FCBS CARBON

Guide to the early design stage lifecycle carbon review tool

FeildenCleggBradleyStudios

FCBS CARBON

As part of our commitment to Architects Declare and our ongoing work to mitigate climate change, we are sharing our in-house whole life carbon tool with the wider industry.

FCBS CARBON has been designed to estimate the whole life carbon of a building, from the very inception of the project. This makes the carbon impacts clear to the client, architect, and wider design team.

At its heart is an algorithm that estimates the embodied carbon based on simple geometry and a curated list of materials/build-ups. This removes the need for detailed CAD models or schedules of materials, increasing the speed of iterative design changes and ease of decision making.

This tool is still in beta testing, and we are releasing it for wider testing. If you have suggestions and feedback please contact Joe Jack Williams on: joe.jack.williams@fcbstudios.com

January 2021

Introduction to Whole Life Carbon Assessment

Whole life carbon accounts for all emissions arising over the entire life of a built asset. It also considers the future reusability and recyclability of constituent elements. This encompasses all stages of the asset lifecycle: from material extraction and component manufacture; through building construction, maintenance and operation; to end of life deconstruction or demolition and the potential secondary lifecycles of components beyond.

Whole life carbon is considered in terms of operational and embodied carbon. Operational carbon represents the emissions relating to the energy use of building-integrated systems, and is largely well understood. Embodied carbon is intuitively understood from a material efficiency perspective, but also includes the impact of various other key lifecycle stages.

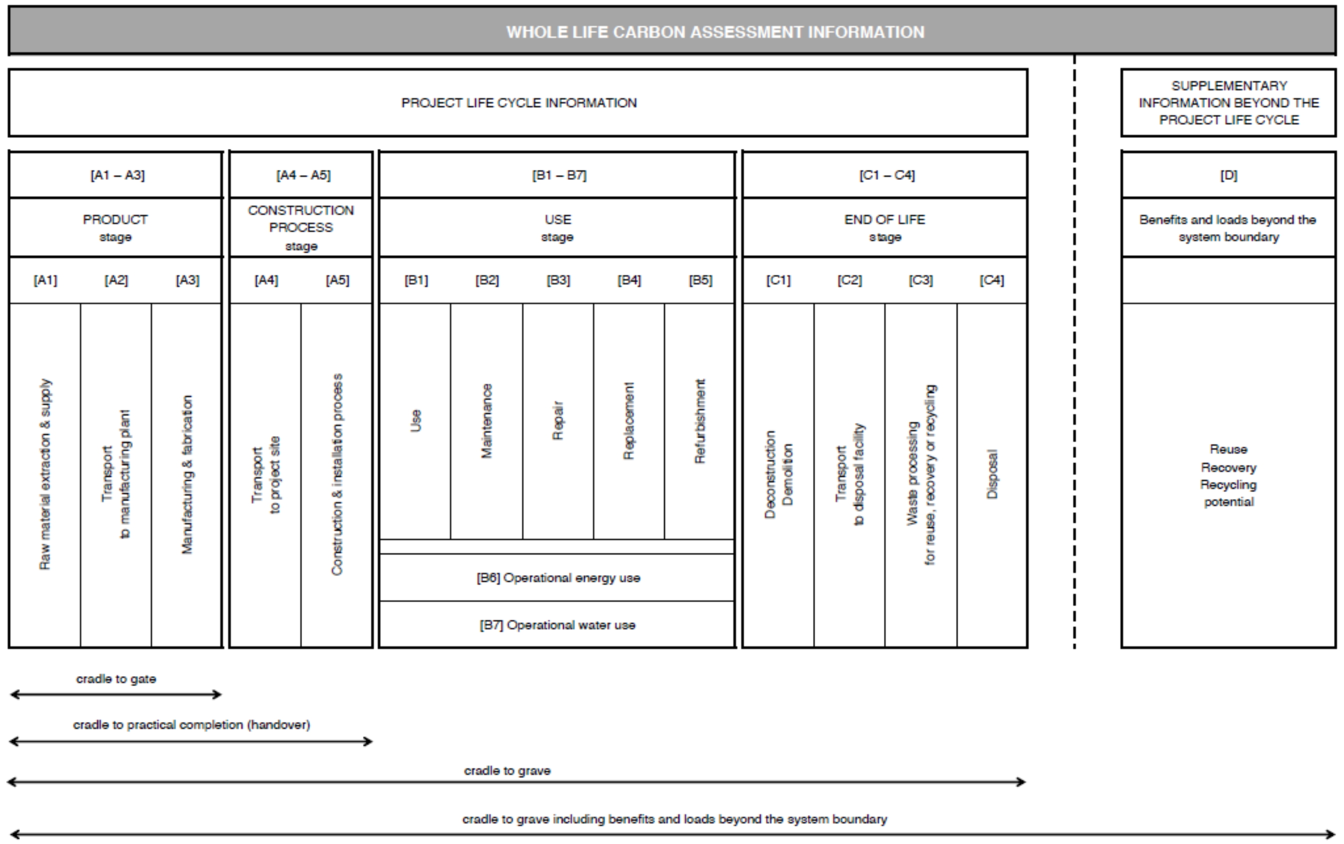
This is set out in the RICS Professional Statement on Whole life carbon assessment for the built environment:

"…embodied emissions arise from producing, procuring and installing the materials and components that make up a structure. These also include the lifetime emissions from maintenance, repair, replacement and ultimately demolition and disposal."

Understanding the embodied carbon of materials allows us to make informed choices about how we use them. With a limited timescale in which to dramatically curb such emissions, embodied carbon is becoming increasingly important, as a large part of these emissions are incurred immediately. Appreciation of embodied carbon also helps us to understand the value of the materials we already have.

How do we report Whole Life Carbon, and why should we?

For whole life carbon estimates to be most useful, it is important that they are produced to a widely adopted standard. It is only possible to benchmark good practice and measure progress if studies are conducted with similar scope and methodology. This tool is aligned with the RICS Professional Statement referenced above and structured around the EN 15978 modular system for whole life carbon assessment.

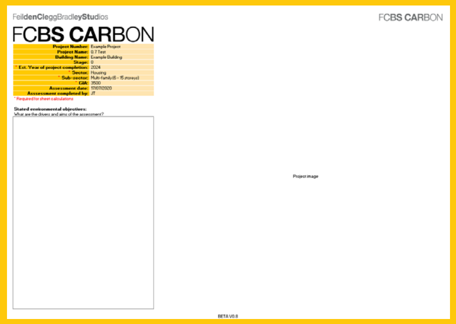


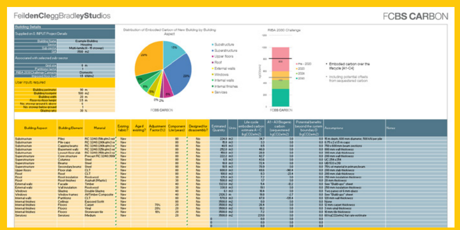
The tool considers all modules except module B7, water usage. The methodology for the estimates of each module are included in the notes and clarifications.

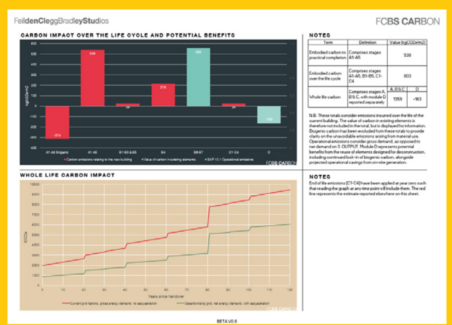
Capturing and publishing this information is a crucial step in supporting wider progress towards sustainable practices in the construction industry. It will help to identify opportunities for improvement as well as highlight best practice.

Calculating embodied carbon has been a relatively niche exercise until recently, with no collective knowledge that can guide early design decisions. This tool is aiming to fill the gap at those early stages, enabling embodied carbon to be represented with minimal technical knowledge required. During RIBA stages 1&2 designers and clients will be able to not only grasp the scale of the embodied carbon of their proposed buildings, but also explore options using a consistent methodology, giving immediate directional and magnitudinal feedback for consideration.

USER GUIDE CONTENTS







the early design stage lifecycle carbon review tool

FCBS CARBON is an interactive Excel worksheet intended to inform a comparative understanding of the whole life carbon performance of early-stage design options.

The tool makes an estimate of the operational emissions and embodied emissions of key building elements from cradle to grave over a 60-year lifespan. The tool also considers the emissions offsets within a project attributable to: carbon sequestration (for reuse of timber elements); reuse of building elements at end of life; and on-site renewable energy generation.

It consists of three interactive input sheets and two output sheets.

INPUT

Within each of the input sections, data from different sources can be input to generate the overall carbon footprint of the building.

These are compared to industry benchmarks and targets to understand relative performance.

Input sheets are colour-coded to indicate cell function:

Yellow boxes indicate user input cells

Grey boxes indicate information provided for your reference and information

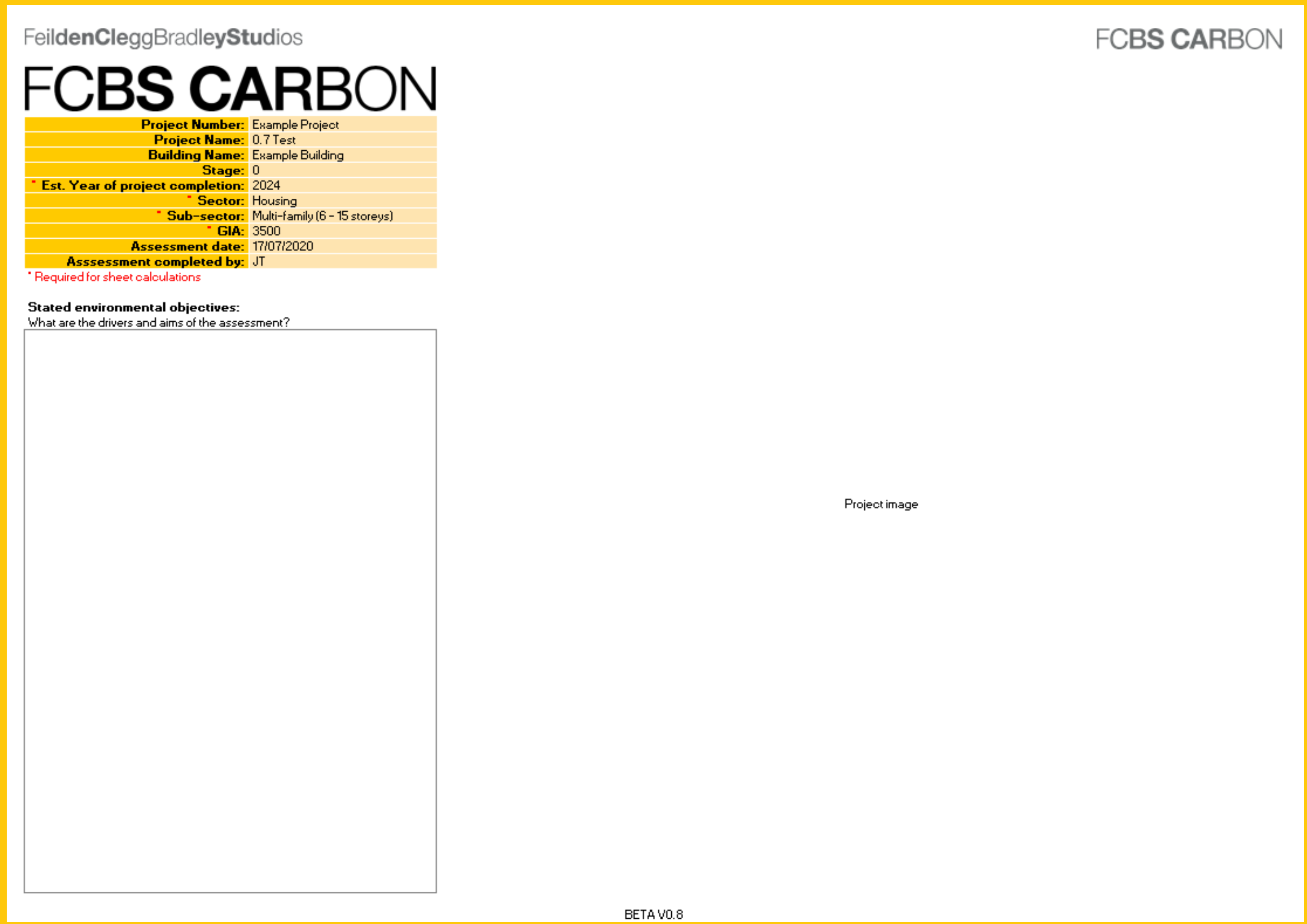
OUTPUT

Overall impact of the project is captured on the output sheets.

These are set up to be exported to stage reports and form part of the discussion as a project progresses.

Results should not be viewed as exact values for the carbon associated with any project, but rather as a platform from which to investigate the relative impact of early stage design choices, and as a starting point for more detailed analyses as a project moves through the design stages.

GUIDE TO INPUTS
0 INPUT Project Details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FCBS CARBON

FCBS CARBON

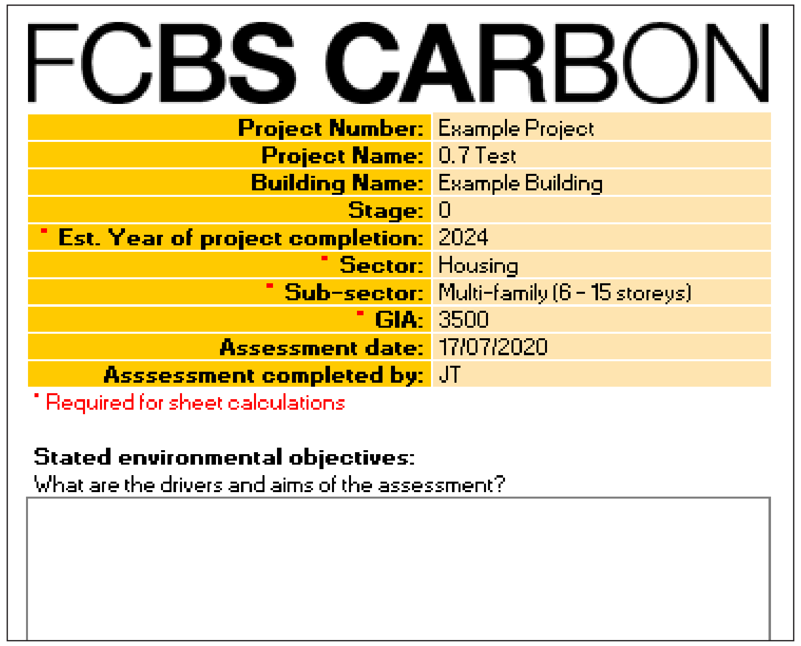
Project Number:	Example Project
Project Name:	0.7 Test
Building Name:	Example Building
Stage:	0
* Est. Year of project completion:	2024
* Sector:	Housing
* Sub-sector:	Multi-family (6 - 15 storeys)
* GIA:	3500
Assessment date:	17/07/2020
Asssessment completed by:	JT

* Required for sheet calculations

Stated environmental objectives:
What are the drivers and aims of the assessment?

Project image

BETA V0.8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Stated environmental objectives:
What are the drivers and aims of the assessment?

The Project Details sheet acts as a cover page for the carbon report.

It records key project information for identification, tracking, and comparison of results across projects.

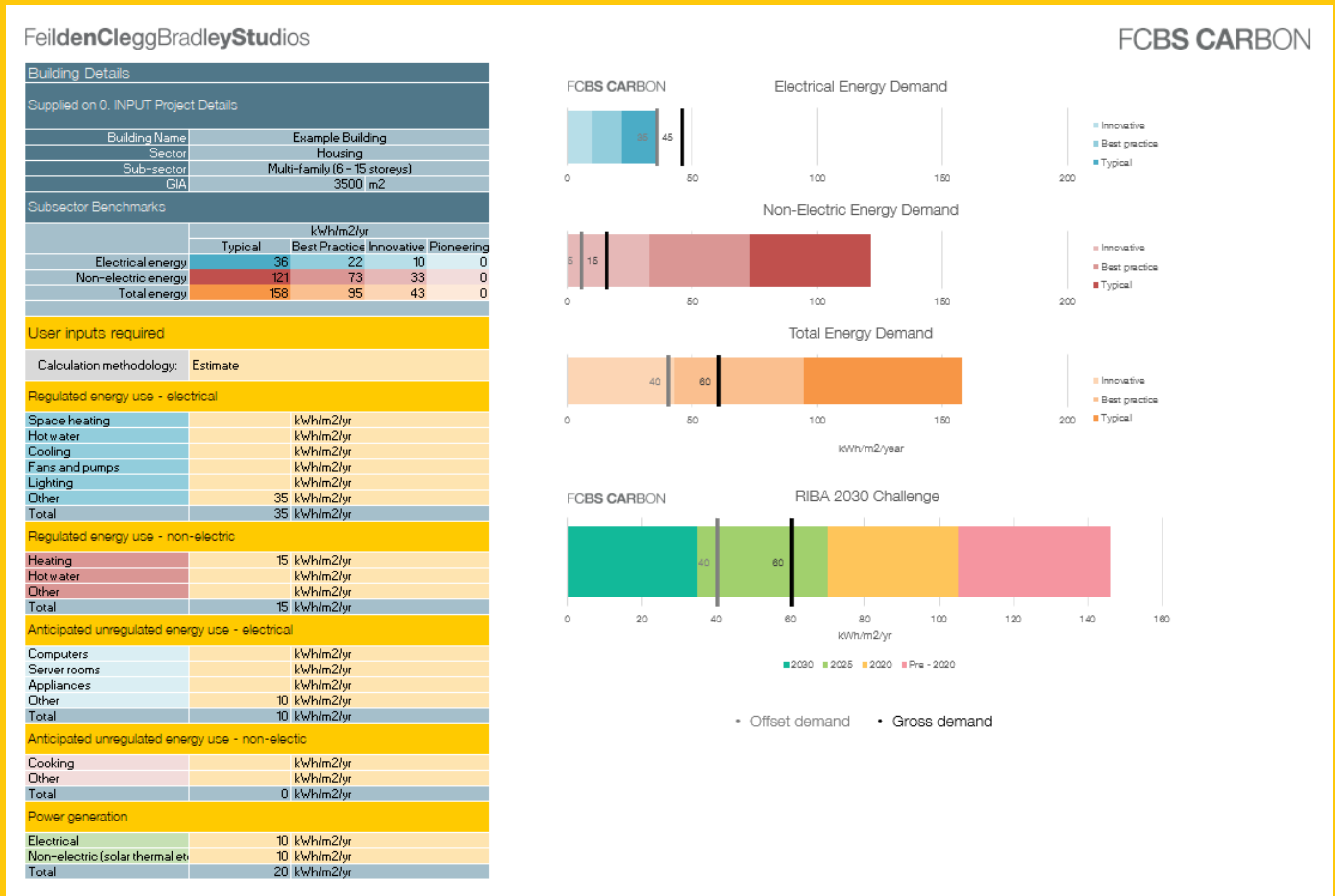
Fields marked with a red asterisk are required for sheet functionality. These values are reported elsewhere in the worksheet for reference but can only be adjusted on the Project Details sheet.

Currently, FCBS CARBON only predicts future carbon emissions, so year of completion can be no earlier than 2020.

Sector selection affects underlying assumptions on the structural design of the building, for example spans, as well as the benchmarks the building will be compared to. Two main typologies, offices and housing, are available, with sub-sectors to adjust the assumptions further.

There is also a space to record the drivers and aims of the assessment, which is a requirement of a full whole life carbon assessment as per the RICS Professional Statement, as well as illustrations for reference.

GUIDE TO INPUTS
1 INPUT Operational Energy



This sheet consists of a set of manual input fields to record the operational energy requirements of the project. These are split into regulated and unregulated, electrical and non-electrical sections.

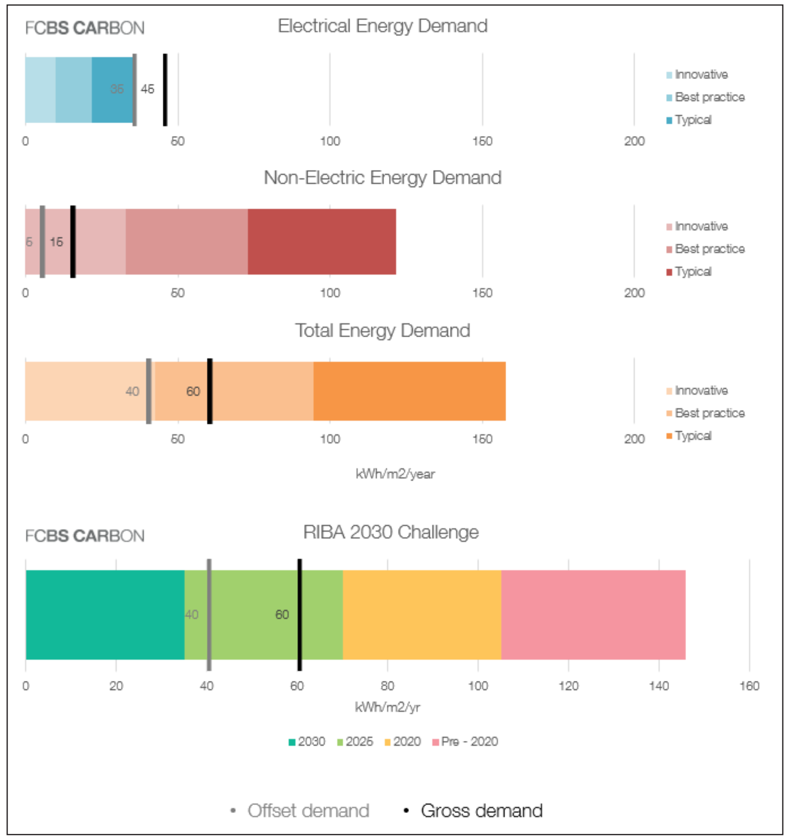
User inputs required		
Calculation methodology:	Estimate	
Regulated energy use - electrical		
Space heating		kWh/m2/yr
Hot water		kWh/m2/yr
Cooling		kWh/m2/yr
Fans and pumps		kWh/m2/yr
Lighting		kWh/m2/yr
Other	35	kWh/m2/yr
Total	**35**	**kWh/m2/yr**
Regulated energy use - non-electric		
Heating	15	kWh/m2/yr
Hot water		kWh/m2/yr
Other		kWh/m2/yr
Total	**15**	**kWh/m2/yr**
Anticipated unregulated energy use - electrical		
Computers		kWh/m2/yr
Server rooms		kWh/m2/yr
Appliances		kWh/m2/yr
Other	10	kWh/m2/yr
Total	**10**	**kWh/m2/yr**
Anticipated unregulated energy use - non-electic		
Cooking		kWh/m2/yr
Other		kWh/m2/yr
Total	**0**	**kWh/m2/yr**
Power generation		
Electrical	10	kWh/m2/yr
Non-electric (solar thermal et	10	kWh/m2/yr
Total	20	kWh/m2/yr

Specific use fields are included to capture details of energy load if known, but otherwise a combined estimate can be entered into the “Other” field. Also to be completed is a record of the calculation methodology used – this is to provide an indication of how thorough the estimate is (e.g. CIBSE TM54, Part L, estimate based on the benchmarks, etc). This is for future reference and can be left blank.

It is intended that the sustainability consultants will be able to help with the figures on this sheet. Compliance calculations, such as Part L, will not include data on the unregulated energy consumption arising from occupants. In practice this can at least double the energy usage. So where engineers are appointed, they should be engaged to estimate this unregulated component using an approved methodology such as CIBSE TM54, Design for Performance, or PHPP.

The user input operational energy figures can simply be targets or aspirations. In this case, once the embodied carbon section has been completed, it may be worth revisiting the figures for the operational energy to understand the sensitivity of the overall footprint to operational energy. Sector specific benchmarks provided are there to help guide your thoughts, but do consider whether you use gas or electricity for heating.

Non-electric energy uses are currently assumed to be gas, representing the most common alternative energy source.

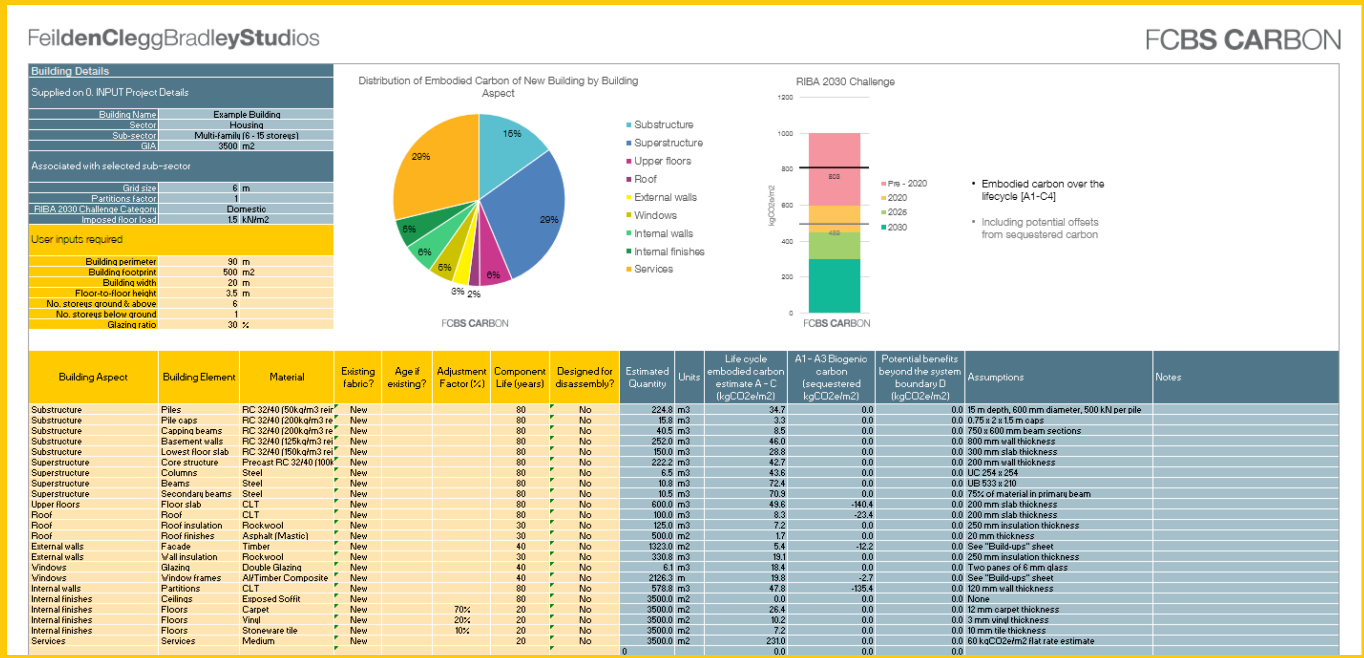


Expected PV generation for your site can be estimated by the free PVWatts tool developed by NREL (available online at www.pvwatts.nrel.gov/).

All data is in kWh/m²/year format, representing the annual energy use per GIA. Note that the renewables data is also in this format (per m² GIA rather than per m² of solar panelling, for example).

The graphs on the right of the sheet show how the operational energy consumption of your building compares to the RIBA 2030 Climate Challenge target, as well as against current industry benchmarks (CIBSE Guide F). Note that there are two benchmark values: one representing the gross operational demand of your building; and another demonstrating the potential reduction achieved via the use of on-site renewables.

GUIDE TO INPUTS
2 INPUT Embodied Carbon



This sheet has been designed to give an estimate of the embodied carbon to inform design decisions prior to detailed design.

The interface on this sheet is a combination of manual data entry fields and drop-down menus referenced to existing data sets including the carbon impact of various materials. This is to ensure consistency and comparability amongst data generated from projects.

With any of the inputs, the aim is to use the most representative figure, using averages where there is a range, for example floor to floor heights. These can be quickly changed once all the data has been entered to see the sensitivity these inputs have on the whole life carbon.

User inputs required		
Building perimeter	90	m
Building footprint	500	m2
Building width	20	m
Floor-to-floor height	3.5	m
No. storeys ground & above	6	
No. storeys below ground	1	
Glazing ratio	30	%

The unique project details required are shown above

These are based on simple measurements available during massing studies. These figures are used to generate a schematic building model to represent the area or volume of building elements present in your design and should be averages for the whole building. These details must be completed first, as they are required in the generation of embodied carbon estimates in the following drop-down portion of the sheet. Note that GIA is an important calculation quantity and is entered on 0. INPUT Project Details. This is not linked to details of footprint or number of storeys and must be updated separately.

Once your building measurements have been entered, you can populate the drop-down table below. Buildings are broken down by aspect, element and material as specified in the RICS Professional Statement on Whole life carbon assessment for the built environment.

Building Aspect	Building Element	Material	Existing fabric?	Age if existing?	Adjustment Factor (%)	Component Life (years)	Designed for disassembly?
Substructure	Piles	RC 32/40 (50kg/m3 reinfc	New			80	No
Substructure	Pile caps	RC 32/40 (200kg/m3 rein	New			80	No
Substructure	Capping beams	RC 32/40 (200kg/m3 rein	New			80	No
Substructure	Basement walls	RC 32/40 (125kg/m3 rein	New			80	No
Substructure	Lowest floor slab	RC 32/40 (150kg/m3 rein	New			80	No
Superstructure	Core structure	Precast RC 32/40 (100kg	New			80	No
Superstructure	Columns	Steel	New			80	No
Superstructure	Beams	Steel	New			80	No

The table is pre-populated with one row for each possible element, although more can be added as needed. Note that a project may not require all of the default options – for example, a piled building will likely not need a raft foundation as well. In these cases, you can simply leave the material field as blank.

Each element has an associated list of possible material selections, which, once selected, will show any assumptions (such as thicknesses) to the right of the table, alongside individual impact estimates. Choose the material closest to your design. At this stage, we are looking for general indicators rather than detailed analysis.

The Adjustment factor

The intention of the Adjustment Factor is to provide a straightforward method to adjust the carbon impact of individual building elements.

In testing, it has proved useful to:

- Split the total volume of a building element where multiple materials are used (e.g. a project may have its floor area split between carpet and vinyl finishes).
- Proportionally adjust the assumptions associated with a selected element or material (e.g. a project with floor slabs twice as thick as the tool assumptions would represent an adjustment factor of 2).
- Simply match the estimated material quantities to a bill of materials provided by the engineers.
- Investigate the sensitivity of the overall footprint to the material efficiency of an individual building element.

The Adjustment Factor will be blank by default, which indicates that the sheet is following the normal calculation method. Any value entered into the field will modify the embodied carbon estimate by the proportional amount.

Building Element	Material	Existing fabric?	Age if existing?	Adjustment Factor (%)
Floors	Carpet	New		70%
Floors	Vinyl	New		20%
Floors	Stoneware tile	New		10%

For example, the Adjustment Factor has been used above to model a 70/20/10% split of floor coverings over the internal area between carpet, vinyl, and tiling. These do not have to add up to 100%.

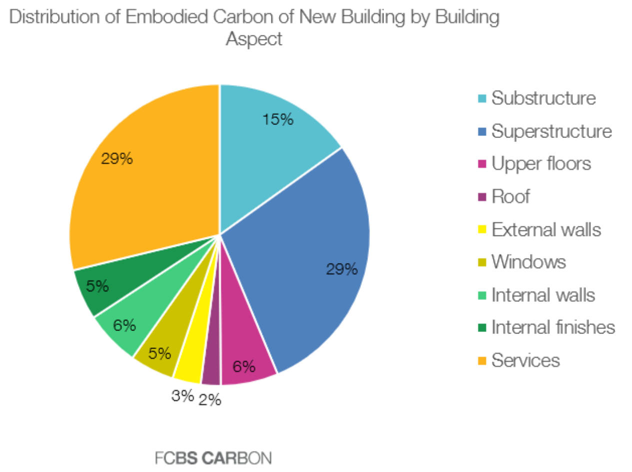
Life cycle embodied carbon estimate A - C (kgCO2e/m2)	A1 - A3 Biogenic carbon (sequestered kgCO2e/m2)	Potential benefits beyond the system boundary D (kgCO2e/m2)	Assumptions	Notes
34.7	0.0	0.0	15 m depth, 600 mm diameter, 500 kN per pile	
3.3	0.0	0.0	0.75 x 2 x 1.5 m caps	
8.5	0.0	0.0	750 x 600 mm beam sections	
46.0	0.0	0.0	800 mm wall thickness	
28.8	0.0	0.0	300 mm slab thickness	
42.7	0.0	0.0	200 mm wall thickness	
43.6	0.0	0.0	UC 254 x 254	
72.4	0.0	0.0	UB 533 x 210	
70.9	0.0	0.0	75% of material in primary beam	

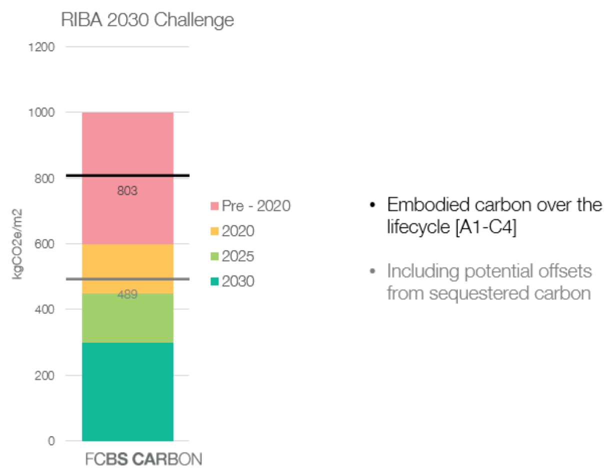
In addition to selecting the material, the status of the material as new or existing fabric, age if existing, and expected component life should be entered. These fields each influence the calculation of whole life carbon. Including an estimated lifespan for all elements is important, as this allows the capturing of emissions relating to replacement cycles over the building life (module [B4]). For some elements with a high churn, such as internal finishes and services, this can be particularly significant. Lifespan will depend heavily on your particular project, component, and materials.

Marking an element as retained existing fabric will exclude its associated [A1-A5] emissions from the project total and providing details of its age will adjust replacement cycles accordingly. The replacement cycles take into account the age of existing building elements.

Live Output Graphs

The embodied carbon input sheet features two graphical outputs which will update as you enter building information.





The pie chart presents the breakdown of relative embodied carbon of new elements by building aspect. This provides an indication of where in the building fabric most of the new embodied emissions associated with a project are falling.

The bar chart demonstrates how the whole life embodied carbon estimate performs against RIBA 2030 Climate Challenge targets. There are two totals presented here: the embodied carbon over the lifecycle; and the potential offset impact including carbon sequestration, should the correct conditions for treatment of biogenic materials be met. This is detailed in the notes and clarifications.

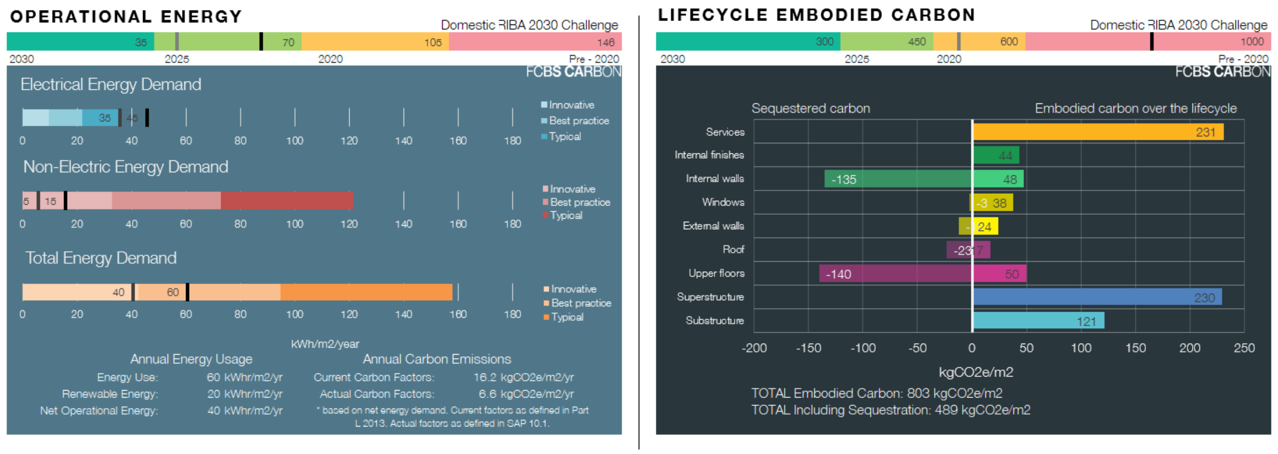
Changes to emissions due to varying the building details, or the selected materials, will be immediately reflected in these graphs. Note that the quantities of some elements, such as piles, are dynamically dependent on other building elements and their impact will vary as such.

GUIDE TO OUTPUTS
3 OUTPUT Graphics

Output Sheet 1

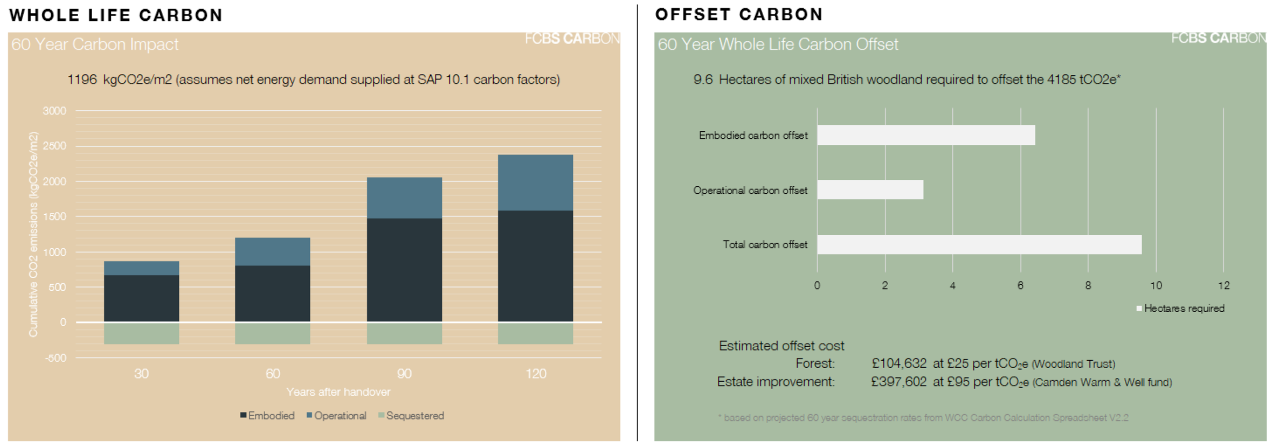
Provides a quantitative breakdown of the carbon emissions associated with the project. This output is intended to provide the clearest overview of the whole life carbon of the modelled project, identifying performance against RIBA 2030 targets, and the relative impacts of the operational and embodied carbon. We expect this output to be the most widely useful.

The top two quadrants demonstrate the operational and embodied carbon impacts. The operational energy graphs show how the energy use compares to the CIBSE Guide F benchmark and predictions for annual carbon emissions with and without any renewable energy sources. The embodied carbon graph shows the emitted and sequestered carbon by building aspect across all the LCA modules, per m².

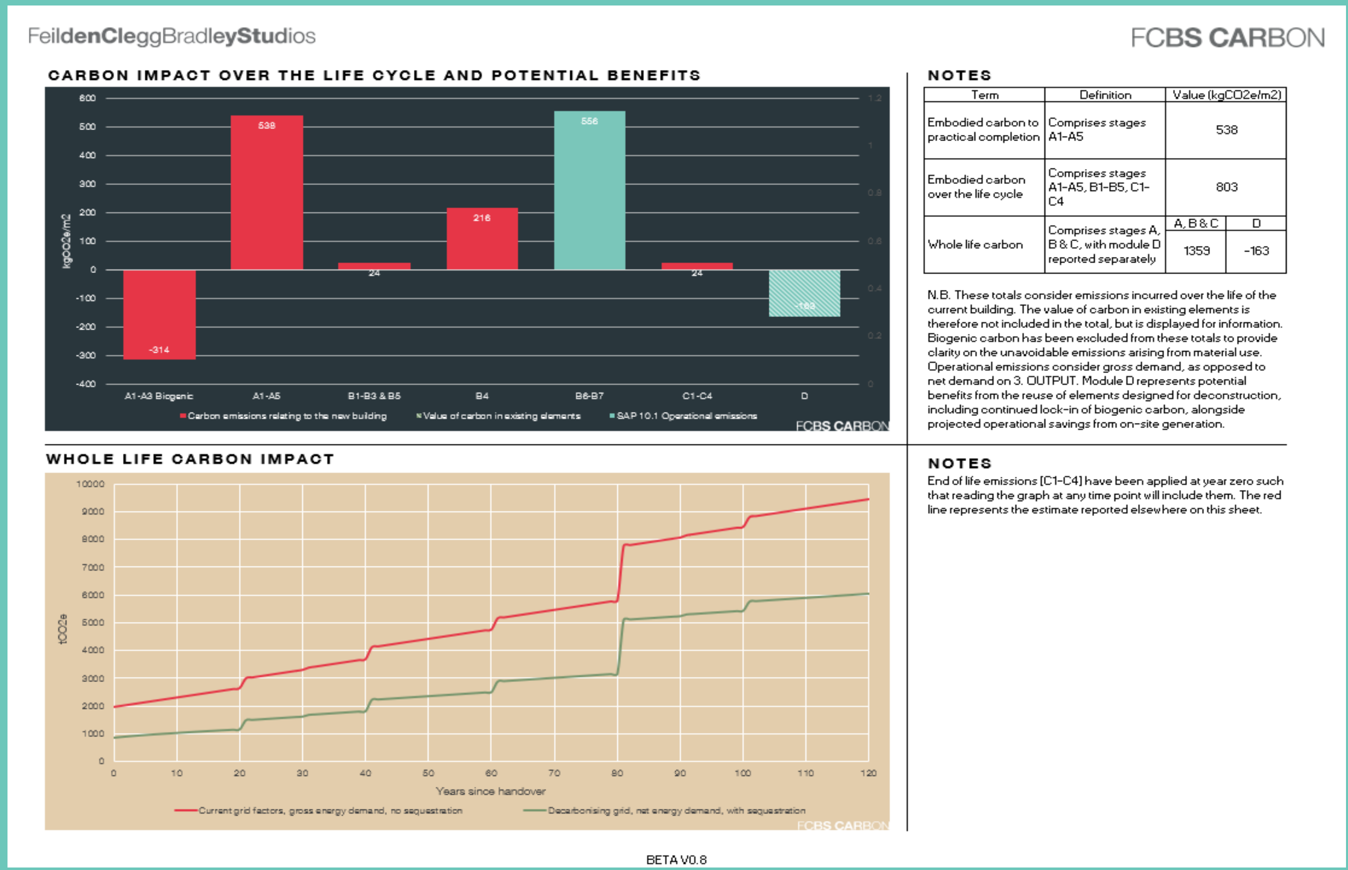


The bottom left quadrant displays the combined impact of the project at lifetime milestones, providing a quick reference as to the proportions attributable to embodied and operational carbon, as well as the relative magnitude of any carbon sequestration due to biogenic building materials.

The bottom right quadrant provides an estimate as to scale and cost of offsetting required for a project should you wish to achieve a net zero impact over a 60-year lifespan.



GUIDE TO OUTPUTS
4 OUTPUT Graphics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FCBS CARBON

CARBON IMPACT OVER THE LIFE CYCLE AND POTENTIAL BENEFITS

WHOLE LIFE CARBON IMPACT

NOTES

Term	Definition	Value (kgCO2e/m2)	
Embodied carbon to practical completion	Comprises stages A1-A5	538	
Embodied carbon over the life cycle	Comprises stages A1-A5, B1-B5, C1-C4	803	
		A, B & C	D
Whole life carbon	Comprises stages A, B & C, with module D reported separately	1359	-163

N.B. These totals consider emissions incurred over the life of the current building. The value of carbon in existing elements is therefore not included in the total, but is displayed for information. Biogenic carbon has been excluded from these totals to provide clarity on the unavoidable emissions arising from material use. Operational emissions consider gross demand, as opposed to net demand on 3. OUTPUT. Module D represents potential benefits from the reuse of elements designed for deconstruction, including continued lock-in of biogenic carbon, alongside projected operational savings from on-site generation.

NOTES

End of life emissions [C1-C4] have been applied at year zero such that reading the graph at any time point will include them. The red line represents the estimate reported elsewhere on this sheet.

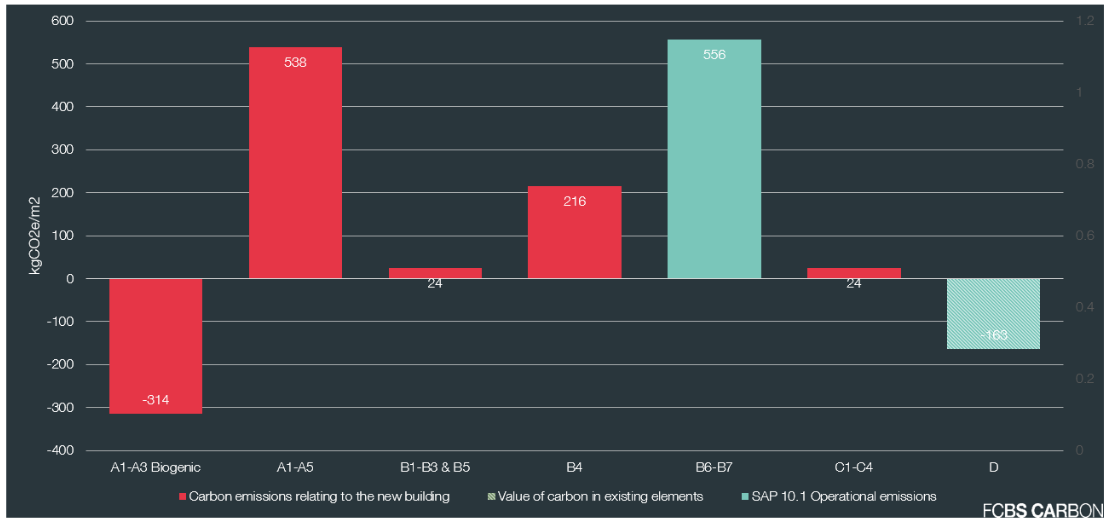
BETA V0.8

Output Sheet 2

Provides a higher resolution attribution of the carbon in a project, providing an additional overview for discussion on how the carbon is emitted over time and at each LCA stage.

The graph on the top half of the sheet provides a breakdown of emissions across the assessment modules. It also displays the carbon value of any existing fabric retained in the new building, to give a more complete picture of the 'carbon-value' of a project. Module D total include any elements that have be identified as reusable at the end of their life, as well as any renewable energy generation exported to the grid.

CARBON IMPACT OVER THE LIFE CYCLE AND POTENTIAL BENEFITS



The graph on the bottom half represents a continuous tracking of the carbon impact of the building over its lifetime. Step jumps represent the replacement of building elements.

Two scenarios are modelled to capture the "business as usual case", as well as potential decarbonisation of the energy grid and successful carbon sequestration. This provides a very rough envelope in which the impact of the project might sit, although the upper-bound estimates are those reported . End of life emissions [C1 – C4] are applied at year 0, such that they are included in a reading of the graph at any year.

Large jumps in embodied carbon may indicate the simulated replacement of 'big ticket' items, such as MEP services plant, facade or foundations or structural frames. Ensure that key structural elements have a component life which is relevant to the building lifespan under consideration.

WHOLE LIFE CARBON IMPACT

Notes and clarifications

Calculation of the WLCA modules

In this version of the tool, some of the modules are calculated with direct data, while others are estimated as uplifts based on available data from previous WLCA studies. Details are provided below:

FeildenCleggBradleyStudios — EN15978 Methodology — FCBS CARBON

Module	Description	Methodology
A1-A3 Biogenic	Biogenic carbon sequestered at the product stage	Biogenic carbon per functional unit of selected materials applied to material quantities estimated by the tool. Elements marked as existing do not contribute to the reported total.
A1-A3	Product stage (extraction, transport and manufacturing emissions associated with fabrication of the product)	Embodied carbon per functional unit of selected materials applied to material quantities estimated by the tool. Elements marked as existing do not contribute to the reported total.
A4	Transport to project site	Sub-sector defined uplift of A1-A3 value. Assumes a combined impact of 10% of A1-A3 emissions. Split evenly across modules [A4, A5] by default.
A5	Construction and installation process	Elements marked as existing do not contribute to the reported total.
B1	Use	Sub-sector defined uplift of A1-A3 value. Assumes a combined impact of 5% of A1-A3 emissions incurred over 60 years. Split equally across modules [B1, B2, B3] by default and accrued on a yearly basis.
B2	Maintenance	
B3	Repair	
B4	Replacement	User input component life determines number of replacement cycles. Each replacement event incurs emissions from modules [A1-A5] and [C1-C4]. N year component life triggers replacement in year N+1.
B5	Refurbishment	Sub-sector defined uplift of A1-A3 value. Defaulted to zero.
B6	Operational energy use	User input operational demand applied to various emissions factors for electrical and non-electrical energy. Accrued on a yearly basis.
B7	Operational water use	Not currently considered.
C1	Deconstruction and demolition	Sub-sector defined uplift of A1-A3 value. Assuming a combined impact of 5% of A1-A3 emissions. Split evenly across modules [C1, C2, C3, C4] by default.
C2	Transport to disposal facility	
C3	Waste processing for reuse, recovery or recycling	
C4	Disposal	
D	Benefits and loads beyond the system boundary	Potential emissions offset of on-site renewables calculated as equivalent demand being met with grid electric. Elements marked as designed for disassembly generate a potential benefit equal to their [A1-A3] emissions impact, with any benefit from biogenic carbon also carried over. Only elements in the final replacement cycle are considered.

Embodied carbon data

The majority of material data are averages taken from ICE V3 Nov 2019, with default specifications on strength classes/recycling rates aligned with the RICS Professional Statement on Whole life carbon assessment for the built environment.

In cases where no value was available in the ICE database, EN15978 compliant Environmental Product Declarations have been used.

Treatment of recycled materials

Any savings from recycled material are included in the values input in the materials list. Guidance on calculating recycling benefits can be found in Embodied Carbon: The Inventory of Carbon and Energy (ICE) G Hammond & C Jones, BSRIA, 2011, Annex B.

Treatment of biogenic carbon

RICS suggests that biogenic carbon only be taken into account when:

1. The whole life carbon assessment of the project includes the impacts of the EoL stage [C]

2. The timber originates from sustainable sources (certified by FSC, PEFC or equivalent)

Biogenic carbon is reported separately throughout this tool to illustrate the potential benefit of carbon sequestration should the correct conditions be met. It is not included in the primary reported totals which reflect estimates of the unavoidable emissions that will occur should a certain material choice be made. Note, this is not inline with BS EN 15978:2011 which would include biogenic carbon in A1-3, but also model their release in module C3 as the waste is assumed to be burnt, neutalising any benefit. We are investigating the best way of representing it, so use with caution as is.

Grid decarbonisation

Government projections of UK grid decarbonisation from the BEIS are included in the tool. These projections are based on “assumptions of future economic growth, fossil fuel prices, electricity generation costs, UK population and other key variables”. The potential benefit of decarbonised grid values is illustrated on sheet 4. OUTPUT Graphics, but reported figures use SAP10.1 factors which do not account for further decarbonisation.

Estimating the cost of carbon offsetting

Estimates of offsetting via carbon credits accrued from new woodland and building retrofit schemes have been included in the tool as a way of contextualising the lifetime impact of projects.

Values for tree planting are based on carbon sequestration rates for a hectare of native, mixed British woodland, as estimated by the Woodland Carbon Code Carbon Calculation Spreadsheet V2.2. The expected cost of carbon credits from such woodland is set at £25 per tonne of CO_2e.

The equivalent cost of offsetting by investing in upgrading the thermal performance of existing housing stock in London is included for comparison. Camden Warm & Well fund estimates this cost at £95 per tonne of CO_2e.

Geographical relevance of included data and benchmarks

This tool is aimed at UK construction, and the included data and assumptions reflect this. Varying climate, material specifications, building standards, construction practices, and energy grids are only some of the factors that influence the emissions impact of a project. Consideration of these factors is important when using the tool in a different geographical context.

The tool has been developed by FCBStudios Ltd using carbon factors derived from the Inventory of Carbon and Energy (ICE) database and Environmental Product Declarations (EPDs).

FCBStudios wish to thank Dr Joe Jack Williams and Joe Taylor for the development of the tool.

FCBStudios also wish to thank the following individuals for their guidance in the preparation of the tool for free release to the industry:
For discussion on structural assumptions:
- Marta Galinanes Garcia and Edoardo Tibuzzi at AKT II
- Steve Webb and Alex Lynes, at Webb Yates
- Julia Ratcliffe at Scale Consulting

For discussion on the benchmarking of whole life carbon methodologies
- Simon Sturgis at Targetting Zero

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