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Information paper – 12
Embodied carbon case studies for office buildings

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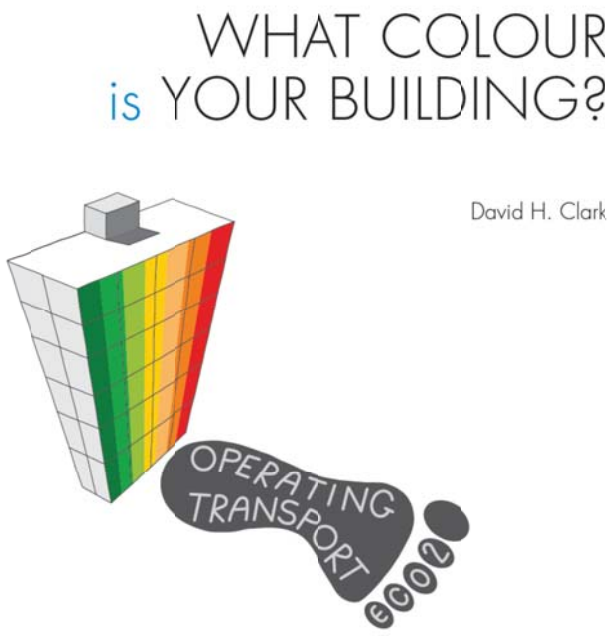
A paper referenced in the book:



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This information paper is one of a series of papers written during the preparation of the book **What Colour is Your Building?** (www.whatcolourisyourbuilding.com). The papers do not form part of the book and have not been peer reviewed. They provide further technical detail, analysis and information to support statements made in the book. All of the papers can be downloaded from www.wholecarbonfootprint.com.

Embodied carbon case studies for office buildings

This information paper provides a summary of the embodied carbon case study data used to create Figure 3.7 in Chapter 3 of the book. The studies were undertaken by different companies using different methodologies and, except where noted, all the information was sourced from case studies publically available in 2013. The author has made minor adjustments to the data, as described in this paper, in order to generate Figure 3.7 (copied below).

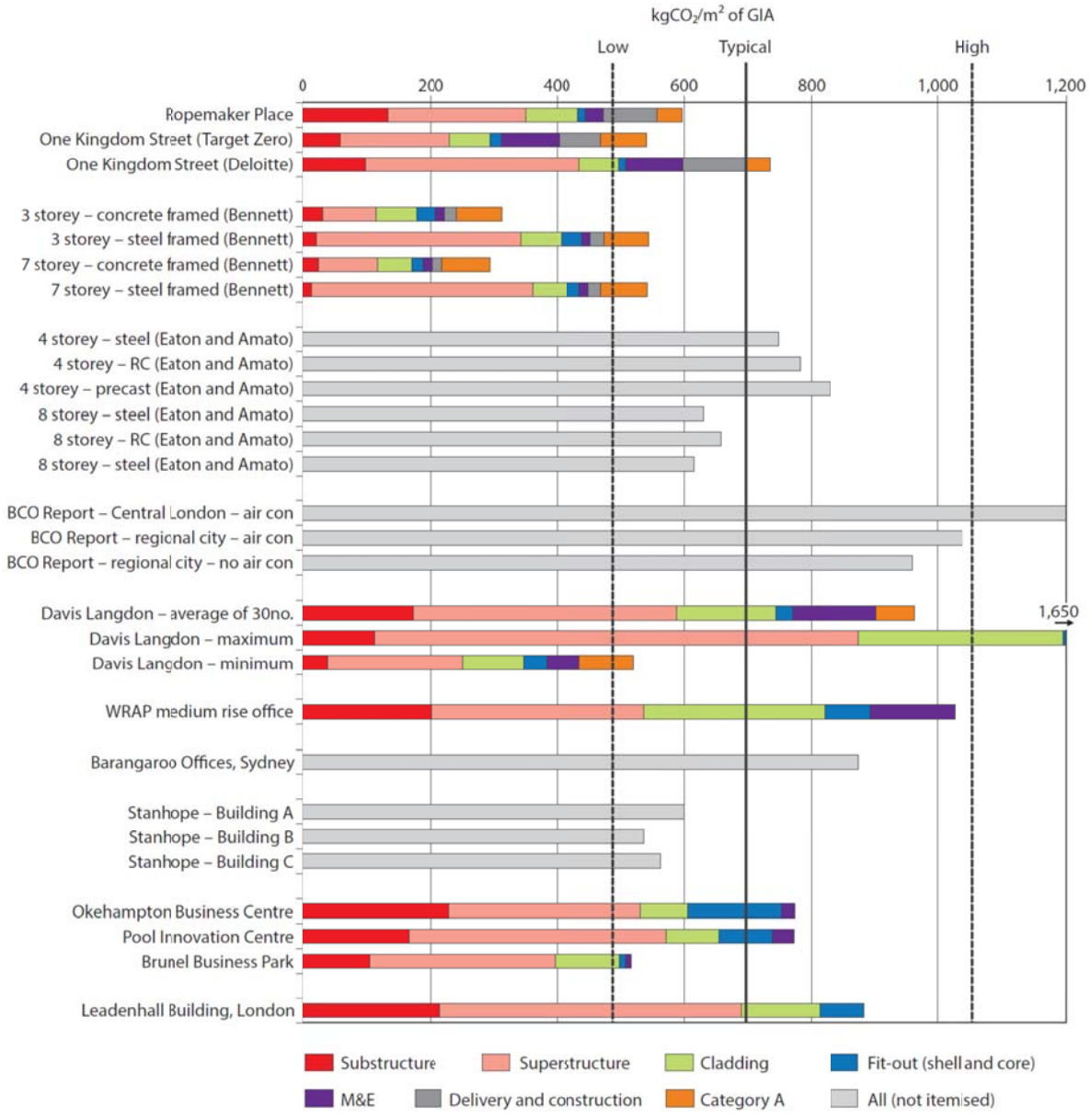

Fig 3.7 **Summary of embodied carbon in construction of new office buildings from various studies**

1. ROPEMAKER PLACE, LONDON

Ropemaker Place in London, a British Land developed building which opened in 2009, is one of the most high profile embodied carbon case studies in the UK and the data has been reported widely including:

- *Redefining Zero: Carbon profiling as a solution to whole life carbon emission measurement in buildings*, RICS Research Report, May 2010
- *Embodied Carbon - Concrete and Perceptible?* – presentation at UKGBC seminar in April 2010 by Sarah Cary of British Land
- *Ropemaker Place Life Cycle Carbon Assessment* – report prepared by dcarbon8 for British Land (date not known)
- *Carbon Profile: Ropemaker Place* – report prepared by Sturgis Associates for British Land, Feb 2010

Figure 1 shows a summary breakdown of the initial construction embodied carbon of the 80,800m^2, 20 storey building from the Assessment Table in the Carbon Profile report by Sturgis Associates.[1] The Category A fit-out items (1,129 tCO_2) were put under Fit-out (shell and core) in Figure 3.7 and the raised floor, floor finishes and ceilings itemised under the Category B fit-out (3,015 tCO_2) were moved by the author into Category A for the purpose of comparison in Figure 3.7. The remaining Category B items (788 tCO_2) were excluded from Figure 3.7.

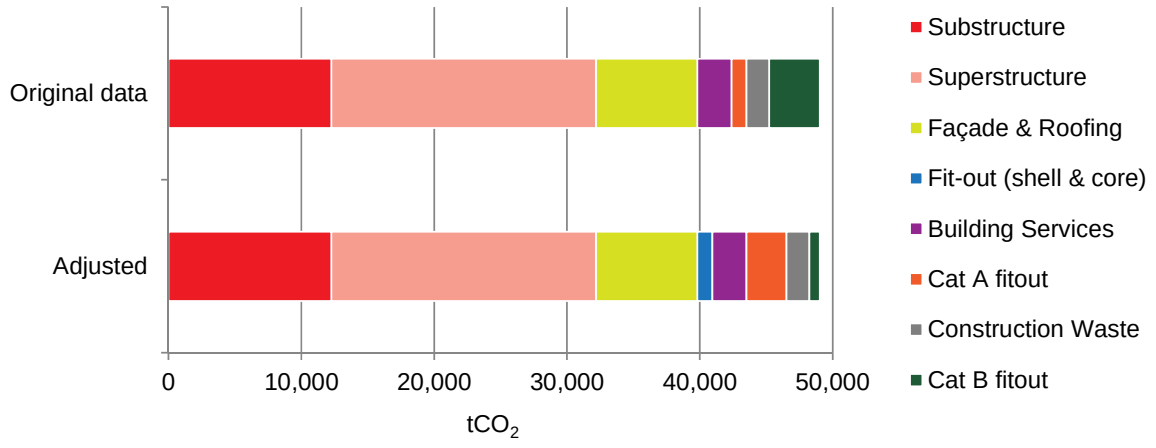

Fig 1 **Embodied carbon split for Ropemaker Place, London (source: adapted from Sturgis / British Land)**

2. ONE KINGDOM STREET, LONDON

Two different embodied case studies have been published for One Kingdom Street, a 10 storey, 33,000m^2 building in London:

- Chapter 10.0 Embodied Carbon from *Target Zero: Guidance on the Design and Construction of Sustainable Low Carbon Office Buildings*,[2] report v2.0, January 2012 contains data prepared by AECOM and Cyril Sweet.
- dcarbon8 case study of the building for Development Securities, undertaken in 2007. This was downloaded from the Deloitte website on 5 February 2012.[3] The diagram from the case study also appeared in the Institution of Civil Engineering's New Civil Engineer magazine in October 2009.

Figure 2 summarises the breakdowns from both of these studies. For the dcarbon8 study the breakdown shown is based on the stated initial construction embodied carbon of 24,319 tCO_2 multiplied by the percentage breakdown given in the case study, and then allocated under the categories used in Figure 3.7. The 'shell and core fit-out' was assumed to account for 20% of the raised floors, walls and partitions with the remainder allocated to Category A fit-out.

The Target Zero assessment gave a total embodied carbon of 14,937 tCO_2 for the base case (steel framed) building. To this was added 2,953 tCO_2 for building services (the same value taken from the dcarbon8 study) to give a total of 17,890 tCO_2.

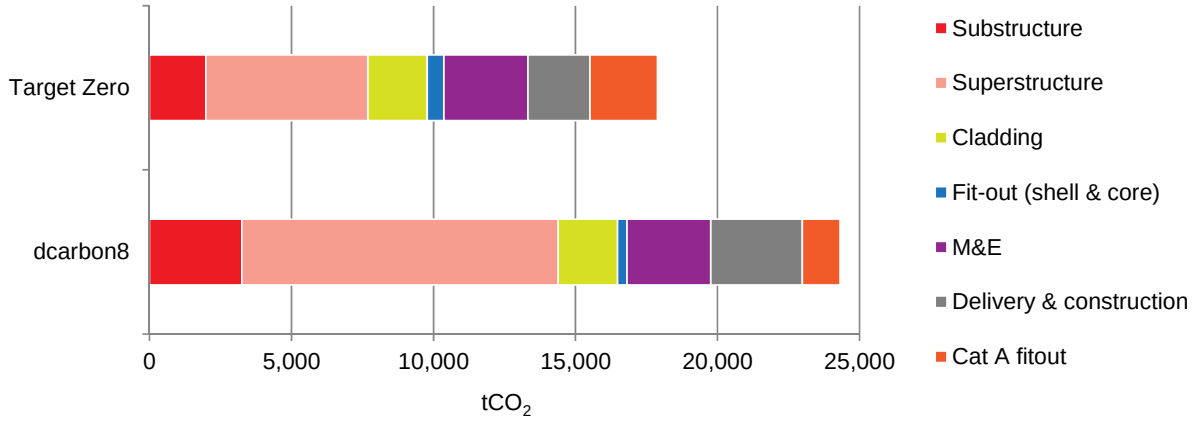

Fig 2 **Two embodied carbon studies for One Kingdom Street, London (source: adapted from Target Zero / dcarbon8)**

The large difference in values for the same building by experienced consultants illustrates the diversity of assumptions, ECO_2 factors and methodologies used when undertaking embodied carbon assessments. No attempt is made in this information paper to explain the reasons for the differences.

3. SUSTAINABLE CONCRETE ARCHITECTURE

The book, *Sustainable Concrete Architecture* by David Bennett (RIBA Publishing, 2010) contains a detailed breakdown of an embodied carbon calculation for two typical office buildings, a 3 storey (4,200m^2) and a 7 storey (9,850m^2), with versions in both concrete and in steel. Figure 3 shows the breakdown of embodied carbon for these. 5 kgCO_2/m^2 has been added for 'cradle to site' (transport and construction) for all scenarios for inclusion in Figure 3.7 by the author.

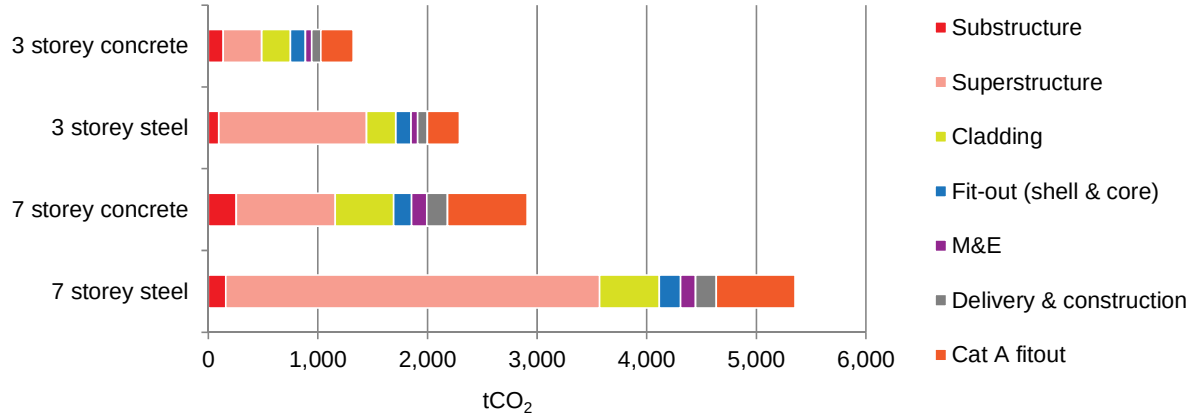

Fig 3 **Embodied carbon studies from Sustainable Concrete Architecture (source: adapted from Bennett)**

The ECO_2 factors used for steel are over 3 times higher than the values commonly used while the concrete and reinforcement factors are lower. Refer to Appendix I and *Information Paper 31 – Embodied carbon of steel versus concrete buildings* for a comparison of the original and adjusted embodied carbon which shows little difference between steel and concrete if ECO_2 emission factors from the ICE v2 database are used.[4]

4. EATON & AMATO

A Comparative Environmental Life Cycle Assessment of Modern Office Buildings by K J Eaton and A Amato, SCI Publication 182 was published by the Steel Construction Institute in 1998. The embodied carbon for two typical offices, Building A (4 storey, 2,600m^2) and Building B (8 storey, 18,000m^2), were calculated for five different structural options:

- Concrete – reinforced concrete frame & slab.
- Concrete – precast concrete & hollow core units.
- Steel – slim floor beams & hollow precast.
- Steel – composite beams & composite slabs.
- Steel – cellular beams & composite slabs.

Figure 4 shows the breakdown of results. As this was not split into the components used in other case studies only the total value was shown in Figure 3.7.

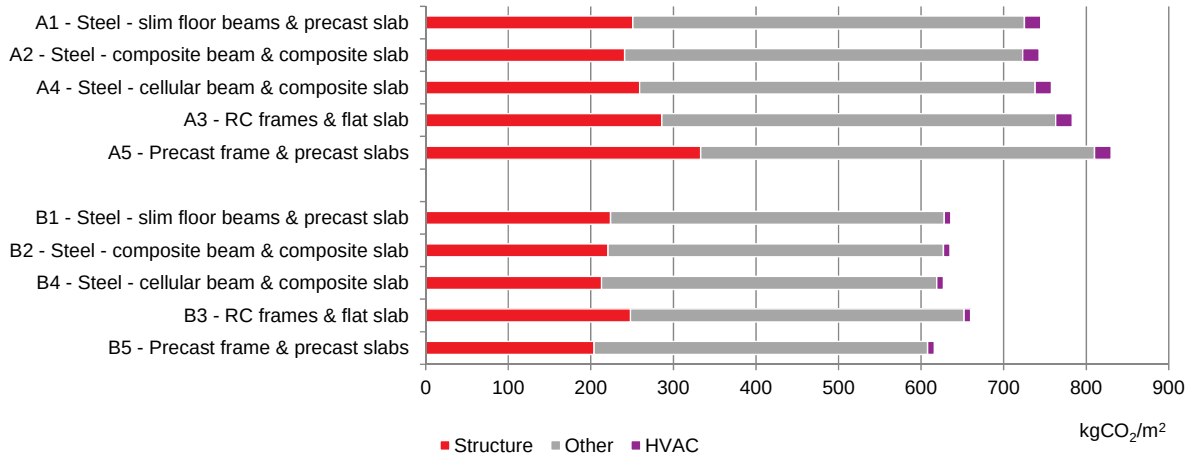

Fig 4 **Embodied carbon results from Eaton & Amoto study (source: adapted from Eaton & Amato)**

The 'other embodied' in Figure 4 includes raised access floors, carpet tiles, suspended ceiling, cladding and transport of goods to site. Building A has brick and block cladding while building B is curtain walling. As the results for the three steel options were quite similar the average of the three was taken and used as the 'steel' option in Fig 3.7 in Chapter 7.

5. BCO REPORT 2011

The *Whole-Life Carbon Footprint Measurement & Offices* report was prepared for the British Council of Offices (BCO) in May 2011 by Angus McIntosh of King Sturge LLP and Gareth Roberts of Sturgis Carbon Profiling LLP. The report provides some typical whole life figures for a range of different new build office typologies including operational energy, embodied carbon and commuting transport emissions. The embodied carbon values in Figure 3.7 are based on the values used to establish the baseline study for offices:

- Central London with air conditioning.
- Regional city with air conditioning.
- Regional city with no air conditioning.
- Out-of-town business park.

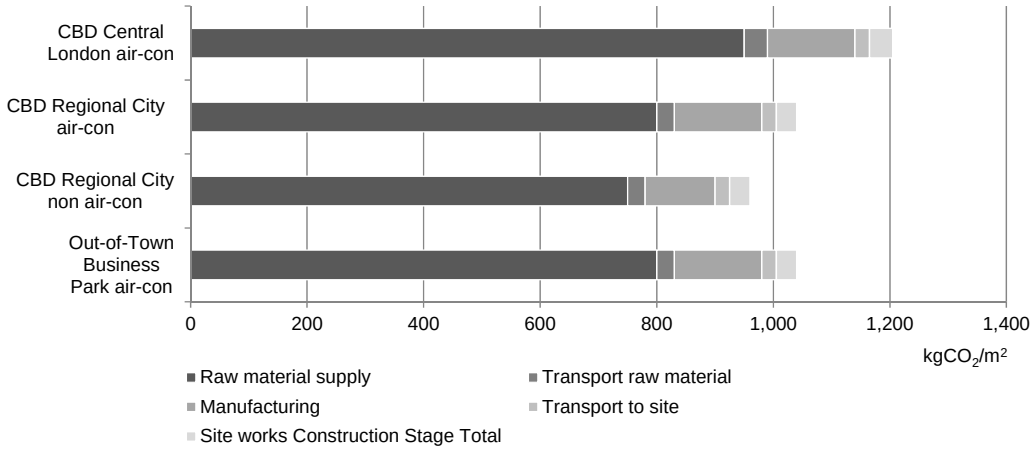

Fig 5 **Embodied carbon breakdown for typical office building types (source: adapted from BCO)**

6. DAVIS LANGDON

Data from embodied carbon assessments undertaken by the team at Davis Langdon for 30 new build offices over a number of years was kindly supplied to the author by John Connaughton and David Weight in 2011. Figure 5 summarises this data and shows a wide variation of results – there is no such thing as a 'typical' building. The average of the case studies was 964 $kgCO_2e/m^2$. The maximum value was 1,650 $kgCO_2e/m^2$ and the minimum was 520 $kgCO_2e/m^2$.

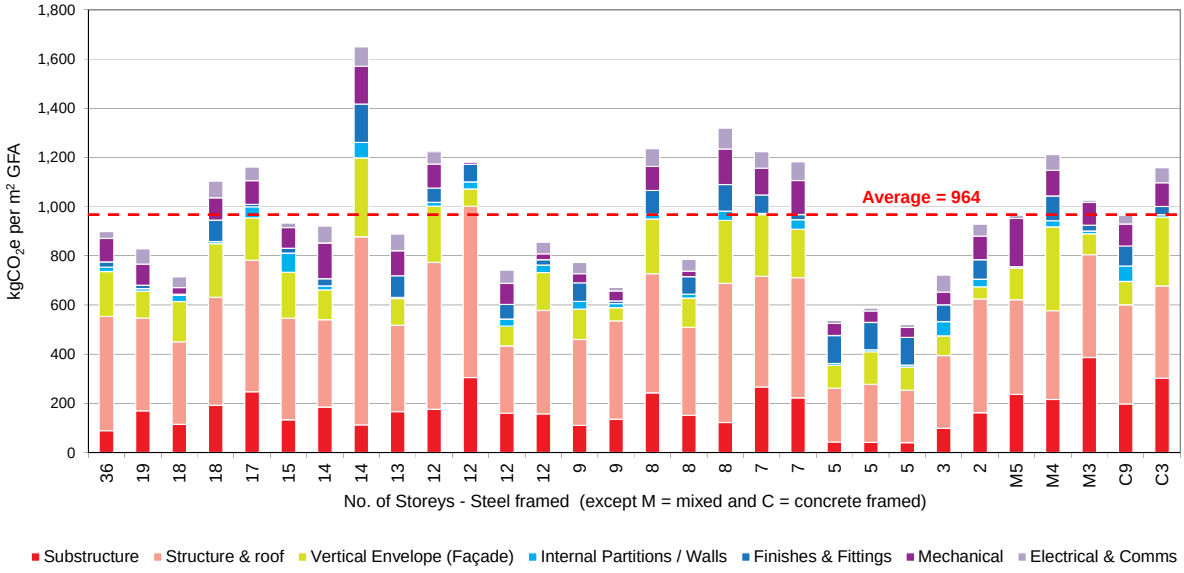

Fig 6 **Summary of embodied carbon studies for new office buildings (source: Davis Langdon)**

The proportion of embodied carbon in the structural elements is shown in Figure 7 with the average being 60%.

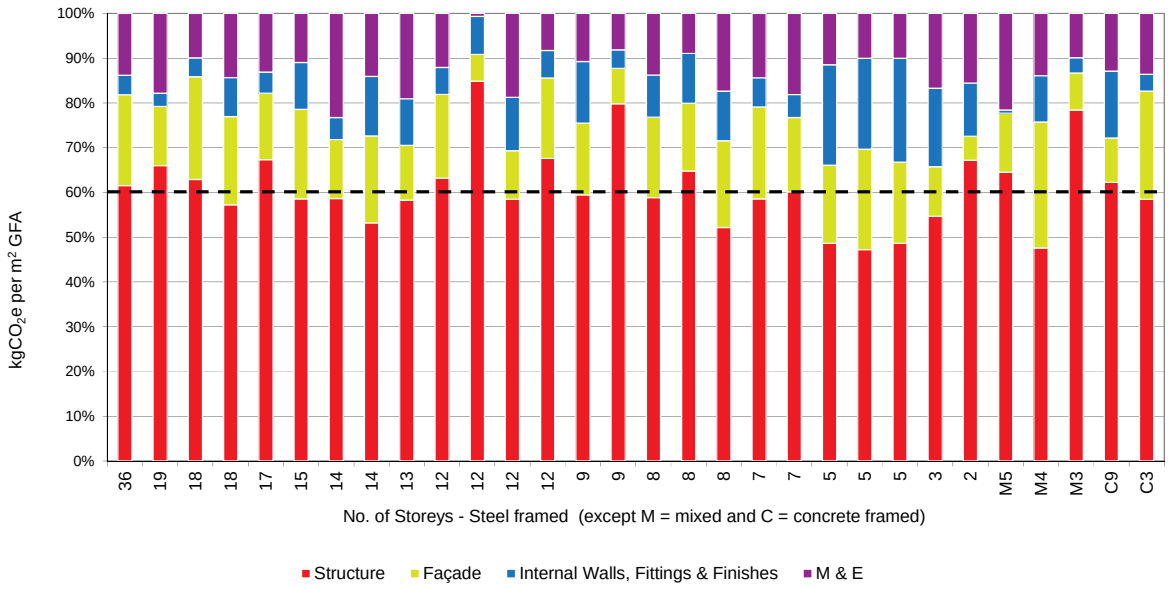

Fig 7 **Proportion of structure in embodied carbon studies for new office buildings (source: Davis Langdon)**

7. WRAP MEDIUM RISE OFFICE STUDY

In *Cutting embodied carbon in construction projects, an information sheet for construction clients and designers*[5] published by WRAP embodied carbon values for a medium rise office building and office fit-out were given. These are shown in Figure 8. The Fit-out (shell and core) value of 73 $kgCO_2/m^2$ used in Figure 3.7 included internal walls (20), internal doors (3) and an allowance for internal finishes (50). The total for the finishes in the office building case study was 95 $kgCO_2/m^2$ and in the fit-out case study it was 45 $kgCO_2/m^2$. The difference of 50 $kgCO_2/m^2$ was assumed for the internal finishes included in Figure 3.7. The values for a school (810 $kgCO_2/m^2$) and a house (600 $kgCO_2/m^2$) were also given in the WRAP report.

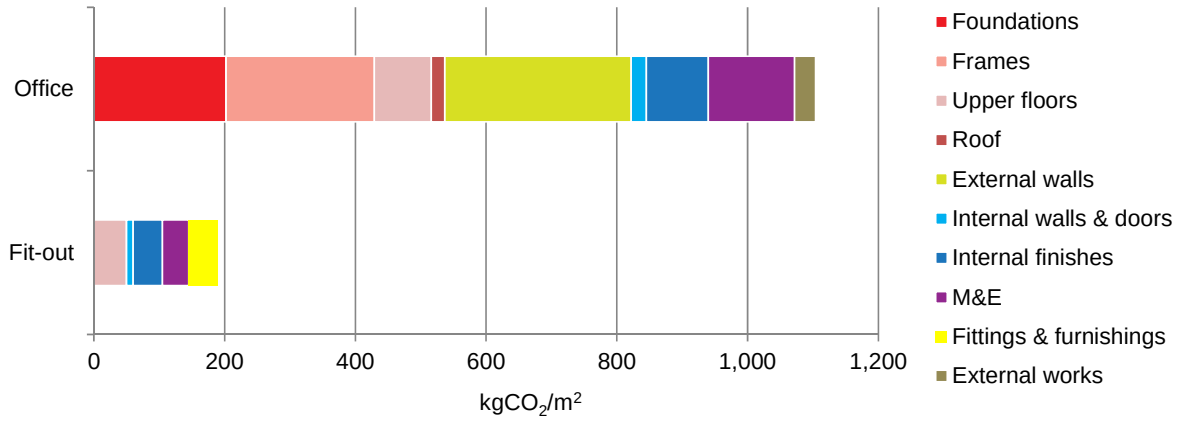

Fig 8 **WRAP case study data for an office and fit-out (source: adapted from WRAP)**

8. BARANGAROO OFFICES, SYDNEY

The data was taken from a dcarbon8 case study undertaken in 2008/09 for Lend Lease. The Barangaroo development in Sydney, Australia includes 339,725m^2 of commercial development.[6] The breakdown from the case study sheet is shown in Figure 9.

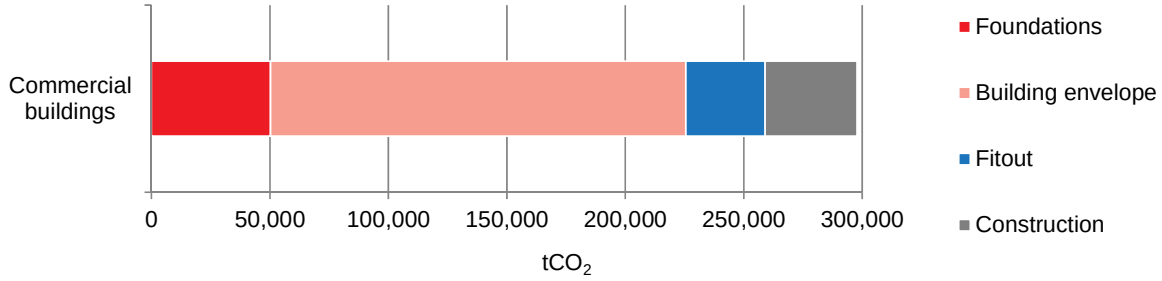

Fig 9 **Commercial building embodied carbon from Barangaroo assessment (source: adapted from dcarbon8)**

9. STANHOPE BUILDINGS

In their 2010 report *Energy Labelling: a broader perspective*, development company Stanhope examined four of their office developments.[7] The embodied carbon values stated in the report have been converted from kgCO_2/m^2 of NIA to GIA using a factor of 1.25 as shown in Table 1.

	kgCO_2 / m^2 of GIA			
Building	A	B	C	D
Construction	600		537	563
Major refurbishment		186		
Fit-out	212	98 *	103	

* excludes substructure and superstructure works from refurbishment total

Table 1 **Embodied carbon from Stanhope case studies converted to GIA (source: adapted from Stanhope)**

10. HALCROW CASE STUDIES

The *Embodied Carbon: Sustainable Offices – a supplementary report*, prepared by Halcrow Yolles in September 2010 for South West Regional Development Agency,[8] contained three case studies:

- Okehampton Business Centre (1,140 m^2, 1 storey)
- Pool Innovation Centre, Camborne (3,441 m^2, 2 storey)
- Brunel Business Park, St Austell (2,341 m^2, 2 storey)

The breakdown from the case studies is shown in Figure 10. The values used in Figure 3.7 excluded the external landscaping. On the Okehampton project this accounted for 16% of the total.

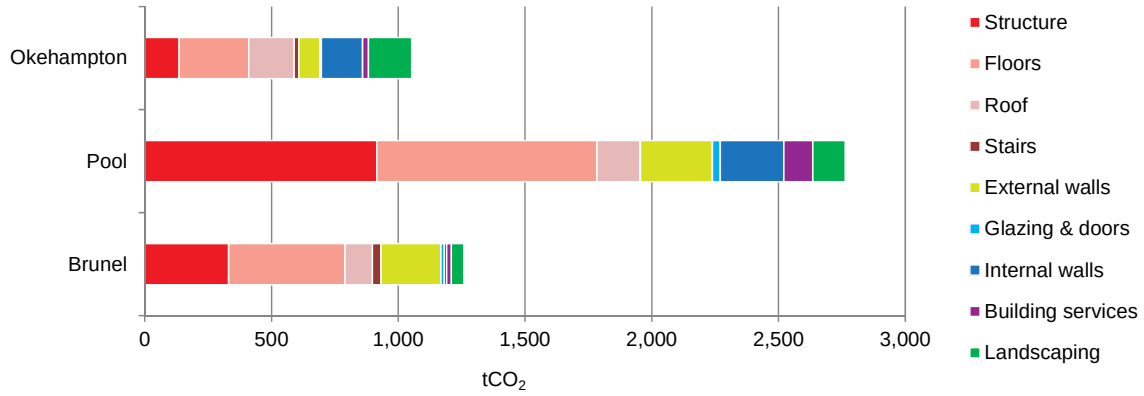

Fig 10 **Embodied carbon for three regional office buildings (source: adapted from Halcrow Yolles)**

11. LEADENHALL BUILDING

Leadenhall is a 51 storey building in London. A case study by Davis Langdon in a RICS draft information paper[9] gave the total embodied carbon as 76,158 tCO_2e. Based on a GIA of around 86,450m^2 the embodied carbon per m^2 was stated as 881 $kgCO_2e/m^2$. A breakdown is shown in Figure 11.

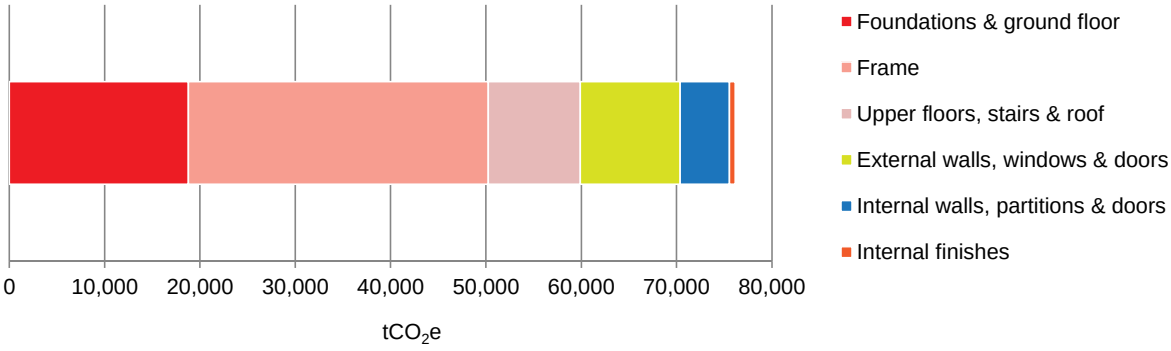

Fig 11 **Leadenhall building embodied carbon breakdown (source: adapted from RICS / Davis Langdon)**

Notes

All websites were accessed on 16 June 2013 unless noted otherwise.

1. www.britishland.com/~/media/Files/B/British-Land/press-release/2010/BL-Ropemaker-Carbon-Sturgis.pdf

2. www.steelconstruction.info/Target_Zero

3. www.deloitte.com/assets/Dcom-UnitedKingdom/Local%20Assets/Documents/Market%20insights/Sustainability%20Services/UK_MI_Sustainability_dcarbon8_CS1_(LOCKED).pdf

4. *Embodied Carbon: The Inventory of Carbon and Energy* (ICE), by M. G. Hammond and C. Jones, BSRIA Guide BG10/2011.

5. www.wrap.org.uk/sites/files/wrap/FINAL%20PRO095-009%20Embodied%20Carbon%20Annex.pdf

6. www.deloitte.com/assets/Dcom-UnitedKingdom/Local%20Assets/Documents/Market%20insights/Sustainability%20Services/UK_MI_Sustainability_Barangoo_(LOCKED).pdf

7. www.stanhopeplc.com/?page=42&id=601 – accessed 21 January 2013.

8. www.halcrow.com/Documents/building_engineering/Halcrow_sustainable_offices_embodied_carbon.pdf

9. *RICS draft information paper - Methodology for the calculation of embodied carbon as part of the life cycle carbon emissions for a building*, 2012. https://consultations.rics.org/consult.ti/embodied_carbon/viewCompoundDoc?docid=2598132&partid=2599060&sessionid=&voteid=