Ensure that the quantity of adobe brick and stones used is minimised without affecting the structural integrity of the house.

8.2. Criteria 2: *Carbon emissions*

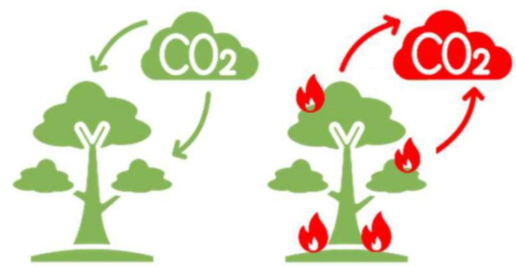
8.2.1. *Carbon emissions* of the house model

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.

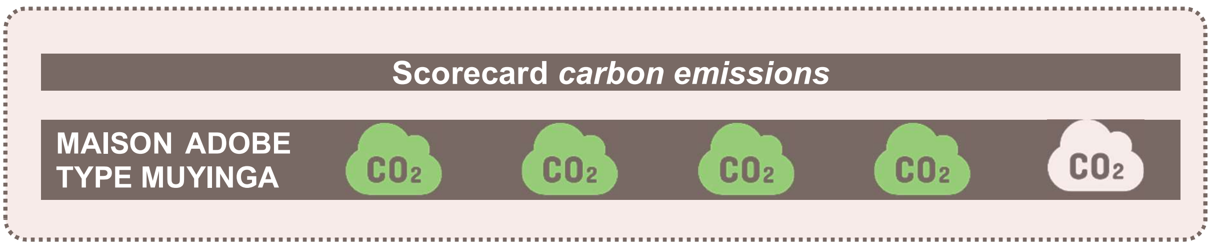
The following Graphic 1 show the breakdown of the *carbon emissions*.



It is important to explain why there are significant carbon emissions generated from the “*end of life”* phase. It is because the house model use a considerable amount of wood. The reason for these emissions is that the SMAC tool assumes that these materials are burnt at the end of their useful life, which is the case here, releasing the carbon emissions that were sequestered in the materials while growing. However, if these natural materials are left to decompose, or composted, these emissions would be eliminated resulting in even lower total emissions for the house model.



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 *“end of life”* are significant compared to *“transport”* the second contributor, followed by *"component material”.* This is primarily due to the extensive use of wood in the house. As previously explained, the SMAC tool assumes that natural materials like wood are burnt at the end of their useful life. As confirmed by the local team, this is indeed the case here, resulting in a relatively high level of CO_2 eq. emissions released into the air. However, if these materials were instead disposed of in an open field, the carbon emissions at the *"end of life"* phase should be reduced to zero, leading to a lower overall carbon footprint.

The “*component material”* phases do not generate a substantial amount of emissions. This is also attributed to the significant amount of wood used, as wood captures carbon during its growth, offsetting the carbon emissions of other materials that would generate higher carbon emissions. Therefore, when evaluating the materials as per Annex 6, the adobe bricks are the largest contributors to carbon emissions. Despite their inherently low embodied carbon emissions per kilogram, the substantial quantity used significantly amplifies their overall environmental impact. Nevertheless, choosing adobe bricks is still a favourable option; using alternative materials such as Compressed Earth Block (CEB)[78] or clay bricks would have led to substantially higher embodied carbon emissions.[79] Additionally, CGI sheets, though used in smaller quantities, have a pronounced effect on emissions due to their high embodied CO_2 eq. emissions, which are the highest among all the materials used, followed by cement.

78 *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.*
79 *Guide de Reference ABRIS-ANA Burundi. 2019. Croix-Rouge luxembourgeoise*

Moreover, the CGI materials are transported from Tanzania, which generates a significant amount of emissions during transportation.

How to improve the *carbon emissions* score

Ensure that the natural materials like wood are not burnt at the end of their useful life, and are composted instead.

Procure CGI (corrugated galvanized iron) that is locally produced, if possible, to reduce emissions from transport.

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

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

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. Additionally, it's important to note that scale plays a role in environmental impact. Perhaps in smaller quantities, the impact may be insignificant and therefore considered acceptable.

In Burundi, rapid population growth has given rise to a pressing issue: the excessive use of natural resources, particularly wood. Over time, deforestation has become a deep concern, exacerbated by rapid forest loss during past conflicts, which has left the country with less than 11 percent forest cover. [80] This deterioration of Burundi's forests results from various factors, including unregulated exploitation of forest resources, recurrent bushfires, forest clearance for agricultural purposes, overgrazing, climate change, and heavy reliance on wood for cooking, with approximately 95 percent of households using firewood for domestic energy. [81] [82]

Environmentally, deforestation in Burundi leads to soil erosion, which reduces soil fertility and agricultural productivity. This negatively impacts food security, as agriculture is a primary livelihood for many Burundians, Over 90 percent of the population relies on agriculture.[83] Additionally, the loss of forested areas results in habitat destruction and biodiversity loss, threatening unique and vulnerable species. The degradation of forest ecosystems also contributes to issues like increased sedimentation in rivers and lakes, negatively affecting water quality and aquatic ecosystems. Additionally, trees and vegetation play a protective role against landslides and floods. These natural evens are expected to worsen in Burundi due to the effects of climate change, exacerbating the problem.

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.

To tackle some of these challenges, the government has initiated the national reforestation project "Ewe Burundi Urambaye," with the primary objective of reforesting all deforested areas nationwide to protect terrestrial ecosystems and forests.[84] Therefore, in the effort to mitigate deforestation and land degradation, it is imperative to carefully assess the use of local natural resources in construction. This analysis should prioritise sustainable practices that strike a balance between meeting construction needs and preserving the environment in Burundi.

80 *https://data.worldbank.org/indicator/AG.LND.FRST.ZS?locations=BI*
81 *Burundi: pourquoi la persistante déforestation malgré tous nos efforts ? (yaga-burundi.com)*
82 *Burundi Eco La déforestation, un défi difficile à relever - Burundi Eco (burundi-eco.com)*
83 *Burundi Eco La déforestation, un défi difficile à relever - Burundi Eco (burundi-eco.com)*
84 *https://sdgs.un.org/partnerships/national-reforestation-project-ewe-burundi-urambaye*

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 were made to contact a local environmental organisation in the country without success.[85]

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[86] 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.[87]

Environmental issues[88]

- 30 % of global tree species are threatened with extinction. And over the past 300 years, the global forest area has decreased by about 40%.
- The main threats to tree species are forest clearance and other forms of habitat loss, direct exploitation for timber and other products. Climate change, like fire, extreme weather and sea level rise, is also having a clearly measurable impact.
- Around 25% of global emissions come from the land sector. About half of these come from deforestation and forest degradation.
- In total, between 1990 and 2010, Burundi lost 40.5% of its forest cover.[89]
- About 6% of all land in Burundi is forested, totalling 152,000 hectares, of which 14% are natural forests and the remaining 86% are forest plantations.[90]
- The 14% remaining natural forests is protected by law and are prohibited from being exploited for timber.
- A high population growth rate puts pressure of the few remaining forest lands.

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.

Eucalyptus timber is used in the house model as the structure for the roofing.

85 *Refer to Annex 1 to see the list of people contacted.*
86 *Forests and climate change. IUCN*
87 *Forests and climate change. IUCN*
88 *State of the World's Trees. Sept 2021. Botanic Gardens Conservation International*
89 *Safe Access to Fuel and Energy in Burundi An Appraisal Repor. WFP docs.wfp.org/api/documents/WFP-0000019952/download/*
90 *Rapport de mission Burundi. Amélioration de la résilience des populations vulnérables aux aléas naturels et sociaux économiques. 2019. CRA terre*

The introduction of the eucalyptus was in the 1950s in African countries.[91] 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.[92]
In Burundi, one of the most common types of eucalyptus is Eucalyptus globulus. This species is not native to the region but has been widely planted due to its adaptability and usefulness. It's commonly used for various purposes, including construction, firewood, and sometimes for medicinal uses due to its essential oils.

The use of eucalyptus wood in Burundi 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.

Grevillea wood is used in the house model to made door and window panels. Grevillea tree, is not native to Burundi, it's often planted for purposes such as timber, fuelwood, shade, soil conservation, and sometimes as ornamental trees.

Grevillea it is listed as invasive and potentially invasive in many regions worldwide.[93] Using Grevillea wood in Burundi poses environmental concerns such as potential overexploitation leading to deforestation and habitat degradation. Although non-native, Grevillea might impact local biodiversity adversely if not managed properly. The species might also affect soil composition and water usage in certain areas. Challenges also include the need for careful management, planning in plantation, harvesting, and waste generated during wood processing.

Soil is used in the house model to make home bricks and mortars. Families directly source it from their land to build the houses. Adobe bricks, used since the late 19th century, became widespread in Burundi in the 1950s. The 2008 census shows that adobe constructions are predominant in the country (59.5%), except in the Kirundo and Muyinga regions. [94]

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.

Sand and gravel are used in the house model to make the sub-base along with cement and mortar. These materials are sourced by extracting them from rivers. Transportation can cover distances up to 40 kilometres.

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.

91 *Expansion, research and development of the eucalyptus in Africa Wood production, livelihoods and environmental issues: an unlikely reconciliation. Dominique Louppe and Denis Depommier. 2010*
92. *Chaojun Chu, P.E. Mortimer, P.E. Mortimer, Hecong Wang, Yongfan Wang, Xubing Liu, Shixiao Yu. 2014*
93 *https://www.cabidigitallibrary.org/doi/10.1079/cabicompendium.25866*
94 *Rapport de mission Burundi. Amélioration de la résilience des populations vulnérables aux aléas naturels et sociaux économiques. 2019. CRA terre*

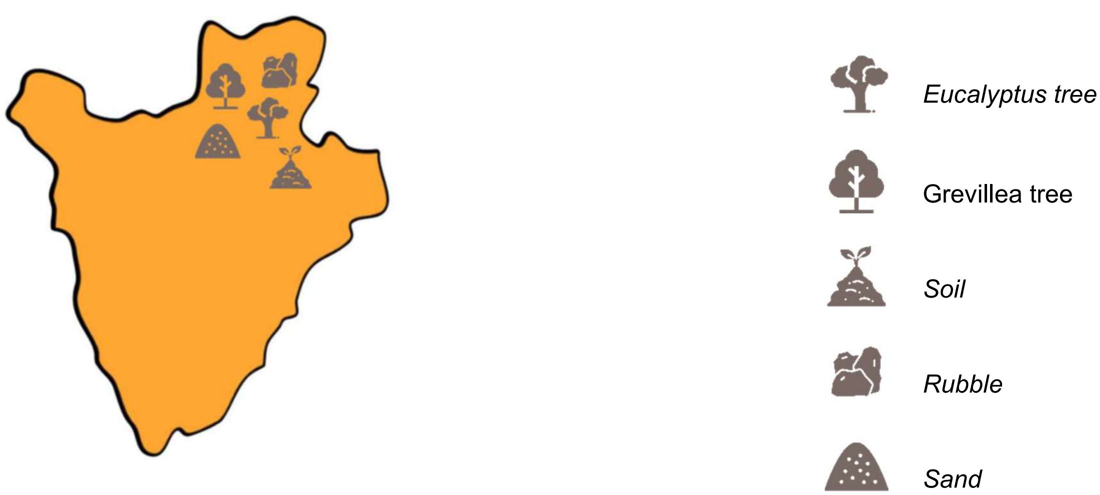
8.3.3. Quantity of the *local natural resources* in the house model

The follow Table 2 shows a simplified representation of the amount of *local natural resources* used by the house model. Please refer to Annex 7 to see the actual quantities of the *local natural resources* used by the house model in kilograms. The data was provided by the AICRL logistics teams in each country.

This assignment gives the maximum amount (soil) a score of 10 points and the minimum amount (grevillea tree) a score of 1 point, with scores for the other materials falling in between based on their amounts relative to the maximum and minimum.

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

House model	*Local natural resources*	Amount
Maison adobe type Muyinga	Eucalyptus tree	
	Grevillea tree	
	Soil	
	Rubble	
	Sand	



Map of the source of the natural resources used

8.3.4. Scorecard for impact on *local natural resources*

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. As per one report, [95] in Burundi, it's common to find several pits on plots of land where earth has been dug up to make adobe bricks. These pits pose risks to children and animals, and during the rainy season, they can become breeding grounds for mosquitoes. The edges of these pits are often unstable due to the steep sides, so it's vital not to dig them near any existing or future buildings. Encouraging people to extract clay for adobe bricks by levelling the land in a way that manages rainwater and supports farming would be wise. Terrace farming is recommended over slope farming to reduce soil erosion, a major concern in Burundi. The fertile topsoil should be preserved and then spread back over the area after digging is done. Each situation involving excavation must be carefully managed, especially when trying to preserve the natural vegetation. So it is crucial to implement sustainable practices, such as erosion control, proper site selection, and soil conservation.

The second-largest materials in terms of quantity used in the model are sand and rubble. The local team reports that sand is readily available throughout the region, necessitating transport over distances of roughly ten kilometres. These materials are typically sourced from the beds of rivers and alluvial plains. Additionally, quality rubble is easily found in mountainous areas, particularly in places like Muyinga.[96] However, excessive extraction of sand and stone can lead to significant environmental issues, such as alterations to the landscape and changes to river courses, which may have lasting effects on both the natural world and local communities. It is vital to incorporate measures to mitigate the risks of habitat disruption, erosion, pollution, and land degradation. Such measures should be an integral part of construction and quarrying practices to minimise their impact on the local environment.

The house model employs eucalyptus as its primary hardwood timber, and grevillea wood for doors and windows, ensuring the exclusion of tropical wood and sourcing only from official providers. Eucalyptus offers specific benefits but also has associated environmental concerns such as its high water consumption, potential for soil degradation, loss of biodiversity, creation of monocultures, risk of becoming invasive, and negative impacts on local community land use. The local team notes that the eucalyptus used is sourced from private plantations with sustainability practices in place. These practices should include harvesting methods that allow the trees to regrow substantially over time, thereby avoiding all the environmental concerns as explained above. However, exploring eco-friendlier

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95 Guide de Reference ABRIS-ANA Burundi. 2019. Croix-Rouge luxembourgeoise
96 Guide de Reference ABRIS-ANA Burundi. 2019. Croix-Rouge luxembourgeoise

alternatives like bamboo is always encouraged. Despite the local team's view of Burundi's bamboo as low quality,

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

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 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.

Ensure that the use of eucalyptus and grevillea wood does not lead to the loss of native forests in Burundi, and if so, consider to use different material. 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.

Continue with reforestation and forest protection initiatives, as well as endorsing and collaborating with capable local organizations to facilitate these projects in the pertinent areas is crucial. It's worth noting that these efforts not only help offset the total carbon emissions produced but also contribute significantly to the safeguarding of the local ecosystem.

reports suggest its use in construction in Burundi and roofing[97] Further exploration of this alternative is recommended.

What is clear is that these resources offer various benefits, 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.

It is important to note that the Luxembourg Red Cross has implemented key mitigation measures to address environmental issues, such as tracing contour lines for erosion control, planting soil-binding grasses, establishing nurseries for plant cultivation, introducing agroforestry trees for ecological stability, and planting fruit trees for sustainable agriculture. These practices are highly beneficial and it is recommended that they continue.

97 *Rapport de mission Burundi. Amélioration de la résilience des populations vulnérables aux aléas naturels et sociaux économiques. 2019. CRA terre*

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.

The analysis suggests that there is no well established *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. However, it is important to highlight that each household is required to have a compost bin for organic waste management. Although the local team indicates that adherence to this requirement is not consistent. Additionally, it is mandatory for community members to commit half a day each week for communal work, which is aimed at maintaining public spaces and streets. Non-participation could lead to a monetary fine. [98] Yet, reports from the team suggest that enforcement of this rule is inconsistent, stating: *"While participation in the scheduled maintenance day for public areas is obligatory, the application of penalties is at the discretion of the officials. In some cases, those who do not partake in communal work may face restrictions on access to certain services. The decision to enforce such consequences is based on the moral discretion of the local base administrative authority, and there are no legal texts governing this activity."*

Forward-thinking regarding waste management should be a priority for all programs, considering various initiatives that could be implemented. This should also include the handling of packaging for materials and other items purchased. Packaging is a clear source of waste, but it is also one of the simpler problems to mitigate. Strategies to reduce waste from packaging include minimising packaging materials, switching to biodegradable options, and completely eliminating single-use plastics.

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 Burundi,[99] according to ideas shared by some of the interviewees.

According to the 2019 Guide de Référence Abirs-ANA Burundi, there is a steel recycling plant producing rebar and nails of moderate quality, and a facility that transforms imported steel plates into construction products located in Musamba. This information could not be verified during the study, but further investigation into these initiatives is recommended. The local team has also confirmed that there are some steel recycling initiatives. Contact information for this organization was provided; however, attempts to reach out have been unsuccessful.

98 *Rapport de mission Burundi. Amélioration de la résilience des populations vulnérables aux aléas naturels et sociaux économiques. 2019. CRA terre*
99 *Refer to Annex 1 to see the list of people contacted.*

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 Muyinga			

The *Global Joint Initiative on Sustainable Humanitarian Assistance Packaging Waste Management*[100] 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. However, Burundi is no covered at the moment.[101]

JI has also created a guide of best practices and innovations in packaging waste management in humanitarian operations. However, at the moment, none of these innovations have been implemented in Madagascar. Nonetheless, it serves as a basis for examples of what can be done.[102]

On the questions of packaging and single-use plastics, Burundi issued a decree in 2018 that prohibit the manufacture, importation, marketing, and use of plastic bags and other plastic packaging.[103] However this not well enforced. The field teams confirmed some materials come packaged in single-use plastic.[104] Attempts could be made to eliminate this, in discussion with suppliers.

8.4.3. Scorecard for *waste management*

Scorecard *waste management*	
MAISON ADOBE TYPE MUYINGA	

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

The house scores 4 out of 5. Mostly because the house model uses mostly materials that will decompose quickly and will not generate waste and pollution, like adobe bricks, soil mortar, and wood (if the wood is left to decompose and not burnt). Other materials like rubble and sand won't pollute either at the end of their useful life.

100 *Information can be found at https://eecentre.org/2019/07/15/https-www-eecentre-org-2019-07-15-sustainable-humanitarian-packaging-waste-management/*
101 *The information is then uploaded onto the Global Logistic Cluster LCA; https://dlca.logcluster.org/display/public/DLCA/LCA+Homepage.*
102 *OPTIONS FOR HUMANITARIAN PACKAGING REUSE, REPURPOSING, AND RECYCLING (eecentre.org)*
103 *Information can be found at Maps – plasticpollutioncoalition (plasticpollutioncoalitionresources.org)*
104 *Refer to Annex 3*

As can be seen in Annex 8, most of the materials possess some local potential for reuse or recycling. For instance, adobe bricks, being the most extensively used material, can be 100% 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, it's essential to minimise the consumption of the other products that produce long-lasting waste in landfills. From this viewpoint, one of the major concerns in this model are the steel products and the cement/concrete. If these materials are used, it's vital to have a waste management strategy in place for their potential reuse or recycling once they are no longer in use. The existing program doesn't incorporate any of these strategies, leaving the responsibility of waste management to local communities and governments. As a result, some of these materials often end up discarded in open fields, harming the environment. On a brighter note, it seems from the feedback from the team that the steel products are sold to private companies for recycling. Such initiatives are highly positive, and it's beneficial to continue encouraging them.

On top of this, a few products, like the wire, bolts and screws, come in single-use plastic packaging. It's essential to minimise this practice wherever possible.

Another consideration to reduce waste is by prolonging the life expectancy of the house, and, consequently, the materials. This can be achieved by using good quality materials and construction practices. This is of utmost importance. Poor construction not only poses safety risks but also increases the material turnover period, further exacerbating the environmental impact of house construction. While the current life expectancy of the house is reasonably satisfactory, 30 years according to the field team, measures to enhance its durability should be always actively promoted. Therefore, advocating for superior construction standards is essential in every programme.

Based on the information shared with the team, it appears that the programme does not incorporate any protective measures to safeguard the adobe walls, such as the use of lime, as observed in the case of the adobe houses in the DRC program. According to the team, households employ plastering techniques involving materials such as red clay, limestone, and plant residues to both protect and adorn their homes. It is strongly recommended that the programme actively promotes this practice and ensures that families are executing it correctly while using the appropriate materials.

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.

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.

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

Attempt to locate the steel recycling facility in Burundi, which produce rebar and nails. Confirm the facility's existence and evaluate the quality of the recycled steel materials. Explore potential collaborations and assess the feasibility of using these recycled materials if they meet the necessary quality standards.

Incorporate a waste management system into the project. Set up a reuse/recycling/repurposing site to sort and process the waste.

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 shelter wood products releases *carbon emissions* (meaning worse environmental impact from the house), but on the other, it also provides a source of fuel for households, avoiding more deforestation. If we want to advocate to not burn the wood from the shelter, to avoid emissions, and also to avoid further deforestation, then the household energy question (especially for cooking) needs to be considered.

Around 3 billion people globally still cook over an open fire, usually using some form of biomass (wood, charcoal etc.). In 2019 the Moving Energy Initiative (MEI) estimates that forcibly displaced families living in camps are burning 64,700 acres of forest (equivalent to 49,000 football pitches) each year.[105]

In Burundi, the majority of the population primarily depends on solid biomass, such as firewood or charcoal, for their daily energy requirements. Fewer than 1% of its residents had access to clean cooking fuels and stoves. This dependence on biomass for daily essentials places strain on the country's diminishing forests and subjects people to harmful smoke, affecting their health. This practice constitutes 90% of the nation's energy consumption. Introducing contemporary, clean energy alternatives for homes can both elevate living conditions and combat deforestation and land deterioration.[106]

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.[107]

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.

105 *Cooking in displacement Setting. Engaging the Private Sector in Non-wood-based Fuel Supply. Laura Patel and Katie Gross. January 2019*
106 *World Bank Document*
107 *Cooking in displacement Setting. Engaging the Private Sector in Non-wood-based Fuel Supply. Laura Patel and Katie Gross. January 2019*

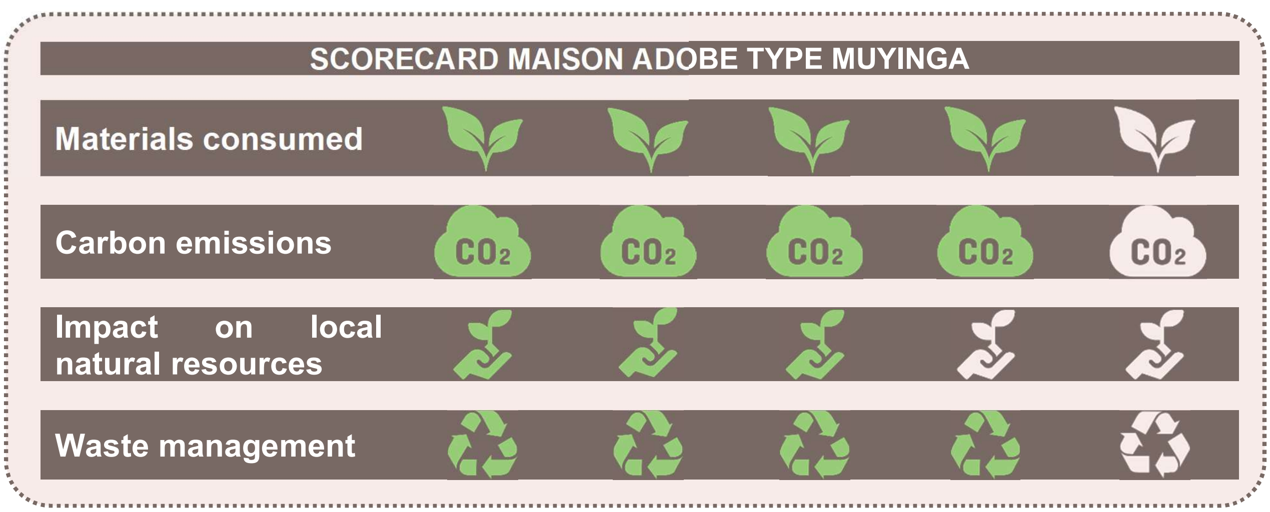
8.5. Summary of the results

The house model predominantly uses natural raw materials, especially soil, 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 low carbon emissions mainly because it uses adobe bricks which, despite their volume, have a lower embodied carbon than other materials. However, most of its carbon emissions arises during the 'end of life' stage, primarily attributed to the wood, since the wood is burnt at the end of its useful life, releasing carbon emissions into the atmosphere. Additionally, the transportation of materials like CGI sheets from Tanzania further adds to the overall carbon footprint.

The model primarily utilises local natural resources such as soil, stones, sand, eucalyptus and grevillea 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 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 very satisfactory, 30 years according to the local team.



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

9. Conclusion

This research emphasises the importance of examining the entire lifecycle of a house and its materials, from their production to their disposal. The evaluation not only considers carbon emissions but also factors such as the utilisation of local natural resources and waste management. While reducing carbon emissions is crucial and widely recognised, it is equally important to consider the impact of using natural resources on the local environment. Furthermore, management of waste represents a hidden challenge in the humanitarian sector, often overlooked during project planning 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. It is recommended that a simple environmental impact assessment or at least environmental screening using a tool such as the NEAT+[108], 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.

The soil used to make adobe bricks is locally available and is dried using sunlight, which is energy-efficient, and provides income opportunities for the communities and families involved in production. Since these materials are locally sourced, transportation requirements are minimal, resulting in low environmental pollution. Furthermore, at the end of their lifecycle, these materials are entirely recyclable and biodegradable when not mixed with stabilisers like cement, ensuring zero waste and pollution. Also, the use of adobe aligns with traditional local architecture, is energy-efficient due to its low embodied energy and therefore carbon emissions, high thermal mass, compatibility with passive solar design strategies, and the sustainable nature of its production process. Additionally, it provides added safety in earthquake-prone areas when well-constructed.

However, concerns do arise regarding the extraction of soil for adobe production. While manual extraction is less environmentally detrimental than mechanical methods, the lack of stringent regulations can also result in problems such as soil erosion and land degradation. Notably, the practice of excavating pits for adobe brick production can disrupt the local landscape. To address these concerns and maintain sustainable construction practices, it is imperative to implement erosion control measures, carefully select excavation sites, and adopt soil conservation techniques.

The local sourcing of rock and sand, while eco-friendly, poses issues as well. Uncontrolled extraction harms ecosystems and the environment. To combat this, it's essential to ensure sustainable extraction. This involves creating a management plan for resource extraction and implementing measures to avoid issues like riverbed over-extraction, habitat disturbance, and erosion. However this task can be challenging for the local team, since they are not responsible for extracting the sand and rock, as it is supplied by a provider. So it is necessary to ensure that no damage is being done during the extraction process. If any harm is identified, this needs to be addressed with the supplier and the right measures taken.

108 *https://neatplus.org/*

As for timber, eucalyptus and grevillea, 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 (if not burnt which results in release of the stored carbon). 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; otherwise, consider options like reforestation, forest protection projects, or alternative materials like bamboo. Further studies on material quality, environmental impact, and mitigation strategies are essential.

The use of timber as firewood at the end of its life cycle leads to the release of carbon that was previously sequestered, thus negating its environmental benefits. Addressing this issue is complex due to the dependence of affected families on firewood for cooking. This presents a dilemma, as the use of such material for heating and cooking purposes could also help to avoid the consumption of other forest resources, given that it is estimated that 95 percent of the cut wood is used as firewood. Stoves operating on non-organic materials would be beneficial in this context. The programme has already taken this into account; according to the local team, these stoves are being built at the families' homes. It is crucial to ensure that families are using them correctly. Additionally, integrating reforestation and tree-planting activities within housing projects is beneficial, a step that the programme is also implementing. These initiatives highlight the programme's commitment to environmental issues and its efforts to address them. Continuously promoting these initiatives and ensuring correct usage of the stoves by families is important.

Focus should be on materials like steel and cement due to their high 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 Burundi, 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 use of plants like banana leaves, might encounter resistance from local families, who may be concerned about the high maintenance required. Furthermore, reducing the reliance on steel and cement may not always be practical.

Nevertheless, as highlighted by the local team, these materials do hold potential for recycling and can be sold by weight to recycling enterprises. The study has not been able to identify such enterprises, but it is strongly recommended to locate them and facilitate connections between these enterprises and the affected families. Additionally, there is reportedly a steel recycling plant in Burundi producing rebar and nails of moderate quality. Although this study has not confirmed its existence, efforts could be made to verify this and explore further possibilities. While these materials are durable, with lifespans of up to 30 years as per the team's observations, forward-thinking strategies are essential. Educating families about the significance of waste management is imperative for sustainable living, health and environmental conservation.

Also, improper treatment of materials in the construction, maintenance, and repair of houses can adversely affect their integrity and durability, leading to a shorter lifespan and frequent need for material replacements. The durability of a house is not only cost-effective but also environmentally efficient. This is particularly relevant for adobe houses, whose longevity can vary greatly based on soil quality, climate, construction and maintenance techniques.

Therefore, reinforcing certain construction techniques can also significantly extend the lifespan of the houses, which is currently estimated at around 30 years by the local team. The application of certain construction techniques is recommended, such as using protective plaster layers like mud or lime to shield the bricks from weathering. Households are already using materials such as red clay and limestone for plastering. Additionally, protecting the house from concentrated rainwater and capillary rise[109] is crucial, which can be achieved by fortifying the base of the walls and creating effective water runoff channels. Designing adequate roof overhangs to protect wall tops and regular maintenance of the roof and surrounding areas are also important.

109 *In the context of buildings and construction, capillary rise refers to the way water can move upwards through porous materials, such as soil or certain building materials like brick, mortar, and concrete.*

By implementing these protective measures, the lifespan of adobe walls can be significantly extended, making them comparable to other conventional construction materials used in Burundi. Regular maintenance and the use of good construction techniques and materials, are key to extending the lifespan. Continuing and reinforcing existing training programs on house maintenance and construction improvement is essential to support these efforts.

While procurement of locally produced products is encouraged, it can pose challenges in Burundi. Frequent imports of shelter materials to meet quality standards often hinder the promotion of local materials. An alternative approach, as suggested by the Shelter Cluster in DRC and worth considering here, is to collaborate with shelter and NFI manufacturers in East Africa to enhance quality standards that meet humanitarian needs. Sourcing materials from this region could potentially reduce the environmental impact of transportation and expedite delivery.

In conclusion, the house model prioritises environmental sustainability by employing locally sourced materials, such as adobe bricks. This approach offers advantages like energy-efficient production, minimal transportation, and recyclability. However, challenges include the need to regulate soil extraction. Managing the sustainable extraction of resources like rock, sand, and timber is also crucial to prevent environmental degradation. Timber use raises concerns about soil conservation and carbon emissions when used as firewood. Introducing alternative cooking methods and promoting reforestation could help mitigate these issues. Steel and cement, though in smaller quantities, still require attention due to their environmental impact, which can be addressed through recycling initiatives. Collaboration with East African manufacturers can improve local material standards while reducing environmental impacts from the supply chain. Ultimately, durability and proper maintenance of housing are essential for environmental efficiency, emphasising 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 and sand is done sustainably, preventing problems like overusing resources from riverbeds, habitat disruption, erosion, pollution, and land damage. Another alternative is to promote awareness campaigns through the National Disaster Risk Management platform

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.

Attempt to locate the steel recycling facility in Burundi, which produce rebar and nails. Confirm the facility's existence and evaluate the quality of the recycled steel materials. Explore potential collaborations and assess the feasibility of using these recycled materials if they meet the necessary quality standards.

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.

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

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.

Continuing with reforestation and forest protection initiatives, as well as endorsing and collaborating with capable local organizations to facilitate these projects in the pertinent areas is crucial. It's worth noting that these efforts not only help offset the total carbon emissions produced but also contribute significantly to the safeguarding of the local ecosystem.

Continue implementing mitigation measures to address environmental issues, such as tracing contour lines for erosion control, planting soil-binding grasses, establishing nurseries for plant cultivation, introducing agroforestry trees for ecological stability, and planting fruit trees for sustainable agriculture.

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.

Reduce the packaging for all materials, and eliminate any single-use plastic, or support the reuse of packaging for other purposes.[110] Efforts could be undertaken to address this issue by engaging in discussions with suppliers.

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.

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

Continue providing 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 continue reducing the dependency on firewood and take pressure off of forest resources. This can also prevent the burning of eucalyptus and grevillea 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[111] and other partners in the country and the region, to pass key environmental messages.

Consider doing a simple environmental impact assessment or at least environmental screening using a tool such as the NEAT+[112], 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[113] from a project that has been accredited by a recognised standard.[114]

111 *Attempts to contact them were made without success*
112 *https://neatplus.org/*
113 *One potentially interesting case study in Chad that might be of use as an example of how the provision of stoves can impact refugee settings is the CooKit Solar Cooker, which utilised carbon credits from saving CO2 emissions to facilitate expansion of the programme https://www.fairclimatefund.nl/en/projects/chad-solar-cookers-for-refugee-families*
114 *European Parliament*

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- 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

- THEISEN, Claudine ; Gestionnaire de projets – Desk RDC et Burundi
- LEDESMA, Daniel Research officer
- TATENAU, Lionel
- NINGANZA, Josélyne: Responsible pay
- NIMPAYE, Tite , Assistant Opérationnel

Global Shelter Cluster

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

Other organisation contacted in Burundi

- OBPE (Office Burundais pour la Protection de l'Environnement)
- Fabrimétal

Other person contacted

- Samantha brangeon. Consultant- JI Sustainable Humanitarian Packaging Waste Management

Other organisation contacted

- CRA-Terre

ANNEX 2 - House model Technical Information

MAISON ADOBE TYPE MUYINGA

The "Maison en Adobe de type Muyinga" is designed as a sustainable housing solution, with the assistance of the Muyinga branch of the Burundi Red Cross. Built since 2017 in the Muyinga region.

Total area
44.8 m^2

Occupancy
6 persons

Construction time
30 hours

Cost
930 euros

Durability
30 years

Total # Built
965

To Build
0

Dimensions
8m x 5.6m

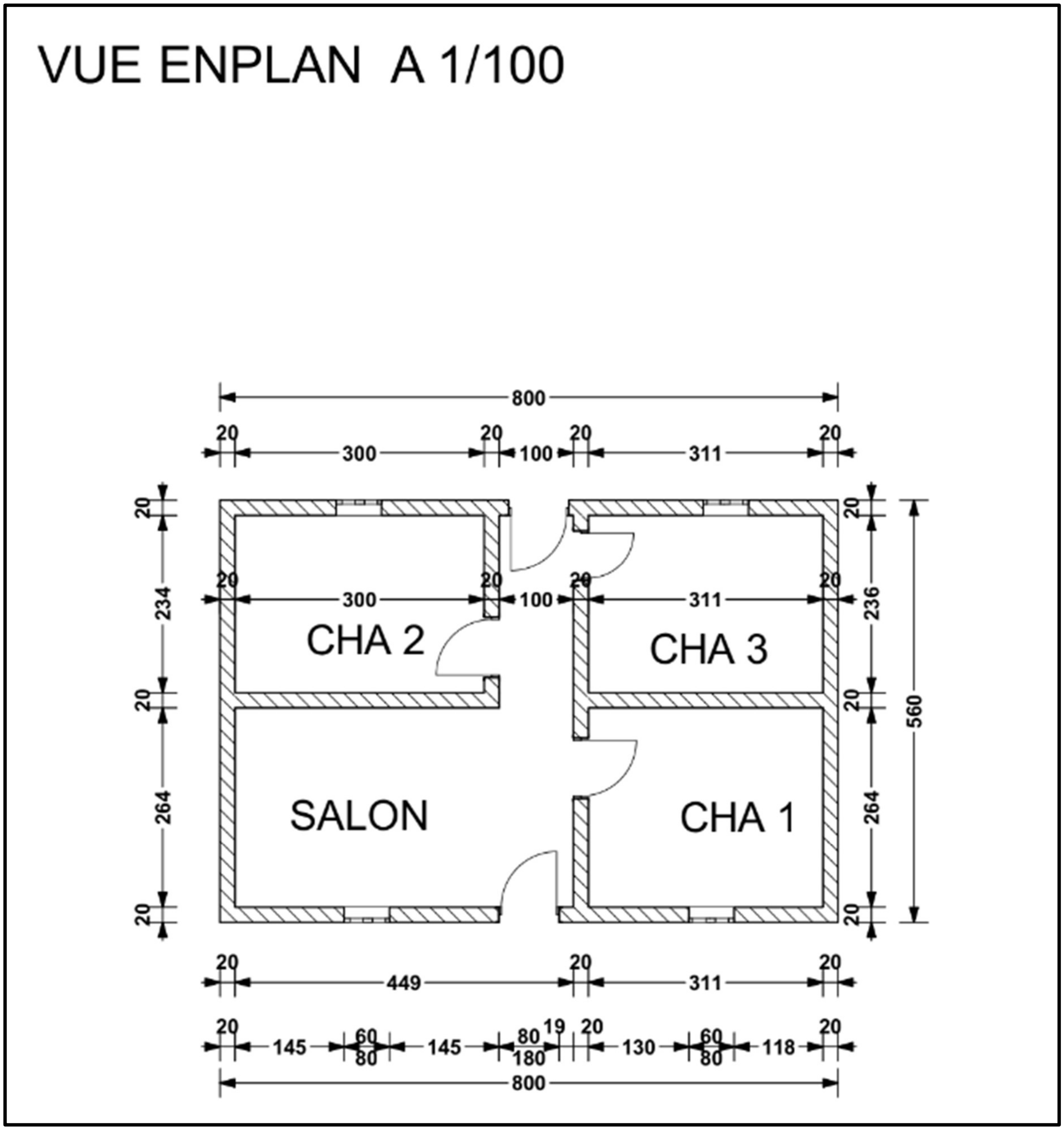
Foundation
The foundation has a depth of 40-60 cm, (adjustable based on soil resistance at the plot) width of 40 cm, and is longer by 10 cm at each end than the house (8.20 m x 5.80 m).
The foundation is composed of adobe bricks and earth mortar, and a sub-base made of cement, sand, and stones.

Walls
The walls are built of adobe bricks (40x20x15 cm) made by families, and earth mortar, requiring an estimated 2,000 to 2,200 bricks.

Wall cladding
The family is responsible for the cladding, using available materials within their means. Some use red earth, limestone, and plant residues for wall plastering to protect and decorate their homes.

Roof covering
The roof has two slopes with a 30% grade, covered with metal roofing, and has a structure made of eucalyptus wood.

Openings
5 doors (0.80 m x 1.8 m) and 4 windows (0.60 m x 0.80 m) made of grevillea wood.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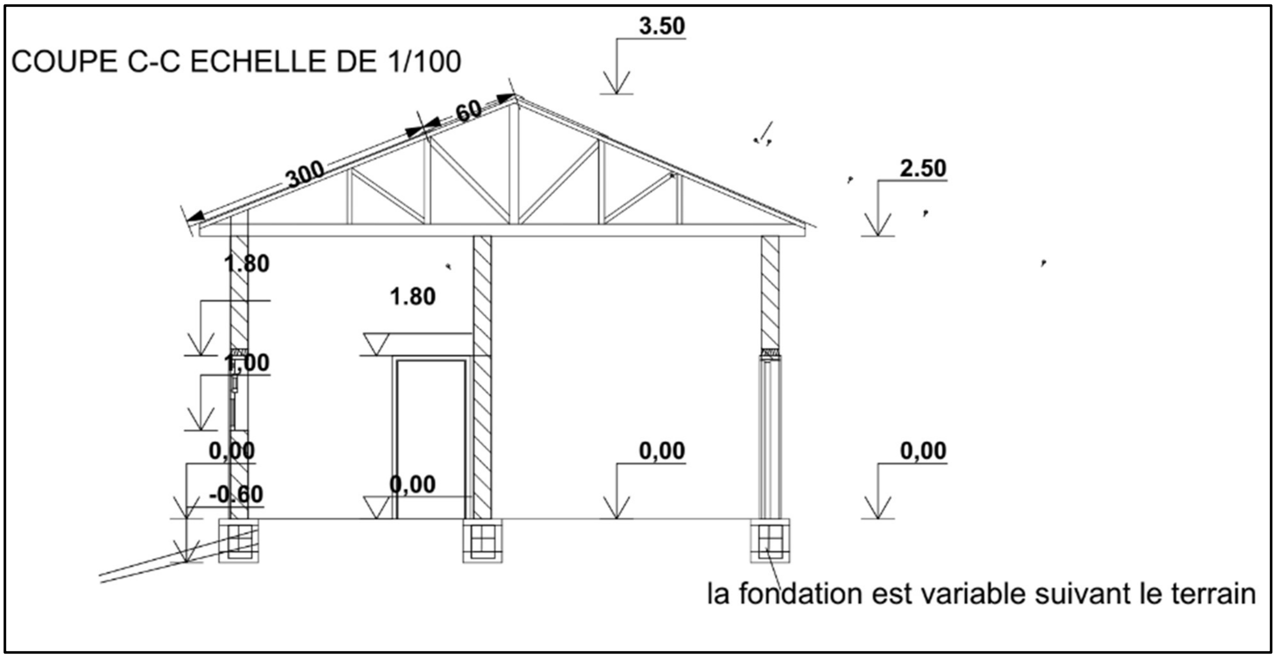
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la fondation est variable suivant le terrain

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

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

Table 1 - Maison en Adobe de type Muyinga

Name	Raw material	Quantity/ Kg	Country of origin	Packeting	Quantity/ Kg
Timber	Eucalyptus wood	656 kg	Burundi	None	None
Doors and Windows panels	Grevillea wood	122 kg	Burundi	None	None
Adobe bricks	Soil	25000 kg	Burundi	None	None
Mortar	Soil	1200 kg	Burundi	None	None
Rubble	Stone	2580 kg	Burundi	None	None
Sand	Sand	3200 kg	Burundi	None	None
Cement	Cement	100 kg	Burundi	Polypropylene Bag	0.5
Cement Bricks	Cement	56 kg	Burundi	None	None
Corrugate Galvanised Iron Sheets (CGI)	Steel covered in zinc	124 kg	Tanzania	None	None
Wire	Steel	2 kg	Tanzania	Polyethylene strapping	0.02 kg
Roofing nails (umbrela type)	Steel	6 kg	Tanzania	Nylon bag	0.1 kg
Ordinary nails	Steel	10.5 kg	Tanzania	Nylon bag	0.1 kg

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.
- The distances in kilometres have been provided by the field team.
- Since it is not known exactly what happens with disposal, transportation from the site of construction of the shelters for disposal is not included.

Distance by road

Country of origin to point of arrival in country

Departing point	Arrival point	Distance
Tanzania (Dar es Salaam)	Bujumbura	1499 km

Warehouse to Construction Site (km)

Departing point	Arrival point	Distance
Muyinga	Giteranyi	45.1 km

Place of local manufacture to Construction Site (km)

Departing point	Arrival point	Average Distance
Giterangi	Construction side	10 km

ANNEX 5 - Materials used in the house model

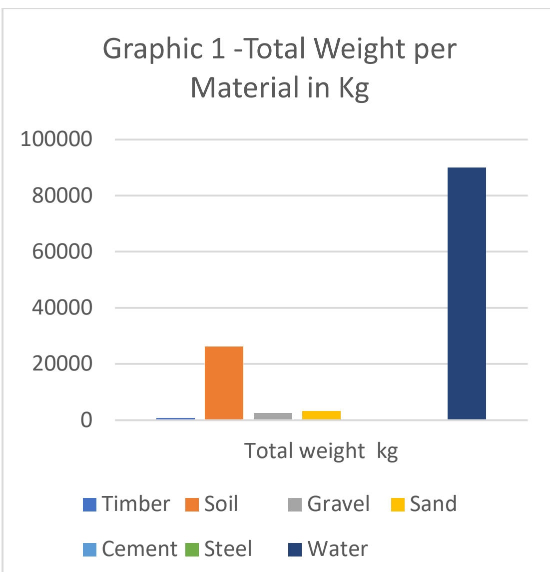
Below are the tables showing the materials used in the house model, by weight (kilograms). The data was provided by the AICRL logistics teams in the country.

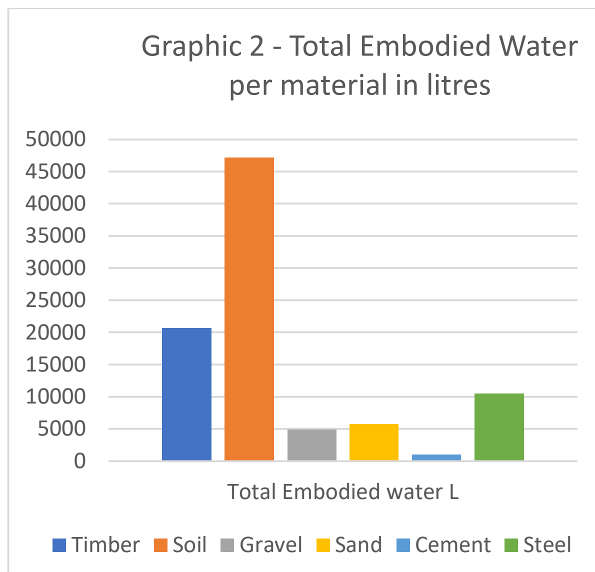
Water consumption is calculated for all the materials used to build the shelters. To calculate the embody water in litres, the UNHC shelter and sustainability tool baseline[115] have been used.

Table 1 – MAISON ADOBE TYPE MUYINGA

Raw material	Quantity / Kg	Embodied water (L)
Timber	778 Kg	20,648 L
Soil	26,200 Kg	47,160 L
Gravel	2,612 Kg	4,902 L
Sand	3,216 Kg	5,760 L
Water consumption	89,928 L	-
Man-made material	**Quantity / Kg**	**Embodied water (L)**
Steel	143 Kg	10,471 L
Cement	108 Kg	987 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





115 UNHCR-TSS (epfl.ch)

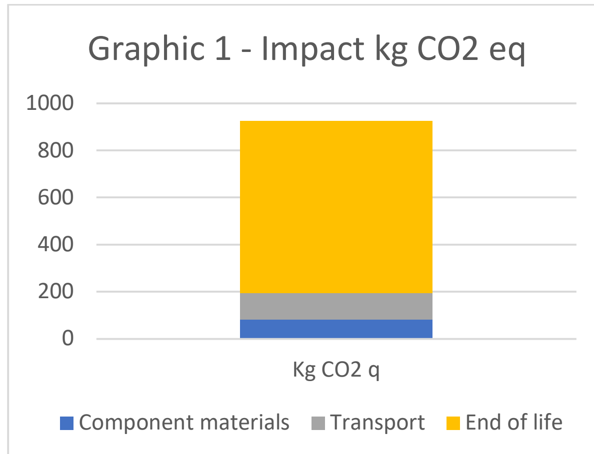
ANNEX 6 - *Carbon emissions* calculations

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

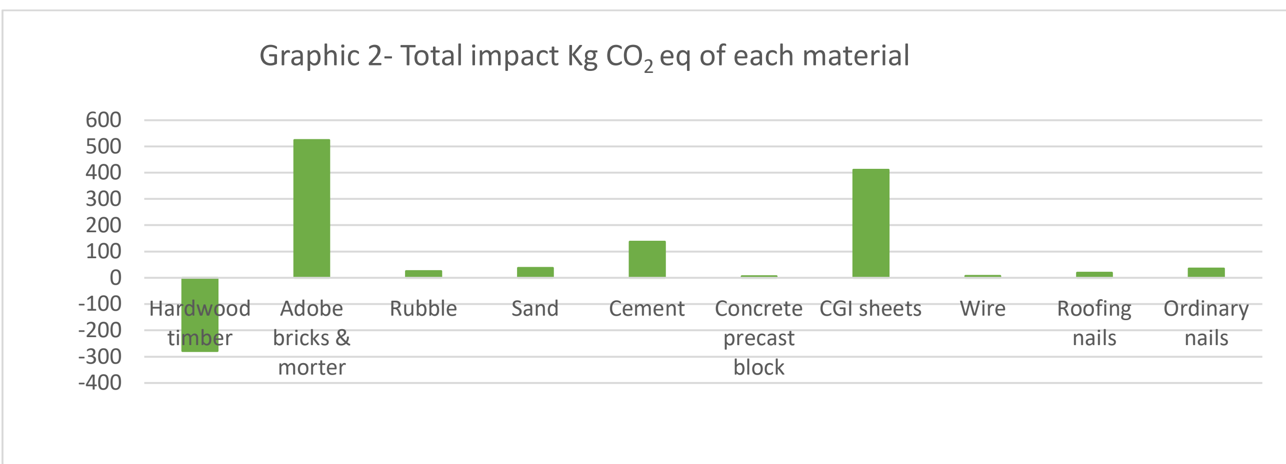
Below are the total *carbon emissions* generated by the house model, in CO_2 equivalent. This is using the SMAC calculator and taking into account all the parameters and assumptions explained in section 7.2. The follow Table 1 & and Graphic 1 show the breakdown of the *carbon emissions*, in terms of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

Table 1

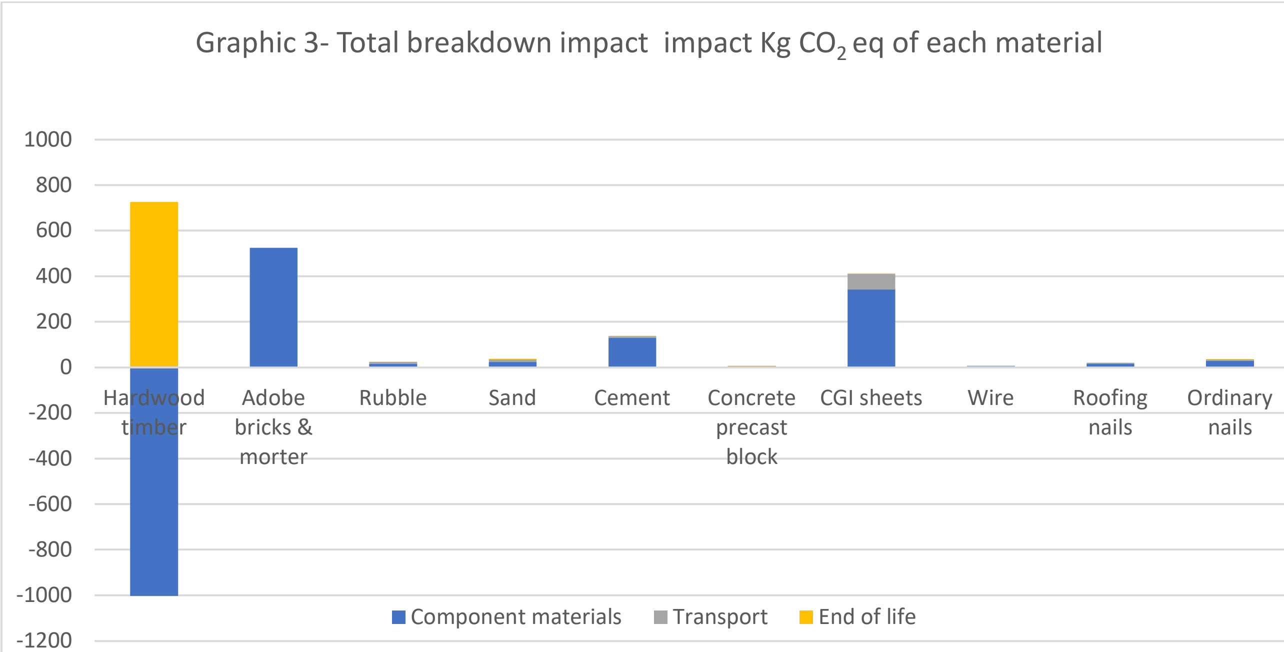
Impact	Carbon emissions Kg CO_2 eq.
Production of the component materials	87
Packaging	*Data not considered*
Transport	111
End of life	726
Total	**925**



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".*



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

Natural material "captures carbon" when they are growing

When burnt, the carbon is relisted

ANNEX 7 - *Local natural resources* used

Total amount of eucalyptus tree used in the house model

- Approximately 656 kilos for the roofing structure.

Total amount of grevillea tree used in the house model

- Approximately 122 kilos for the door and window panels

Total amount of soil used in the house model

- Approximately 26200 kilos to build adobe brick and mortar

Total amount of gravel used in the house model

- Approximately 2580 kilos as part of the sub-base

Total amount of sand used in the house model

- Approximately 3200 kilos as part of the sub-base

ANNEX 8 - Protentional reuse option and recycling options

The Table 1 below examine 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 the country[116]. It is important to note that the rate of decomposition can depend upon disposal or landfill conditions.

Table 1 – Maison adobe type Muyinga

Material	Life expectancy[117]	Time to decompose	Reuse	Recycling
wood[118]	Around 30 years[119]	10–15 years[120]	Yes	Yes
Soil	Around 30 years [121]	*Not relevant*	Yes	Yes
Gravel	Around 30 years	*Not relevant*	Yes	*Not relevant*
Sand	Around 30 years	*Not relevant*	Yes	*Not relevant*
Cement	Around 30 years	*Around 50 years*[122]	No[123]	No[124]
Concrete block	Around 40 years	*Around 50 years*[125]	Yes	Yes
CGI	Around 30 years	200 to 500 years	Yes	Yes
Screw	Around 30 years	200 to 500 years[126]	No	Yes
Wire	Around 40 years	200 to 500 years	Yes	Yes

According to the field team, some of the materials are discarded once they are no longer used or reach an advanced state of deterioration (cement and concrete blocks), or use as firewood (timber). Such burning contributes to air pollution. The rest of the materials are sold to be recycled (CGI, screw and wire)

116 *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.*
117 *Information provided by the field team through direct observation on the field.*
118 *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.*
119 *Depending on the weather conditions and drying before use*
120 *How Long It Takes 50 Common Items to Decompose | Stacker*
121 *Depending on the construction technique and the weather conditions*
122 *How Long Does Concrete Take to Decompose? (concreterecruiters.com)*
123 *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.*
124 *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.*
125 *How Long Does Concrete Take to Decompose? (concreterecruiters.com)*
126 *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 Burundi

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.[127]	• Disintegrating earth block can be added to the house's garden and became fertilizer for the grass[128]
Timber	• To reuse for auxiliary construction (like stable) • Combustible wood • Art objects	• Art objects
Cement & Concrete block	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. • 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. • 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. • Crushed concrete can be used as a subbase for roads and driveways, providing a method to reuse concrete from old pavements and structures. • 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. • gravel, aggregate and paving materials can be used.
Steel	• To reuse for auxiliary construction • Handicrafts (earrings, home decorations/accessories, etc.) •	• Made into various functions if welding is available. Like school tables and benches
Wire	• To reuse for auxiliary construction • Handicrafts (earrings, home decorations/accessories, etc.) • Used for various functions – can be used for attachments of reused mats, etc	• Made into various functions if welding is available.
Screw	• They are not reused	• Production of carts; wheelbarrows, keys, shovels; pickaxes; hoes; machetes, chair, etc

127 *Experimental Research on the Recyclability of the Clay Material used in the Fabrication of Adobe Bricks Type Masonry Units*
128 *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, mpacts and best practice of the materials

MATERIALS	ADVANTAGES	IMPACTS	BEST PRACTICES
Soil	• Used for millennia in the Burundi • Local material that does not require transportation. • Soil does not create pollution and waste. • It is recyclable if not stabilised (with cement). • A wide variety of solutions allowing a high level of comfort if the bioclimatic conditions of each site are taken into account. • 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. • The extracted soil can be useful for creating canals, retention basins, dikes, etc. • Improve the strength of walls with inert materials for foundations (stone, cement blocks, baked bricks). • Avoid building earth walls in flood-prone areas. • Support local livelihoods / industries. • Extract earth in areas where it cannot cause danger or environmental impact. • Enhance surface strength by applying an earth coating annually
Timber	• It “captures carbon” (and other greenhouses gases) during their growth. • Doesn’t take long time to decompose. • It is a renewable resource when managed well.	• “Life expectancy” is short, if not well treated. • If the material is burnt at the end of its useful life, it released a hight amount of CO_2 eq. into the atmosphere. • Growing eucalyptus in low rainfall areas may cause adverse environmental impacts due to competition for water with other species. • 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. • Transporting wood can further damage forests and rural roads. • Where processing is carried out, poorly managed factories cause pollution from solid waste, noise, and air.	• Whenever possible, avoid oversizing or specifying too many requirements. Carry out appropriate structural design and calculate wood requirements accordingly. • Minimise wood cuts. • Treat wood properly to ensure its long-term durability. There are certainly several wood treatment recipes that can vary locally depending on product availability. • Minimize the use of wood for formwork (if applicable), prefer reusable modular formwork. • Encourage wood reuse (e.g., door and window frames, structural elements). • Cuts of chemically treated wood must be considered

		• The use of toxic chemicals for treatment purposes poses risks to the environment and health.	hazardous and should never be used as firewood.
Rubble	• Local stone requires no transportation and doesn't create pollution or waste. • It is a recyclable material. • “Life expectancy” can be very long	• Unplanned rock extraction can lead to landslides and hydrogeological impacts. Without planning or protection, blasting poses occupational risks. • Transporting rocks can affect rural roads. • Extraction can leave large pits that may pose health risks. • Stone construction in earthquake-prone areas must be carried out with seismic design.	• Design and construct properly to ensure long-term durability. • Use stone only in areas where it can be extracted without causing danger or environmental impact. • Employ good storage and loading practices during transportation. • Implement measures to mitigate the negative impacts of extraction, such as erosion control, sedimentation ponds, and proper disposal of waste materials.
Sand and Gravel	• 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. • 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. • Cement structures can be less susceptible to soil erosion compared to traditional mud or earth-based construction, which can help prevent land degradation. • Cement structures often have a longer lifespan, reducing the frequency of construction and	• CO_2 production and impacts on climate change. The cement industry is one of the most polluting sectors. The use of these construction solutions. • Cement production requires substantial amounts of water, and improper water management can lead to local water shortages and environmental degradation. • Cement production requires significant quantities of raw materials, including	• Use alternatives to concrete and cement-based products, such as earthen wall if possible. • Use cement efficiently in construction to minimise waste and maximize its benefits. • Never dispose of concrete or cement-based products in the environment. This can be: Reused on-site/off-site for construction purposes (e.g., filling);

	its associated environmental impacts.	limestone, clay, and shale, which can lead to resource depletion if not managed sustainably	Safely transported to a construction material recycling space, Safely transported to a controlled landfill site.
Steel	• Production of steel is the most energy-consuming in the world. • The production of the steel, generated a high amount of *carbon emissions*. • Long-lasting material, which take long time to decompose.	• Can be reused and recycled • “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. • Implement stringent quality control measures to verify the quality and strength of the steel used in construction, • Optimise the design to minimise the amount of steel required. • Consider alternative materials or designs that use less steel while maintaining structural integrity. • Encourage recycling and proper disposal practices.