Energy and Low Income Tropical Housing

CPD: SUSTAINABLE CONSTRUCTION

ENERGY ANALYSIS OF BUILDINGS & BUILDING MATERIALS

TANZANIA

Tuesday 13th January 2015

gaia group

NHBRA TANZANIA www.nhbra.go.tz

Professor Sandy Halliday

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Energy and Low Income Tropical Housing

Tuesday 13th: Introduction to Gaia Group - Professor Halliday

Ambitions for the Training session - Participants

Introduction to Embodied Energy - Professor Halliday

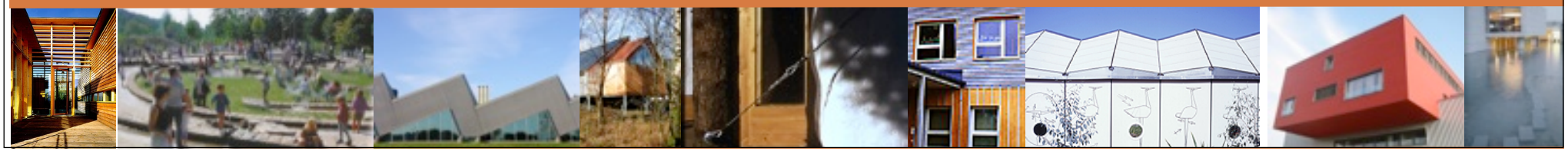
Workshop on Embodied Energy in a building Life cycle -All

An Engineers View Of Sustainability - Professor Halliday

Tuesday 13th - Part 1

INTRODUCTION TO GAIA GROUP

- Climatic & cultural differences
- Dedication & Gaia in Tanzania - Kijiji, Songea
- Passive Design Approach
- Gaia Group - Practice Philosophy
- Research, Design, Evaluate, Disseminate, Training, Capacity Building
- Range of Projects
- Development Tools




Seasonal Climatic Variations


Seasonal Climatic Variations

Solar Variations


Solar Variations

Gaia Architects in Songea

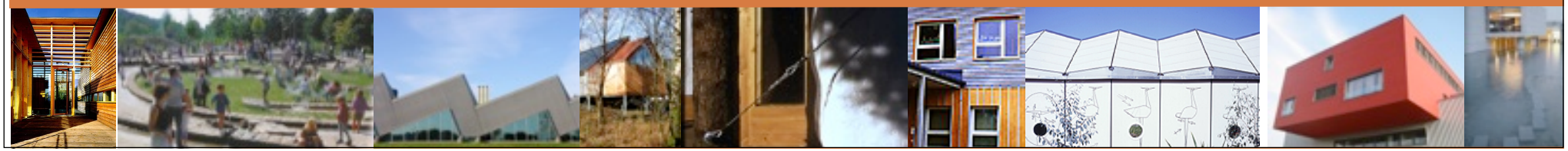
Helping the charity - **Children of Songea -** to develop school & housing facilities for orphans of HIV/AIDS

Gaia Architects in Songea


Gaia Architects in Songea
Using low cost /low embodied energy materials


Gaia Architects in Songea

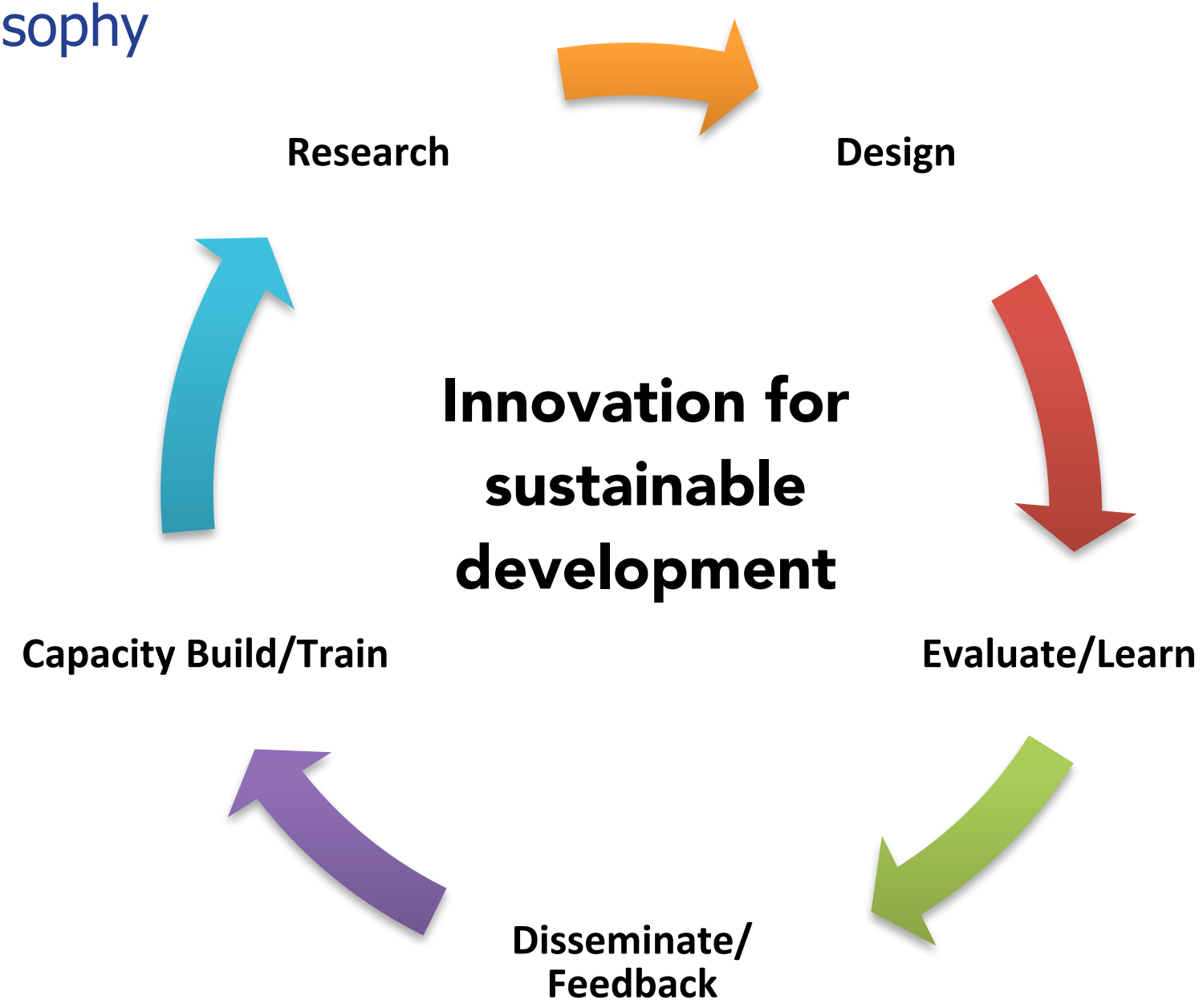
- **Gaia Group was formed in1995.**
- **I opened Gaia Research creating a partnership with the existing Gaia Architects & Gaia Planning founded in1982 by my late husband Howard Liddell.**
- **We shared an interest in passive design and a desire to minimise the mechanical services in buildings.**



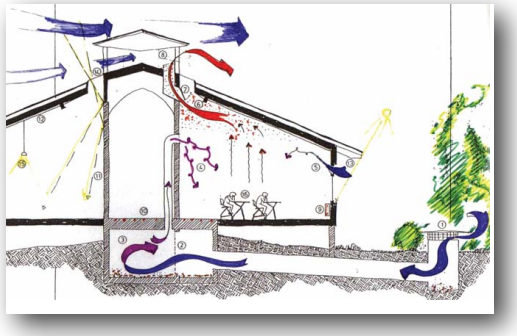
Philosophy

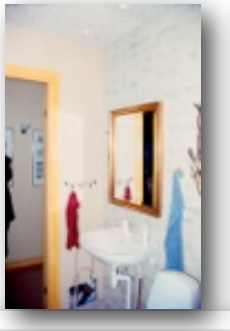
Our philosophy was to initiate research that fed into design, evaluate & learn from this, disseminate & use to train and help others to get a more sustainable built environment

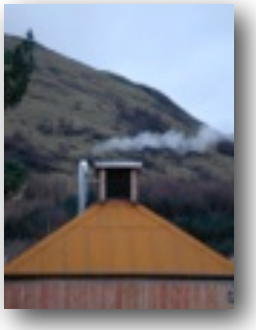
Philosophy

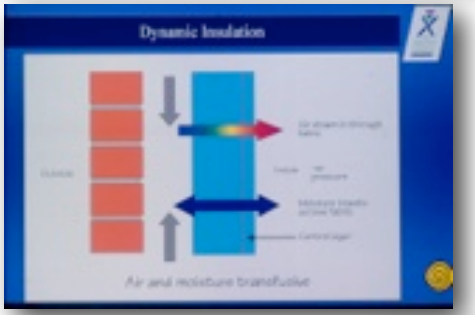


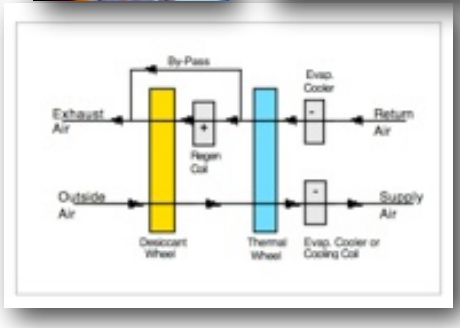
Generate research and create a cycle of continual improvement & innovation

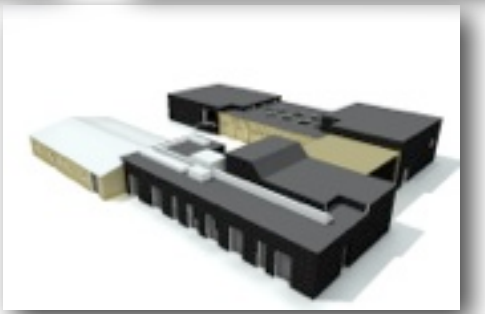


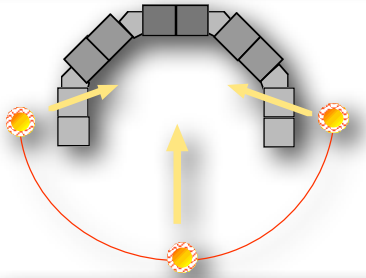


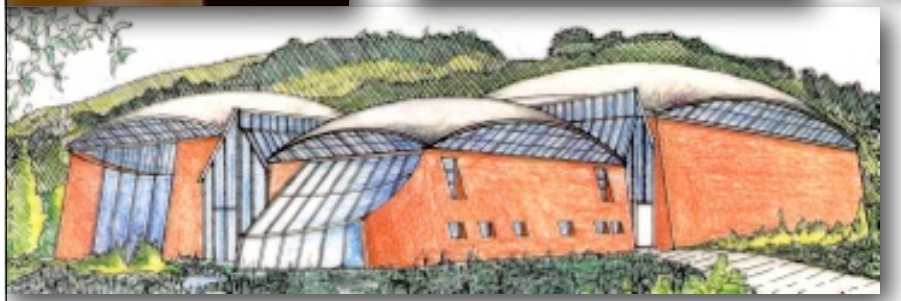








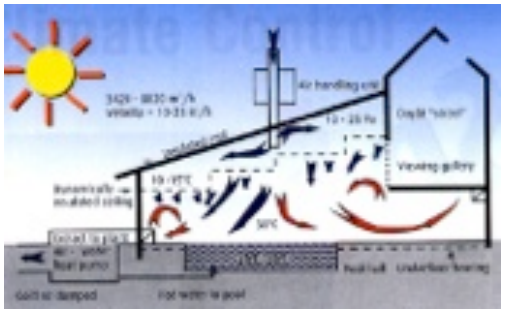


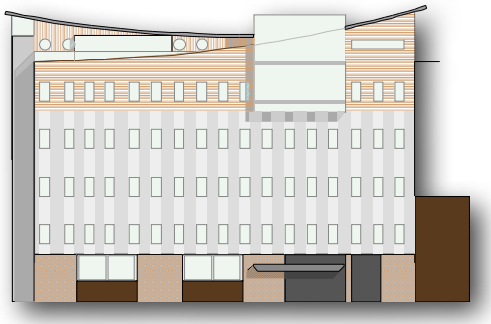
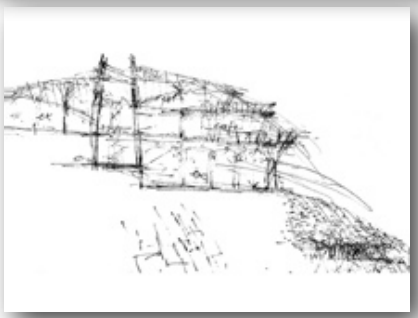
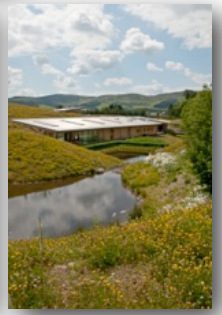



Asthma children 'no better off ' in the fume-free country air

Research

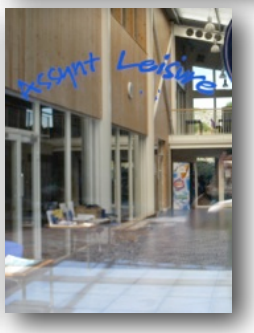
Innovative ventilation, healthy environments, low impact materials, solar air conditioning, passive solar, low energy refurbishment, innovative use of timber, hygroscopic mass, dynamic insulation, animal architecture, daylighting, biomass, earth & straw building, dementia design

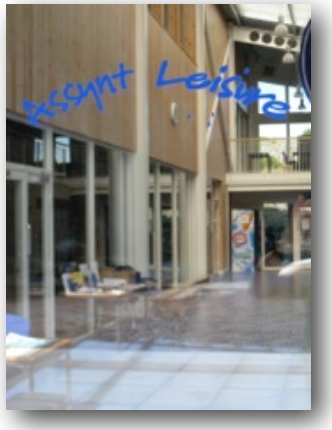






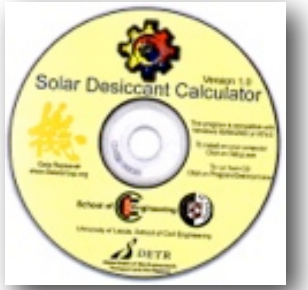

Design

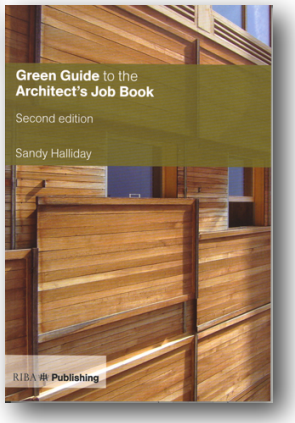
Built to demonstrate innovative use of natural resources and passive design:- dynamic insulation, low allergy housing, minimising building services, ventilation, healthy internal environments, hygroscopic mass, daylighting, biomass, low impact materials.

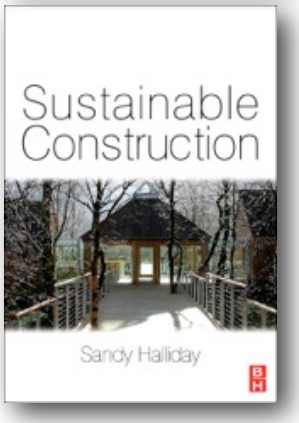


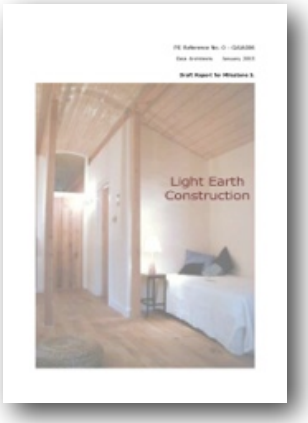
Evaluate

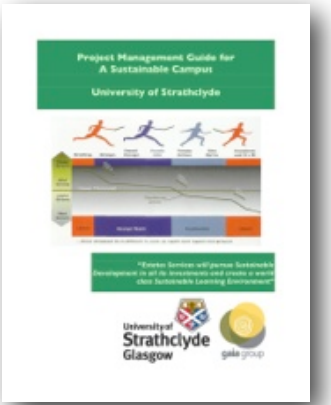
Money for evaluation is difficult to find but we have had some success and were able to monitor sports facilities, housing and schools to assess and improve their performance.











Disseminate

Much of the research is published and available at www.gaiagroup.org

CPD

Resource Pack

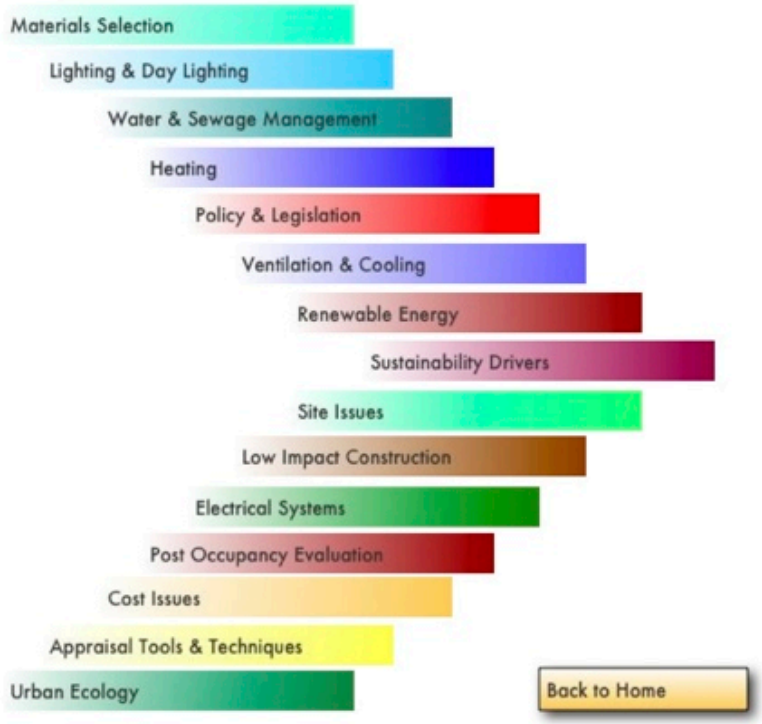
Resource Pack

The material produced here is based on a training course in Sustainable Construction that was developed and delivered by Gaia Research between 2001 and 2004.

The course was developed on a modular basis and this format has been maintained. Each of the modules is presented in its original edition and these are being supplemented by lectures which are being placed on the sites as slide shows.

In addition there is case study information based on recent research and consultancy projects by Gaia.

The paper based modules are currently being updated and will be published by Butterworth-Heinemann in 2007. At that time the existing modules will be removed from the web-site for contractual reasons.



Training

Produced a continuing professional development course as a series of 15 modules

Ventilation&Cooling

This module is intended to help the reader to develop and implement strategies for ventilation & cooling which deliver high quality buildings.
There is guidance already available. However, many buildings remain less comfortable and healthy then they might be and consume unnecessary energy for ventilation & cooling.

No other design issue has been subject to as much dramatic change & controversy as a consequence of the requirements of sustainable building. There is a need to bring the most contemporary information affecting cooling & ventilation in the design of buildings and services to wider attention.

Of the case studies selected three are referred to as naturally ventilated, at least three are hybrid /mixed-mode designs, only one has no fans, and no two use the same approach. The module seeks to discuss the principal issues; enable the reader to find best practice information and assist communication between the disciplines, which can follow through into better quality spaces. Careful consideration of the available options is vital. There are few absolutes.

Coventry University Library
Photo: Sandy Halliday

Gaia's work on Ventilation & Cooling includes

- Dynamic Insulation
- Affordable Low Allergy Housing

Gaia Buildings

Back to Resources

Back to Home

Each was linked to buildings and other projects

Sustainable Construction

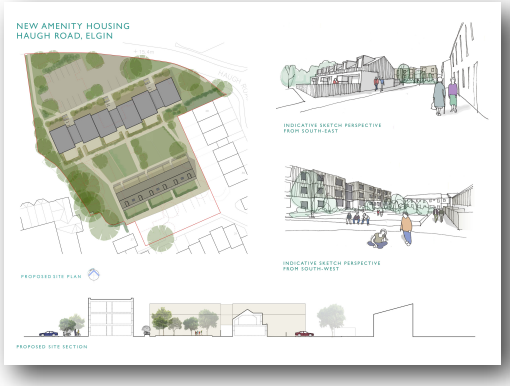
Sustainable Construction

Sandy Halliday

Sustainable Construction

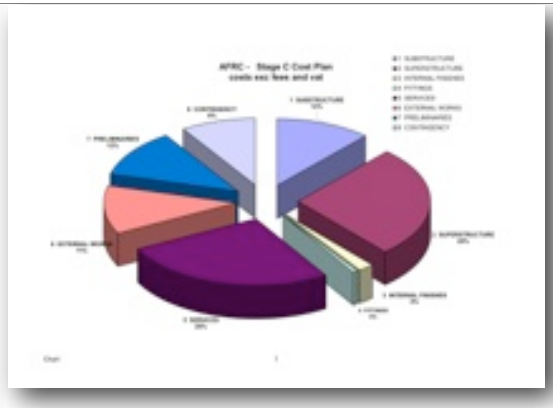
Halliday

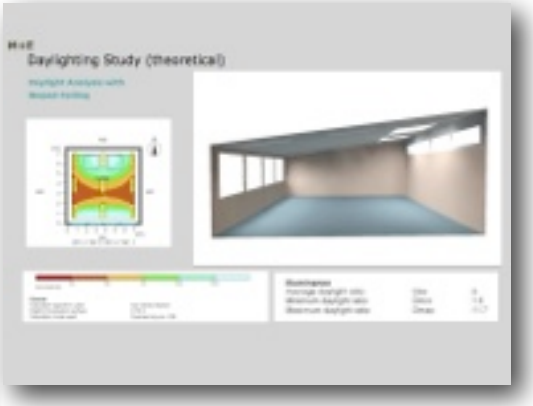
Updated in 2007 and published

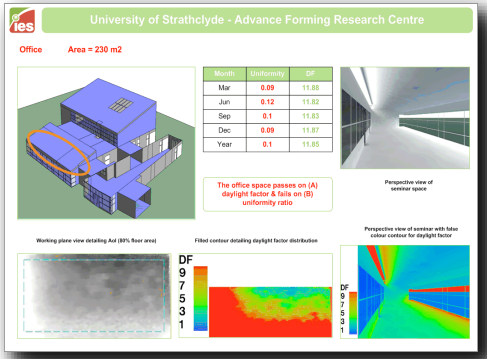


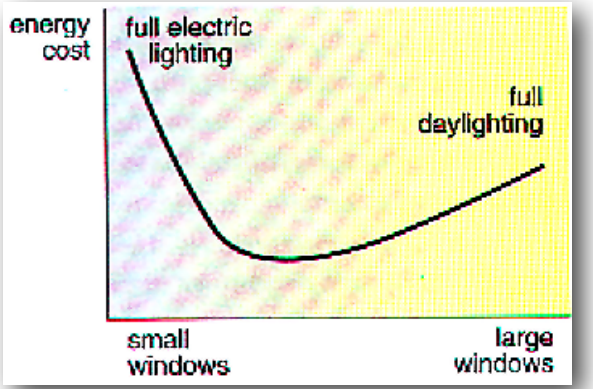
Capacity Building

Now a lot of work involves providing support to clients and consultants to deliver more sustainable buildings and places without excessive cost.



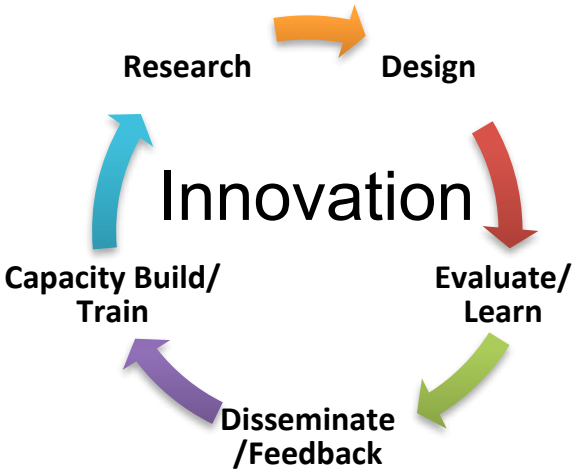






We use a wide variety of physical testing, analytical, modelling, community consultation and gaming tools.

Design Philosophy/ Resources



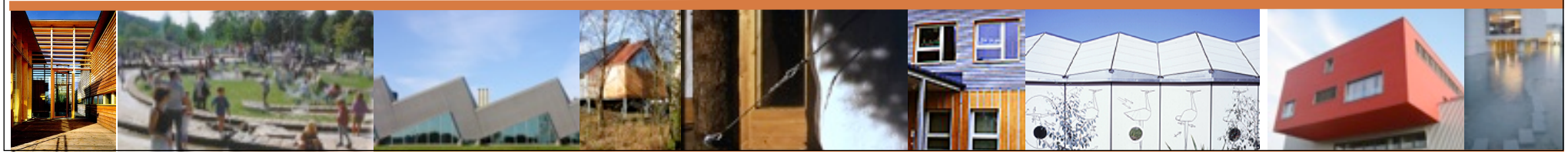
www.gaiagroup.org

Tuesday 13th - Part 2

WORKSHOP

AMBITIONS FOR THE TRAINING SESSION

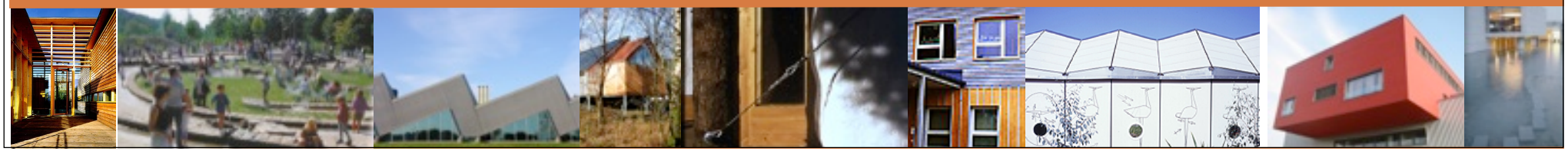
- The participants briefly documented their strengths and weaknesses and what they hoped to get out of the training session.
- These were revisited in the session on Friday morning.



Tuesday 13th - Part 3

INTRODUCTION TO EMBODIED ENERGY

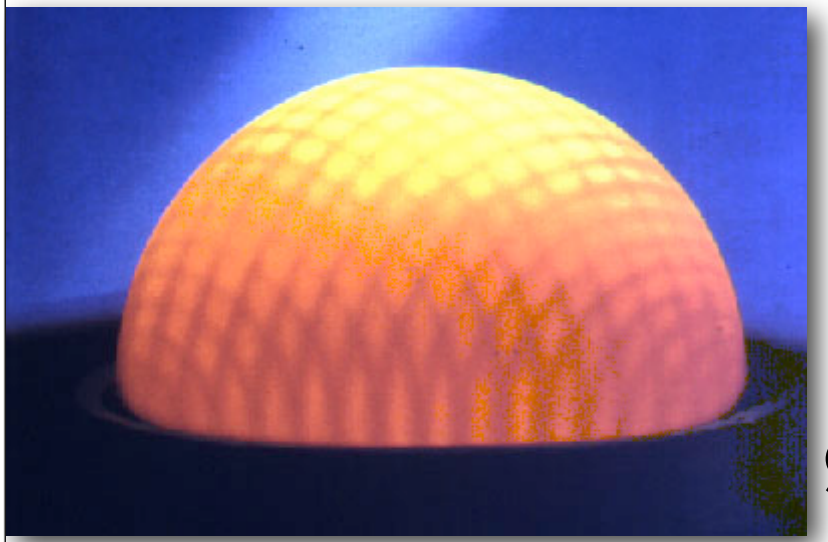
- Energy
- Embodied Energy
- Drivers
  - Climate Change
  - Significant Contribution of Built Environment
  - Legislative Response
  - Design Response
- Methodology
- Projects
- Calculations
- Issues



Primary Energy

- Energy found in nature in raw fuels
- It has not been subjected to any conversion or transformation process.
- It can be non-renewable (fossil fuels) or renewable

Non-renewable (fossil fuel) Energy



gas

oil

coal

Renewable (Clean) Energy

wave

hydro-electric

solar

wind

Embodied Energy

Everything we use has embodied energy





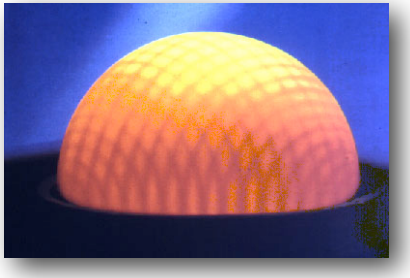



Embodied Energy

- The sum of all the energy required to produce any goods or services
- It is treated as if that energy was incorporated or 'embodied' in the product.
- Allows comparison between products independent of the source of the energy ....which may be renewable (clean) or non-renewable (fossil fuel)
- It is measured in MegaJoules







IT DOES NOT INCLUDE HUMAN ENERGY!

Embodied Energy in buildings

- It includes the energy taken to get raw goods such as plants, stone, sand or aggregate

Embodied Energy in buildings

- and it includes the energy taken to move these raw goods to a factory

Embodied Energy in buildings

- and it includes the energy taken to manufacture or transform these into a product

Embodied Energy in buildings

- and it includes the energy taken to move these products to where they are needed

Embodied Energy in buildings

- and it includes the energy taken to operate the building

Embodied Energy in buildings

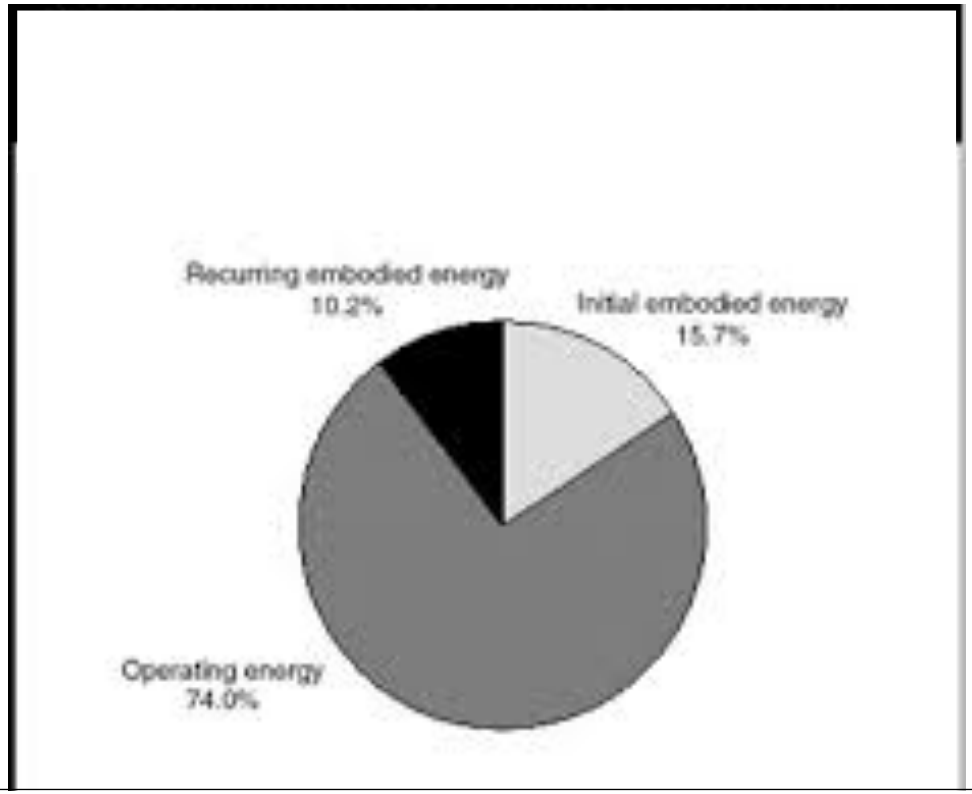
- and it includes the energy taken to maintain or repair them - for example paints, mortars, polish

Embodied Energy in buildings

- and it includes the energy taken to demolish and dispose of them

The embodied energy can be identified and quantified at each stage

and can then be used to plan an effective reduction strategy.



Example

Comparing Housing Components

Embodied energy comparisons			New Zealand house about 195 m^2.
MATERIAL TYPE	**APPROX WEIGHT (KG)**	**EMBODIED ENERGY INTENSITY (MJ/KG)**	**TOTAL EMBODIED ENERGY (MJ)**
Wall cladding			
Timber weatherboard cladding* – kiln-dried, dressed	2,646	9.50	25137
Brick veneer	13,780	6.70	92326
Fibre-cement sheet	2,940	9.40	27636
Roof cladding			
Steel roofing	1,048	34.80	36470
Concrete tile roofing	10,350	0.81	8384
Insulation			
Glasswool insulation	294	30.30	8908
MIneral Wool			

Wall cladding

- **Consider different wall cladding materials - (a)timber, (b) brick veneer, (c) fibre cement**
- **Identify weight of each that would be required**
- **Identify the embodied energy intensity of each**
- **Hence the total embodied energy of each wall.**

☑ **- Timber wall cladding has lowest embodied energy**

Embodied energy comparisons			New Zealand house about 195 m^2.
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Insulation			
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MIneral Wool			

Roof cladding

- **Consider different roofing materials (a) Steel (b) concrete tile**
- **Identify weight of each that would be required**
- **Identify the embodied energy intensity of each & total embodied energy of each roof.**

☑ Steel has an embodied energy/kg around 43 times greater than concrete roof tiles, but the weight of steel required for a roof is far less than the weight of concrete tiles. The comparative EE of a steel roof reduces to about 4 times that of a concrete roof.

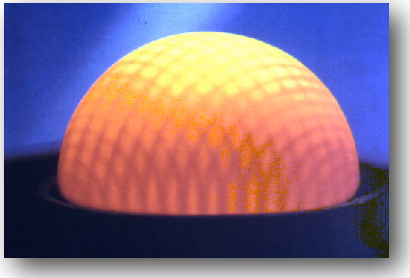
But... it’s about more than energy

Consequences

- Using energy creates pollution
- But some energy creates more pollution:-
  - non-renewable (fossil fuel) energy releases carbon dioxide when burned
  - renewable (clean) energy does not
- Carbon dioxide contributes to climate change
- We call this pollution **embodied carbon**





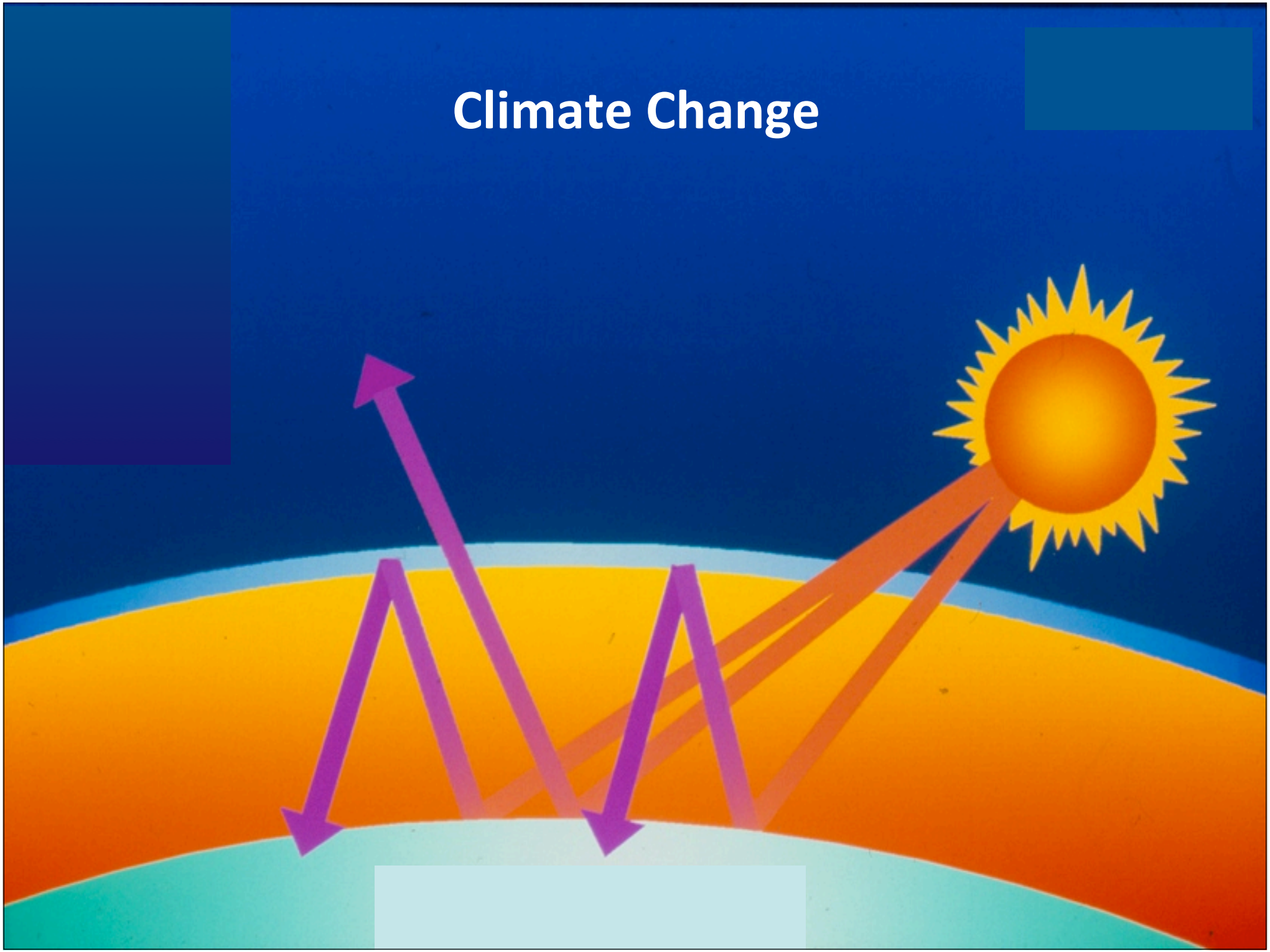


Embodied Carbon ($kgCO_2/kg$)

- The energy used by buildings creates carbon emissions throughout a building life cycle

- due to energy consumption and chemical processes during extraction, manufacture, transportation, assembly, replacement and deconstruction of construction materials or products.
- Embodied carbon is usually expressed in kg of CO_2 per kg of product or material.

Climate Change



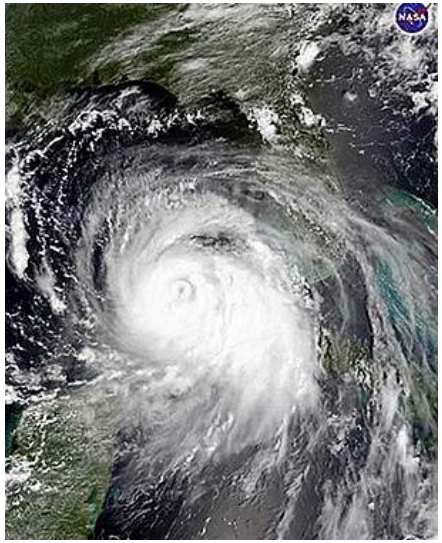
The Greenhouse Effect

- **Shortwave radiation from the sun is reflected from the earth's surface and re-radiated as infra-red heat**
- **CO_2, Methane, Water Vapour and Nitrous Oxide make our world habitable by trapping some of this in the lower atmosphere**
- **Leading to average surface temperatures of 15°C**
- **Without them the earth's surface temperature would be -18°C**

The Greenhouse Effect

- **Anthropogenic gases - CO_2, methane, water vapour, Nitrous Oxide and fluorinated gases such as SF_6 have vastly increased in concentration**
- **So we are trapping more of the sun's heat resulting in global warming and climate change**
- **Deforestation through expansion of land use and acidification of the world's seas has also reduced the natural carbon sinks, making the situation worse.**

Effects



Global Warming Potential - GWP (kgCO2e)

- A measure of the relative impact of a gas on global warming.

Table 1 Global warming potentials (GWP) of greenhouse gases

Greenhouse gas	GWP over 100 years	Typical sources
Carbon dioxide (CO_2)	1	Energy combustion, biochemical reactions
Methane (CH_4)	25	Decomposition
Nitrous oxide (N_2O)	298	Fertilizers, car emissions, manufacturing
Sulfur hexafluoride (SF_6)	22,800	Switch gears, substations
Perfluorocarbon (PFC)	7,390–12,200	Aluminium smelting
Hydrofluorocarbon (HFC)	124–14,800	Refrigerants, industrial gases

Based on *Climate Change 2007: The Physical Science Basis*. Working Group I Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Table 2.14. Cambridge University Press.

- E.g., Methane has a global warming potential of 25
  - 1 kg of Methane has the same impact on climate change as 25 kg of CO_2
  - 1 kg of Methane counts as 25 kg of CO_2 equivalent emissions or CO_{2e}

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E.g., Perfluorocarbon (PFC) has a GWP of 7,390-12,200

- 1 kg of Perfluorocarbon (PFC) has the same impact on climate change as 7,390-12,200 kg of CO_2
- 1 kg of Perfluorocarbon (PFC) counts as 7,390-12,200 kg of CO_2 equivalent emissions or CO_{2e}

How much Pollution can the world take?

	State of the World	
	Optimists Right	**Pessimists Right**
Optimistic Policy		
Pessimistic Policy		

- There is widespread but not total agreement that we need to behave in a precautionary manner
- Use less energy and less polluting forms of energy

Data

Analysis can be undertaken on the basis of:

- **Embodied Energy**
- **Embodied Carbon**
- **Embodied Carbon Equivalence**

Care should be taken to ensure that comparisons undertaken on the same basis.

- **It is increasingly common practice to use embodied carbon**
- **Most available data is based on embodied carbon.**

Why is embodied energy important?

- The built environment is responsible for 30% of GHG emissions worldwide
- Regulation, taxation and design developments are making it increasingly important

European Tax & Regulatory Changes

1. **Taxation - Carbon Levy**
2. **Regulated improvements to thermal performance of buildings - fabric, air tightness**
3. **Regulated Improvements to Operational energy - to manage and reduce the energy consumption from lighting, heating, ventilation and air conditioning**

This has led to buildings with:-

- more glazing
- increased controls
- increased thermal mass
- increased insulation
- passive solar design
- enhanced daylighting
- reduced air changes - decrease heating & cooling
- more renewable energy
- rainwater harvesting

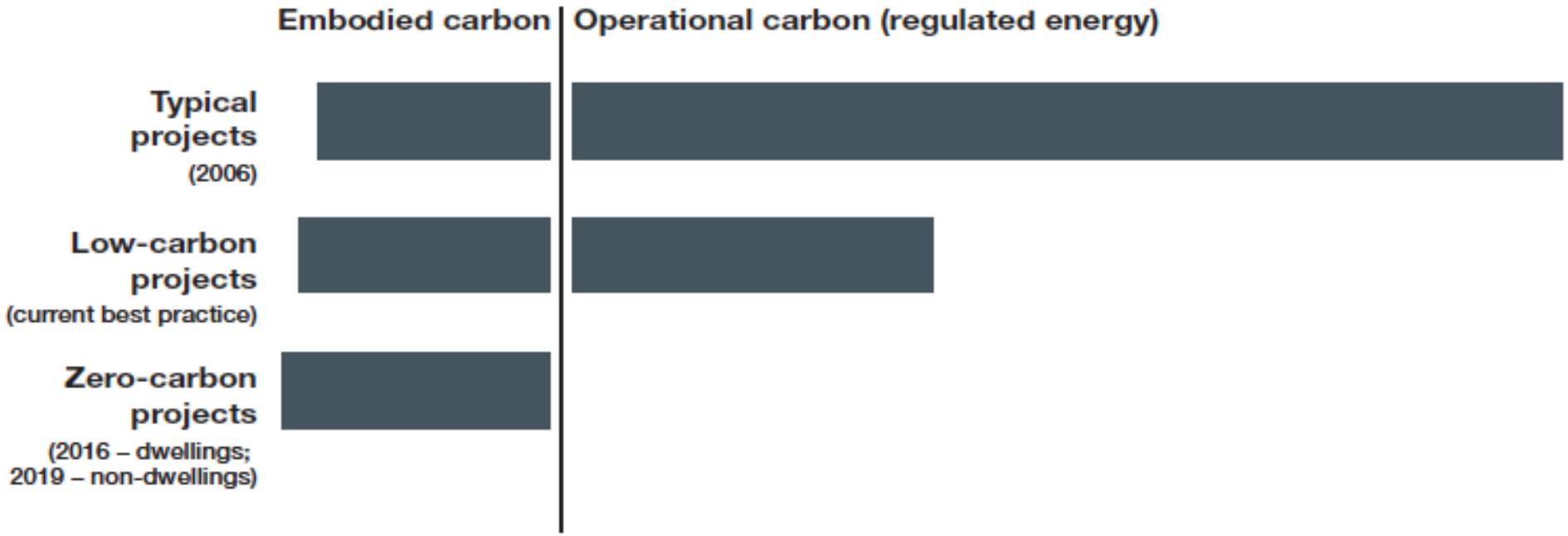
This has decreased operational energy

but increased embodied energy

- increased thermal mass increases embodied energy
- increased insulation increases embodied energy
- renewable energy has **embodied energy in concrete, equipment & controls**
- **rainwater harvesting has embodied energy in tanks, pipes & pumps**

Changes

- **the relative contribution of embodied carbon to the overall life cycle embodied energy is continuously increasing**



The embodied carbon used to create a building may be as high as 62% of its total whole life emissions

UK Tax and Regulatory Changes

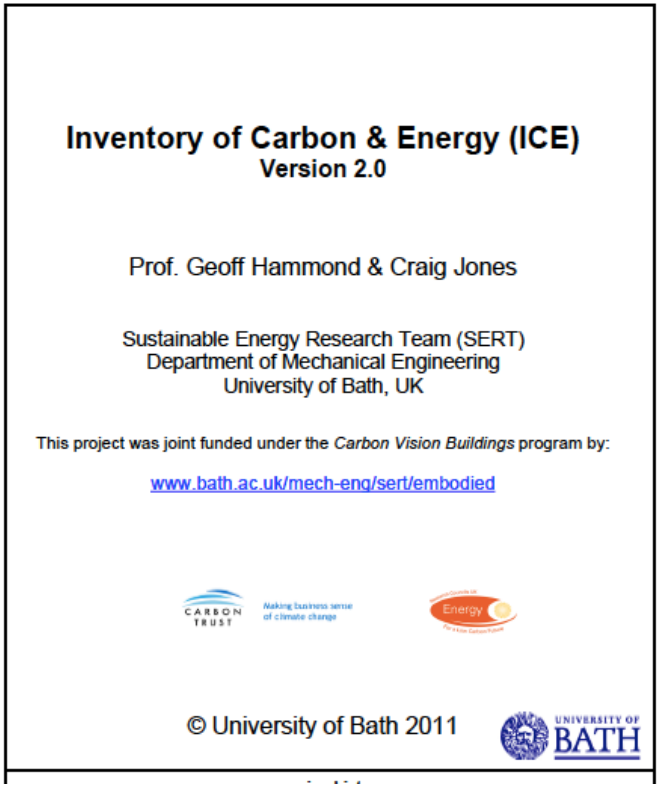
1. Taxation - Carbon Levy
2. Regulated improvements to thermal performance of buildings - fabric, air tightness
3. Regulated Improvements to Operational energy - to manage and reduce the energy consumption from lighting, heating, ventilation and air conditioning
4. Now targeting embodied energy & embodied carbon

Resources


RICS QS & Construction Standards IP 32/2012
RICS Professional Information, UK
Methodology to calculate embodied carbon of materials
1st edition, information paper
RICS
the mark of property professionalism worldwide
rics.org/standards

ICE Database

- Generic data base
- Produced by University of Bath
- Data Supplied by manufactures
- Average values for materials
- Global sources
- Range of studies
- Comprehensive in materials
- Comprehensive breakdown of building types



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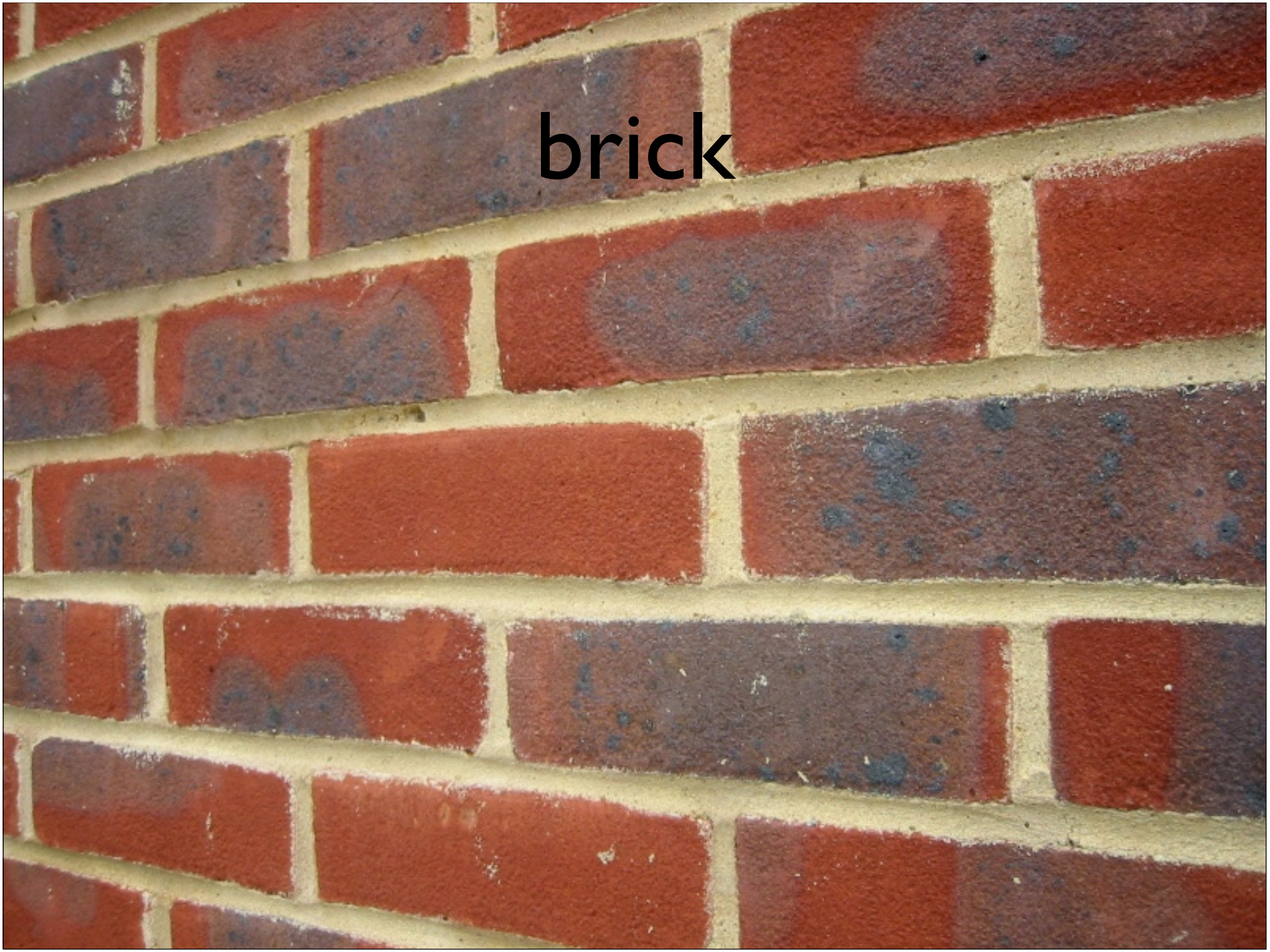
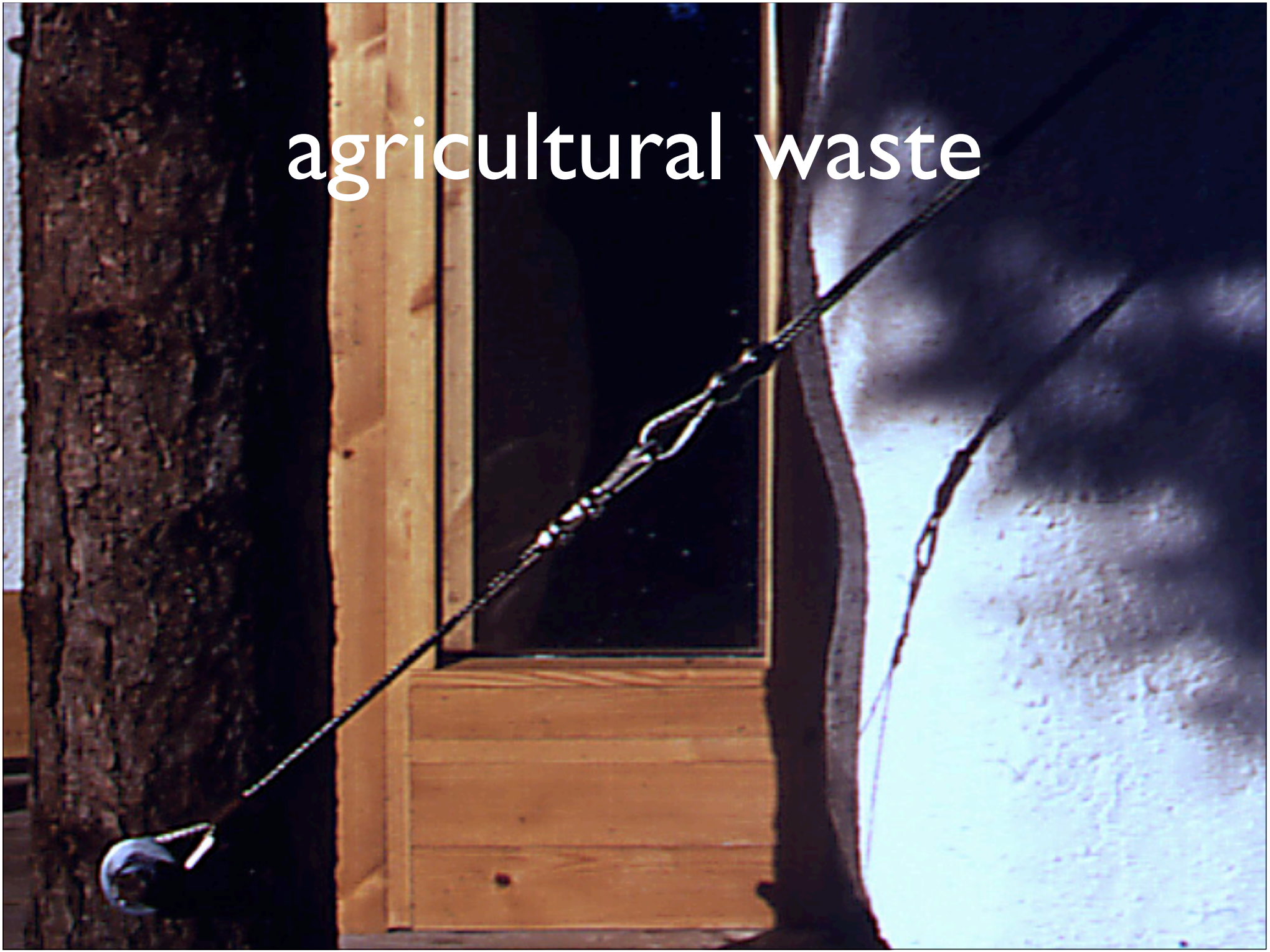
concrete

steel


brick


earth


timber


agricultural waste

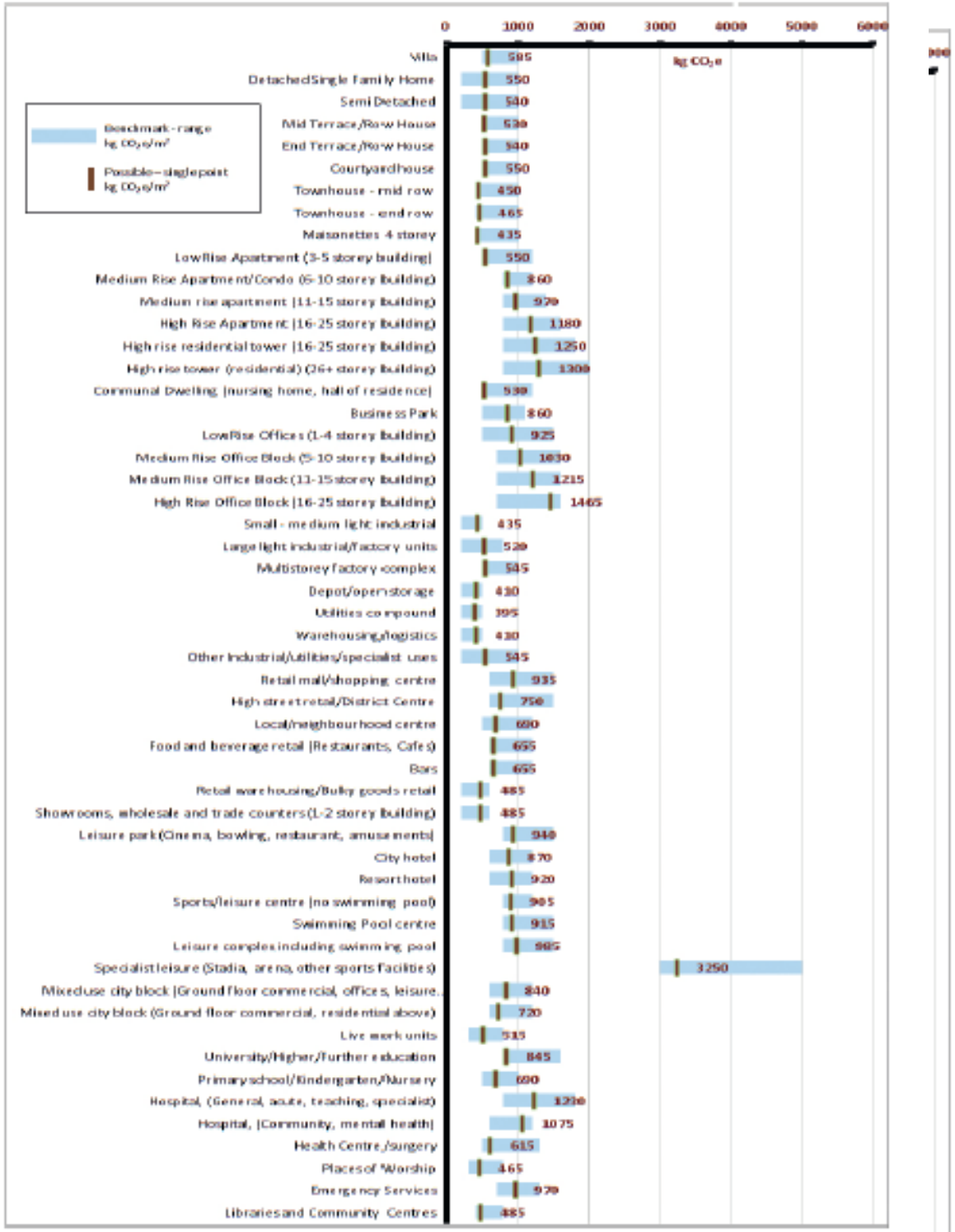

stone

plastic

Building types

Large range indicates a small data set /lack of captured boundaries and high level of inaccuracy

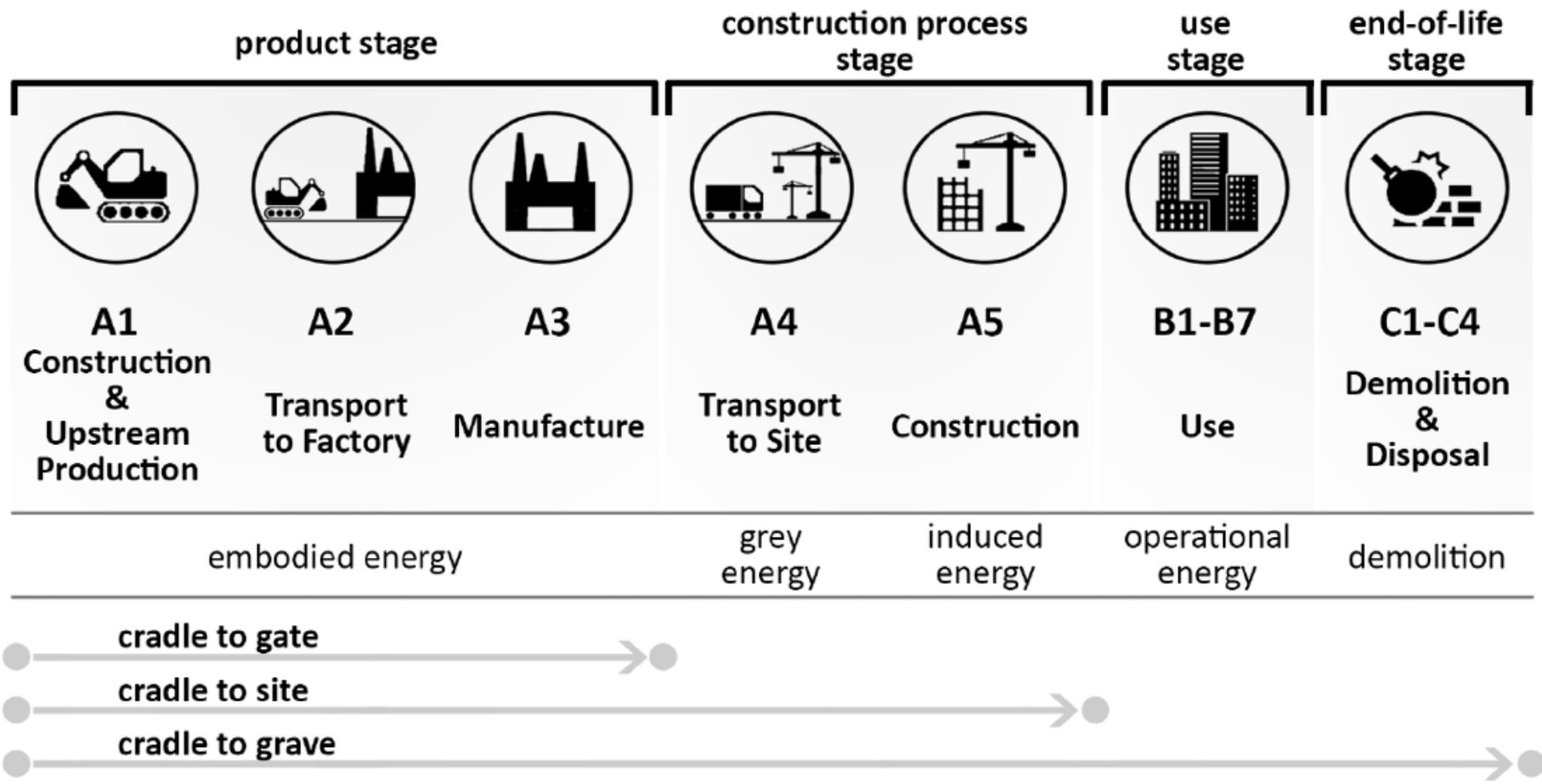
(i.e. there is uncertainty whether some studies included basements, external works, furniture, etc.)



System Boundary

Embodied carbon can be measured from

- cradle-to-gate,
- cradle-to-site,
- cradle-to-end of construction,
- cradle-to-grave,
- cradle-to-cradle.


product stage
construction process stage
use stage
end-of-life stage
A1
Construction & Upstream Production
A2
Transport to Factory
A3
Manufacture
A4
Transport to Site
A5
Construction
B1-B7
Use
C1-C4
Demolition & Disposal
embodied energy
grey energy
induced energy
operational energy
demolition
cradle to gate
cradle to site
cradle to grave

Glossary

- **Cradle-to-gate carbon emissions**

Carbon emissions between the confines of the 'cradle' (earth) up to the factory gate of the final processing operation. This includes mining, raw materials extraction, processing and manufacturing.

- **Cradle-to-site carbon emissions**

Cradle-to-gate emissions plus delivery to site (construction/installation site).

- **Cradle-to-end of construction**

Cradle-to-site plus construction and assembly on site.

- **Cradle-to-grave carbon emissions/Life cycle carbon**

Cradle-to-end of construction plus maintenance, refurbishments, demolition, waste treatment and disposals ('grave').

Glossary

- **Cradle-to-cradle**

The process of making a component or product and then, at the end of its life, converting it into a new component of

- a) the same quality (e.g. recycling of aluminium cans) or
- b) a lesser quality (downcycling of a computer plastic case into a plastic container, which is then turned into a building insulation board, eventually becoming waste).

Glossary

- **Operational carbon**

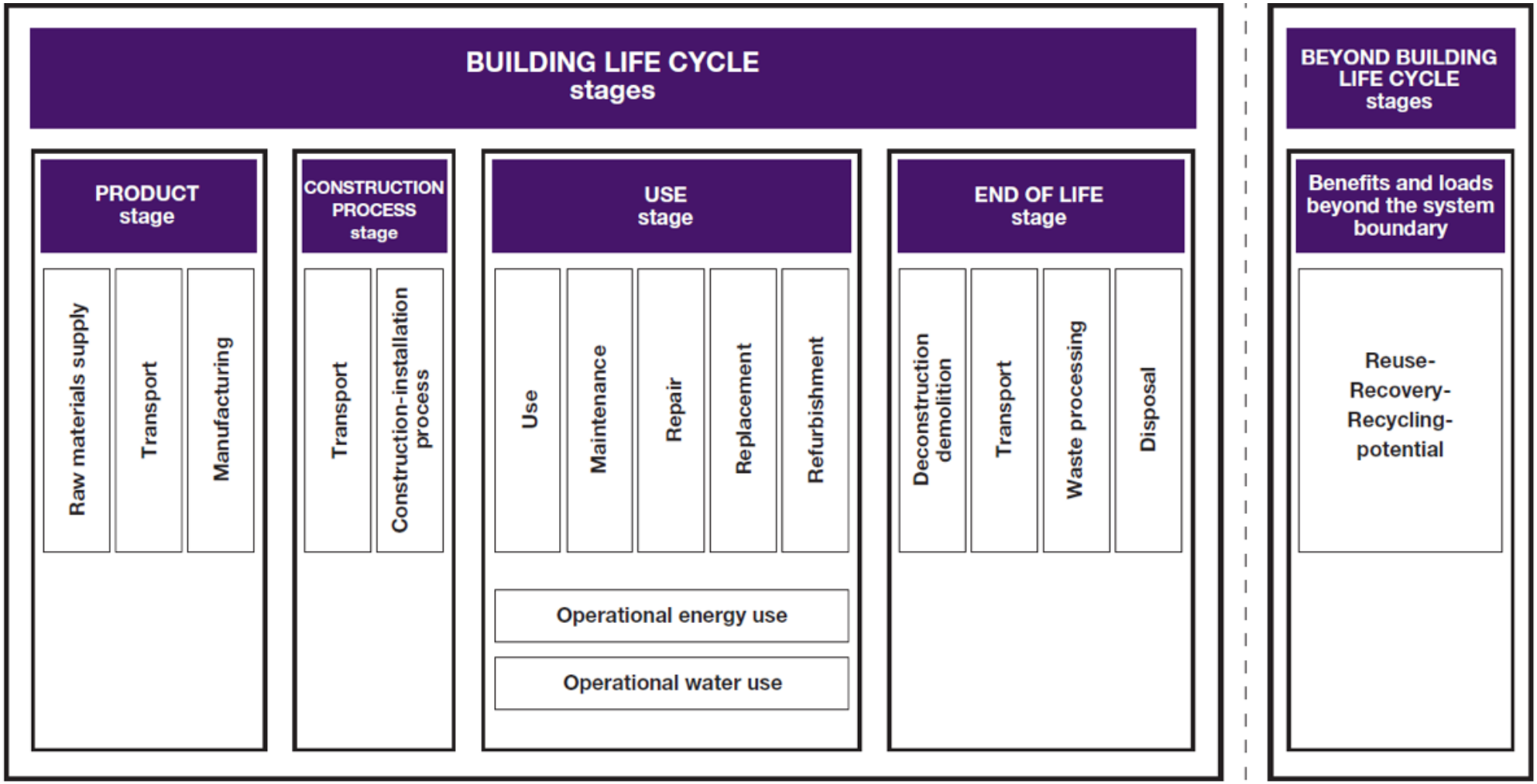
Carbon emissions' association with energy consumption (operational energy) while the building is occupied.
This includes the so-called regulated load (e.g. heating, cooling, ventilation, lighting) and unregulated/plug load
(e.g. ICT equipment, cooking and refrigeration appliances)

- **Carbon hotspot**

The carbon significant aspect of a project which should be targeted for reduction. Carbon hotspots represent not only carbon-intense elements but also quick wins, where measurement data is more easily available and where carbon reductions are possible.

- **Recycled content**

The portion of a product that contains materials that have been recovered or otherwise diverted from the solid waste stream.


BUILDING LIFE CYCLE
stages
PRODUCT
stage
Raw materials supply
Transport
Manufacturing
CONSTRUCTION
PROCESS
stage
Transport
Construction-installation
process
USE
stage
Use
Maintenance
Repair
Replacement
Refurbishment
Operational energy use
Operational water use
END OF LIFE
stage
Deconstruction
demolition
Transport
Waste processing
Disposal
BEYOND BUILDING
LIFE CYCLE
stages
Benefits and loads
beyond the system
boundary
Reuse-
Recovery-
Recycling-
potential

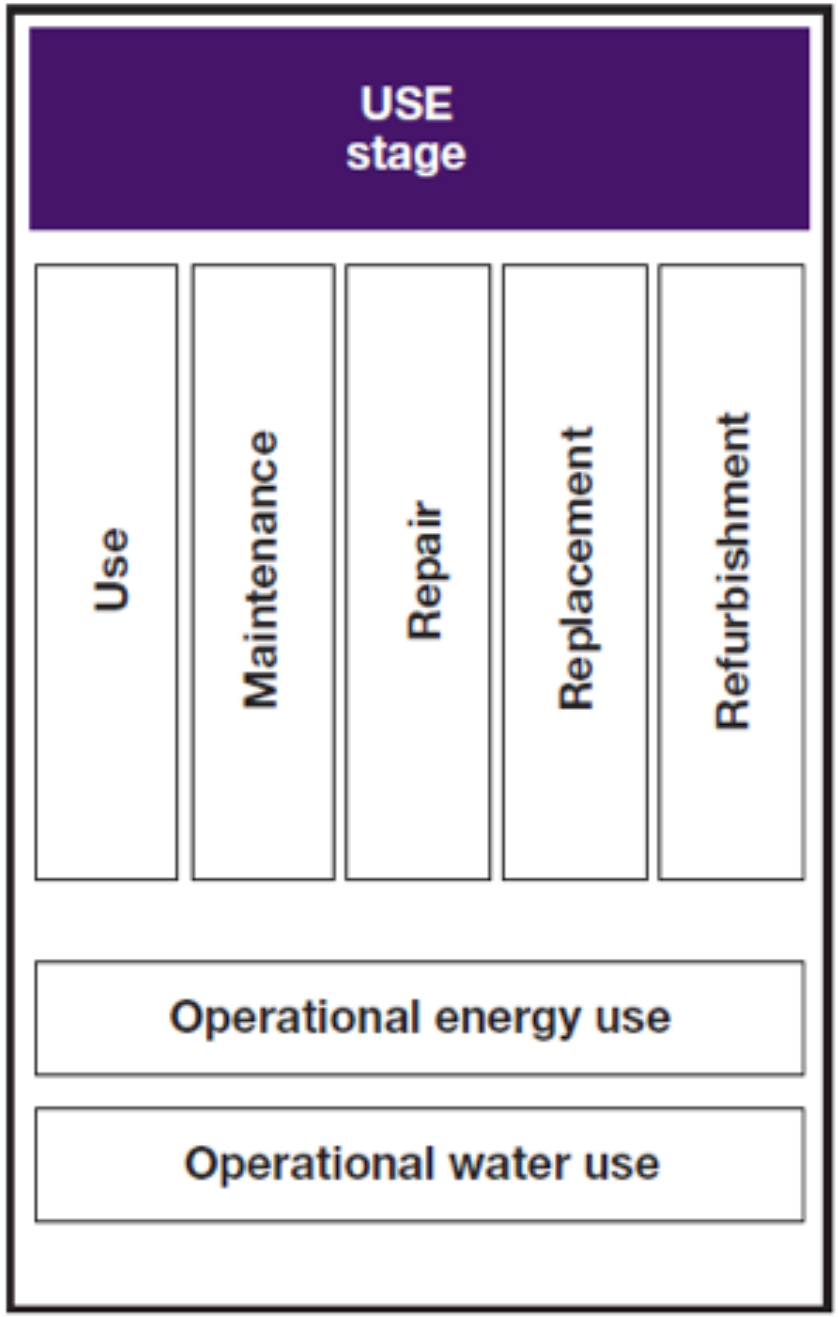
stages

Materials or product manufacture cradle-to-gate emissions are those associated with the production of construction products/ materials.

- The emissions arise from the energy used in
  - ✦extracting materials,
  - ✦refining them (i.e. primary manufacture),
  - ✦transporting &
  - ✦ processing them to produce a finished product (i.e. secondary manufacture).

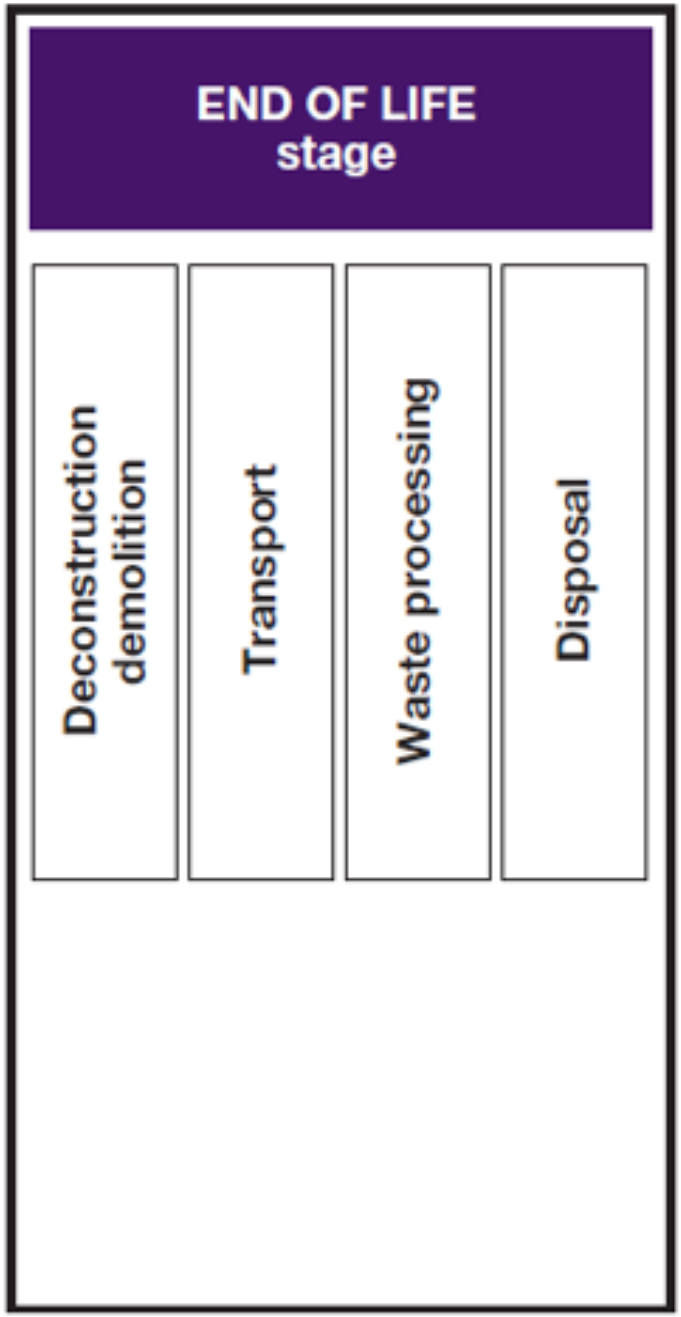
Emissions from the construction phase include energy and fuel consumption during:

- transportation of material to and from site,
- enabling works,
- remediation,
- clearance,
- removal/ demolition of existing structures,
- ground improvements,
- earthworks,
- assembly.



Carbon emissions from the building use include :-

- operations emissions resulting from heating, lighting, ventilation, air conditioning, etc.(75%)
- maintenance, repair, replacements and refurbishments of building elements (e.g. fabric or services).



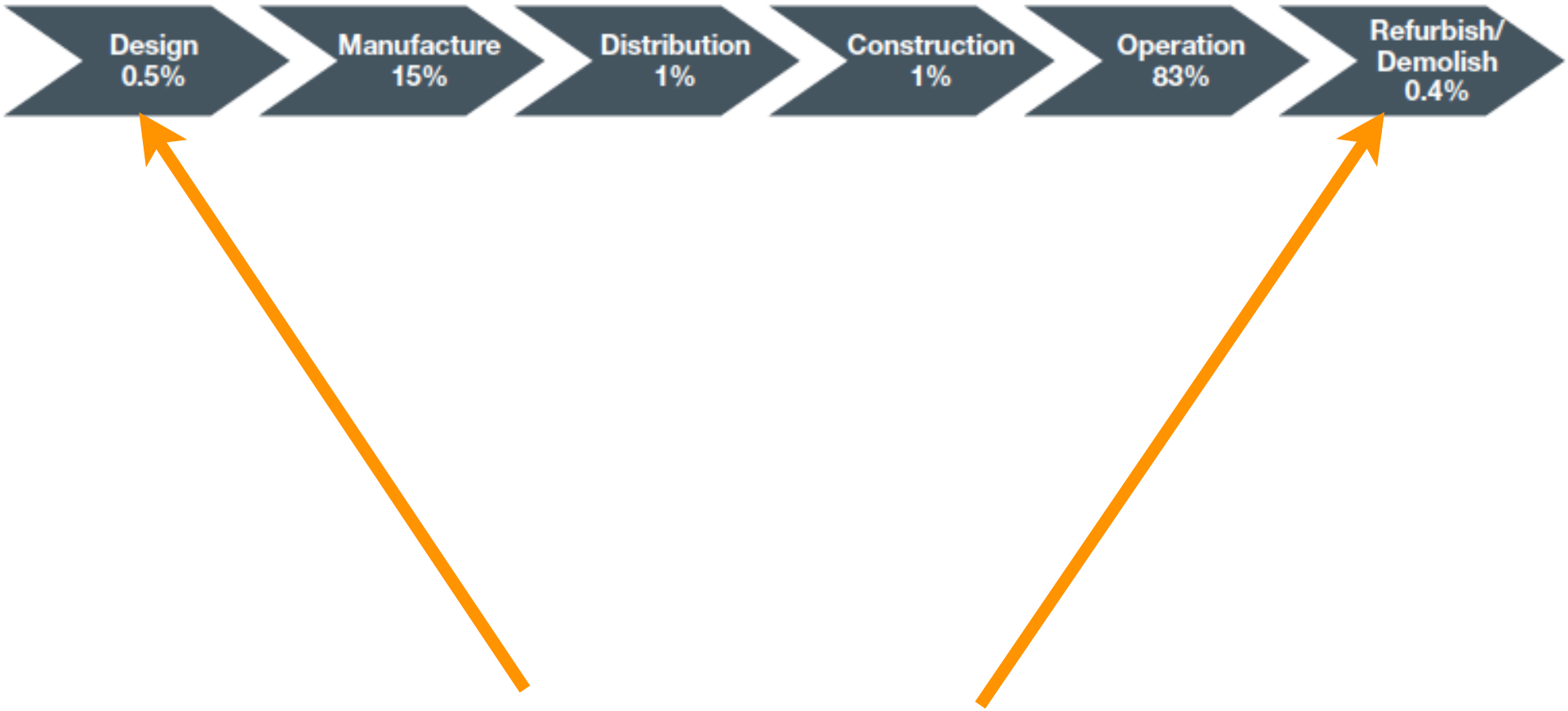
End of life emissions are those associated with energy consumed during building demolition and waste disposal processes.

Benefits and loads beyond the system boundary

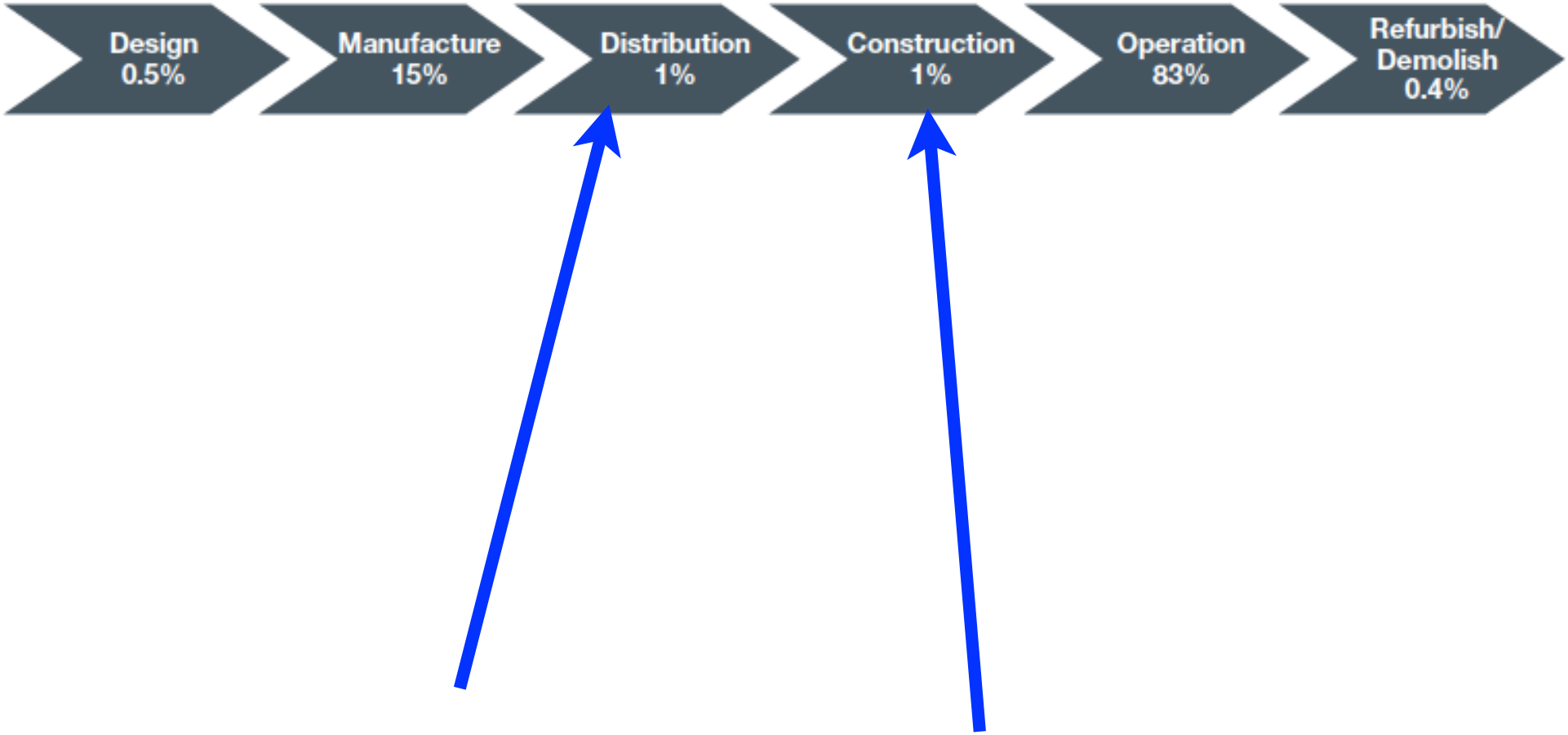
Reuse-
Recovery-
Recycling-
potential

The carbon impacts beyond the building lifecycle emissions.

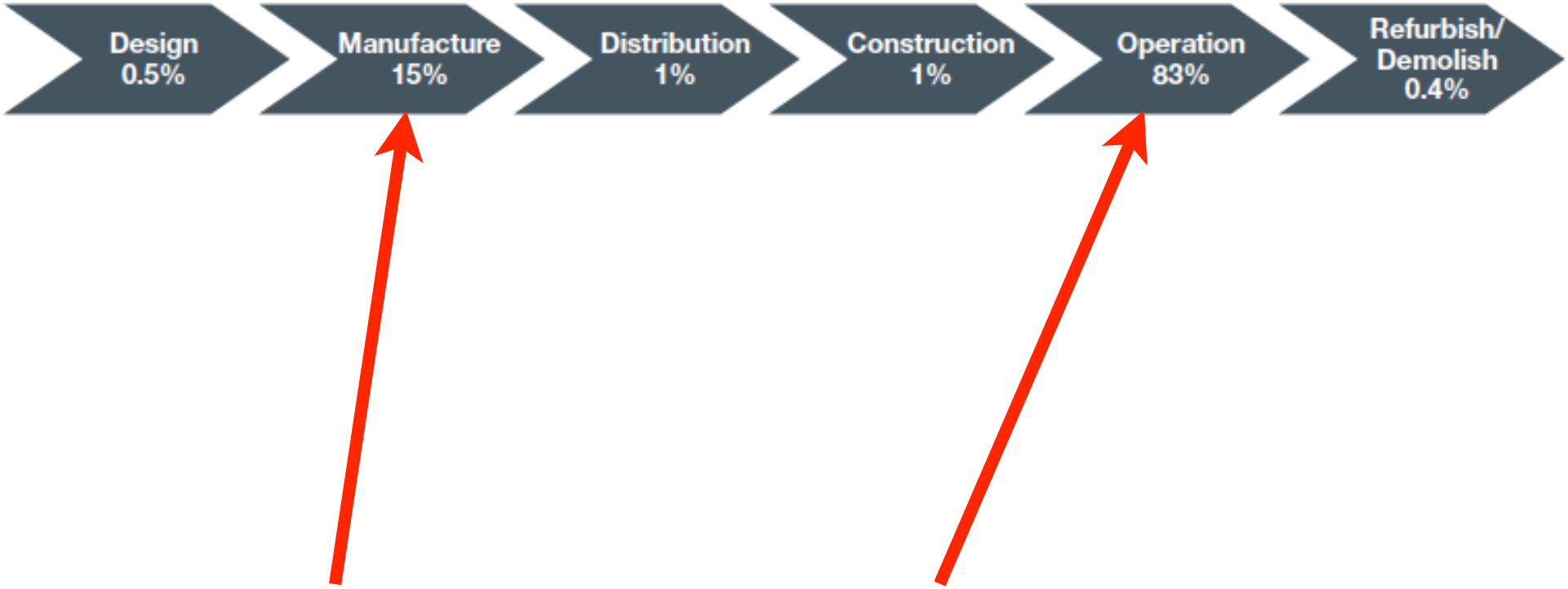
CO2 emissions - UK Context



UK Context

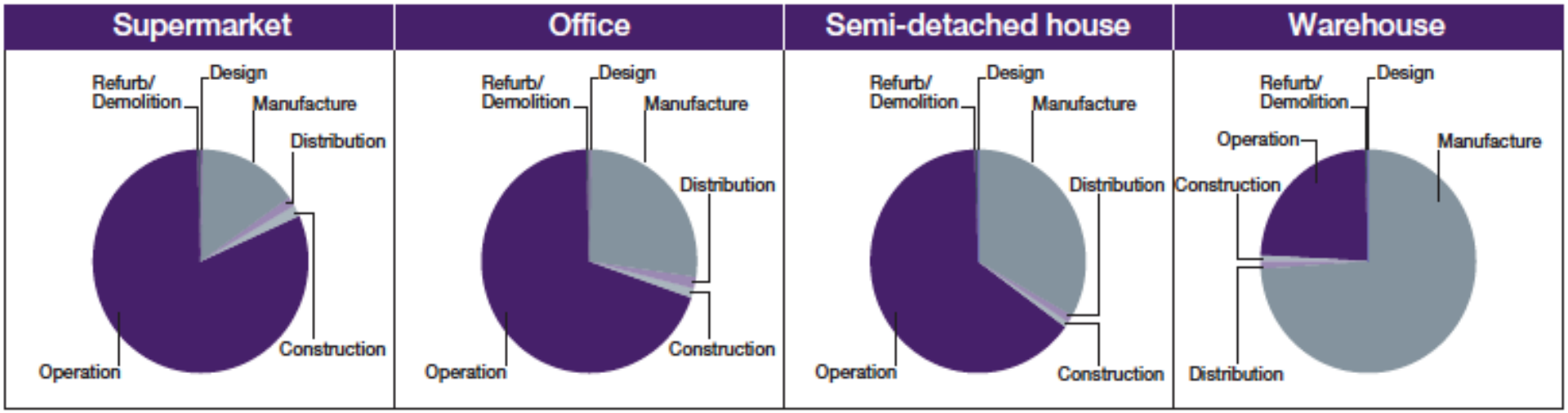

Design
0.5%
Manufacture
15%
Distribution
1%
Construction
1%
Operation
83%
Refurbish/
Demolish
0.4%

UK Context

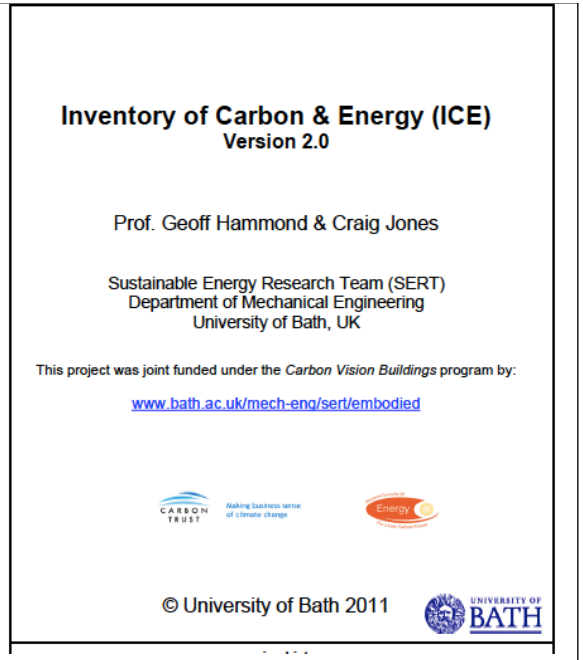


- Because of this typical embodied carbon datasets in the UK are **cradle-to-gate**.
- Expectation that operation is calculated separately

But it differs for different building types.....



System Boundary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- ICE carbon datasets are cradle-to-gate
- With typical ranges for building types
- These figures are unlikely to be replicable in Tanzania context
- So we need to gather the data

WORKSHOP

WHAT FACTORS DO WE NEED TO CONSIDER AT EACH STAGE?

CO_2 emissions - Design

- Drawings
- Use machinery, computer
- Site visit
- Transport
- Site planning/design
- Design with/for the site

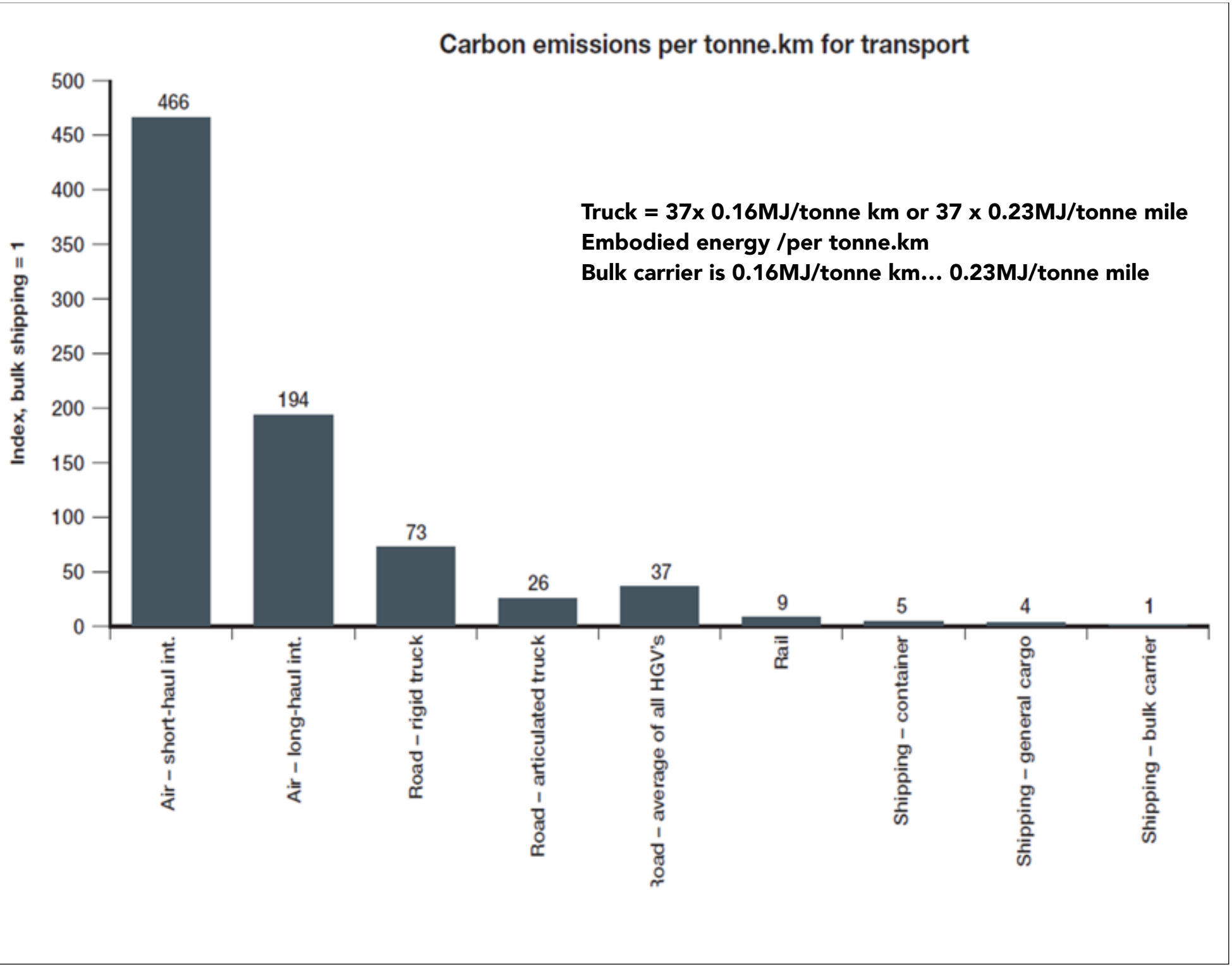
CO_2 emissions - Manufacturing

- Bricks
- Windows frames
- Expanded metal
- Weld meshes
- Mosquito gauze
- Ceiling board
- Finishing materials - paints, flooring
- Sanitary /electrical appliances/Pipes
- Power tools
- Timber for roofing
- Processing and transportation
- Waste removal
- Sand
- Reinforcement bars
- Cement
- Aggregates
- Burglar bars

Example - Soil cement brick

- Soil
- Cement
- Transportation
- Water
- Extraction of soil
- Production of cement
- Roofing tiles
- Water source
- Production energy

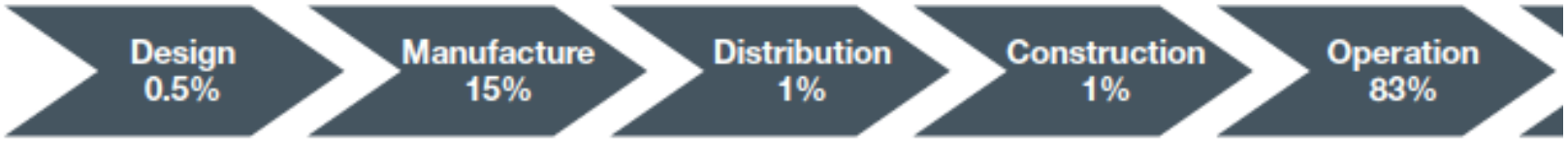
CO_2 emissions - Distribution


Carbon emissions per tonne.km for transport
Index, bulk shipping = 1
500
450
400
350
300
250
200
150
100
50
0
466
194
73
26
37
9
5
4
1
Air – short-haul int.
Air – long-haul int.
Road – rigid truck
Road – articulated truck
Road – average of all HGV's
Rail
Shipping – container
Shipping – general cargo
Shipping – bulk carrier
Truck = 37x 0.16MJ/tonne km or 37 x 0.23MJ/tonne mile
Embodied energy /per tonne.km
Bulk carrier is 0.16MJ/tonne km... 0.23MJ/tonne mile

CO_2 emissions - Construction

- Transport
- Machinery
- Energy for complimentary building works (foundation etc)
- Septic pits
- Wetland
- Water tank and tower
- Roads

CO_2 emissions - Operation & Use



- Availability of utilities, electricity, water supply
- Transport facilities
- Time consumption
- Light
- Water
- Cooking
- Cooling

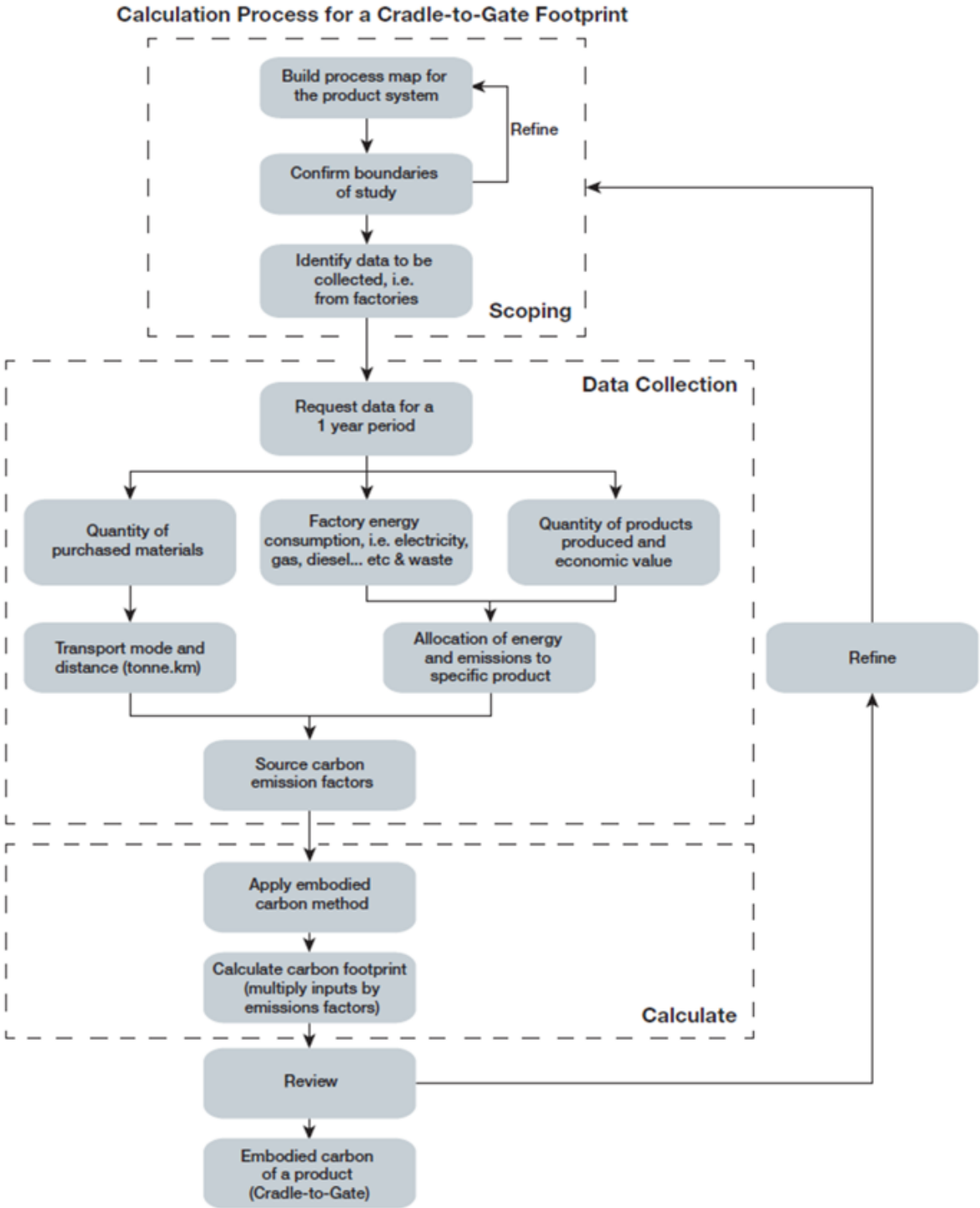
CO_2 emissions - Maintenance

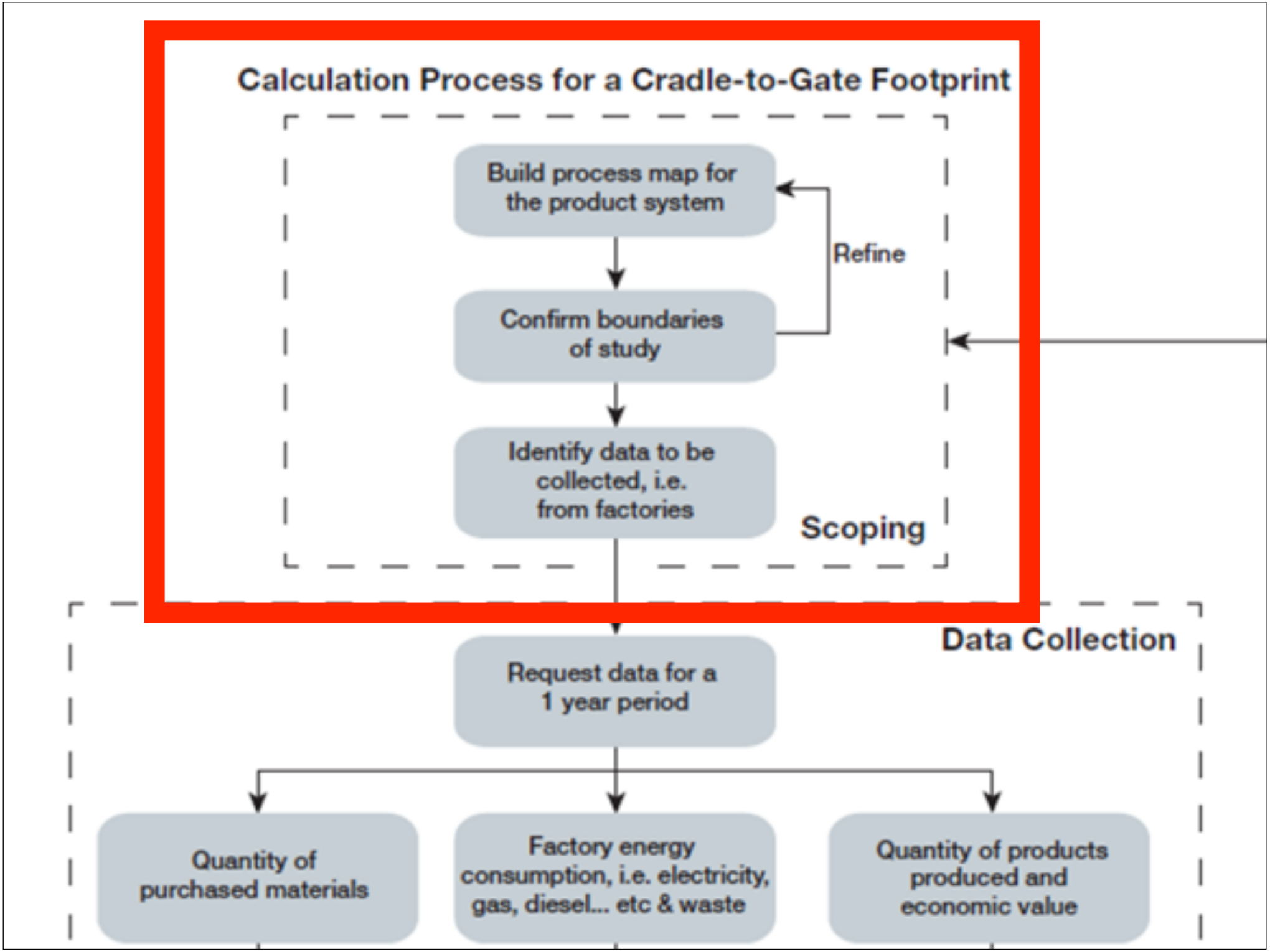
- Paints
- Transport
- Fumigation
- Cleaning
- Electrical systems
- Maintaining air conditioning
- Landscape
- Roads

CO_2 emissions - Disposal

- Waste water
- Excavated soil (disposed soil)
- Solid wastes
- Recycling materials
- Equipment for demolishing

Methodology


Calculation Process for a Cradle-to-Gate Footprint
Build process map for the product system
Refine
Confirm boundaries of study
Identify data to be collected, i.e. from factories
Scoping
Data Collection
Request data for a 1 year period
Quantity of purchased materials
Factory energy consumption, i.e. electricity, gas, diesel... etc & waste
Quantity of products produced and economic value
Transport mode and distance (tonne.km)
Allocation of energy and emissions to specific product
Source carbon emission factors
Refine
Apply embodied carbon method
Calculate carbon footprint (multiply inputs by emissions factors)
Calculate
Review
Embodied carbon of a product (Cradle-to-Gate)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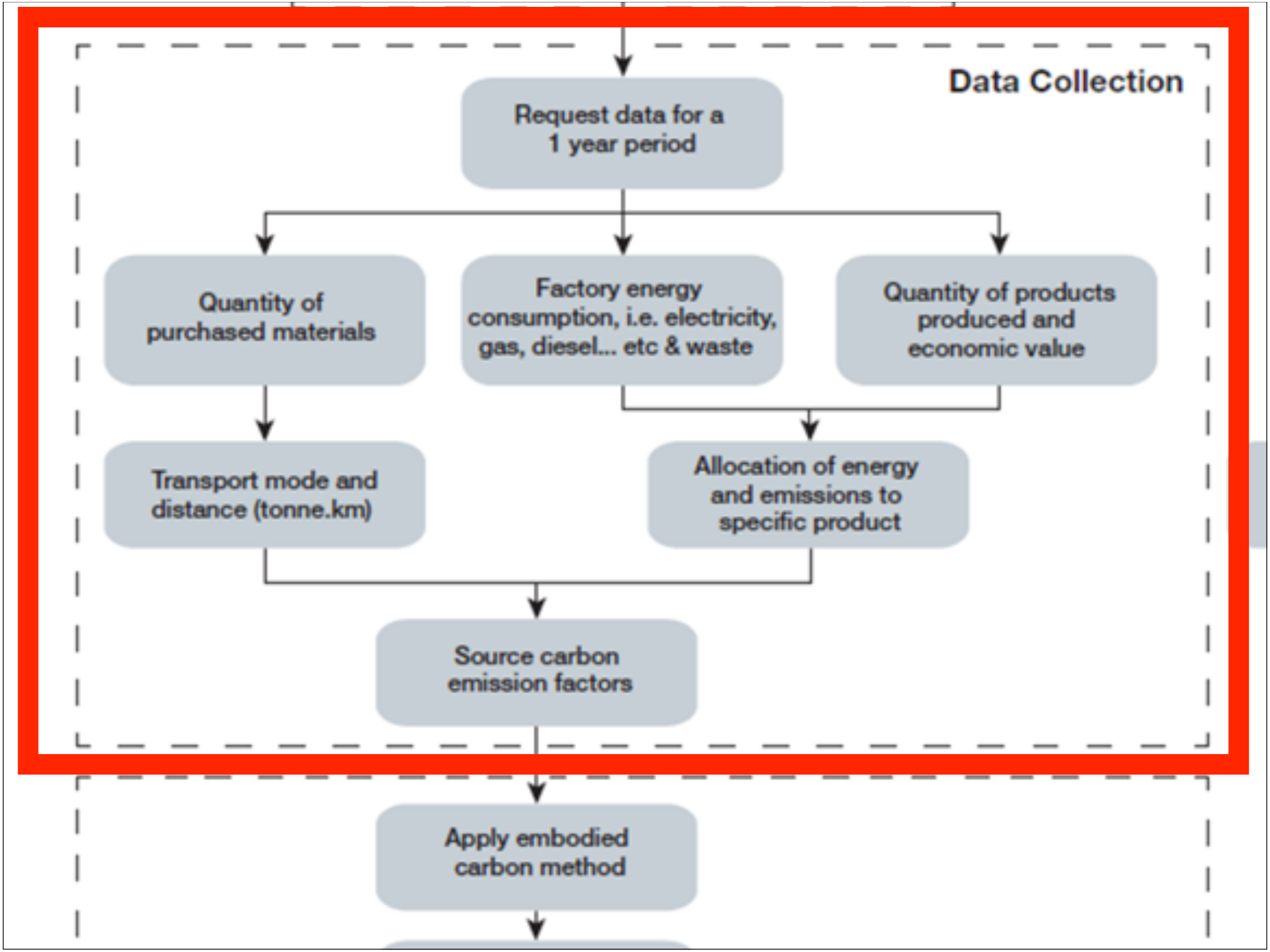
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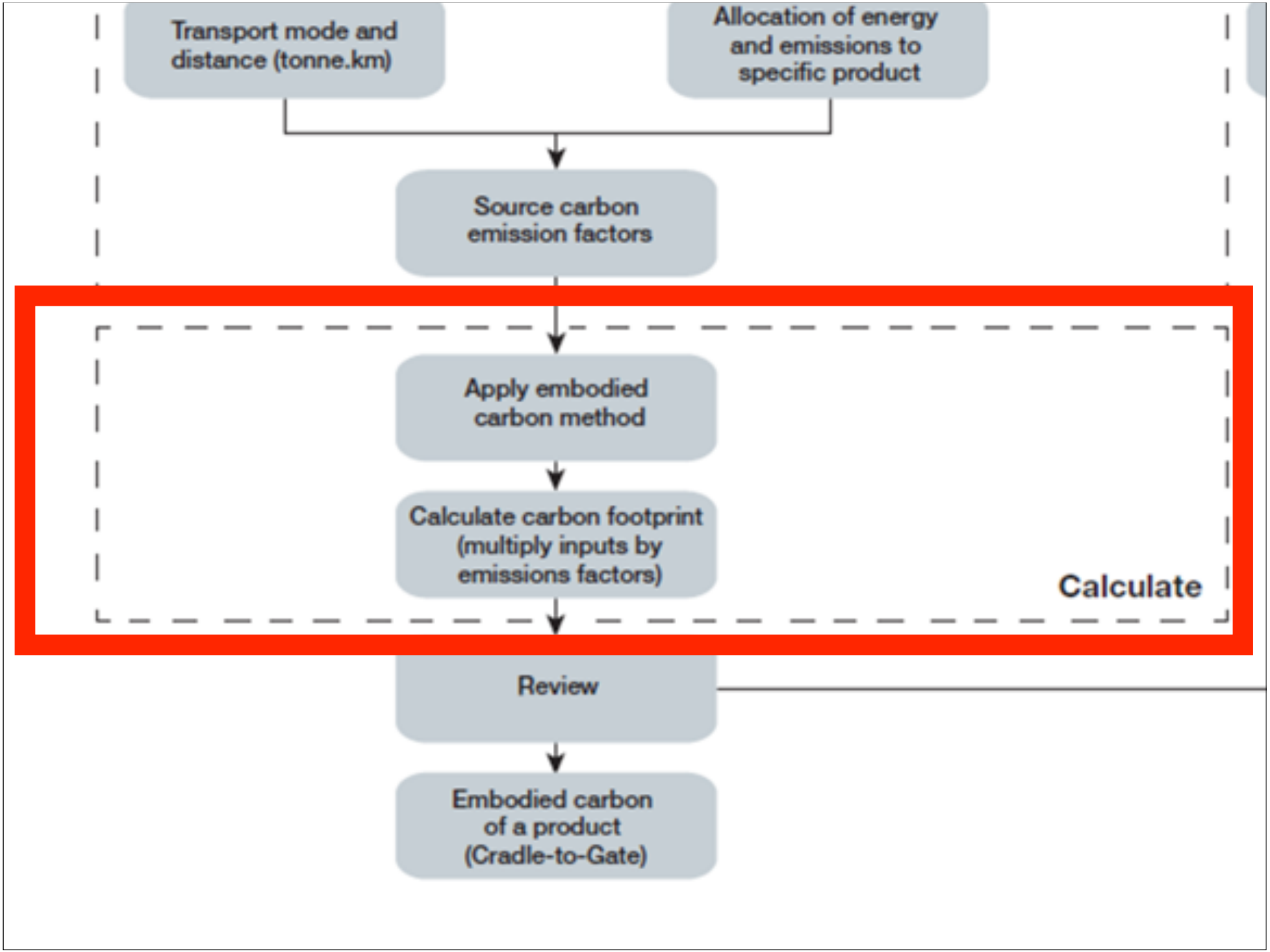
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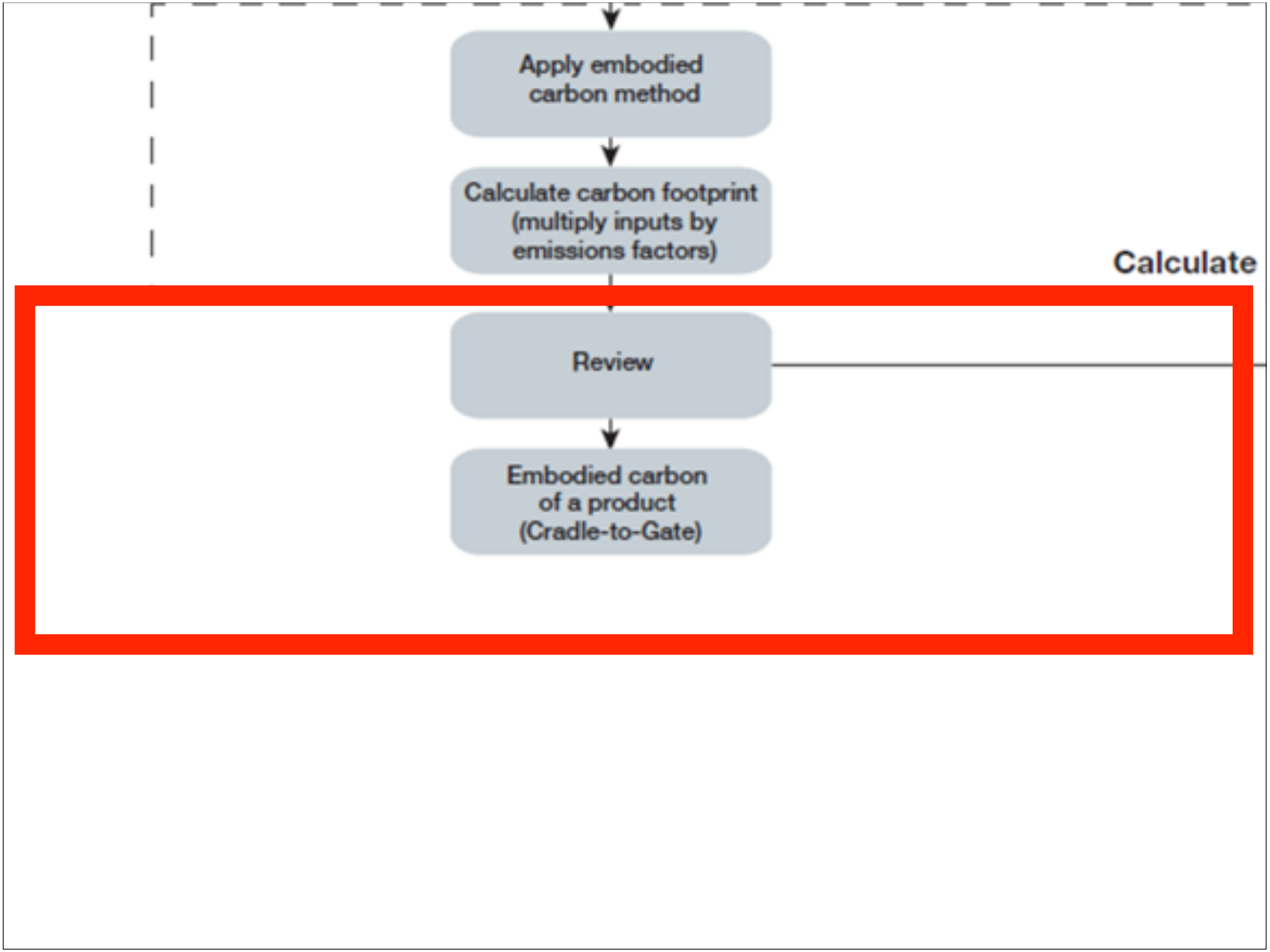
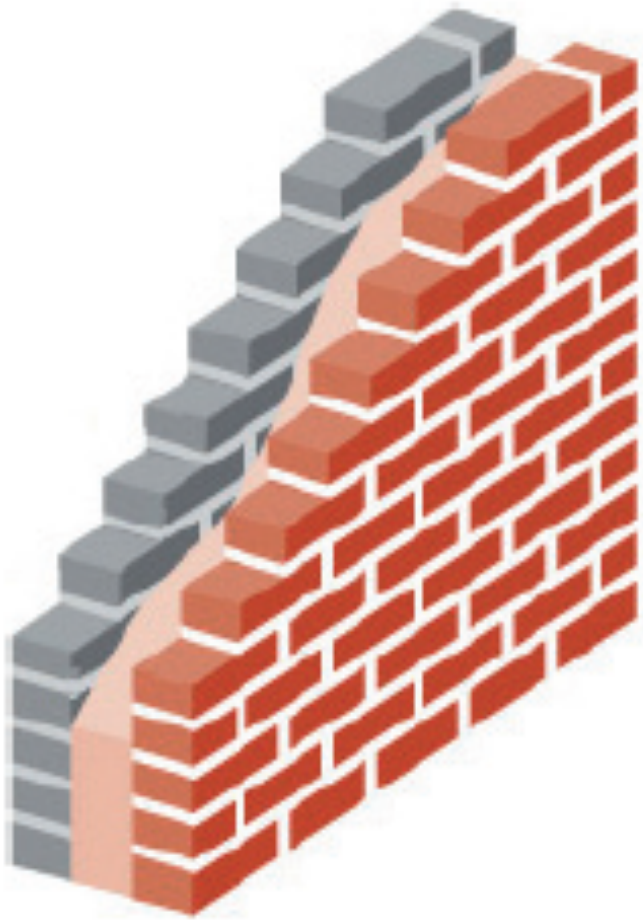
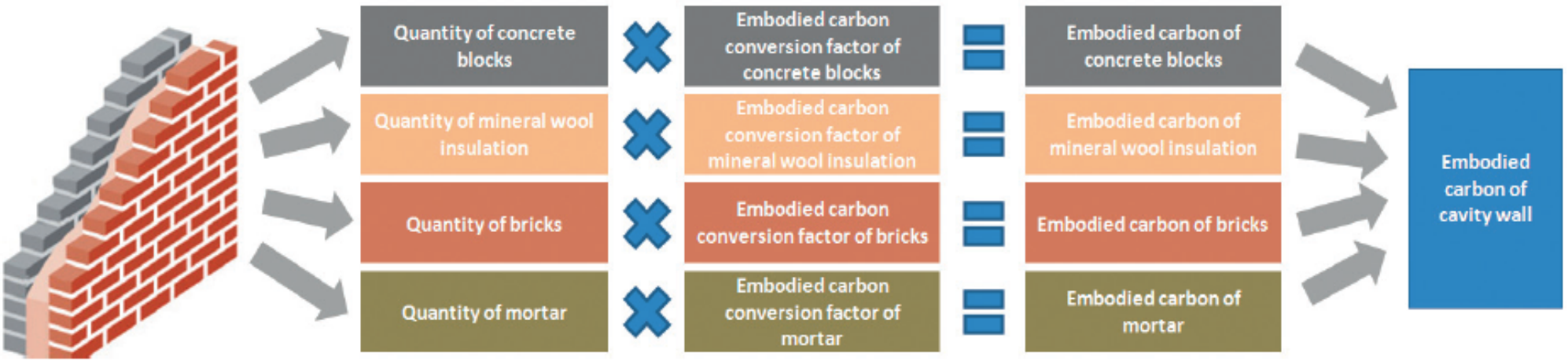

Apply embodied carbon method
Calculate carbon footprint (multiply inputs by emissions factors)
Calculate
Review
Embodied carbon of a product (Cradle-to-Gate)

Consider a cavity Wall





Break into component parts

Establish quantities and types of materials source

Establish embodied carbon for each part ($kgCO_2/kg$)

Multiply

Summate


Case Study

Hydro-Electric Plant - Considerations

Components

- Materials

Construction

- Construction supervision

In Use

- Ongoing routine maintenance
- Imported energy - occasional lighting, heating, instrumentation

Item	Material	Unit	Density	Mass	Embodied emissions / Unit	TOTAL Embodied emissions	TOTAL Embodied emissions
Components		m3	kg/m3	Kg	KgCO2/Kg	kgCO2	tCO2
			Concrete 1750-2400kg/m3				
Intake 1	Concrete, 2% steel re-enforcing	30	2307	69,210	0.265	18,341	18.3
Intake 2	Concrete, 2% steel re-enforcing	10	2307	23,070	0.265	6,114	6.1
Turbine House	Concrete, 1% steel re-enforcing	41	2307	94,587	0.222	20,998	21.0
Turbine House	Autoclaved aerated blocks	100	360	36,000	0.375	13,500	13.5
Pipe line	High Density Polyethylene	134	955	127970	2	255,940	255.9
Turbine & Housing	Steel			8000	1.8	14,400	14.4
Generator & Control Equipment	Steel			2000	1.8	3,600	3.6
	Copper			6000	5.57	33,420	33.4
Construction		Litres			KgCO2/L		
Travel	Diesel Fuel (estimated)	25,000			2.7	67,500	67.5
TOTAL							**433.8**

Item	Annual Demand	Carbon intensity Unit	TOTAL Embodied emissions	TOTAL Embodied emissions
IN USE	KWh	KgCO2/kWh	kgCO2	tCO2
Imported Energy	600	0.622	373.20	0.37
	Litres	KgCO2/L		
Diesel Fuel	1,040	2.7	2,808.00	2.81
	KWh	KgCO2/kWh		
Exported Energy	2,062,000	0.622	1,282,564.00	1282.56
Total				1279.38

Net carbon Balance

Operational emissions - Embodied Emissions

Yr 1 = 1279.3 - 433.8 = 846.5 tCO_2

Yr 2 - Yr 40 = 1279.3 tCO_2

Life time = 846.5 + 39 x 1279.3 = 50,738.2 tCO_2

Discuss

- Has anything been excluded?
- What are the boundary conditions?

Carbon capture and sequestration

- The process of removing carbon dioxide (CO_2) from the atmosphere
- Natural sinks are:
  - Absorption of CO_2 by the oceans via physicochemical and biological processes
  - Photosynthesis by plants
- It is a potential means of mitigating the contribution of fossil fuel emissions to global warming and ocean acidification.
- New methods are developing such as capturing waste carbon dioxide from large point sources, such as fossil fuel power plants, transporting it to a storage site, and depositing it where it will not enter the atmosphere, normally an underground geological formation.

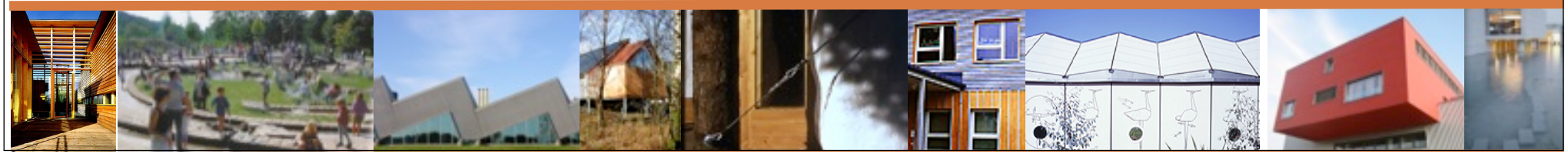
More on Embodied Energy tomorrow

Tuesday 13th - Part 4

AN ENGINEERS VIEW OF SUSTAINABILITY

- **A version of this lecture is available on line at.....**

[An Engineers view of Sustainability]



Energy and Low Income Tropical Housing

Close of Day