Opportunities and risks of material innovation in a developing construction industry

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Opportunities and risks of material innovation in a developing construction industry

Why radical change is needed

What we do

How and why we innovate

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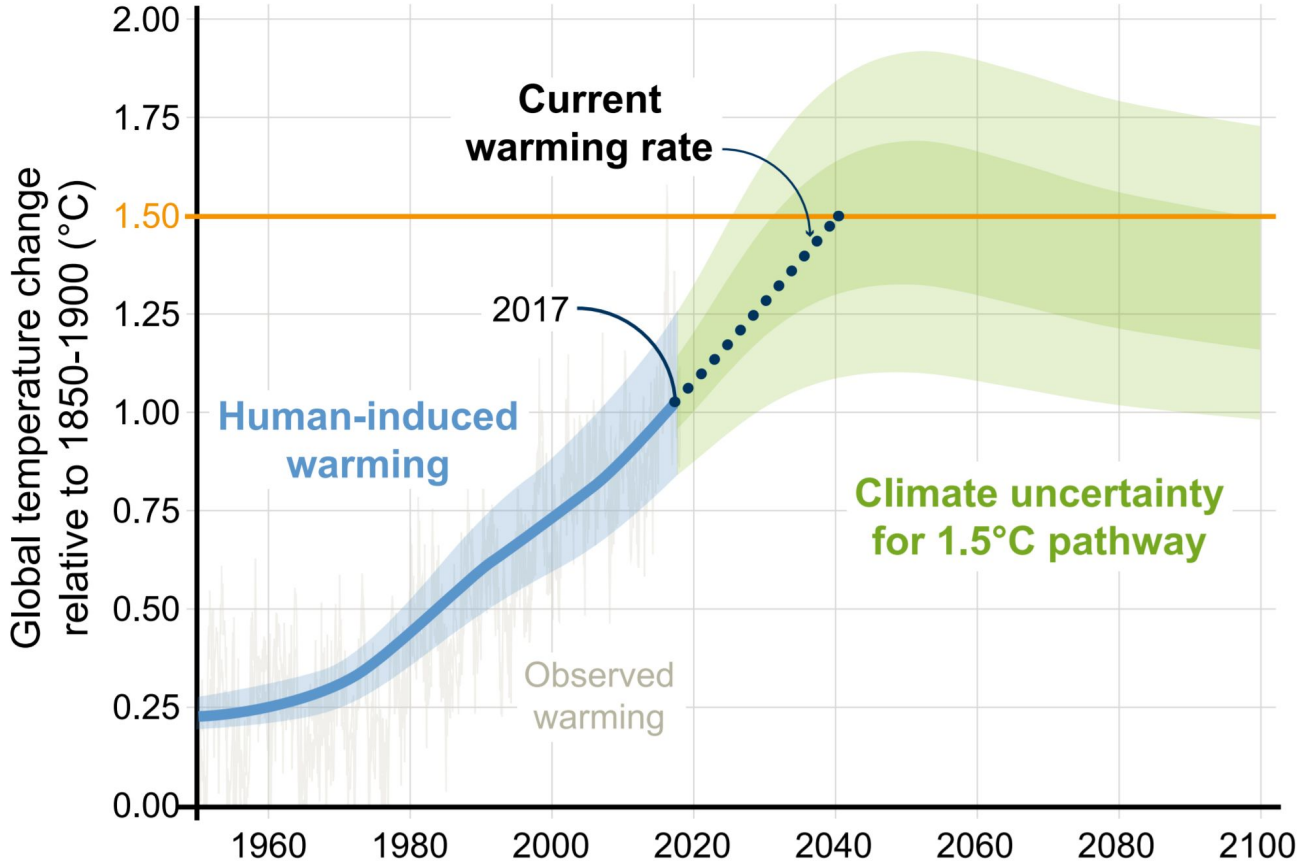
Why radical change is needed

2030 / 2050

1/2 current CO_2 levels by 2030

Net zero by 2050



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

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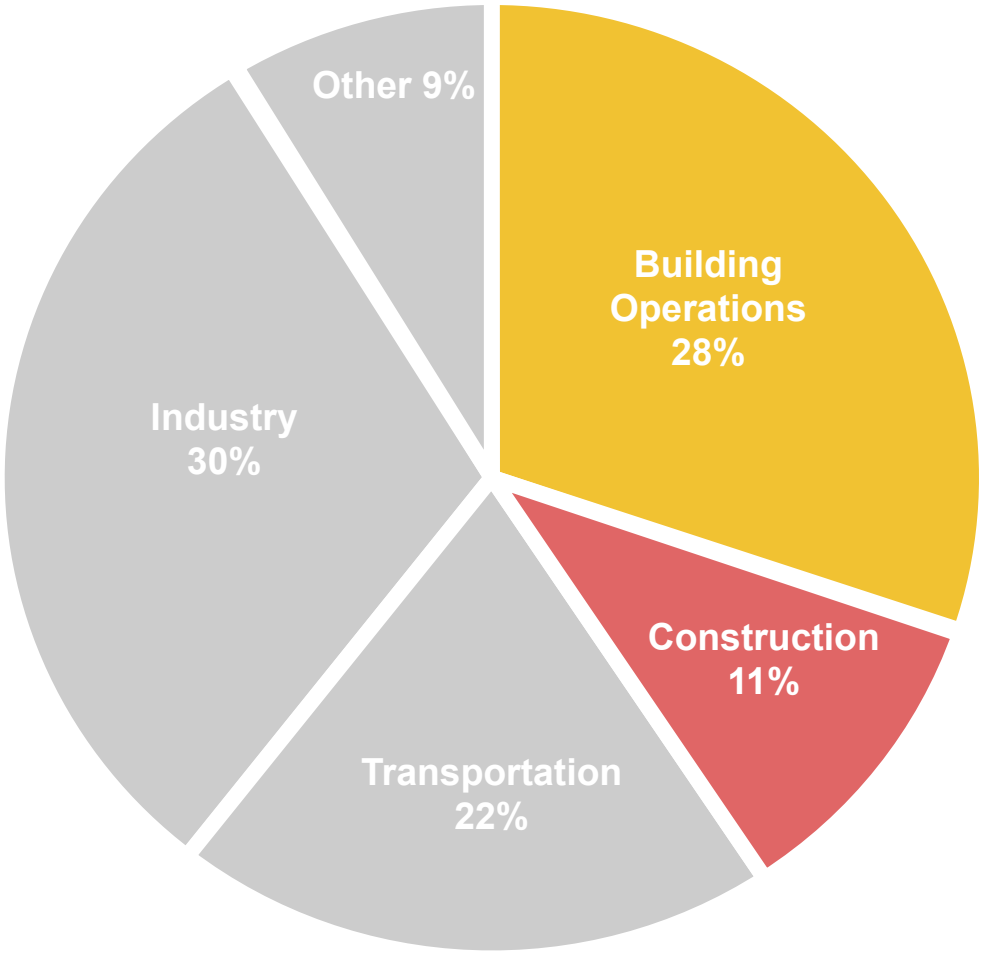
Construction GHG

39% of Global Greenhouse Gas Emissions



Source: UN Environment, Global Status Report 2017

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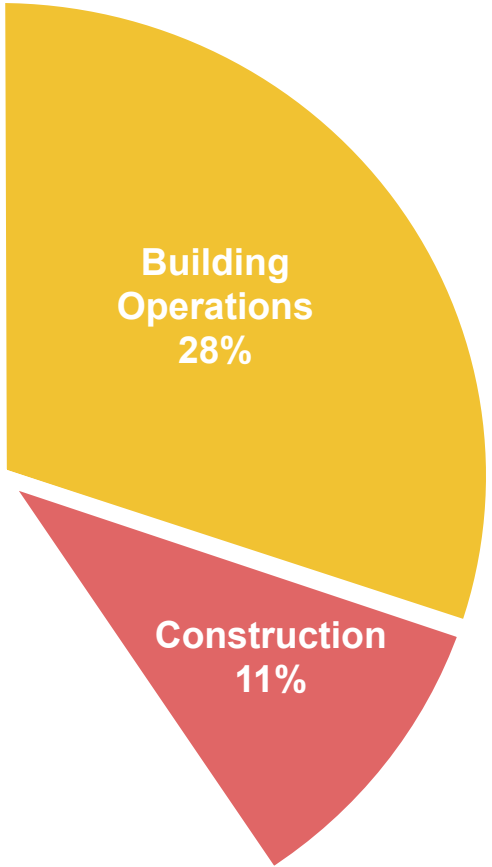
Operational vs Embodied

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

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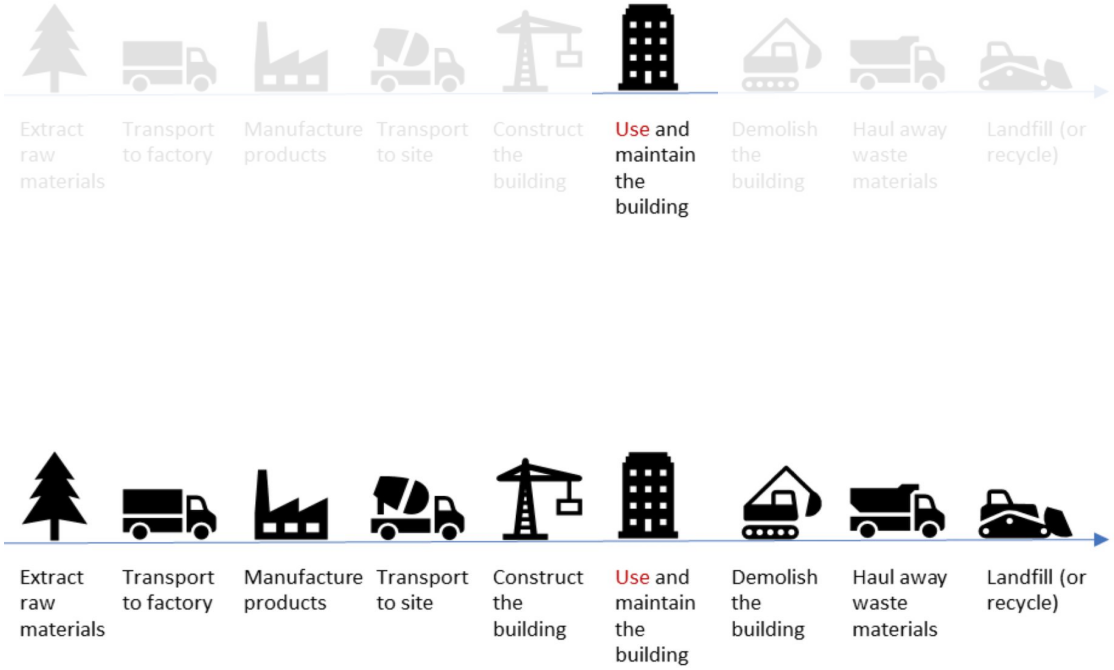
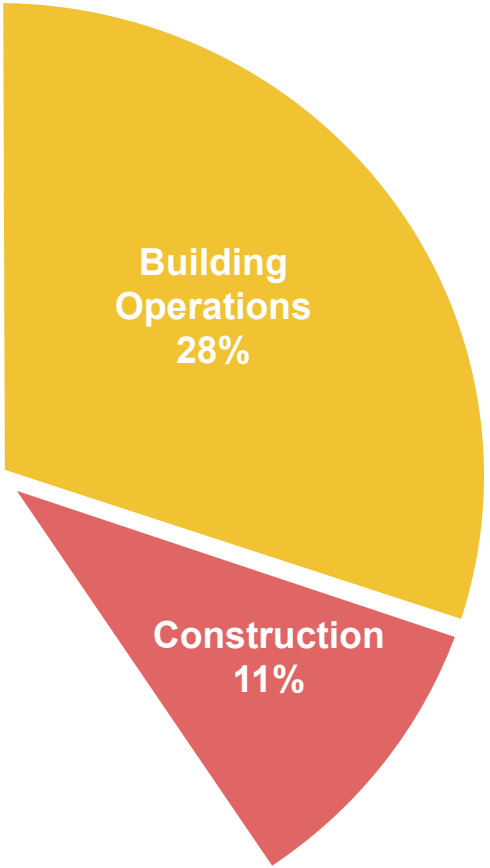
Operational vs Embodied





Source: UN Environment, Global Status Report 2017

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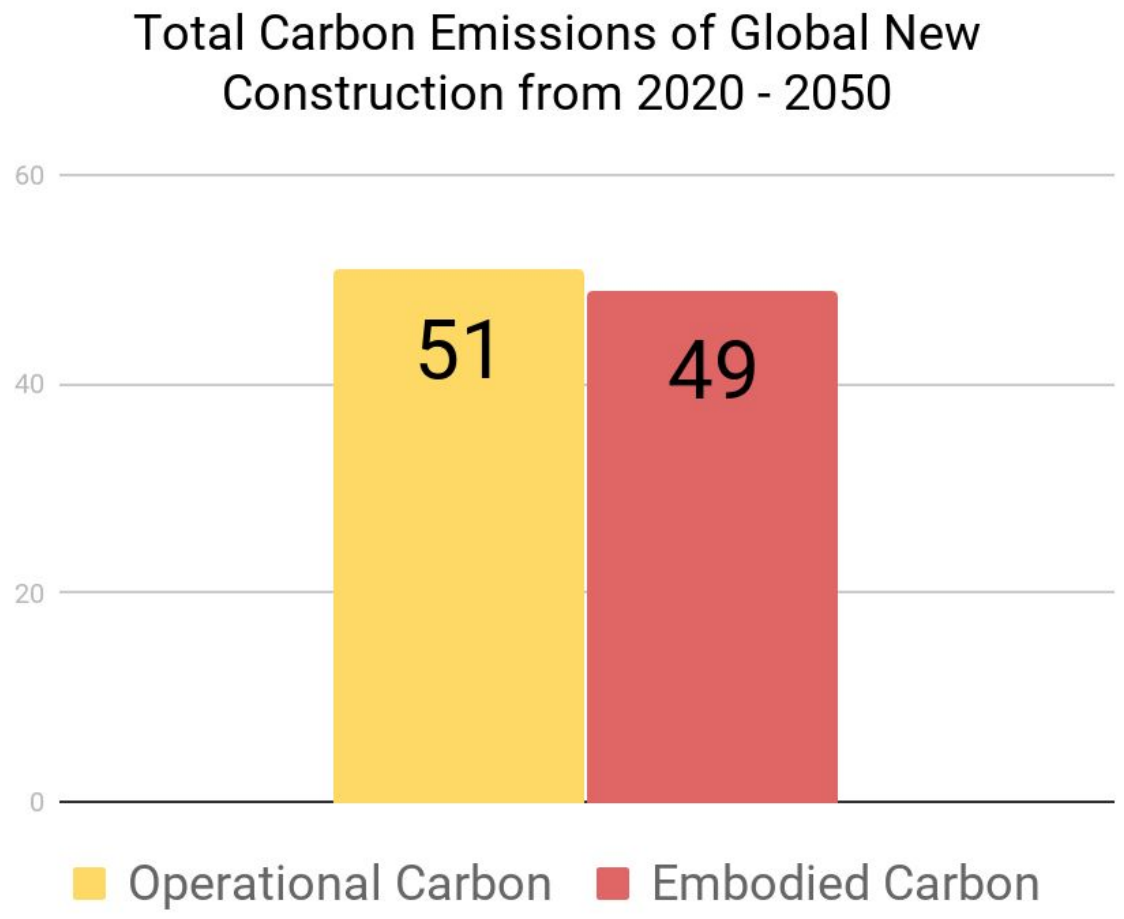
Operational vs Embodied



Source: Architecture 2030

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Embodied carbon

A new New York every month for 40 years

Source: Architecture 2030

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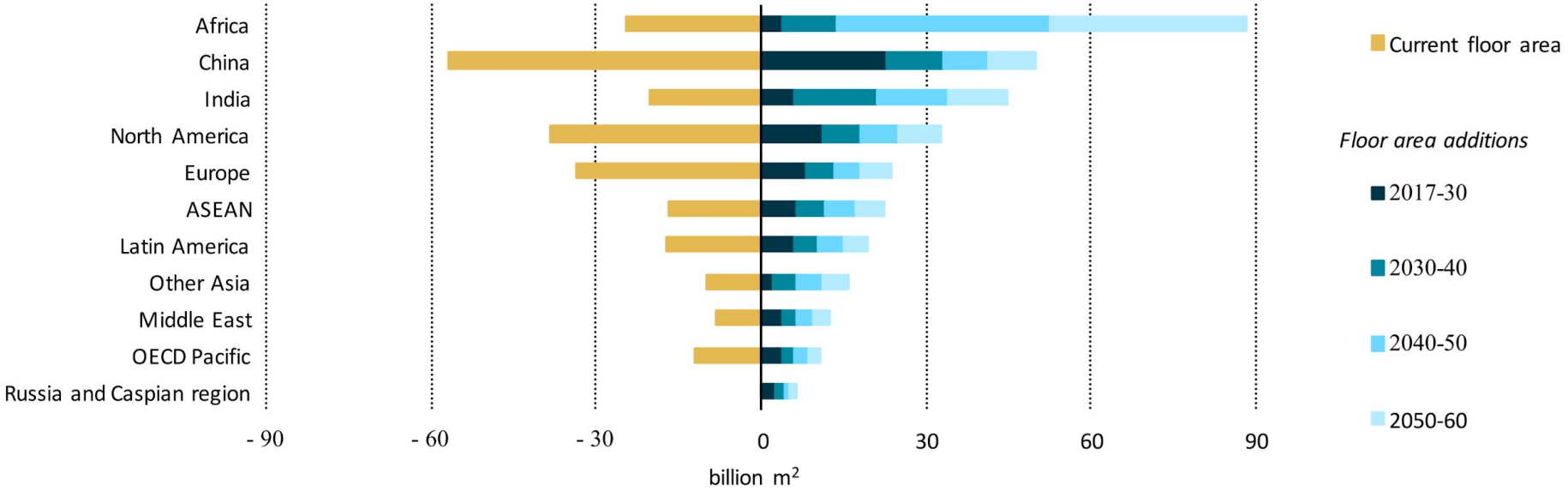
Expected construction by 2060



Source: IEA, Energy Technology Perspectives 2017

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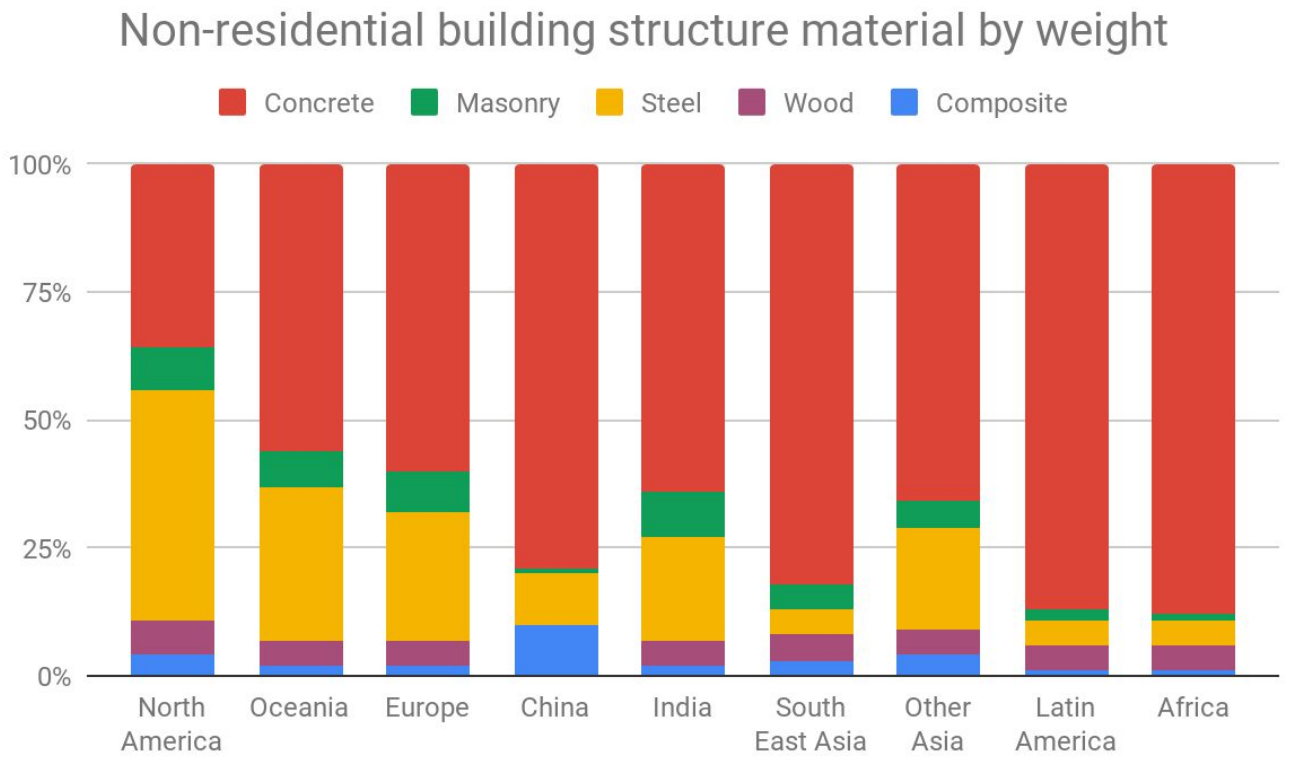
Building structure materials

Concrete is the most used construction material



Source: IEA, Energy Technology Perspectives 2017

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Design is never neutral. It either hurts or heals. Our mission is to research, build, and advocate for architecture that promotes justice and human dignity.

We help organizations amplify their missions.

Organization

3 Offices
3 Studios
125 Team Members
51% Women
20+ Nationalities

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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


MASSACHUSETTS
GENERAL HOSPITAL


BECHTEL


Les Centres
GHESKIO


IDEO·ORG


BOSTON HEALTH CARE for
the HOMELESS PROGRAM


unicef


ARIADNE LABS


THE
GREEN
WAY
Rose Kennedy Greenway.org


Hudson Ri
Housing, In


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

Impact design methodology

Create a shared understanding of needs and goals.

Encourage broad and realistic expectations for what the project can do.

Identify potential metrics for impact and evaluation.

Can a building heal?

Butaro District Hospital
Burera, Rwanda

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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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Locally-fabricated Construction

Hire locally

Source regionally

Invest in training

Uphold dignity

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Butaro District Hospital

Rwanda, 2008

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Butaro District Hospital

Volcanic stone walling

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GHESKIO Cholera Treatment Center

Haiti, 2015

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GHESKIO Cholera Treatment Center

Perforated metal cladding

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Ilima Primary School

Democratic Republic of Congo, 2015

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Ilima Primary School

Wooden shingles

Timber trusses

Earth blocks

Maternity Waiting Village

Malawi, 2015

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Maternity Waiting Village

Compressed stabilised earth blocks (CSEB’s)

Timber roof frame

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Rwanda Institute for Conservation Agriculture: a Lo-Fab at scale case study

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Location

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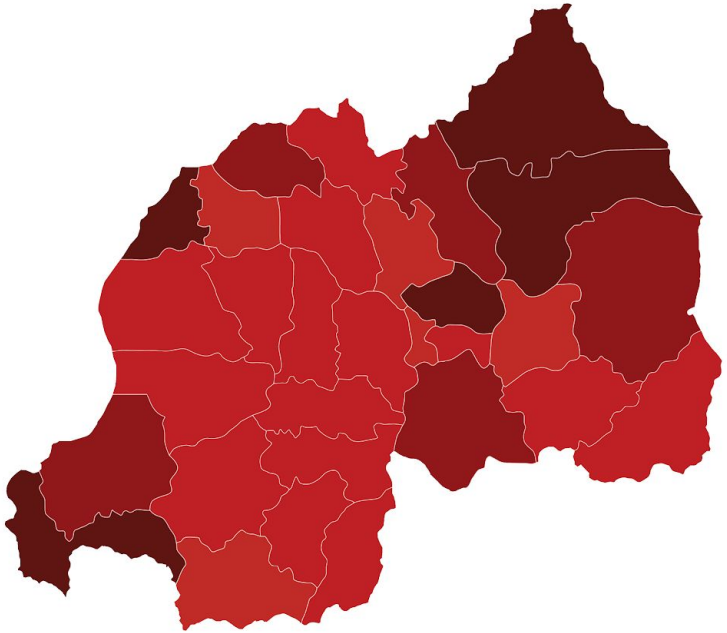
Population

12.6 million



2019

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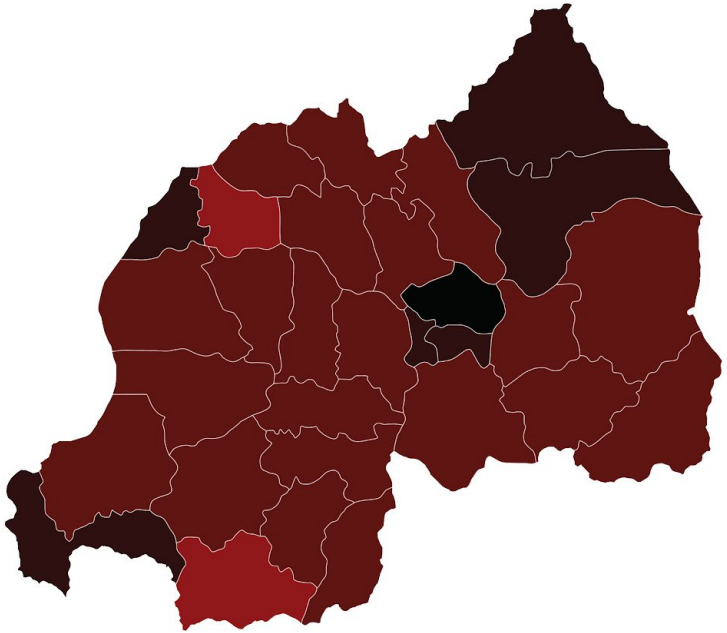
Population

25 million



2050

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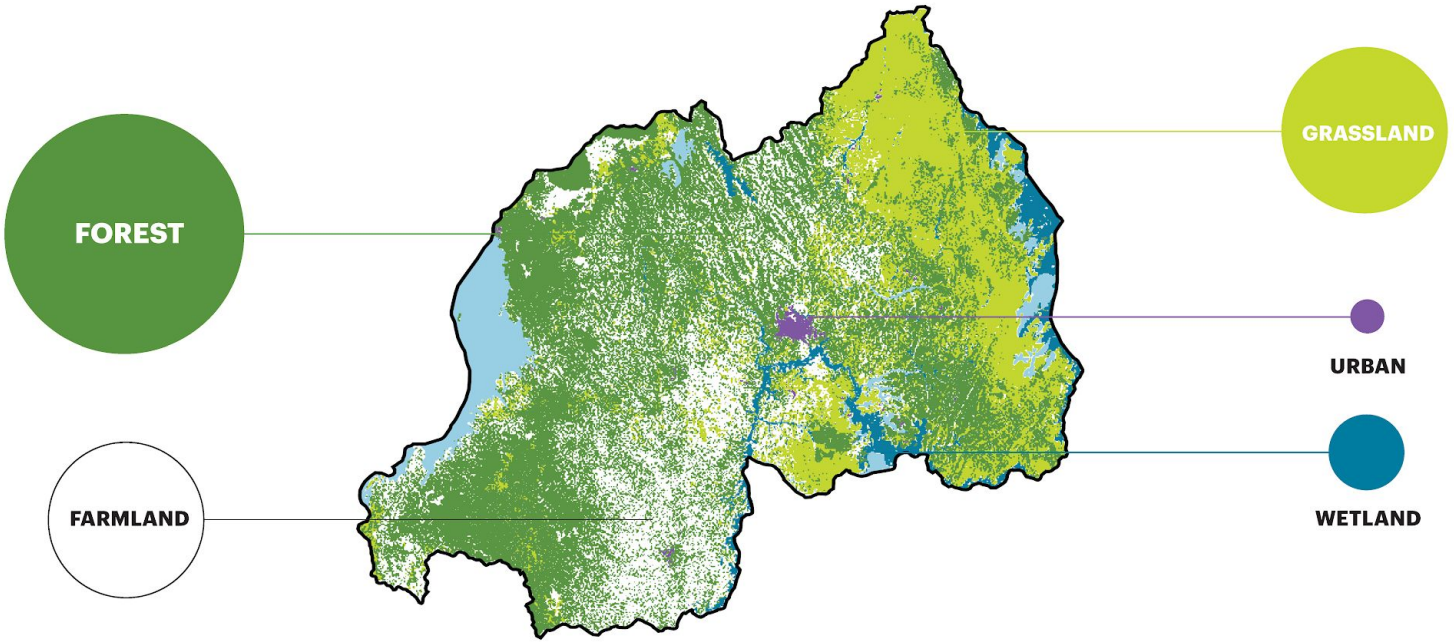
Land type



1990

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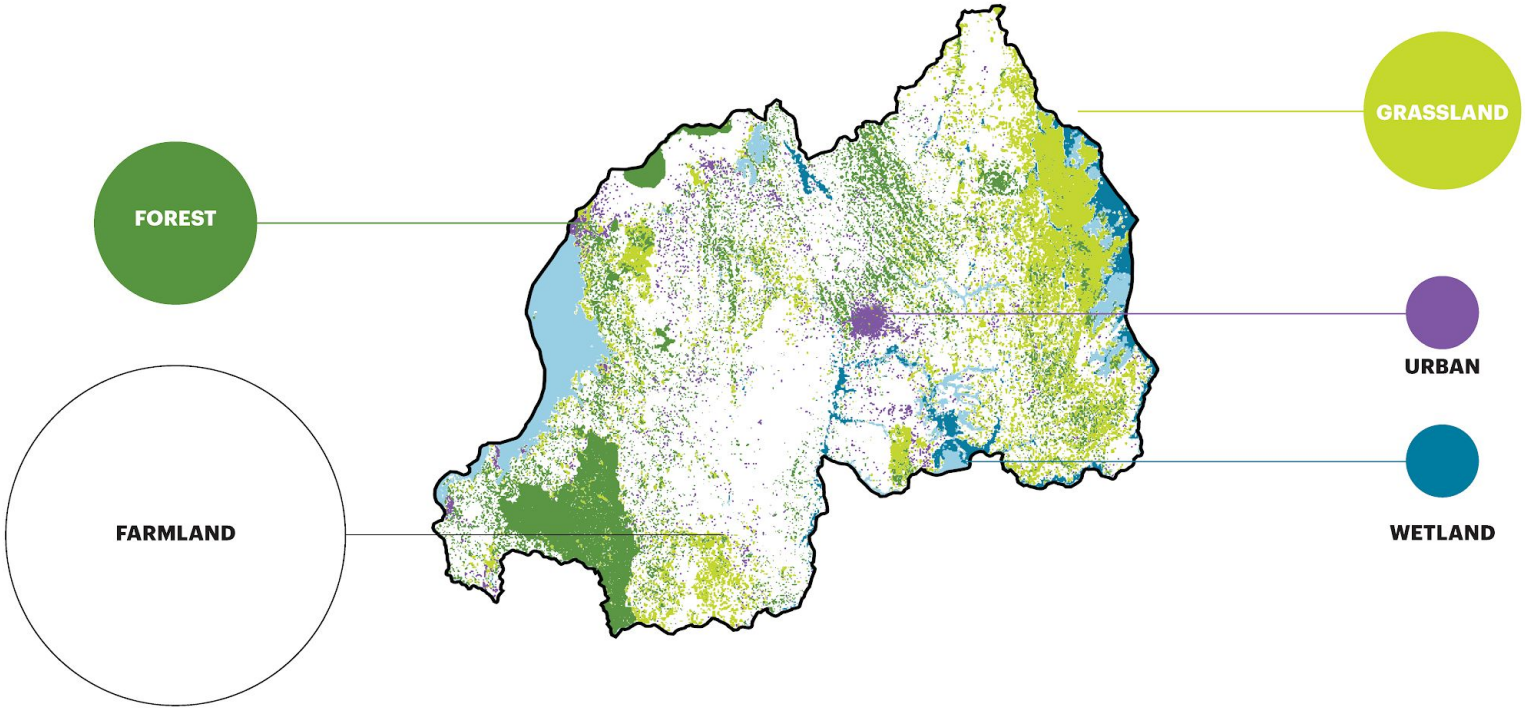
Land type



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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

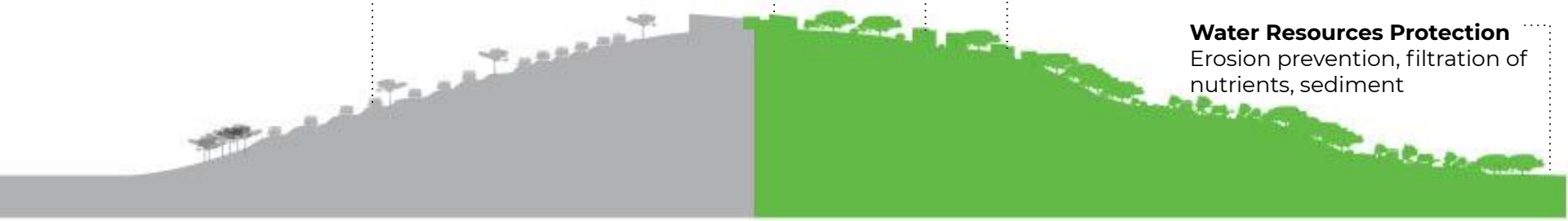
Existing
Monoculture crops, livestock grazing

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



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First Year Farms

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Enterprise buildings

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Campus Centre

Locally-fabricated Construction

Hire locally

Source regionally

Invest in training

Uphold dignity

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Clay tiles

Roof tiles sourced
60km away

Timber

New construction skills being developed.

Sourced from Rwanda and Tanzania.

Furniture

90% local materials

800+ people engaged

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Earth construction

Soil is 25% of the building materials

Soil from site

Rwanda Institute for Conservation Agriculture, 2019

2/5ths of global average

Embodied carbon:
175 kgCO2e/m²

Global education building average:
425 kgCO2e/m²

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Challenges and lessons learnt in design and construction using earth

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Design brief

Sustainable

Replicable

Seismically designed

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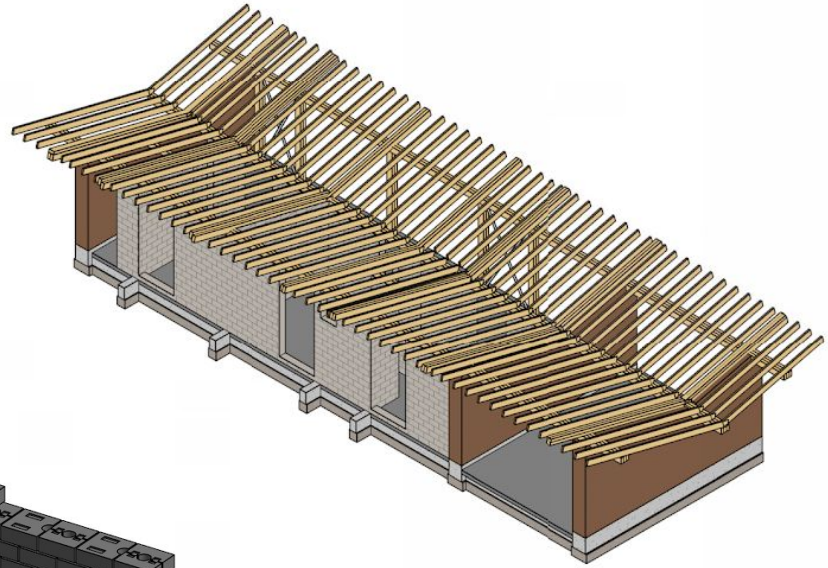
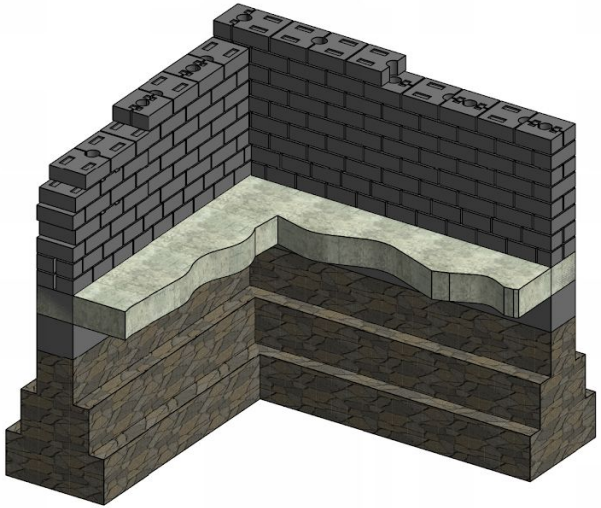
1 storey residential buildings

Stone foundations

Unreinforced earth construction

Timber rafters





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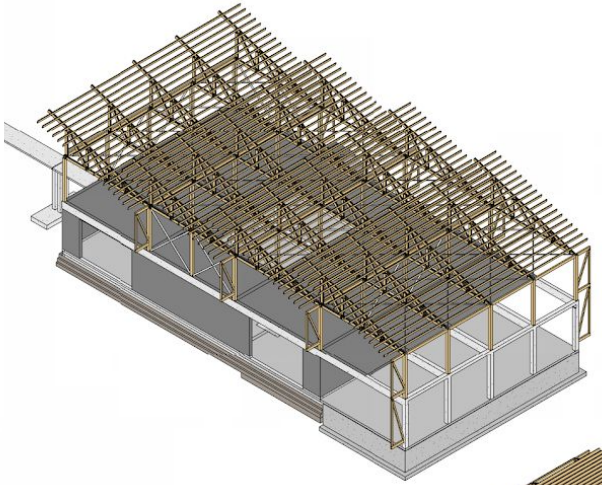
1-2 storey educational buildings

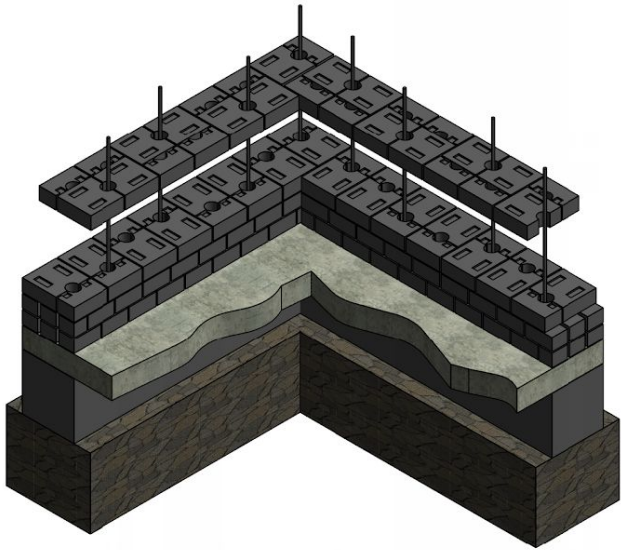
Stone foundations

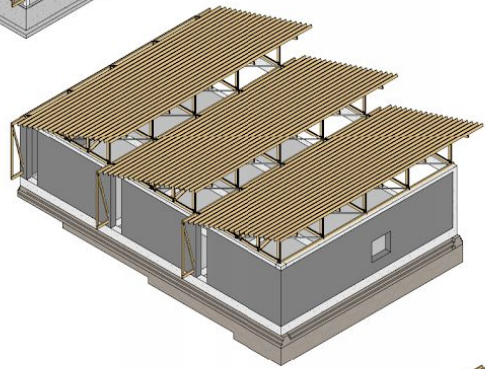
Reinforced earth construction

Reinforced concrete suspended slab

Timber roof trusses







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Soil selection

4 different soils tested from site

Stabilisation

Tested unstabilised, lime stabilised and cement stabilised

Initial mix design

Thorough pre-design feasibility testing

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Material properties

Limited testing facilities

Codes

Rwanda Building Code

Eurocode

New Zealand Standard

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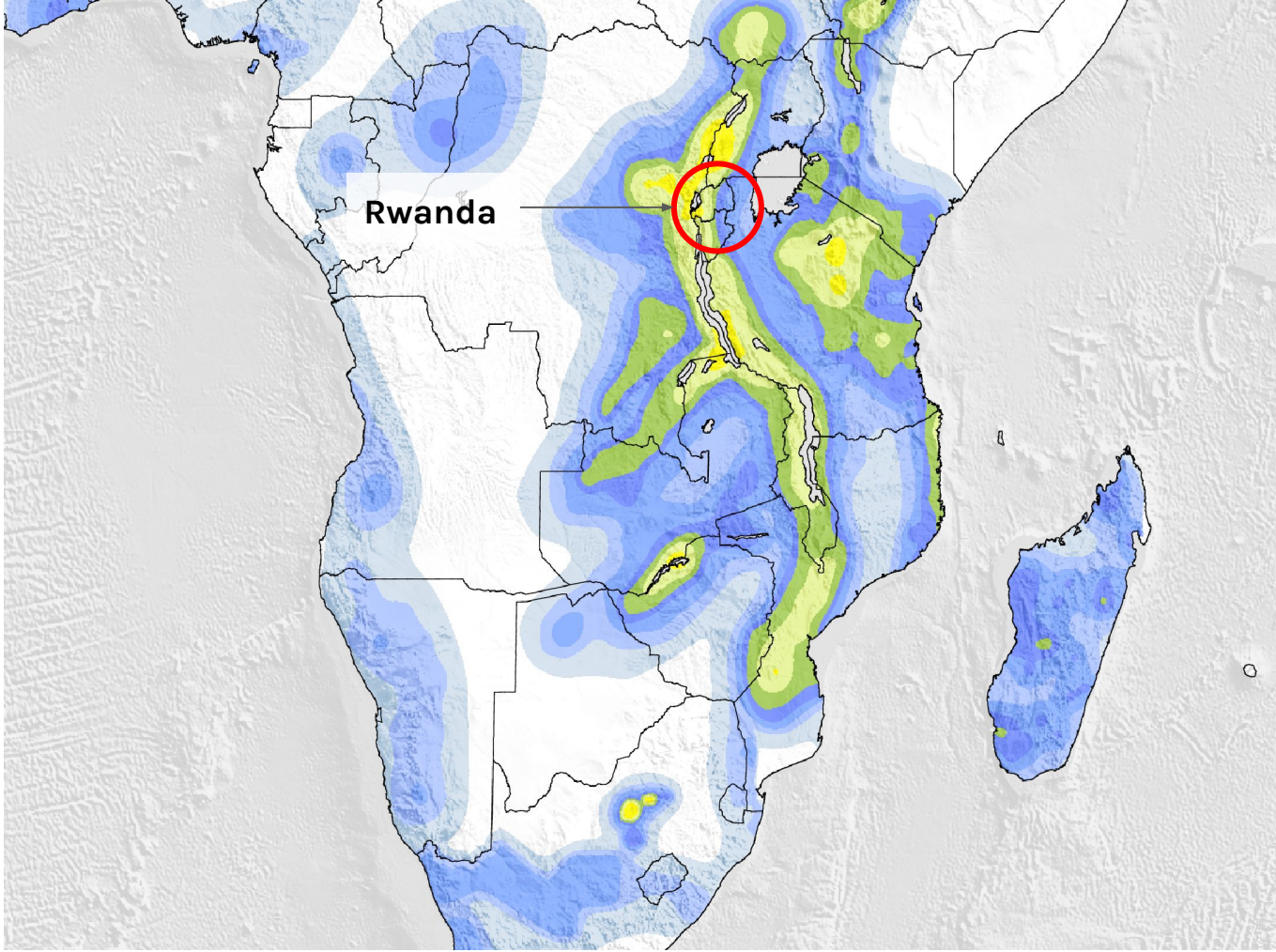
Seismicity

Peak ground acceleration = 0.16g



Source: Global Earthquake Model

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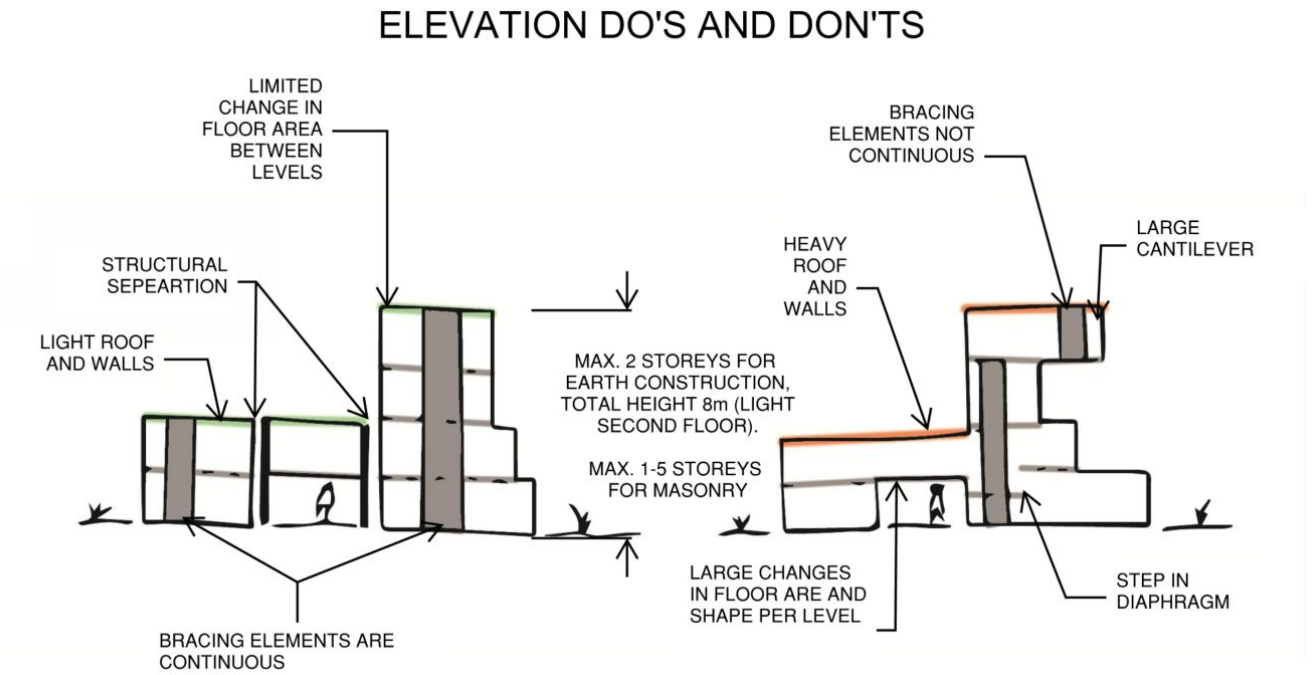
Simple buildings

Early collaboration with architects

More predictable in earthquakes



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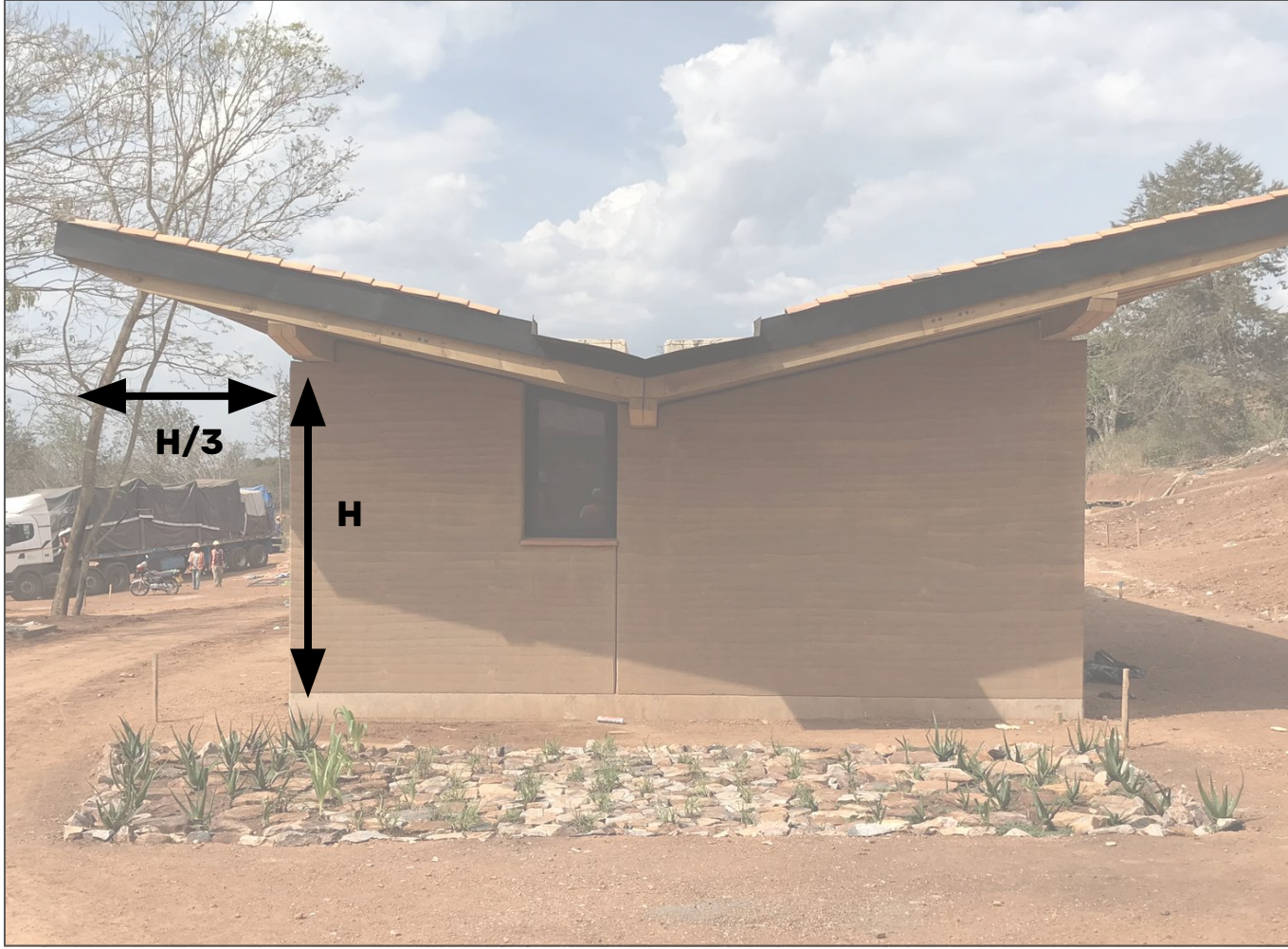
Durability

Roof overhangs

Window sill

Raised off ground



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Wall slenderness

Code

Constructability

CSEB production

2.5 million blocks

CSEB curing

28 days curing

Weathering

Protection from rain

Reinforcement

Coordination challenge

Rammed earth production

Hand compacted

Rammed earth shrinkage

Lessons learnt

Preparation

Codes and guides

Engineering judgement

Material capacity

Why is earth construction important?

Housing

3 billion live in earth houses

90% of people in Rwanda live in earth homes

Lo-fab

Cost

Adobe
$7/m^3

Concrete block
$165/m^3

Fired brick
$110/m^3

Embodied carbon

Adobe
3 $kgCO2e/m^3$

Concrete block
69 $kgCO2e/m^3$

Fired brick
202 $kgCO2e/m^3$

Quality

70% of masons have no training

85% of roofs leak

65% don’t feel safe

Source: Earth Enable Rural Housing Survey

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Maintenance

Typical cost: $500

38% earn less than $175/year

Loans not common

Major repairs expected after 10 years

Source: EICV 5 2016/17

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Systemic change

Change that fundamentally affects the whole system.

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Systemic change

Systemic change

Assist in developing a specification for adobe blocks

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What next?

The Ellen DeGeneres Campus of the Dian Fossey Gorilla Fund

Purpose built home to increase impact in conservation and community outreach

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The Ellen DeGeneres Campus of the Dian Fossey Gorilla Fund

Volcanic stone aggregate

Pozzolanic ash

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Grumeti Fund Rise Research Facility

Advance the Fund's research, monitoring, management initiatives

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Grumeti Fund Rise Research Facility

Glulam

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Environmental Product Declaration

EPD®
THE INTERNATIONAL EPD® SYSTEM

Source: The International EPD System

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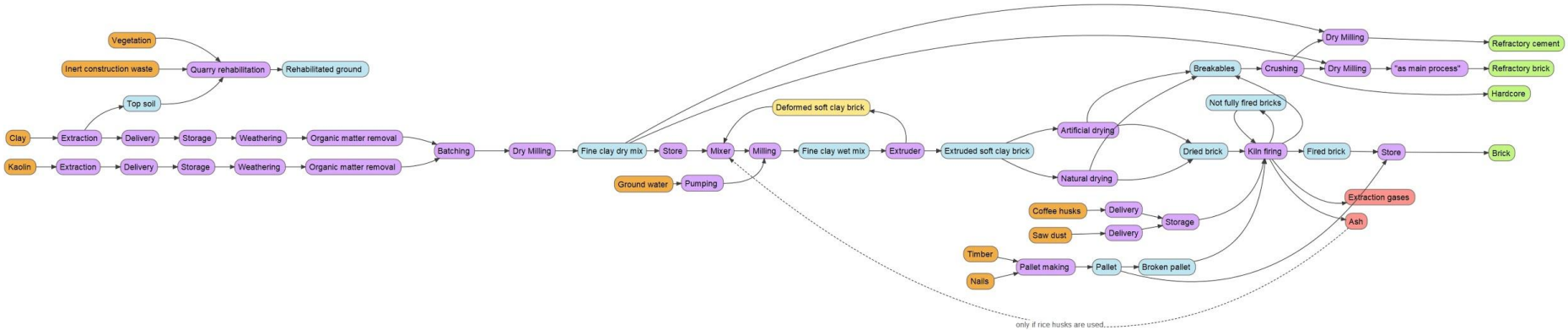
Environmental Product Declaration



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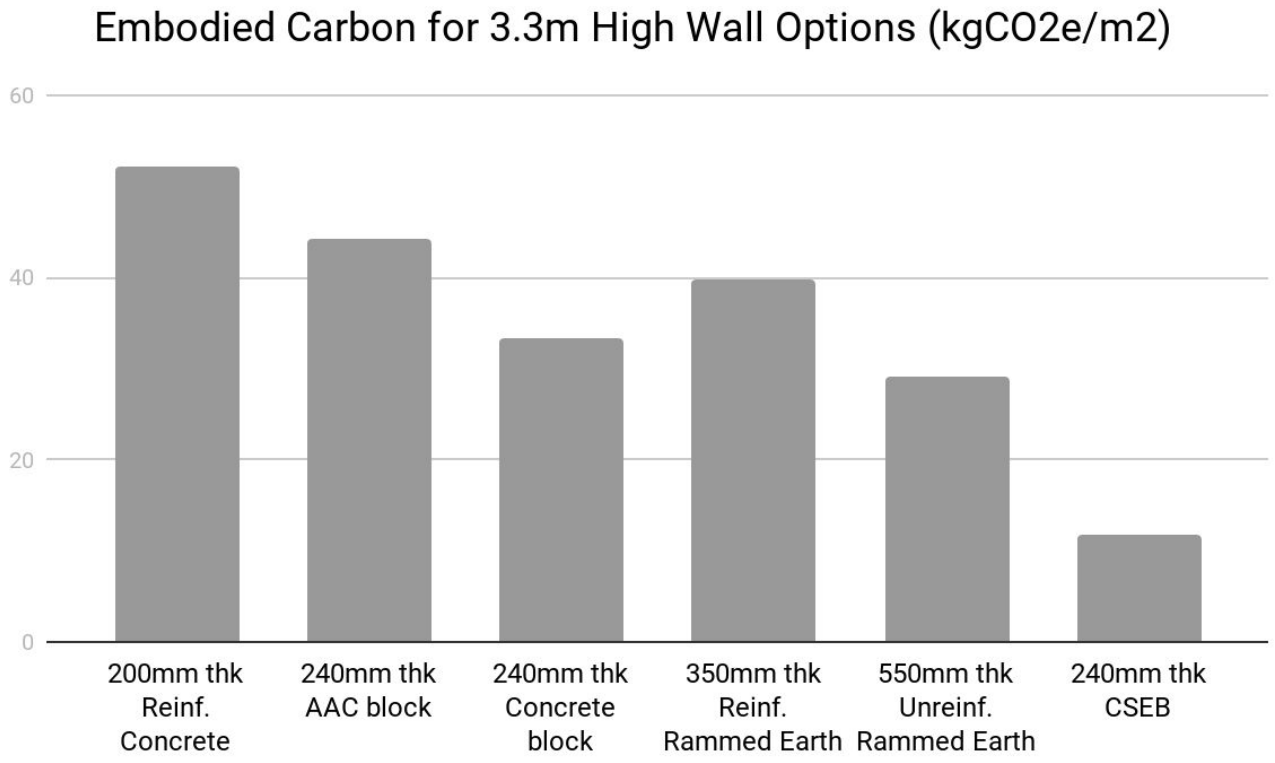
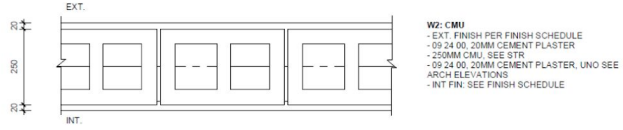
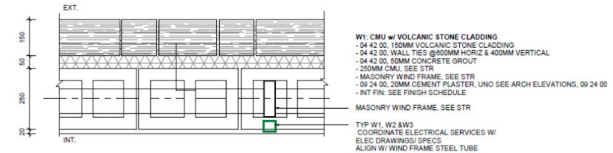
Design decisions



Design decisions

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	**Architecture - Wall finishes**															
2	All results are per m2															
3	**Name**	CMU														
4	**Total Width**	290														
5	**Drawing**															
7	**Projects**	Fossey Fund														
8	Element	Material	Material quantity	Material quantity unit	Material quantity multiplier	Material quantity multiplier unit	New material quantity	New material quantity unit	A1-A3 low (kgCO2e)	A1-A3 best guess (kgCO2e)	A1-A3 high (kgCO2e)	A1-A3 low (kgCO2e)	A1-A3 best guess (kgCO2e)	A1-A3 high (kgCO2e)	Cost ($)	Cost source
9	Paint	Finish - Paint	1.00	m2	0	m2/kg	0	m2	0.132	0.873	1.128	0.264	62.043	2.256	48.48	Fossey Fund
10	Cement Plaster	Finish - Plaste	0.02													
11	CMU	Masonry - So	0.25	m3	1	-	0	m3	0.000	49.533	0.000					
12	Cement Plaster	Finish - Plaste	0.02	m3	849	kg/m3	17	kg	0.000	2.207	0.000					
13	Horizontal Rein	Steel - Masor	1.00	kg	4	-	4	kg	0.000	7.323	0.000					
14	Vertical Reinfor	Steel - Masor	1.00	kg	1		1		0.000	1.234	0.000					
15	Paint	Finish - Paint	1.00	m2	0	m2/kg	0	m2	0.132	0.873	1.128					
18																
19	**Name**	CMU w/ Volcanic Stone Cladding (Exterior)														
20	**Total Width**	470														
21	**Drawing**															
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25	Volcanic Stone	Stone - Undre	0.15	m3	2400	kg/m3	360	kg	0.000	1.577	0.000	12.732	169.381	22.128	113.00	
26	Wall Ties						0									
27	Concrete Grout	Finish - Scree	0.05	m3	2100	kg/m3	105	kg	12.600	17.115	21.000					
28	CMU	Masonry - Ho	1.00	m3	1	-	1	m3	0.000	135.350	0.000					
29	Cement Plaster	Finish - Plaste	0.02	m3	849	kg/m3	17	kg	0.000	2.207	0.000					
30	Horizontal Rein	Steel - Masor	1.00	kg	4	-	4	kg	0.000	7.323	0.000					
31	Vertical Reinfor	Steel - Masor	1.00	kg	2		2		0.000	4.935	0.000					
32	Paint	Finish - Paint	1.00	m2	0	m2/kg	0	m2	0.132	0.873	1.128					

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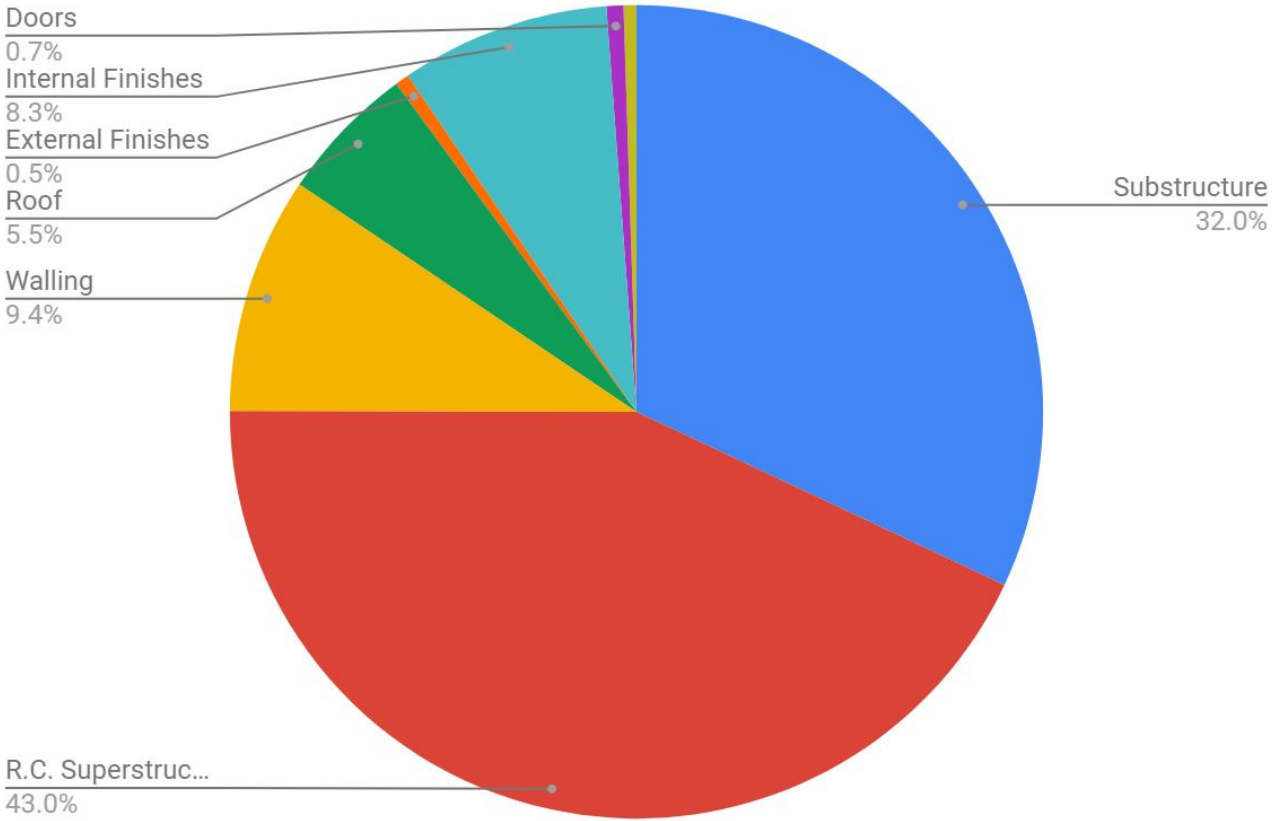
Carbon hotspots



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University of Global Health Equity, 2018

4/5ths of global average

Embodied carbon: 375 kgCO2e/m²

Global education building average: 425 kgCO2e/m²

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Rwanda Institute for Conservation Agriculture, 2019

2/5ths of global average

Embodied carbon:
175 kgCO2e/m²

Global education building average:
425 kgCO2e/m²

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What can you do

Communicate

Collaborate

Educate

Regulate

Innovate

Further reading:
architecture2030.org
worldgbc.org
Carbonleadershipforum.org
UNEP Global Status Report 2018

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