Whole life carbon analysis

David Williams

EPSRC
Engineering and Physical Sciences Research Council

UNIVERSITY OF SURREY

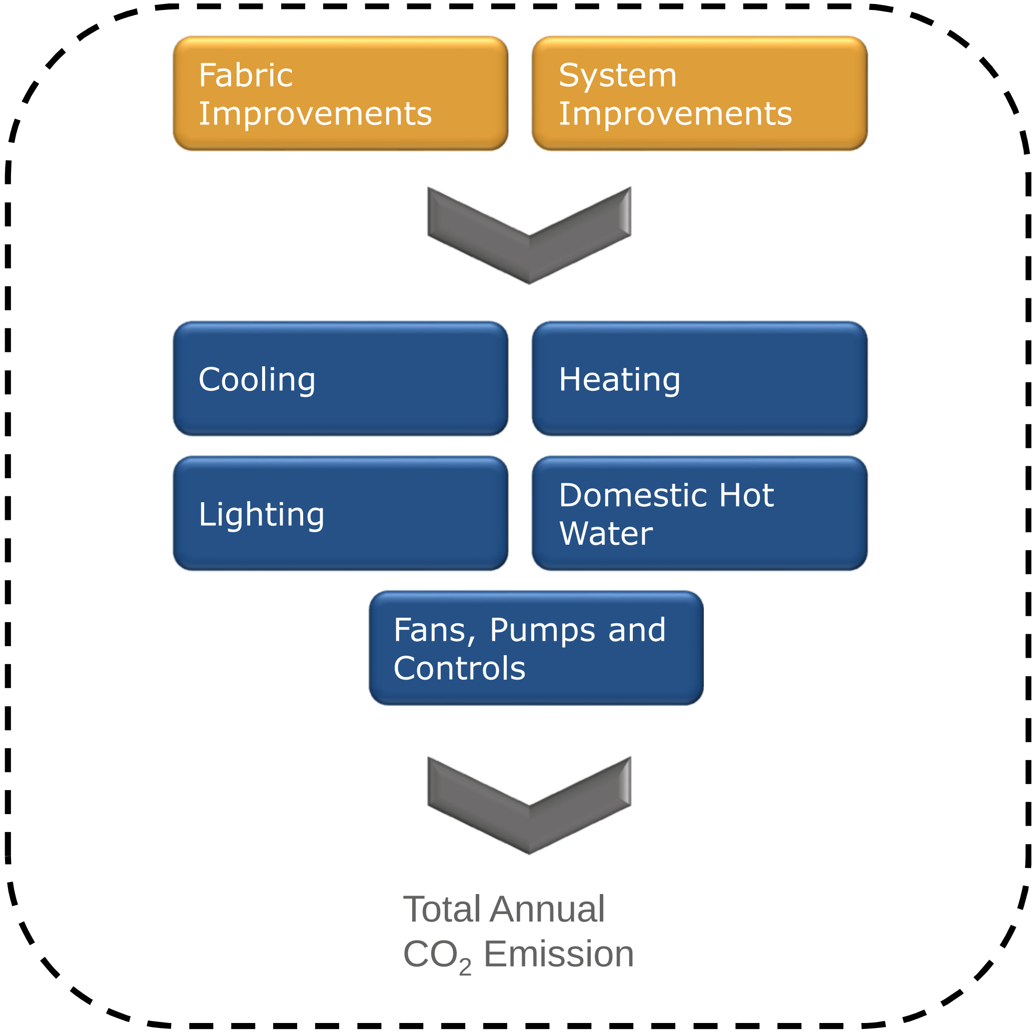
PARSONS BRINCKERHOFF

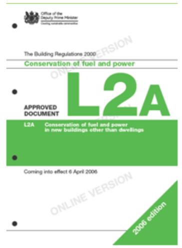
Balfour Beatty

Introduction

- Background to whole life carbon assessment
- Recent developments
- Background data
- Process of lifecycle assessment
- Case study project
- Results and discussion

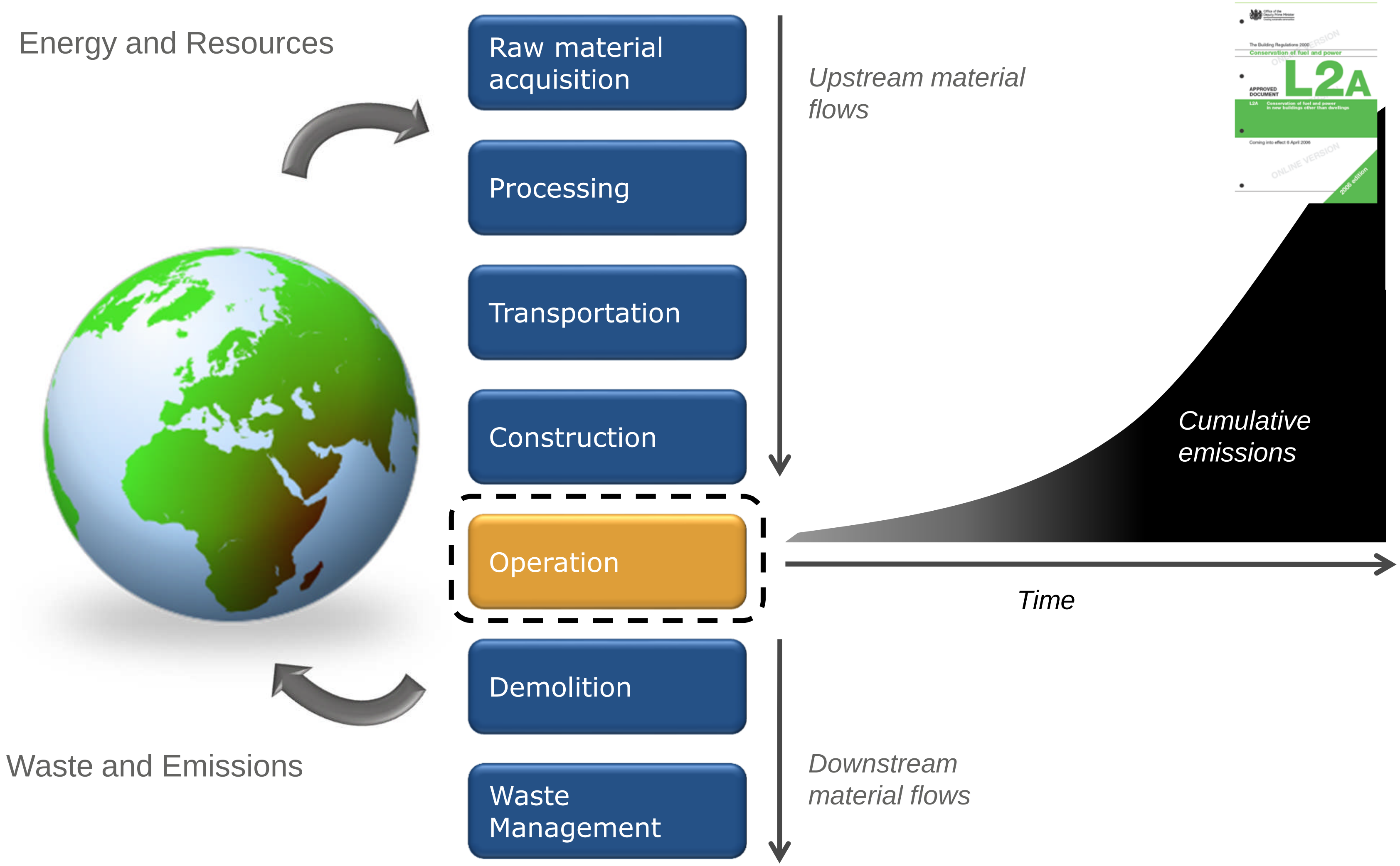
Regulatory requirements





Operational System Boundary

Life cycle perspective



Recent developments
BREEAM 2011

8.1 Life cycle impacts

This is a re-titled issue, previously 'materials Specification – major building elements' in BREEAM 2008.

The criteria and calculation procedures account for the differing levels of verification of LCA data currently available, and therefore robustness of any specified products declaration of environmental performance.

For offices and retail, floor finishes will be added to the elements list for assessment.

Where available (via the Green Guide online) for the elements assessed, the embodied CO_2 of those elements shall be reported via the BREEAM assessment and certification process.

There are between two and six credits available for this issue (dependent on building type).

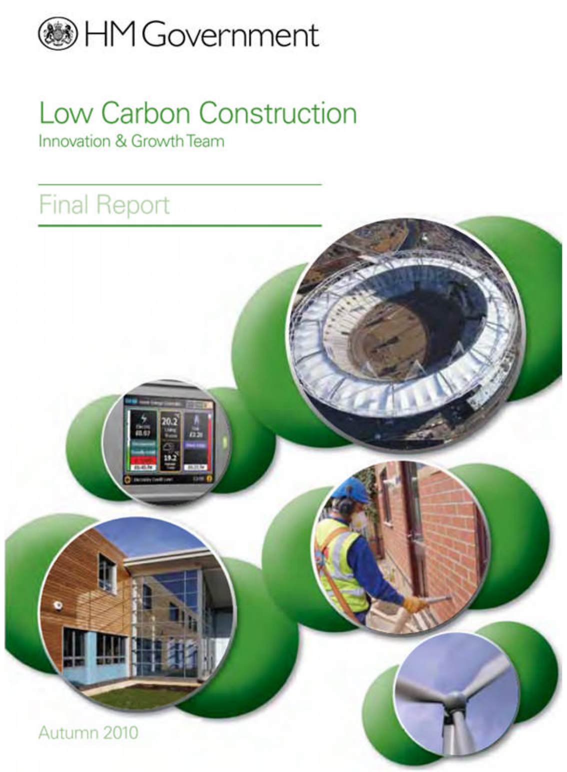
BREEAM 2011: A summary paper of the technical changes

1st February 2011

Recent developments

Looking forward…

Innovation and Growth Team



November 2010

“ Embodied energy is therefore important, and it needs to be brought into the systems used for appraisal of projects – and hence into the design decisions made in developing projects. ”

“ The assessment would require a CO_2 equivalent figure for each year of a project's life, considering emissions in the year they occur and not distinguishing embodied from operational emissions. ”

“ This is not instead of paying due attention to operational energy, but rather in addition – so that "whole life carbon" becomes as important a means of appraisal as whole life cost should be. ”

Recommendation 2.1: That as soon as a sufficiently rigorous assessment system is in place, the Treasury should introduce into the Green Book a requirement to conduct a whole-life (embodied + operational) carbon appraisal and that this is factored into feasibility studies on the basis of a realistic price for carbon.

Recommendation 2.2: That the industry should agree with Government a standard method of measuring embodied carbon for use as a design tool and (as Recommendation 2.1 above) for the purposes of scheme appraisal.

Recent developments
Looking forward…

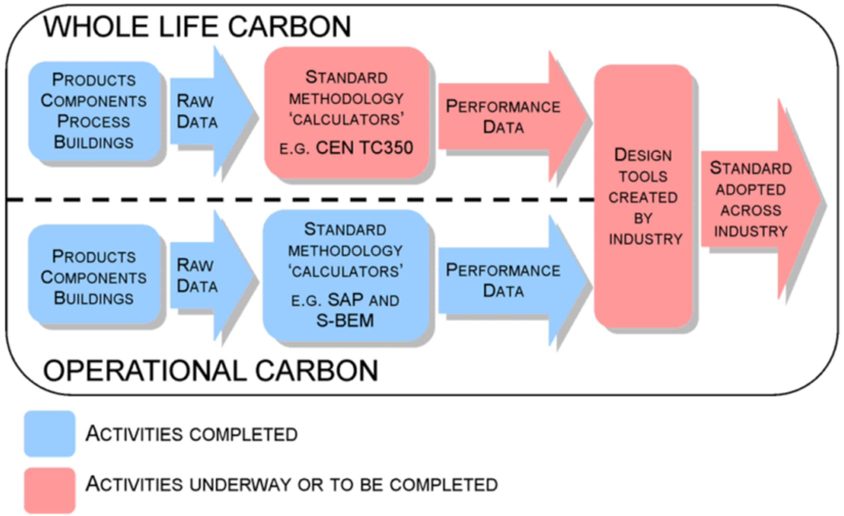
Government response

HM Government

June 2011

“ **Measuring embodied and whole life carbon**

Since the publication of the IGT report, this is the single biggest issue that organisations have made representations to Government on. ”



Owner	Action	Date	IGT Rec.
DCLG	Continued support for the development of a European standard for embodied carbon measurement tool by CEN TC350[26]	Ongoing	2.2 6.15
Industry	Continued support for the development of embodied carbon measurement tools. Including support from BRE, UK-GBC, CIC, BSI, RICS, EEPH and CPA	Ongoing	2.2 6.15

Who cares about whole life carbon?

Underestimate embodied energy at peril

Measuring the embodied carbon in buildings is a vitally important piece of the sustainability jigsaw that has until now been missing argues Davis Langdon's John Connaughton

Building.c

Construction sector rises to challenge of building eco-friendly homes of the future

Companies say going green will help the planet - and generate higher profits

Architects must not hide the carbon footprints of their buildings

30 July, 2009 | By Hattie Hartman

Sustainability in practice: Architects should be ashamed of their abysmal record on carbon

Embodied energy: The next big carbon challenge

04 June 2010 | By Thomas Lane

Reducing the amount of embodied energy in building materials won't but it's essential

Building

PropertyWeek.com

Software . technology: hit 'enter' for carbon footprint

14 September 2007 | By David Lawson

Web-enabled technology can provide an instant picture of eco-friendliness.

bdonline.co.uk

Know your building's carbon footprint

21 May 2010 | By Hugh Davies

Online carbon calculator tools help architects understand energy and environmental issues

...re its footprint

3 October 2007 | By Phil Clark

Labbad stresses the need for companies to report their environmental performance as his firm reveals its own carbon impact

Who cares about whole life carbon?

Carbon in the property lifecycle

British Land

your carbon footprint

'You cannot have well humans on a sick planet'.
Thomas Berry

BMA

London 2012
Carbon footprint study – Methodology and reference footprint
March 2010

london

Measuring your Organisation's Carbon Footprint

Measuring the carbon footprint of your organisation is an important step in managing and reporting on its carbon emissions.

To help you do this we have highlighted a number of areas which already have measurement processes in place.

NHS
Sustainable Development Unit

Public buildings can help reduce Wales' carbon footprint

TESCO

What museums can learn from carbon footprints

Maurice Davies, 17.05.2010

Once you've got your carbon footprint, the next step is to understand what the numbers mean and use this information to make positive changes

MUSEUMS ASSOCIATION

MP

corus

The carbon fo

To accurately establis
manufacture, the Wo
'system expansion' m

CITY OF LONDON

Footprint of the City of London

Life cycle influence of construction materials

Life cycle perspective

- **What guidance and measurement tools are currently available?**
  - BREEAM / LEED
  - BRE Green Guide / Environmental Profiles
  - Site Waste Management Plans
  - Environment Agency Carbon Calculator
  - Invest2 Software…

- *Currently, no widely applied tool to allow thinking of material flows in the same way as detailed operational demands*

Raw material acquisition

Processing

Transportation

Construction

Operation

Demolition

Waste Management

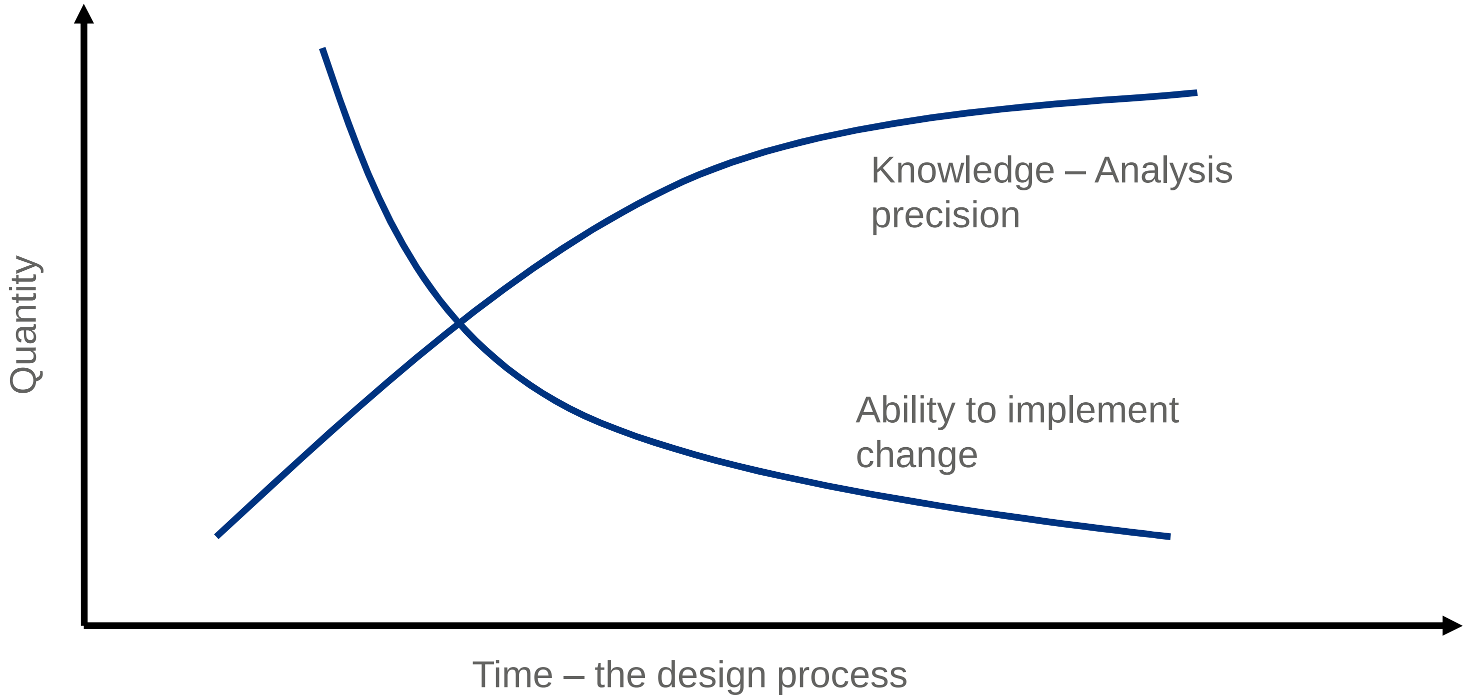
Challenges of building life cycle assessment

Where do we draw the boundaries of analysis?

What are the environmental impacts of a particular material?

How much material have we got in the first place?

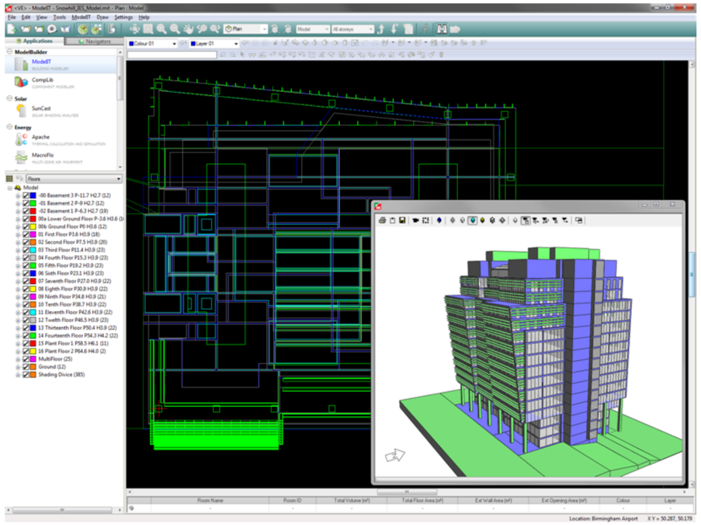
How do we assess this in the early stages of design?



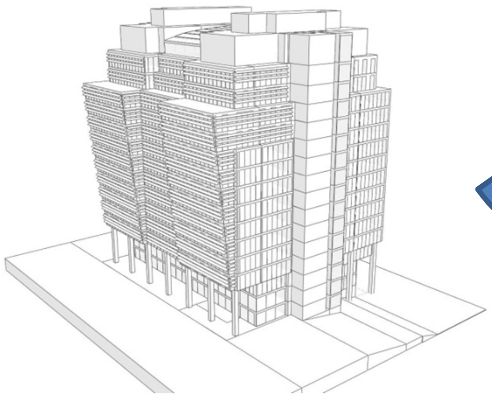
Structuring the building life cycle

Building up the lifecycle

IES Geometry



IES Geometry



Export

Building Summary Sheet

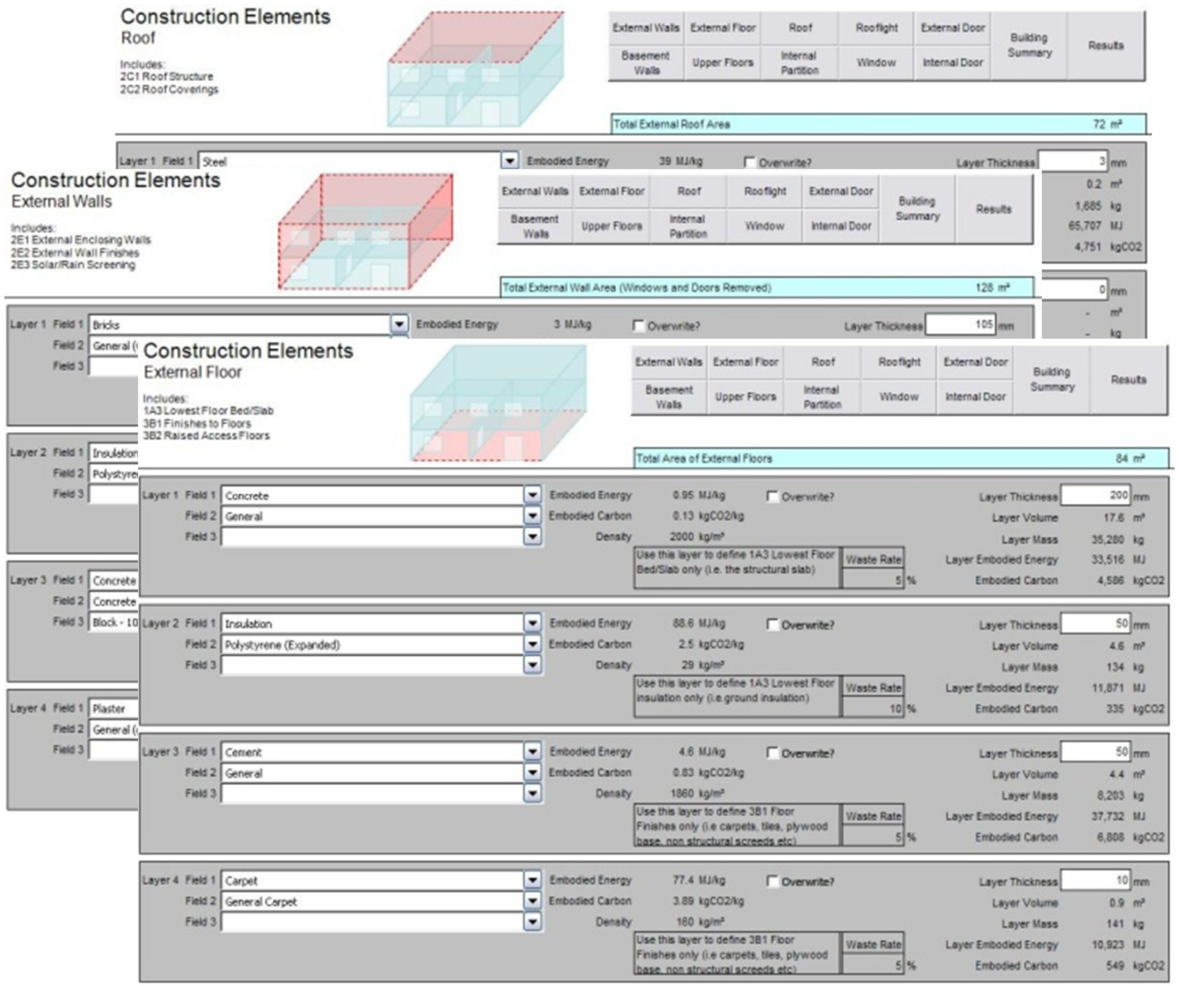
Refresh Building Geometry Data

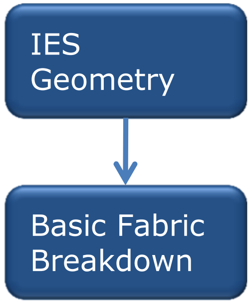
Enter number of internal doors	3	
Enter height of internal doors	2	m
Enter width of internal doors	1	m
Enter number of external doors	4	
Enter height of external doors	2	m
Enter width of external doors	1	m
Enter number of external rooflights	4	
Enter length of external rooflights	2	m
Enter width of external rooflights	1	m
Total Area of Below Ground Basement Walls	60	m²

	Compiled from IES / m²	Manually Input / m²	Overwrite		
Total External Floor Area	84.0	-	☐	External Floor	3B1, 3B2
Total Upper Floor Area	84.0	-	☐	Upper Floors	2B, 3C2
Total Above Ground External Wall Area	128.0	-	☐	External Walls	2E1, 2E2, 2E3
Total Below Ground Basement Wall Area	-	60	☐	Basement Walls	1A5, 2E4
Total External Roof Area	72.0	-	☐	Roof	2C1, 2C2
Total Internal Partition Area	144.0	-	☐	Internal Partition	2G1
Total Window Area	44.0	-	☐	Window	2F1
Total External Door Area	-	8.0	☐	External Door	2F2
Total Internal Door Area	-	6.0	☐	Internal Door	2H
Total Rooflight Area	-	8.0	☐	Rooflights	2C4

Room Name	Room Code	Room Floor Area	External Floor	Internal Floor Area	External Wall Area (windows and doors not removed)	External Wall Area (windows only removed)	External Roof Area	Internal Partition Area (internal doors not removed)	Window Area
Ground Floor Office 1	GRND0000	15	15	0	24	22	0	22	2
Ground Floor Office 2	GRND0001	21	21	0	30	24	0	28	6
Ground Floor Office 3	GRND0002	48	48	0	60	50	0	36	10
First Floor Office 1	FRST0000	48	0	48	68	54	40	32	14
First Floor Office 2	FRST0001	36	0	36	58	46	32	32	12

Building up the lifecycle

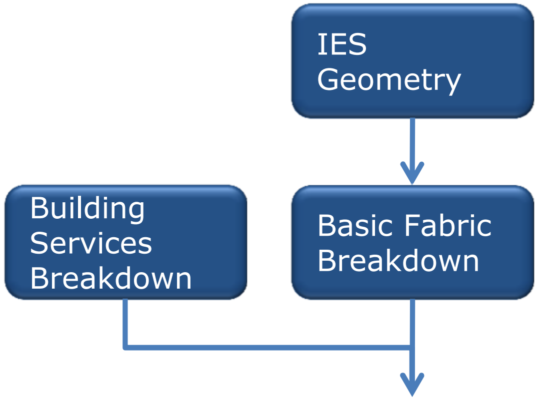




Building up the lifecycle

Heat emitter (choose maximum of 5 types)

Manufacturer	Model	Height / mm	Thermal output at (75/65/20°C) / W/m	Radiator Mass / kg/m	Radiator Length / mm	Number of items of this types	Item Thermal Output / kW	Item Mass / kg	Primary Material	Matertial Catergory	Primary Material Embodied CO2eq / kgCO2eq/kg	Total Embodied CO2eq / kgCO2eq/ kg	Total carried Mass / kg	Aprox. total volume / m³
USER SPECIFIED						3		10	Cast Iron	Metal-Ferro	1.53	45.9	30.0	0.5
USER SPECIFIED									Cast Iron	Metal-Ferro	1.53	0.0	0.0	
USER SPECIFIED									Cast Iron	Metal-Ferro	1.53	0.0	0.0	
USER SPECIFIED									Cast Iron	Metal-Ferro	1.53	0.0	0.0	
USER SPECIFIED									Cast Iron	Metal-Ferro	1.53	0.0	0.0	
Stelrad	K1	300	517	8.38	1000	1	517	8.38	Cast Iron	Metal-Ferro	1.53	12.8	8.4	0.2
		450	768	13.34	1000		768	13.34	Cast Iron	Metal-Ferro	1.53	0.0	0.0	
		600	1000	18.3	1000		1000	18.3	Cast Iron	Metal-Ferro	1.53	0.0	0.0	
		700	1142	21.33	1000		1142	21.33	Cast Iron	Metal-Ferro	1.53	0.0	0.0	
	P+	300	776	13.71	1000		776	13.71	Cast Iron	Metal-Ferro	1.53	0.0	0.0	
		450	1106	21.31	1000		1106	21.31	Cast Iron	Metal-Ferro	1.53	0.0	0.0	
		600	1409	28.9	1000		1409	28.9	Cast Iron	Metal-Ferro	1.53	0.0	0.0	
		700	1597	33.5	1000		1597	33.5	Cast Iron	Metal-Ferro	1.53	0.0	0.0	
	K2	300	1012	15.9	1000		1012	15.9	Cast Iron	Metal-Ferro	1.53	0.0	0.0	
		450	1409	24.8	1000		1409	24.8	Cast Iron	Metal-Ferro	1.53	0.0	0.0	
		600	1778	33.7	1000		1778	33.7	Cast Iron	Metal-Ferro	1.53	0.0	0.0	
		700	2011	39.13	1000		2011	39.13	Cast Iron	Metal-Ferro	1.53	0.0	0.0	
	P1	300	388	6.17	1000		388	6.17	Cast Iron	Metal-Ferro	1.53	0.0	0.0	
		450	476	9.25	1000		476	9.25	Cast Iron	Metal-Ferro	1.53	0.0	0.0	
		600	610	12.33	1000		610	12.33	Cast Iron	Metal-Ferro	1.53	0.0	0.0	
		700	699	14.19	1000		699	14.19	Cast Iron	Metal-Ferro	1.53	0.0	0.0	

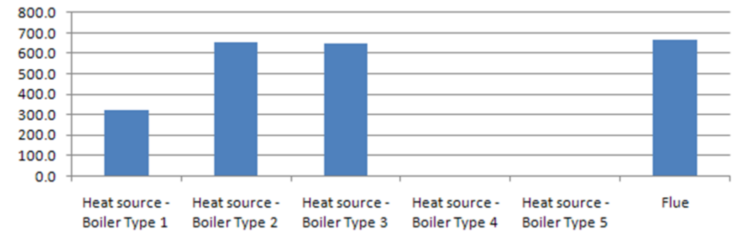


Basket Tray

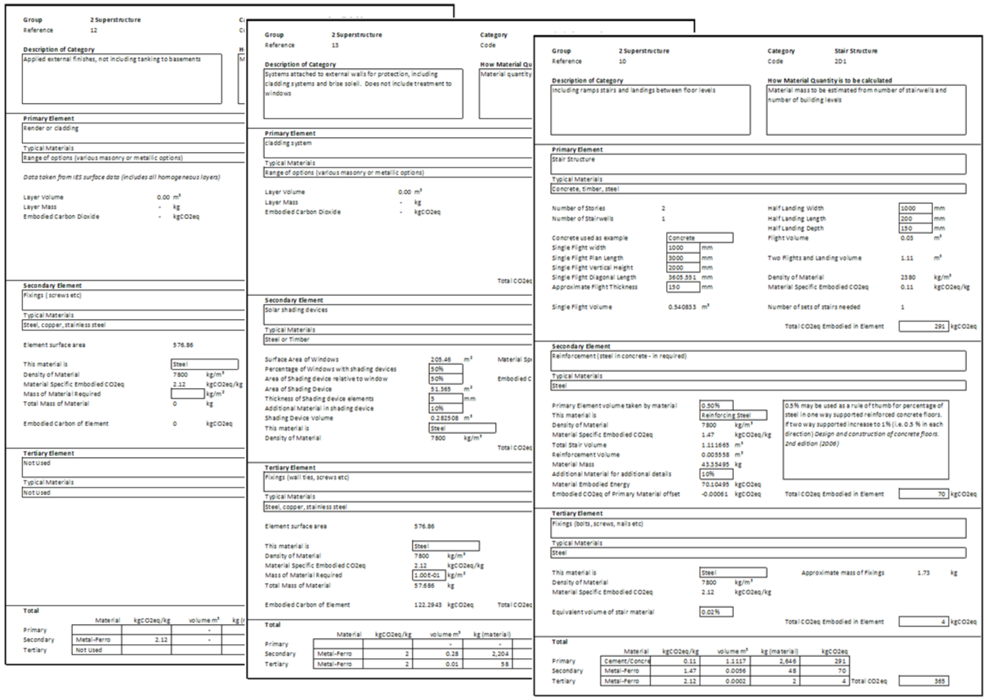
Material: Stainless Steel
Material Category: Metal-Ferro
Material Density: 8000 kg/m³
Material manufacturing emissions: 5.31 kgCO2eq/kg

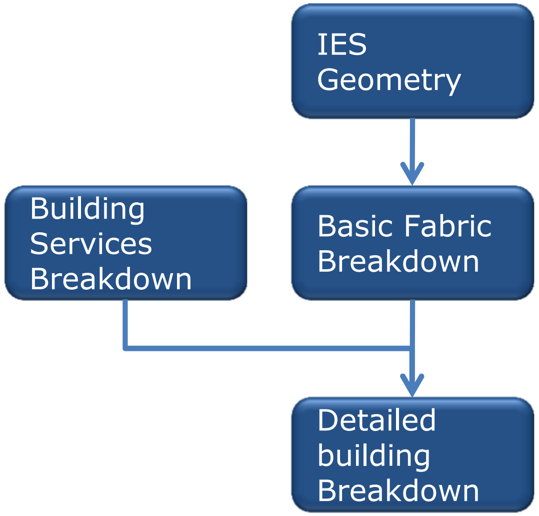
Type	Width / mm	Depth / mm	Item mass (per 3m length) / kg	Requireed length / m	Material Volume / m³	Material Mass / kg	Embodied CO2eq / kgCO2eq
Unistrut Light Basket tray	50	30	1.53		0.00	0.00	0.00
	100	30	2.04		0.00	0.00	0.00
	150	30	2.67		0.00	0.00	0.00
	200	30	3.24	3.00	0.02	3.24	9.14
	300	30	4.38		0.00	0.00	0.00
Unistrut Medium Basket tray	50	54	1.8		0.00	0.00	0.00
	100	54	2.4		0.00	0.00	0.00
	150	54	2.82		0.00	0.00	0.00
	200	54	3.24		0.00	0.00	0.00
	300	54	5.4		0.00	0.00	0.00
	400	54	8.1		0.00	0.00	0.00
	450	54	8.85		0.00	0.00	0.00
	500	54	9.6		0.00	0.00	0.00
	600	54	11.1		0.00	0.00	0.00
Unistrut Heavy Basket tray	100	100	3.24		0.00	0.00	0.00
	200	100	5.4		0.00	0.00	0.00
	300	100	8.1		0.00	0.00	0.00
	400	100	9.6		0.00	0.00	0.00
	500	100	11.1		0.00	0.00	0.00
					0.02	3.24	9.14

Summary			Material Category	Material Volume / m³	Material Mass / kg	Material Embodied CO2eq / kgCO2eq	Notes
5E	Heat Source	Primary	Miscellaneous	1.0	86.0	319.5	Heat source - Boiler Type 1
			Miscellaneous	2.0	360.0	657.0	Heat source - Boiler Type 2
			Miscellaneous	3.0	355.0	647.9	Heat source - Boiler Type 3
			Not Used				Heat source - Boiler Type 4
			Not Used				Heat source - Boiler Type 5
		Secondary	Metal-Ferro	2.5	125.9	668.6	Flue



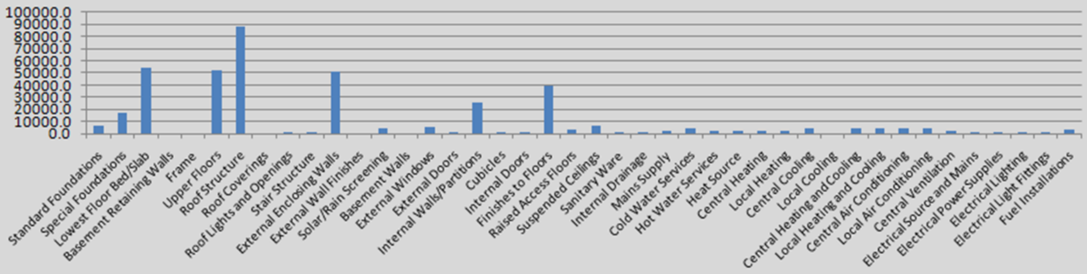
Building up the lifecycle

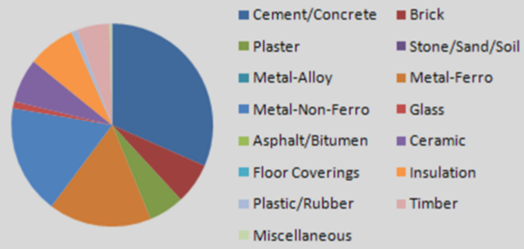




Full Breakdown

- Input data
- 1 Substructure
- 2 Superstructure
- 3 Finishes
- 5 Services
- Manufacturing Summar
- Full breakdown
- Transport Emissions
- Construction Emissions
- Replacement Rate
- Lifecycle Plot





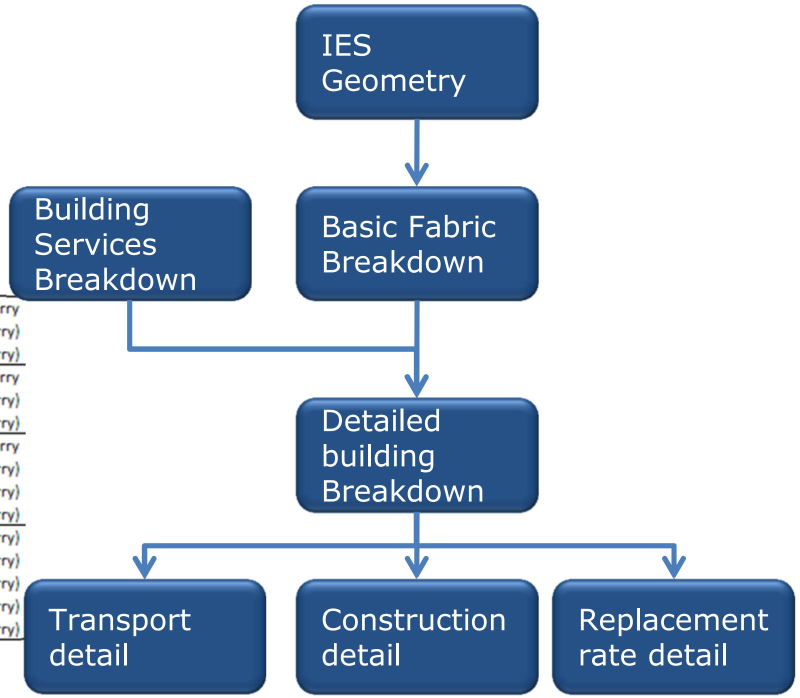
Building up the lifecycle

defra Department for Environment Food and Rural Affairs

Department for Transport

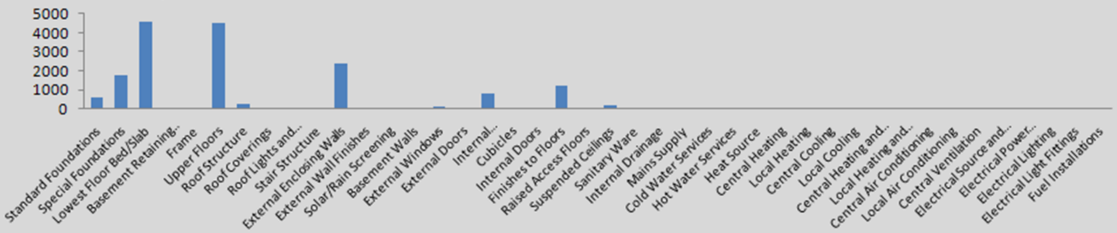
DEPARTMENT OF ENERGY & CLIMATE CHANGE

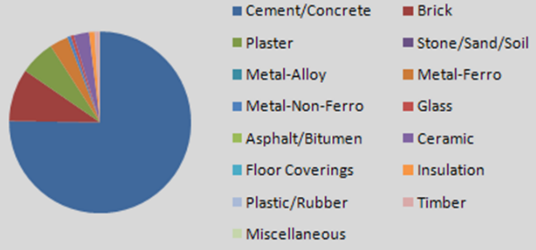
Group			Category			Material Volume / m³	Material Mass / kg	Vehicle Type
1 Substructure	1	1A1	Standard Foundations	Primary	Cement/Concrete	16.1	38,334	8m³ Concrete lorry
				Secondary	Metal-Ferro	0.1	1,236	>17t (Rigid Lorry)
				Tertiary	Not Used	-	-	>17t (Rigid Lorry)
	2	1A2	Special Foundations	Primary	Cement/Concrete	3.8	121,973	8m³ Concrete lorry
				Secondary	Metal-Ferro	0.3	2,199	>17t (Rigid Lorry)
				Tertiary	Not Used	-	-	>17t (Rigid Lorry)
	3	1A3	Lowest Floor Bed/Slab	Primary	Cement/Concrete	129.1	307,217	8m³ Concrete lorry
					Insulation	67.6	1,690	>17t (Rigid Lorry)
				Secondary	Metal-Ferro	1.0	8,438	>17t (Rigid Lorry)
				Tertiary	Not Used	-	-	>17t (Rigid Lorry)
	4	1A5	Basement Retaining Walls	Primary	Brick	-	-	>17t (Rigid Lorry)
					Insulation	-	-	>17t (Rigid Lorry)
					Cement/Concrete	-	-	>17t (Rigid Lorry)
				Secondary	Metal-Ferro	-	-	>17t (Rigid Lorry)
				Tertiary	Metal-Ferro	-	-	>17t (Rigid Lorry)



Initial Component Transportation

- Input data
- 1 Substructure
- 2 Superstructure
- 3 Finishes
- 5 Services
- Manufacturing Summary
- Full breakdown
- Transport Emissions
- Construction Emissions
- Replacement Rate
- Lifecycle Plot



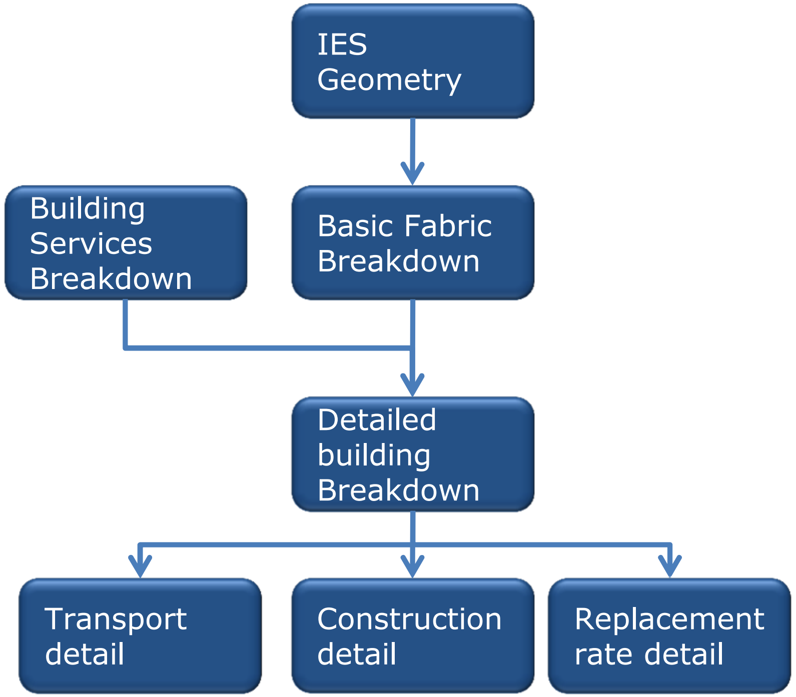


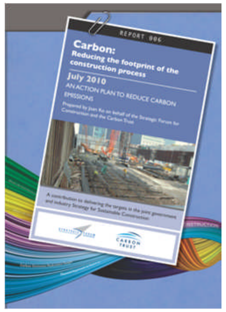
Building up the lifecycle

Building category	Emissions per £ project value / tonnes CO_2eq/£million
New Domestic	23
New Infrastructure	34
New Shops	8
New Office	16
New Education	10
New Health	12
New Other non domestic	20
Refurbishment and maintenance	11

Worker Transportation Emissions

Project size	Small		*Construction cost less than £1.5 million, fewer than 8 people permanently on site*
Expected number of workers permantly on site *(leave blank if not known)*			
Expected Duration of construction	10	weeks	
Average travel distance for workers *(one direction only)*	50	km	
Emissions from average vehicle	246	gCO2eq/km	
Assumed number of working days per week	5	days/week	
Assumed number of workers travelling	5	people	
Total distance traveled per worker	5000	km	
total distance traveled by work force	25000	km	
Total emissions from worker transportation	6,150	kgCO2eq	





PARSONS BRINCKERHOFF

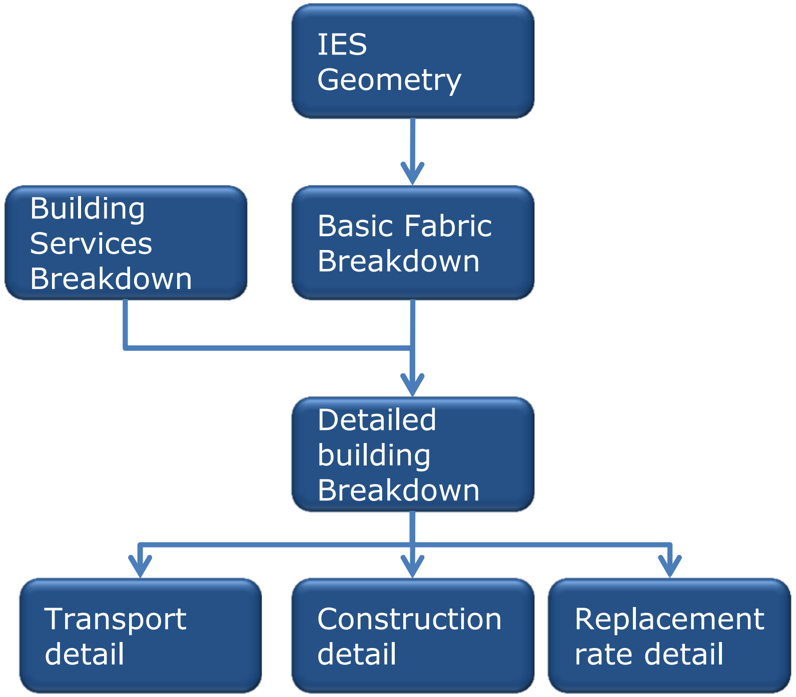
Balfour Beatty

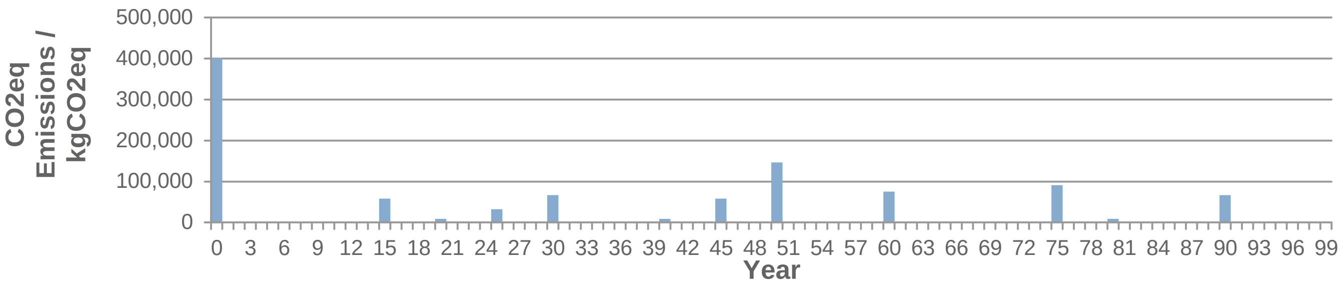
Building up the lifecycle

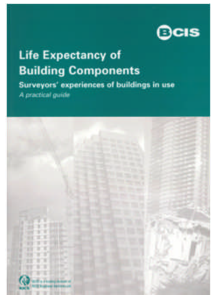
BCIS

RICS

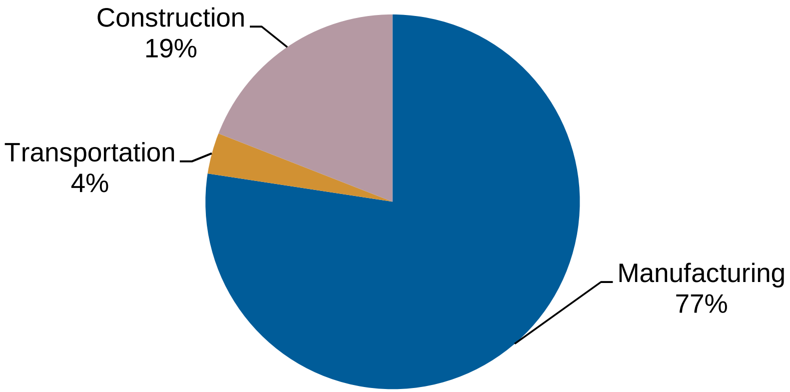
Element	Component	Median Life Expectancy		
		Typical	Minimum	Maximum
5C Disposal Installations	Soil/Waste Stacks: Cast Iron: Pipes incl. fittings; primed; to masonry	37	27	47
	Soil/Waste Stacks: Polypropylene: Waste pipes and fittings; pipe clips	20	15	30
	Soil/Waste Stacks: muPVC: Waste pipes and fittings; pipe clips	20	15	30
5D Water Installations	Pipes: Medium Density Polyethylene (MDPE): Pipework and fittings	25	15	30
	Pipes: PVCu: Pipework and solvent welded fittings	25	20	35
	Pipes: ABS: Pipework and solvent welded fittings	25	15	30
	Pipes: Polybutylene: Pipes and fittings	25	15	30
	Pipes: Ductile Iron: Pipes and fittings; socketed, flexible joints	30	20	35
	Pipes: Copper: Pipework generally	40	25	50
	Pumps: Centrifugal Heating: Belt driven	15	10	20

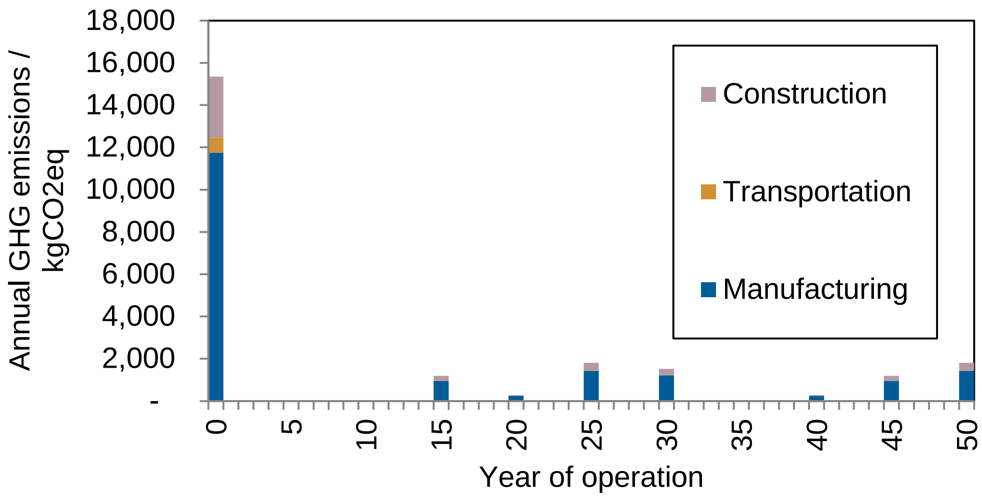


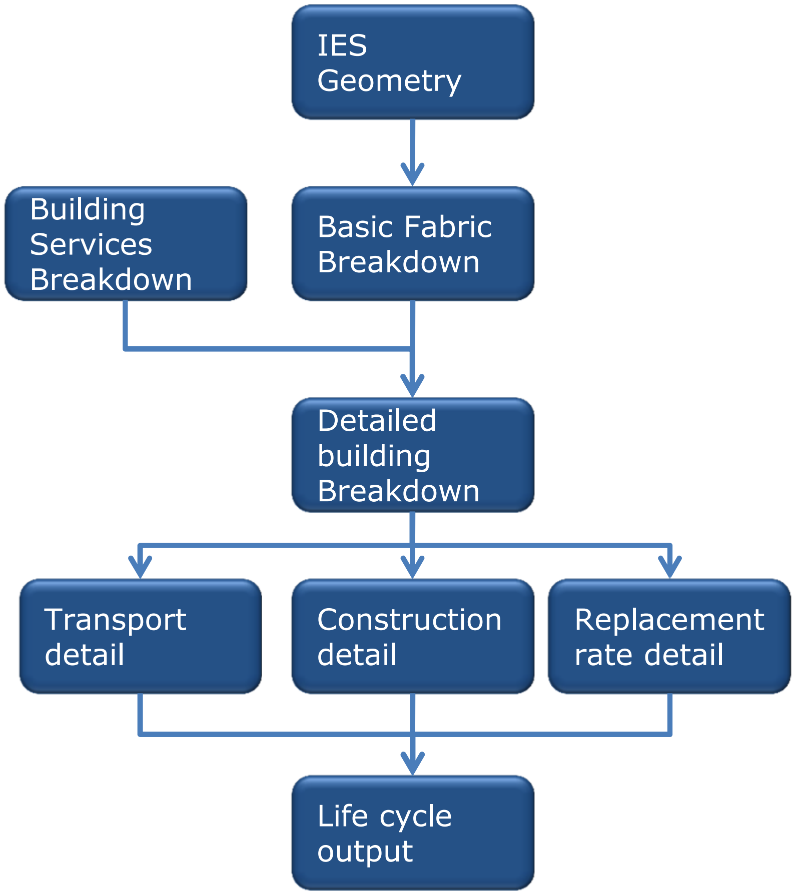




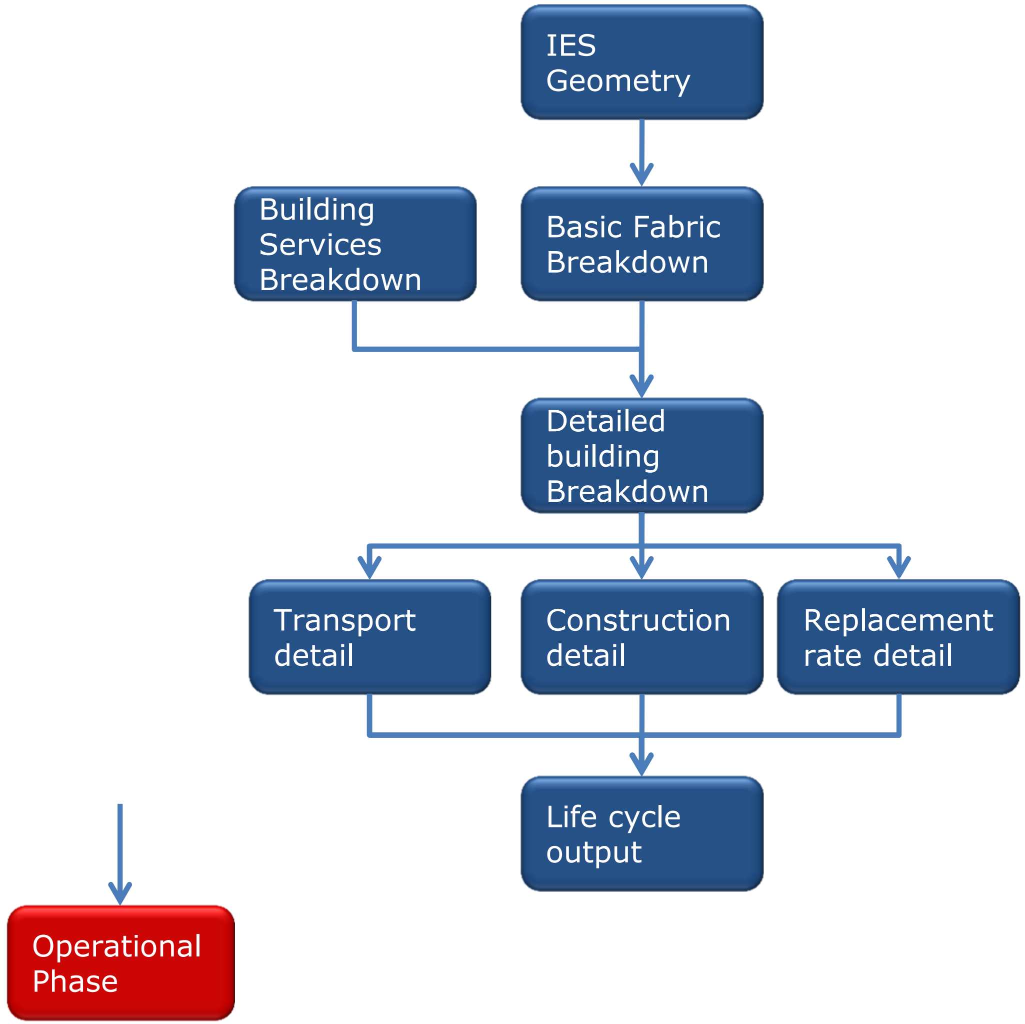
Building up the lifecycle



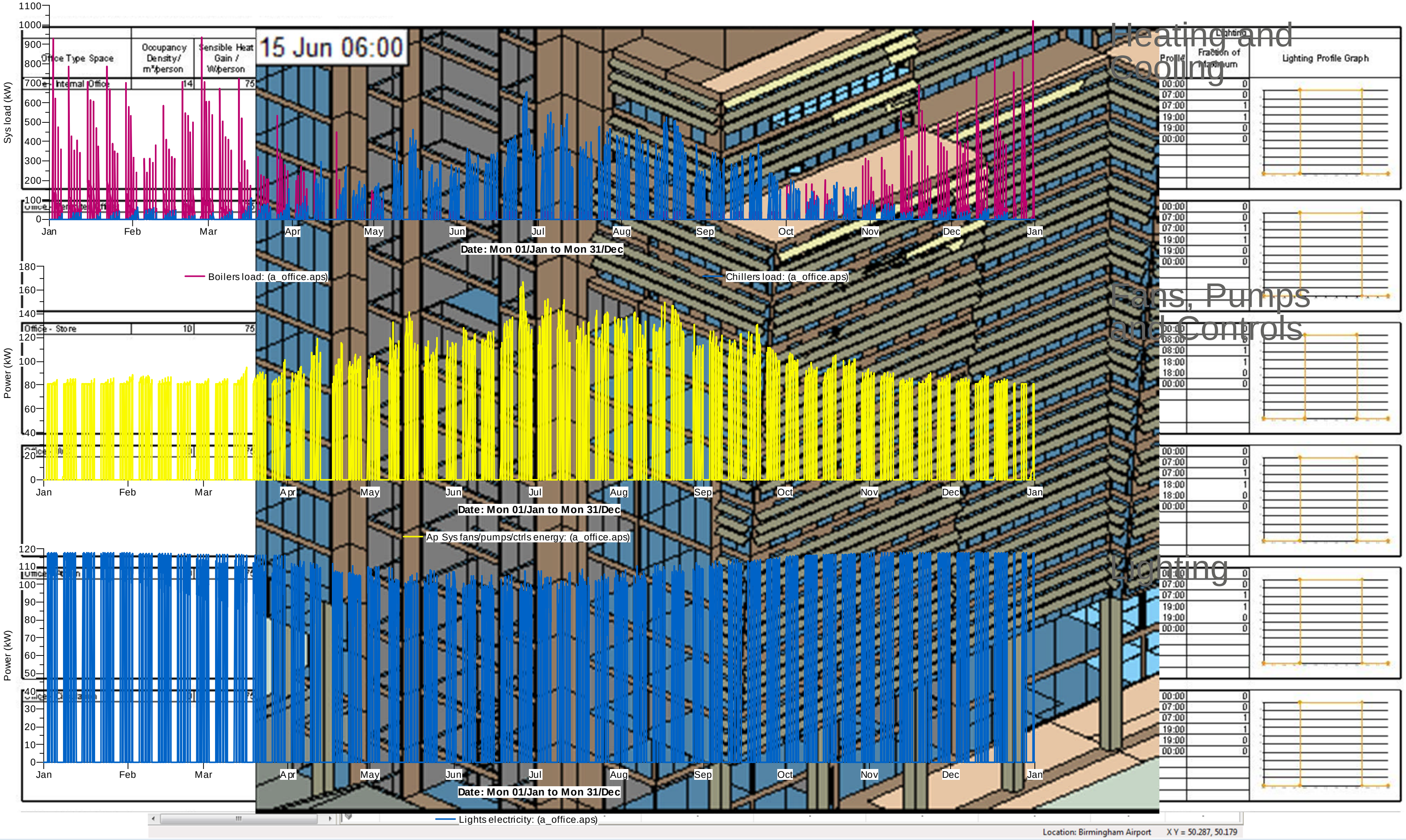




Building up the lifecycle



Operational emissions

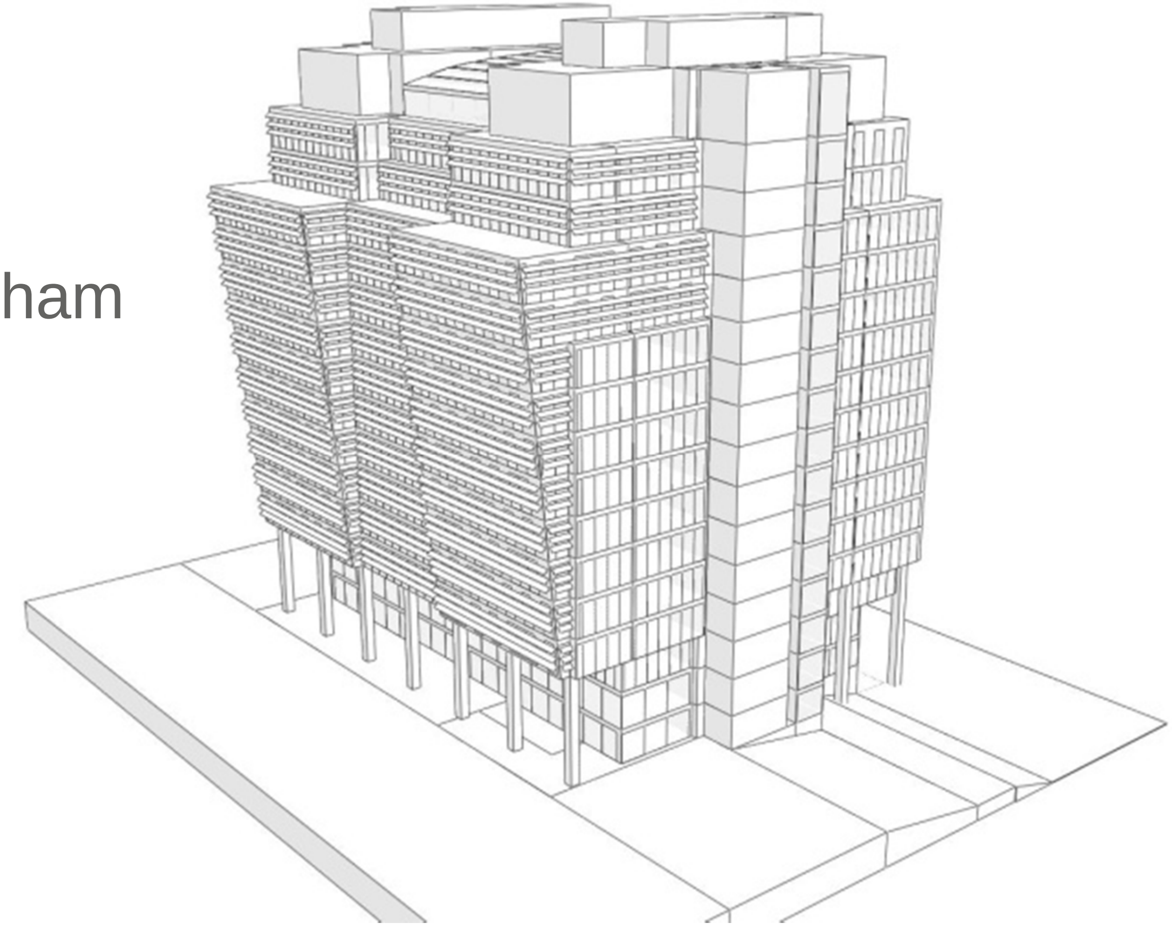


PARSONS BRINCKERHOFF

Balfour Beatty

Case Study

Snowhill2, Birmingham



PARSONS BRINCKERHOFF

Balfour Beatty

Case Study

Snowhill2

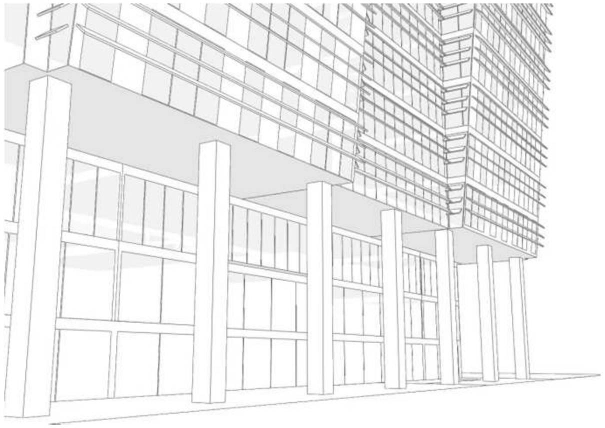
PARSONS BRINCKERHOFF

Balfour Beatty

Case Study

Snowhill2

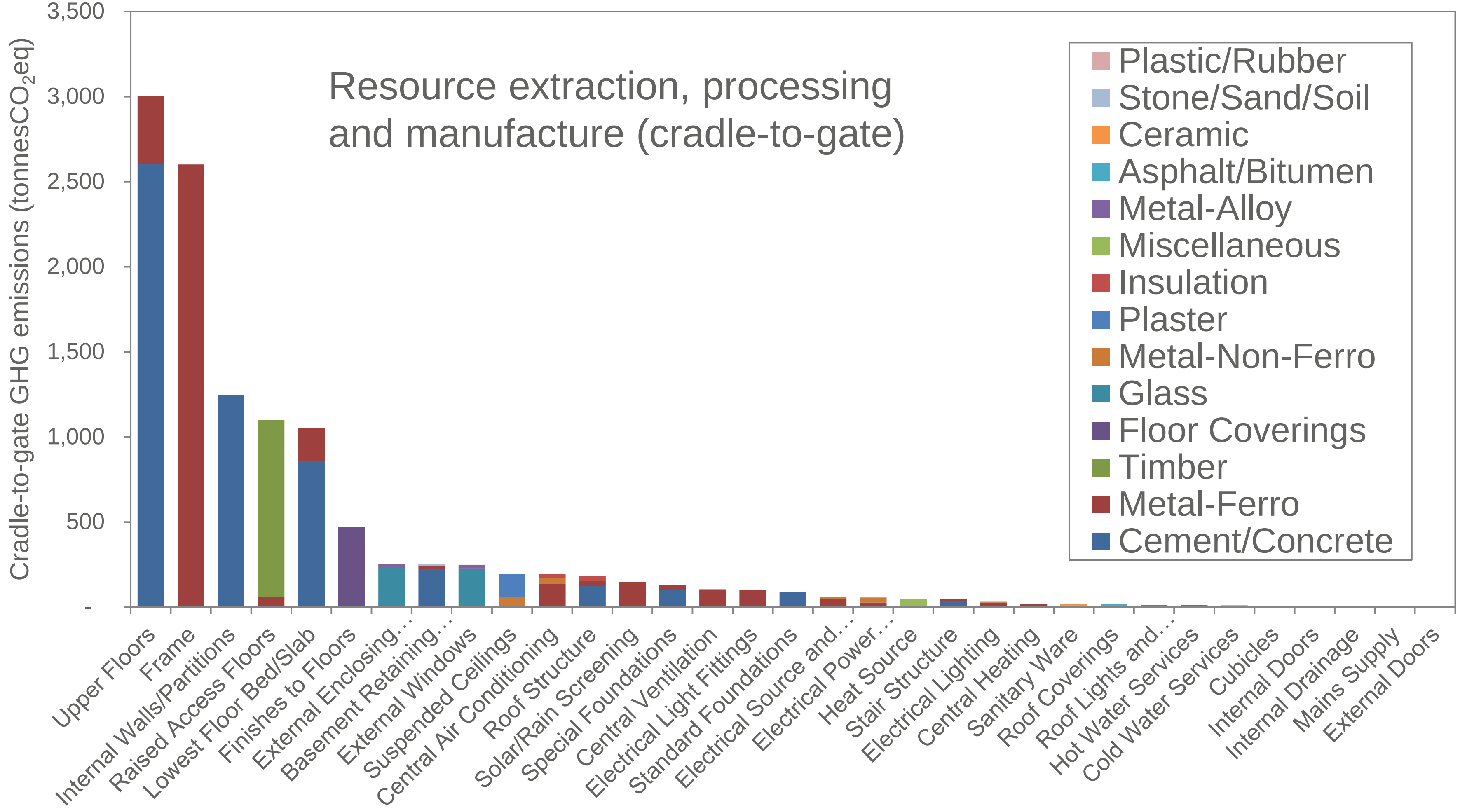
Parameter	Value
Curtain Walling U-value	1.9 W/m²K
Roof U-value	0.2 W/m²K
Window U-Value	1.9 W/m²K
Office Occupant Heat Gain	75 W/person (sensible); 55 W/person (latent); 10 m²/person
Retail Occupant Heat Gain	80 W/person (sensible); 80 W/person (latent); 6 m²/person
Office Lighting Heat Gain	12 W/m²
Retail Lighting Heat Gain	20 W/m²
Office Equipment Heat Gain	20 W/m²
Retail Equipment Heat Gain	10 W/m²
Heating set point temperature	21°C (06:00-20:00); 12°C out of hours
Cooling set point temperature	24°C (07:00-20:00) 50%RH ±10
Mechanical ventilation rate	12 litres/s/person (occupied hours only)
Heating system seasonal efficiency	90%
Cooling system seasonal energy efficiency ratio	2.5
Natural gas carbon intensity (for heating)	0.198 kgCO_2eq/kWh
Electricity carbon intensity (for cooling)	0.517 kgCO_2eq/kWh



Manufacturing (cradle-to-gate) | Material transportation | On-site Construction | Operation

Case Study

Snowhill2

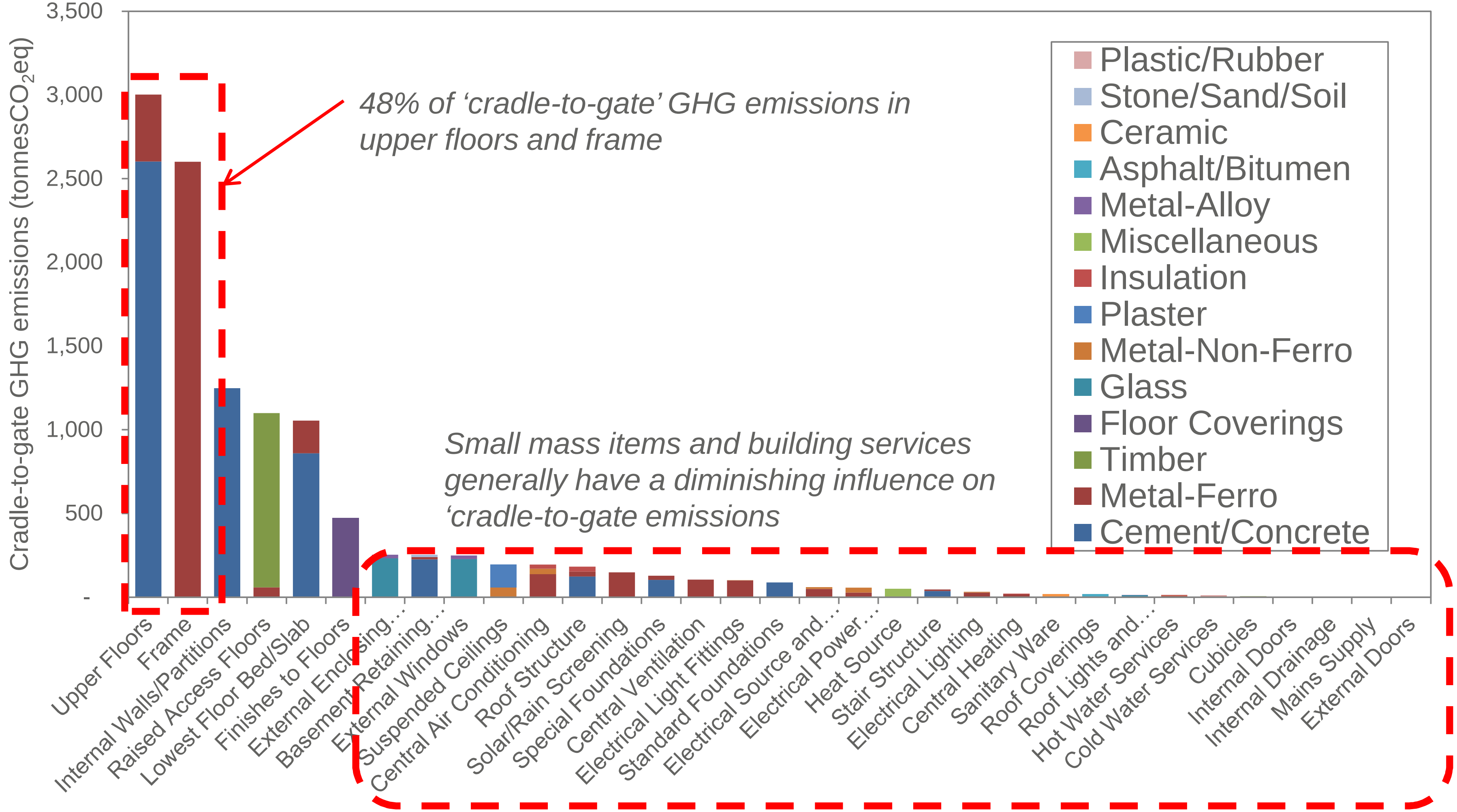


PARSONS BRINCKERHOFF

Balfour Beatty

Case Study

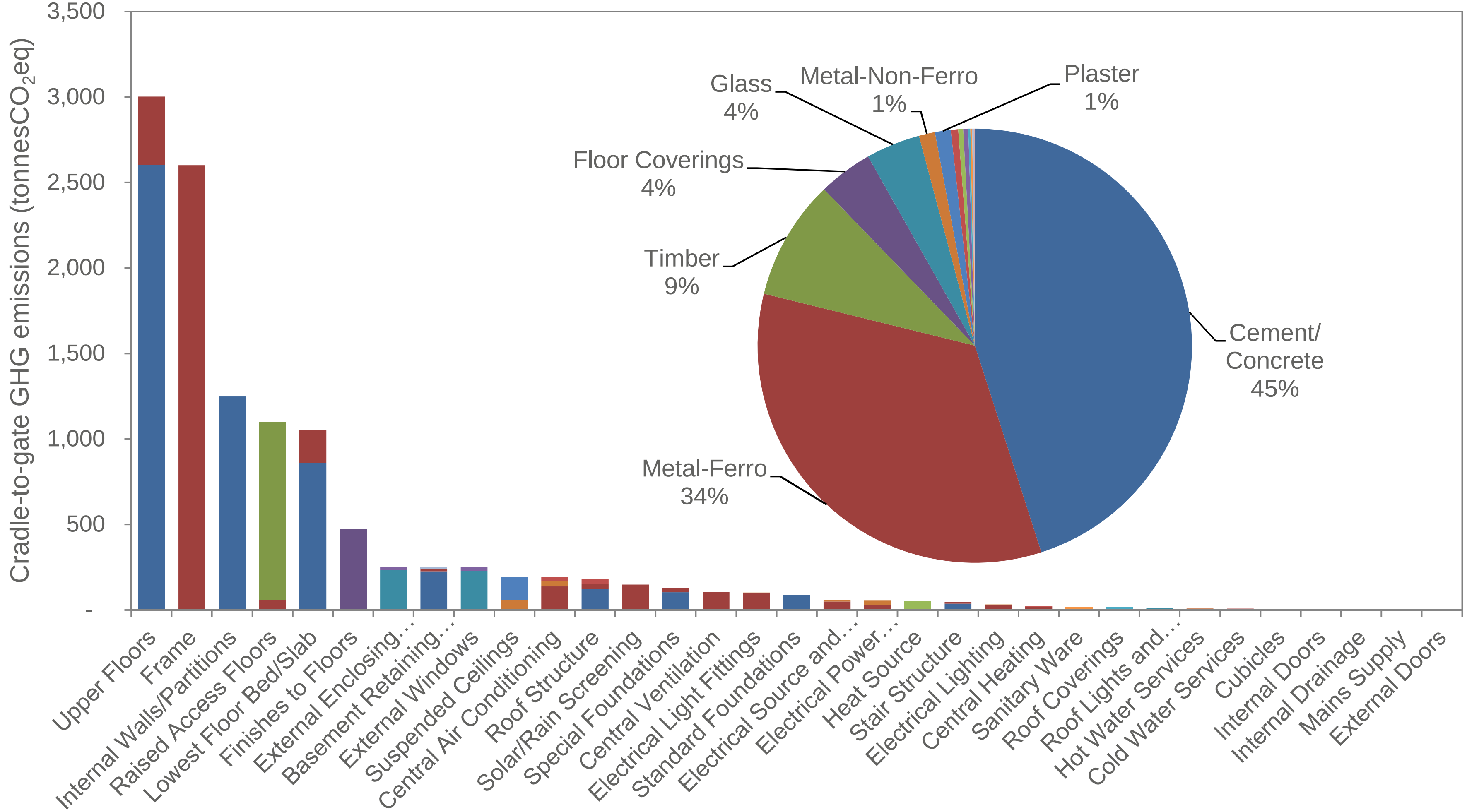
Snowhill2



Manufacturing (cradle-to-gate) | Material transportation | On-site Construction | Operation

Case Study

Snowhill2

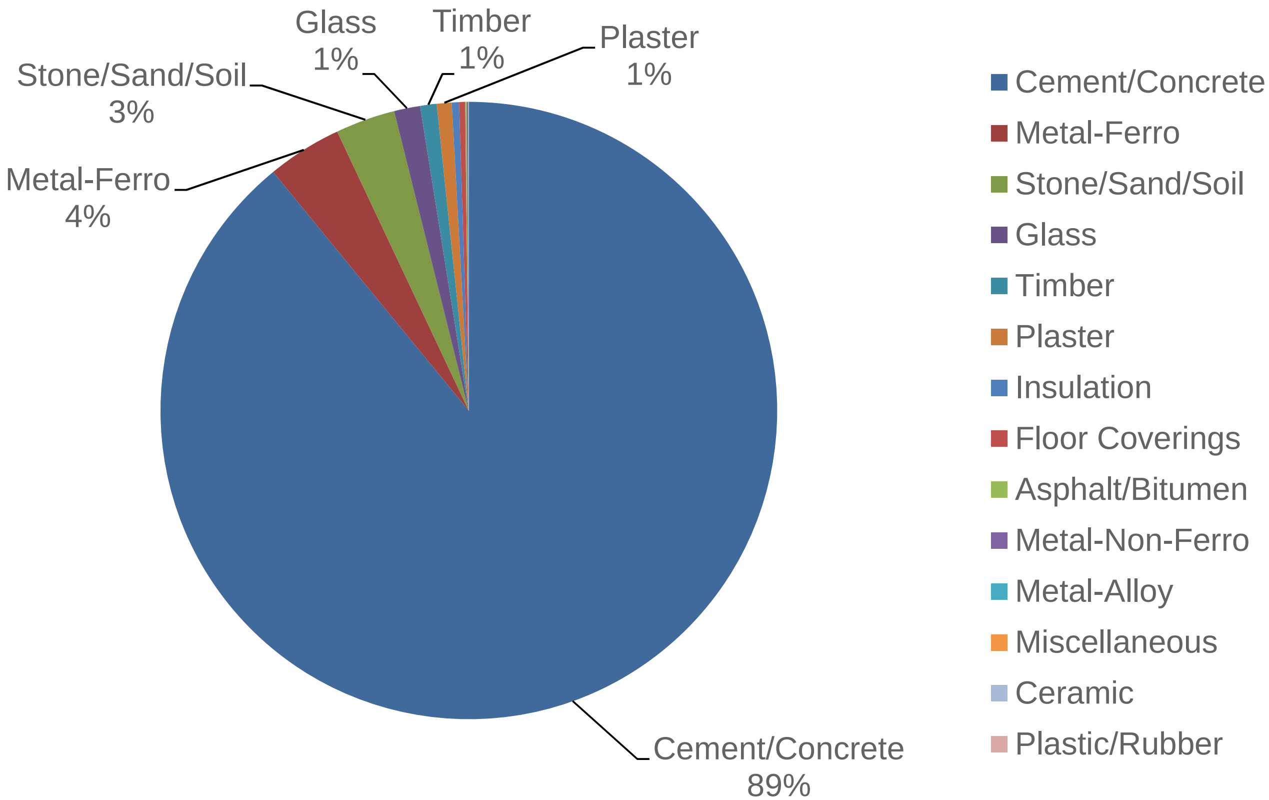


Manufacturing (cradle-to-gate) — Material transportation — On-site Construction — Operation

Case Study

Snowhill2

Material Transportation



High-mass items have largest transportation emissions

Concrete 89%

All other materials only 11%

Manufacturing (cradle-to-gate) | Material transportation | On-site Construction | Operation

Case Study

Snowhill2

On-site construction

Building category	Emissions per £ project value / tonnes CO_2eq/£million
New Domestic	23
New Infrastructure	34
New Shops	8
New Office	16
New Education	10
New Health	12
New Other non domestic	20
Refurbishment and maintenance	11

Size of Project		tCO_2 / month
Very large	Construction cost more than £10 million, more than 25 people permanently on site	25
Large	Construction cost £5 to £10 million, between 16 and 25 people permanently on site	12
Medium	Construction cost £1.5 to £5 million, between 9 and 15 people permanently on site	5
Small	Construction cost less than £1.5 million, fewer than 8 people permanently on site	2

STRATEGIC FORUM FOR CONSTRUCTION

CARBON TRUST

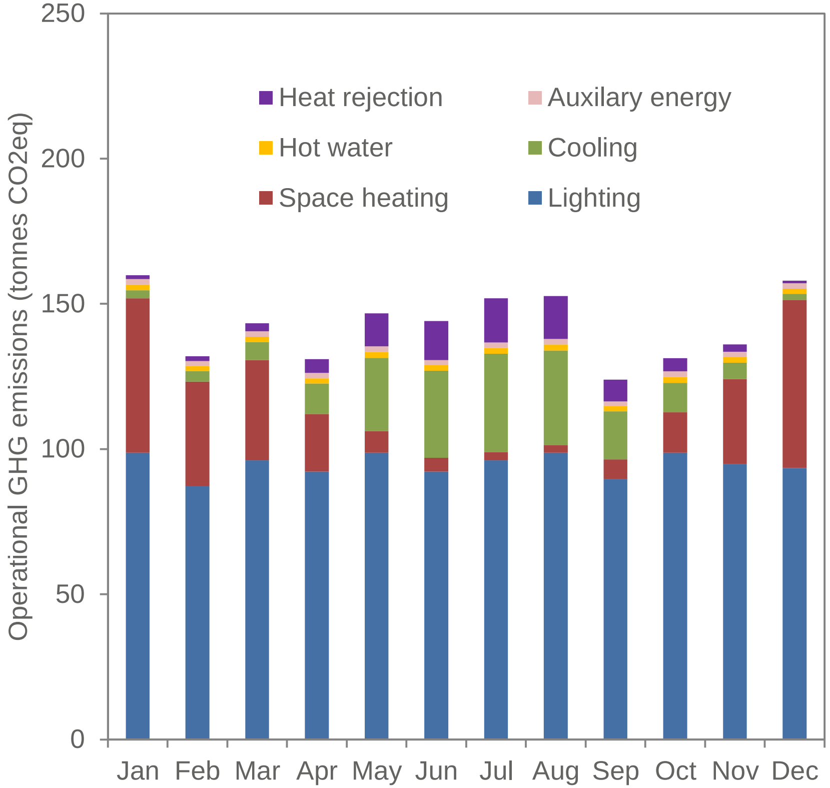
Environment Agency

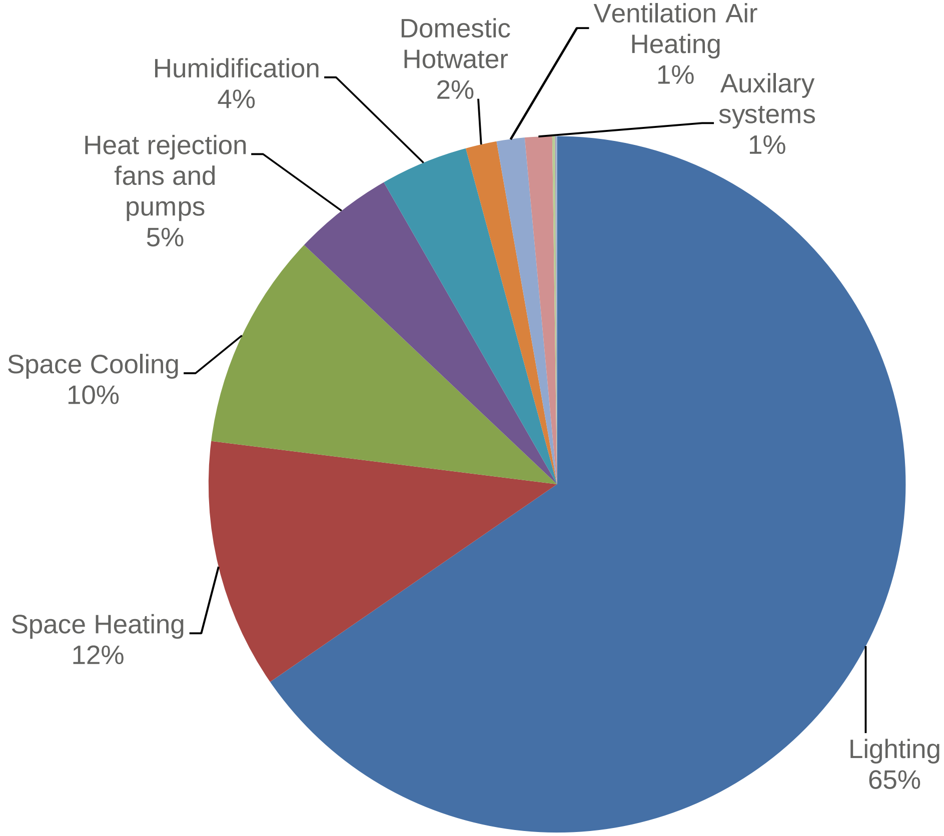
Manufacturing (cradle-to-gate) | Material transportation | On-site Construction | Operation

Case Study

Snowhill2

Building operation



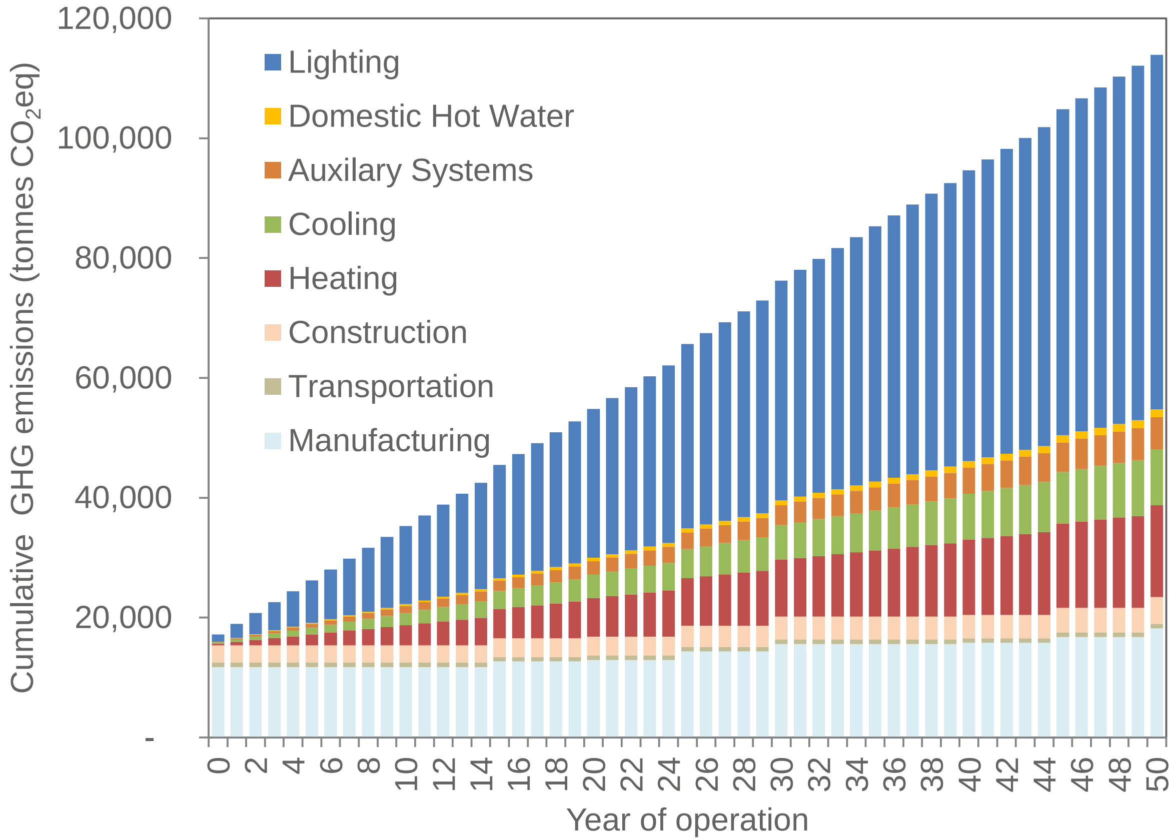


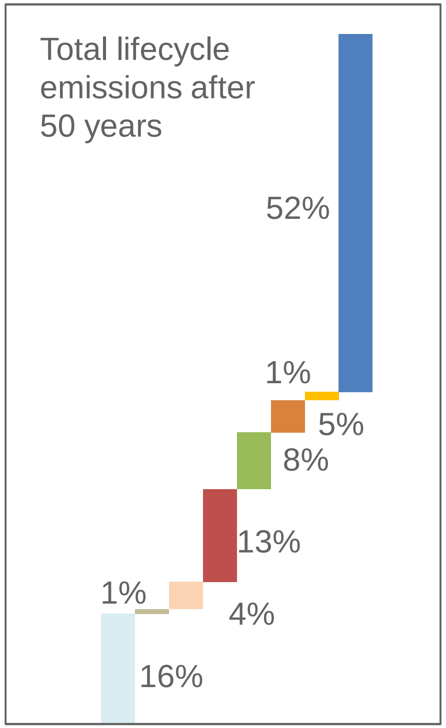
Manufacturing (cradle-to-gate) — Material transportation — On-site Construction — Operation

Case Study

Snowhill2

Lifecycle performance





PARSONS BRINCKERHOFF

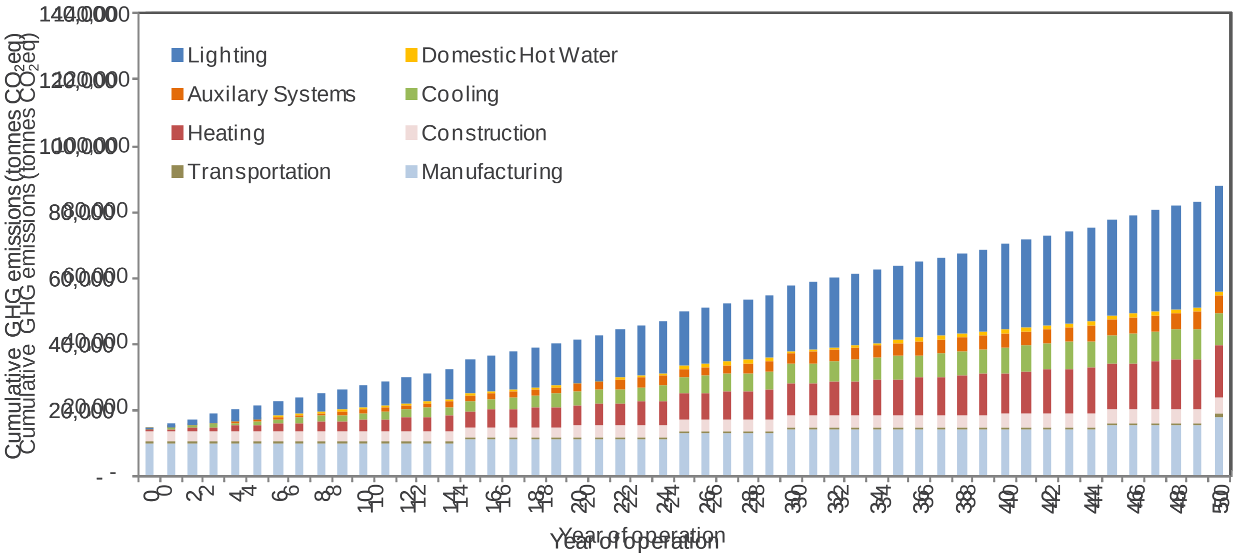
Balfour Beatty

Manufacturing (cradle-to-gate) — Material transportation — On-site Construction — Operation

Case Study

Snowhill2

Lifecycle performance – Potential design modifications



Base case design –

117,729 tonnes CO_2eq

Improved lighting scheme–

89,570 tonnes CO_2eq

(23.9% lifecycle improvement)

Use of cement replacement–

87,982 tonnes CO_2eq

(25.3% lifecycle improvement)

Improvement 1

Change fluorescent lighting to LED and include daylight dimming

Improvement 2

Change cement product to 50% Blast Furnace Slag Replacement

PARSONS BRINCKERHOFF

Balfour Beatty

Discussion

- Focus on ‘hotspots’ can address the majority of embodied carbon:
  - Approximately 77% of manufacturing emissions are due to only five components
  - Almost half of embodied emissions in the fabric are found in the primary concrete and steel elements. Making improvements to these elements will have significant impact.
  - Embodied emissions within flooring and finishes was also shown to be significant and worthy of focused improvement
  - Excessive detail on smaller elements could lead to ‘analysis paralysis’
- In the context of a complete building lifecycle, material transportation and onsite construction are relatively negligible
  - Despite this, across the sector, these issues are significant

Conclusions

- Government objectives, client concerns and polarised focus on operational lifecycle phases has driven the need for whole life carbon analysis

- To be effective, this must be integral to the design process and completed at a project stage that is able to influence design decisions

- The developed tool achieves this by 'bolting' on to existing analysis processes and requiring minimal effort to produce high level results

Publication

Williams, D., Elghali, L., Wheeler, R. and France C. (2012) Climate change influence on building lifecycle greenhouse gas emissions: Case study of a UK mixed-use development, *Energy and Buildings*, 48, pp. 112-126

PARSONS BRINCKERHOFF

Balfour Beatty

Whole life carbon analysis

David Williams
Parsons Brinckerhoff
Westbrook Mills
Godalming
Surrey
GU7 2AZ

Tel: 44-(0)1483-528406
Mobile: 44-(0)7990-564227

williamsdav@pbworld.com
www.pbworld.com/ea

EPSRC
Engineering and Physical Sciences Research Council

UNIVERSITY OF SURREY

PARSONS BRINCKERHOFF

Balfour Beatty