AUTODESK UNIVERSITY

An Approach to Environmental Justice in Design and Construction

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An Approach to Environmental Justice in Design and Construction

Why radical change is needed

What we do

Case study of our work

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Why radical change is needed

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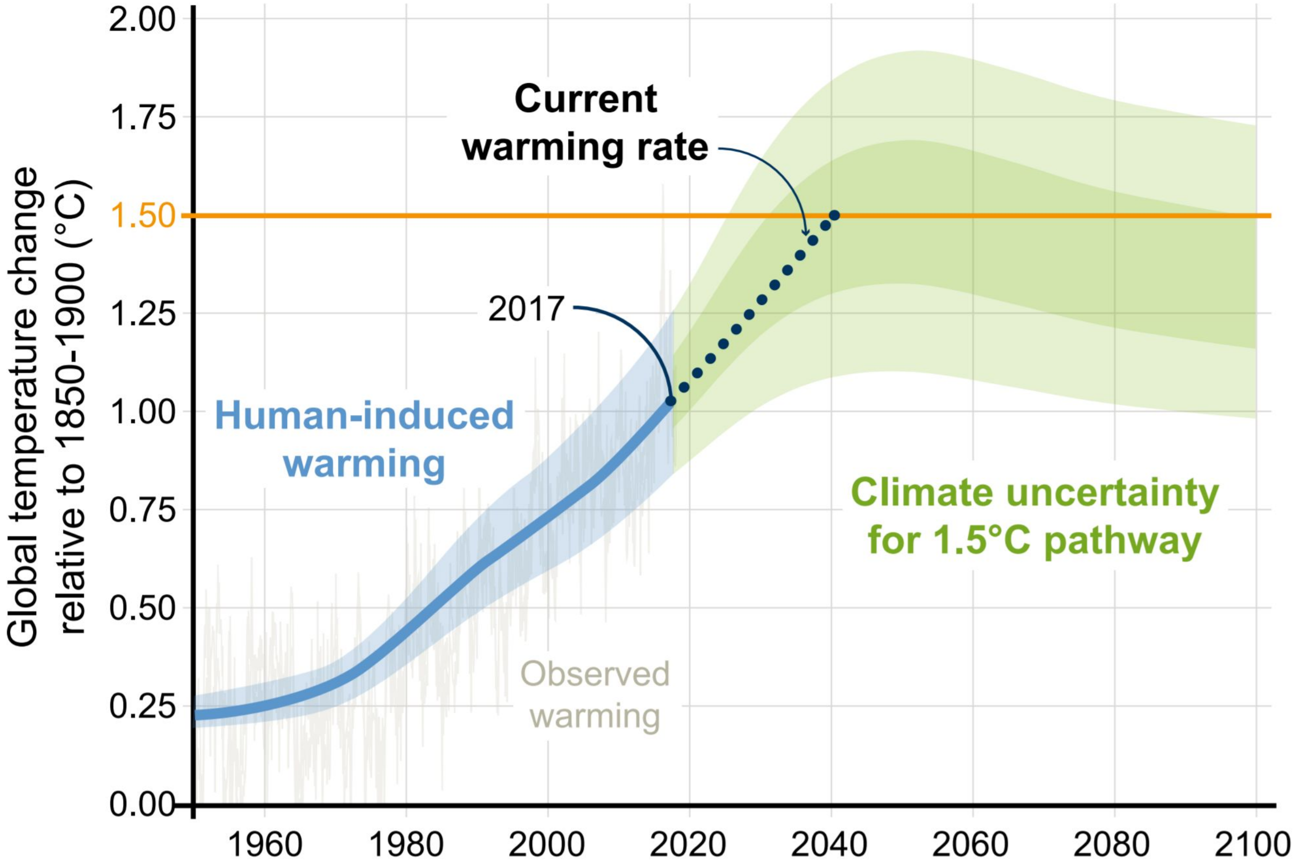
2030 / 2050

UN: 1/2 current CO_2 levels by 2030

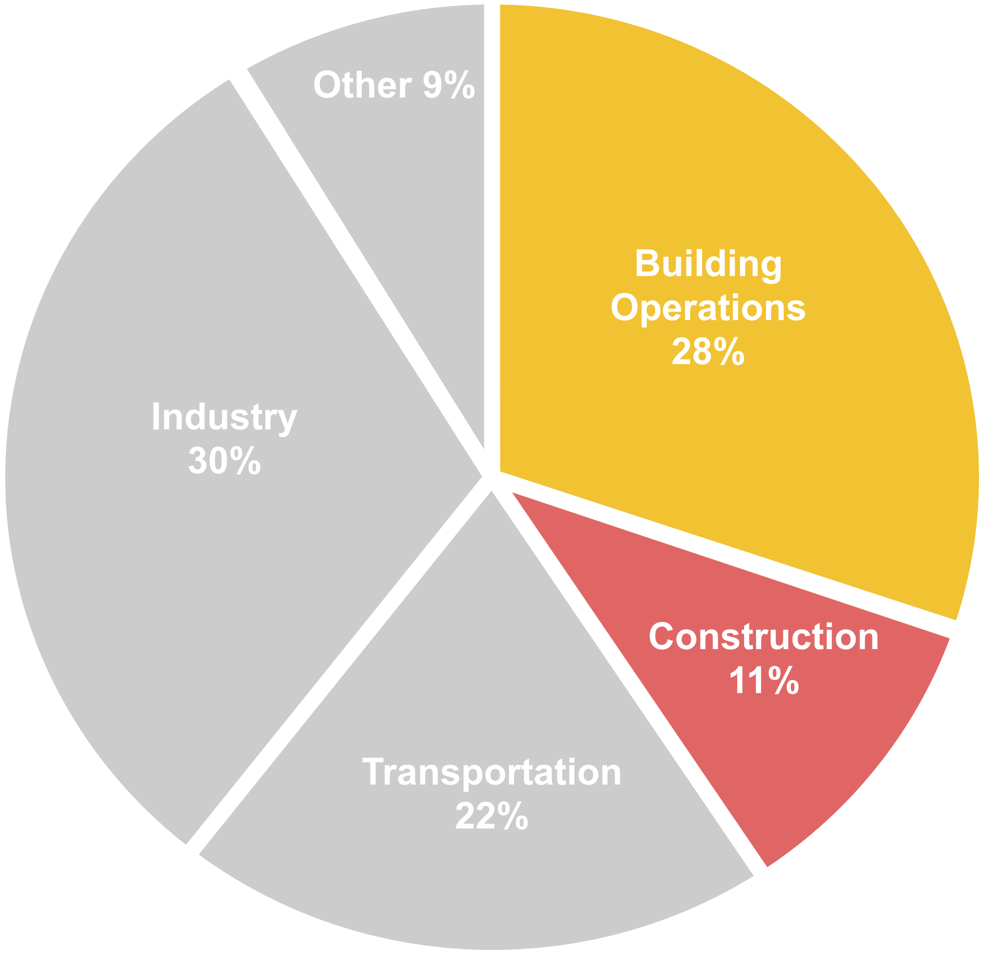
Net zero by 2050



Source: IPCC (2017), Global Warming of 1.5°C

Construction Greenhouse Gas

39% of global total comes from Building Industry



Source: UN Environment, Global Status Report 2017

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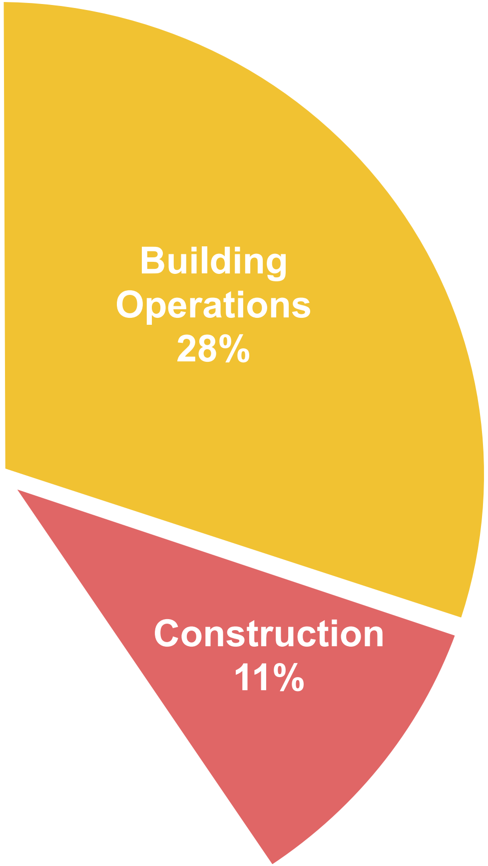
Operational vs Embodied

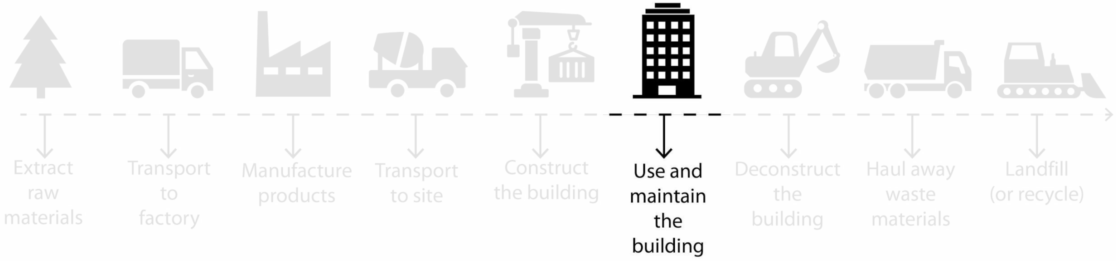
Operational carbon from heating, cooling and electrifying our existing building stock.

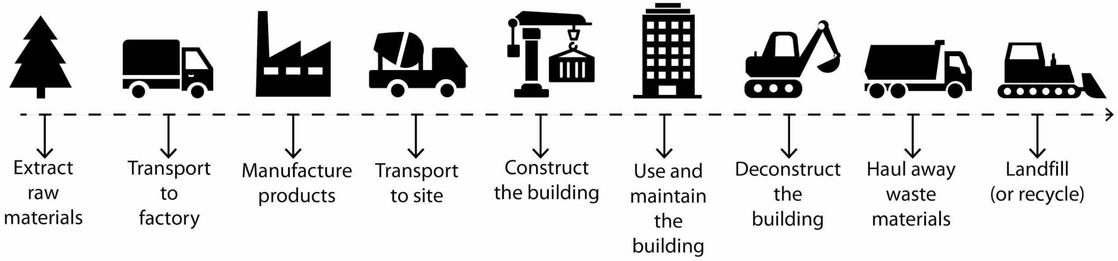
Embodied carbon from extracting, manufacturing, installing, and disposing building materials.

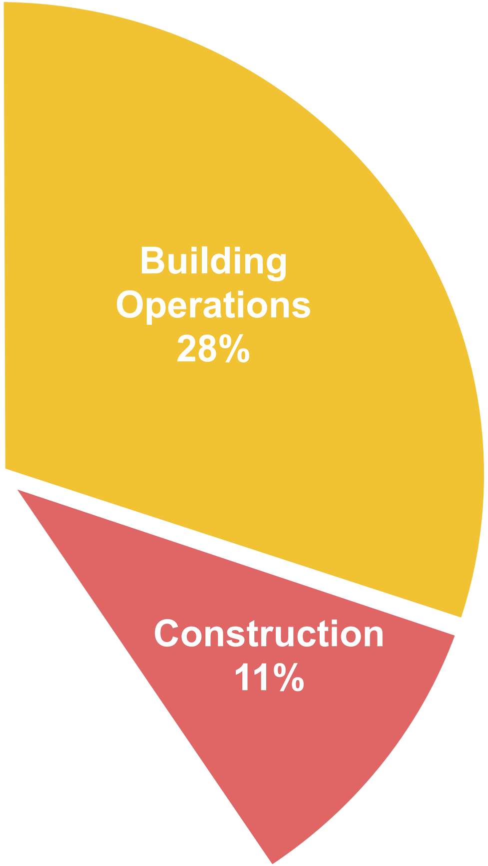


Source: UN Environment, Global Status Report 2017

Operational vs Embodied







Source: UN Environment, Global Status Report 2017

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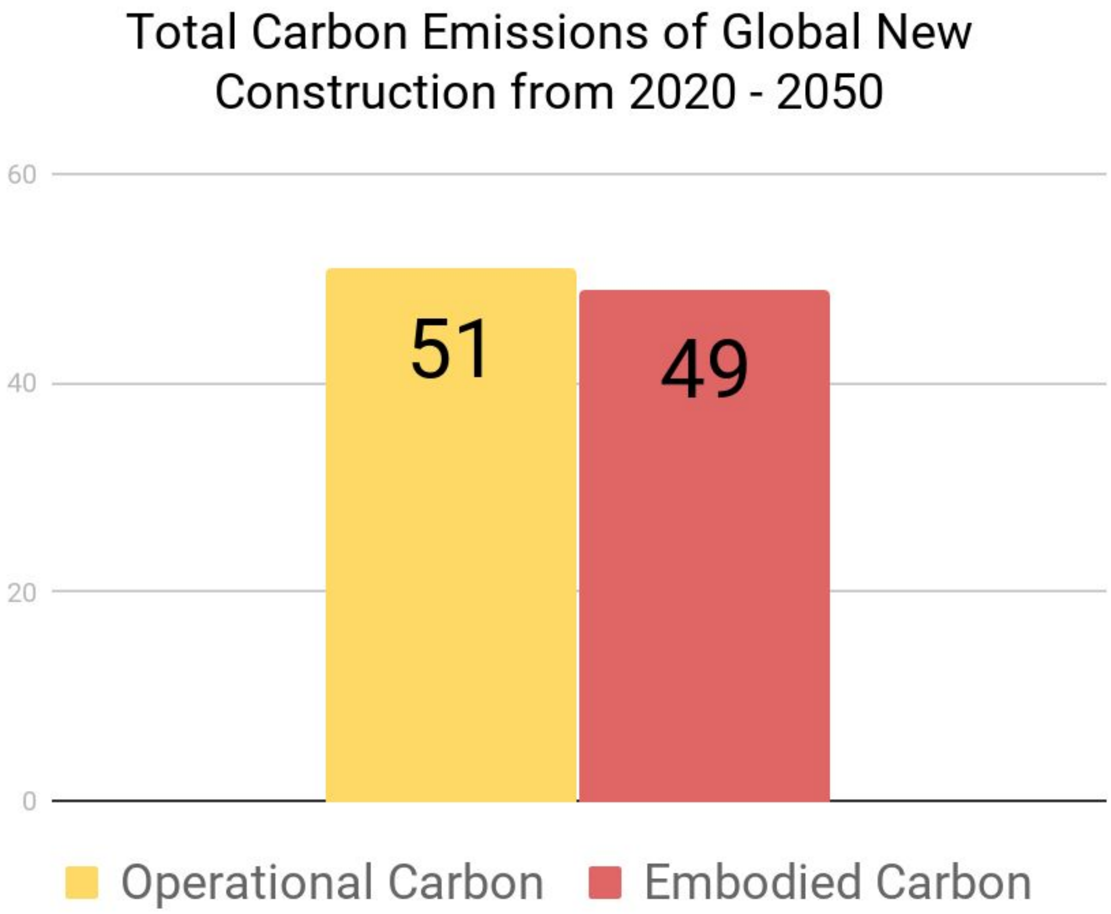
Operational vs Embodied



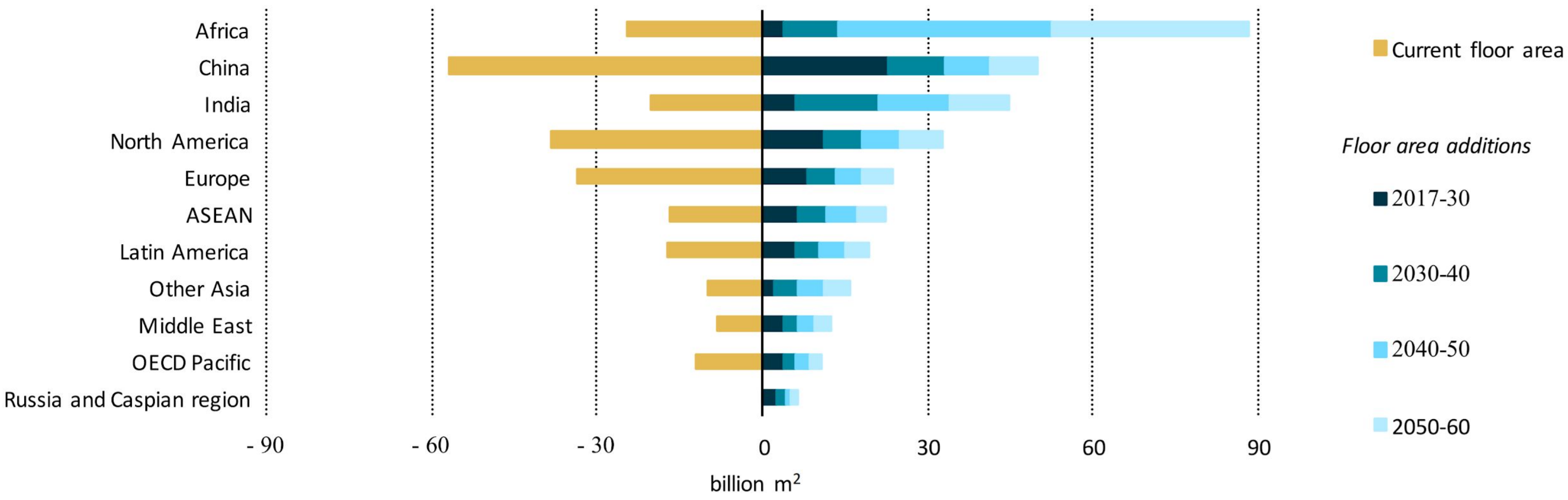
Source: Architecture 2030

Embodied carbon

A new New York every month for 40 years

Source: Architecture 2030

Expected construction by 2060



Source: IEA, Energy Technology Perspectives 2017

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Architecture is never neutral,
It either hurts or it heals.

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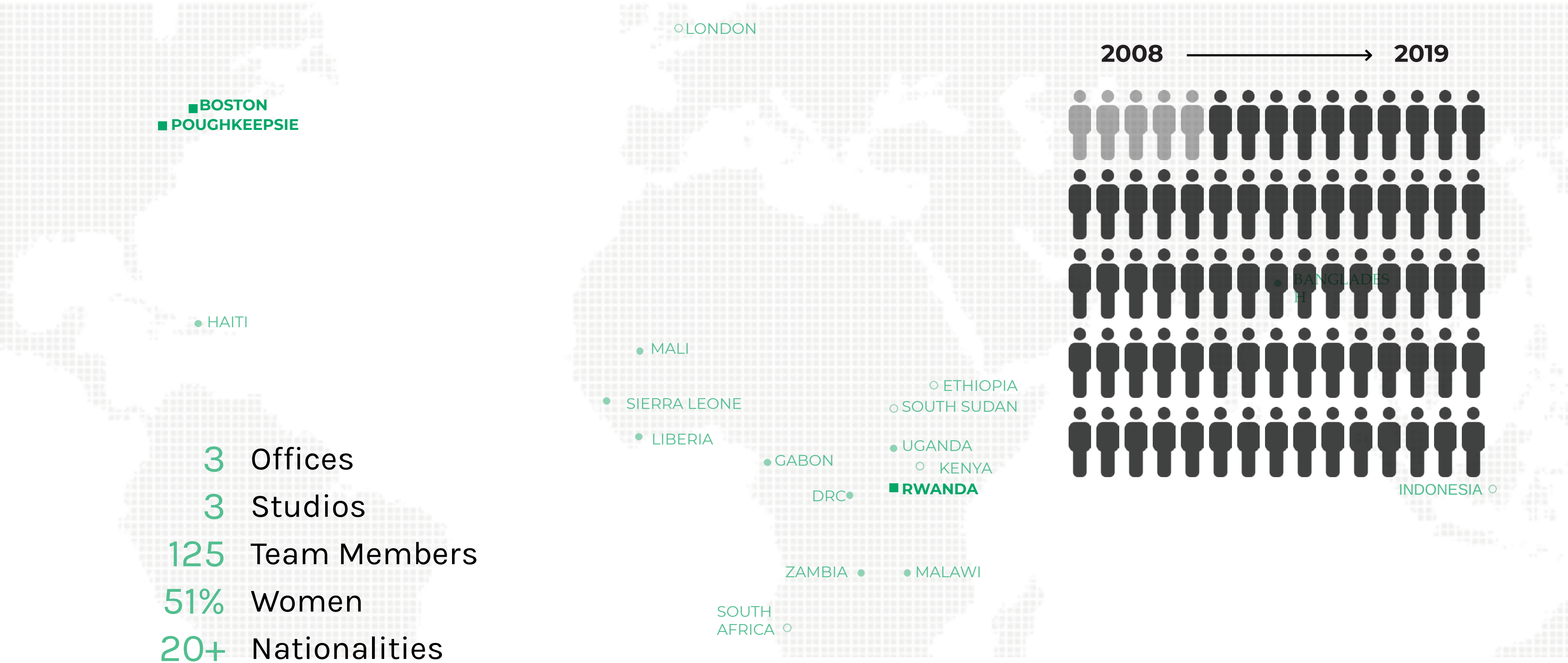
Architecture is never sustainable,
It is either climate negative or climate positive.

What we do

Organization



3 Offices

3 Studios

125 Team Members

51% Women

20+ Nationalities

Over 10 years of delivering projects

Butaro Hospital
2008

Butaro Doctors Share Housing
2015

University of Global Health Equity
2019

GHESKIO Cholera Treatment Center
2015

Ilima Primary School
2015

The National Memorial for Peace and Justice
2018

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Partners

The Atlantic Philanthropies

RICA Rwanda Institute For Conservation Agriculture

Family Services
Providing Hope. Improving Lives. Strengthening Community.

USAID FROM THE AMERICAN PEOPLE

ARUP

Dian Fossey Gorilla Fund Est. 1967

MGH 1811 Massachusetts General Hospital

Bechtel

Les Centres GHESKIO

IDEO.ORG

Boston Health Care for the Homeless Program

unicef

Ariadne Labs

The Greenway
RoseKennedyGreenway.org

Hudson River Housing, Inc

Partners In Health

Robert Wood Johnson Foundation

EJI Equal Justice Initiative

M2 Foundation

Fondation Internationale de l'hôpital Albert Schweitzer Lambaréné

Nuestra Comunidad Development Corporation
Our Community Working Together

Autodesk Foundation

Nous Engineering

University of Rwanda

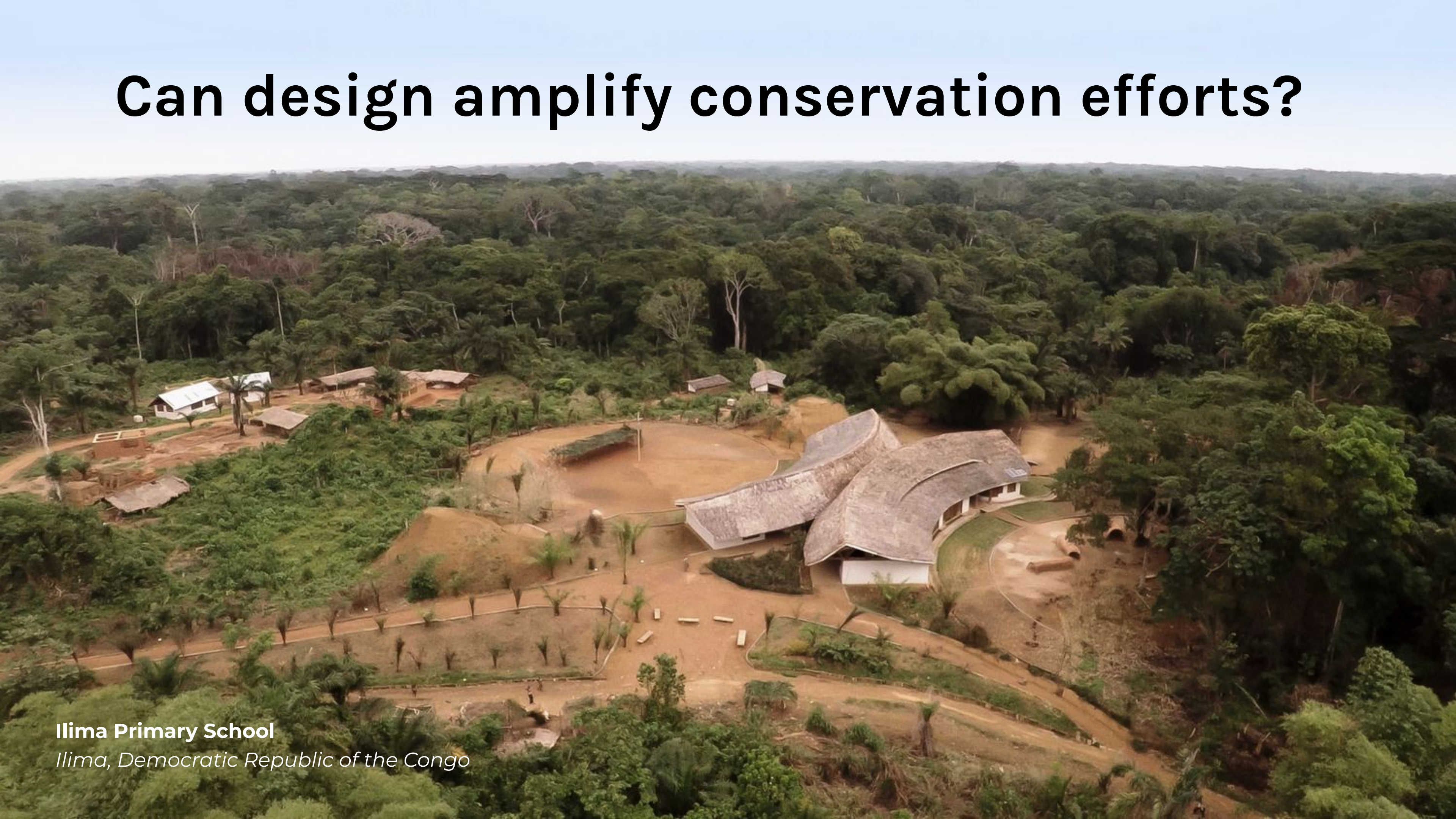
Can a building heal?

Butaro District Hospital
Burera, Rwanda

Can a building help resist an epidemic?

GHESKIO Cholera Treatment Center
Port-au-Prince, Haiti

Can design amplify conservation efforts?



Ilima Primary School
Ilima, Democratic Republic of the Congo

Can a school's design improve the quality of education?

Mubuga Primary School
Musanze, Rwanda

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Good

We believe everyone deserves good design. Good design is beautiful and just. It is essential to delivering human rights, essential services, and the spaces that will build a better world.

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Clean

Being climate positive is an imperative. Our projects strive for not only efficient operation, but the design of the entire supply chain to be resilient, restorative and regenerative.

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Fair

Looking at the design and construction process holistically—from material extraction to assembly and operation—ensures we have safe and equitable labour practices.

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Butaro District Hospital

Rwanda, 2008

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Operational Carbon

Natural ventilation

Daylight

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Volcanic stone walling

Embodied Carbon

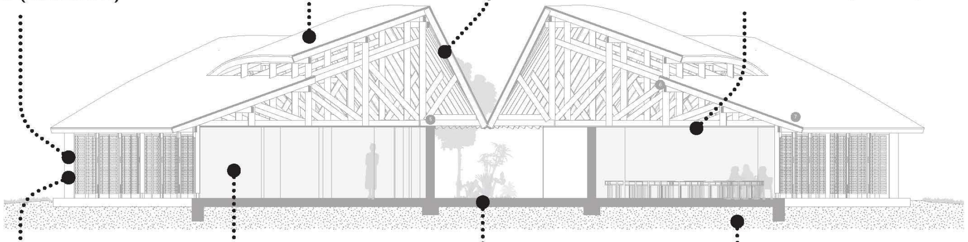
½

240kgCO2e/m2

Ilima Primary School

Democratic Republic of Congo, 2015

Material Sourcing



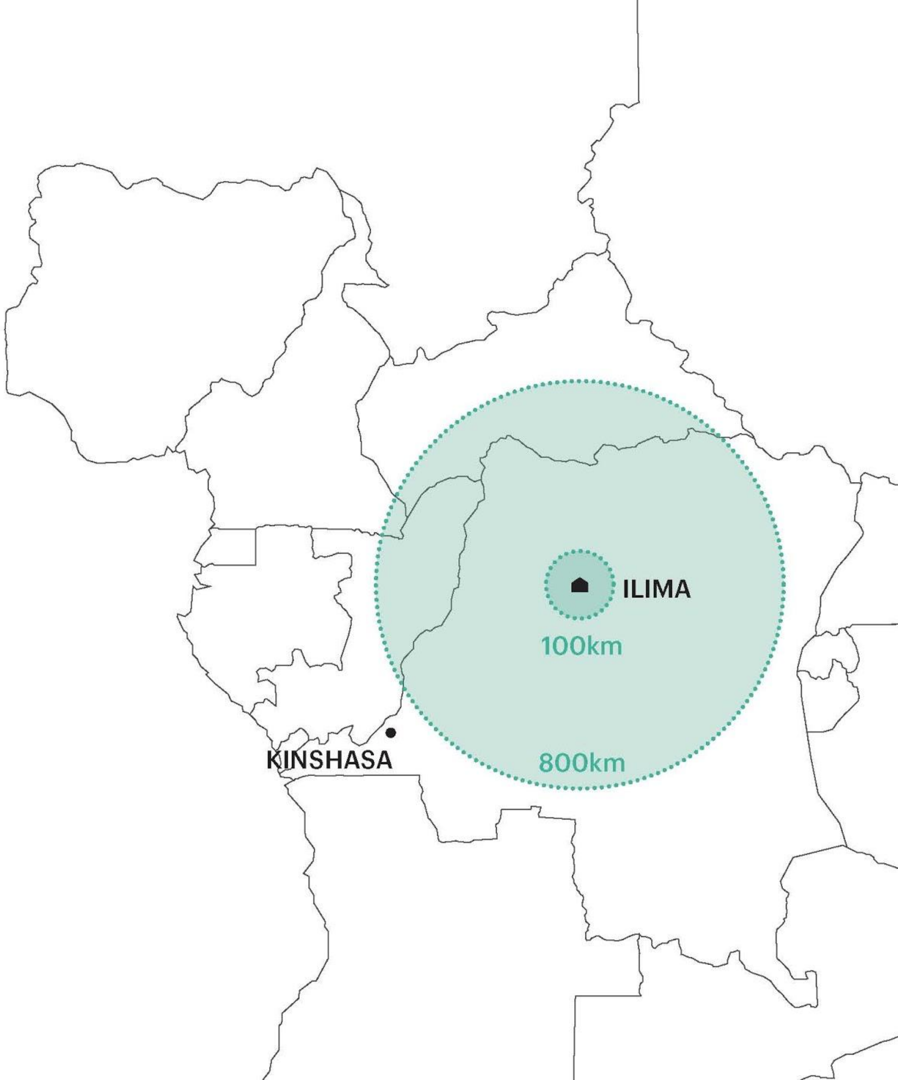
Local investment

84% spent locally

$317,420 spent within 100km radius

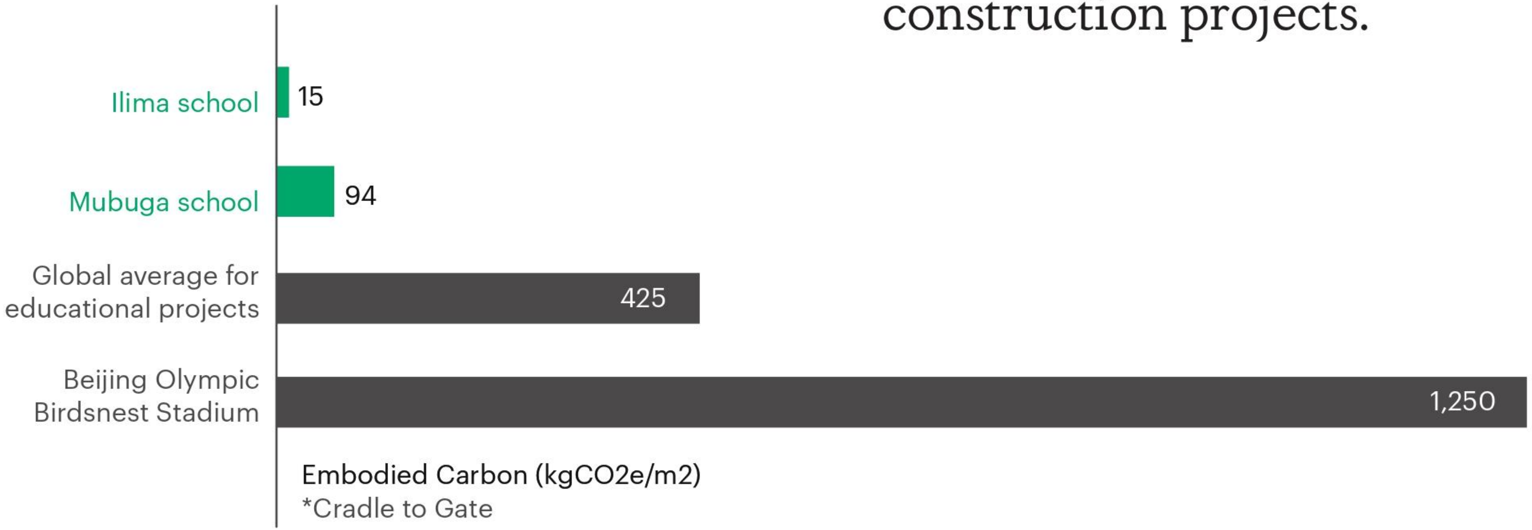
95% spent regionally

$359,690 spent within 800km radius or country



Embodied carbon

The construction of Ilima emitted 28 times less carbon/m² than the global average for educational construction projects.



Ilima Primary School

Wooden shingles

Timber trusses

Earth blocks

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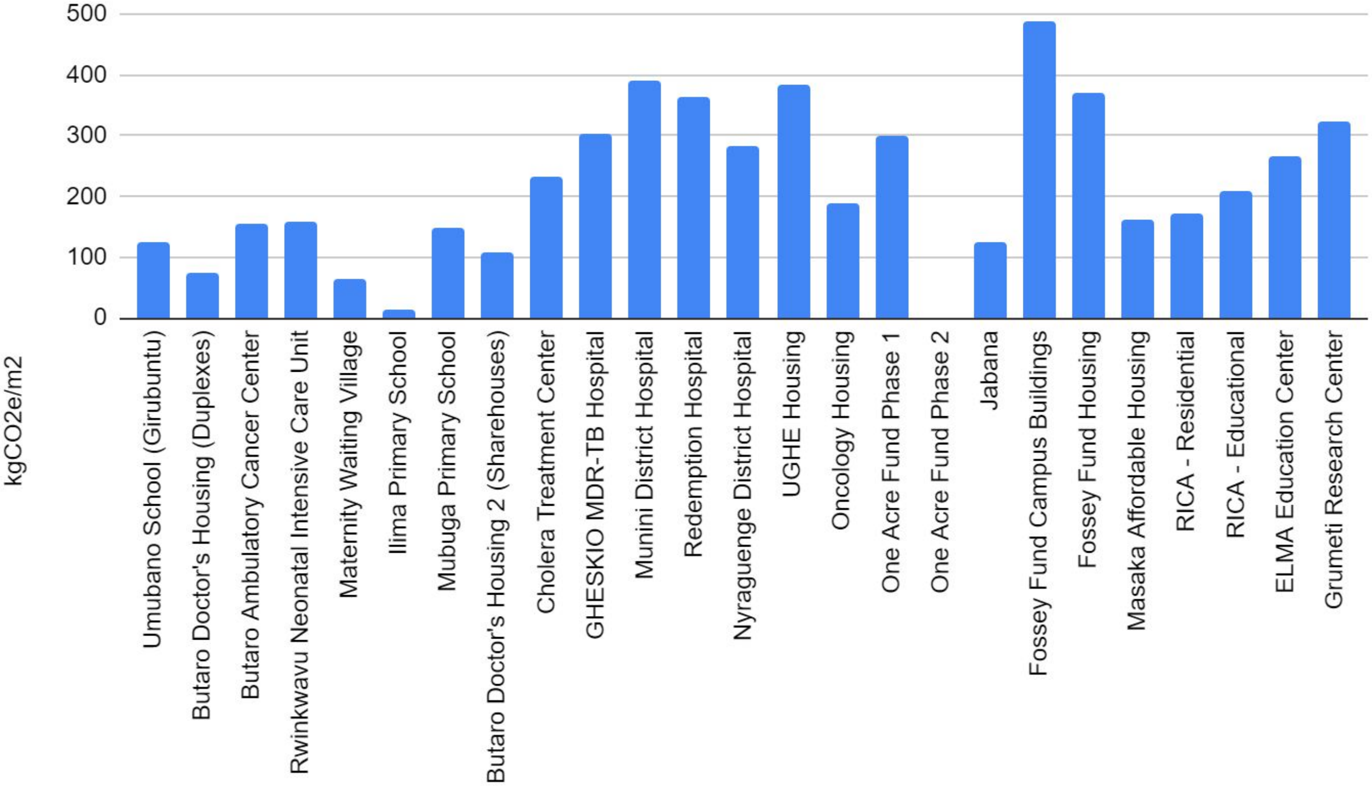
Project embodied carbon



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Rwanda Institute for Conservation Agriculture: Good, Clean, Fair at scale

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Location

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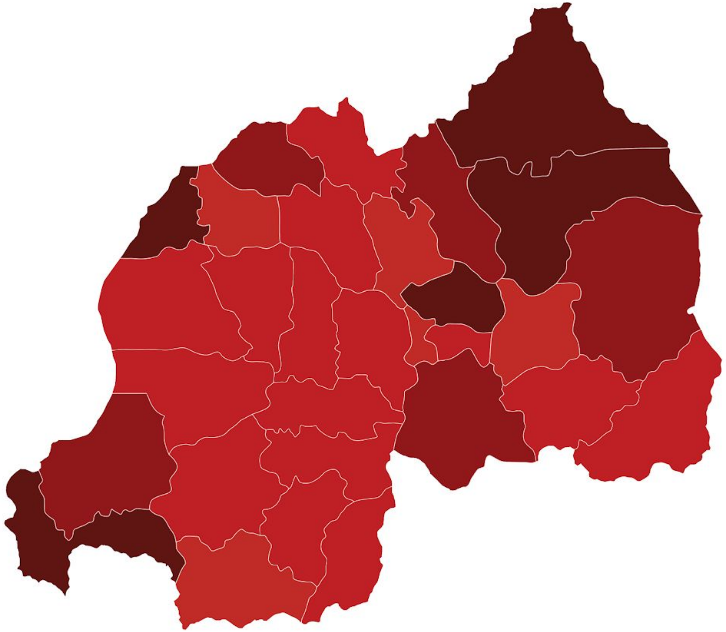
Population

12.6 million



2019

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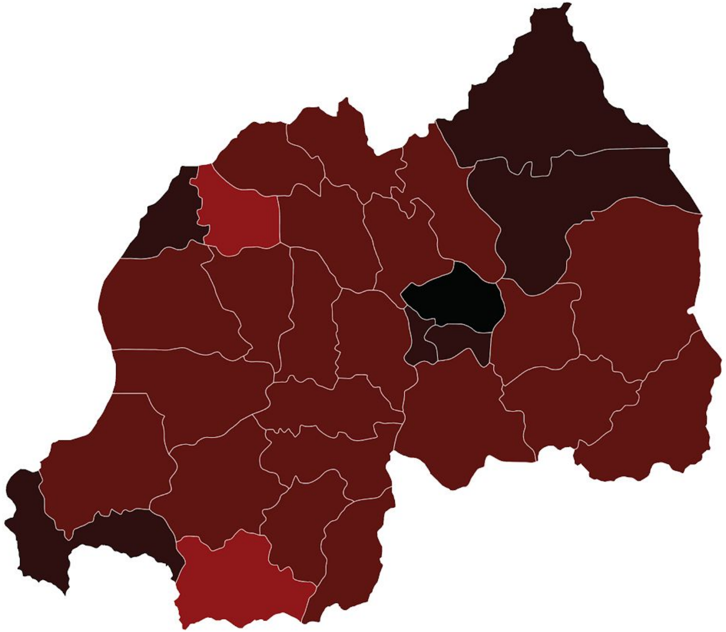
Population

25 million



2050

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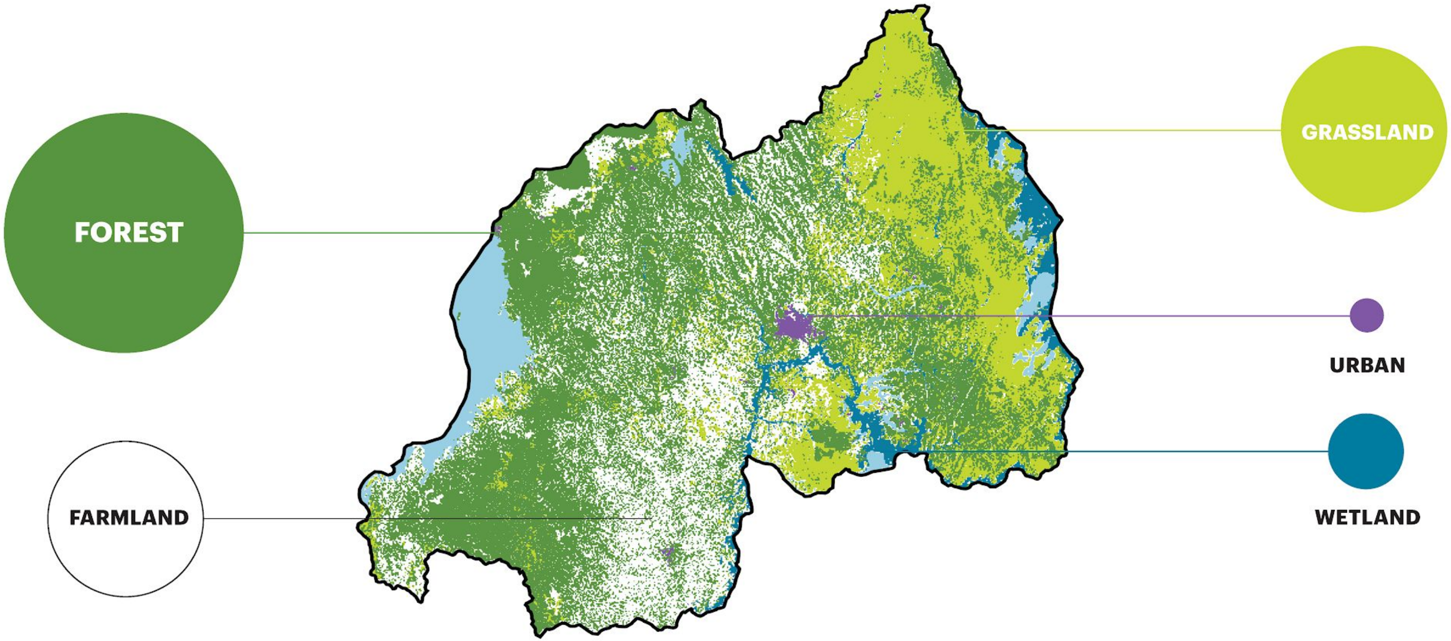
Land type



1990

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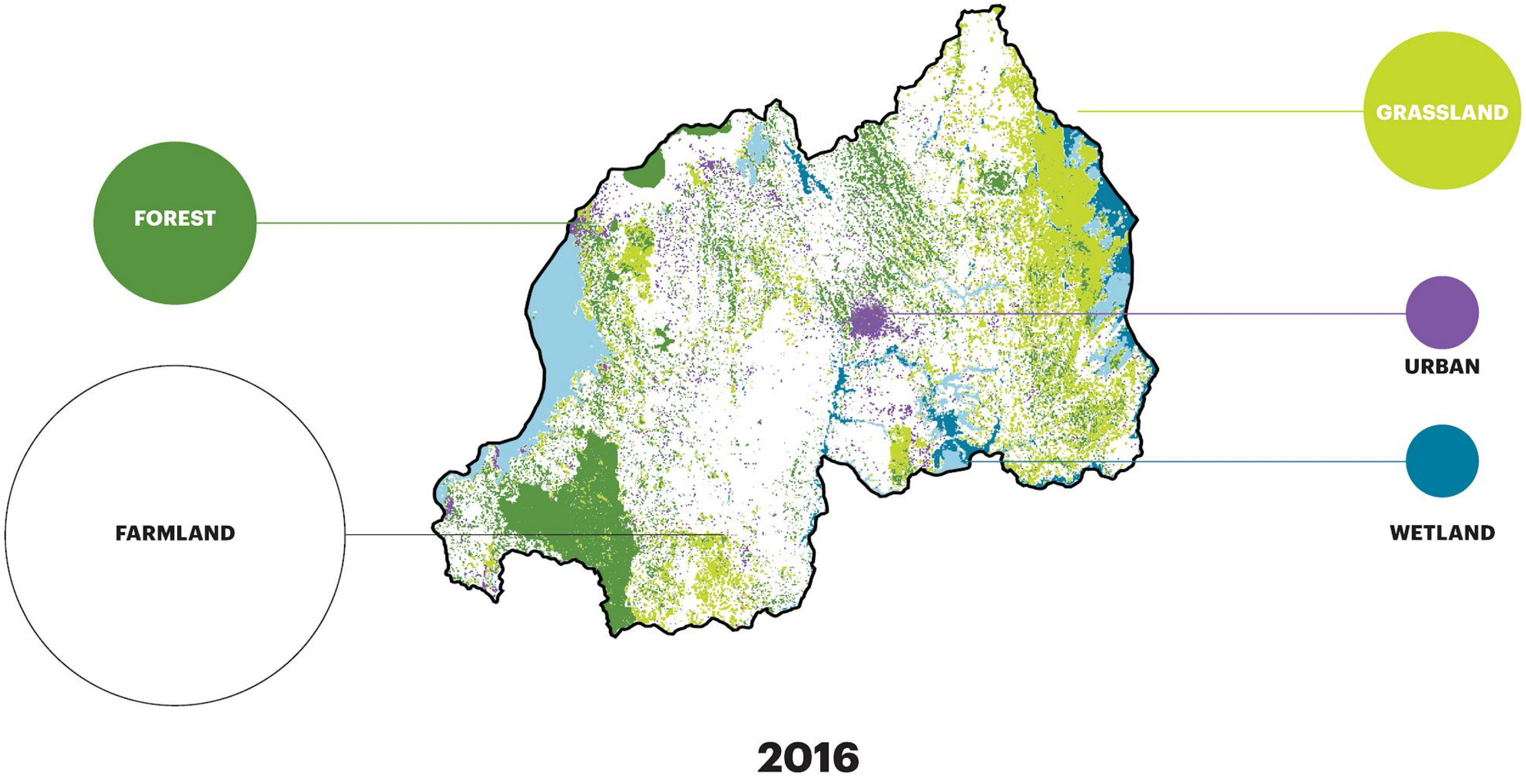
Land type



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Can design improve human, ecological, and animal health?

RICA
Bugesera, Rwanda

Rwanda Institute for Conservation Agriculture (RICA)

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One Health

Existing Conditions
Degraded soil, food insecurity, deforestation

One Health Conditions
Ecological, Human, Economic Health

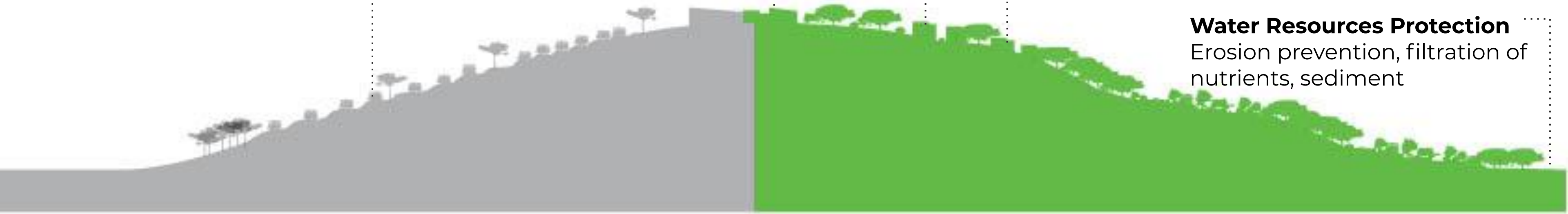
Existing
Monoculture crops, livestock grazing

Native Ornamental Landscapes
Native species builds biodiversity, a seed bank, ecological stability.

Silviculture
Providing biomass, natural resources, livelihoods

Agroforestry
Soil improvement, biodiversity, food security

Water Resources Protection
Erosion prevention, filtration of nutrients, sediment



First Year Farms

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Enterprise buildings

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Campus Centre

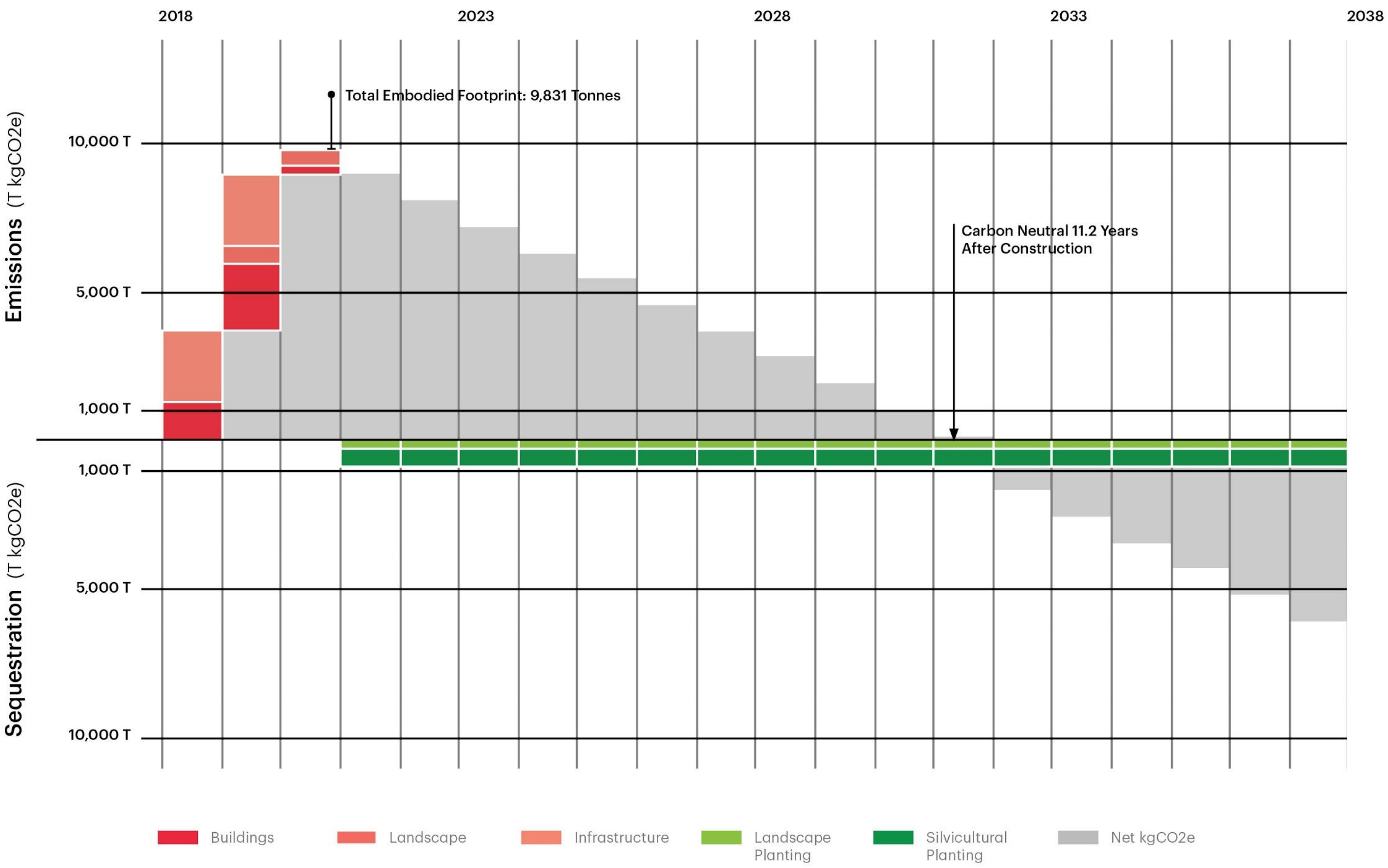
Embodied Carbon

2/5

175 kgCO2e/m2

Climate Positive

12 years



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How we reduced carbon at RICA

Influence the brief

Upstream with client

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Masterplan

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Natural Ventilation, Cooling and Daylight

Solar

Carbon payback period:

3 years

Local materials

96% of RICA's materials excavated, harvested, and sourced in Rwanda


RICA | <1 Mile
Sources:
1. Timber
2. Soil (Laterite)
3. Water
1
2
3


RICA | 1-10 Miles
Sources:
1. Stone
2. Aggregate
3. Sand
Kinazi
Rilima
Mugesera
Nyamata
1&2
RICA
3
Kagasera
Lake Rweru

RICA | 10-100 Miles

Sources:

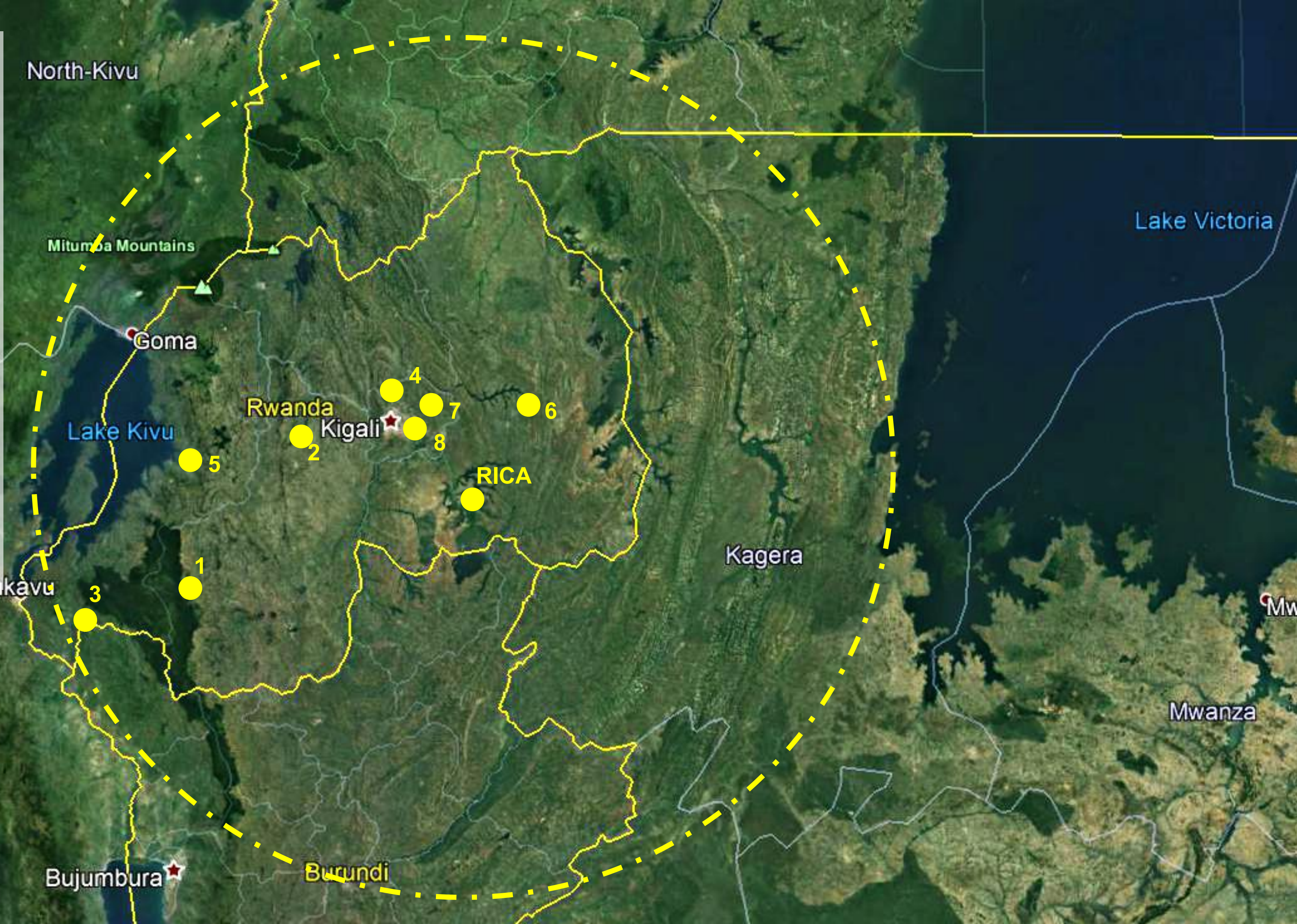
1. Timber
2. Sand

Manufacturers:

3. Cement
4. Terra Cotta
5. Ceramics

Suppliers:

6. Reinforcing Steel
7. Structural Steel
8. Windows and Doors



RICA | 100-1000 Miles

Sources:

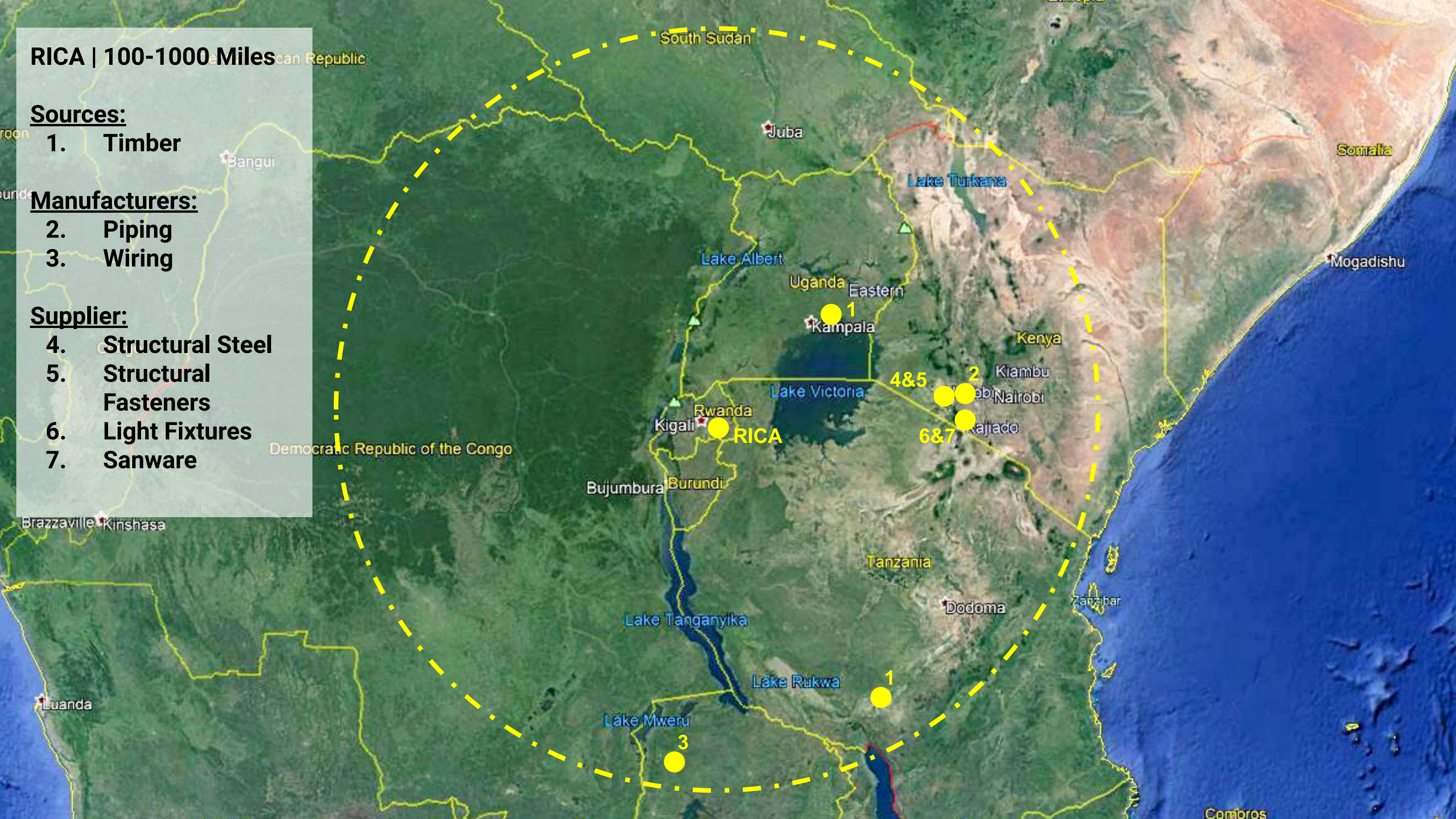
1. Timber

Manufacturers:

2. Piping
3. Wiring

Supplier:

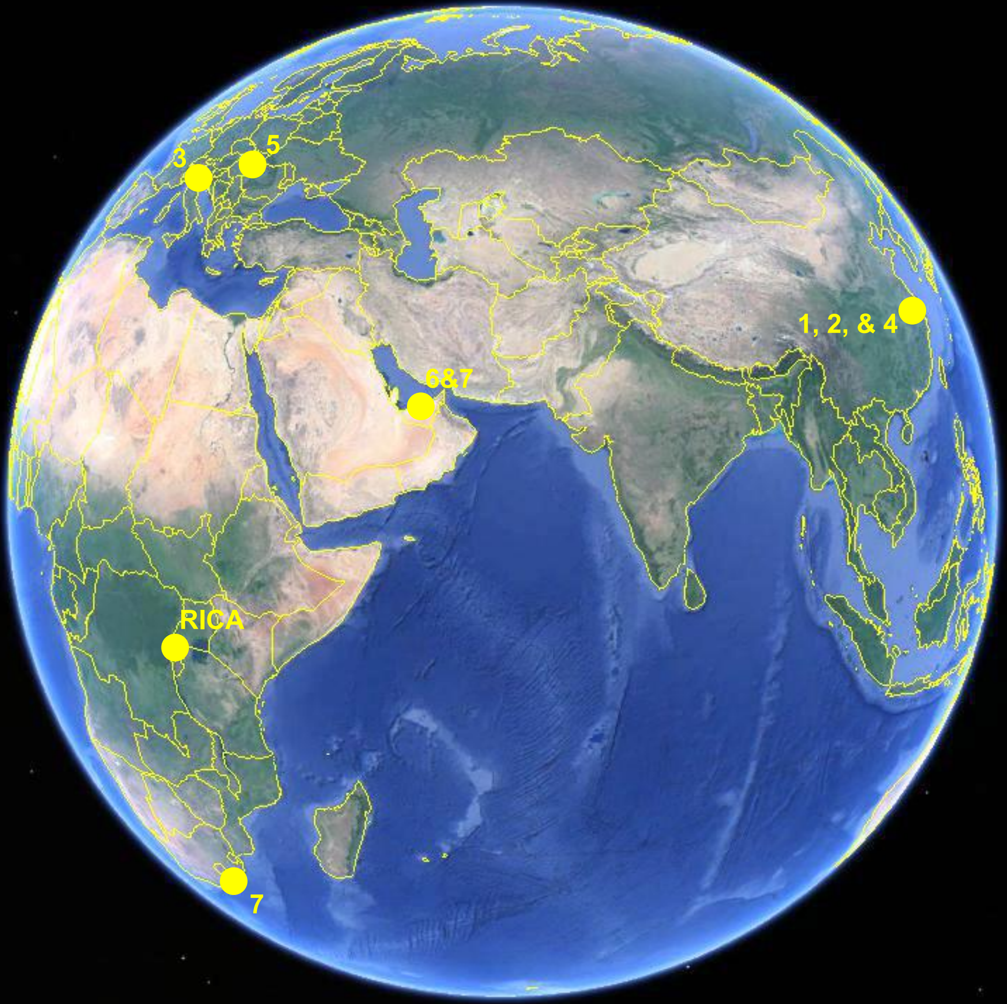
4. Structural Steel
5. Structural Fasteners
6. Light Fixtures
7. Sanware



RICA | > 1000 miles

Manufacture:

1. Solar Panels
2. Batteries
3. Water Treatment Plant
4. Wastewater Treatment Plant
5. Pumps
6. Gypsum Board
7. Fasteners



Low embodied carbon materials

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Timber

Sourced in Rwanda and Tanzania

From forests with growing stock

Clay tiles

Sourced 60km away

Coffee husks used to fire the clay

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Stone foundations

Alternative to concrete foundations

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Swales

Natural infrastructure instead of buried concrete culverts

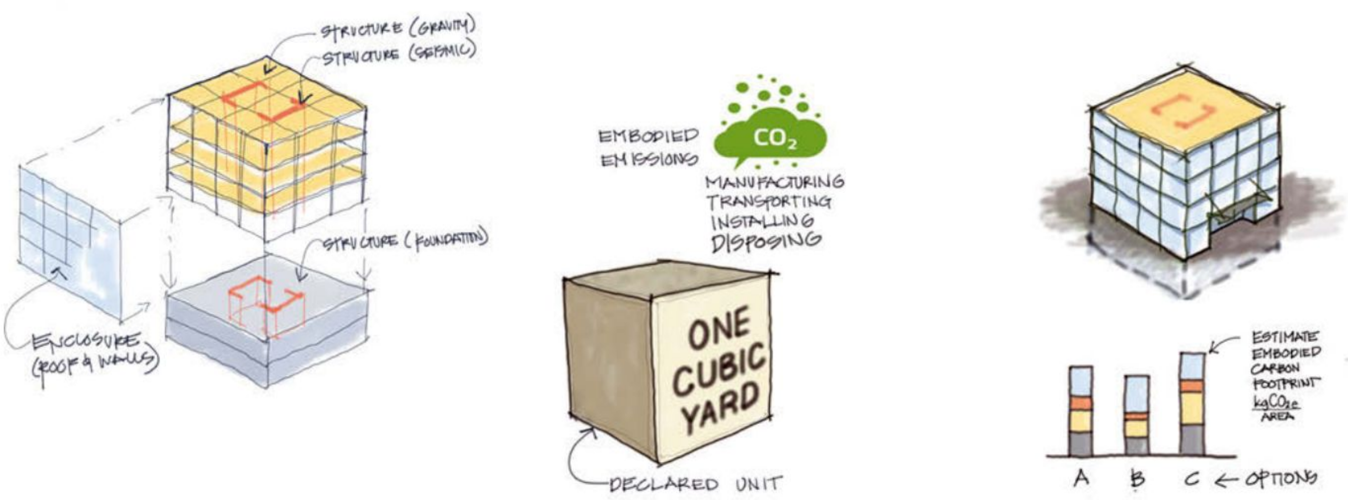
Earth construction

Sourced from site

25% of all building materials by weight

Calculating embodied carbon

How to calculate product stage embodied carbon



MATERIAL QUANTITY ESTIMATE × **EMBODIED CARBON PER UNIT MATERIAL** = **BUILDING EMBODIED CARBON (EC) ESTIMATE**

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Environmental Product Declaration

EPDs contain environmental impact data for products

Nutrition Facts

16 servings per container

Serving size **1 Tbsp. (21g)**

Amount per serving

Calories **60**

	% Daily Value*
Total Fat 0g	**0%**
Saturated Fat 0g	**0%**
Trans Fat 0g	
Cholesterol 0mg	**0%**
Sodium 0mg	**0%**
Total Carbohydrate 17g	**6%**
Dietary Fiber 0g	**0%**
Total Sugars 17g	
	34%†
Protein 0g	
Vitamin D 0mcg	0%
Calcium 0mg	0%
Iron 0mg	0%
Potassium 0mg	0%

* The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

† One serving adds 17g of sugar to your diet and represents 34% of the Daily Value for Added Sugars.

Environmental Product Declaration

EPD®
THE INTERNATIONAL EPD® SYSTEM

Little data where the most construction is happening

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Generic documents

D	E	F	G	H	I	J	K

ICE (Inventory of Carbon & Energy)

Authors: Dr Craig Jones* — Professor Geoffrey Hammond

Affiliation: circular ecology (Resource efficiency at its best) — University of Bath

*corresponding author. Contact details: http://www.circularecology.com/contact.html

Version Control

Version:	V3.0 Beta - 9 August 2019
Is this version still valid?	Check link below, to see if a newer version is available.
Check if this copy is up to date at:	http://www.circularecology.com/embodied-energy-and-carbon-footprint-database.html

AUROVILLE EARTH INSTITUTE — UNESCO Chair Earthen Architecture

EMBODIED ENERGY OF VARIOUS MATERIALS AND TECHNOLOGIES

COMPILATION AND CALCULATIONS
May 2005
Revision November 2013

Satprem Maïni
Varun Thautam

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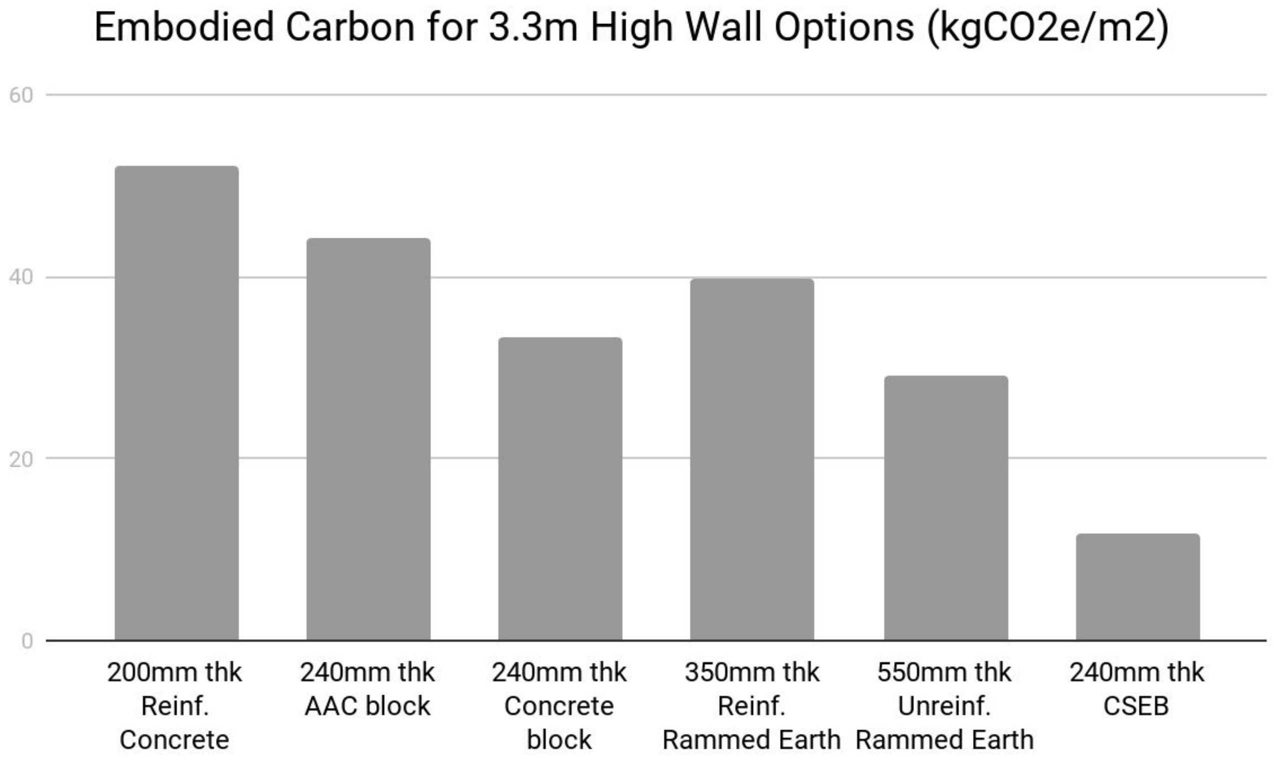
Email: earthinstitute@auroville.org.in — Web: http://www.earth-auroville.com

Earth construction

Embodied carbon drove design decisions



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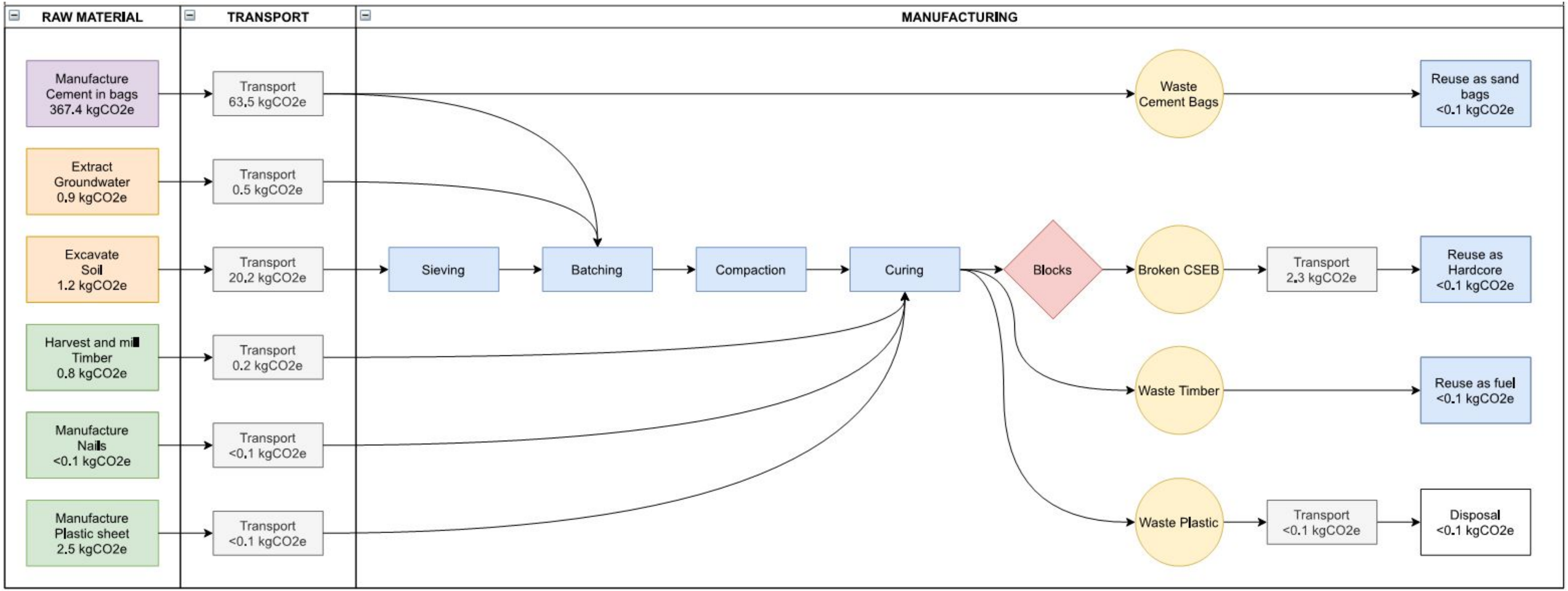
Design

Manufacturing

Measured Coefficient



A1-3: **0.046** kgCO2e/kg of CSEB

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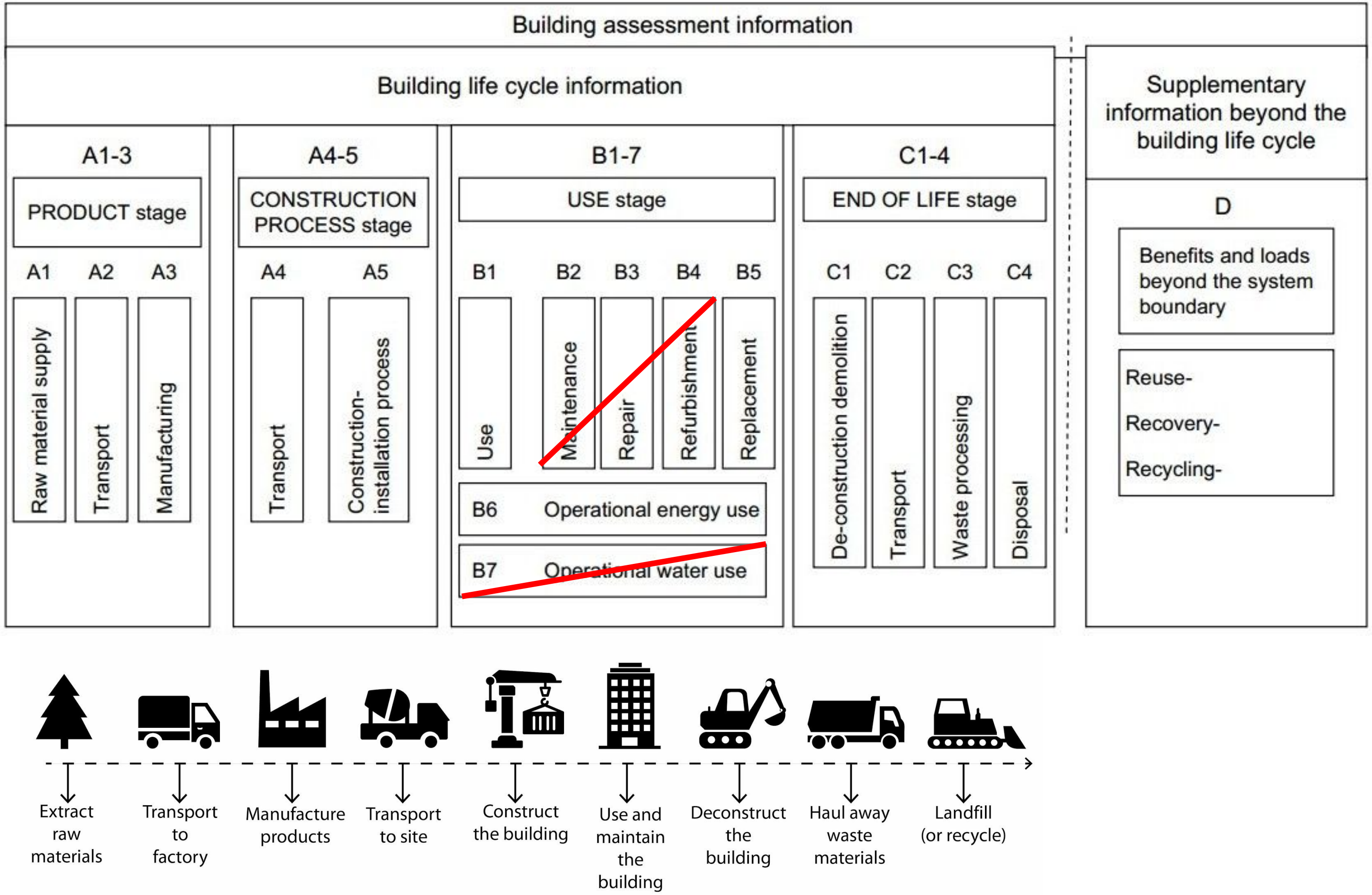
How we perform whole campus life cycle analysis

System boundary



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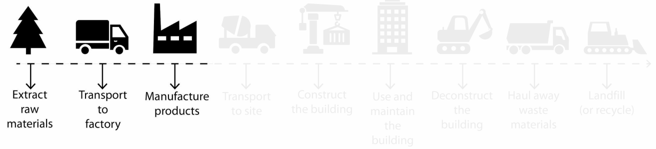
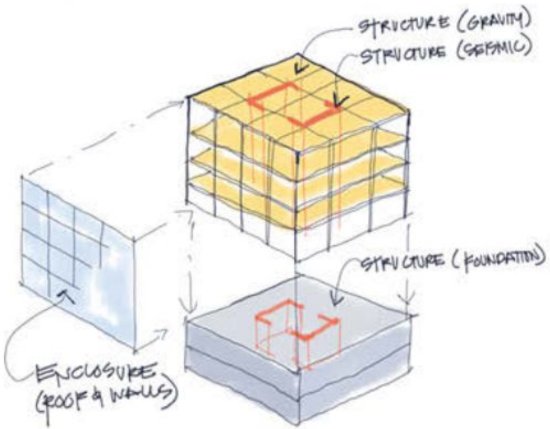
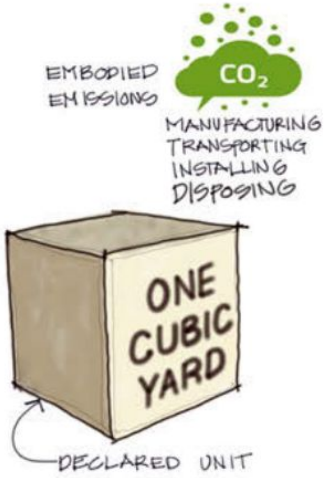
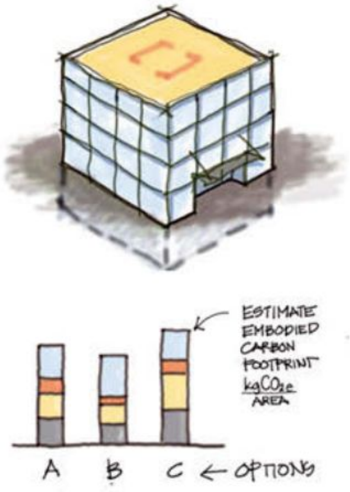
A1-3 Product stage

A1-3 Product stage









MATERIAL QUANTITY ESTIMATE × **EMBODIED CARBON PER UNIT MATERIAL** = **BUILDING EMBODIED CARBON (EC) ESTIMATE**

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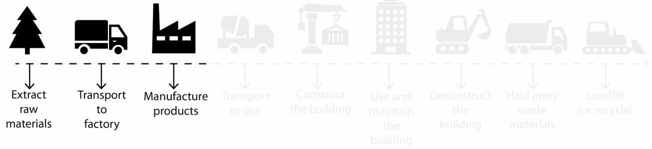
A1-3 Product stage



Reinforced 240mm Thk CSEB wall with earth plaster (Declared unit = 1m2)

Earth	365kg	x 0.00438 kgCO2e/kg	= 1.60 kgCO2e
Cement	20kg	x 0.798 kgCO2e/kg	= 15.96 kgCO2e
Sand for mortar	90kg	x 0.00438 kgCO2e/kg	= 0.39 kgCO2e
Cement for mortar	15kg	x 0.798 kgCO2e/kg	= 11.97 kgCO2e
Reinforcement	6kg	x 1.99 kgCO2e/kg	= 11.94 kgCO2e
Earth for plaster	40kg	x 0.00438 kgCO2e/kg	= 0.18 kgCO2e
Cement for plaster	2kg	x 0.798 kgCO2e/kg	= 1.60 kgCO2e
		A1 - A3 Sum	= 44 kgCO2e/m2 of wall area

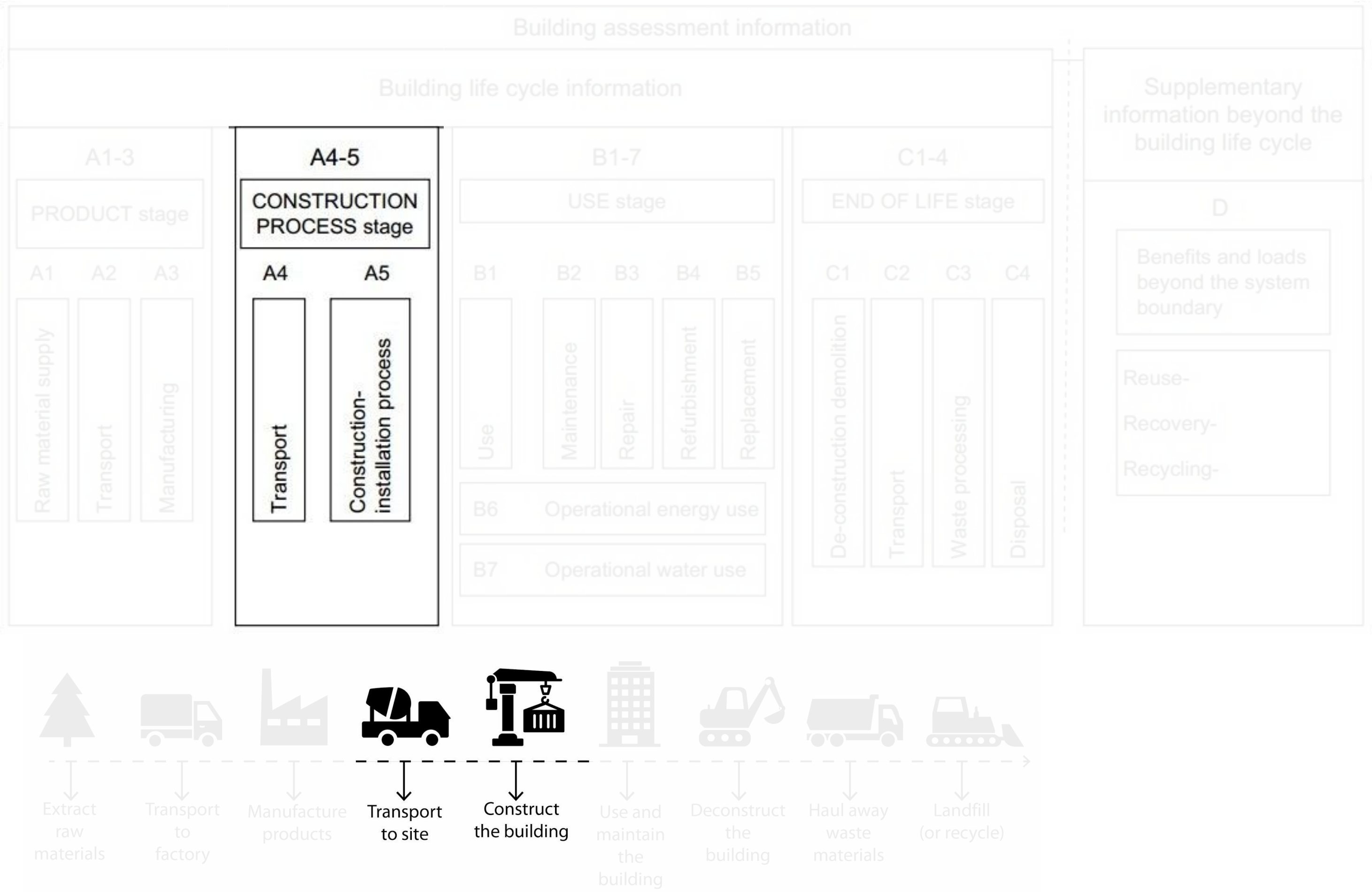
Sources and assumptions

Sand and earth: ICE v3: from virgin land won resources, bulk, loose

Reinforcement: ICE v3: Steel, Rebar

Cement: ICE v3: CEM II/A-P - 13% natural pozzolanic ash

A4-5 Construction process



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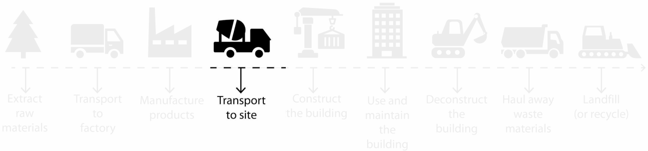
A4 - Transport



Transport scenario	Km by road	Km by sea
Locally manufactured e.g. concrete, aggregate, earth	50	-
State manufactured e.g. plasterboard, blockwork, insulation	300	-
Nationally manufactured e.g. timber, carpet	1,500	-
Globally manufactured.	200	10,000

Transport Types	kgCO2e/kgkm	Source
Motorbike	0.001647	Motorbike average
Van	0.0008115	Vans petrol average
HGV (rigid)	0.00021334	HGV All rigids average laden
HGV (articulated)	0.00008525	HGV All artics average laden (Assume for road transport)
Air Freight	0.00123205	Freight flights international with radiative factors
Rail	0.00003351	Freight train
Cargo ship	0.00001614	Container ship Average

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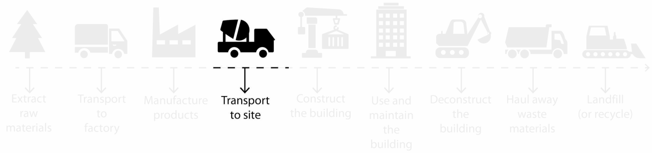
A4 - Transport



<u>Reinforced 240mm Thk CSEB wall with earth plaster (Declared unit = 1m2)</u>

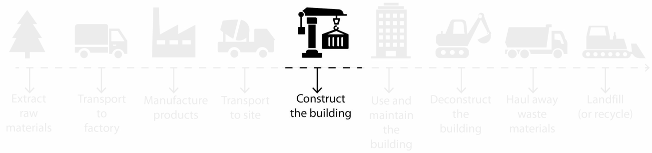
Earth	365kg	x 5km	x 0.00021334 kgCO2e/kgkm	= 0.39 kgCO2e
Cement	20kg	x 150km	x 0.00021334 kgCO2e/kgkm	= 0.64 kgCO2e
Sand for mortar	90kg	x 50km	x 0.00021334 kgCO2e/kgkm	= 0.96 kgCO2e
Cement for mortar	15kg	x 150km	x 0.00021334 kgCO2e/kgkm	= 0.48 kgCO2e
Reinforcement	6kg	x 75km	x 0.00021334 kgCO2e/kgkm	= 0.10 kgCO2e
Earth for plaster	40kg	x 5km	x 0.00021334 kgCO2e/kgkm	= 0.04 kgCO2e
Cement for plaster	2kg	x 150km	x 0.00021334 kgCO2e/kgkm	= 0.06 kgCO2e
			A4 Sum	= 2.67 kgCO2e/m2 of wall area

<u>Sources and assumptions</u>
Rigid HGV used for transportation
Actual distances from manufacturers known

<u>RICA Campus Summary</u>

Buildings	3,848 tonnes CO2e
Infrastructure	4,861 tonnes CO2e
Landscape	1,123 tonnes CO2e
A1-A4 Sum	9,831 tonnes CO2e

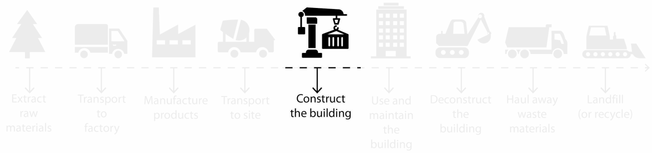
A5 - Construction



Consider electricity, fuel, waste and transportation impacts

Activity	Rate
Excavation	1.39 kgCO2e/m3

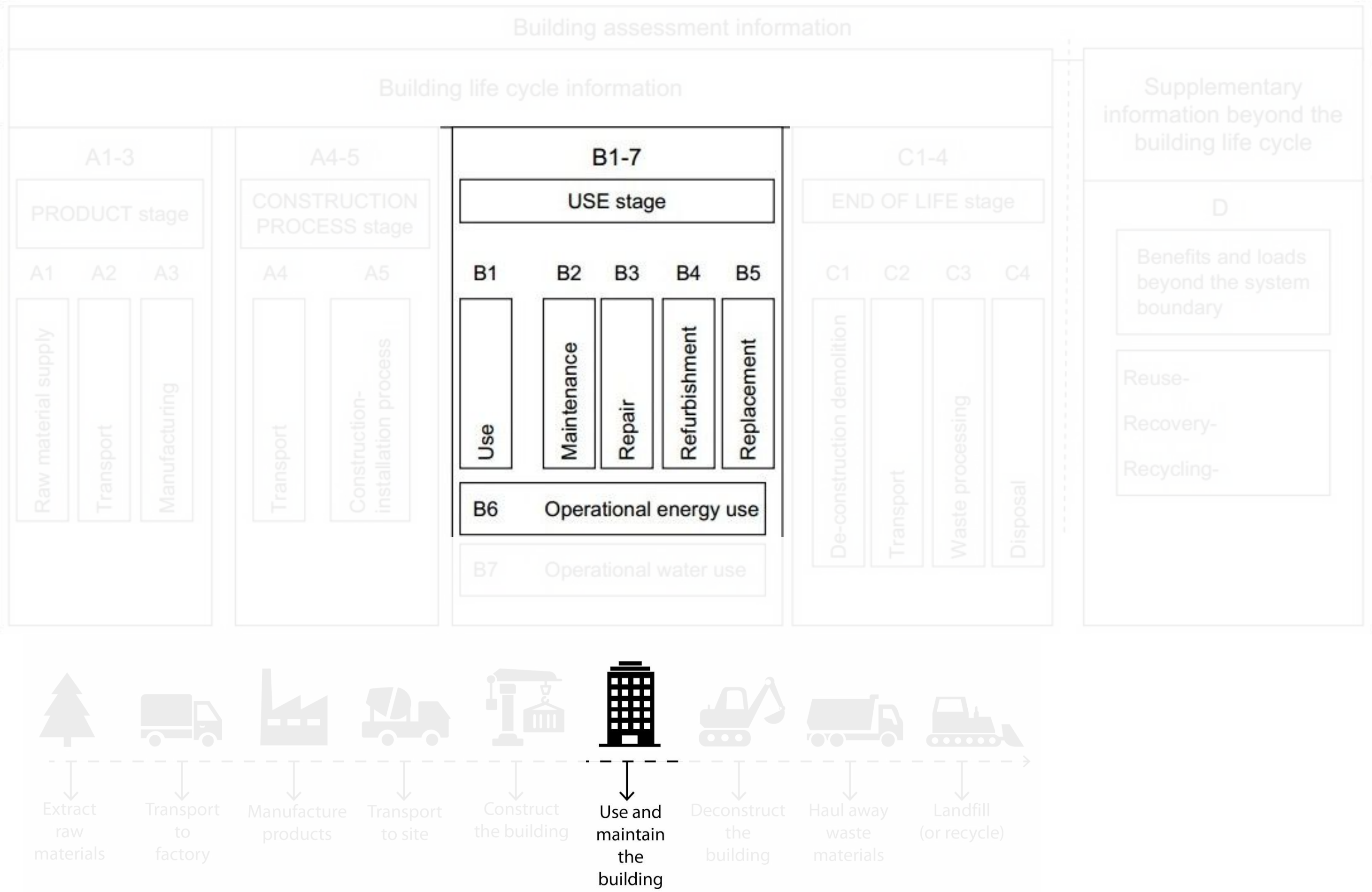
A5 - Construction



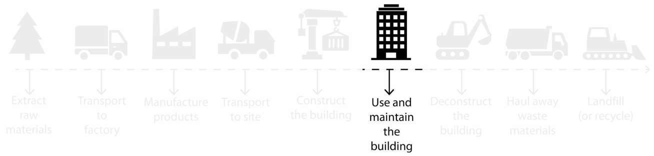
<u>RICA Campus Construction</u>

Buildings	= 18,267m2	x 20kgCO2e/m2	= 365 tonnes CO2e
Excavation	= 250,000m3	x 1.39kgCO2e/m3	= 348 tonnes CO2e
		A5 Sum	= 712 tonnes CO2e

B1-7 Use stage



B1 - Use

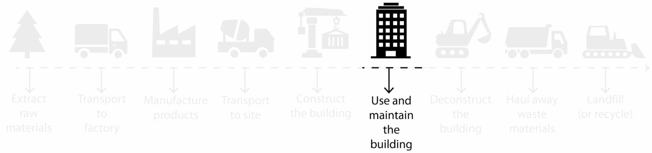


Use EPDs if B1 is relevant e.g. GHG from HFC blown insulation

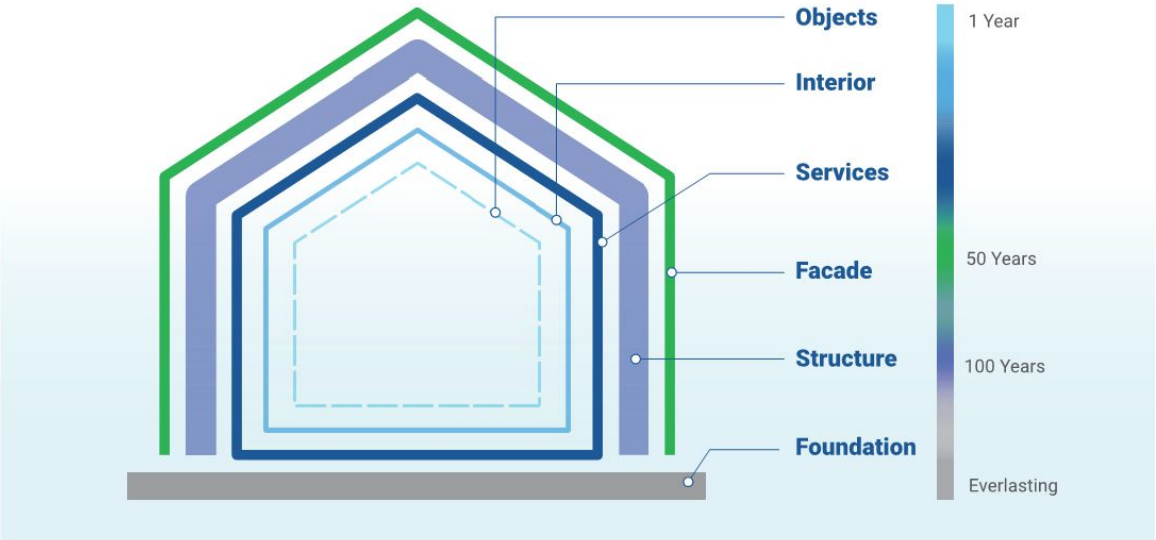
Table 12. 2K-LP, HFC results

TRACI v2.1	A1-A3	A4	A5	B1	C2	C4	D
GWP 100 [kg CO_2 eq]	3.21E+00	9.80E-02	7.05E+00	1.52E+01	2.72E-03	1.02E+01	-1.41E-04
GWP 100, IPCC AR5 [kg CO_2 eq]	3.24E+00	9.83E-02	5.93E+00	1.27E+01	2.73E-03	8.50E+00	-1.41E-04
ODP [kg CFC-11 eq]	5.37E-08	2.82E-15	2.20E-13	-	7.87E-17	6.03E-15	-4.51E-16
AP [kg SO_2 eq]	1.03E-02	4.40E-04	2.81E-03	-	1.23E-05	1.52E-04	-8.24E-07
EP [kg N eq]	7.11E-04	3.64E-05	2.09E-04	-	1.02E-06	7.68E-06	-3.14E-08
POCP [kg O_3 eq]	1.41E-01	1.45E-02	9.29E-02	1.11E-05	4.05E-04	3.01E-03	-3.64E-06
ADP_{fossil} [MJ, LHV]	7.19E+00	1.93E-01	6.71E-01	-	5.39E-03	6.57E-02	1.80E-04

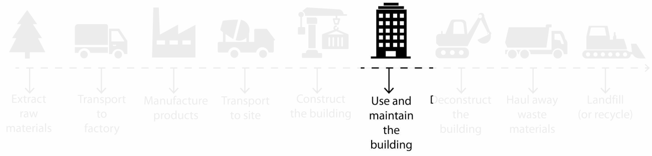
B5 - Replacement



Building element/ component	Expected lifespan (years)
Structure and foundations	Service life
Roof coverings	30
Internal partitioning and dry lining	30
Wall renders	30
Paint	10
Raised floor finishes	30
Floor finish layers	10
Substrate to ceiling finishes	20
FFE	10
Mechanical services	20
Electrical installations	30
Lighting and communications	15
Water and disposal installations	25
Sanitaryware	20
Lift installation	20
Opaque cladding	30
Glazed cladding	35
Windows and doors	30



B5 - Replacement



<u>Earth plaster replacement (Declared unit = 1m2)</u>

Plaster service life: 11 years
Number of replacements: 60 years/11 years -1 = 4.5, this is rounded up to 5

Earth for plaster = (0.18 [A1-3]+ 0.04 [A4]+ 0.51 [C2]+ 0.52 [C3-4] kgCO2e) x 5 = 6.25 kgCO2e
Cement for plaster = (1.60 [A1-3]+ 0.06 [A4]+ 0.03 [C2]+ 0.03 [C3-4] kgCO2e) x 5 = 8.60 kgCO2e

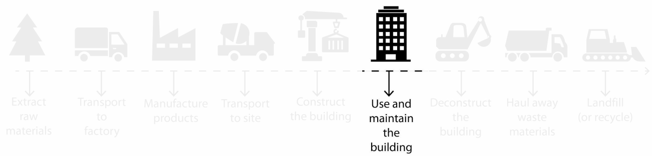
B5 Sum = 14.85 kgCO2e/m2 of wall area

<u>Sources and assumptions</u>
Refer to other LCA stages to understand how numbers in calculation were developed
11 years has been used because it doesn't fit evenly into 60 years for demonstration only

<u>RICA Campus Replacements</u>

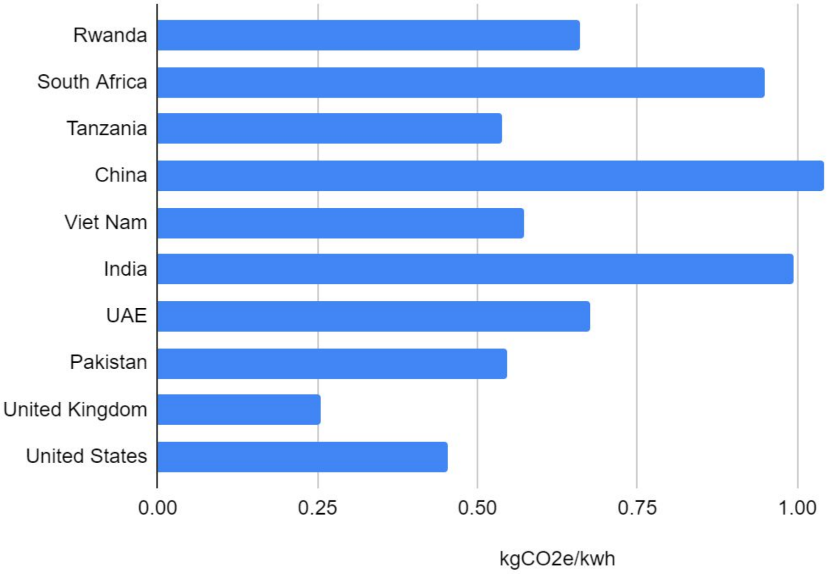
Buildings	770 tonnes CO2e
Infrastructure	6,567 tonnes CO2e
Landscape	224 tonnes CO2e
B5 Sum	7,562 tonnes CO2e

B6 - Operational



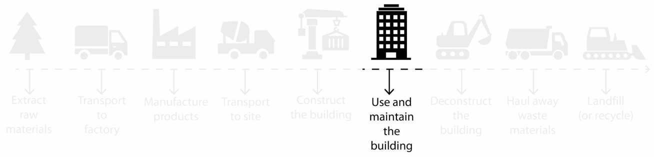
Energy use x carbon intensity of source

Export to grid reported in module D



Fuel	Global warming potential, kgCO2e
Natural gas	2.26 per m3
Diesel fuel	3.24 per litre
Petrol	2.80 per litre
Coal	2.96 per kg
Wood logs	67.63 per m3
Biogas	0.46 per m3
Wood pellets	0.19 per kg

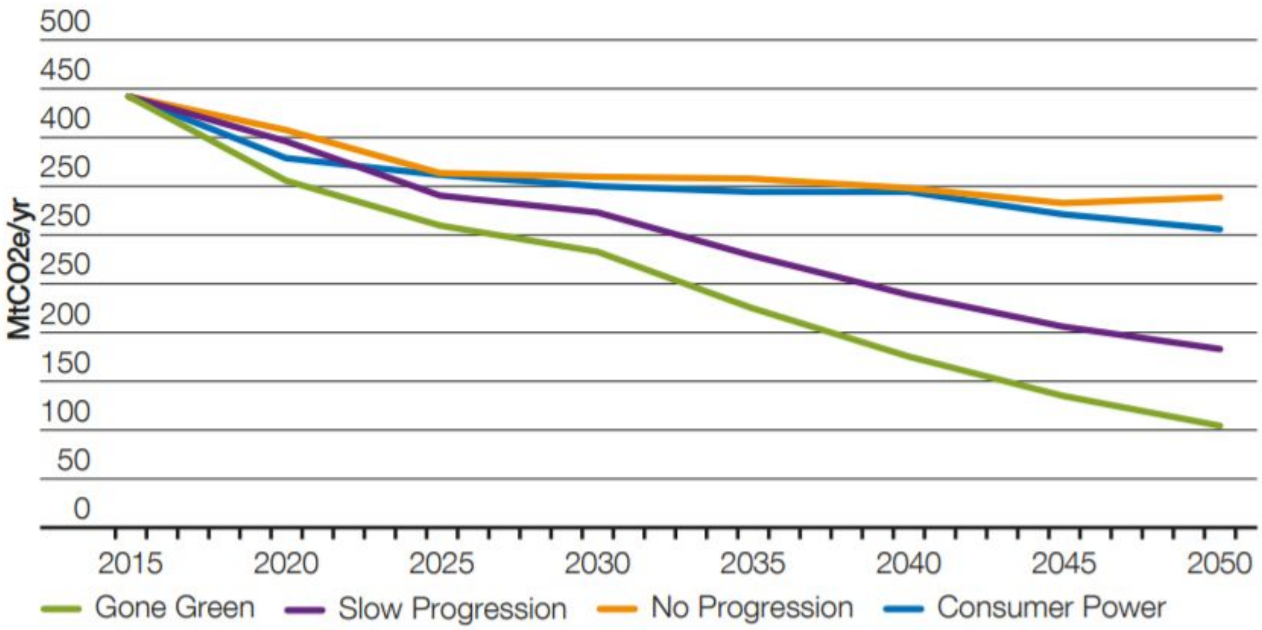
B6 - Operational



Can consider decarbonisation of grid if there is evidence

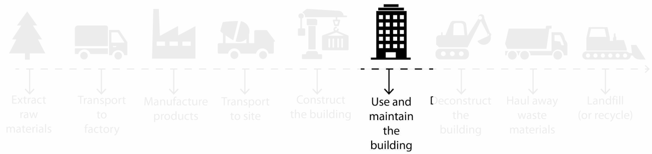
Can also be used for other B, C and D modules

Figure 5.2.4
Total UK carbon emissions from energy



MASS.

B6 - Operational



<u>RICA Camus Operational Energy</u>

PV Panels meet majority of the need and generator used as back up.

Diesel generator: 15,000 kWh/year x 60 years / 3 kWh/litre x 3.24 kgCO2e/litre = 97 tonnes CO2e

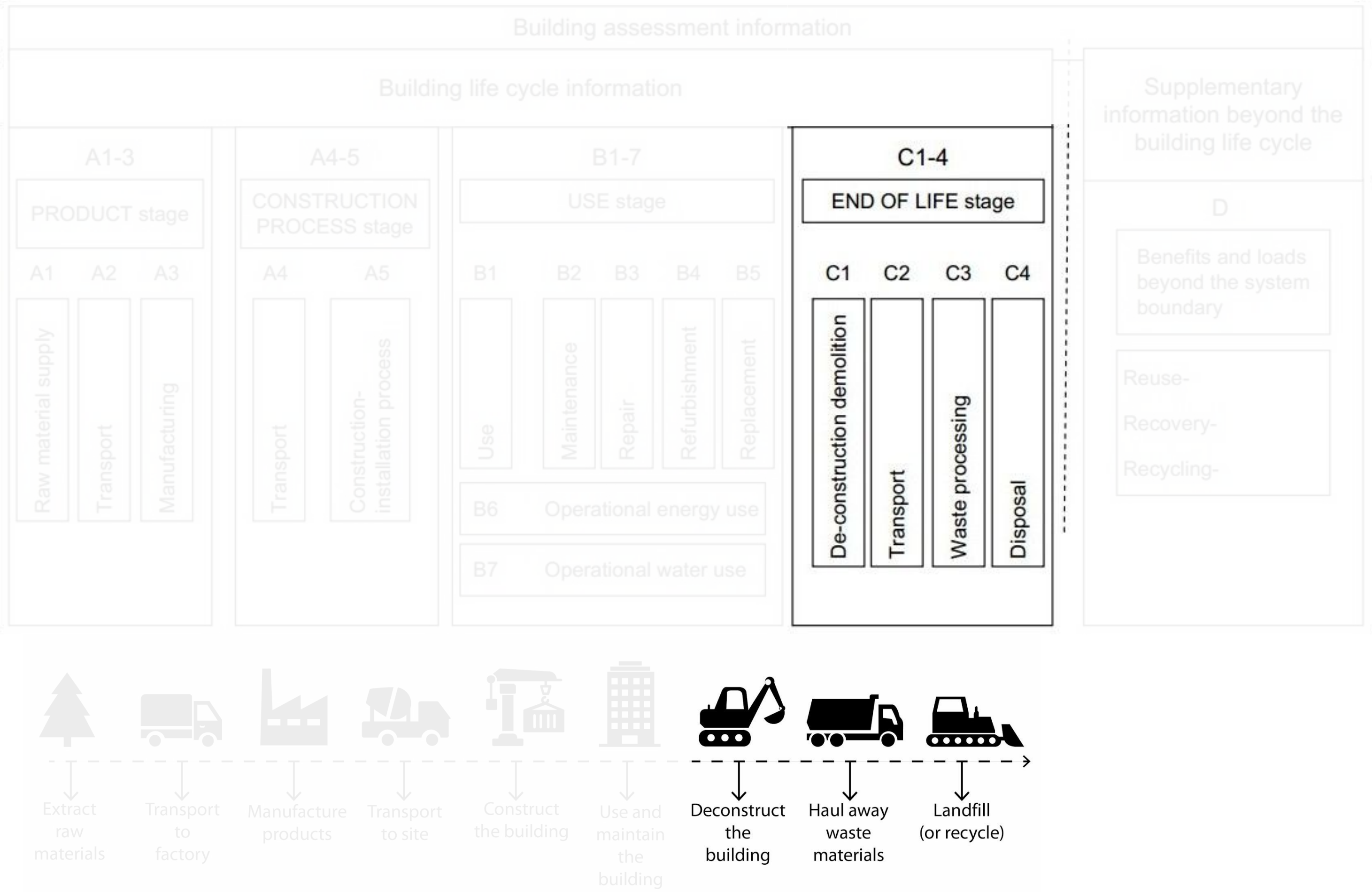
B6 Sum = 97 tonnes CO2e

<u>Sources and assumptions</u>

Generator produces 3 kWh/litre of diesel

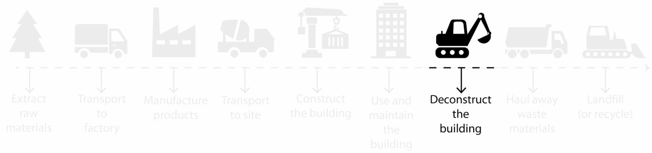
Generator energy use is from actual data

C1-4 End of Life



MASS.

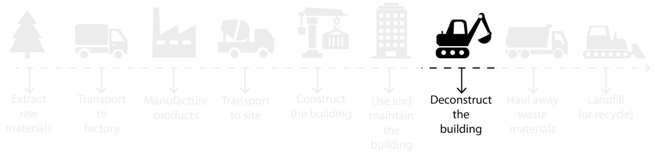
C1 - Deconstruction



Generic demolition rate from central London:

3.4 kgCO2e/GFA

C1 - Deconstruction



RICA Camus Deconstruction

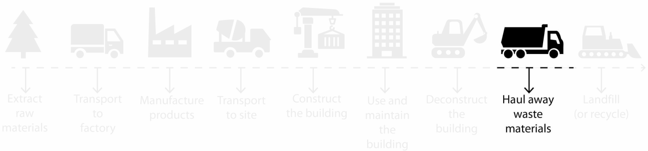
Buildings = 18,267m2 x 3.4kgCO2e/m2 = 62 tonnes CO2e

C1 Sum = 62 tonnes CO2e

Sources and assumptions

Deconstruction of infrastructure is not included because it is assumed this will remain operational and buildings may be replaced

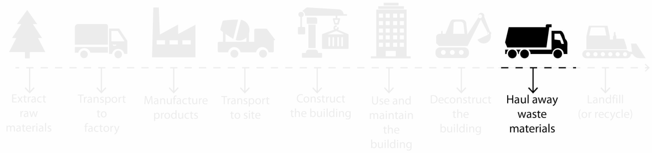
C2 - Transport



End of Life Scenario	Transport distance
Reuse/ recycling on site	0km
Reuse/ recycling elsewhere	50km
Landfill/ incineration	Average between 2 closest landfill/incineration sites

MASS.

C2 - Transport



<u>Reinforced 240mm Thk CSEB wall with earth plaster (Declared unit = 1m2)</u>

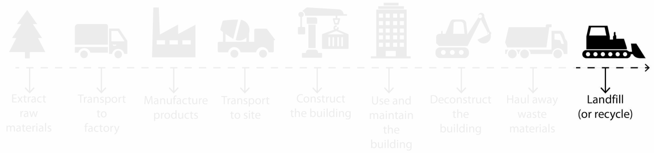
Earth	365kg	x 5km	x 0.00021334 kgCO2e/kgkm	= 0.39 kgCO2e
Cement	20kg	x 5km	x 0.00021334 kgCO2e/kgkm	= 0.02 kgCO2e
Sand for mortar	90kg	x 60km	x 0.00021334 kgCO2e/kgkm	= 1.15 kgCO2e
Cement for mortar	15kg	x 60km	x 0.00021334 kgCO2e/kgkm	= 0.19 kgCO2e
Reinforcement	6kg	x 5km	x 0.00021334 kgCO2e/kgkm	= 0.01 kgCO2e
Earth for plaster	40kg	x 60km	x 0.00021334 kgCO2e/kgkm	= 0.51 kgCO2e
Cement for plaster	2kg	x 60km	x 0.00021334 kgCO2e/kgkm	= 0.03 kgCO2e
			C2 Sum	= 2.30 kgCO2e/m2 of wall area

<u>Sources and assumptions</u>
Articulated truck used for transportation
Assumed reinforcement and CSEBs are recycled/ reused

<u>RICA Campus Summary</u>

C2 sum 232 tonnes CO2e

C3-4 - Waste processing and disposal



Use EPDs for C3 if waste is processed before disposal, reuse or recycle

Construction waste	kgCO2e/kg waste
Typical to landfill	0.013
Timber to landfill without gas recovery	2.15
Timber incinerated	biogenic
Energy recovery from timber	biogenic (reported in module D)

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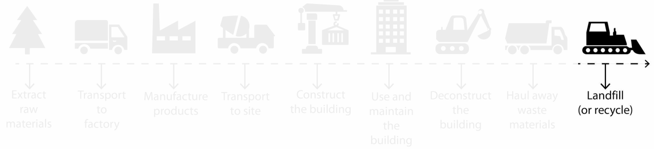
C3-4 - Waste processing and disposal



Reinforced 240mm Thk CSEB wall with earth plaster (Declared unit = 1m2)

Earth	365kg	x 0 kgCO2e/kg	= 0 kgCO2e
Cement	20kg	x 0 kgCO2e/kg	= 0 kgCO2e
Sand for mortar	90kg	x 0.013 kgCO2e/kg	= 1.17 kgCO2e
Cement for mortar	15kg	x 0.013 kgCO2e/kg	= 0.20 kgCO2e
Reinforcement	6kg	x 0 kgCO2e/kg	= 0 kgCO2e
Earth for plaster	40kg	x 0.013 kgCO2e/kg	= 0.52 kgCO2e
Cement for plaster	2kg	x 0.013 kgCO2e/kg	= 0.03 kgCO2e
		C3-4 Sum	= 1.92 kgCO2e/m2 of wall area

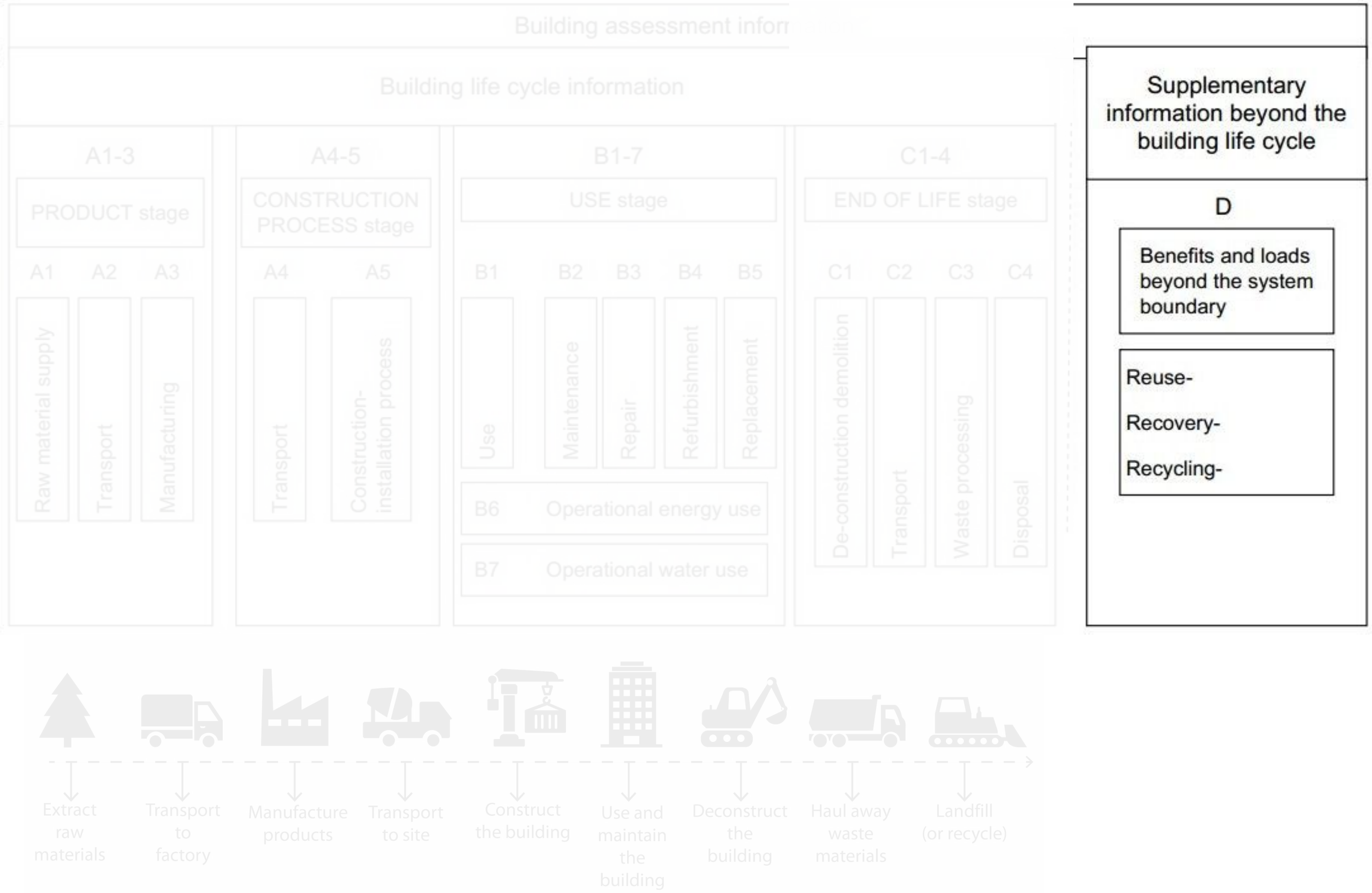
Sources and assumptions

Assumed reinforcement and CSEBs are recycled/ reused and processed by hand

RICA Campus Summary

C3-4 sum 191 tonnes CO2e

D - Benefits and loads beyond system boundary



MASS.

D - Benefits and loads beyond system boundary

Accounts for all building benefits

- Reuse and recycle
- Biogenic carbon
- Exporting energy

MASS.

D - Benefits and loads beyond system boundary

RICA Campus Sequestration

Farmland	128Ha	x 800 kgCO2e/year	x 60 years	= 6,144 tonnes CO2e
Savanna Woodland	20Ha	x 1400 kgCO2e/year	x 60 years	= 1,680 tonnes CO2e
Silviculture	20Ha	x 15000 kgCO2e/year	x 60 years	= 18,000 tonnes CO2e
Other				= 27,048 tonnes CO2e
			D Sum	= 52,872 tonnes CO2e

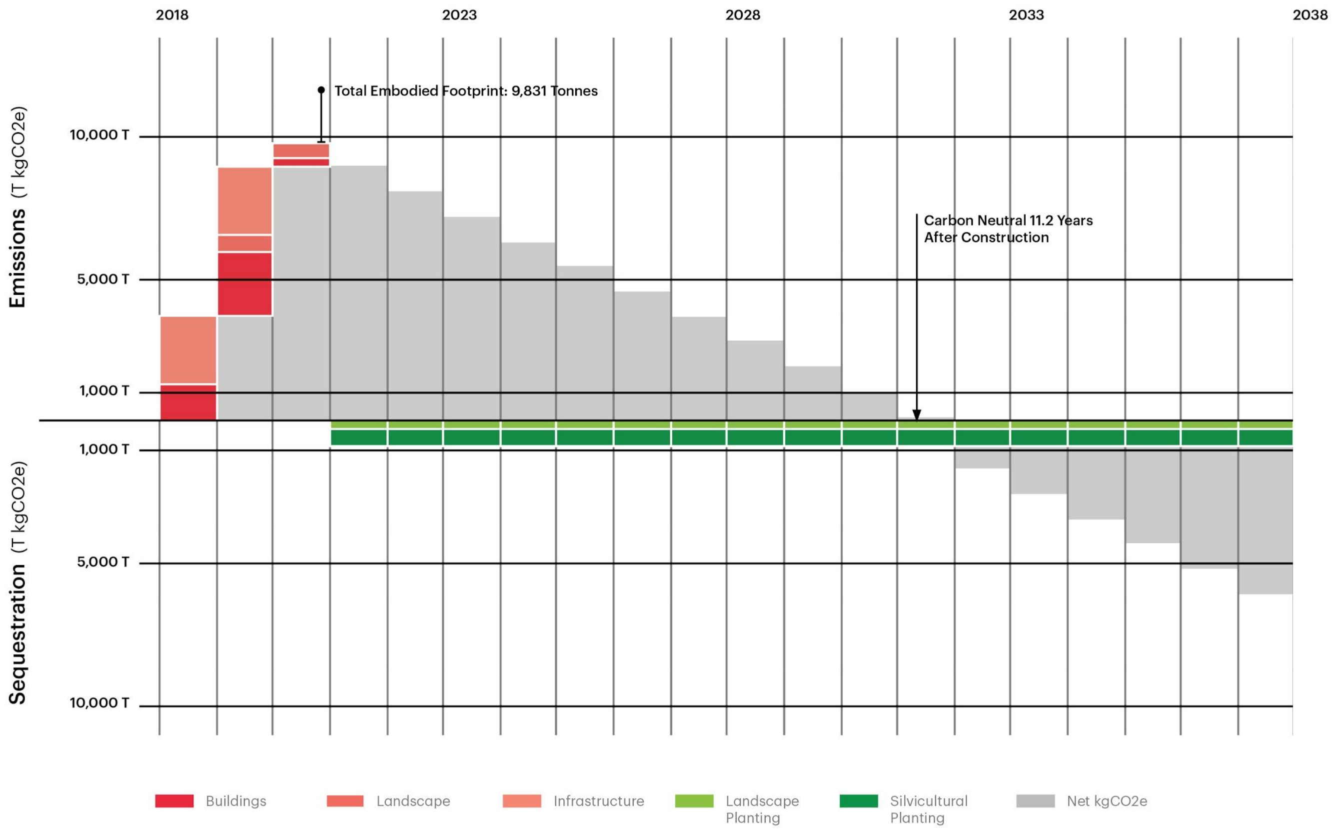
MASS.

Climate Positive

A-C: 19,000 tCO2e

A-D: - 34,000 tCO2e

12 years



MASS.

Great. You can do that in Rwanda,
but how could you do it in
___________________________?

(insert country here)