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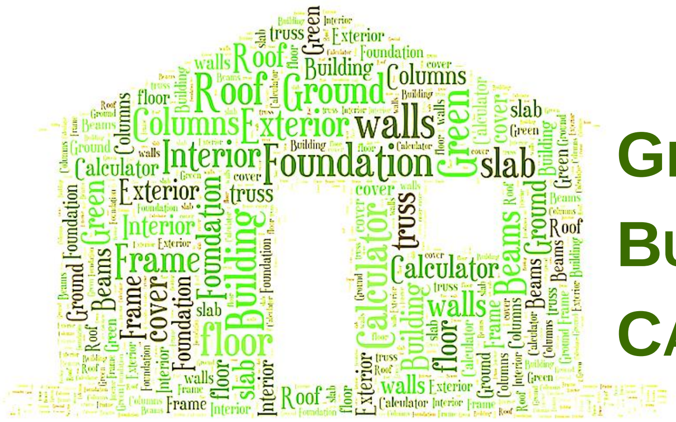

Green Building Calculator

- Manual -

January 2017

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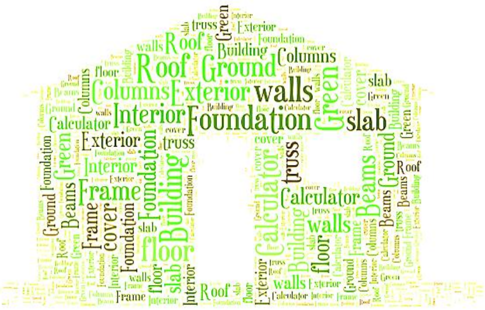

GREEN BUILDING CALCULATOR

For buildings in Rwanda

MANUAL

Authors

Mirjam Busch

Christian Zeitz

Bernd Franke

Nana Obeng

Jan Bader

Prepared within the scope of the BMBF funded project „Rapid Planning”

Contact:
ifeu – Institut für Energie- und Umweltforschung Heidelberg GmbH
Wilckensstraße 3
D-69120 Heidelberg
Tel. +49 (0)6221 47 67-0; Fax: -19
http://www.ifeu.de

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1. INTRODUCTION

The Republic Government of Rwanda has adopted the National Housing Policy in 2015 (MININFRA 2015) with the overall vision addressing the growing demand for housing in urban and rural areas and to encourages the use of local, green and affordable building materials. For future development, the use of construction minerals in Rwanda is expected to grow significantly. Materials for new dwellings represent almost 40 % of the mass flow for solids matter in Kigali; the contribution to the energy flow is about 12 % and to GHG emissions about 20 %.

A comprehensive comparison of construction materials (e.g. traditional, compressed earth blocks, concrete, bricks, STRAWTEC panels) would be highly valued contribution to support the National Housing Strategy.

Therefore, IFEU developed a building material calculator (BMC) as part of the Rapid Planning project that has been developed under the umbrella of the Future Megacities Research Program of the German Federal Ministry for Education and Research (BMBF). The Microsoft Excel-based calculator is designed to analyse buildings by applying LCA results for their constituent materials. The LCA modelling covers the extraction of resources, the transportation and pre-construction of the building materials.

The BMC covers a selected range of material types and construction methods applicable to Rwanda. The user interface shows the house structure elements encompassing foundation design, shell, ground floor, structural frame through to the roof elements. Users can choose for each element the desired material and specify the related quantity. Based on the chosen values the calculator provides results for the categories Climate Change, Energy Demand, Fresh Water Use and Land Use.

2. EXKURSUS: LIFE CYCLE ASSESSMENT

2.1 What's about?

A life cycle analysis is a method, an instrument. It enables the user to describe systems and determine the environmental pollution and damage caused by these systems. It is the first and until now the only instrument for environmental assessment that has been homogenised according to an ISO standard worldwide.

The original thought behind a standardised norm for life cycle analyses was to take a look at the complete life cycle of a product beginning with its production and going on to its service life on up to its final disposal after use. This holistic approach of evaluating the complete life cycle of a product gave this method its name (LCA).

For the BMC a simplified LCA has been applied. A simplified LCA is especially preferable for individual decisions in regulatory implementation since it is practicable and proportionate to the demand. With simplified LCA tools indicative findings could be drawn. It is also possible to identify the influence of single process steps on the total resource demand or on environmental impacts of the total process chain.

A simplified LCA represents a sub-system of Life Cycle Assessment (LCA). While LCA has a focus on all phases from "cradle to grave" of a product or a service, simplified LCAs investigate only a sector of the full life cycle, namely the phases from "cradle to gate" (where "gate" means in this case the building site of the houses).

Following life cycle phases are covered by the BMC:

- Production of component
- Transportation of components
- Production of building material on construction site in **Kigali**
- CO2-fixation

Thus, extraction and refining of raw materials, energy production and supply, and all necessary processes until the product under investigation are covered by the Eco-profile. All resource inputs and all emissions to air and water are investigated along this production chain. Downstream processes like maintenance and end-of-life treatment of the building materials are not covered by this simplified LCA.

2.2 The model behind

For modelling of the building materials, the computer tool UmbertoNXT® has been used.

Calculations of input/output balances are scaled to 1 kg of building material. The composition of the building materials, transport distances to building site in Kigali and energy assumptions at the building sites are summarized in the product sheets Appendix A-Q.

Data on processes for production of building components and the final production of the building material on site were either collected in cooperation with the engineers, manufacturers, distributors or taken from literature. All data used are considered to be as representative as possible for the selected scope. Concerning background processes (energy generation, transportation, chemical pre-chains), the Ecoinvent 3.2 database was used. The underlying energy mixes of the countries are summarised in Appendix Q.

2.3 Which building materials are included?

The following materials are included in the LCA model:

- Cobwork
- Adobe dried bricks
- Traditional fired brick
- Modern fired bricks
- Modern fired tiles
- Industrial fired bricks
- Industrial fired roof tiles
- Concrete and cement mortar from Rwanda
- Concrete and cement mortar from Uganda
- Concrete and cement mortar from Tanzania
- Boulder stones
- Damp Proof Course
- Cement block with cement from Rwanda
- Cement block 1kg with cement from Uganda
- Cement block 1kg with cement from Tanzania
- Strawtec
- Hydraform with cement from Rwanda
- Hydraform with cement from Uganda
- Hydraform with cement from Tanzania
- Modulus with cement from Rwanda
- Modulus with cement from Uganda
- Modulus with cement from Tanzania
- Earthenable
- Reinforcing Steel
- Screws
- Metal (poles, shoes)
- Wood
- Plywood
- Engineered Wood
- Corrugated metal roof sheet

2.4 The results: Life cycle impact/inventory assessment

The life cycle impact assessment (LCIA) is the phase in LCA, in which the collected inventory data is assigned to relevant environmental impact categories and aggregated into impact category indicator results. The inventory data consists of all emissions and raw materials (including use of nature) which are released and consumed by the analysed product system. The results for the impact categories represent potential environmental impacts per functional unit and do not quantify an actual environmental damage.

Inventory level categories differ from impact categories to the extent that no characterisation step using characterisation factors is used for assessment. They could be used as valuable additional information to address e.g. resource aspects.

As emission related category, the impact category Climate Change has been chosen.

For resources following inventory categories are examined:

- Cumulated Energy Demand (CED) renewable & non-renewable [MJ]
- Land use agriculture & forest area & extraction area [m^2*a]
- Freshwater use [m^3]

The selected categories are briefly addressed below.

Climate change

Climate Change addresses the impact of anthropogenic emissions on the radiative forcing of the atmosphere. Greenhouse gas emissions enhance the radiative forcing, resulting in an increase of the earth's temperature. The characterisation factors applied are based on the category indicator Global Warming Potential (GWP) for a 100-year time horizon [IPCC 2013]. In reference to the functional unit (fu), the category indicator results, GWP results, are expressed as kg CO2-e per functional unit.

The CO2 fixation in bio based materials (e.g. straw and wood) refers to the biological process by which CO2 is transformed into organic compounds.

Cumulative Energy Demand (renewable and non-renewable)

The Cumulative Energy Demand is a parameter to quantify the primary energy consumption of a system. It is calculated by adding the energy content of all used fossil fuels, nuclear and renewable energy (including biomass). This indicator is described in [VDI 1997]. It is a measure for the overall energy efficiency of a system, regardless the type of energy resource which is used.

Freshwater use

Considering the decrease in world freshwater resource availability and the water scarcity in many parts of the world, extracting water in a dry area can cause important damages to ecosystems and human health. However, so far no models are available to express the damage on the endpoint level. For the purpose of this study, the factors from the inventory level, only expressing the total amount of freshwater water used, are taken, represented in m3.

Land Use

The Land Use impact category reflects the damage to ecosystems due to the effects of occupation of land. Land Use has large impacts on the natural environment, such as decrease in biodiversity due to direct loss of natural area or indirect impacts like area fragmentation, and impacts on the life support function of the biosphere. In this study, the factors from the inventory level, only expressing the total amount of land occupied per year, are taken, represented in m^2*a.

3. HOW TO USE THE TOOL?

3.1 Opening the tool file

A number of functions of the calculation tools are operated with macros. These have to be enabled after opening the files.

3.2 General structure

There are two different types of worksheets, the "BOQ_Entry" and "Export" worksheets (Figure 1). The Export worksheets are not connected to the BOQ_Entries, but can provide assistance for export and further processing of the results. The input of data and all calculations are included in the BOQ_Entry sheets.

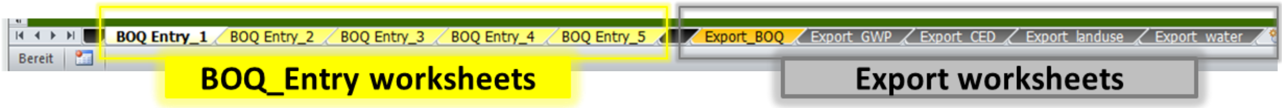


Figure 1: Overview: worksheets

The BOQ_Entry worksheets consist of 3 areas (Fehler! Verweisquelle konnte nicht gefunden werden.~~Fehler! Verweisquelle konnte nicht gefunden werden.~~):

1. Input area: specification of the building material type and quantity
2. Calculation of quantity: serves as basis for the impact and indicator calculations
3. Output area: calculation of results based on mass per material

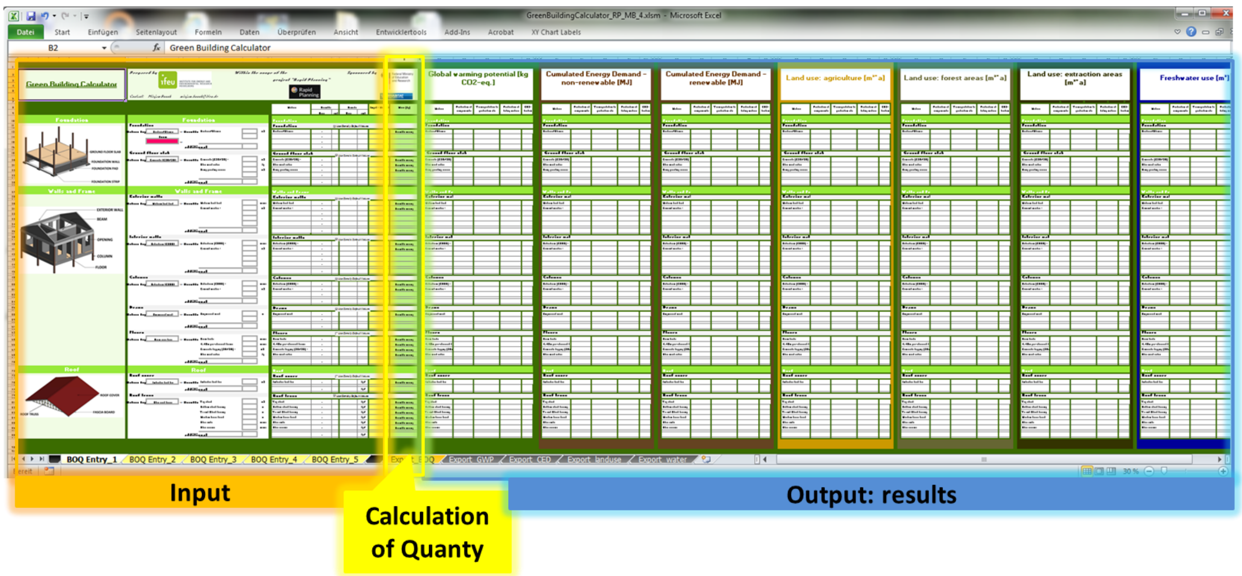


Figure 2: Overview: BOQ_Entry worksheet

Results for following impact and inventory indicators are presented in the output area:

- Global Warming Potential (GWP) [kg CO_2-eq.]
- Cumulated Energy Demand (CED) renewable & non-renewable [MJ]
- Land use agriculture & forest area & extraction area [m²*a]

- Freshwater use [m³]

3.3 Input of building specifications

The input area is divided into the following building components:

A) Foundation
   - Foundation
   - Ground floor slab

B) Walls and Frame
   - Exterior walls
   - Interior walls
   - Columns
   - Beams
   - Floors

C) Roof
   - Roof cover
   - Roof truss

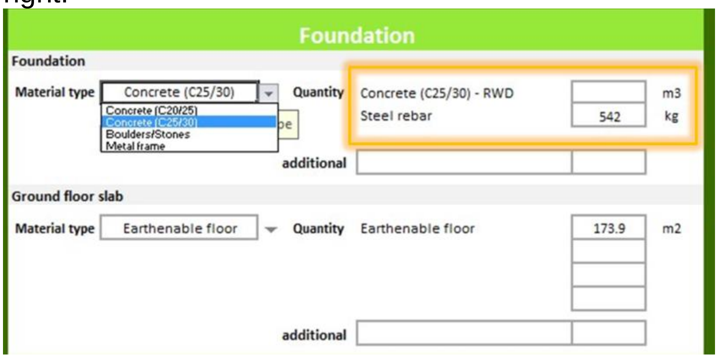
Each building component has to be specified by choosing a material type and entering the respective quantity according to following instructions:

1. Choose the **material type** from the given drop down list in column J

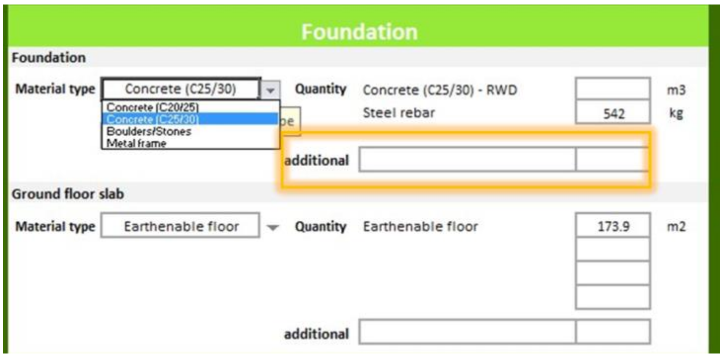
Note: please do not write the types by hand, this could lead to calculation mistakes

Note: change of material type will result in deleting the quantities (column N, W and U) in the respective building components.

You can choose for every building component one material type. Based on this selection, relevant materials and the respective quantity unit will show up in the cells to the right:

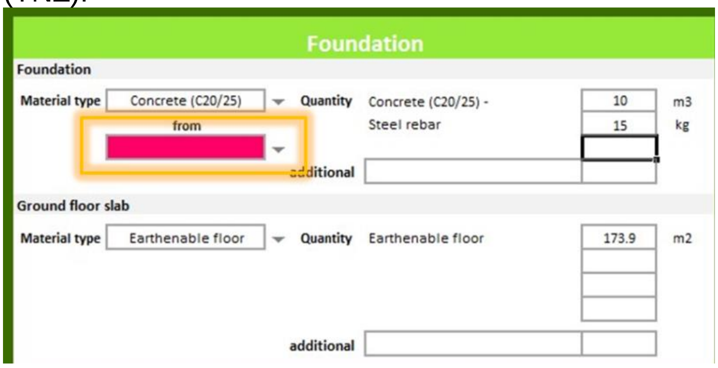


If a relevant material is missing, you could add additional materials on the right side of the cell named “additional”:



You can also adapt the unit for this material in column O.

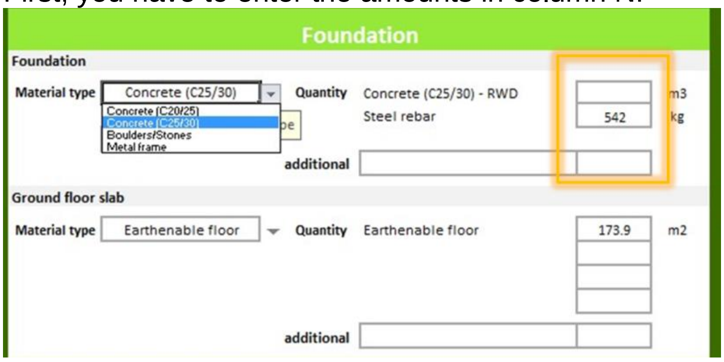
If you choose any material which contains cement, you have to specify the cement origin in Cell J15. You can choose between Rwanda (RWD), Uganda (UGA) and Tanzania (TNZ):



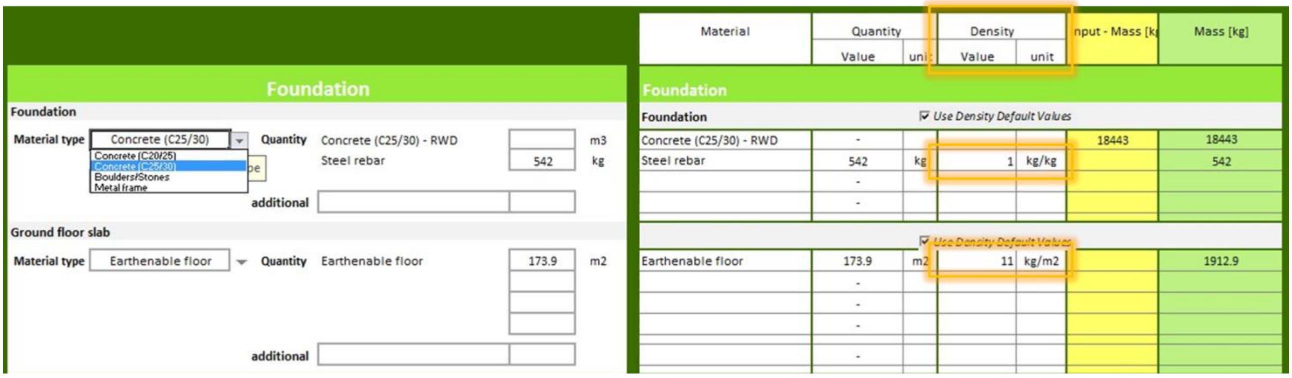
Note: missing origin input will be highlighted by red background colour

2. **Enter the quantity** either A) according to the material specific units given in column O or B) by entering directly the masses.

   A) **Input of quantities** according to the material specific units
   First, you have to enter the amounts in column N:

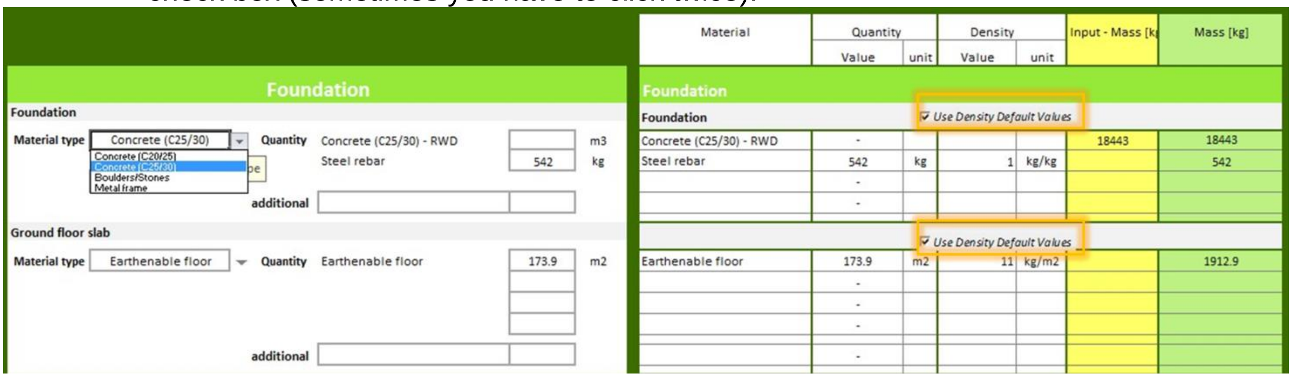


You cannot change the units for the given materials, except of the additional ones. In the next step, you have to specify the density for the automatic mass calculation:



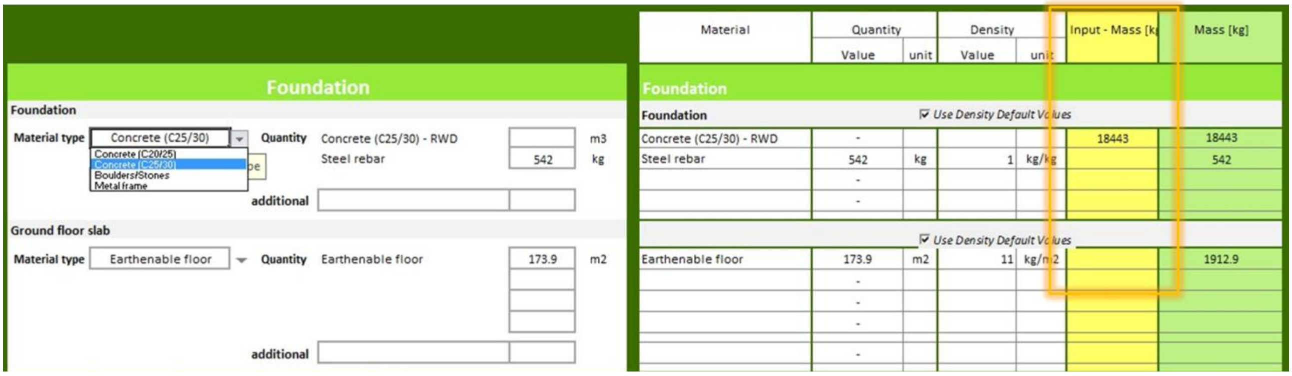
The density refers always to the units in column O.

You can also use default values (see Appendix R) of the densities by clicking the check box (sometimes you have to click twice):



B) Input of masses

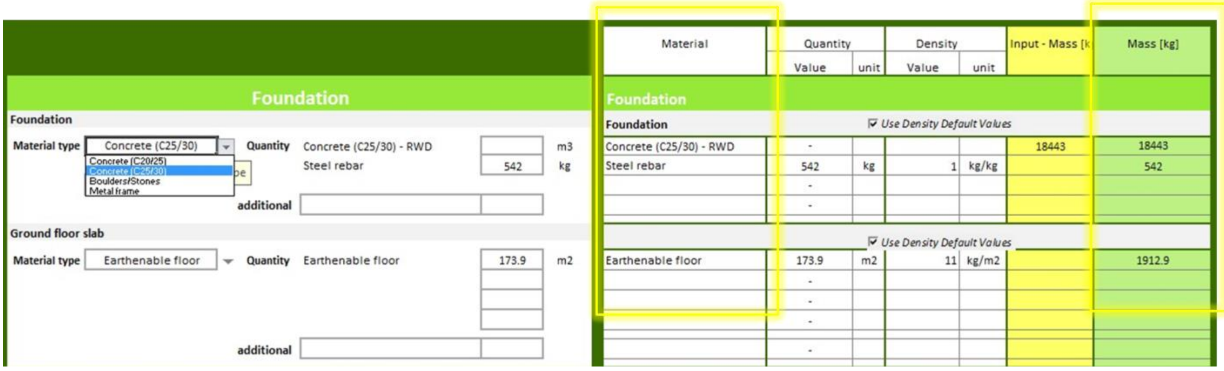
You can also enter directly the masses in column W:



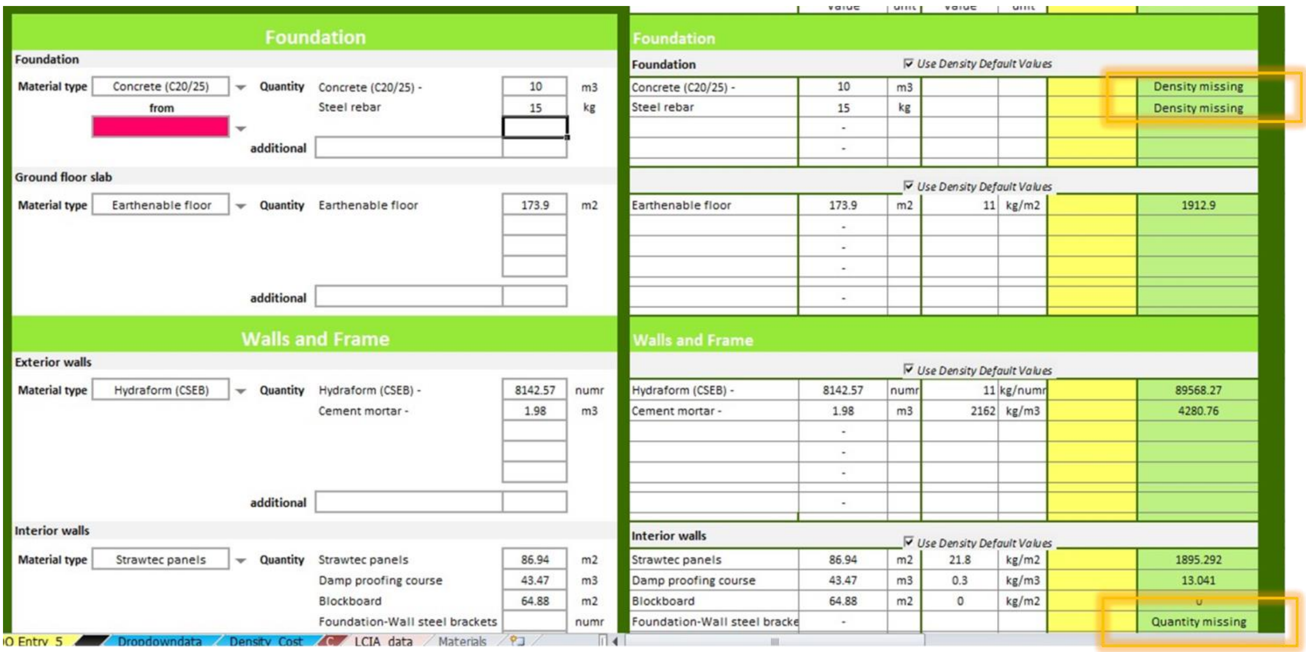
These values are treated preferential. If you enter a quantity in column W, the other amounts are neglected.

3.4 Bill of quantity

The complete list of materials and their weights are summarized in column R and X:



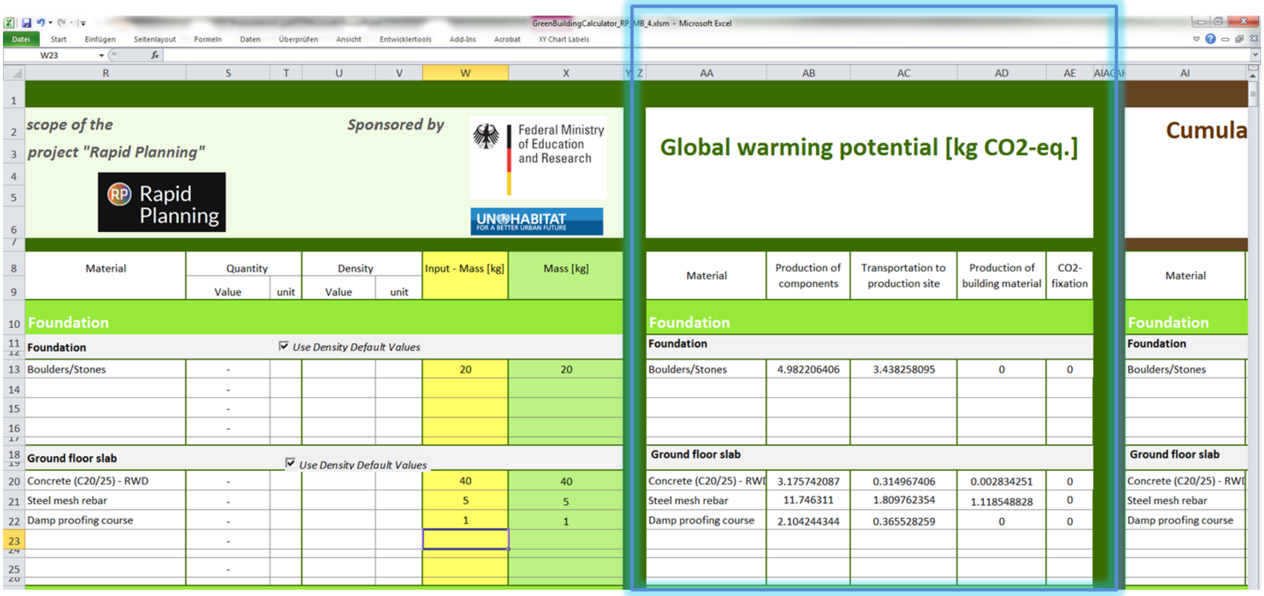
If any quantities are missing, a message appears in column X, which refers to missing quantities or densities:



The masses in kilogram are the basis of the environmental impact and indicator calculations.

3.5 Results

The results are presented in the result area per life cycle phase:



Following life cycle phases are covered:

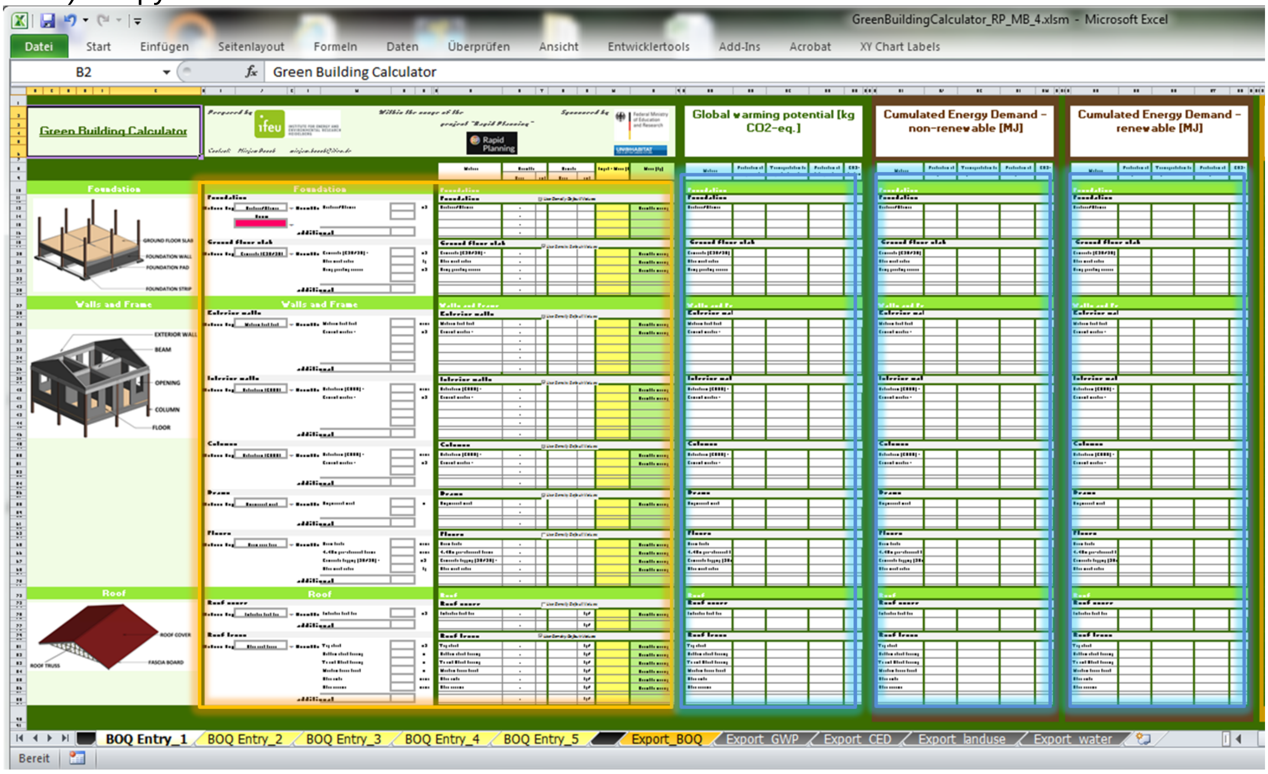
- Production of component
- Transportation of components
- Production of building material
- CO2-fixation

The results are presented by impact or indicator categories.

3.6 Export of input and results

The building specifications and the results sheet can be manually copied to the export work-sheets. They are not connected to the BOQ_Entries, but are intended to provide assistance for export and further calculations or creating diagrams as described in the following:

1) Copy the cells from line 10 to 88 as follows:



2) Paste them to the respective export sheet by paste contents.

Appendix A: Cobwork

Building material name used in BMC

- Wood and clay (Cobwork)

Composition of construction materials

Material	Value	Unit	Comment
Wood chips	0.104	kg per kg	Correspondence with engineers
Water	0.113	kg per kg	
Clay	1,010	kg per kg	

Energy demand ~~for mixing of the composition~~at building site

no energy is needed on building site

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]
Wood chips	Kigali – on site	0
Water		0
Clay		0

Appendix B: Adobe dried bricks

Building material name used in BMC

- Adobe bricks

Composition of construction materials

Material	Value	Unit	Comment
Clay	0.97	kg per kg	Correspondence with engineers
Lime	0.02	kg per kg	
Sand	0.01	kg per kg	

Energy demand ~~for mixing of the composition~~at building site

no energy is needed on building site

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]
Wood chips	Kigali – on site	0
Water		0
Clay		0

Appendix C: Traditional fired brick

Building material name used in BMC

- Traditional fired brick

Composition of construction materials

Material	Value	Unit	Comment
Clay	0.96	kg per kg	Correspondence with industry
Lime	0.025	kg per kg	
Sand	0.015	kg per kg	

Energy demand ~~for mixing of the composition~~at building siteat building site

Material	Value	Unit	Comment
Wood ~~(Energy mix: Rwanda)~~	6	MJ/kg	Traditional brick furnaces are exclusively being lit with wood

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
Sand	Rwanda	7.5 by truck	Sand extracted locally and gets directly delivered to manufacture
Clay	Rwanda	0	Material comes directly from the ground
Lime	Rwanda	0	Material comes directly from the ground
Mixed logs (hard & soft wood)	Rwanda	80 by truck	Assumption based on forestry in Rwanda [Promar 2012]

Appendix D1: Modern fired bricks

Building material name used in BMC

- Modern fired bricks

Composition of construction materials

Material	Value	Unit	Comment
Clay	0.96	kg per kg	Correspondence with industry
Lime	0.025	kg per kg	
Sand	0.015	kg per kg	

Energy demand ~~for mixing of the composition~~at building siteat building site

Material	Value	Unit	Comment
Saw dust ~~**(Energy mix: Rwanda)**~~	~~1.25~~0.625	MJ/kg	- Industrial furnaces are primarily being lit up with saw dust and/or coffe husks. to ignite the flame a small amount of wood is needed
coffee husks	0.625~~1.25~~	MJ/kg	- Assumption based on correspondence with industry
Diesel for extruder	0.0012	litre/kg	Ecoinvent 3.2

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
Sand	Rwanda	7.5 by truck	Sand extracted locally and gets directly delivered to manu-facture. Presumably from Ruhango/Kajumbo/Bugesera/Kabuga
Lime	Rwanda	7.5 by truck	Assumption: local extraction
Clay			
Saw dust	Rwanda	80 by truck	Assumption based on coffee production & forestry in Rwanda based on [Promar 2012]
coffee husks			

Appendix D2: Modern fired tiles

Building material name used in BMC

- Modern clay tiles

Composition of construction materials

Material	Value	Unit	Comment
Clay	0.9	kg per kg	Correspondence with SKAT
Kaolin	0.1	kg per kg	

Energy demand ~~for mixing of the composition~~at building siteat building site

Material	Value	Unit	Comment
Saw dust ~~**(Energy mix: Rwanda)**~~	0.625~~1.25~~	MJ/kg	- Industrial furnaces are primarily being lit up with saw dust and/or coffee husks. to ignite the flame a small amount of wood is needed
Coffee husks	0.625~~1.25~~	MJ/kg	- Assumption based on correspondence with industry
Diesel for extruder	0.0012	litre/kg	Ecoinvent 3.2

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
Clay	Rwanda	7.5 by truck	Assumption: local extraction
Kaolin			
Saw dust	Rwanda	80 by truck	Assumption based on coffee production & forestry in Rwanda based on [Promar 2012]
Coffee husks			

Appendix E1: Industrial fired bricks

Building material name used in BMC

- Industrial fired brick

Composition of construction materials

Material	Value	Unit	Comment
Clay	0.75	kg per kg	Correspondence with industry
Kaolin	0.25	kg per kg	

Energy demand ~~for mixing of the composition~~at building siteat building site

Material	Value	Unit	Comment
coffee husks	0.132	MJ per kg ~~/~~product	Correspondence with industry
Electricity ~~**(Energy mix: Rwanda)**~~	0.039	kWh/kg product	

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
Clay	Burundi	15.5 by truck	Clay transport from Kinyinya to Kigali
Kaolin	Rwanda	7.5 by truck	Assumption: local extraction
Coffee husks	Rwanda	80 by truck	Assumption based on coffee production in Rwanda based on [Promar 2012]

Appendix E2: Industrial fired roof tiles

Building material name used in BMC

- Industrial fired tiles

Composition of construction materials per kg building material

Material	Value	Unit	Comment
Clay	0.85	kg per kg	Correspondence with industry
Kaolin	0.15	kg per kg	

Energy demand ~~for mixing of the composition~~at building siteat building site

Material	Value	Unit	Comment
coffee husks	0.132	MJ~~kg~~ per kg ~~/~~product	Correspondence with industry
Electricity, medium voltage ~~(Energy mix: Rwanda)~~	0.039	kWh/kg product	

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
Clay	Burundi	15.5 by truck	Correspondence with industry (clay transport from Kinyinya to Kigali)
Kaolin	Rwanda	7.5 by truck	Assumption: local extraction
coffee husks	Rwanda	80 by truck	Assumption based on coffee production in Rwanda based on [Promar 2012]

Appendix F1: Concrete and cement mortar from Rwanda

Building material names used in BMC

1. Concrete (C20/25) with Rwanda cement CIMERWA:
   - Concrete (C20/25) – RWA
   - Concrete topping (20/25) – RWA
2. Concrete (C25/30) with Rwanda cement CIMERWA:
   - Concrete (C25/30) – RWA
3. Cement mortar with Rwanda cement CIMERWA:
   - Cement mortar - RWA

Composition of construction materials

Material	Concrete (C20/25) (42.5N)	Concrete (C25/30) (42.5N)	Cement Mortar (32.5N)	Unit	Comment
Gravel	1303	1140	-	kg/m³ con-crete	Average composition
Sand	686	800	1920	kg/m³ con-crete	Average composition
CEM II/ A-P 42.5N CIMERWA	214	250	-	kg/m³ con-crete	Average composition
CEM II/ B-M 32.5N CIMERWA	-	-	300	kg/m³ con-crete	Average composition
Cement origin	Rwanda	Rwanda	Rwanda		
Tap Water	107	125	150	kg/m³ con-crete	Average composition

Energy demand for concrete mixing

Material	Value	Unit	Comment
Diesel ~~(Energy mix: Rwanda)~~	1.44	MJ/m³	- Half of concrete is mixed by hand and half by 4kW concrete mixer with a capacity of 5 m³/h Assumption based on Lescha concrete mixers[1] - Mortar: only hand mixing is assumed

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
Gravel	Rwanda	40 by truck	Extraction site: Bugesera
Sand	Rwanda	7.5 by truck	Extraction site: Ruhango/Kajumbo/Bugesera/Kabuga
cement production in Uganda	Rwanda	350 by truck	From CIMERWA cement production site to Kigali

[1] LESCHA AT 480 400V 480L: HTTP://WWW.LESCHA.DE/PRODUKTE/BETONMISCHER/LESCHA-AT-480-AT-480-400V-480L/

Appendix F2: Concrete and cement mortar from Uganda

Building material names used in BMC

Materials:

1. Concrete (C20/25) with Ugandan cement HIMA:
   - Concrete (C20/25) – UGA
   - Concrete topping (20/25) – UGA
2. Concrete (C25/30) with Ugandan cement HIMA:
   - Concrete (C25/30) – UGA
3. Cement mortar with Ugandan cement HIMA:
   - Cement mortar - UGA

Composition of construction materials

Material	Concrete (C20/25) (42.5N)	Concrete (C25/30) (42.5N)	Cement Mortar (32.5N)	Unit	Comment
Density	2310	2315	2370	kg/m³	Average density
Gravel	1303	1140	-	kg/m³ concrete	Average composition
Sand	686	800	1920	kg/m³ concrete	Average composition
CEM II/ A-P 42.5N CIMERWA	214	250	-	kg/m³ concrete	Average composition
CEM II/ B-M 32.5N CIMERWA			300	kg/m³ concrete	Average composition
Cement origin	Uganda	Uganda	Uganda		
Tap Water	107	125	150	kg/m³ concrete	Average composition

Energy demand for concrete mixing

Material	Value	Unit	Comment
Diesel ~~(Energy mix: Rwanda)~~	1.44	MJ/m³	- Half of concrete is mixed by hand and half by 4kW concrete mixer with a capacity of 5 m³/h Assumption based on Lescha concrete mixers[2] - Mortar: only hand mixing is assumed

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
Gravel	Rwanda	40 by truck	Gravel extracted locally and gets directly delivered to manufacture
Sand	Rwanda	7.5 by truck	Sand extracted locally and gets directly delivered to manufacture
Cement production	Uganda	350 by truck	From HIMA production site to Kigali

2 LESCHA AT 480 400V 480L: HTTP://WWW.LESCHA.DE/PRODUKTE/BETONMISCHER/LESCHA-AT-480-AT-480-400V-480L/

Appendix F3: Concrete and cement mortar from Tanzania

Building material names used in BMC

Materials:

1. Concrete (C20/25) with Tanzanian cement SIMBA :
   - Concrete (C20/25) – TNZ
   - Concrete topping (20/25) – TNZ
2. Concrete (C25/30) with Tanzanian cement SIMBA:
   - Concrete (C25/30) – TNZ
3. Cement mortar with Tanzanian cement SIMBA IMARA:
   - Cement mortar - TNZ

Composition of construction materials

Material	Concrete (C20/25) (42.5N)	Concrete (C25/30) (42.5N)	Cement Mortar (32.5R)	Unit	Comment
Density	2310	2315	2370	kg/m³	Average density
Gravel	1303	1140	-	kg/m³ concrete	Average composition
Sand	686	800	1920	kg/m³ concrete	Average composition
CEM II/ A-P 42.5N CIMERWA	214	250	-	kg/m³ concrete	Average composition
CEM II/ B-M 32.5N CIMERWA			300	kg/m³ concrete	Average composition
Cement origin	Tanzania	Tanzania	Tanzania		
Tap Water	107	125	150	kg/m³ concrete	Average composition

Energy demand for concrete mixing

Material	Value	Unit	Comment
Diesel ~~**(Energy mix: Rwanda)**~~	1.44	MJ/m³	- Half of concrete is mixed by hand and half by 4kW concrete mixer with a capacity of 5 m³/h Assumption based on Lescha concrete mixers[3] - Mortar: only hand mixing is assumed

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
Gravel	Rwanda	40 by truck	Extraction site: Bugesera
Sand	Rwanda	7.5 by truck	Extraction site: Ruhango/Kajumbo/Bugesera/Kabuga
cement production	Tanzania	1332 by truck	From Simba production site to Kigali

[3] LESCHA AT 480 400V 480L: http://www.lescha.de/produkte/betonmischer/lescha-at-480-at-480-400v-480l/

Appendix G: Boulder stones

Building material name used in BMC

- Boulders/stones

Composition of construction materials

Material	Origin	Value	Unit
Boulder	Kenya	1	kg

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
Boulder stone	Kenya	1250 by truck	- Transport from Kajiado County (Kenya) to Kigali (Rwanda)[4] - Assumption based on [Mining Investment Kenya]

[4]Transport from Kajiado County (Kenya) to Kigali (Rwanda):
https://www.google.de/maps/dir/Kajiado+County,+Kenia/Kigali,+Ruanda/@-2.0862535,28.9839657,6z/data=!3m1!4b1!4m13!4m12!1m5!1m1!1s0x182fd16d5851886f:0x6810f86b051f11ec!2m2!1d36.7819505!2d-2.0980751!1m5!1m1!1s0x19dca4258ed8e797:0xf32b36a5411d0bc8!2m2!1d30.1044288!2d-1.9705786

Appendix I: Damp Proof Course

Building material name used in BMC

- Damp proofing course

Composition of construction materials

Material	Value	Unit
LDPE	1	kg

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
Damp proof course LDPE (foil)	China	1621 by truck	Transport within China and from Tanga (Tanzania) to Kigali (Rwanda)
	China	12548 by cargo ship	Transport from China to Tanzania[5]

[5] Transport from China to Tanzania: https://www.searates.com/reference/portdistance/?A=ChIJwULG5WSOUDERbzafNHyqHZU&K=ChIJfSzAjucSQBgRWtvQNbyLYcs&D=753&G=10327&shipment=1&container=20st&weight=1&product=0&request=0&

Appendix H1: Cement block with cement from Rwanda

Building material name used in BMC

- Cement blocks - RWD

Composition of construction materials

Material	Value	Unit	Comment
Gravel	554.59	kg/m³ concrete	Correspondence with industry
Sand	1556.76	kg/m³ concrete	
Cement	162.16	kg/m³ concrete	
Tap Water	81.08	kg/m³ concrete	

Energy demand ~~for mixing of the composition~~at building siteat building site

Material	Value	Unit	Comment
Diesel	1.44	kg/m³ concrete	- Half of concrete is mixed by hand and half by 4kW concrete mixer with a capacity of 5 m³/h Assumption based on Lescha concrete mixers[6]
Electricity ~~**(Energy mix: Rwanda)**~~	3.77	kWh/m³	- Operation of cement brick forming machine - Assumption based on cement brick forming machine QJT4-40[7]

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
Gravel	Rwanda	120 by truck	Assumed distance
Sand	Rwanda	7.5 by truck	Assumption: local extraction
Cement production	Rwanda	350 by truck	From CIMERWA production site to Kigali

[6] LESCHA AT 480 400V 480L: http://www.lescha.de/produkte/betonmischer/lescha-at-480-at-480-400v-480l/
[7] Brick forming machine QJT4-40: http://www.brick-supplier.com/wp-content/uploads/2016/04/11.jpg

Appendix H2: Cement block with cement from Uganda

Building material name used in BMC

- Cement blocks – UGA

Composition of construction materials

Material	Value	Unit	Comment
Gravel	554.59	kg/m³ concrete	Correspondence with industry
Sand	1556.76	kg/m³ concrete	
Cement	162.16	kg/m³ concrete	
Tap Water	81.08	kg/m³ concrete	

Energy demand ~~for mixing of the composition~~at building siteat building site

Material	Value	Unit	Comment
Diesel	1.44	kg/m³ con-crete	- Half of concrete is mixed by hand and half by 4kW con-crete mixer with a capacity of 5 m³/h - Assumption based on Lescha concrete mixers[8]
Electricity ~~(Energy mix: Rwanda)~~	3.77	kw/m³	- Operation of cement brick forming machine - Assumption based on cement brick forming machine QJT4-40[9]

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
Gravel	Rwanda	120 by truck	Gravel extracted locally and gets directly delivered to manufacture
Sand	Rwanda	7.5 by truck	Assumption: local extraction
Cement production	Uganda	350 by truck	From HIMA production site to Kigali

[8] LESCHA AT 480 400V 480L
http://www.lescha.de/produkte/betonmischer/lescha-at-480-at-480-400v-480l/
[9] Brick forming machine QJT4-40
http://www.brick-supplier.com/wp-content/uploads/2016/04/11.jpg

Appendix H3: Cement block with cement from Tanzania

Building material name used in BMC

- Cement blocks – TNZ

Composition of construction materials

Material	Value	Unit	Comment
Gravel	555	kg/m³ concrete	Average composition
Sand	1557	kg/m³ concrete	
Cement	162	kg/m³ concrete	
Tap Water	81	kg/m³ concrete	

Energy demand ~~for mixing of the composition~~at building siteat building site

Material	Value	Unit	Comment
Diesel	1.44	kg/m³ concrete	- Half of concrete is mixed by hand and half by 4kW concrete mixer with a capacity of 5 m³/h - Assumption based on Lescha concrete mixers[10]
Electricity mix Tanzania	3.77	kWh/m³	- Operation of cement brick forming machine - Assumption based on cement brick forming machine QJT4-40[11]

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
Gravel	Rwanda	120 by truck	
Sand	Rwanda	7.5 by truck	Assumption: local extraction
cement pro-duction	Tanzania	350 by truck	From SIMBA production site to Kigali

[10] LESCHA AT 480 400V 480L
http://www.lescha.de/produkte/betonmischer/lescha-at-480-at-480-400v-480l/
[11] Brick forming machine QJT4-40
http://www.brick-supplier.com/wp-content/uploads/2016/04/11.jpg

Appendix J: Strawtec

Building material name used in BMC

- Strawtec panels

Composition of construction materials

Material	Value	Unit	Comment
Straw	0.94	kg per kg	Assumption based on correspondence with industry
Paper board	0.04	kg per kg	
Glue	0.02	kg per kg	
Hexamine	0.000233	kg per kg	
Kaolin	0.002914	kg per kg	
Phelonic Resin	0.016277	kg per kg	

Energy demand ~~for mixing of the composition~~at building siteat building site

Material	Value	Unit	Comment
Electricity (Energy mix: Rwanda)	0.046	kwh/kg panel	Correspondence with industry

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
Straw	Rwanda	70 by truck	Musanze district to Kigali factory (approx. 100km)[12]
Paper board	France	1500 by truck	Distance from Tanga (Tanzania) to Kigali[13]
		12000 by cargo ship	Distance from Le Havre to Tanga (Tanzania)[14]
Glue	Norway	1500 by truck	Distance from Tanga (Tanzania) to Kigali[15]
		13000 by cargo ship	Distance from Oslo to Tanga[16]

[12] Musanze district to Kigali factory: https://www.google.de/maps/dir/Musanze+District+Office,+Ruhengeri-Gisenyi+Road,+Ruhengeri,+Nordprovinz,+Ruanda/Kigali,+Ruanda/@-1.7362898,29.308399,9z/data=!3m1!4b1!4m13!4m12!1m5!1m1!1s0x19dc5a447020d8a3:0x4183166c56a8b314!2m2!1d29.6332937!2d-1.5019003!1m5!1m1!1s0x19dca4258ed8e797:0xf32b36a5411d0bc8!2m2!1d30.1044288!2d-1.9705786

[13] Distance from Tanga (Tanzania) to Kigali https://www.google.de/maps/dir/Tanga,+Tansania/Kigali,+Ruanda/@-3.6427142,25.5614862,5z/data=!3m1!4b1!4m13!4m12!1m5!1m1!1s0x1843db998b2fc7b5:0xe1c1578528c3ddf3!2m2!1d39.1023228!2d-5.0888751!1m5!1m1!1s0x19dca4258ed8e797:0xf32b36a5411d0bc8!2m2!1d30.1044288!2d-1.9705786

[14] Distance from Le Havre to Tanga (Tanzania): https://www.searates.com/reference/portdistance/?K=ChIJtccvi5nbQxgR893DKIVXweE&A=ChIJfYshlSMv4EcREq8zr3qGwVs&D=4683&G=12812&shipment=1&container=20st&weight=1&product=&request=0&

[15] Distance from Tanga (Tanzania) to Kigali https://www.google.de/maps/dir/Tanga,+Tansania/Kigali,+Ruanda/@-3.6427142,25.5614862,5z/data=!3m1!4b1!4m13!4m12!1m5!1m1!1s0x1843db998b2fc7b5:0xe1c1578528c3ddf3!2m2!1d39.1023228!2d-5.0888751!1m5!1m1!1s0x19dca4258ed8e797:0xf32b36a5411d0bc8!2m2!1d30.1044288!2d-1.9705786

[16] Distance from Oslo to Tanga https://www.searates.com/reference/portdistance/?K=ChIJtccvi5nbQxgR893DKIVXweE&A=ChIJOfBn8mFuQUYRmh4j019gkn4&D=33977&G=12812&shipment=1&container=20st&weight=1&product=&request=0&

Appendix K1: Hydraform with cement from Rwanda

Building material name used in BMC

- Hydraform (CSEB) - RWD

Composition of construction materials

Material	Value	Unit	Comment
Clay	0.88	kg per kg	Average composition[17]
Cement	0.12	kg per kg	

Energy demand ~~for mixing of the composition~~at building siteat building site

Material	Value	Unit	Comment
Diesel ~~(Energy mix: Rwanda)~~	0.017	MJ/kg brick	Based on average usage of 13 litres of diesel per 2500 bricks[18]

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
Cement production	Rwanda	350 by truck	From CIMERWA production site to Kigali
Clay	Rwanda	3 by truck	Assumption: local extraction
Sand	Rwanda	7.5 by truck	Assumption: local extraction

17 GUIDE TO SOIL SELECTION FOR BLOCK PRODUCTION http://www.hydraform.com/technical/guide-to-soil-selection-for-block-production
18 http://www.arushatimes.co.tz/2011/46/front%20page_3.html

Appendix K2: Hydraform with cement from Uganda

Building material name used in BMC

- Hydraform (CSEB) - UGA

Composition of construction materials

Material	Value	Unit	Comment
Clay	0.88	kg per kg	Average composition[19]
Cement	0.12	kg per kg	

Energy demand ~~for mixing of the composition~~at building siteat building site

Material	Value	Unit	Comment
Diesel (Energy mix: Uganda)	0.017	MJ/kg brick	Based on average usage of 13 litres of diesel per 2500 bricks[20]

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
Cement production	Uganda	350 by truck	From HIMA production site to Kigali
Clay	Rwanda	3 by truck	Assumption: local extraction
Sand	Rwanda	7.5 by truck	Assumption: local extraction

[19] GUIDE TO SOIL SELECTION FOR BLOCK PRODUCTION http://www.hydraform.com/technical/guide-to-soil-selection-for-block-production
[20] http://www.arushatimes.co.tz/2011/46/front%20page_3.html

Appendix K3: Hydraform with cement from Tanzania

Building material name used in BMC

- Hydraform (CSEB) - TNZ

Composition of construction materials

Material	Value	Unit	Comment
Clay	0.88	kg per kg	Average composition[21]
Cement	0.12	kg per kg	

Energy demand ~~for mixing of the composition~~at building siteat building site

Material	Value	Unit	Comment
Diesel (Energy mix: Tanzania)	0.017	MJ/kg brick	Based on average usage of 13 litres of diesel per 2500 bricks[22]

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
Cement production	Tanzania	1332 by truck	See source 22
Clay	Rwanda	3 by truck	Assumption: local extraction
Sand	Rwanda	7.5 by truck	Assumption: local extraction

[21] GUIDE TO SOIL SELECTION FOR BLOCK PRODUCTION
http://www.hydraform.com/technical/guide-to-soil-selection-for-block-production
[22] http://www.arushatimes.co.tz/2011/46/front%20page_3.html

Appendix L1: Modulus with cement from Rwanda

Building material name used in BMC

- Modulus bricks - RWD

Composition of construction materials

Material	Value	Unit	Assumption
Clay	0.53	kg per kg	Average composition
Sand	0.39	kg per kg	
Cement	0.08	kg per kg	

Energy demand for modulus mixing

Material	Value	Unit	Comment
Electrical power (Energy mix: Rwanda)	0.0094	kWh/kg	Electricity for interlocking brick machine [23,24]

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
cement produc-tion	Rwanda	350 by truck	From CIMERWA cement production site to Kigali
Clay	Rwanda	3 by truck	Assumption: local extraction
Sand	Rwanda	7.5 by truck	Assumption: local extraction
Modulus	Rwanda	7.5 by truck	Transport from production site in Kigali to building site

[23] ECO 2-25 INTERLOCKING BRICK MACHINE
http://www.yfbrickmachine.com/detail-199-eco225interlockingbrickmachine
[24] http://www.lescha.de/produkte/betonmischer/lescha-at-480-at-480-400v-480l/

Appendix L2: Modulus with cement from Uganda

Building material name used in BMC

- Modulus bricks - UGA

Composition of construction materials

Material	Value	Unit	Comment
Clay	0.53	kg per kg	Average composition
Sand	0.39	kg per kg	
Cement	0.08	kg per kg	

Energy demand for modulus mixing

Material	Value	Unit	Comment
Electrical power (Energy mix: Uganda)	0.0094	kWh/kg	Electricity for interlocking brick machine [25]

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
Cement production	Uganda	350 by truck	From HIMA production site to Kigali
Clay	Kigali	7.5 by truck	Assumption: local extraction
Sand	Kigali	7.5 by truck	Assumption: local extraction
Modulus	Rwanda	7.5 by truck	Transport from production site in Kigali to building site

[25] ECO 2-25 INTERLOCKING BRICK MACHINE

http://www.yfbrickmachine.com/detail-199-eco225interlockingbrickmachine

Appendix L3: Modulus with cement from Tanzania

Building material name used in BMC

- Modulus bricks - TNZ

Composition of construction materials

Material	Value	Unit	Comment
Clay	0.53	kg per kg	Average composition
Sand	0.39	kg per kg	
Cement	0.08	kg per kg	

Energy demand for modulus mixing

Material	Value	Unit	Comment
Electrical power (Energy mix: Tanzania)	0.0094	kWh/kg	Electricity for interlocking brick machine[26]

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
Cement production	Tanzania	1332 by truck	From Simba production site to Kigali
Clay	Rwanda	7.5 by truck	Assumption: local extraction
Sand	Rwanda	7.5 by truck	Assumption: local extraction
Modulus	Rwanda	7.5 by truck	Transport from production site in Kigali to building site

[26] ECO 2-25 INTERLOCKING BRICK MACHINE
http://www.yfbrickmachine.com/detail-199-eco225interlockingbrickmachine

Appendix M: Earthenable

Building material name used in BMC

- Earthenable floor

Composition of construction materials

Material	Value	Unit	Comment
Laterite	0.1280	kg per kg	
Gravel (crushed)	0.1280	kg per kg	
Non sieved sand	0.2629	kg per kg	
Clay	0.1076	kg per kg	Correspondence with industry
Sieved Sand	0.1	kg per kg	
Tap Water	0.0648	litre per kg	
EarthEnable Oil	0.2087	litre/kg	

Energy demand ~~for mixing of the composition~~at building site

Material	Value	Unit	Comment
Electrical power (Energy mix: Rwanda)	0.2329	kWh/kg	Correspondence with industry

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
Clay	Rwanda	7.5 by truck	Assumption: local extraction
Sand	Rwanda	7.5 by truck	Assumption: local extraction
Gravel	Rwanda	7.5 by truck	Assumption: local extraction
Earthe-nable Oil	Rwanda	0.03478 by truck	- km per used kg of EarthEnable - Varnish: by truck from Ndera to our sites in Bugesera, the distance is approximately 49 km - Varnish (oil): Ecoinvent vehicle measurement unit only in km (without load-allocation); Toyota Hilus has permitted maximum load of 680 km Assumption for mass: 300 kg additional load of oil According to this, the distance of 50 km is allocated with the mass of Earthenable per kg 50km/300kg = 0,16667km/kg Multiplied with amount of oil per kg Earthenable - Assumptions based on correspondence with industry

Appendix N1: Reinforcing Steel

Building material names used in BMC

Materials:

1. Reinforcing steel 1kg:
   - 4.45m pre-stressed beams
   - Bottom chord bracing
   - Steel
   - Steel mesh rebar
   - Steel rebar
   - Tie and strut bracing
   - Top chord

Composition of construction materials

Material	Value	Unit
Unalloyed, reinforced steel	1	kg

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
Rein-forcing Steel	China	1621 by truck	Transport within China and from Tanga (Tanzania) to Ki-gali (Rwanda)[27]
	China	12548 by car-go ship	Transport from China to Tanzania[28]

[27] Transport within China and from Tanga (Tanzania) to Kigali (Rwanda) https://www.google.com/maps/dir/Tanga,+Tansania/Kigali,+Ruanda/@-8.5626269,30.5312665,5.5z/data=!4m13!4m12!1m5!1m1!1s0x1843db998b2fc7b5:0xe1c1578528c3ddf3!2m2!1d39.1023228!2d-5.0888751!1m5!1m1!1s0x19dca4258ed8e797:0xf32b36a5411d0bc8!2m2!1d30.1044288!2d-1.9705786

[28] Transport from China to Tanzania https://www.searates.com/reference/portdistance/?A=ChIJwULG5WSOUDERbzafNHyqHZU&K=ChIJtccvi5nbQxgR893DKIVXweE&D=753&G=12812&shipment=1&container=20st&weight=1&product=&request=0&

Appendix N2: Screws

Building material name used in BMC

- Steel screws

Composition of construction materials

Material	Value	Unit
Low alloyed, uncoated steel	1	kg

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
Screws	China	1621 by truck	Transport within China and from Tanga (Tanzania) to Kigali (Rwanda)[29]
	China	12548 by truck	Transport from China to Tanzania[30]

[29] Transport within China and from Tanga (Tanzania) to Kigali (Rwanda) https://www.google.com/maps/dir/Tanga,+Tansania/Kigali,+Ruanda/@-8.5626269,30.5312665,5.5z/data=!4m13!4m12!1m5!1m1!1s0x1843db998b2fc7b5:0xe1c1578528c3ddf3!2m2!1d39.1023228!2d-5.0888751!1m5!1m1!1s0x19dca4258ed8e797:0xf32b36a5411d0bc8!2m2!1d30.1044288!2d-1.9705786

[30] Transport from China to Tanzania https://www.searates.com/reference/portdistance/?A=ChIJwULG5WSOUDERbzafNHyqHZU&K=ChIJtccvi5nbQxgR893DKIVXweE&D=753&G=12812&shipment=1&container=20st&weight=1&product=&request=0&

Appendix N3: Metal (poles, shoes)

Building material names used in BMC

Materials:

1. Metal (poles, shoes) 1kg:
   - Foundation-wall steel brackets
   - Metal frame
   - Steel joints

Composition of construction materials

Material	Value	Unit	Comment
Low alloyed, zinc coated steel	1	kg	

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
Metal	China	1621 by truck	Transport within China and from Tanga (Tanzania) to Kigali (Rwanda)[31]
	China	12548 by truck	Transport from China to Tanzania[32]

[31] Transport within China and from Tanga (Tanzania) to Kigali (Rwanda) https://www.google.com/maps/dir/Tanga,+Tansania/Kigali,+Ruanda/@-8.5626269,30.5312665,5.5z/data=!4m13!4m12!1m5!1m1!1s0x1843db998b2fc7b5:0xe1c1578528c3ddf3!2m2!1d39.1023228!2d-5.0888751!1m5!1m1!1s0x19dca4258ed8e797:0xf32b36a5411d0bc8!2m2!1d30.1044288!2d-1.9705786

[32] Transport from China to Tanzania https://www.searates.com/reference/portdistance/?A=ChIJwULG5WSOUDERbzafNHyqHZU&K=ChIJtccvi5nbQxgR893DKIVXweE&D=753&G=12812&shipment=1&container=20st&weight=1&product=&request=0&weightcargo=1&

Appendix O1: Wood

Building material names used in BMC

Materials:

1. Wood 1kg:
   - Purlins (2" X 3")
   - Rafter (2" X 6")
   - Ridge beam (2" X 6")
   - Wood

Composition of construction materials

Material	Value	Unit
Wood	1	kg

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
Sawlog and veneer log, hardwood, measured as solid wood under bark	Rwanda	80 by truck	Average distance based on [Promar 2012]

Appendix O2: Plywood

Building material name used in BMC

- Blockboard

Composition of construction materials

Material	Value	Unit	Comment
Plywood	1	kg	- Made from eucalyptus - http://www.csudh.edu/oliver/chemdata/woods.htm

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
Plywood	China	1621 by truck	Transport within China and from Tanga (Tanzania) to Kigali (Rwanda)[33]
		12548 by cargo ship	Transport from China to Tanzania[34]
		80 by truck	Average distance based on [Promar 2012]

[33] Transport within China and from Tanga (Tanzania) to Kigali (Rwanda)
https://www.google.com/maps/dir/Tanga,+Tansania/Kigali,+Ruanda/@-8.5626269,30.5312665,5.5z/data=!4m13!4m12!1m5!1m1!1s0x1843db998b2fc7b5:0xe1c1578528c3ddf3!2m2!1d39.1023228!2d-5.0888751!1m5!1m1!1s0x19dca4258ed8e797:0xf32b36a5411d0bc8!2m2!1d30.1044288!2d-1.9705786

[34] Transport from China to Tanzania
https://www.searates.com/reference/portdistance/?A=ChIJwULG5WSOUDERbzafNHyqHZU&K=ChIJtccvi5nbQxgR893DKIVXweE&D=753&G=12812&shipment=1&container=20st&weight=1&product=&request=0&

Appendix O3: Engineered Wood

Building material name used in BMC

- Engineered Wood

Material	Density	Unit
Engineered wood	1	kg

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
Engineered wood	DR Congo	1000 by truck	From Momboa, DR Congo, to Kigali[35] Assumption based on[36]

[35] From Momboa, DR Congo, to Kigali https://www.google.com/maps/dir/Kigali,+Ruanda/Mamboa,+Demokratische+Republik+Kongo/@-0.5770265,25.4654566,7z/data=!3m1!4b1!4m13!4m12!1m5!1m1!1s0x19dca4258ed8e797:0xf32b36a5411d0bc8!2m2!1d30.1044288!2d-1.9705786!1m5!1m1!1s0x1750c0221f3347e9:0xd78d2fe6d9033b43!2m2!1d25.25869!2d1.370862

[36] Transport distance of engineered wood http://landsat.gsfc.nasa.gov/landsat-helps-assess-impacts-of-industrial-logging-in-central-africa/

Appendix P: Corrugated metal roof sheet

Building material name used in BMC

- Corrugated metal

Composition of construction materials

Material	Value	Unit	Comment
Low alloy steel	6.79	kg/m²	- Gauge 0.7 mm - Assumption based on[37]
Aluminium-zinc alloy	0.185	kg/m²	- Assumption based on[38]
Aluminium	0.10175	kg/m²	
Zinc	0.080475	kg/m²	
Silicon (silicium)	0.002775	kg/m²	

Energy demand for corrugated steel manufacturing

Material	Value	Unit	Comment
Energy (Energy mix: Rwanda)	250	kwh/kg	- 80 % electric energy, 20 % diesel generator - Assumption based on Ecoinvent 3.2 data

Transport of composites to construction site in Kigali

Material	Origin	Distance [km]	Comment
Steel sheet	Japan	12790 by cargo ship	Transport from Tokyo to Mombasa[39]
Corrugated steel sheet	Kenya	1440 by truck	Transport from Mombasa to Kigali[40]

[37] Material thickness assumption: https://www.schwedenbleche.de/trapezblech/profil-1876
[38] Alloy composition: http://www.siegmetall.de/produkte/wellbleche/s1876/?no_cache=1#tabs-3
[39] Transport from Tokyo to Mombasa: https://www.searates.com/reference/portdistance/?A=ChIJ51cu8IcbXWARiRtXIothAS4&K=ChIJfSzAjucSQBgRWtvQNbyLYcs&D=10283&G=10327&shipment=1&container=20st&weight=1&product=0&request=0&
[40] Transport from Mombasa to Kigali https://www.google.de/maps/dir/Mombasa,+Kenia/Kigali,+Kigali+City,+Ruanda/@-2.0862459,30.3310839,6z/data=!3m1!4b1!4m13!4m12!1m5!1m1!1s0x184012e78ec02c7d:0xcb618bbc35d0db5a!2m2!1d39.6682065!2d-4.0434771!1m5!1m1!1s0x19dca4258ed8e797:0xf32b36a5411d0bc8!2m2!1d30.1044288!2d-1.9705786

Appendix Q: Energy Mix

Energy Mix Rwanda

Electricity mix	Value	Comment
Hydropower	57.87 %	Reference year: 2012 Based on: The Statistical Yearbook 2014 of National Institute of Statistics of Rwanda 2014[41]
Diesel	40.25 %	
Methane gas/natural gas	1.82 %	
PV	0.06 %	

Energy Mix Uganda

Electricity mix	Value	Comment
Hydropower	81.00 %	Reference year: 2013/2014 Based on: Based on UNEP FI-Working paper[42]
Diesel	12.00 %	
Bagasse co-generation	7.00 %	

Energy Mix Tanzania

Electricity mix	Value	Comment
Hydropower	35.44 %	Reference year: 2014 Based on: Electricity Supply Industry Reform Strategy and Roadmap 2014 – 2025, 30 th June 2014, The United Republic of Tanzania, Ministry of Energy and Minerals[43]
Diesel	31.27%	
Methane gas/natural gas	33.29%	

Energy Mix Kenya

Electricity mix	Value	Comment
Hydropower	55.20 %	Reference year: 2013 Based on: Emissions reduction profile - Democratic Republic of Congo UNEP RISØ, June 2013, supported by ACP-MEA & UNFCCC[44]
Diesel	22.87%	
Methane gas/natural gas	0.31 %	
Bagasse co-generation	0.94 %	
Geothermal	20.69%	

Energy Mix Kenya

Electricity mix	Value	Comment
Hydropower	55.20 %	Reference year: 2013 Based on: Market Study to Strengthen Economic Cooperation in the Energy Sector, presented by Triple E Consulting – Energy, Environment & Economics B.V., 1st of October 2014 [45]
Diesel	22.87%	
Methane gas/natural gas	0.31 %	
Bagasse co-generation	0.94 %	
Geothermal	20.69%	

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[41] http://statistics.gov.rw/publication/statistical-yearbook-2014
[42] https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/8891.pdf
[43] http://www.gst.go.tz/images/TANZANIA%20ELECTRICITY%20SUPPLY%20INDUSTRY%20REFORM%20STRATEGY%20&%20ROADMAP.pdf.
[44] http://www.acp-cd4cdm.org/media/366216/emissions-reduction-profile-dr_congo.pdf
[45] http://trinomics.eu/wp-content/uploads/2015/05/Market-study-to-strenghten-economic.pdf.

Appendix R: Default densities

Densities per lenght

BuildingMaterial	Density	Unit	Sources other than official supplier
Blockboard	0.563	kg/m	based on following dimensions: 10cm x 1.5cm density wood: 375 kg / m³ (1)
Engineered wood	6	kg/m	dimensions: 0.05 x 0.15m density per m³: 375 kg/m³ (1)
Pre-stressed beams	33	kg/m (1)	
Purlins (2" X 3")	1.4	kg/m	density per m³: 375 kg/m³ (1)
Rafter (2" X 6") / Ridge beam (2" X 6")	2.81	kg/m	density per m³: 375 kg/m³ (1)
Wooden facia Board	1.1	kg/m	dimensions: 0.05 x 0.15m density per m³: 375 kg/m³ (1)

(1) Expert judgment based on communication with industry and average online sources

Densities per area

BuildingMaterial	Density	Unit	Sources other than official supplier
Corrugated metal	7	kg/m²	Thickness: 0.7 mm (1)
Damp proof core (DPC)	0.26	kg/m²	Thickness: 0.3 mm (1)
Earthenable	154	kg/m²	Thickness: 7.6 cm (1)
Modern clay tiles	26	kg/m²	Dimensions: 37.5 x 18.5 x 2.5 density per m³: 1025 kg/m³ (1)
Strawtec panels	21.8	kg/m²	Thickness: 6 cm (1)
Top chord (JSI steel roof truss)	10.2	kg/m² (1)	

(1) Expert judgment based on communication with industry and average online sources

Densities per volume

BuildingMaterial	Density	Unit	Sources other than official supplier
Boulders/Stones	2803	kg / m³ (1)	
Cement mortar	2162	kg / m³ (1)	
Concrete C20/25	2380	kg / m³ (1)	
Concrete C25/30	2380	kg / m³ (1)	
Wood	375	kg / m³ (1)	Density per m: 2.813 kg/m (Dimension: 50X150 cm²)
Wood and clay (Cob-work)	1550	kg / m³ (1)	

(1) Expert judgment based on communication with industry and average online sources

Densities per item

BuildingMaterial	Density	Unit	Sources other than official supplier
Adobe bricks	27	Kg/item	dimensions: 40 x 20 x 20 cm³ density per m³: 1700 kg/m³ (1)
Cement block	13	kg/item	dimensions: 40 x 20 x 20 cm³ density per m³: 1000 kg/m³ (1)
Hollow block	9	kg/item	dimensions: 37.5 x 25.5 x 16 cm³ density per m³: 588 kg/m³ (1)
Hydraform (CSEB)	11	kg/item	dimensions: 24 x 22 x 11.5 cm³ density per m³: 1811 kg/m³ (1)
Industrial fired bricks	1.6	kg/item	dimensions: 21 x 10 x 6.3 cm³ density per m³: 1209 kg/m³ (1)
Modern fired bricks	1.4	kg/item	dimensions: 21 x 10 x 6.3 cm³ density per m³: 1025 kg/m³ (1)
Modulus bricks	1.4	kg/item	dimensions: 20 x 10 x 6.5 cm³ density per m³: 1075 kg/m³ (1)
Pre-stressed beams	146.85	kg/item	Length: 4.45m density per m²: 33 kg/m² (1)
Steel joints/ Foundation-Wall steel brackets	0.36	kg/item	Average size (1)
Steel screws	0.0008	kg/item	Average size (1)
Traditional fired bricks	1.65	kg/item	dimensions: 21 x 10 x 5 cm³ density per m³: 1571 kg/m³ (1)

(1) Expert judgment based on communication with industry and average online sources

Appendix S: Appendix literature

[Promar 2012]
Promar 2012. Agriculture, Forestry and Fisheries of Rwanda. Fact-finding Survey for the Support of Aid to Developing Countries (Fiscal Year 2011 Research Project) Supported by the Ministry of Agriculture, Forestry and Fisheries

[Mining Investment Uganda]
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[Mining Investment Kenya]
Government of the Republic of Kenya, 2015, Ministry of Mining