RAPID PLANNING

SUSTAINABLE INFRASTRUCTURE, ENVIRONMENTAL AND RESOURCE MANAGEMENT FOR HIGHLY DYNAMIC METROPOLISES

LIFE CYCLE ASSESSMENT OF SIX BUILDINGS IN KIGALI

REMY RUBERAMBUGA, LEONARD BYIRINGIRO, MICHEL SCHMITT

RAPID PLANNING - LOCATIONS

Da Nang, Vietnam

Kigali, Rwanda

Assiut, Egypt

Frankfurt, Germany

Project goal: Finding planning solutions for rapidly growing cities

RAPID PLANNING – GREEN BUILDING RESEARCH ASSISTANTS IN KIGALI

Leonard Byiringiro

Ba. Of Eng. Buildig and construction engineering

Joshua Ishingwe

Ba. Of Eng. Buildig and construction engineering

Remy Ruberambuga

Ba. of Eng. Building and construction engineering

Michel Schmitt

Ba. of Eng. Green Buildings

Jakob Schweiger

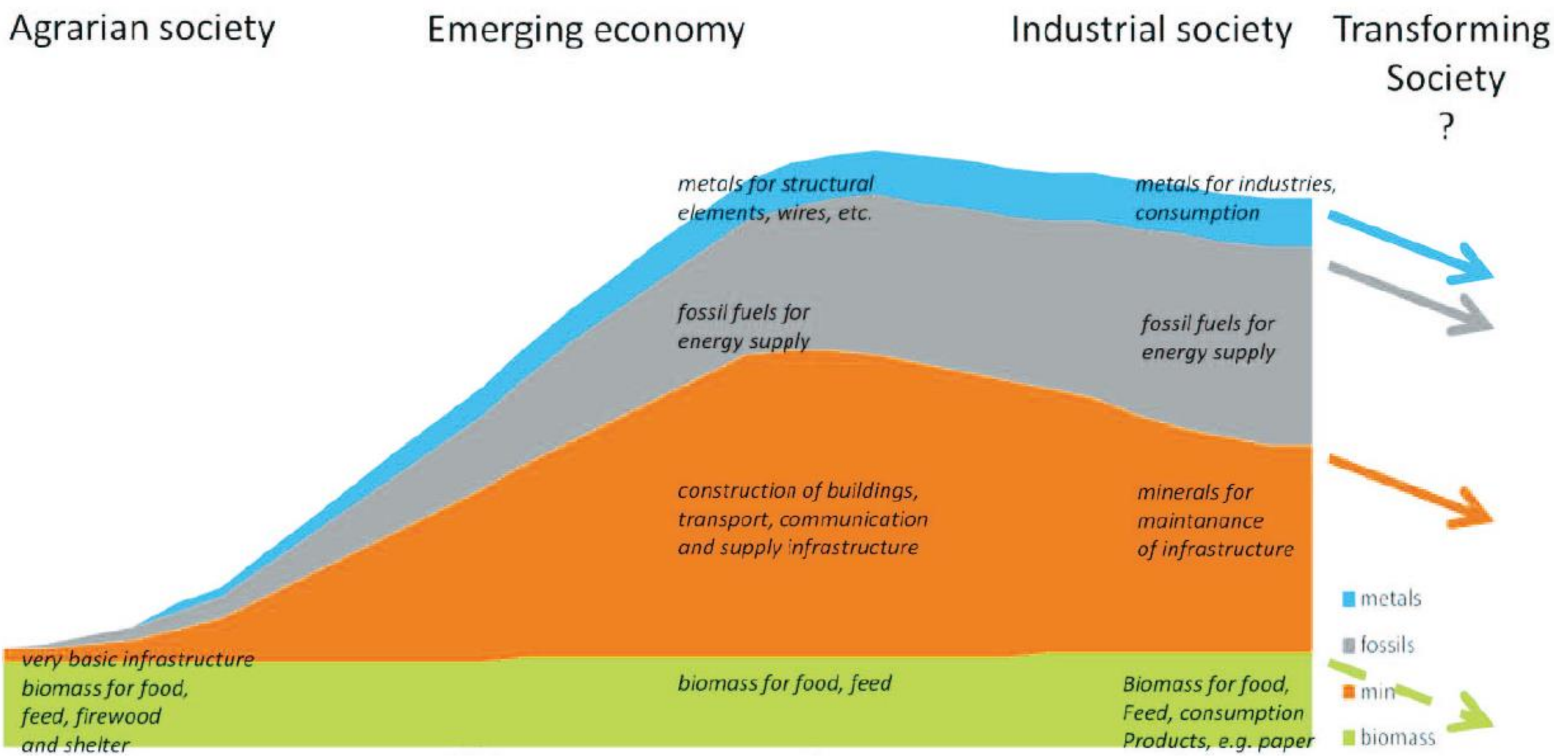
Ma. of Sci. Energyefficient and sustainable buildings

STRUCTURE

- Mass flow in Kigali with comparison to Frankfurt
- Global warming
- Life Cycle Assessment
- Study Area
- Building Material Calculator (BMC)
- Results from the study
- Conclusion and next steps

Goal: Simplify decisionmaking in green building material selection through life cycle assessment

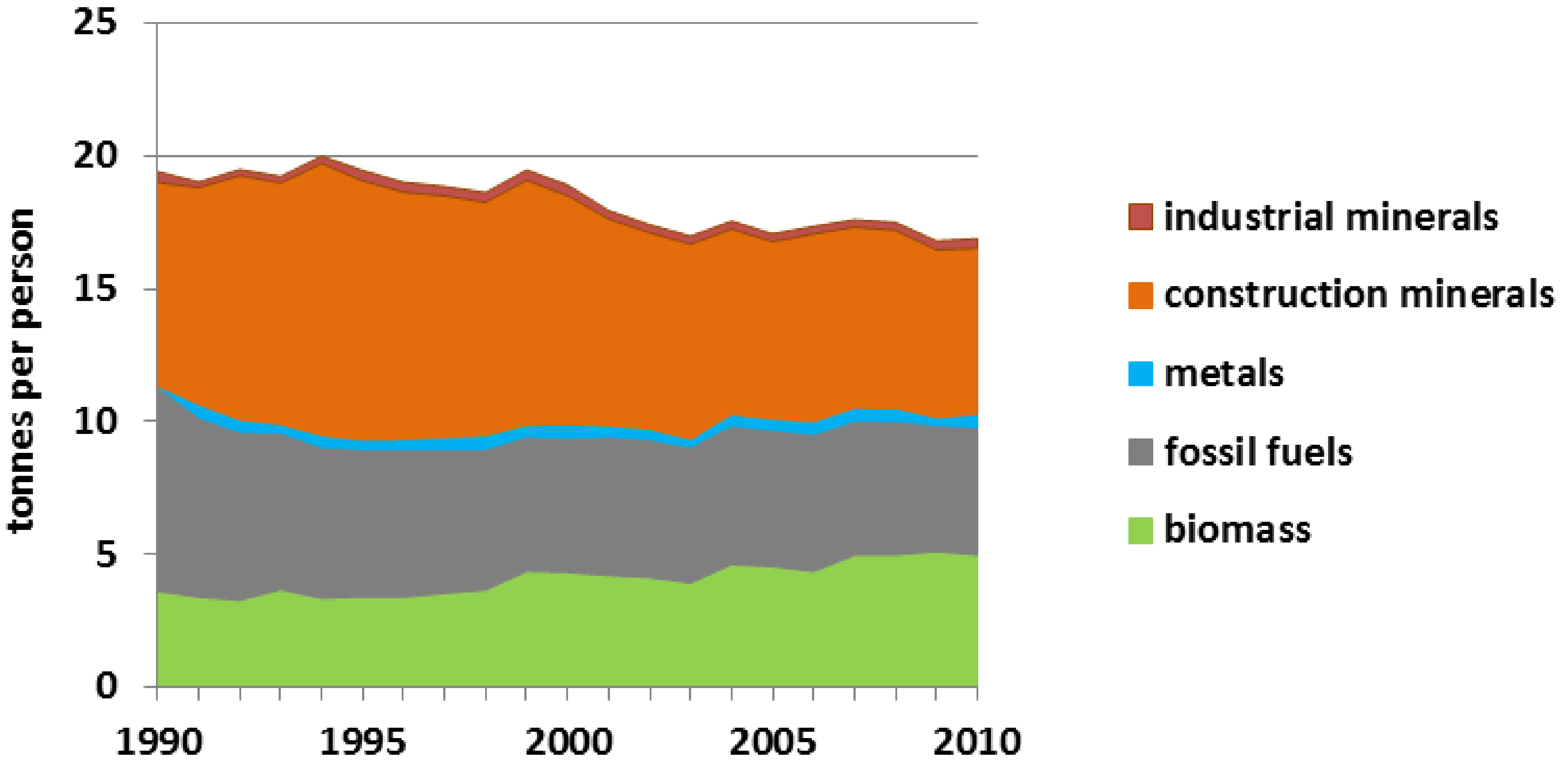
TYPICAL MATERIAL CONSUMPTION PATTERN DURING A DEVELOPMENT



- Resource consumption in emerging and industrial society is very high

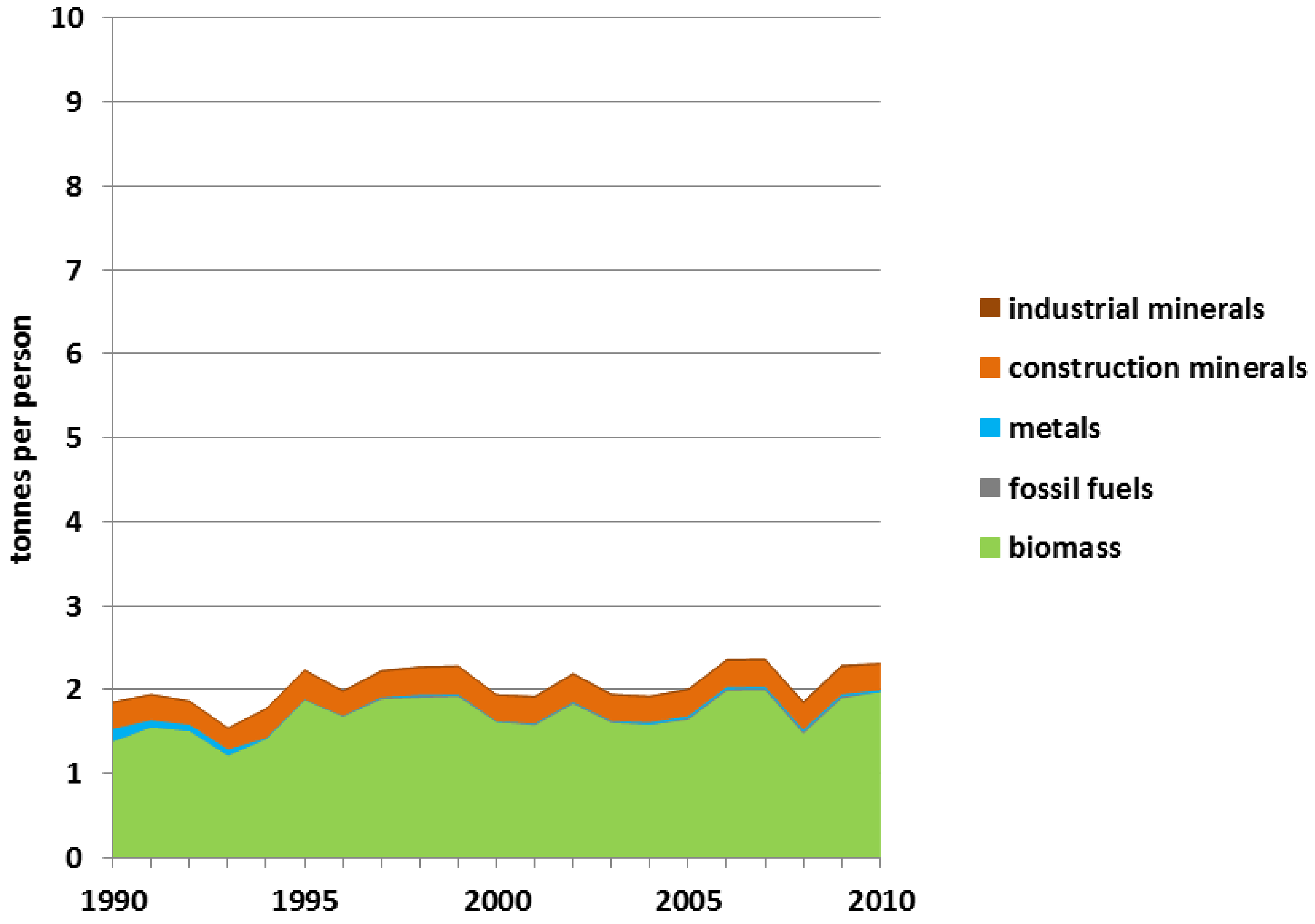
Source: rapid planning research program, materialflows.net

Material consumption in Frankfurt, Germany



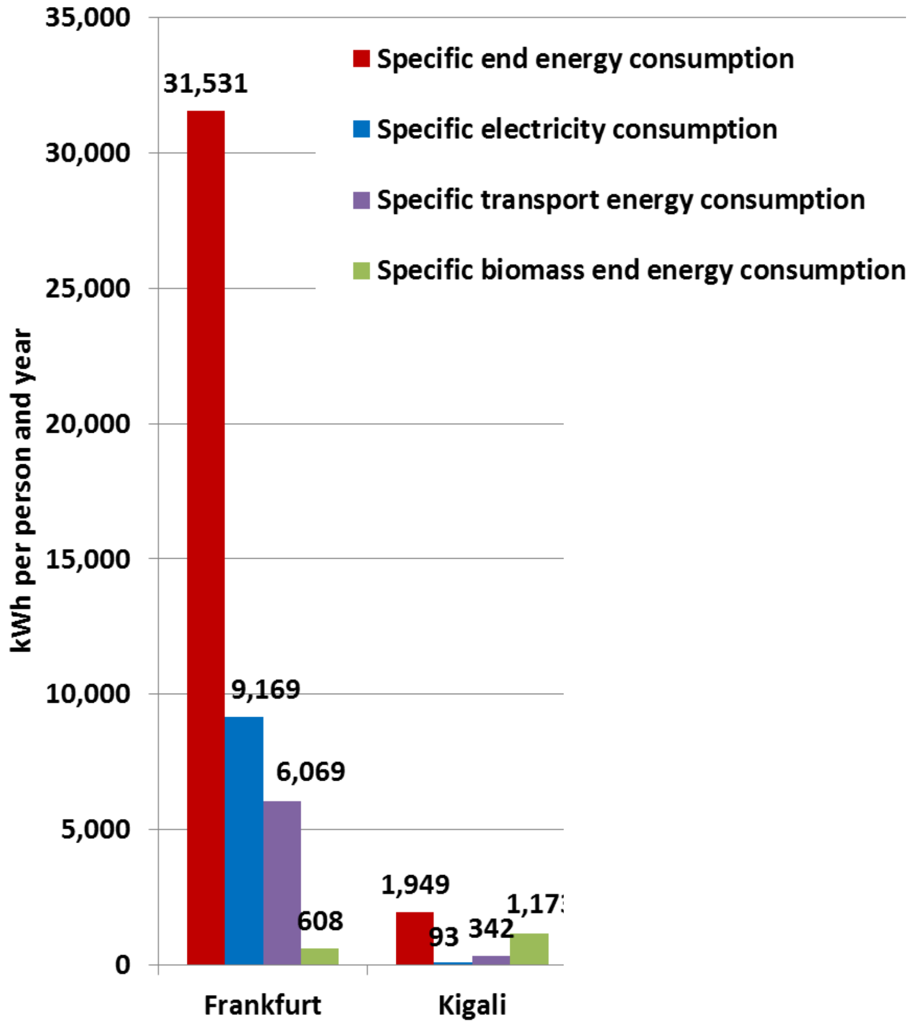
Source: rapid planning research program, materialflows.net

MATERIAL CONSUMPTION IN KIGALI, RWANDA



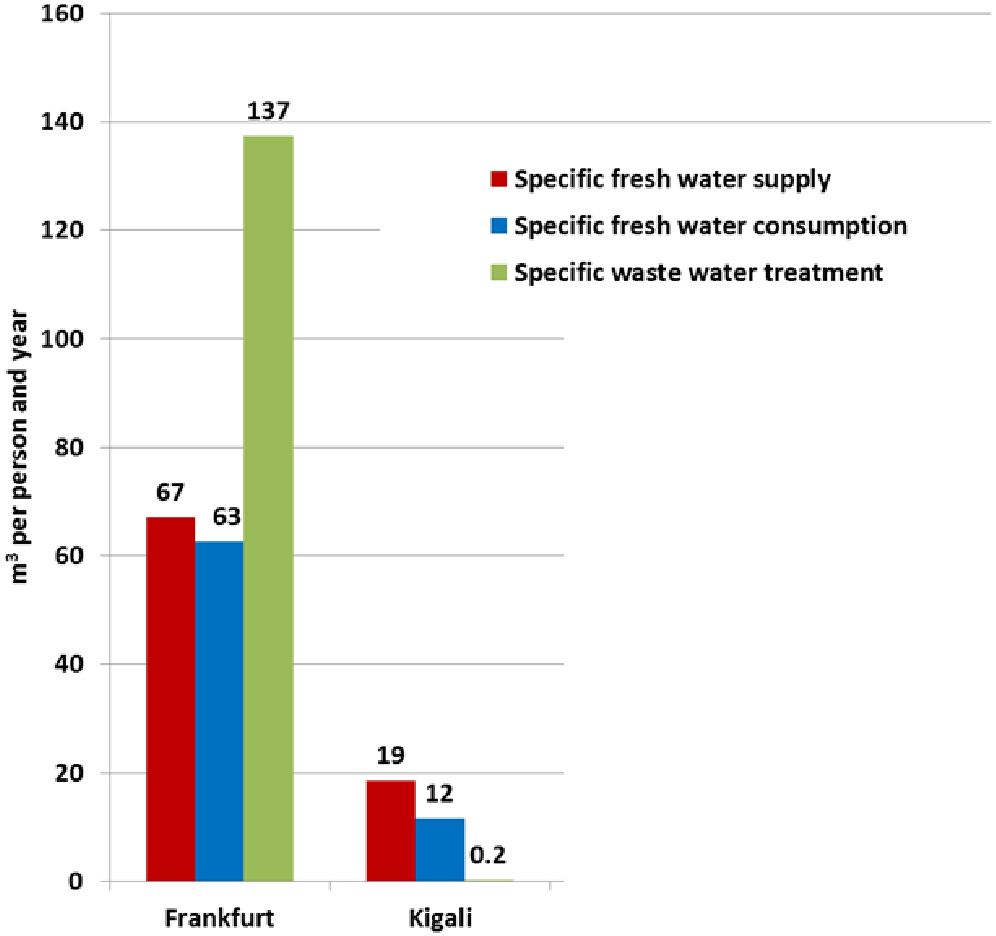
Source: rapid planning research program, materialflows.net

Energy Consumption



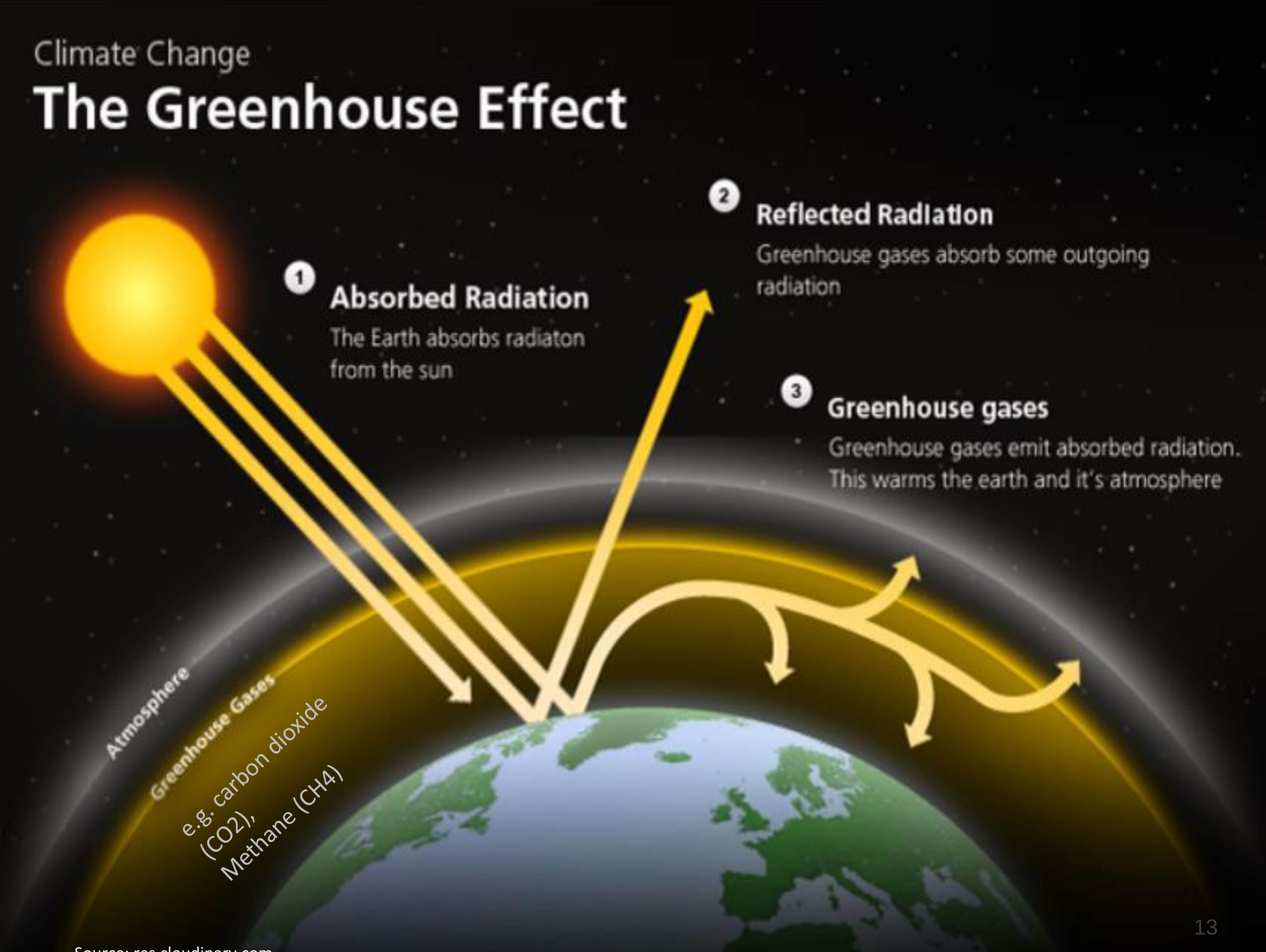
Source: rapid planning research program

WATER CONSUMPTION



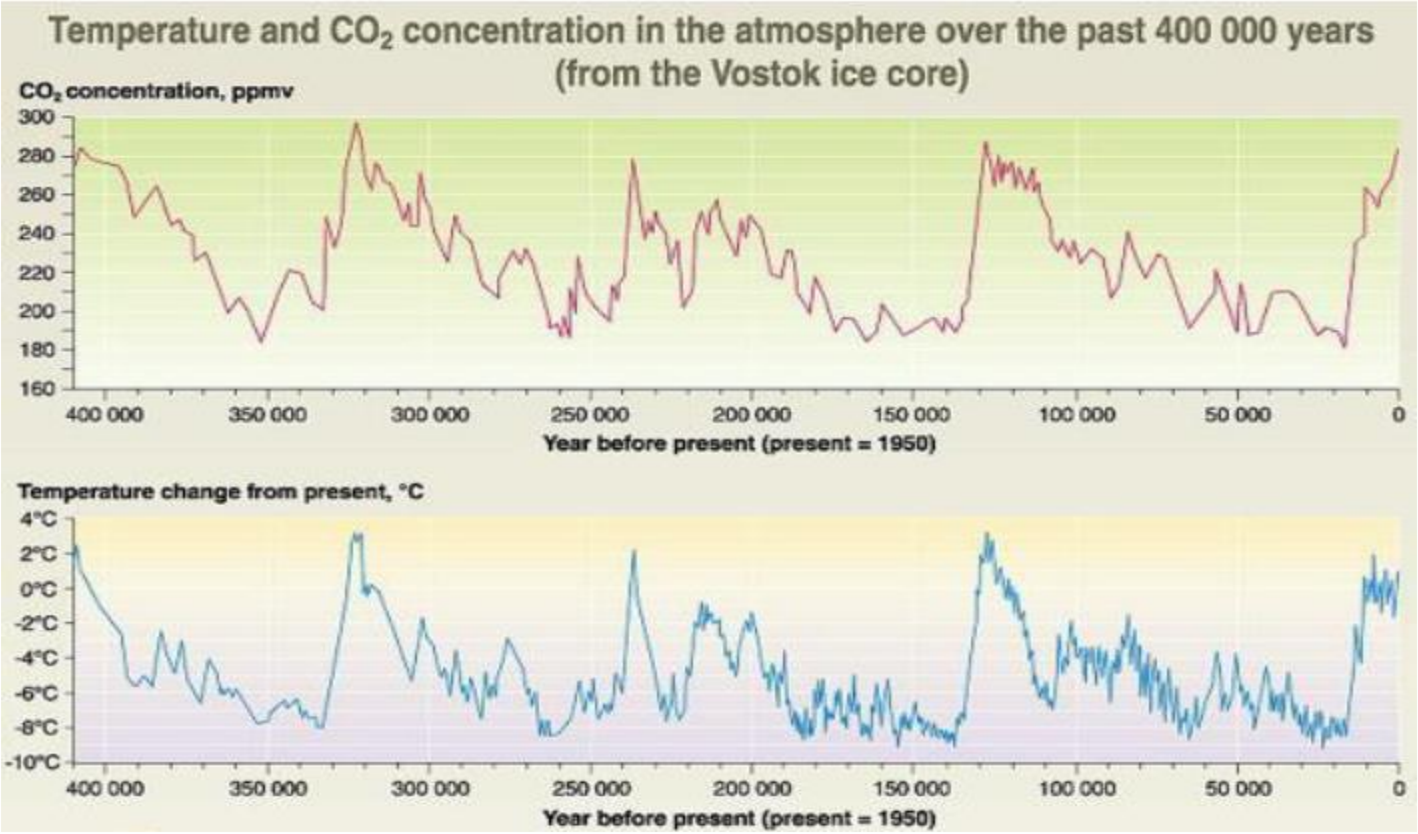
Source: rapid planning research program

What are the CONSEQUENCES of high ressource consumption?



Source: res.cloudinary.com

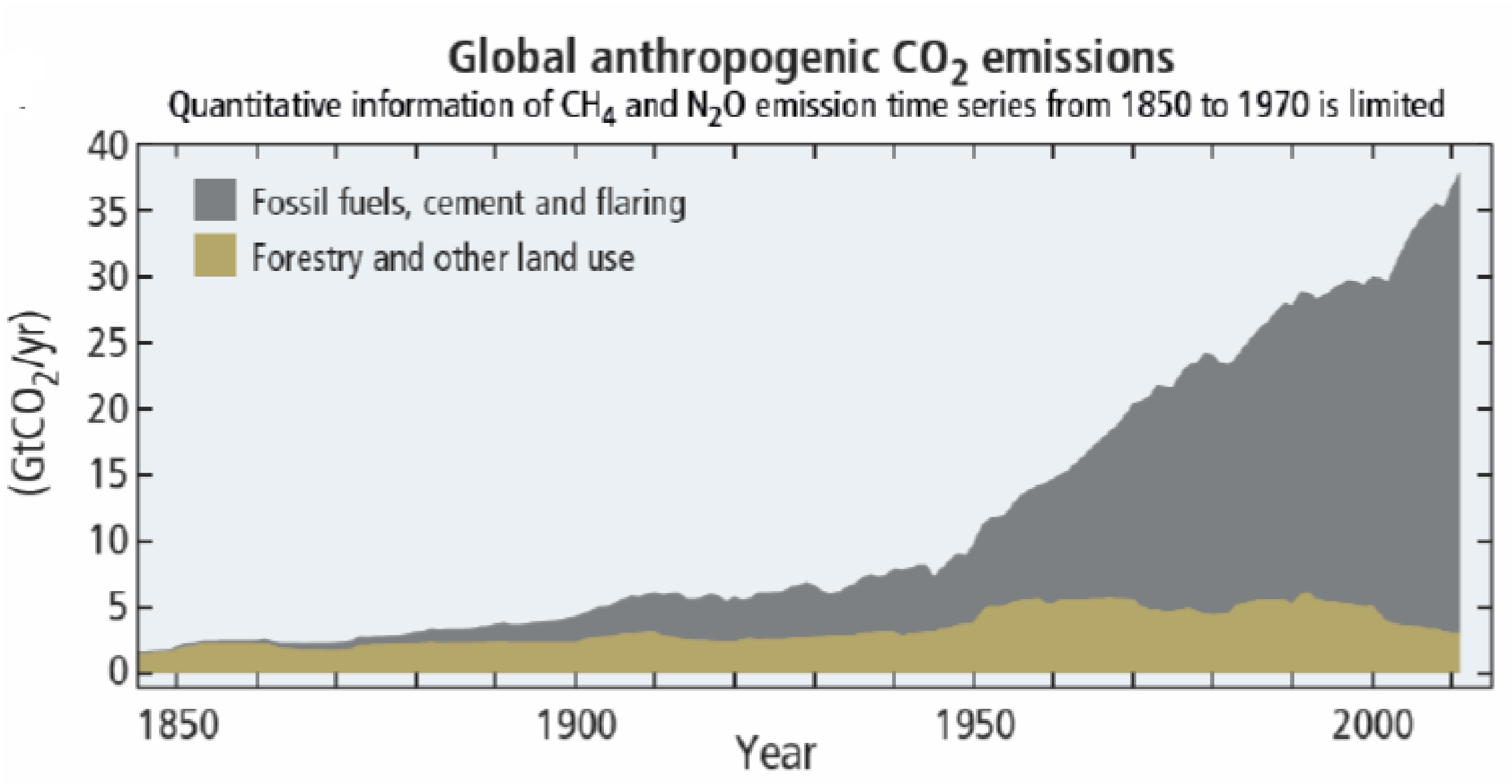
HISTORICAL RELATION OF CO2 CONCENTRATION AND TEMPERATURE



- Increase of CO2 in atmosphere leads to higher average temperatures
- Decrease of CO2 in atmosphere leads to lower average temperatures

Source: GRID-ArendalMaps and Graphics Library

DEVELOPEMENT OF CO2 EMISSIONS



Source: IPCC (2014), ClimateChange –Synthesis Report

RWANDA: PROJECTED GHG EMISSIONS

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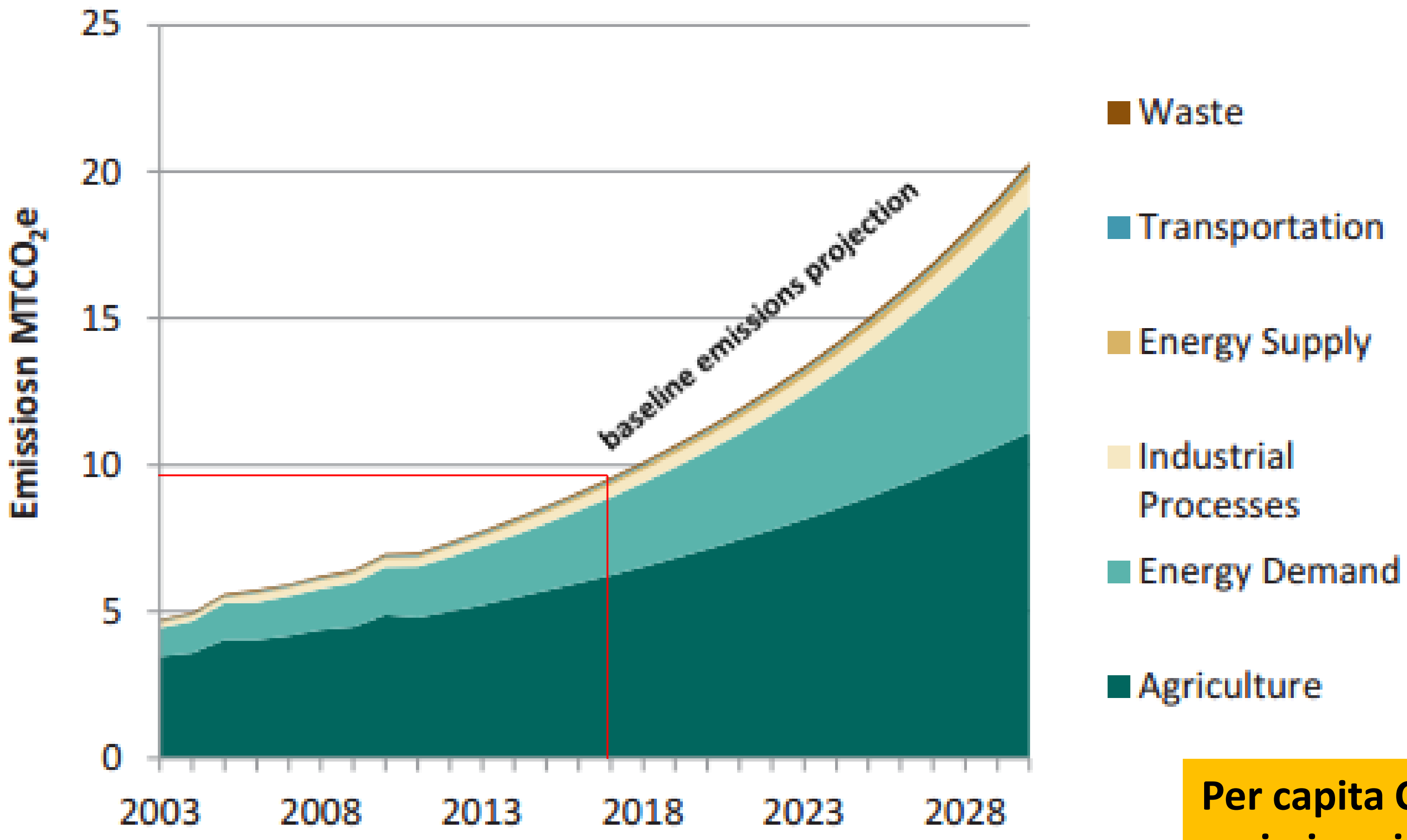


FIGURE 4: EMISSIONS BASELINE PROJECTIONS (EXCLUDING LULUCF)

Per capita CO_2e emissions in 2015
Rwanda: 0.7 tonnes
Germany: 11 tonnes

Source: IISD 2013. Republic of Rwanda: Greenhouse gas emissions baseline projection

CONSEQUENCES OF CLIMATE CHANGE

- Occurrence of extreme phenomena of drought and floods
- Estimated to reduce longterm growth in the region by about 2.4%[1] of gross domestic product (GDP) per year

Climate change is not only affecting the industrial countries which have highest GWP – it‘s a global challenge

Source: Dr. Rose Mukankomeje; medium.com
1 Musafiri et. Al, 2011

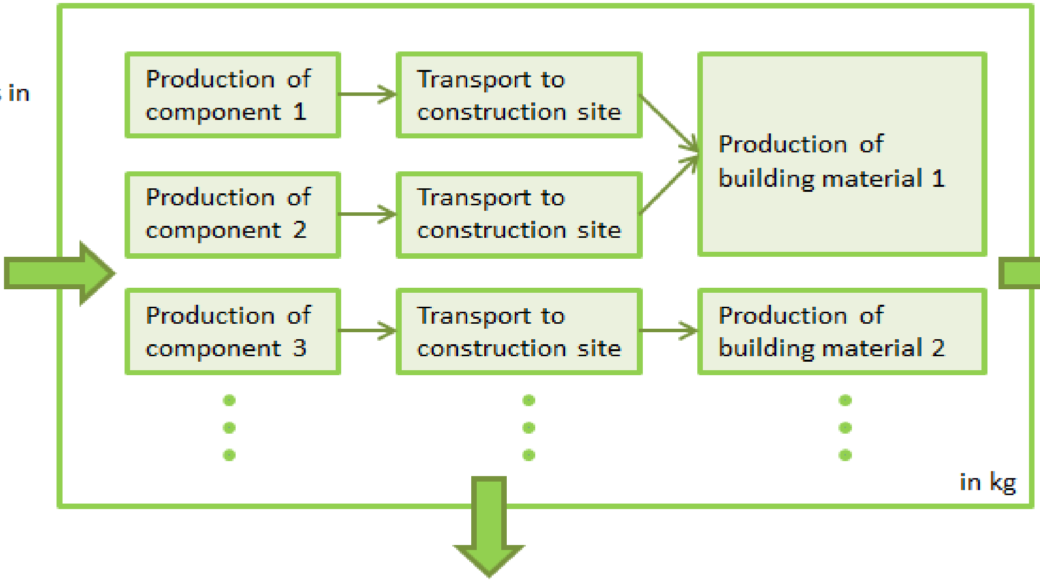
How can someone measure the CO_2 emissions, energy demand, land and fresh water use of a building?

http://portfolios.htwchur.ch

LIFE CYCLE ASSESSMENT (LCA)

Input:

Raw materials in kg
Water in kg
Energy in MJ



Output:

Building in m^2 NFA

Environmental impact:

- Global Warming Potential (GWP) in $kgCO_2eq.$
- Comulated Energy Demand (CED) non- and renewable in MJ
- Land use agriculture, forstry and extraction in m^2*a
- Freshwater use in m^3

Woldwide standard for LCA : DIN EN 14040 and 14044

LIFE CYCLE STAGES

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Raw Material Acquisition | Pre-Production | Production | Use Phase | End of Life

Transport | Transport | Transport





Source: pellets-wood.com; euractiv.com; andorf.de; t-online.de; wikipedia.de;abenteuer-regenwald.de, janiceperson.com

LIFE CYCLE STAGES

RAPID PLANNING
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Raw Material Acquisition	Pre-Production	Production	Use Phase	End of Life

Transport Transport Transport

Source: solarstrom.org; sueddeutsche.de; hamburg.de; wikipedia.org, newtimes.co.rw

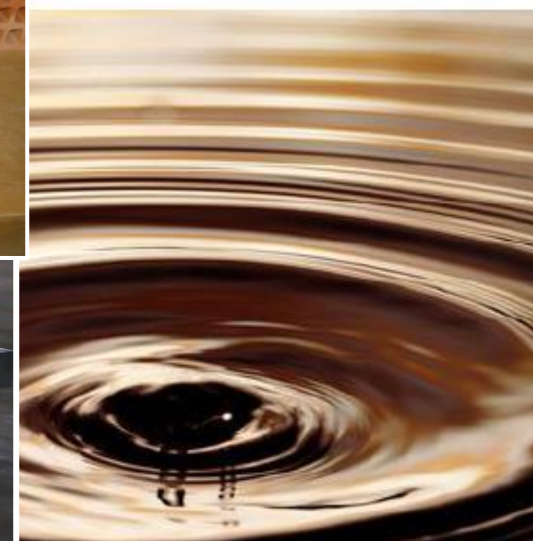
LIFE CYCLE STAGES

Raw Material Acquisition	Pre-Production	Production	Use Phase	End of Life

Transport

Transport

Transport

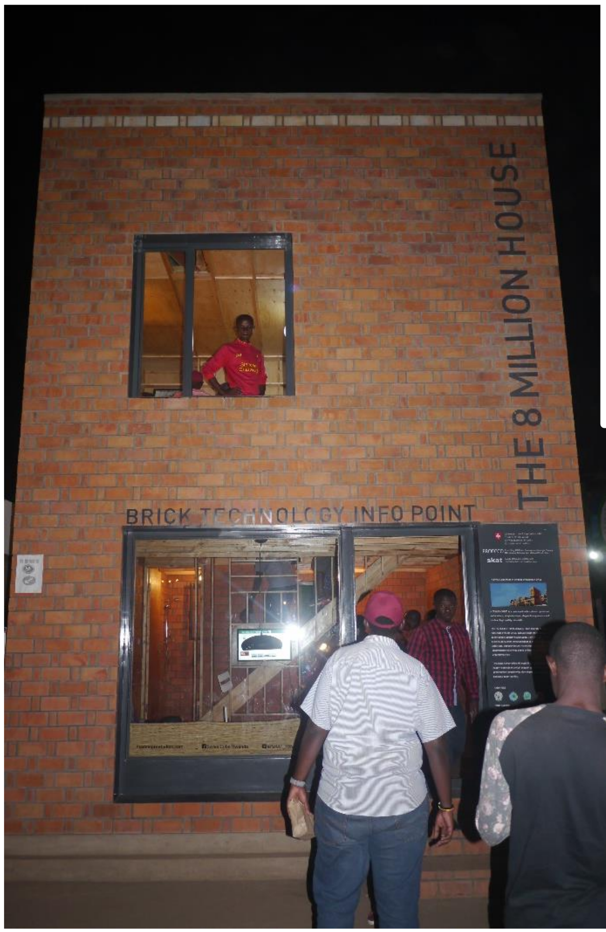


Source: Strawtec, Skat

LIFE CYCLE STAGES

Raw Material Acquisition | Pre-Production | **Production** | Use Phase | End of Life

Transport | Transport | Transport



Source: ses-stahl.de; machseinfach.com; womanshealth.com; merus.de;mukwano.com

LIFE CYCLE STAGES

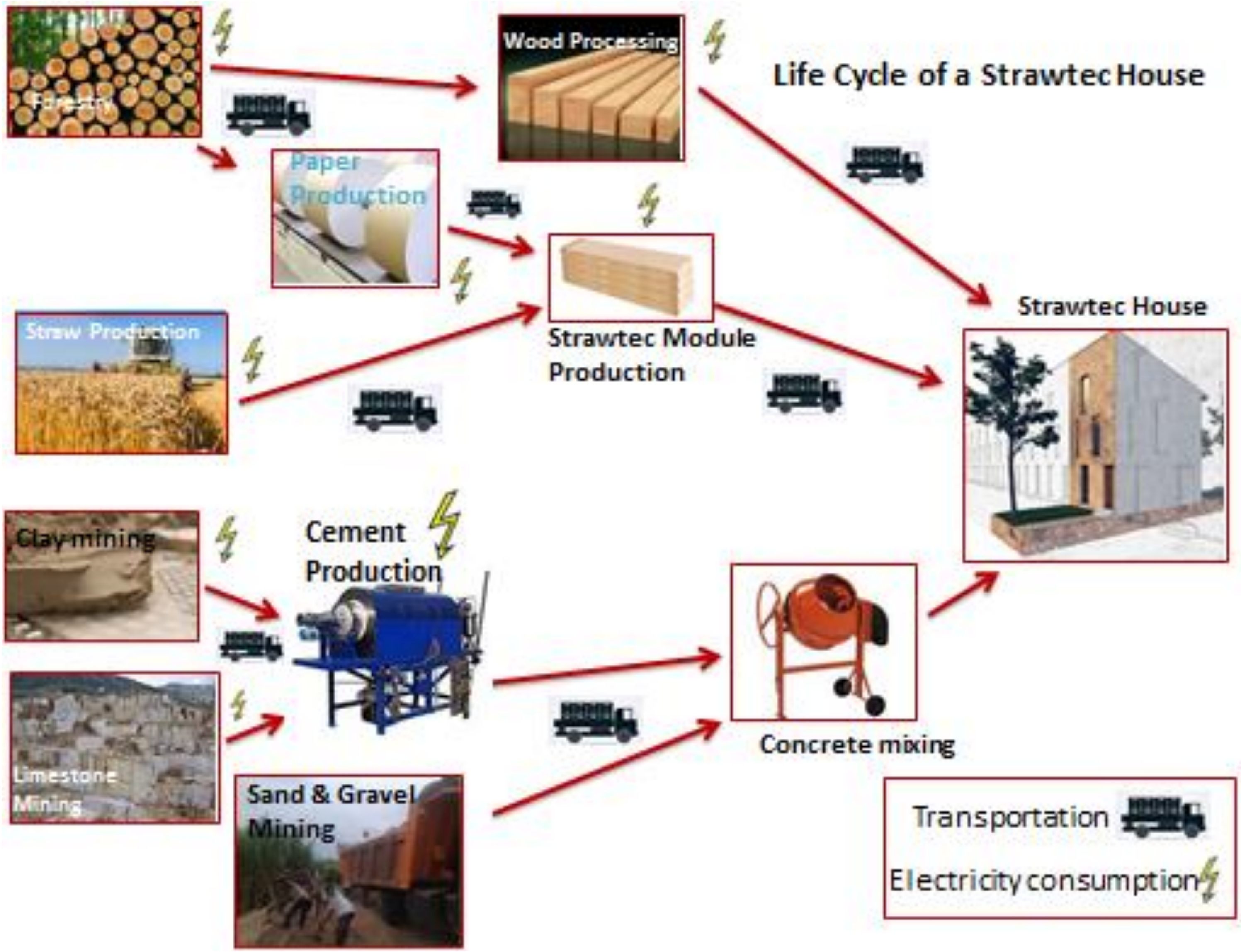
Raw Material Acquisition | Pre-Production | Production | **Use Phase** | End of Life

Transport — Transport — Transport




Source: womanshealth.com; merus.de; kwos.com, commonsensemedia.org

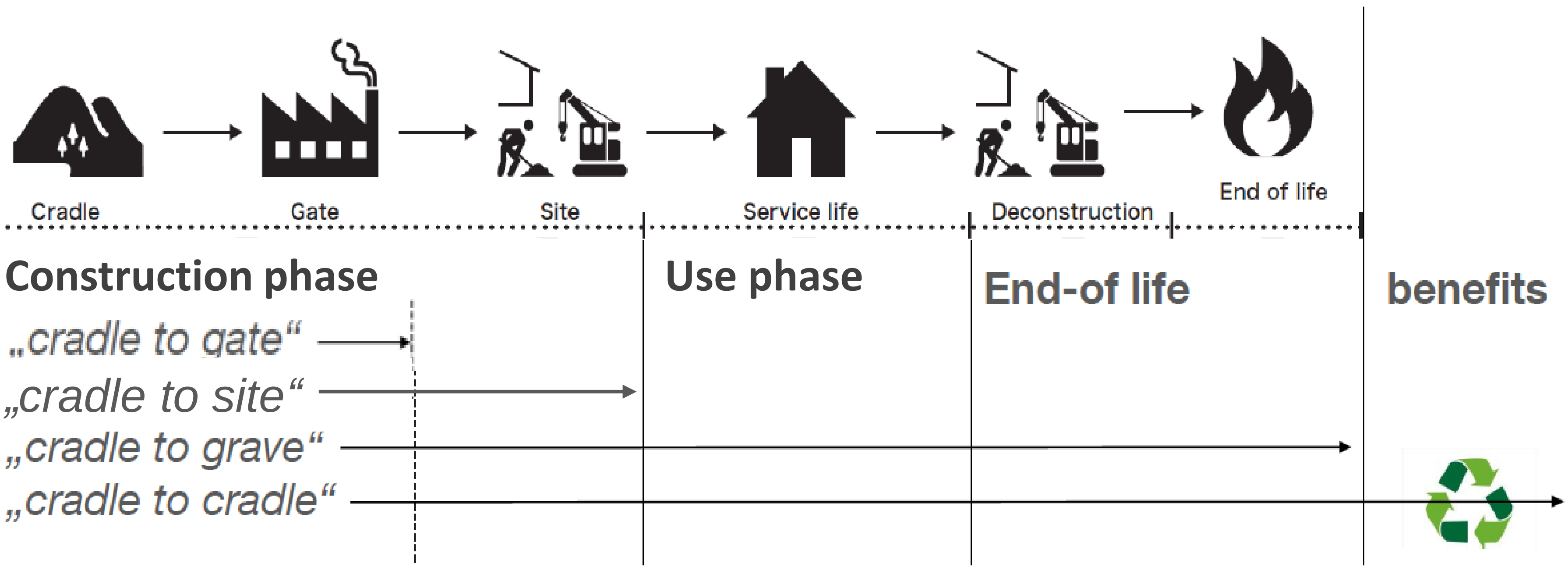
LIFE CYCLE ASSESSMENT



Source: Rapid Planning

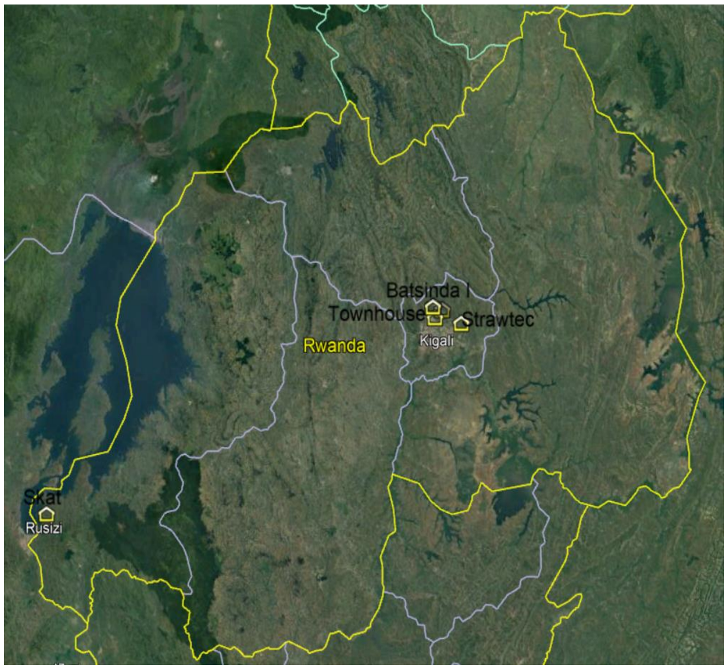
LIFE CYCLE STAGES

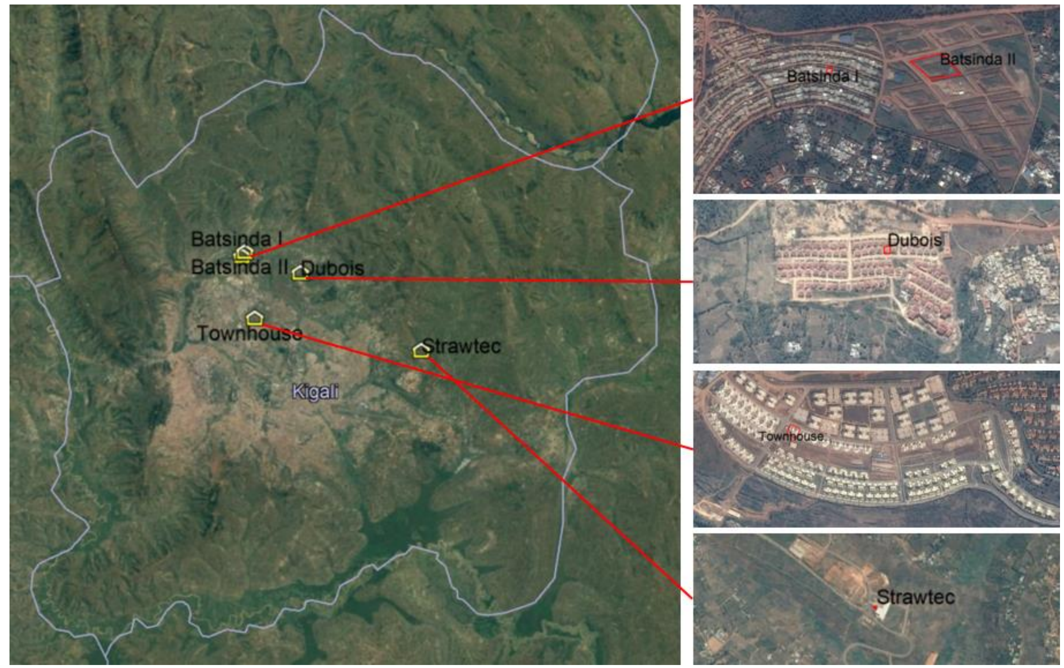
According to DIN EN 15804 and EN 15978



Source: Wiedemann T., Minx J., 2007

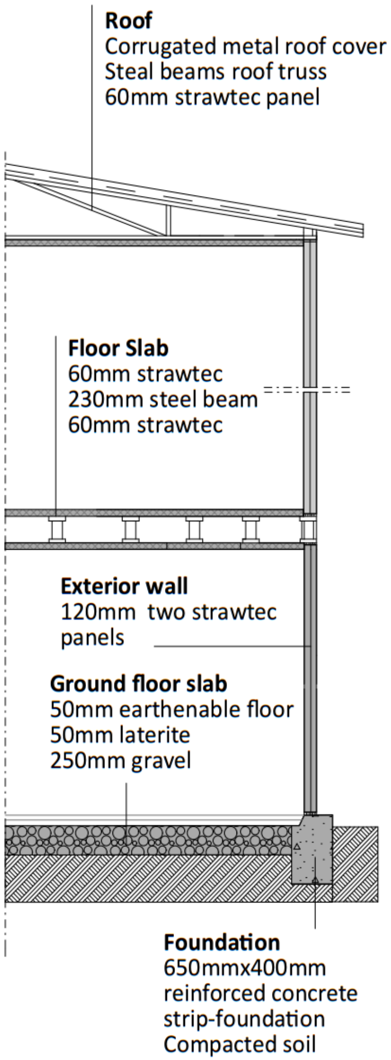
STUDY AREA

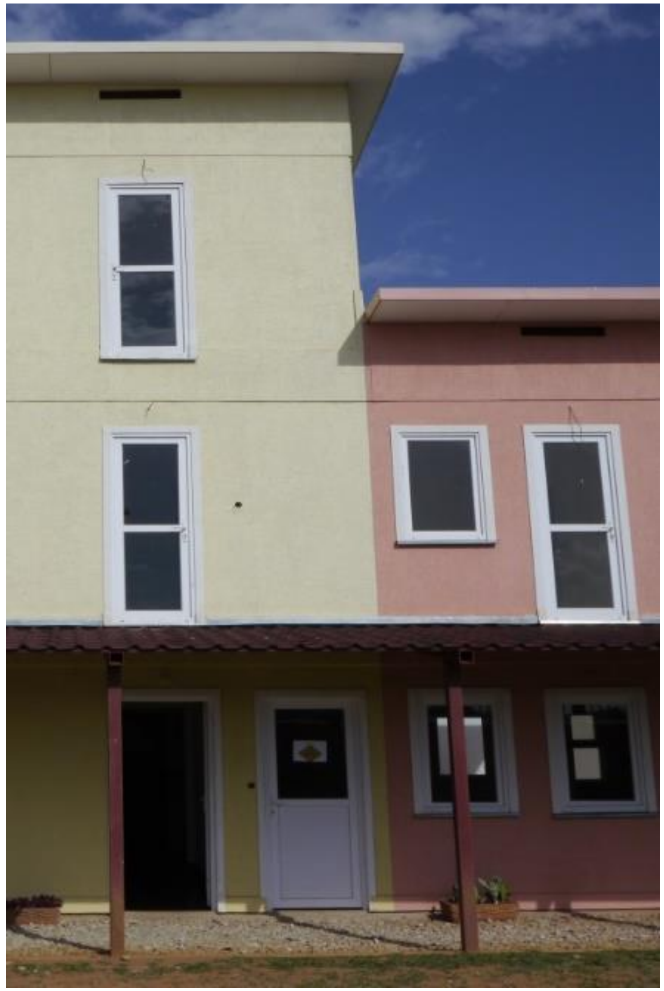




Source: Google Earth

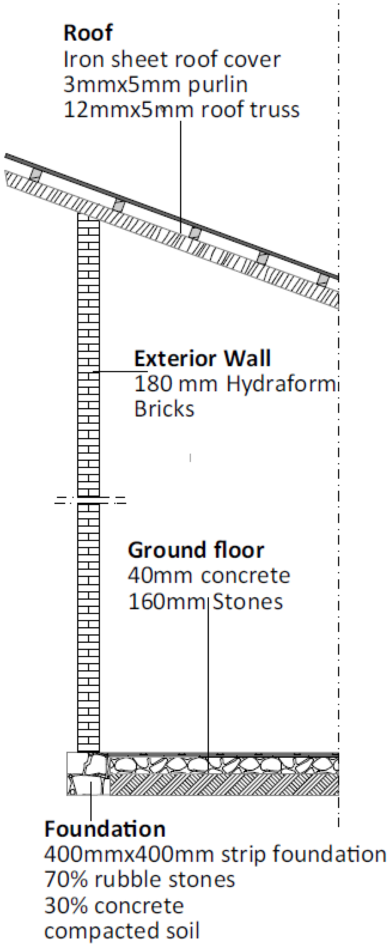
BUILDING 1 – STRAWTEC



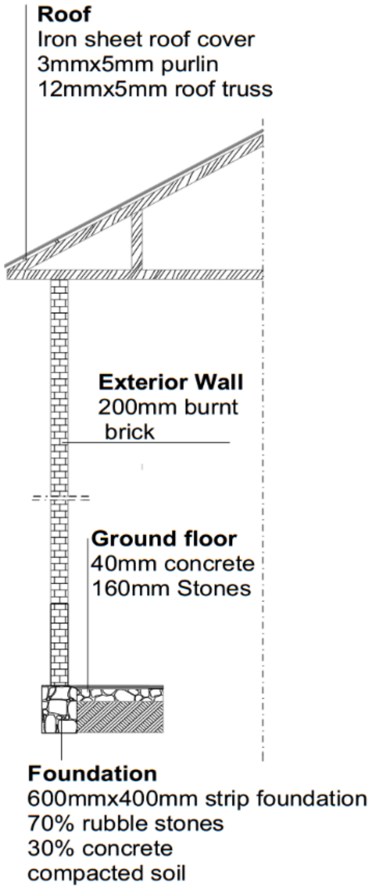


Source: strawtec.com

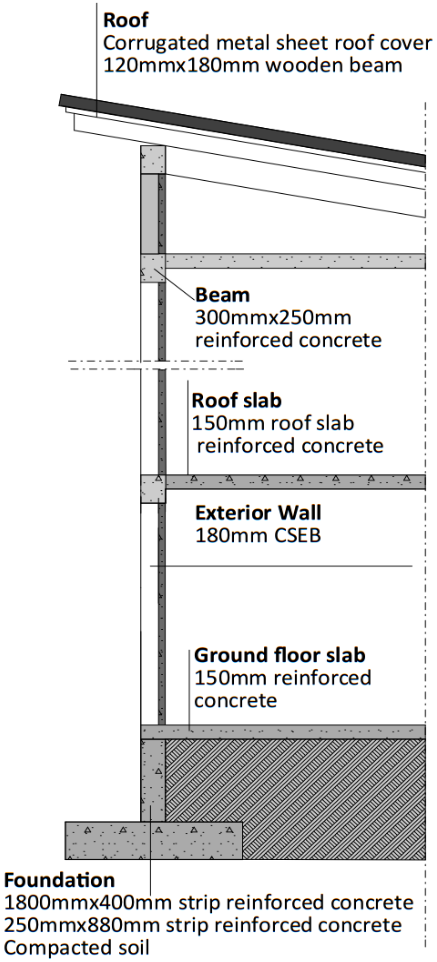
BUILDING 2 – BATSINDA I

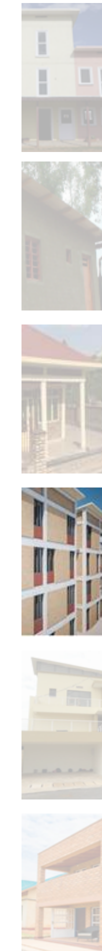


BUILDING 3 – DUBOIS

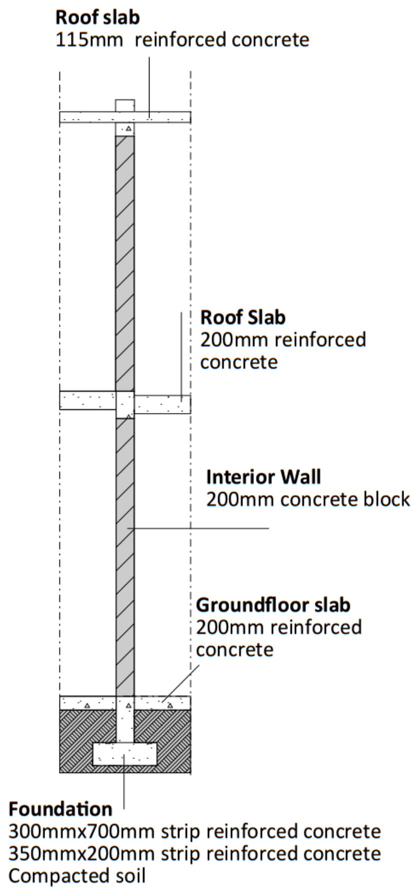


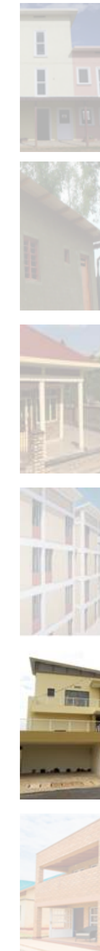
BUILDING 4 – BATSINDA II



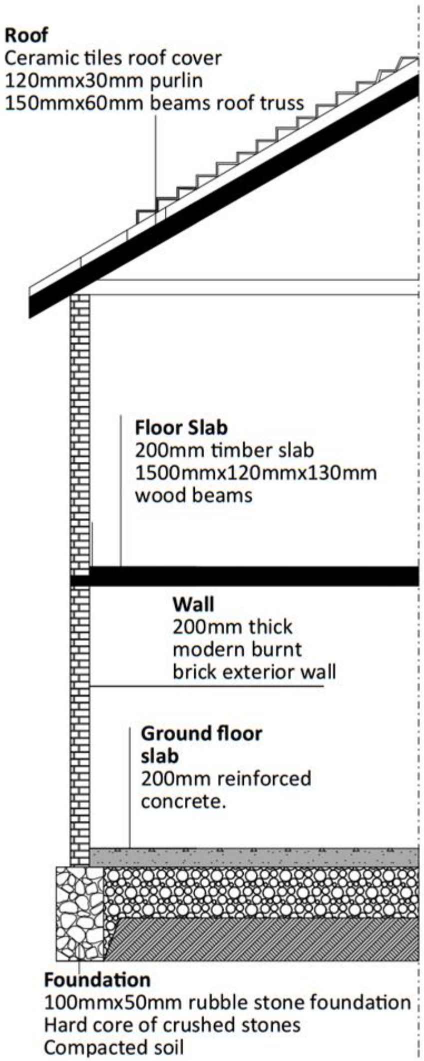


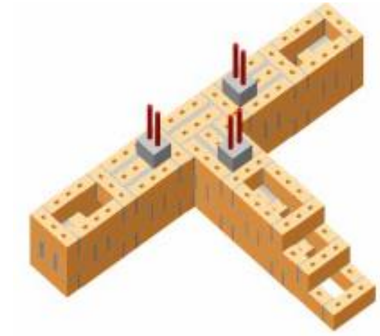
BUILDING 5 – TOWNHOUSE





Building 6 – Skat





BUILDING MATERIAL CALCULATOR

Green Building Calculator

Prepared by ifeu — INSTITUTE FOR ENERGY AND ENVIRONMENTAL RESEARCH HEIDELBERG

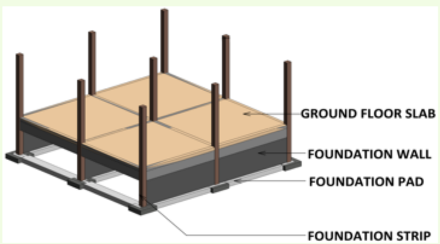
Contact: Mirjam Busch mirjam.busch@ifeu.de

Within the scope of the project "Rapid Planning"

Sponsored by Federal Ministry of Education and Research; UN-HABITAT

Strawtec

Foundation



Foundation

Material type: Concrete (C25/30) from RWD

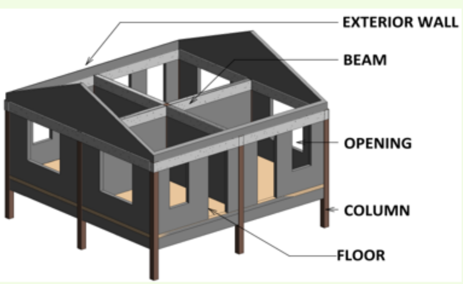
Quantity		
Concrete (C25/30) - RWD	10.9	m3
Steel rebar	871.7	kg
additional		

Ground floor slab

Material type: Earthenable floor

Quantity		
Earthenable floor	89.79	m2
additional: Gravel/Sand		

Walls and Frame



Exterior walls

Material type: Strawtec panels

Quantity		
Strawtec panels	536.8	m2
Damp proofing course	41.6	m2
Blockboard	38.4	m
Foundation-Wall steel brackets	208	numr
Steel screws	5695	numr
additional		

Interior walls

Material type: Strawtec panels

Quantity		
Strawtec panels	397.8	m2
Damp proofing course	35.7	m2
Blockboard	102	m
Foundation-Wall steel brackets	81	numr
Steel screws	5227	numr
additional		

Material	Quantity Value	Quantity unit	Density Value	Density unit	Input - Mass [kg]	Mass [kg]
Foundation						
Foundation (☑ Use Density Default Values)						
Concrete (C25/30) - RWD	10.9	m3	2380	kg/m3		25942
Steel rebar	871.7	kg	1	kg/kg		871.7
	-					
	-					
Ground floor slab (☑ Use Density Default Values)						
Earthenable floor	89.79	m2	11	kg/m2		987.69
	-					
	-					
	-					
Gravel/Sand	-				40231.5	40231.5
Walls and Frame						
Exterior walls (☑ Use Density Default Values)						
Strawtec panels	536.8	m2	21.8	kg/m2		11702.24
Damp proofing course	41.6	m2	0.26	kg/m2		10.816
Blockboard	38.4	m	0.563	kg/m		21.6192
Foundation-Wall steel brackets	208	numr	0.36	kg/numr		74.88
Steel screws	5695	numr	0.0008	kg/numr		4.556
	-					
Interior walls (☑ Use Density Default Values)						
Strawtec panels	397.8	m2	21.8	kg/m2		8672.04
Damp proofing course	35.7	m2	0.26	kg/m2		9.282
Blockboard	102	m2	0.563	kg/m2		57.426
Foundation-Wall steel brackets	81	numr	0.36	kg/numr		29.16
Steel screws	5227	numr	0.0008	kg/numr		4.1816
	-					

Building Material Calculator

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Global warming potential [kg CO2-eq.]

Material	Production of components	Transportation to production site	Production of building material	CO2-fixation
Foundation				
Foundation				
Concrete (C25/30) - R	2379.868683	214.3769338	1.884646803	0
Steel rebar	2047.851861	315.5139688	195.0078027	0
Ground floor slab				
Earthenable floor	707.047749	2.922170634	21.96978917	0
Gravel/Sand	175.007025	221.3220489	0	0
Walls and Frame				

Cumulated Energy Demand - non-renewable [MJ]

Material	Production of components	Transportation to production site	Production of building material	CO2-fixation
Foundation				
Foundation				
Concrete (C25/30) - R	10178.13548	3202.733193	25.63513693	0
Steel rebar	24660.2629	4609.434601	2573.400172	0
Ground floor slab				
Earthenable floor	1991.125024	42.27012156	269.1152284	0
Gravel/Sand	2210.720925	3306.491326	0	0
Walls and Frame				

Cumulated Energy Demand - renewable [MJ]

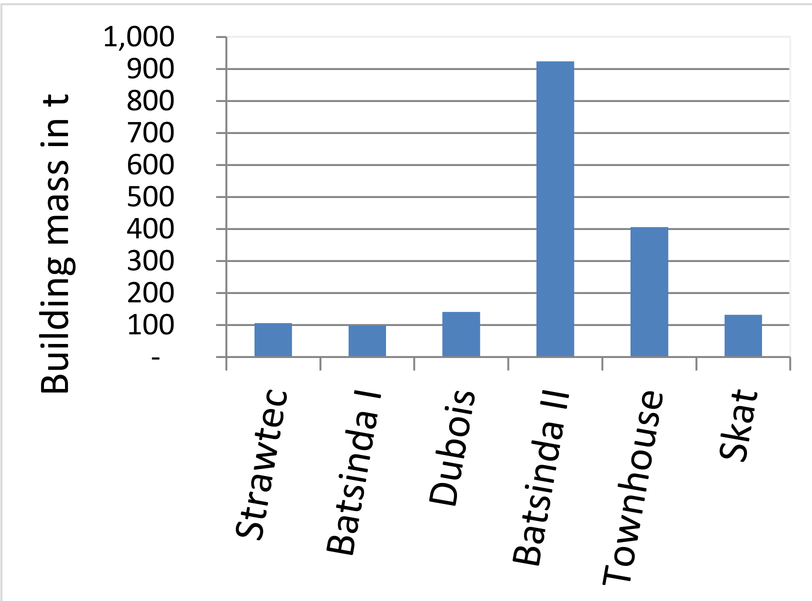
Material	Production of components	Transportation to production site	Production of building material	CO2-fixation
Foundation				
Foundation				
Concrete (C25/30) - R	917.9964133	41.40607275	1.701470407	0
Steel rebar	1101.729732	78.63437522	290.179489	0
Ground floor slab				
Earthenable floor	8703.139292	0.830360581	114.2811848	0
Gravel/Sand	151.8744757	42.74749476	0	0
Walls and Frame				

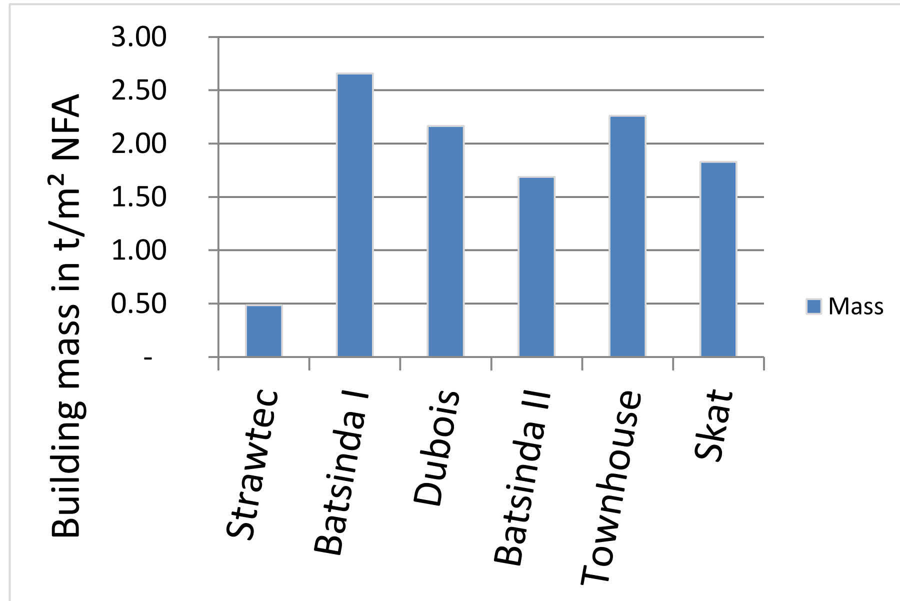
Land use: agriculture [m²*a]

Material	Production of components	Transportation to production site	Production of building material	CO2-fixation
Foundation				
Foundation				
Concrete (C25/30) - R	0.15060816	0.051319738	0.000169451	0
Steel rebar	0.366315059	0.135271734	0.014229777	0
Ground floor slab				
Earthenable floor	1003.957108	0.000452986	0.001939936	0
Gravel/Sand	0.069278643	0.052982331	0	0
Walls and Frame				

- Impact categories
  - Global warming potential
  - Cumulated energy demand (renewable, non-renewable)
  - Land use (agriculture, forest, extraction)
  - Freshwater use

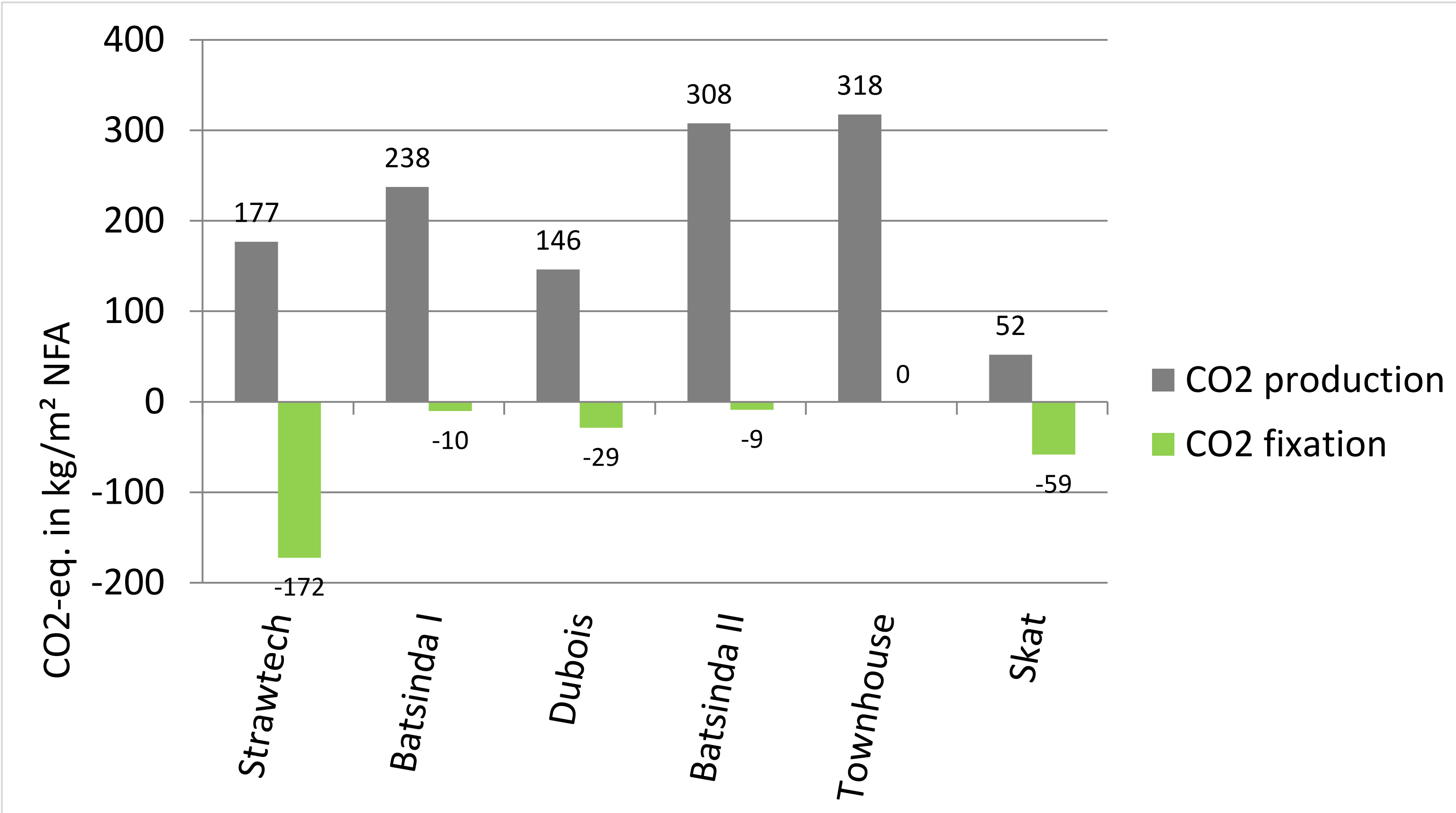
RESULTS FROM OUR STUDY
BUILDING MASSES





1. Massive building structures (concrete, bricks) increase the massflow of Kigali
2. Light building materials (e.g. Straw) can reduce massflow share of building material

RESULTS FROM OUR STUDY
GLOBAL WARMING POTENTIAL (GWP)

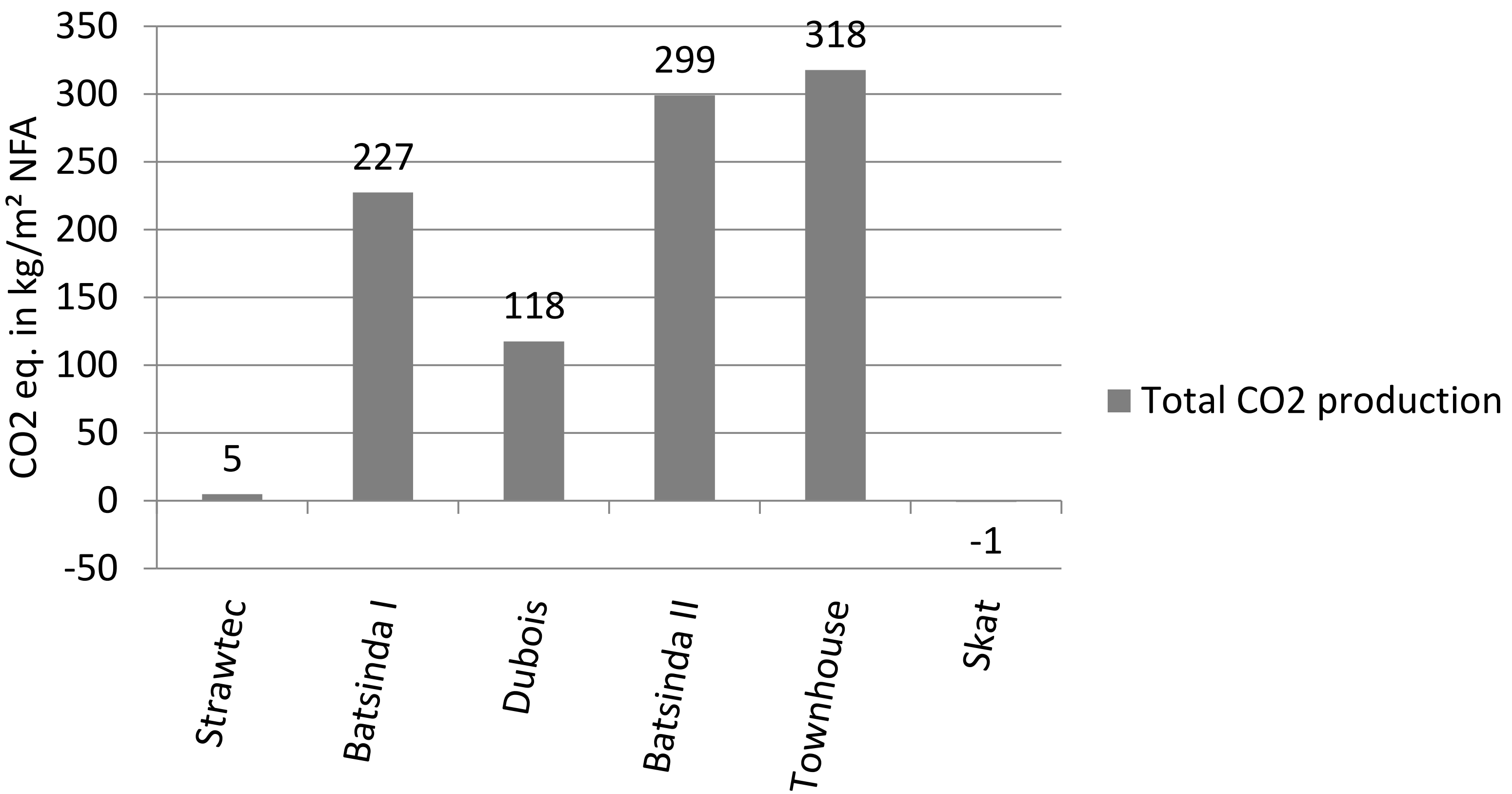







High CO2 production through the use of metals and cement containing building materials (Strawtec, Batsinda I, Batsinda II and Townhouse)

RESULTS FROM OUR STUDY
GLOBAL WARMING POTENTIAL (GWP)

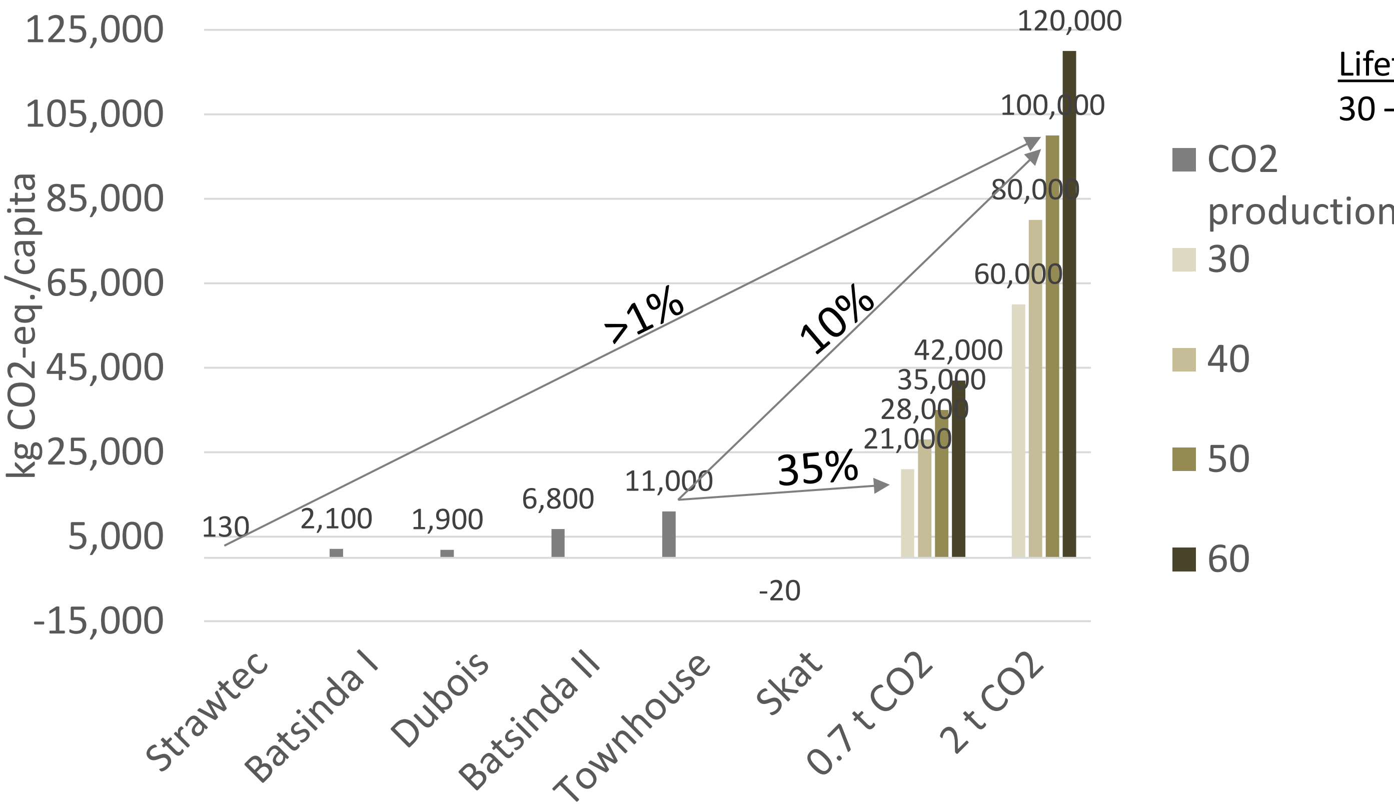


Buildings with renewable materials have zero emissions or can work as a CO2 storage (Strawtec, Skat)

Importance of the Results
GWP comparison to use phase

<u>CO2 emission in Kigali:</u>
2015: 0.7 t/capita/year [1]
Future: 2 t/capita/year [2]

<u>Lifetime of building:</u>
30 – 60 years lifetime



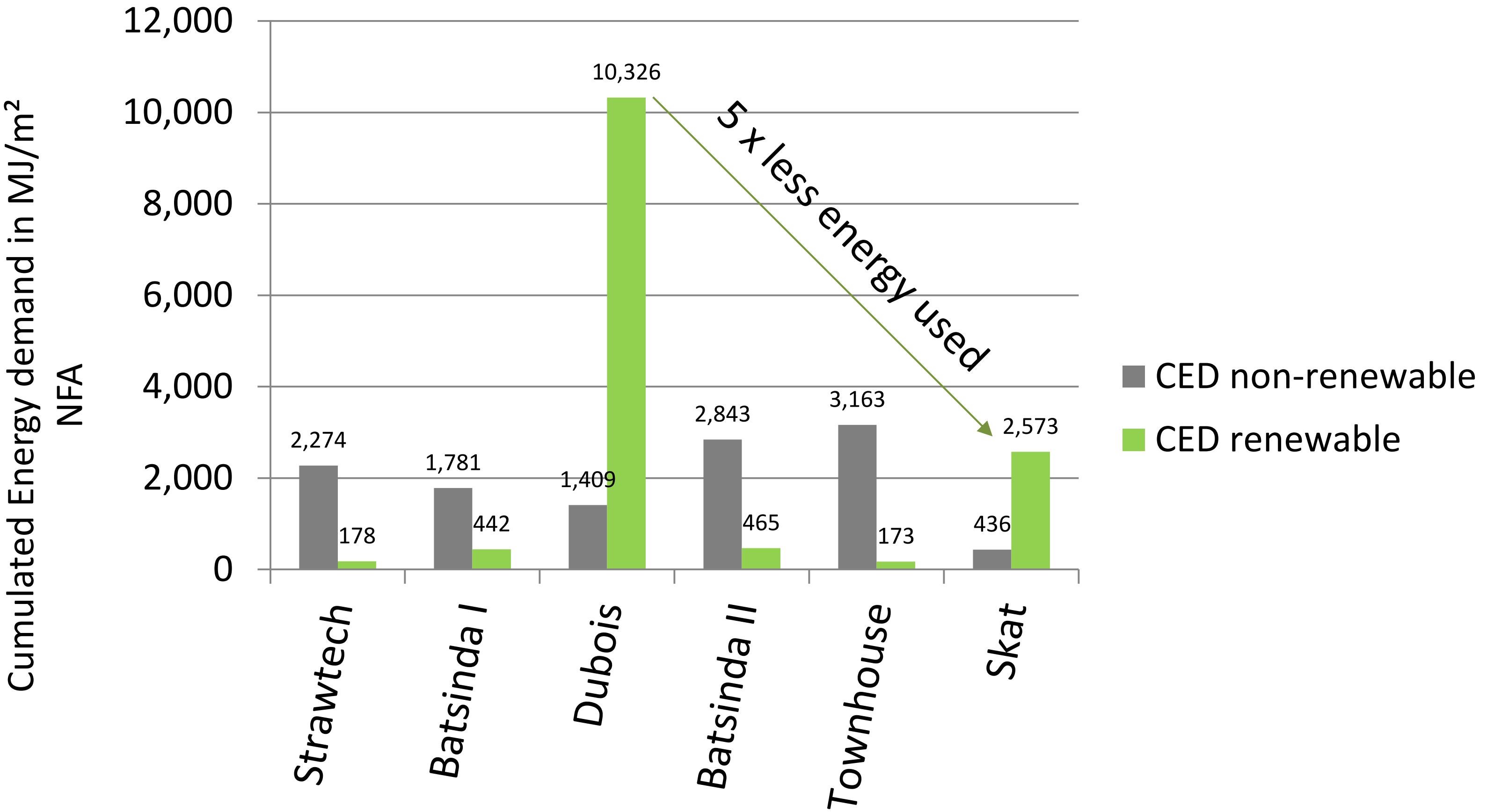


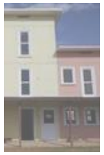



1. Variable relevance of CO2 emissions (0 – 35%)
2. CO2 fixation essential for reducing the impact of the construction phase

[1] IISD 2013. Republic of Rwanda: Greenhouse gas emissions baseline projection
[2] Average annual CO2 emissions to reach climate goal of 1.5 degrees

Results from our study
Cumulative Energy Demand (CED)



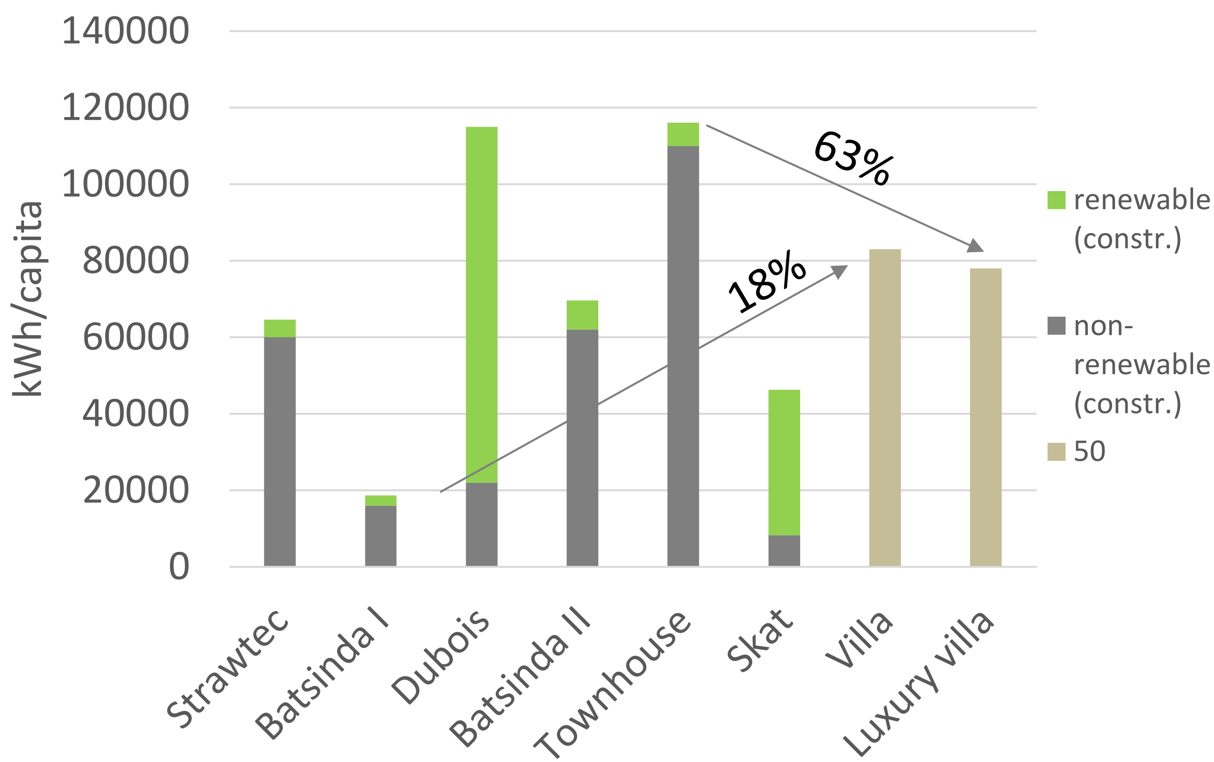





1. Metal and cement containing materials have a high non-renewable energy demand
2. Maximazing the efficiency reduces the energy demand (Dubois, Skat)

RELEVANCE OF THE RESULTS
CED COMPARISON TO USE PHASE

	Building 1 (Strawtec)	Building 2 (Batsinda I)	Building 3 (Dubois)	Building 4 (Batsinda II)	Building 5 (Townhouse)	Building 6 (Skat)
m²/resident	27.4	9.3	16.3	22.8	35.8	18



<u>Primary energy demand in Kigali:</u>
Villa: 6 MWh/capita/year [1]
Luxury Villa: 5.6 MWh/capita/year [1]

<u>Lifetime of building:</u>
50 years

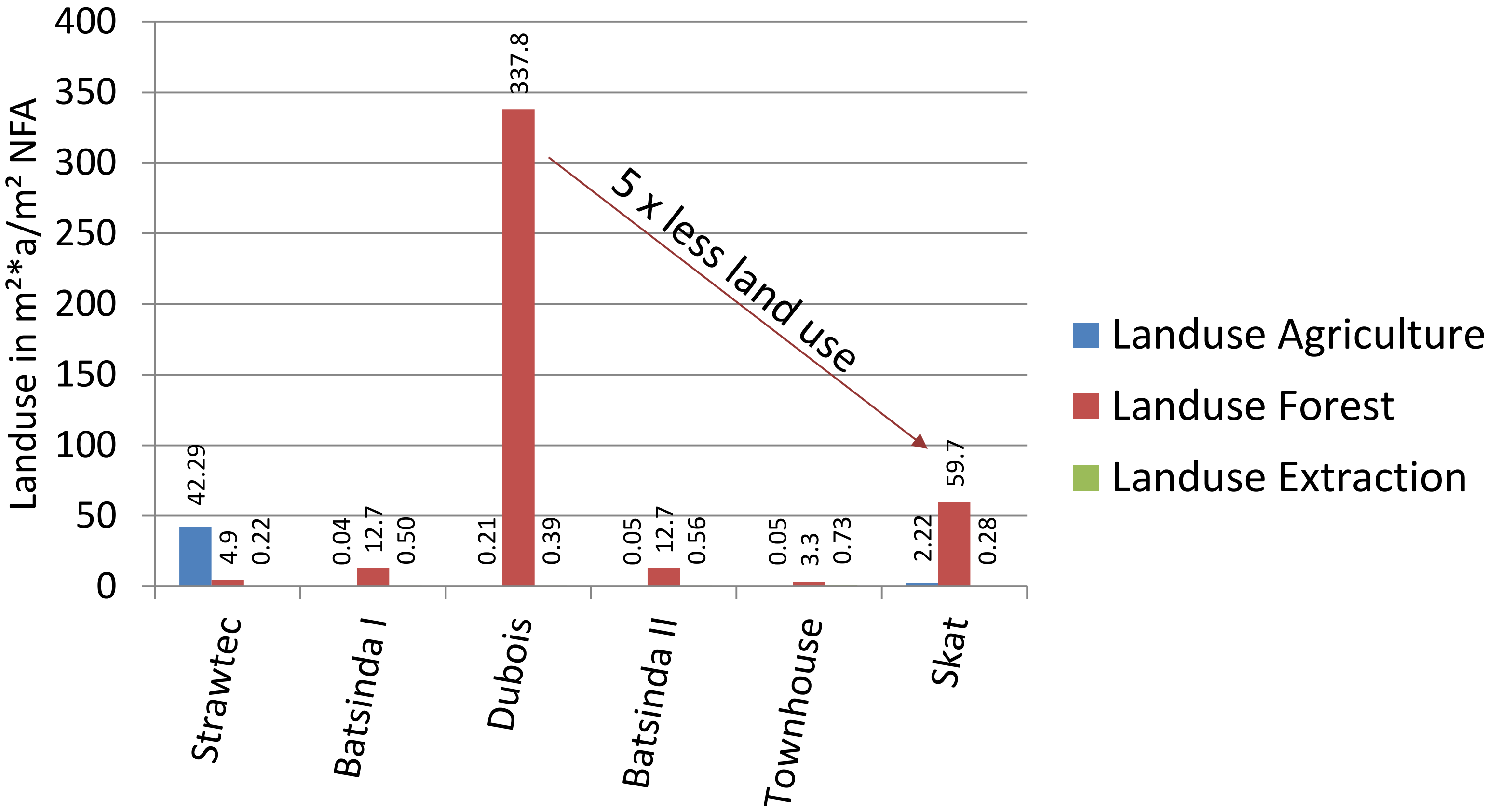





1. High relevance of cumulated energy demand compared to CED of the use phase
2. Size of the m²/resident can reduce CED of construction phase drastically

1 Rapid Planning Survey, IER, 2017

RESULTS FROM OUR STUDY
LAND USE



1. High forest landuse for inefficient brick burnig (Dubois)
2. Low landuse for non-renewable materials (Batsinda I, Batsinda II, Townhouse)

RELEVANCE OF THE RESULTS
LAND USE COMPARISON TO USE PHASE

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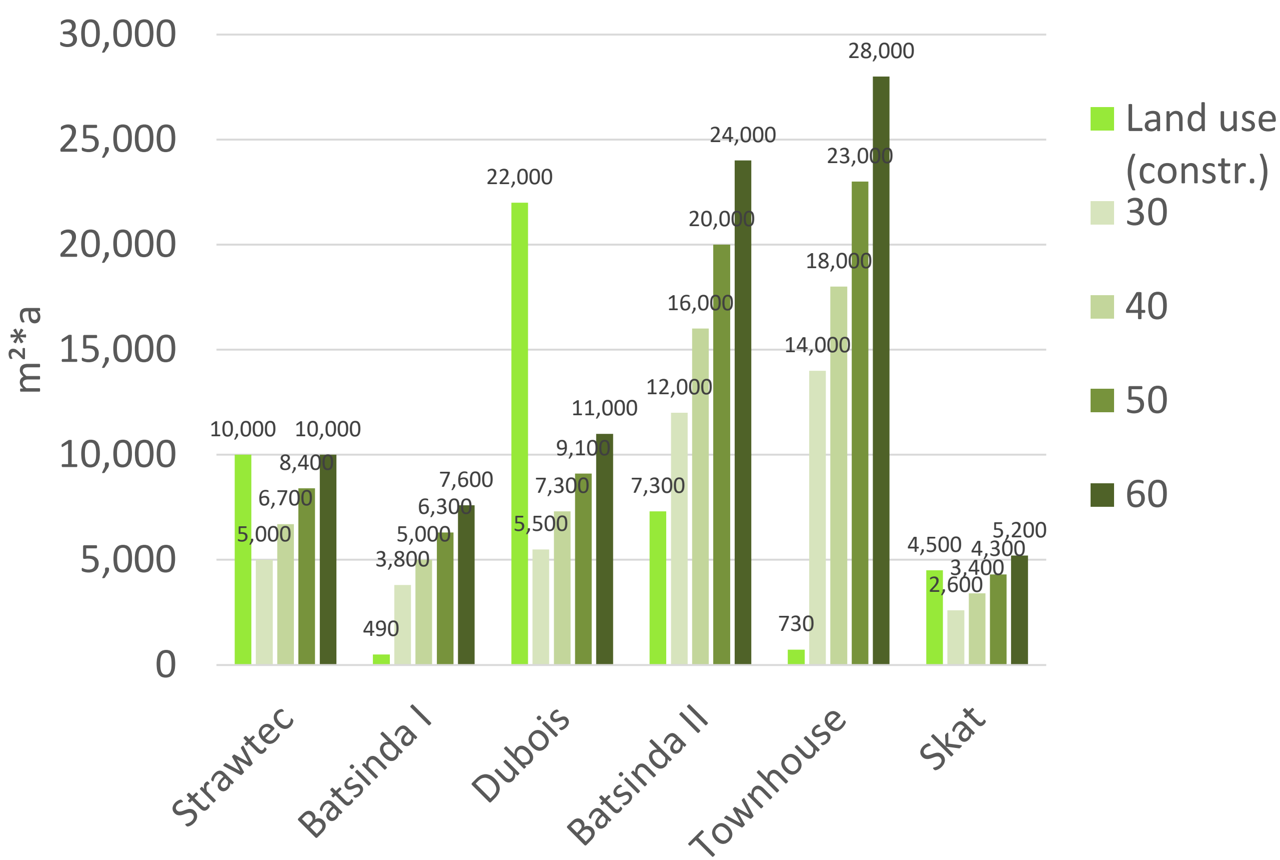
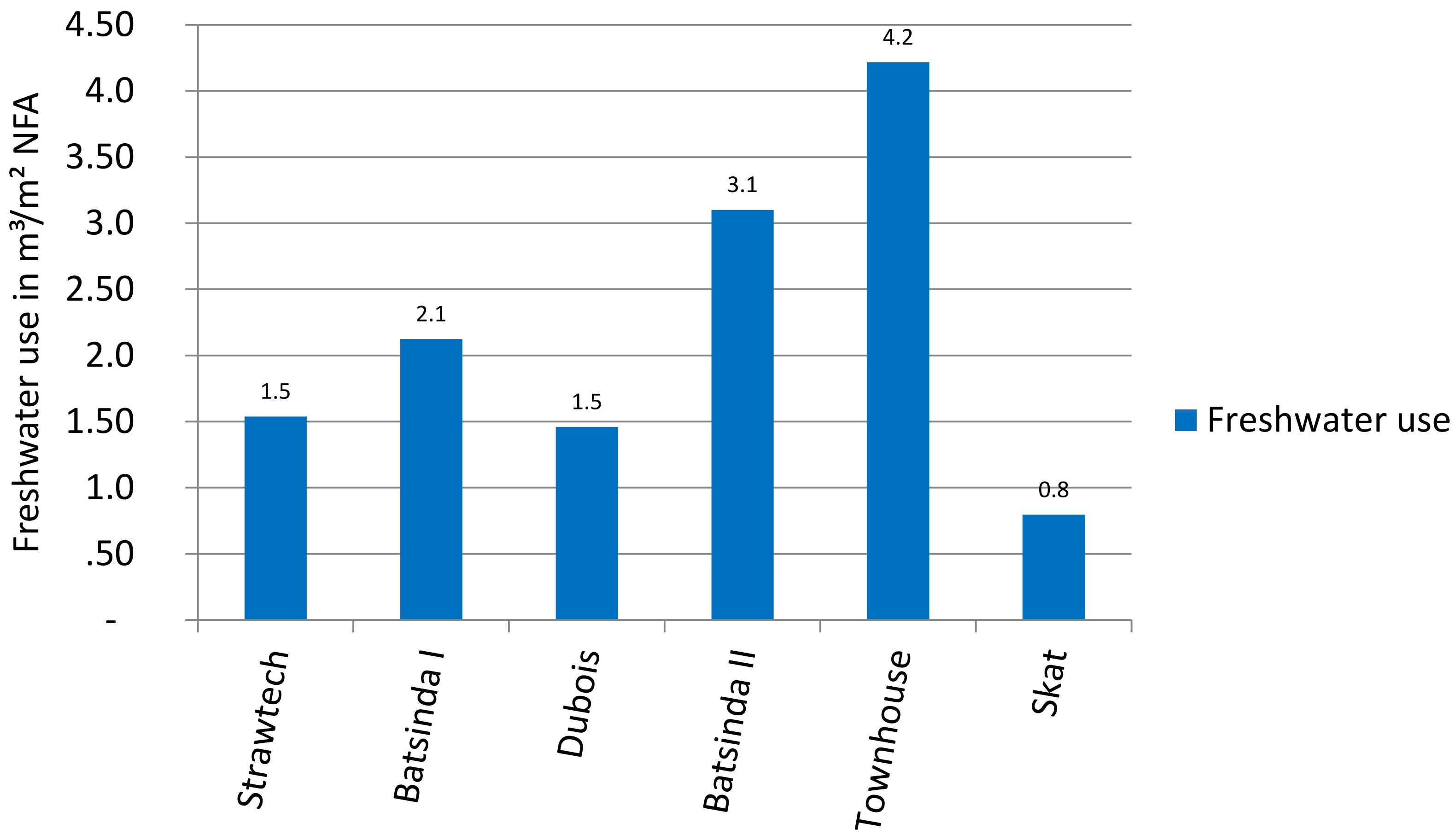


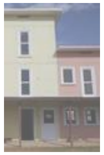
Land use:
2 x Ground floor area of a building

Lifetime of building:
30 – 60 years

High relevance (50 – 75%) of land use using renewable materials (e.g. wood, straw) in the construction phase

RESULTS FROM OUR STUDY
FRESHWATER USE

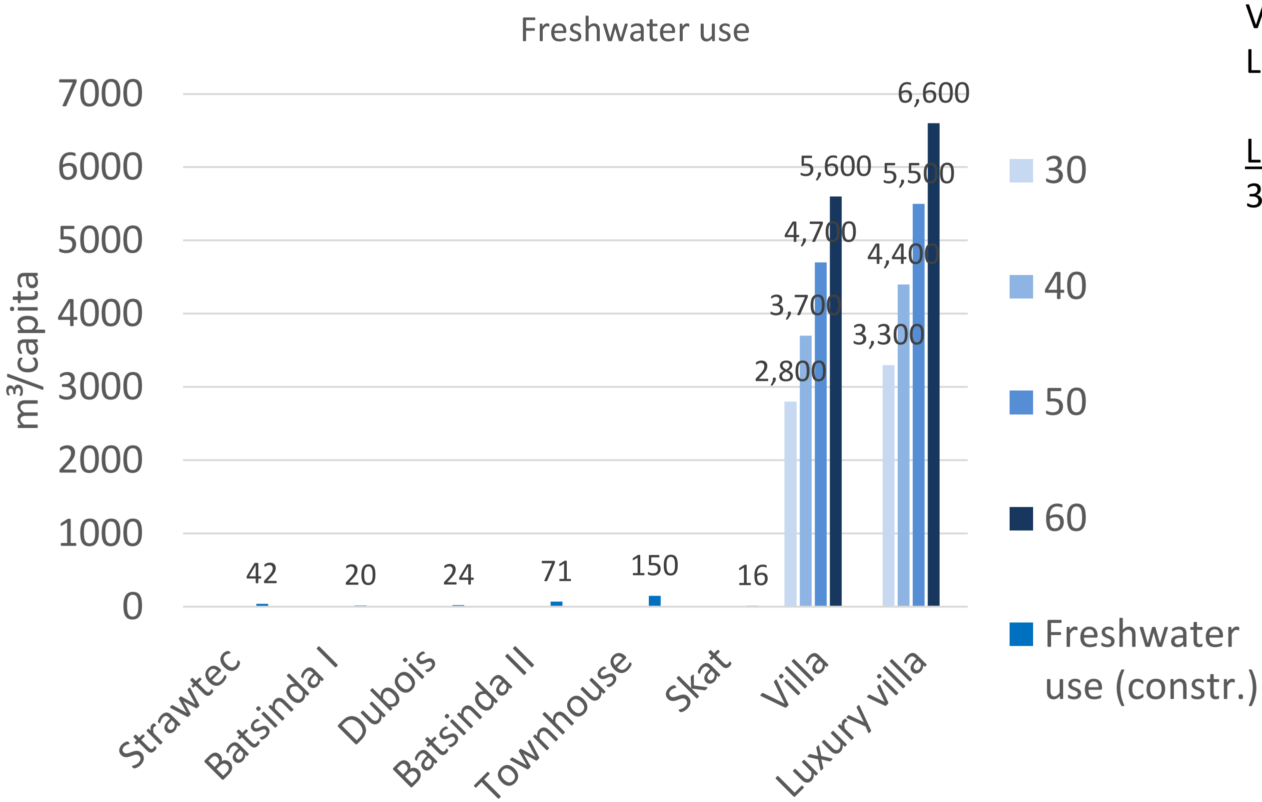







Usage of concrete, mortar and steel, especially corrugated steel roof cover results in higher freshwater demand.

RESULTS FROM OUR STUDY
FRESHWATER USE COMPARISON TO USE PHASE



<u>Freshwater use in Kigali:</u>
Villa: 255 L/capita/day
Luxury villa: 302 L/capita/day

<u>Lifetime of building:</u>
30 – 60 years lifetime

1. Low relevance of freshwater use in the construction phase (1 – 4%)
2. Water saving actions should be implemented in the use phase first

CONCLUSION FROM THE LCA

- The use of renewable materials (e.g. straw, wood) can lead to zero carbon or carbon storage buildings
- Non-renewable building materials (e.g. cement, steel) lead to higher energy demand, CO_2 emissions and water use)
- Ressource efficient buildings (Skat) can reduce the cumulative energy demand by 20%
- Energy use of construction phase has a big impact on total energy use
- Freshwater use of construction phase of all 6 buildings has small impact on total freshwater use
- The *Rwanda Building Material Calculator* can help in setting priorities for indicators, optimizing supply chains and monitoring of the building sector

CURRENT STAGE OF LCA IN RWANDA

Life cycle assessment for buildings in Rwanda

- Building Material Calculator is specific for Rwanda, but it‘s limited in materials and constructions
- No building material database for Rwanda
- No regulations or Green Building rating systems requiring life cycle assessment in Rwanda

Source: Hausladen, Liedl, de Saldanha: Building to Suit the Climate. A Handbook. Basel, 2012

HOUSING POLICIES IN KIGALI

"encourages the use of local, green and affordable building materials.

⌂ National Housing Policy 2015

CITY OF KIGALI
CONSTRUCTION PERMIT SYSTEM

"4 Policy Pillar 2: Resource-Efficient Planning, Green Technology and Professionalism
The production of construction materials shall be "green", considering any energy input required, carbon dioxide output reduction, labor creation, and ensuring no cause of reduction in food production. "

⌂ Urbanization and Rural Settlement Sector Joint Sector Review Report 2015

"Outcome 5: Increased private sector activity in urbanization and human settlement development

Indicator 11:	*Percentage of building permits applying green building / growth principles*
Target:	*10*
Status:	*Not known. New auditing framework adopted which will enable monitoring.*

Republic of Rwanda
Ministry of Infrastructure

Output 12: Investment incentives schemes for affordable housing construction offered by government
Affordable housing incentives have been clarified. Green building incentives are not yet concluded due to the unfinished work on the definition of green criteria for Rwanda."

⌂ Global Green Growth Institute (GGGI) Minimum compliance system (Draft)

"3.1 Sustainable Construction & Materials, 18 Points" (50/100 points needed)
Use of low embodied energy building materials, materials with recycled content

- *Use of locally manufactured materials*
- *Concrete Usage Index (CUI) less or equal to 0.06* m^3/m^2

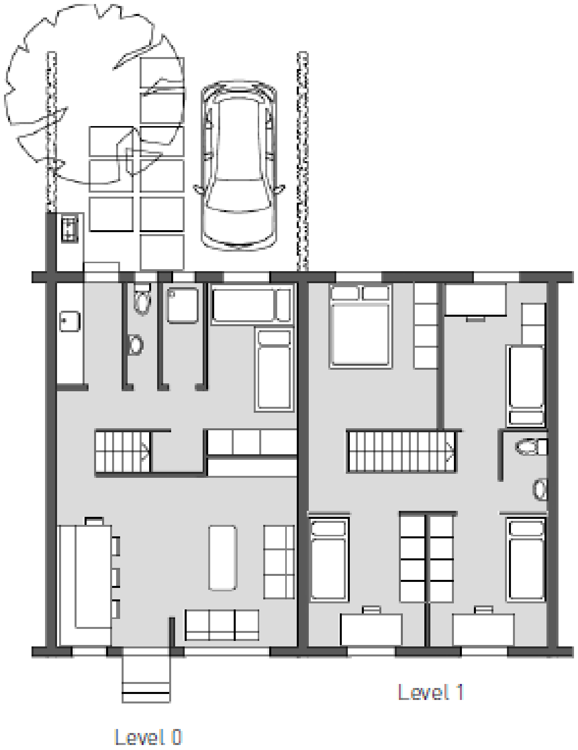
Global Green Growth Institute

Conclusion and Recommendation
Combination of Materials

- Increase use of wood constructions

Source: Strawtec, Skat, iba Hamburg

10 m² appartment (sweden)

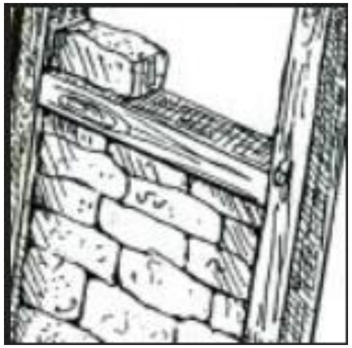


12 m²/person (7 residents)

- Look for: Micro Units, Tiny Houses

Source: vilabacana.com; skat consulting;

Conclusion and recommendation
New building materials



Source: Pinterest

QUIZ: WHAT IS A GREEN BUILDING?

- Is it a green colored building?

- It is a green house?

Green building provide:

- **Positive impact on the environment**
- **Sustainable development**
- **Resource-efficiency**

CONTACTS

Green building team in Kigali

Jakob Schweiger	jakob.schweiger@ifeu.de
Remy Ruberambuga	ruberambugaremy@yahoo.com
Michel Schmitt	michel.schmitt@ifeu.de
Leonard Byiringiro	byiringiroleonard@gmail.com
Joshua Ishimwe	joshimwe@gmail.com

Rapid Planning – Kigali coordinator

Sylvie Kayitesi	ksylvie13@gmail.com

Rapid Planning – Kigali focal point coordinator

Bernd Franke	bernd.franke@ifeu.de

SOURCES

Literature

- www.materialflows.net
- IPCC: Fifth Assessment Report 2013, Synthesis Report end of 2014

Download
http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml#1

Building Material Calculator by IFEU

RAPID PLANNING

SUSTAINABLE INFRASTRUCTURE, ENVIRONMENTAL AND RESOURCE MANAGEMENT FOR HIGHLY DYNAMIC METROPOLISES

Murakoze!

Thank you!