WHAT COLOUR is YOUR BUILDING?

Measuring and reducing the energy and carbon footprint of buildings

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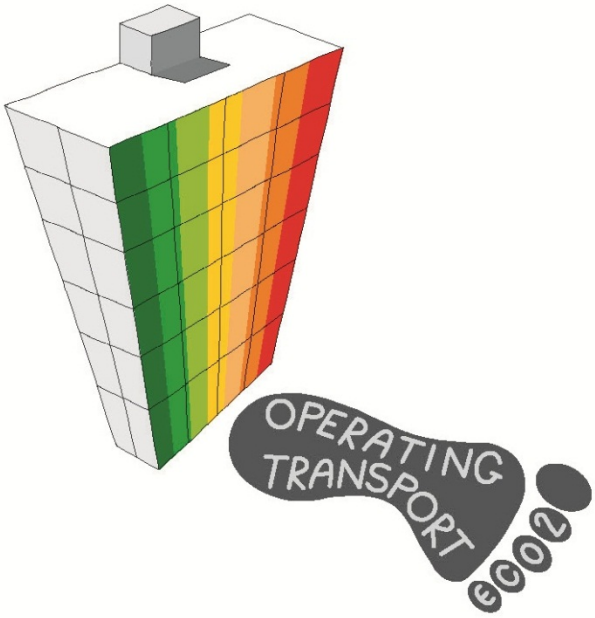

Appendix G

Whole carbon footprint benchmarking

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Appendix G: Whole carbon footprint benchmarking

In order to properly understand the big picture, everyone should fear becoming mentally clouded and obsessed with one small section of truth.
XunZi, Chinese Confucian philosopher.

Contents

The assumptions used in the whole carbon footprint benchmarking methodology in Chapter 5 (Whole carbon footprint) are described in this appendix. A benchmarking tool using this methodology can be downloaded from www.wholecarbonfootprint.com.

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G1. TOOL STRUCTURE

The Whole Carbon Footprint Tool structure is shown in Figure G.1. A series of inputs are required, with a selection of default values available to use in the preliminary design stage for when data is not available. Clearly, if this methodology was ever to be adopted in a formal benchmarking system, then a rating could only be based on verified user input data.

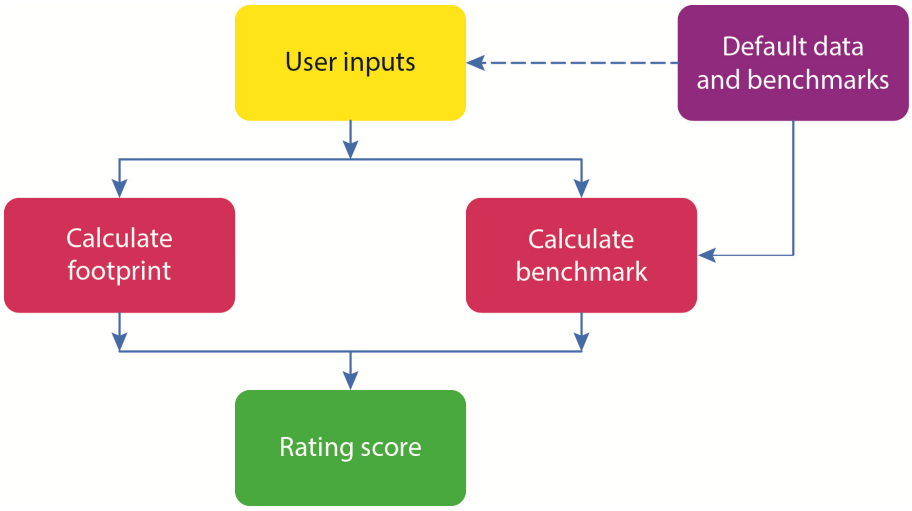


Fig G.1 Benchmarking tool structure

G2. BUILDING DETAILS

Data entry

- Total gross internal floor area (GIA) — m^2 excluding car parking
- Total net lettable area (NLA) — m^2 of floor available to rent
- Average NLA occupied during year — m^2 leased and occupied during the year *
- No. of occupants — full time equivalent (FTE) averaged over the year
- Annual hours of use — default is 2600 hours

** based on time weighted average. For example, in a building with an NLA of 8,000 m^2, if 4,000 m^2 was occupied for 12 months, 2,000 m^2 was occupied for 6 months, and 2,000 m^2 was unoccupied, then the average occupied NLA would be (4,000 x 12 + 2,000 x 6 + 2,000 x 0) / 12 = 5,000 m^2. This gives an average floor area occupancy of 63%.*

Base assumptions

The base assumptions for the tool are set out in Table G.1.

Item	Value	Reference
Occupancy density	15 m^2 per person	Appendix D
Hours of use	2,600 hours	Appendix D
Electricity emissions factor	0.6 $kgCO_2e/kWh$	Chapter 1
Heating emissions factor (gas)	0.2 $kgCO_2e/kWh$	Chapter 1
Life of building	60 years	Chapter 3

Table G.1 Default assumptions for whole carbon footprint rating tool

G3. OPERATING CARBON

Data entry

The operating carbon of the building is calculated in $kgCO_2e$ per year. There are two options to enter operating carbon:

- enter $kgCO_2e/m^2$ of GIA, or
- enter energy consumption in kWh for electricity and heating fuel.

For option 1, the CO_2e emission factors in the book (refer Table G.1) must be used to calculate the operating carbon as the benchmark of 100 $kgCO_2e/m^2$ of oGIA is also based on these factors. For option 2, the user can enter different emission factors and these are used to adjust the operating carbon benchmark (refer below).

If only the landlord energy consumption is known by the user, (i.e. the tenants have a separate utility meter) then the values in Table G.2 can be adopted and added to the landlord energy consumption to estimate the whole building operating carbon for preliminary benchmarking purposes.

		W/m^2 of NLA	W/m^2 of GIA	Hours	kWh/m^2	$kgCO_2e/m^2$
Tenant lighting	Poor	25	20	2600	52	32
	Average	15	12	2600	31	19
	Good	10	8	2600	21	13
		W / person	W/m^2 of GIA	Hours	kWh/m^2	$kgCO_2e/m^2$
Tenant power	Computers	100	6.7	2600	17	11
	Printer	10	0.7	2600	2	1
	Server	20	1.3	8760	12	7
	Fridge	5	0.3	8760	3	2
	Other	10	0.7	8760	6	4
	Total				**40**	**25**

Assumptions: standard occupancy = 15 m^2 of GIA / person, net to gross area ratio = 0.8, standard hours = 10 hrs x 5 days / week

Table G.2 Example values for tenancy energy consumption (if not known / metered by landlord)

Operating carbon benchmark

The base operating carbon benchmark for the whole building (refer Chapter 2) is set at **100 $kgCO_2e/m^2$ of oGIA** using the emission factors in Table G.1.

If data entry option 2 is selected and the user enters different emission factors, then the base operating carbon benchmark is adjusted to reflect the user grid electricity factor. The heating emission factor, while used to calculate the building operating carbon, is not used to adjust the benchmark (which is based on natural gas as per Table G.1). The assumed split in energy consumption to calculate the benchmark is 140 kWh/m^2 for grid electricity and 80 kWh/m^2 for heating fuel consumption. For example, if the user entered 0.8 $kgCO_2e/kWh$ for electricity, the base operating carbon benchmark would be (0.8 x 140 + 0.2 x 80 =) 128 $kgCO_2e/m^2$.

The base benchmark is then adjusted using the occupancy density and hours of use factors described in Appendix D. The hours of use factor is calculated using the following formula, which returns a value of 1 for the default hours of 2,600.

Hours of Use Factor = 0.5345 + (hours of use x 0.000179)

The occupancy factors are shown in Table G.3.

m^2 / person	Occupancy factor		m^2 / person	Occupancy factor
10	1.13		21	0.92
11	1.10		22	0.91
12	1.08		23	0.91
13	1.05		24	0.90
14	1.03		25	0.89
15	1.00		26	0.89
16	0.99		27	0.88
17	0.97		28	0.88
18	0.96		29	0.87
19	0.94		30	0.87
20	0.93			

Table G.3 Occupancy factors for operating carbon benchmark

Finally, the oGIA is calculated. This is total GIA of the building (excluding car parking) adjusted to reflect the average floor area occupied in the year. The average floor occupancy is the occupied NLA divided by the total NLA.

oGIA = GIA x average floor area occupancy

The operating carbon benchmark in $kgCO_2e$ is calculated as follows:

Benchmark = base benchmark x occupancy factor x hours of use factor x oGIA

Indicative Display Energy Certificate (DEC) rating

The tool gives an indication, based on the values entered, of the potential DEC rating excluding any adjustments due to hours of use or allowable separables. For option 1 data entry, the DEC benchmark is set using the emission factors in Table G.1. For option 2, the DEC rating score is based on the official DEC emission factors (0.551 $kgCO_2e/kWh$ for electricity and 0.190 $kgCO_2e/kWh$ for gas) and the user entered energy consumption (in kWh). The rating scores for options 1 and 2 are shown in Table G.4.

DEC rating	Score	$kgCO_2e/m^2$	
		Option 1 (book)	Option 2 (DEC)
A	25	20	19
B	50	41	38
C	75	61	56
D	100	81	75
E	125	101	94
F	150	122	113
G	150+	122+	113+

Table G.4 DEC rating scores using emission factors from Chapter 1 (book) and DEC tool

G4. EMBODIED CARBON

Data entry

If the rating is for an existing building, then the tool assumes no refurbishment is proposed and no data entry is required. The default values for future fit-out and refurbishment in Table G.5 are assumed. These are based on values described in Chapter 3.

	Typical	Low	High	First year	Default frequency (years 2-60)
	($kgCO_2e/m^2$ of GIA)				
New build (including Cat A)	**700**	470	1050	Yes	-
Fit-out (Cat A)	**100**	70	150	-	15 years
Fit-out (Cat B)	**0**	0	0	-	-
Existing building	**0**	0	0	-	-
Minor refurbishment	**25**	15	40	-	15 years
Major refurbishment	**100**	70	150	-	30 years
Reclad	**100**	70	150	-	-
Demolition and disposal	**30**	30	30	-	-

Table G.5 Default values for the embodied carbon benchmark (and existing building)

If the building is new build or refurbished, then the following data is required:

- Embodied carbon values ($kgCO_2e/m^2$) for different activities listed in Table G.5. These can be selected from a drop down menu (low, typical or high in Table G.5) or users can enter their own values.
- Activities in first year – if new build then this occurs in the first year, if refurbished then users can select which activities occur (e.g. Cat A fit-out, major or minor refurb, etc.).
- Frequency of activities in Years 2 to 60 – select how often each activity occurs in the future using the drop down menus (e.g. Cat A fit-out every 15 years).

If a building is being demolished to make way for a new building, then the floor area of the demolished building can be entered.

The tool allows Cat B fit-out values to be entered by the user to consider its effect on the whole carbon footprint, however these values are excluded from the benchmarking calculation due to the lack of reliable benchmarking data.

A chart is provided (refer Figure G.2 for example) to show the value and frequency of each embodied carbon activity selected or entered by the user.

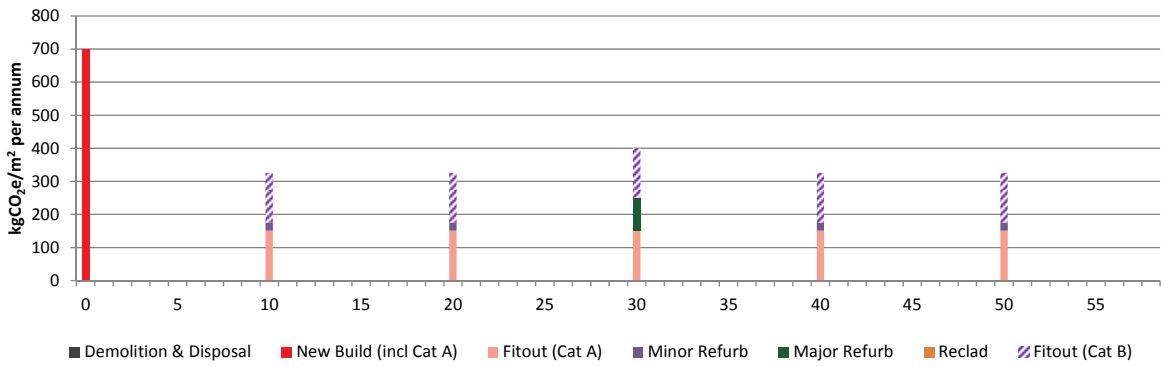


Fig G.2 **Example embodied carbon data entry check in the tool**

Embodied carbon benchmark

The embodied carbon benchmark is calculated by assuming a new building and multiplying the typical embodied carbon values by the default frequency of occurrence over a 60 year period (as shown in Table G.5) and then dividing this by 60 years. Fig G.3 shows the values used in this calculation.

For an existing building assessment, where no refurbishment is occurring, then the same benchmark values apply, except that the initial embodied carbon in the first year is set to zero. A separate benchmark is also calculated, based on the user entered frequency of fit-out and refurbishment multiplied by the typical embodied carbon values in Table G.5. This is provided to

allow comparison between embodied carbon values (i.e. ignoring default frequencies) but does not form part of the overall benchmarking calculation.

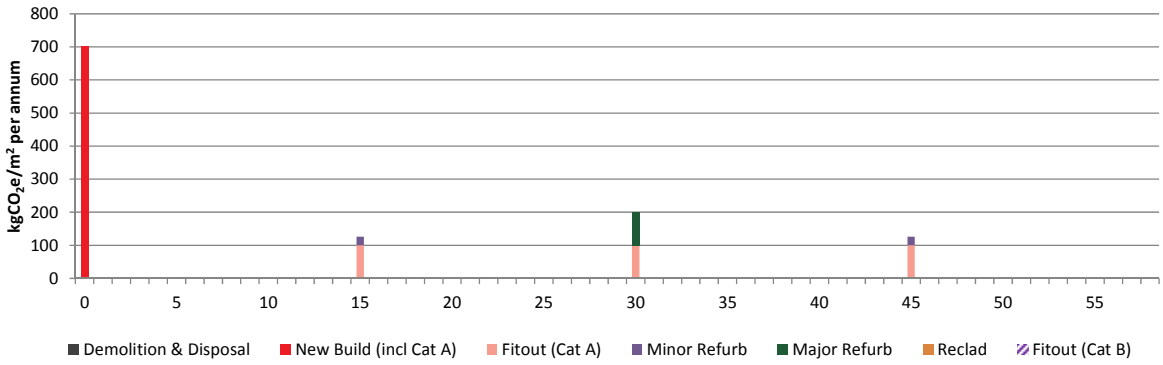


Fig G.3 Benchmark embodied carbon values used for new / refurbished building

G5. TRANSPORT CARBON

Data entry

The user can either select from a drop down menu of typical values of $kgCO_2e$/person or enter a value directly. The drop down values are shown in Table G.6.

	$kgCO_2e$/person/year
Low	500
Central London (typical)	*800*
Medium	1250
Business park (typical)	*1500*
High	2000

Table G.6 Values for transport carbon drop down menu

Transport carbon benchmark

The benchmark in $kgCO_2e/m^2$ is calculated based on **1250 $kgCO_2e$/person/year** (refer Chapter 4) and the occupancy density of the building entered in the tool.

G6. BENCHMARKING CALCULATIONS

The whole carbon footprint benchmarking score is calculated using the formula:

$$\text{Score} = \frac{\text{Total footprint (kgCO}_2\text{e/m}^2\text{) x 100}}{\text{Adjusted benchmark (kgCO}_2\text{e/m}^2\text{)}}$$

The total footprint is calculated based on the input data (operating, embodied and transport) with no adjustments. The adjusted benchmark is calculated by adding together the operating, embodied and transport carbon benchmarks as described above. *Note: the operating carbon footprint is converted from kgCO₂e/m² of oGIA to kgCO₂e/m² of GIA by multiplying by the average floor area occupancy ratio.*

The score is converted into a letter and a star rating (choose which one you prefer) by using the rating scales shown in Table G.7. The benchmark score of 100 is equivalent to a D rating and 3 stars.

Score	Letter rating	Star rating		Score	Letter rating	Star rating
12.5	A+	7		112.5	E+	2.5
25	A	6		125	E	2
37.5	B+	5.5		137.5	F+	1.5
50	B	5		150	F	1
62.5	C+	4.5		162.5	G+	0.5
75	C	4		175	G	0
87.5	D+	3.5		>175	H	0
100	**D**	**3**				

Table G.7 Rating scales and required scores

G7. TOOL OUTPUTS

Typical outputs from the tool are:

- $kgCO_2e/m^2$ of GIA for operating, embodied, transport data and benchmarks.
- Benchmarking score.
- tCO_2e/person.
- Chart of tCO_2e per annum comparing building and benchmark.
- Breakdown of CO_2e by category.
- Total tCO_2e over 60 years.
- Chart of cumulative carbon emissions over 60 years.

An example output for the Cundall Manchester office, an existing building, is shown in Figure G.4.

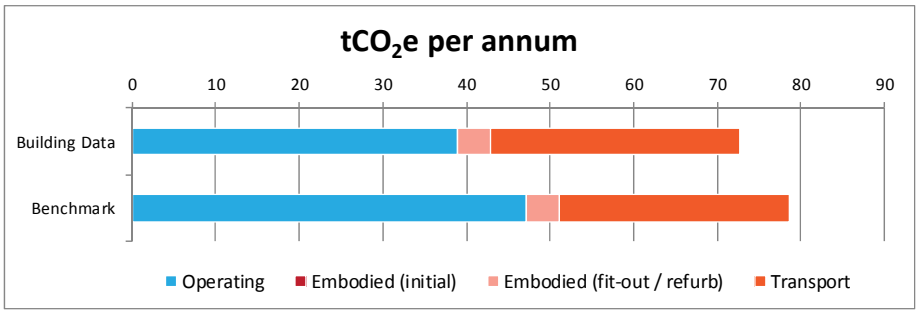
Benchmarking Summary

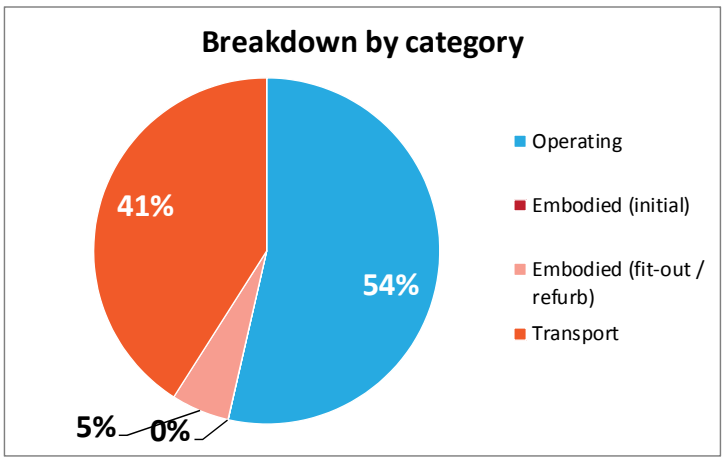
	kgCO$_2$e/m^2 of GIA per year			
	Operating	Embodied	Transport	Total
Building performance	74	8	57	**138**
Benchmark	90	8	52	**150**
% score compared to benchmark	82%	100%	108%	92%

kgCO$_2$e/person	*1,769*	*179*	*1,353*	***3,302***

Rating Score	92.3

	Letter	Stars
Rating	D	3





Total tCO$_2$e over 60 years		%
Operating	2,297	*54%*
Embodied - intial	0	*0%*
Embodied - refurb / fitout	237	*6%*
Transport	1,756	*41%*
Total	**4,289**	***100%***

Cat B not included in the metric or pie chart		
Cat B fitout	0	*0%*
Total with Cat B	**4,289**	***100%***

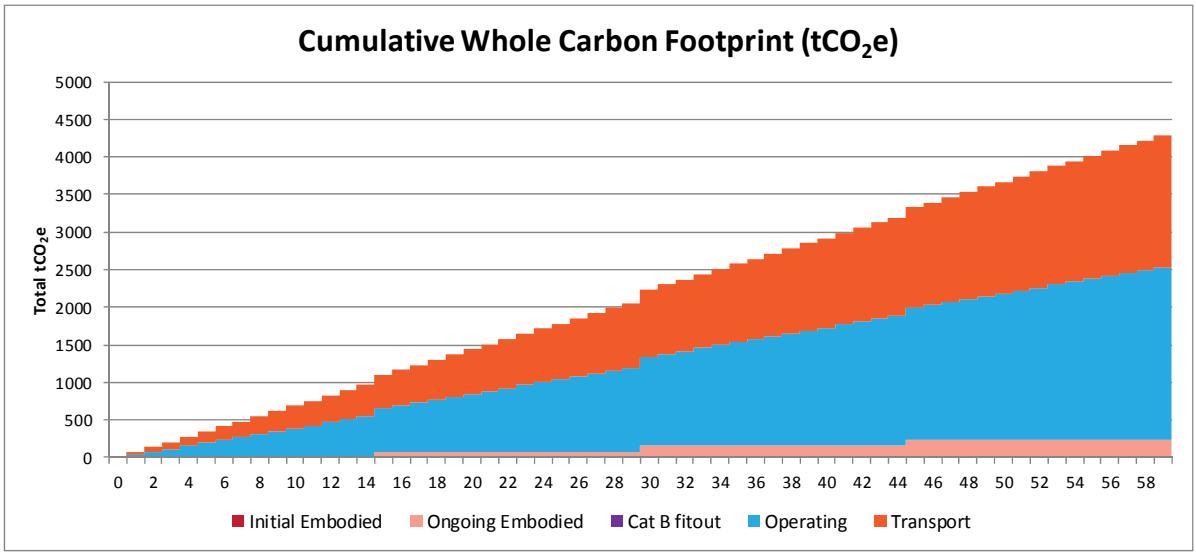


Fig G.4 **Example output from the Whole Carbon Footprint Tool**

G8. CHANGING FOOTPRINT OVER TIME

The tool provides a snapshot of the whole carbon footprint today. It does not take into consideration the future reduction of carbon emissions due to:

- Reducing energy consumption of the building due to energy efficiency improvements, refurbishment and changes in occupant behaviour.
- Decarbonisation of energy supplies (electricity and gas) – refer to Appendix D for more details on this and potential adjustment factors for operating and embodied carbon.
- Increased energy efficiency and recycling/reuse in the product manufacturing industry.
- Decarbonisation of the transport sector – freight, public transport, and cars.

These introduce so many future variables into the equation that it would be difficult to see the wood from the trees and would expose the calculations to manipulation. A benchmark needs to be robust, simple and transparent, and based on the best data available at the time.

The methodology for calculating the whole carbon footprint can be easily expanded to allow different values for operating, embodied and transport carbon to be entered each year if required.