THE GLOBAL ENGINEERING CONFERENCE ON SUSTAINABLE DEVELOPMENT AND WORLD FEDERATION OF ENGINEERING ORGANISATIONS EXECUTIVE COMMITTEE MEETINGS.

15th - 18th October 2024, Kigali, Rwanda

Theme: Engineering Innovations for a Sustainable Future

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EMBODIED CARBON RESEARCH IN RWANDA’S BUILT ENVIRONMENT

Aimable Mukire
Structural Engineer, MASS Design Group

Alex Ndibwami
Architect, University Of Rwanda

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Embodied Carbon Research in Rwanda's Built Environment

Royal Academy of Engineering

MASS.

Feilden Clegg Bradley Studios

University of Rwanda

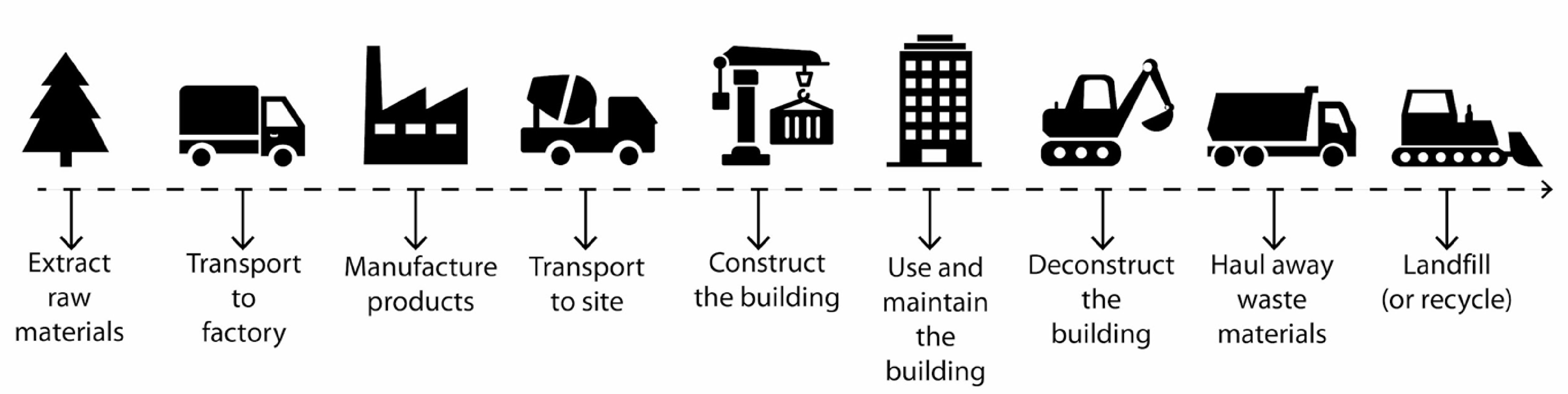
ARUP

Learning Objectives and Outcomes

1. To introduce and define Embodied Carbon (in practical terms).
2. Using examples, elaborate why we need to measure and reduce Embodied Carbon.
3. To highlight key findings from recent research on Embodied Carbon in Rwanda.
4. To introduce the Embodied Carbon Toolkit highlighting how Embodied Carbon can be measured and later reduced using the Rwanda Embodied Carbon Calculator (RwECC).
5. To suggest some immediate to future steps.

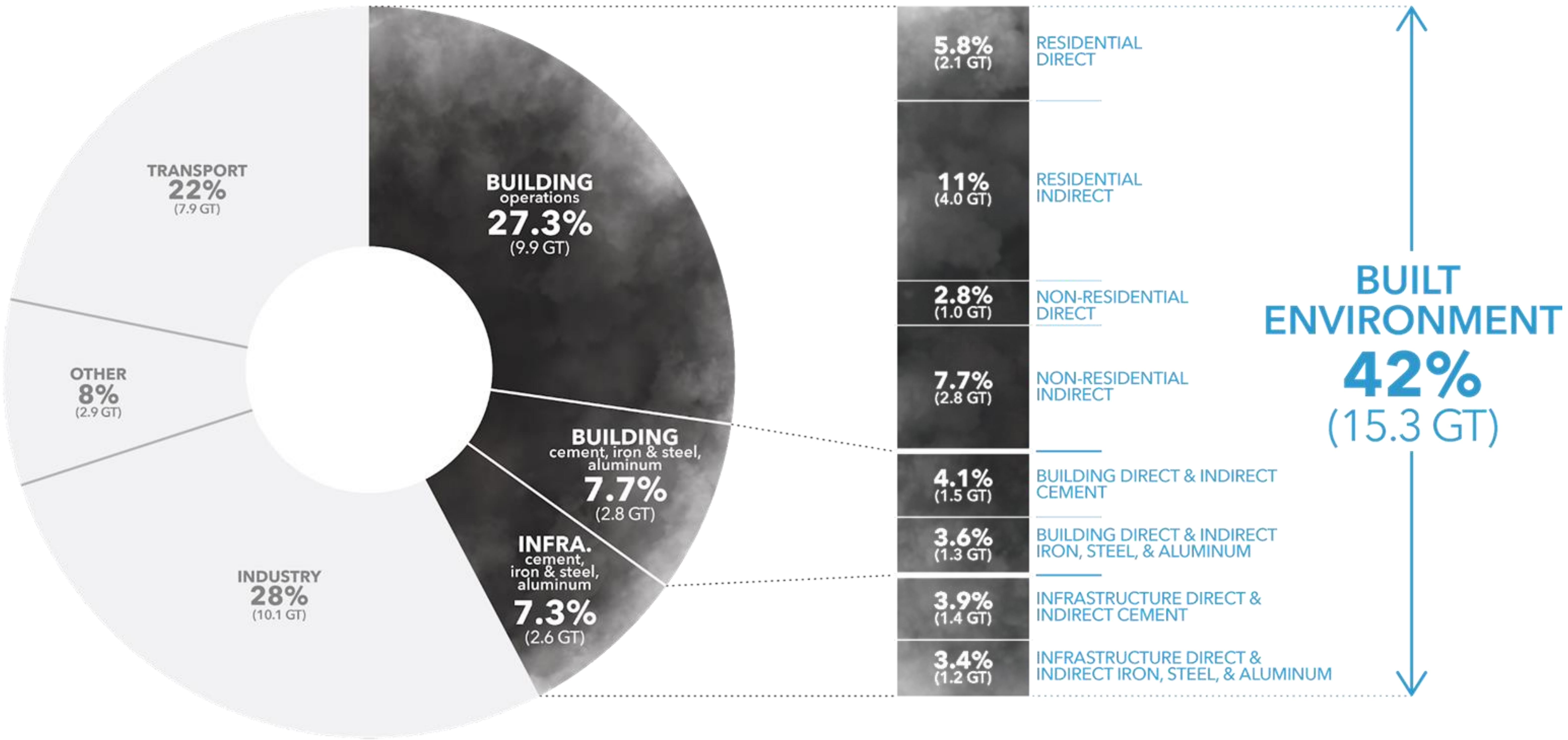
What is Embodied Carbon?

The total amount of greenhouse gas emission produced throughout the lifecycle of a building material or product



What is Embodied Carbon?

Buildings play a huge role, representing about 42% of emissions globally, and much more in urban centers



TOTAL ANNUAL GLOBAL CO_2 EMISSIONS
Direct & Indirect Energy & Process Emissions (36.3 GT)

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Analysis & Aggregation by Architecture 2030 using data sources from IEA & Statista.

Why do we need to reduce it ?

Increasing urbanisation

Rwanda needs an additional 3 million housing units to accommodate a population of 22 million people by 2050.

Extreme weather

In Rwanda, the mean annual temperature has risen by about 1.4deg since 1971. Unusually heavy rains have since occurred in the North and more severe droughts in the East and South in the last two decades.

Why do we need to reduce it ?

Damaged infrastructure

Flooding due to heavy rain destroys infrastructure such as roads, bridges and electricity supplies.

Waste

Kigali’s municipal waste is estimated to have doubled over the past ten years due to population growth.

Compared to BAU

Building with low Embodied Carbon materials can actually guarantee:

- Durability if quality assurance is prioritised.
- Availability and reduced cost as technology becomes more familiar.
- Improved thermal and acoustic properties and, aesthetics.
- "Green-ness" and improved user well being.

Key Findings from Recent Research

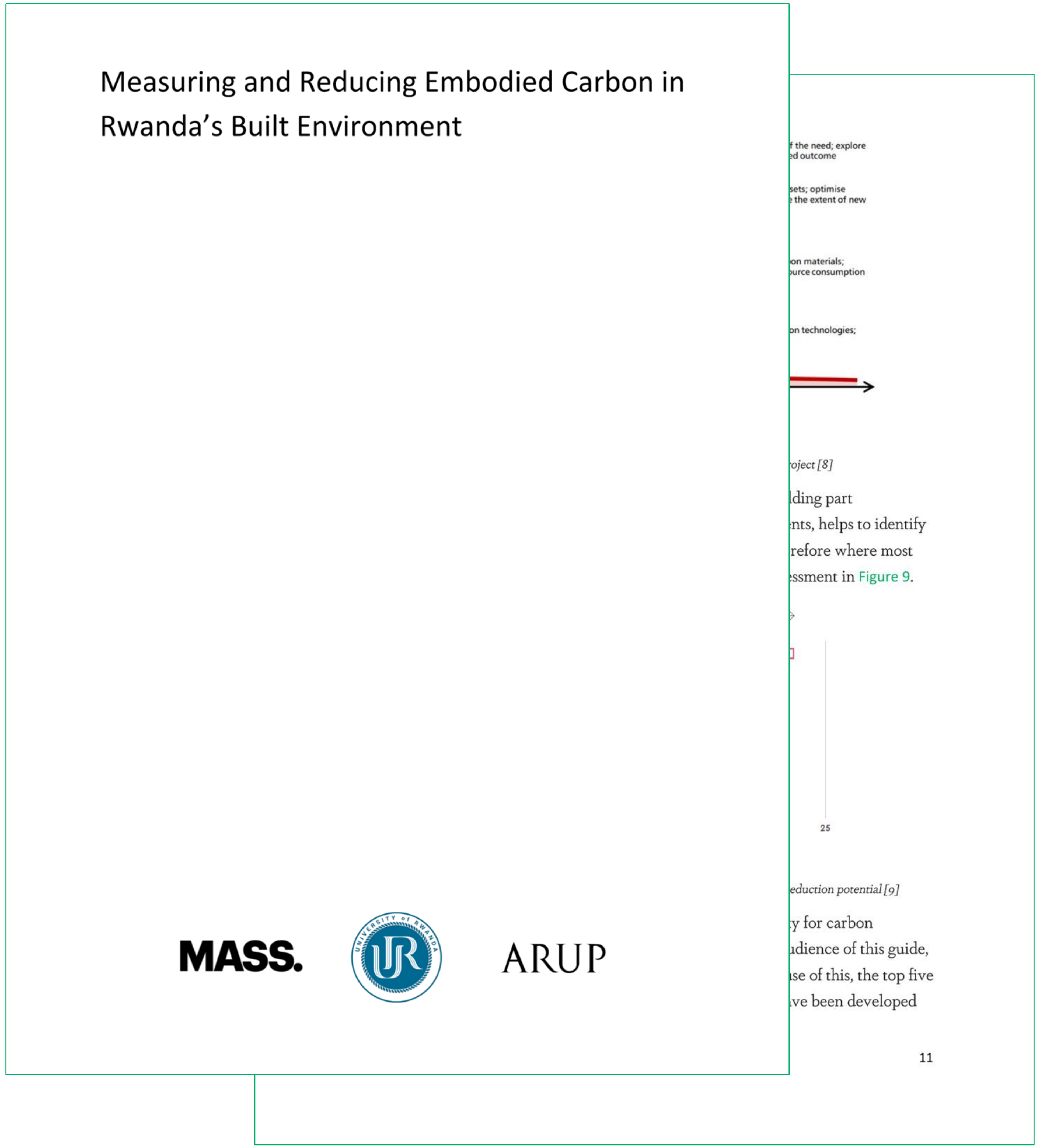
Assessments carried out on 15 buildings suggested:

a. Embodied carbon measurement is not a major consideration.
b. Key considerations are cost, availability and proven material properties.
c. Decisions on low carbon materials/ processes are mostly developer facilitated.
d. Institutional buildings proved to be the most freely accessible for such assessments.
e. Successful implementation of low carbon materials/ processes is mostly out of consultant’s keenness and competence.
f. Curricula are vague on Embodied Carbon.
g. Policy is rather nonspecific on measurement and reduction targets.

A Toolkit for Built Environment Practitioners to Measure and Reduce Embodied Carbon in Rwanda

The Embodied Carbon Toolkit - at a glance

Part 1 - The Guidance Document



Measuring and Reducing Embodied Carbon in Rwanda's Built Environment

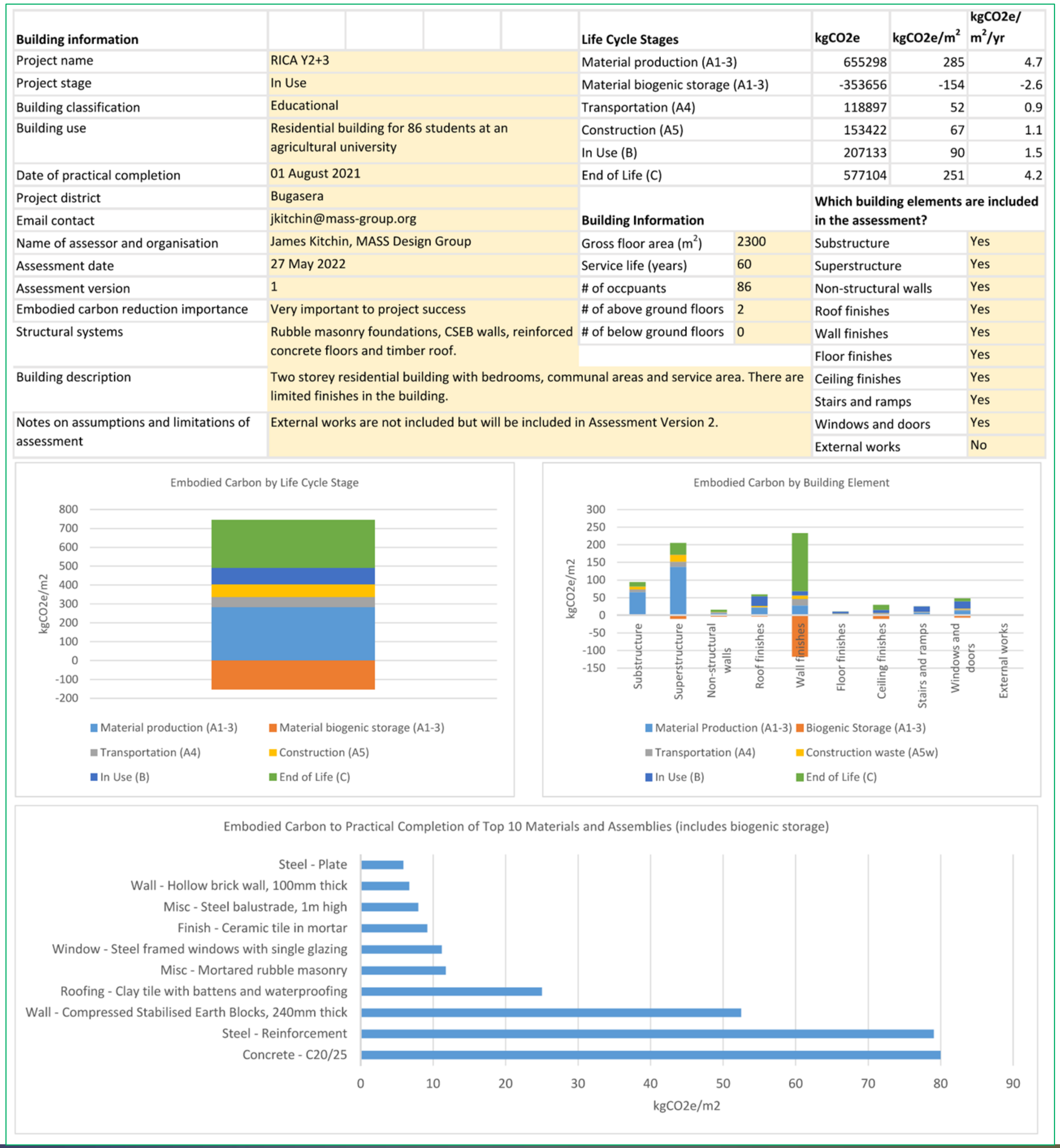
MASS.
ARUP

Key Contents:

- Assessments
- Calculation Steps
- Case Studies
- Reduction Strategies
- Enabling Mechanisms

The Embodied Carbon Toolkit - at a glance

Part 2 - The Rwanda Embodied Carbon Calculator (RwECC)



Building information	
Project name	RICA Y2+3
Project stage	In Use
Building classification	Educational
Building use	Residential building for 86 students at an agricultural university
Date of practical completion	01 August 2021
Project district	Bugasera
Email contact	jkitchin@mass-group.org
Name of assessor and organisation	James Kitchin, MASS Design Group
Assessment date	27 May 2022
Assessment version	1
Embodied carbon reduction importance	Very important to project success
Structural systems	Rubble masonry foundations, CSEB walls, reinforced concrete floors and timber roof.
Building description	Two storey residential building with bedrooms, communal areas and service area. There are limited finishes in the building.
Notes on assumptions and limitations of assessment	External works are not included but will be included in Assessment Version 2.

Life Cycle Stages	**kgCO2e**	**kgCO2e/m^2**	**kgCO2e/ m^2/yr**
Material production (A1-3)	655298	285	4.7
Material biogenic storage (A1-3)	-353656	-154	-2.6
Transportation (A4)	118897	52	0.9
Construction (A5)	153422	67	1.1
In Use (B)	207133	90	1.5
End of Life (C)	577104	251	4.2

Building Information	
Gross floor area (m^2)	2300
Service life (years)	60
# of occpuants	86
# of above ground floors	2
# of below ground floors	0

Which building elements are included in the assessment?	
Substructure	Yes
Superstructure	Yes
Non-structural walls	Yes
Roof finishes	Yes
Wall finishes	Yes
Floor finishes	Yes
Ceiling finishes	Yes
Stairs and ramps	Yes
Windows and doors	Yes
External works	No

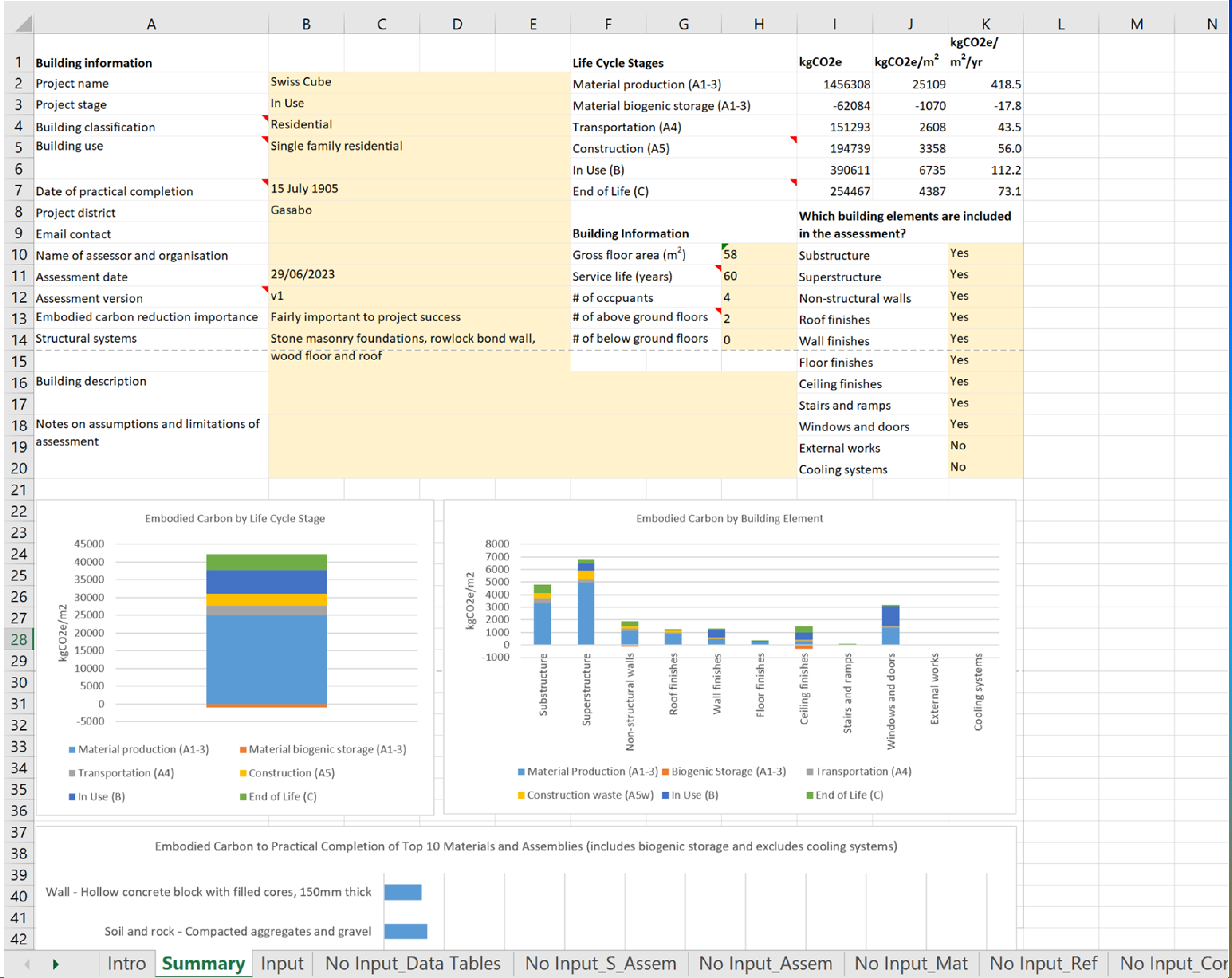
Key tabs:

- The Summary tab - project information
- The Input tab - materials and assemblies

RwECC

Step 1:

Enter project information in the Yellow Cells under the **Summary Tab**



Building information	
Project name	Swiss Cube
Project stage	In Use
Building classification	Residential
Building use	Single family residential
Date of practical completion	15 July 1905
Project district	Gasabo
Email contact	
Name of assessor and organisation	
Assessment date	29/06/2023
Assessment version	v1
Embodied carbon reduction importance	Fairly important to project success
Structural systems	Stone masonry foundations, rowlock bond wall, wood floor and roof
Building description	
Notes on assumptions and limitations of assessment	

Life Cycle Stages	**kgCO2e**	**kgCO2e/m²**	**kgCO2e/ m²/yr**
Material production (A1-3)	1456308	25109	418.5
Material biogenic storage (A1-3)	-62084	-1070	-17.8
Transportation (A4)	151293	2608	43.5
Construction (A5)	194739	3358	56.0
In Use (B)	390611	6735	112.2
End of Life (C)	254467	4387	73.1

Building Information	
Gross floor area (m²)	58
Service life (years)	60
# of occpuants	4
# of above ground floors	2
# of below ground floors	0

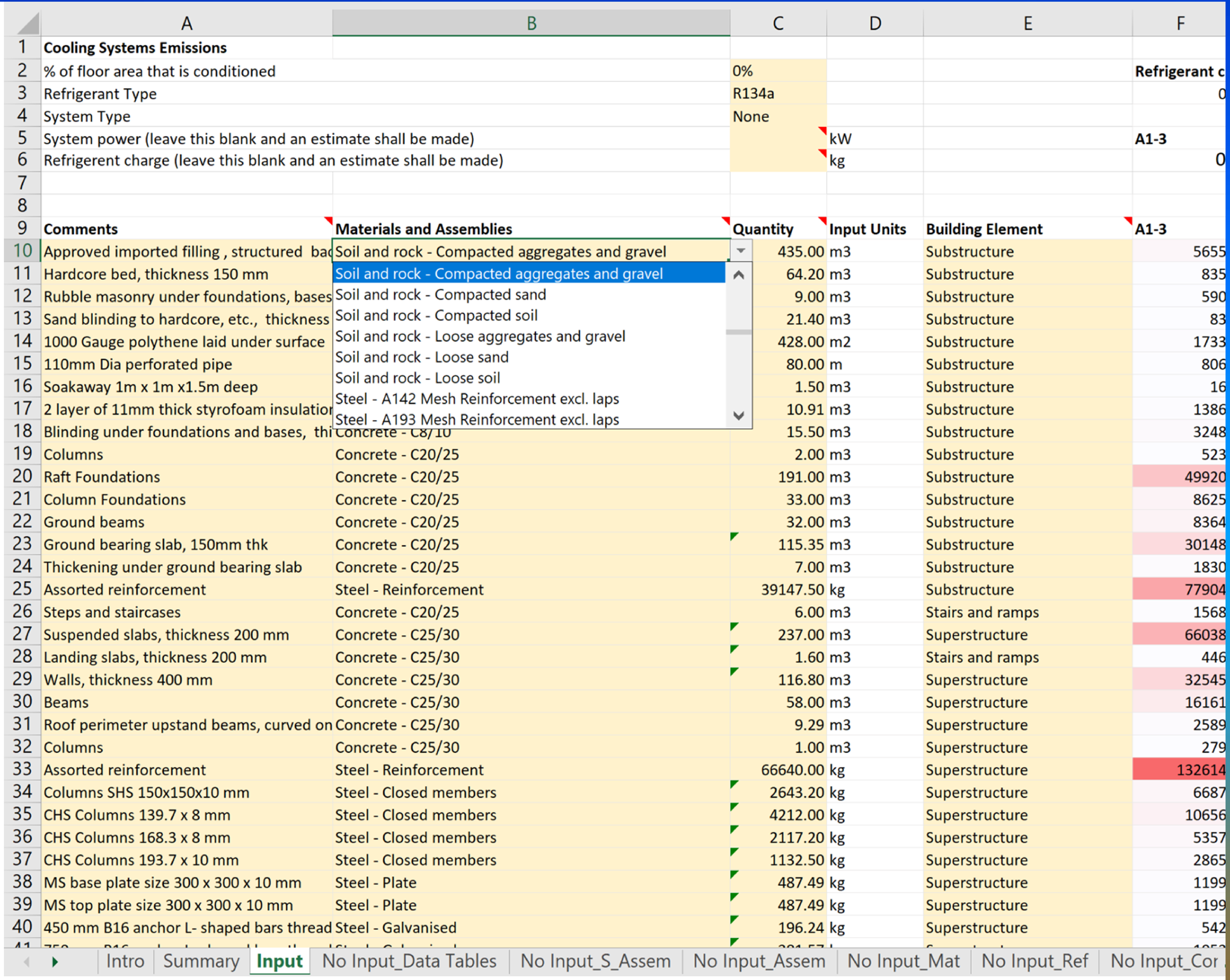
Which building elements are included in the assessment?	
Substructure	Yes
Superstructure	Yes
Non-structural walls	Yes
Roof finishes	Yes
Wall finishes	Yes
Floor finishes	Yes
Ceiling finishes	Yes
Stairs and ramps	Yes
Windows and doors	Yes
External works	No
Cooling systems	No

RwECC

Step 2:

Under the Input tab, enter information under each column - for example: select materials and assemblies from the drop down menus and then in the subsequent column enter the quantity of material.

Browse each column heading for more precise instructions.

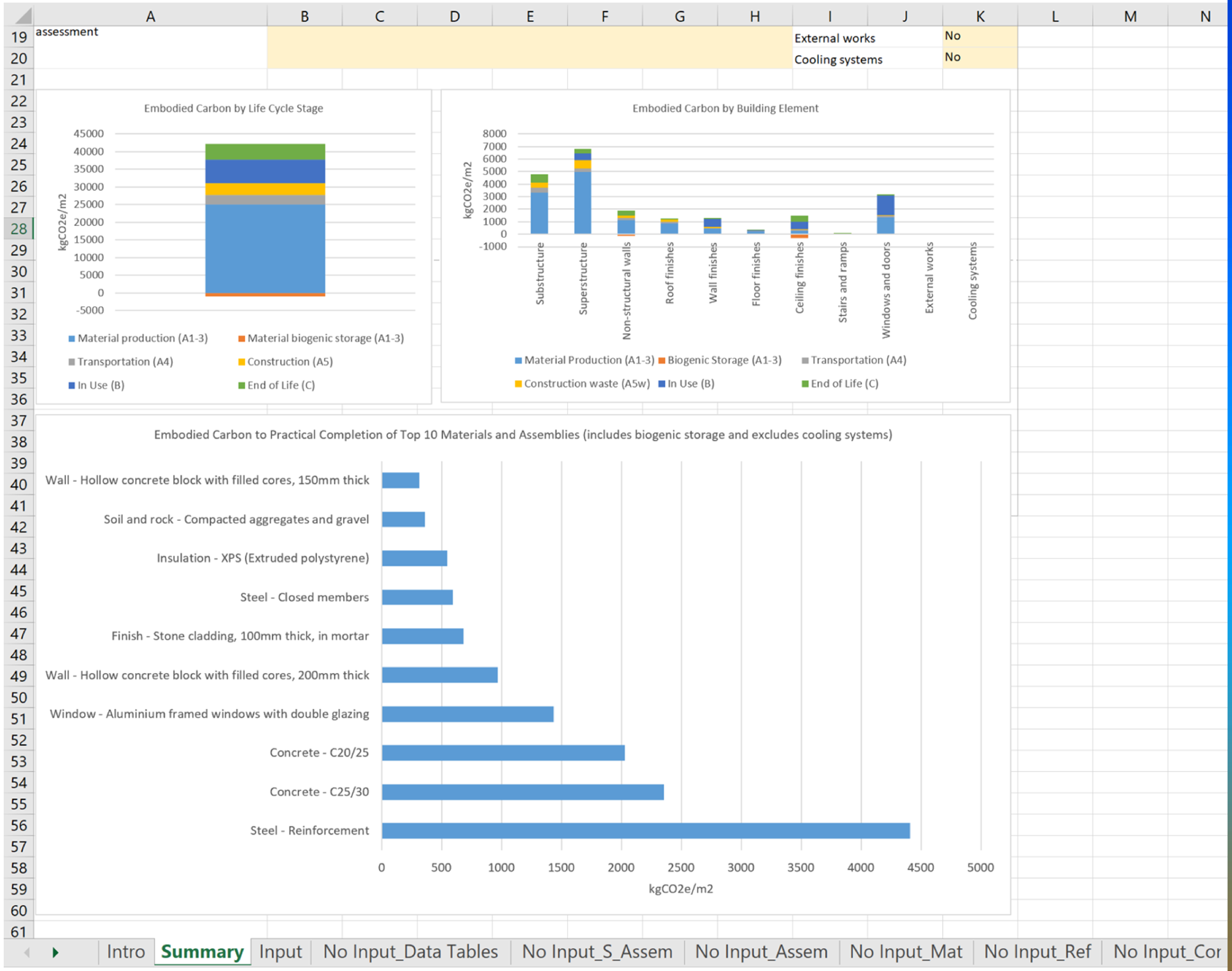


	A	B	C	D	E	F
1	**Cooling Systems Emissions**					
2	% of floor area that is conditioned		0%			**Refrigerant c**
3	Refrigerant Type		R134a			0
4	System Type		None			
5	System power (leave this blank and an estimate shall be made)			kW		**A1-3**
6	Refrigerent charge (leave this blank and an estimate shall be made)			kg		0
7						
8						
9	**Comments**	**Materials and Assemblies**	**Quantity**	**Input Units**	**Building Element**	**A1-3**
10	Approved imported filling , structured bac	Soil and rock - Compacted aggregates and gravel	435.00	m3	Substructure	5655
11	Hardcore bed, thickness 150 mm		64.20	m3	Substructure	835
12	Rubble masonry under foundations, bases		9.00	m3	Substructure	590
13	Sand blinding to hardcore, etc., thickness		21.40	m3	Substructure	83
14	1000 Gauge polythene laid under surface		428.00	m2	Substructure	1733
15	110mm Dia perforated pipe		80.00	m	Substructure	806
16	Soakaway 1m x 1m x1.5m deep		1.50	m3	Substructure	16
17	2 layer of 11mm thick styrofoam insulatior		10.91	m3	Substructure	1386
18	Blinding under foundations and bases, thi	Concrete - C8/10	15.50	m3	Substructure	3248
19	Columns	Concrete - C20/25	2.00	m3	Substructure	523
20	Raft Foundations	Concrete - C20/25	191.00	m3	Substructure	49920
21	Column Foundations	Concrete - C20/25	33.00	m3	Substructure	8625
22	Ground beams	Concrete - C20/25	32.00	m3	Substructure	8364
23	Ground bearing slab, 150mm thk	Concrete - C20/25	115.35	m3	Substructure	30148
24	Thickening under ground bearing slab	Concrete - C20/25	7.00	m3	Substructure	1830
25	Assorted reinforcement	Steel - Reinforcement	39147.50	kg	Substructure	77904
26	Steps and staircases	Concrete - C20/25	6.00	m3	Stairs and ramps	1568
27	Suspended slabs, thickness 200 mm	Concrete - C25/30	237.00	m3	Superstructure	66038
28	Landing slabs, thickness 200 mm	Concrete - C25/30	1.60	m3	Stairs and ramps	446
29	Walls, thickness 400 mm	Concrete - C25/30	116.80	m3	Superstructure	32545
30	Beams	Concrete - C25/30	58.00	m3	Superstructure	16161
31	Roof perimeter upstand beams, curved on	Concrete - C25/30	9.29	m3	Superstructure	2589
32	Columns	Concrete - C25/30	1.00	m3	Superstructure	279
33	Assorted reinforcement	Steel - Reinforcement	66640.00	kg	Superstructure	132614
34	Columns SHS 150x150x10 mm	Steel - Closed members	2643.20	kg	Superstructure	6687
35	CHS Columns 139.7 x 8 mm	Steel - Closed members	4212.00	kg	Superstructure	10656
36	CHS Columns 168.3 x 8 mm	Steel - Closed members	2117.20	kg	Superstructure	5357
37	CHS Columns 193.7 x 10 mm	Steel - Closed members	1132.50	kg	Superstructure	2865
38	MS base plate size 300 x 300 x 10 mm	Steel - Plate	487.49	kg	Superstructure	1199
39	MS top plate size 300 x 300 x 10 mm	Steel - Plate	487.49	kg	Superstructure	1199
40	450 mm B16 anchor L- shaped bars thread	Steel - Galvanised	196.24	kg	Superstructure	542

RwECC

Step 3:

View graphs and results under the Summary Tab to determine EC hotspots.

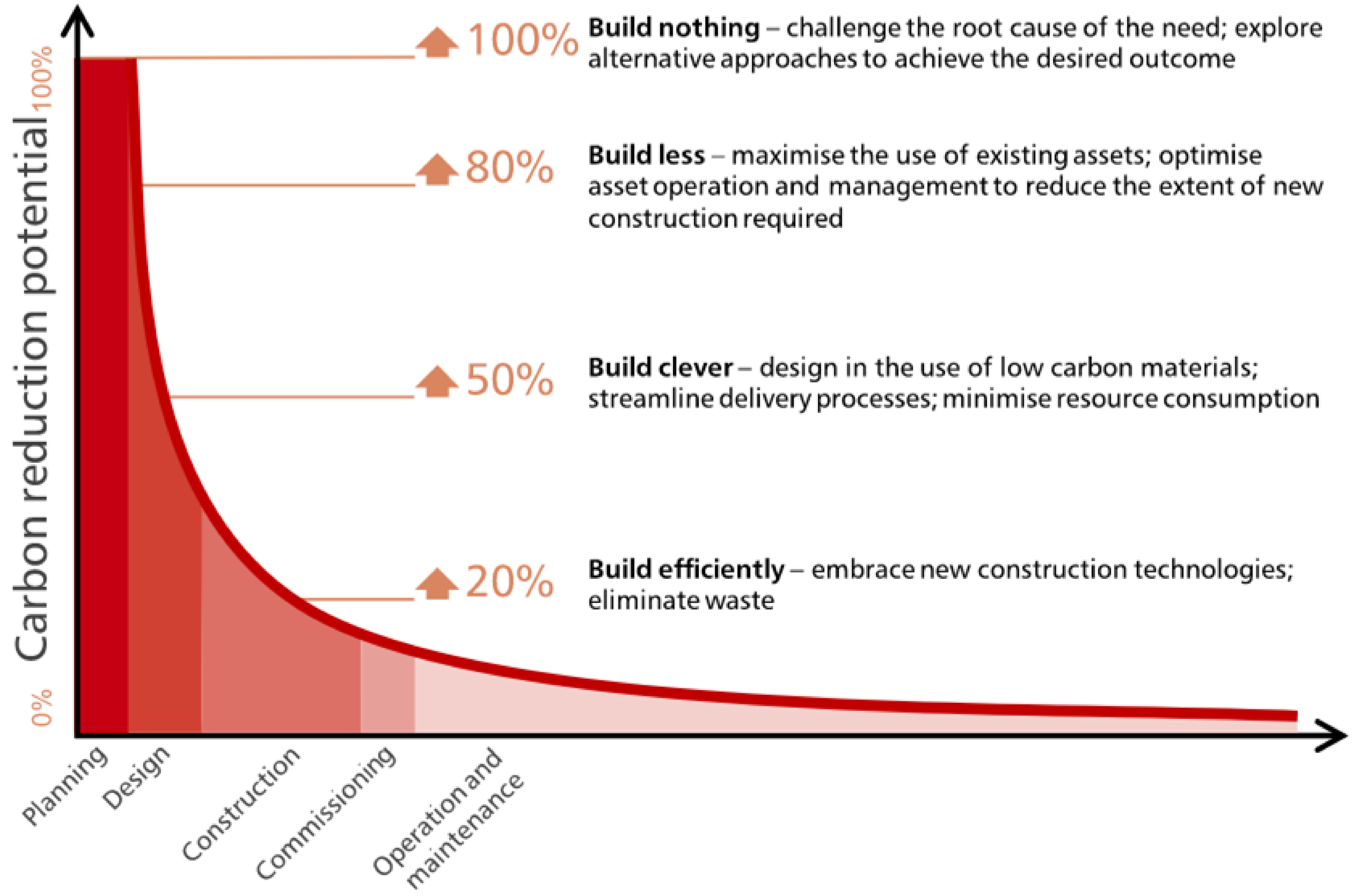


External works No

Cooling systems No

Guidance Document

Impact reduction methods



Build nothing – challenge the root cause of the need; explore alternative approaches to achieve the desired outcome

Build less – maximise the use of existing assets; optimise asset operation and management to reduce the extent of new construction required

Build clever – design in the use of low carbon materials; streamline delivery processes; minimise resource consumption

Build efficiently – embrace new construction technologies; eliminate waste

Guidance Document

Impact reduction methods

Client Objective

Award winning
Meet their ESG goals
Less maintenance
Quick construction
Improve user wellbeing
Accommodate change in use
Low costs

Guidance Document

Impact reduction methods

Embodied Carbon Reduction
Achieve AIA 2030 or RIBA 2030 Climate Challenge
Align ESG goal with climate goals
Reduce finishes and use durable material
Off-site manufacturing and design for deconstruction
Natural materials
Design for flexibility and adaptability
Smaller buildings

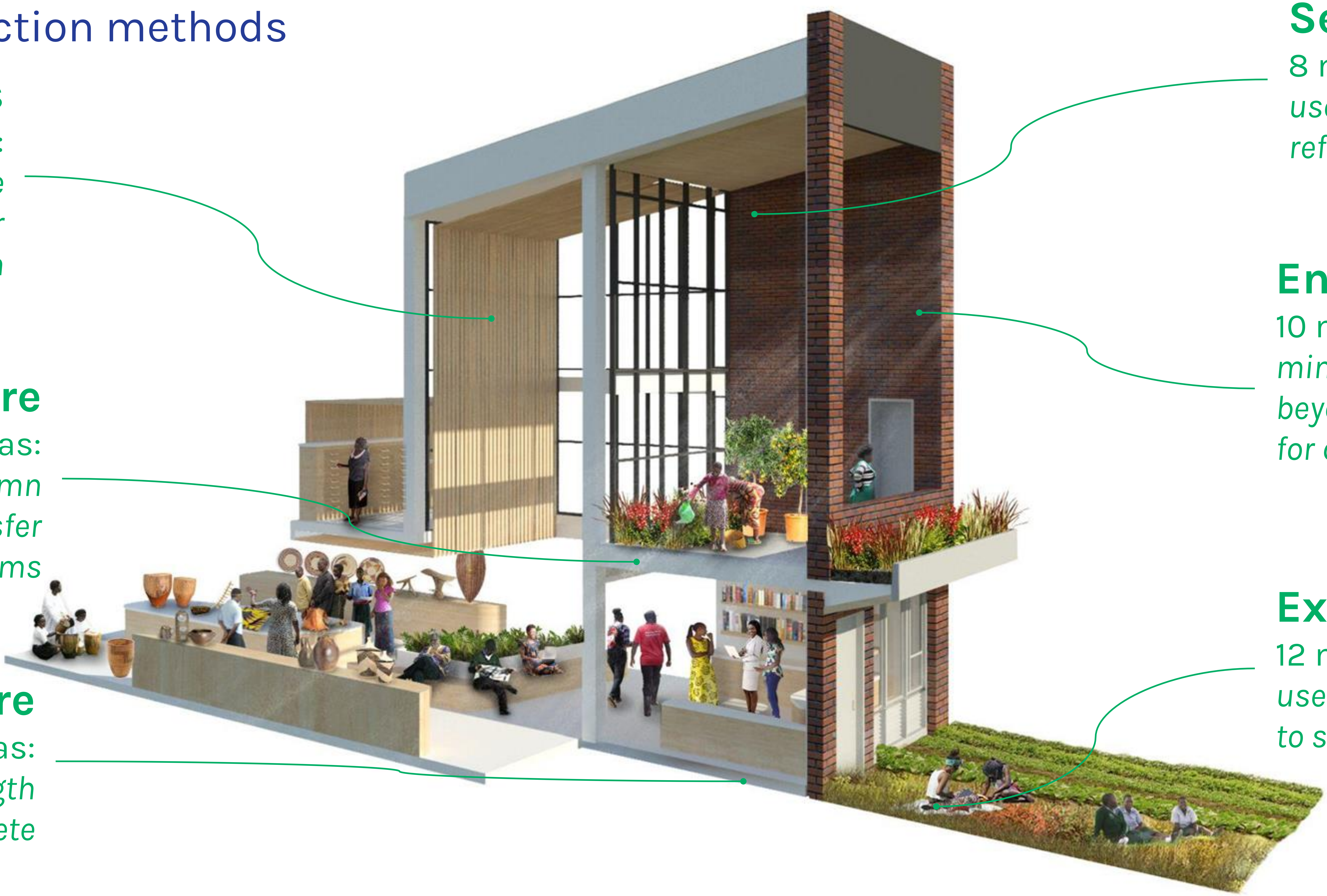
Guidance Document

Impact reduction methods

Client Objective	Embodied Carbon Reduction
Award winning	Achieve AIA2030 or RIBA 2030 Climate Challenge
Meet their ESG goals	Align ESG goal with climate goals
Less maintenance	Reduce finishes and use durable material
Quick construction	Off-site manufacturing and design for deconstruction
Improve user wellbeing	Natural materials
Accommodate change in use	Design for flexibility and adaptability
Low costs	Smaller buildings
	Adaptive reuse
	No building
	Multi purposes spaces
	Columns
	Passive environmental design
	Off site manufacturing
	Regular repeating elements
	Limiting basements
	Limiting podium structures
	Optimal window to wall ratio

Guidance Document

Impact reduction methods



Interiors

8 methods such as:
avoid adhesive attachments for easier deconstruction

Superstructure

14 methods such as:
embrace the column and avoid transfer beams

Substructure

11 methods such as:
use 56-day strength concrete

Services

8 methods such as:
use low GWP refrigerants

Envelope

10 methods such as:
minimise glazing beyond what is needed for daylight and views

External works

12 methods such as:
use permeable pavers to save 40% material

Guidance Document

Case Studies - "Institutional Buildings"

School of Architecture and Built Environment

Whole Building A-C Embodied carbon:
983 kgCO2e/m²

RICA Year 2&3 Housing

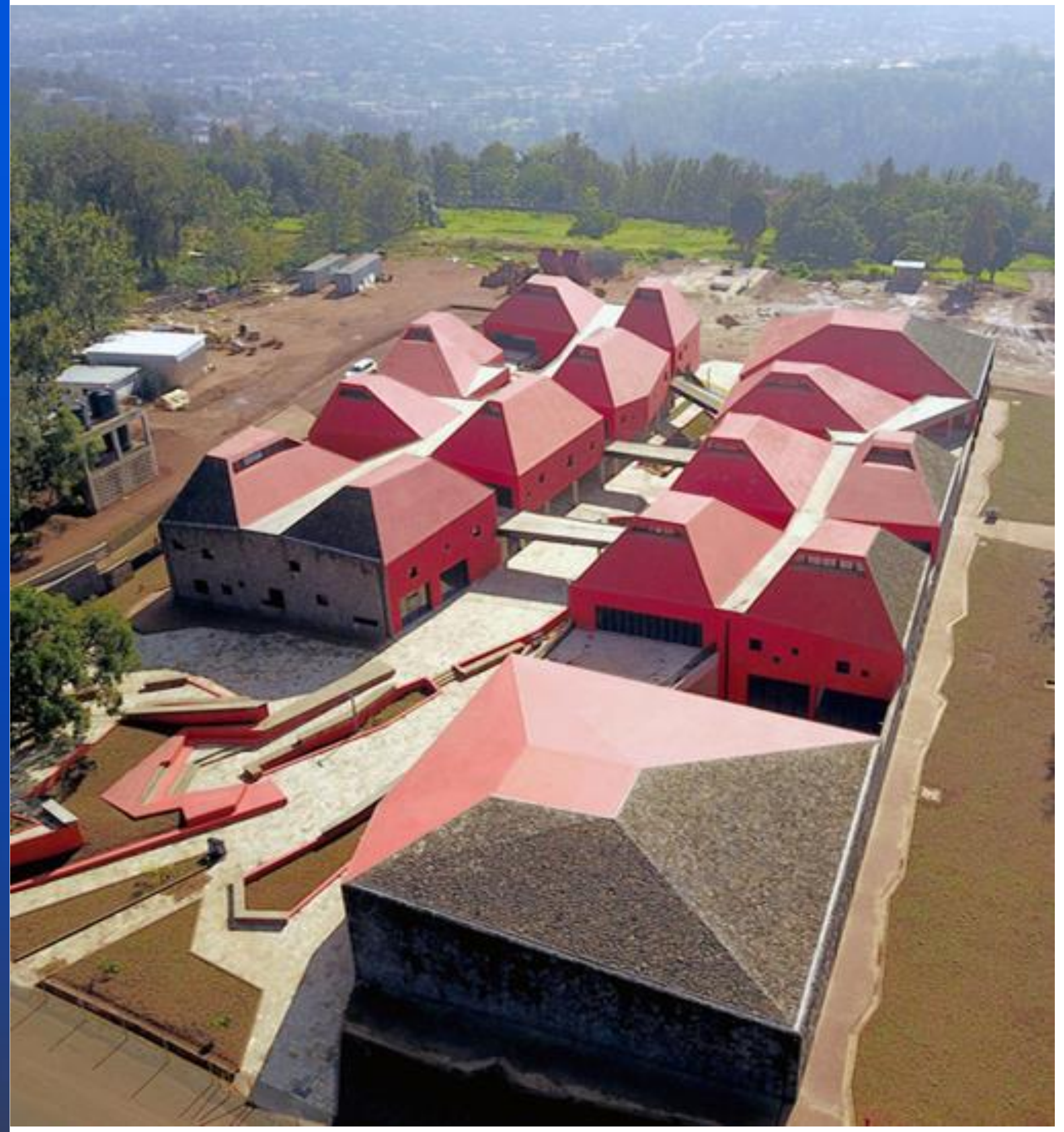
Whole Building A-C Embodied carbon:
566 kgCO2e/m²

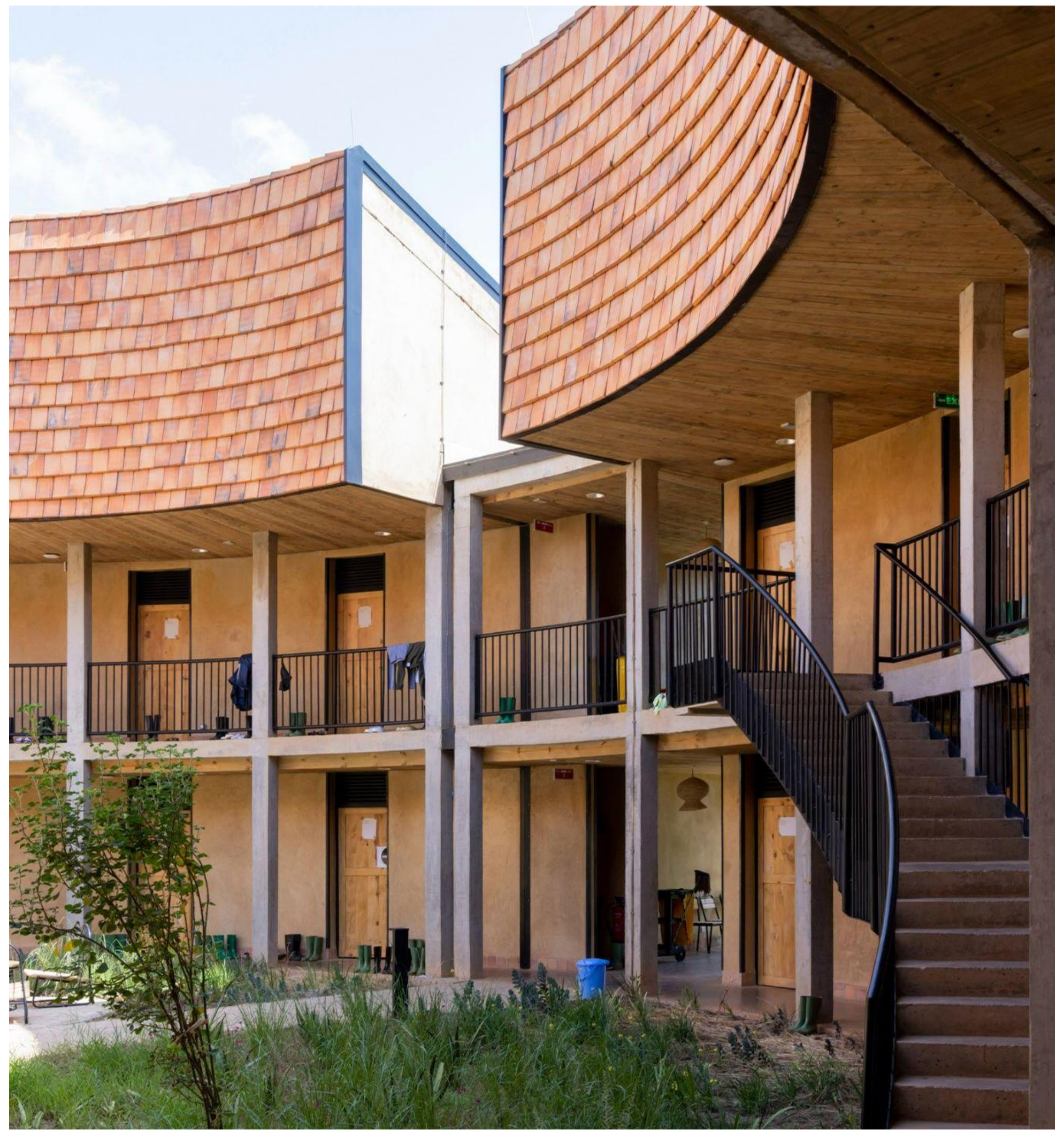
Rwanda Cricket Stadium

Whole Building A-C Embodied carbon:
443 kgCO2e/m²

School of Mining and Geology

Whole Building A-C Embodied carbon:
1600 kgCO2e/m²





Immediate to Future Steps - Key Reflections

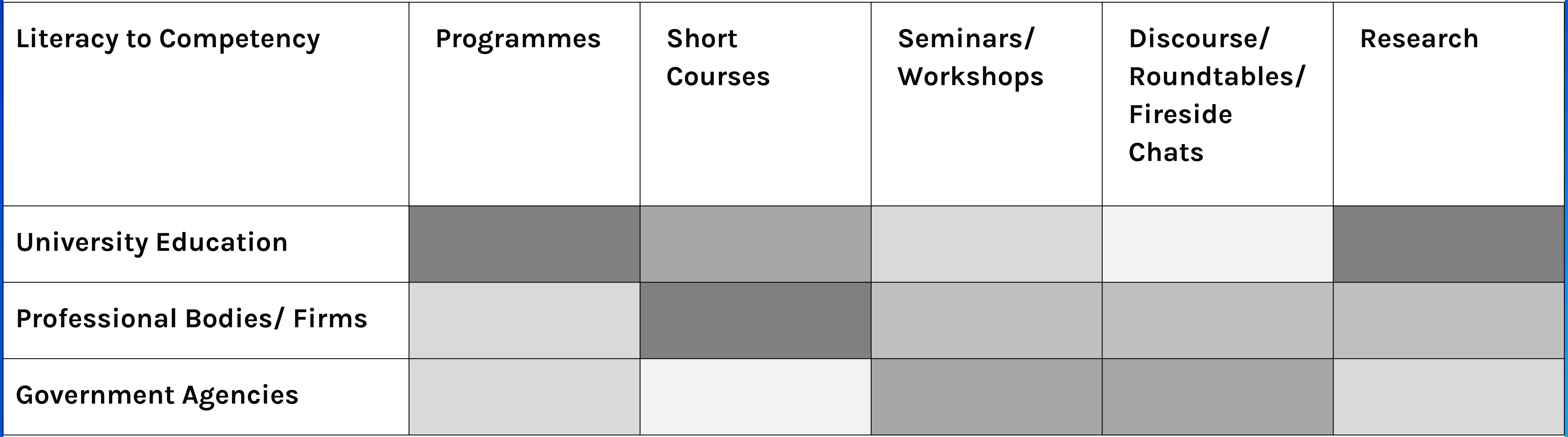
Understanding motivators of diffusion/ uptake

- Common Practice
- Mass Media Advertisement
- Exemplar Projects
- Sustainability led Initiatives
- Building Code

Immediate to Future Steps - Shaping Key Competencies

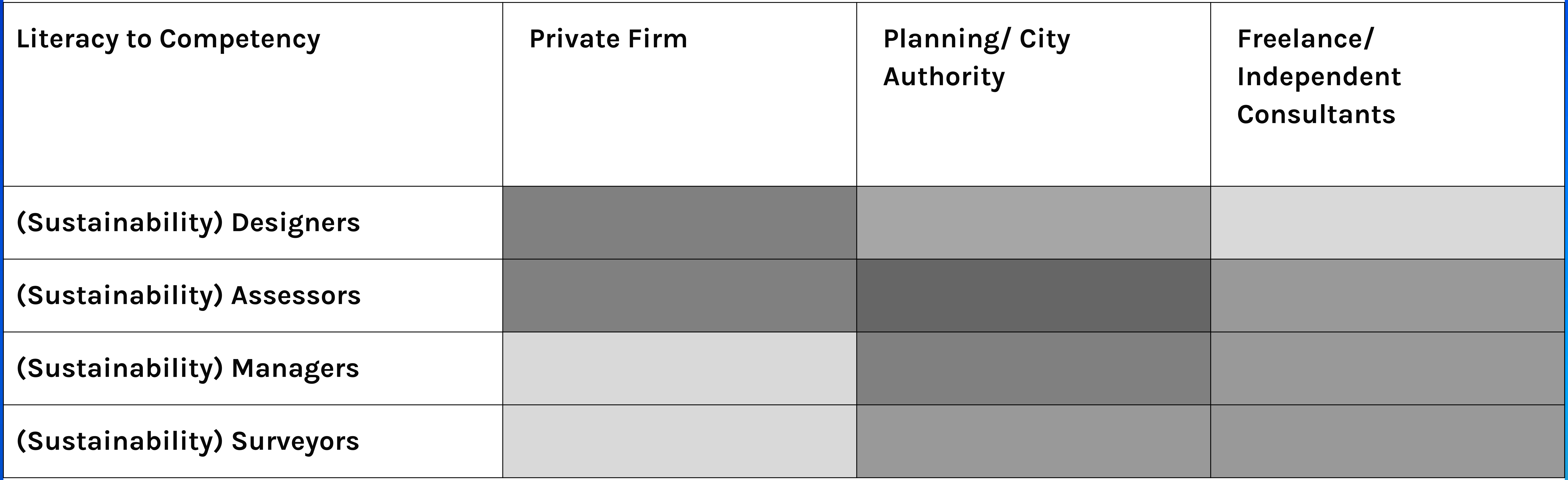
Literacy to Competency	Knows What	Knows How	Knows Why	Shows What	Shows How	Shows Why
Climate	▓	░	▓	░	░	▒
Carbon	▓	░	▓	░	░	▒
LCA	▓	░	▓	░	░	▒
Resource Efficiency	▓	░	▓	░	░	▒
Measurement	░	█	░	░	█	▒
Reduction	░	█	░	░	█	▒
Assessment	░	█	░	░	█	▒
Practice	░	█	░	░	█	▒

Immediate to Future Steps - Key Players and Modes



Literacy to Competency	Programmes	Short Courses	Seminars/ Workshops	Discourse/ Roundtables/ Fireside Chats	Research
University Education	█	▓	░		█
Professional Bodies/ Firms	░	█	▒	▒	▒
Government Agencies	░		▓	▓	░

Immediate to Future Steps - Positioning



Literacy to Competency	Private Firm	Planning/ City Authority	Freelance/ Independent Consultants
(Sustainability) Designers	▓	▒	░
(Sustainability) Assessors	▓	█	▒
(Sustainability) Managers	░	▓	▒
(Sustainability) Surveyors	░	▒	▒

A Recap

- What is Embodied Carbon? “If you can not measure it, you can not Improve it.” Lord Kelvin
- We need to confront the concerns over a climate crisis, its impacts and the impending volume of construction.
- Inevitably, there are opportunities for enhancing local construction processes and earning potential savings.
- Indeed, investing in local materials, local technology and processes has the potential to mitigate both carbon and cost.
- The Embodied Carbon Toolkit highlights precisely how to measure and reduce Embodied Carbon and is applicable at several stages, preferably early on in the design process..
- Academia, Policy and Practice ought to strategise how to mainstream such tools, competencies and expectations..

A Toolkit for Built Environment Practitioners to Measure and Reduce Embodied Carbon in Rwanda

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