Regulating Embodied Carbon in the Built Environment

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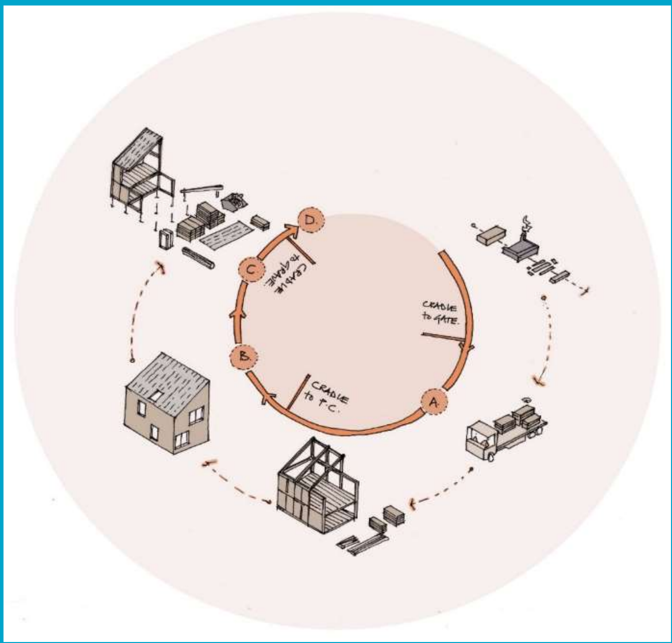

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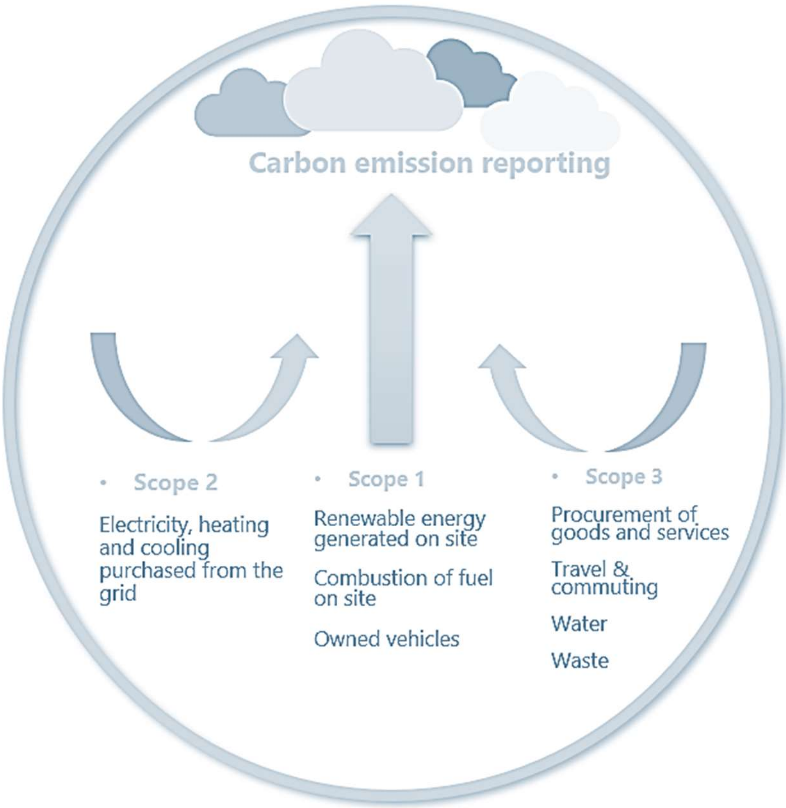
1 Introduction

Scottish Government has set a requirement to deliver net-zero emissions of all greenhouse gases by 2045, as set out in the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019.

The built environment is one of the biggest contributors to carbon emissions and with the public sector acknowledged as a major customer, with Scottish Government reporting an annual spend of more than £4 billion on building and civil engineering works, there is a recognised opportunity and need to mitigate future impact and significantly reduce associated carbon emissions in support of meeting National emissions reduction targets.

Scottish Government's recent updates to public procurement guidance, with respect to climate and circular economy considerations, requires public bodies to consider and act on opportunities to improve environmental wellbeing and to report on targets for reducing direct (Scope 1 emissions) and indirect (Scope 2 and Scope 3 emissions) emissions of Greenhouse gases.



Carbon Scope Emissions

Scottish Government has reported that, on average, 60% of an organisation's climate impact may relate to Scope 3 emissions. Early-stage decision making during construction procurement and the resulting embodied carbon emissions that accumulate throughout every life cycle stage, all contribute to scope 3 emissions.

The built environment is estimated to account for nearly 40% of total direct and indirect CO_2 emissions. For new buildings, RICS report that embodied carbon contributions can account for as much as 70% of a building's total carbon emissions over its lifecycle. The significance of embodied carbon in the delivery of new buildings and major refurbishment projects, demonstrates the need for a whole life carbon approach, where consideration is given to mitigating both operational and embodied carbon.

Reducing embodied carbon emissions across the built environment will support Scottish Government in meeting their net-zero emissions targets. Furthermore, this presents an opportunity to support inter-connected policy, such as circular economy and sustainable construction procurement, and deliver multiple socio-economic outcomes, in addition to environmental outcomes.

Despite the rapidly growing interest around embodied carbon and the recognised need for construction projects to consider and mitigate embodied carbon at the earliest opportunity, the subject remains a relatively new concept for a number of construction professionals and is an area where many would benefit from clarity and consistency of approach.

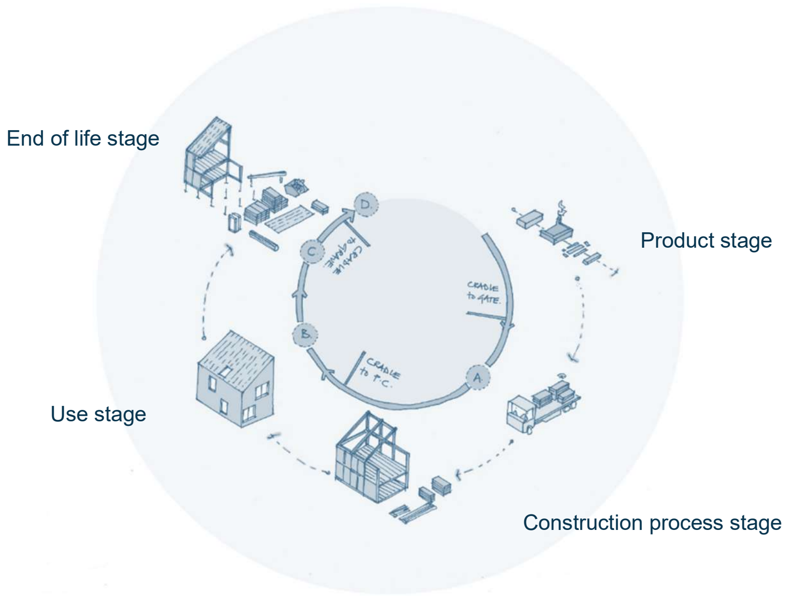
The purpose of this report is to identify the scope of information and activity that will be required to enable Zero Waste Scotland to prepare and submit a proposal to Scottish Government which will explore potential future opportunities for regulating embodied carbon in the built environment, in support of meeting Scottish Government Emission Reduction Targets. The focus of this commission is specifically on buildings.

2 Defining embodied carbon

Embodied carbon is the total Greenhouse Gas (GHG) emissions generated to produce a built asset, including emissions that result from:

- product stage, including emissions associated with:
  - raw material supply
  - transportation of materials
  - manufacturing processes
- construction process stage, including emissions associated with:
  - transportation of materials to a site
  - construction process
- use stage, including emissions associated with:
  - in use
  - maintenance
  - repair
  - replacement
  - refurbishment
- end of life stage, including emissions associated with:
  - deconstruction and demolition
  - transportation of materials to disposal site
  - waste processing for reuse, recovery or recycling
  - disposal

Embodied carbon excludes operational emissions of the asset, such as those associated with operational energy use and operational water use.



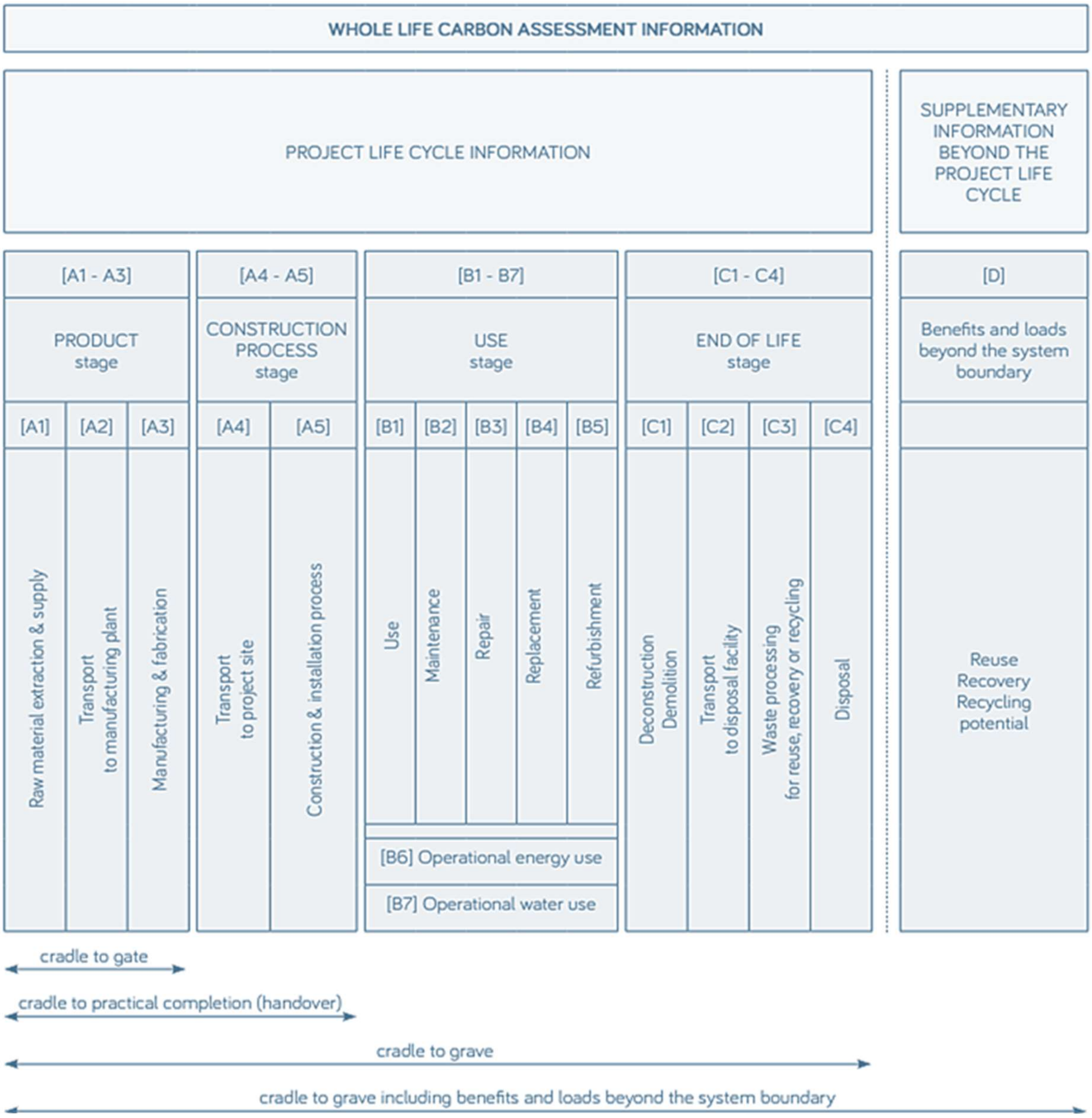
Construction life cycle stages

The construction industry recognised and adopted framework for appraising environmental impacts of the built environment is provided by BS EN 15978:2011 Sustainability of construction works (BS EN 15978). A modular reporting structure for whole life carbon (including operational and embodied carbon) is detailed in BS EN 15978, which references:

- product stage: modules A1 – A3
- construction process stage (transport to site and construction installation process): modules A4 and A5
- use stage: modules B1 – B7
    - use – module B1
    - maintenance – module B2
    - repair – module B3
    - replacement – module B4
    - refurbishment – module B5
    - operational energy use – module B6
    - operational water use – module B7
- end of life stage: modules C1 – C4
    - deconstruction and demolition process – module C1
    - transport – module C2
    - waste processing for reuse, recovery or recycling – module C3
    - disposal – module D4
- benefits and loads beyond the system boundary: module D

A whole life carbon assessment would require all of the modules listed above to be considered. Module D is reported separately and is intended to provide a broader picture of the environmental impacts of a project by accounting for the future potential of its components when these are repurposed. Module D can be used as a metric for quantifying circularity and assessing future resource efficiency.

An embodied carbon assessment would typically require Modules A1 – A5, B1 – B5 and C1 – C4 to be considered. When assessing embodied carbon, it is important to consider the boundary of the assessment to ensure consistency and comparability. For example, an assessment of embodied carbon to practical completion would require only Modules A1 – A5 to be considered. This is summarised in the modular reporting structure of BS EN 15978 in the image below:



Modular reporting structure of BS EN 15978 (as referenced in RICS PS)

The scope of the embodied carbon assessment must also be considered as this will influence the results of any assessment. The scope of the assessment should reflect the scope of project being considered and will require building elemental information and groups to be considered.

The building element groups that are typically considered when delivering an embodied carbon assessment are usually based on the ‘BCIS Elemental standard form of cost analysis, 4th edition’. This ensures consistency and interoperability between bills of quantities and cost plans and carbon assessments. This is becoming increasingly important as clients seek to undertake whole life appraisals and understand more about how the project decision making process influences the whole life costs and whole life carbon.

Aligning carbon and cost management in the built environment is an activity that is currently being supported by a global cross-working group of 49 professional bodies, being led by RICS. This has resulted in the publication of the International Cost Management Standard (ICMS) 3 publication, which aims to encourage more sustainable construction practices to achieve net-zero ambitions.

The different building elements and sub-groups that are considered when determining the scope of an embodied carbon assessment are summarised in the table below:

Building Elements			
	0	Facilitating works	0.1 Temporary/Enabling works/Preliminaries 0.2 Specialist groundworks
	1	Substructure	1.1 Substructure
	2	Substructure	2.1 Frame 2.2 Upper floors incl. balconies 2.3 Roof 2.4 Stairs and ramps
		Superstructure	2.5 External walls 2.6 Windows and external doors
		Superstructure	2.7 Internal walls and partitions 2.8 Internal doors
	3	Finishes	3.1 Wall finishes 3.2 Floor finishes 3.3 Ceiling finishes
	4	Fittings, furnishings and equipment (FF&E)	Building-related Non-building-related
	5	Building services / MEP	5.1 – 5.14 Building related services Non-building-related
	6	Prefabricated Buildings and Building Units	6.1 Prefabricated buildings and building units
	7	Work to Existing Building	7.1 Minor demolition and alteration works
	8	External works	8.1 Site preparation works 8.2 Roads, paths, pavings and surfaces 8.3 Soft landscaping, planting and irrigation systems 8.4 Fencing, railings and walls 8.5 External fixtures 8.6 External drainage 8.7 External services 8.8 Minor building works and ancillary buildings

Building elements, groups and classification codes based on the RICS New Rules of Measurement (NRM)

To ensure consistency in approach and to enable comparability between assessments (during different project stages and between buildings) it is essential that there is transparency and consistency in relation to the boundary and scope of the embodied carbon assessment.

3 Embodied carbon assessments

The credibility and robustness of an embodied carbon assessment is significantly influenced by the adopted methodology. A clear and consistent approach is required, providing industry with much needed guidance and instilling confidence in delivery.

RICS Professional Statement (PS) for Whole Life Carbon Assessment for the Built Environment is very much regarded as the ‘go to’ methodology for industry; it sets out the principles for whole life assessment of the environmental impacts from built projects based on life cycle assessment (LCA). The PS is intended to standardise whole life carbon assessment and enhance consistency in outputs. Documents marked as ‘Professional Statements’ are the most highly rated documents by RICS and documents that RICS require their members to act in accordance with.

The first and current edition of the RICS PS for Whole Life Carbon Assessment for the Built Environment was published in 2017. Since then, the PS has been endorsed by many leading professional membership organisations (including RIBA, IStructE, ICE, CIOB etc.), advisory groups (including UK Green Building Council and LETI) and local government (including Greater London Authority). The PS is also referenced in Scottish Government’s Net Zero Public Sector Building Standard as a recognised route to compliance for Objective 2 Construction Embodied Carbon and Objective 4 Whole Life Carbon.

The RICS PS Whole Life Carbon Assessment for the Built Environment is currently in the process of being updated, with the second edition due Q3 or Q4 of 2022. RICS received funding from the UK Government Department for Business, Energy and Industrial Strategy (BEIS) and the backing of peer professional membership bodies to update the PS. The second edition of the PS is expected to include additional early-stage guidance for practitioners undertaking Life Cycle Assessments and provide further guidance for infrastructure projects, in addition to building projects.

The RICS PS for Whole Life Carbon Assessment for the Built Environment methodology can and does provide a consistent, standardised and transparent approach for whole life and embodied carbon assessment. Key principles include:

- Life Cycle Assessment (LCA) is delivered in line with the modular structure of BS EN 15978
- assessments must account for all components making up the finished building
- a minimum of 95 per cent of the costs allocated to each building element category should be accounted for in the assessment
- can be applied to new and existing assets, as well as refurbishment, retrofit an fit-out
- requires the use and reporting of consistent units
- requires the use of credible carbon data sources (e.g. Environmental Product Declarations produced in accordance with the relevant EN, ISO and PAS standards)
- provides clear guidance on the recognition of carbon sequestration (for example, this can only be taken into account where a whole life carbon assessment is delivered and the timber originates from sustainable, certified sources)

4 Life Cycle Assessment reporting tools

Life Cycle Assessment (LCA) is a methodology for assessing environmental impacts associated with the different stages of the life cycle of an asset. LCA can quantify embodied and whole life carbon impacts. At present, there are a number of available tools that help automate the LCA and generate environmental impact results (for embodied and whole life carbon and for various life cycle stages).

The accuracy of LCA calculations and reporting is influenced by the tool itself and the use of data sources. The use of credible tools and reliable data sources is not only essential when considering routes to regulating embodied carbon, it is also vitally important for ensuring accuracy of assessment and to confidently make the right choices to mitigate embodied carbon impacts. The consistent production of accurate and reliable data would make it easier to benchmark, compare, learn and improve from other projects.

IMPACT is a specification and database for software developers to incorporate into their tools to enable consistent Life Cycle Assessment (and Life Cycle Costing). IMPACT is the only standardised specification and dataset currently available in the UK. The use of 'IMPACT compliant' LCA tools can enhance the consistency and accuracy of results.

IMPACT tools are third-party tested to ensure the specification meets the requirements and the dataset has been implemented within the LCA tool accurately. All IMPACT compliant tools produce near identical LCA results given the same set of inputs. IMPACT allows for creation of benchmarks that are standardised and reliable.

IMPACT is also designed to work within 3D/BIM software tools, where data can be extracted and then uploaded to the LCA tool, promoting 'one source of truth' on projects which can enhance the accuracy of the information being fed through the LCA tool.

Some LCA tools also have the capability of quantifying and reporting circularity, which can further support option appraisals and decision-making during planning and delivery stages.

In the UK, there are freely available versions of IMPACT compliant LCA tools, including One Click Planetary (made available as a result of a collaboration between One Click LCA tool provider and the UK Green Building Council) and eTool.

5 Embodied carbon benchmarking

The introduction and adoption of embodied carbon benchmarks is essential in supporting a transition from typical to good and then best practice.

The World Green Building Councils, including the UK Green Building Council, are actively encouraging the construction industry to work towards achieving a 40% reduction in embodied carbon by 2030. This has encouraged a number of organisations, including professional bodies, advisory groups and local government, to introduce a series of staged aspirational targets in support of the Green Building Council ambitions.

There is, however, a lack of consistency with regards to boundary and scope when considering a number of the existing embodied carbon targets, which does cause some confusion within the industry and amongst clients when looking to adopt targets or compare projects.

The embodied carbon targets introduced by RIBA, LETI and Greater London Authority are summarised in the following sections.

RIBA embodied carbon targets

During 2021, Royal Institute of British Architects (RIBA) published version 2 of their 2030 Climate Challenge and introduced an updated suite of performance targets, including targets for embodied carbon. The recommendation from RIBA is for buildings that are being designed today to aim for the 2025 target as a minimum and 2030 whenever possible.

The RIBA embodied carbon targets exclude External Works and non-fixed Fittings, Furnishings and Equipment. RIBA report a figure of 1400kgCO_2e/m^2 for non-domestic and 1200kgCO_2e/m^2 for domestic buildings as a ‘business as usual’ baseline for embodied carbon. RIBA embodied carbon targets cover modules A1 – A5, B1 – B5 and C1 – C4. The RIBA guidance also promotes the use of the RICS PS for whole life carbon assessment for the built environment and the use of circular economy strategies.

RIBA has introduced different reduction targets for new build offices, schools and residential buildings as follows:

RIBA 2030 Climate Challenge target metrics for non-domestic (new build offices)

RIBA Sustainable Outcome Metrics	Business as usual (new build, compliance approach)	2025 Targets	2030 Targets
Embodied Carbon kgCO_2e/m^2	1400 kgCO_2e/m^2	< 970 kgCO_2e/m^2	< 750 kgCO_2e/m^2

RIBA 2030 Climate Challenge target metrics for non-domestic (new build schools)

RIBA Sustainable Outcome Metrics	Business as usual (new build, compliance approach)	2025 Targets	2030 Targets
Embodied Carbon kgCO_2e/m^2	1400 kgCO_2e/m^2	< 675 kgCO_2e/m^2	< 540 kgCO_2e/m^2

RIBA 2030 Climate Challenge target metrics for domestic / residential

RIBA Sustainable Outcome Metrics	Business as usual (new build, compliance approach)	2025 Targets	2030 Targets
Embodied Carbon kgCO_2e/m^2	1200 kgCO_2e/m^2	< 800 kgCO_2e/m^2	< 625 kgCO_2e/m^2

LETI embodied carbon targets

Similarly, LETI update their embodied carbon targets during 2021, seeking to ensure greater alignment with the RIBA 2025 and 2030 targets. LETI guidance also provides a breakdown of the embodied carbon target, providing an overall target and a separate target for ‘Upfront Carbon’ which cover Modules A1 – A4.

The LETI guidance also promotes the use of the RICS PS for whole life carbon assessment for the built environment. However, the LETI embodied carbon targets exclude External Works and renewable electricity generation (e.g. PV).

LETI assume a current average for embodied carbon as 1400kgCO_2e/m^2 and an embodied carbon to practical completion average as 950kgCO_2e/m^2. Design targets for 2020 and 2030 have been introduced for office, education, retail and residential buildings, as follows:

Upfront Carbon, A1-5 (exc. sequestration)

	Band	Office	Residential	Education	Retail
	A++	<100	<100	<100	<100
	A+	<225	<200	<200	<200
LETI 2030 Design Target	A	<350	<300	<300	<300
	B	<475	<400	<400	<425
LETI 2020 Design Target	C	<600	<500	<500	<550
	D	<775	<675	<625	<700
	E	<950	<850	<750	<850
	F	<1100	<1000	<875	<1000
	G	<1300	<1200	<1100	<1200

Embodied Carbon, A1-5, B1-5, C1-4 (inc. sequestration)

	Band	Office	Residential	Education	Retail
	A++	<150	<150	<125	<125
	A+	<345	<300	<260	<250
	A	<530	<450	<400	<380
RIBA 2030 Built Target	B	<750	<625	<540	<535
	C	<970	<800	<675	<690
	D	<1180	<1000	<835	<870
	E	<1400	<1200	<1000	<1050
	F	<1625	<1400	<1175	<1250
	G	<1900	<1600	<1350	<1450

All values in kgCO_2e/m^2 (GIA)

Comparison of RIBA and LETI embodied carbon targets

A comparison of the LETI and RIBA embodied carbon targets for new buildings is summarised in the points below:

- RIBA guidance provides one target for embodied carbon over the whole life of the building (i.e. for modules A1 – A5, B1 – B5 and C1 – C4), whereas LETI guidance provides embodied carbon targets up to the point of practical completion (i.e. for modules A1 – A5) and target for embodied carbon over the whole life of the building (i.e. for modules A1 – A5, B1 – B5 and C1 – C4)

- LETI targets relate to the year of design; however, RIBA targets are performance targets to be realised in buildings completed in 2025 and 2030

- RIBA has set one interim target for 2025 and one target for 2030, however LETI has introduced incremental targets and has designated an equivalent letter banding to each target (ranging from A++ through to G) up to a target year of 2030 and beyond

- LETI and RIBA state that non-fixed FF&E and external work can be excluded from the target, however LETI also state that building renewable electricity generation (e.g. PVs) can also be excluded

- LETI provides 4 separate sets of targets for Office, Residential (based on a dataset for multi-residential of 6 storeys and above), Education (based on a dataset of schools) and Retail, whereas RIBA provides 3 separate sets of targets for non-domestic (schools), non-domestic (offices) and domestic / residential building types

Greater London Authority embodied carbon targets

The Greater London Authority (GLA) has introduced a requirement for whole life carbon assessment and a range of minimum and aspirational embodied carbon and embodied carbon to practical completion targets, as part of their London Plan. This requires whole life carbon assessments and a circularity statement to be submitted as part of planning requirements.

The London Plan guidance also promotes the use of the RICS PS for whole life carbon assessment for the built environment. However, the GLA embodied carbon targets, unlike the RIBA and LETI targets, includes External Works.

The London Plan guidance reports a range of embodied carbon targets that reflect current averages for different building types, which have been informed from a range of sources that have gathered data on actual projects. These represent the minimum embodied carbon targets for each building type. A range of aspirational embodied carbon targets have also been provided for similar building types and are reflective of the Green Building Councils aspiration of 40% by 2030. Minimum and aspirational targets have been introduced for office, education, retail and apartment and hotel buildings, as follows:

Education

	Education WLC benchmarks - Carbon at Completion (A1-A5)	Education WLC benchmarks - Carbon Over Life Cycle	Education aspirational WLC benchmarks - Carbon at Completion (A1-A5)	Education aspirational WLC benchmarks - Carbon Over Life Cycle
Substructure	-	-	-	-
Superstructure	-	-	-	-
Finishes	-	-	-	-
FFE	-	-	-	-
Services	-	-	-	-
External works	-	-	-	-
Total	700 to 800 kg CO2e/m2 GIA	200 to 300 Kg CO2e/m2 GIA	450 to 500 kg CO2e/m2 GIA	120 to 180 kg CO2e/m2 GIA

Offices

	Office WLC benchmarks - Carbon at Completion (A1-A5)	Office WLC benchmarks - Carbon Over Life Cycle	Office aspirational WLC benchmarks - Carbon at Completion (A1-A5)	Office aspirational WLC benchmarks - Carbon Over Life Cycle
Substructure	-	-	-	-
Superstructure	-	-	-	-
Finishes	-	-	-	-
FFE	-	-	-	-
Services	-	-	-	-
External works	-	-	-	-
Total	900 to 1000 kg CO2e/m2 GIA	400 to 500 kg CO2e/m2 GIA	550 to 600 kg CO2e/m2 GIA	250 to 300 kg CO2e/m2 GIA

Retail

	Retail WLC benchmarks - Carbon at Completion (A1-A5)	Retail WLC benchmarks - Carbon Over Life Cycle	Retail aspirational WLC benchmarks - Carbon at Completion (A1-A5)	Retail aspirational WLC benchmarks - Carbon Over Life Cycle
Substructure	-			
Superstructure	-			
Finishes	-			
FFE	-			
Services	-			
External works	-			
Total	-	100 to 200 kg CO2e/m2 GIA	550 to 600 kg CO2e/m2 GIA	60 to 120 kg CO2e/m2 GIA

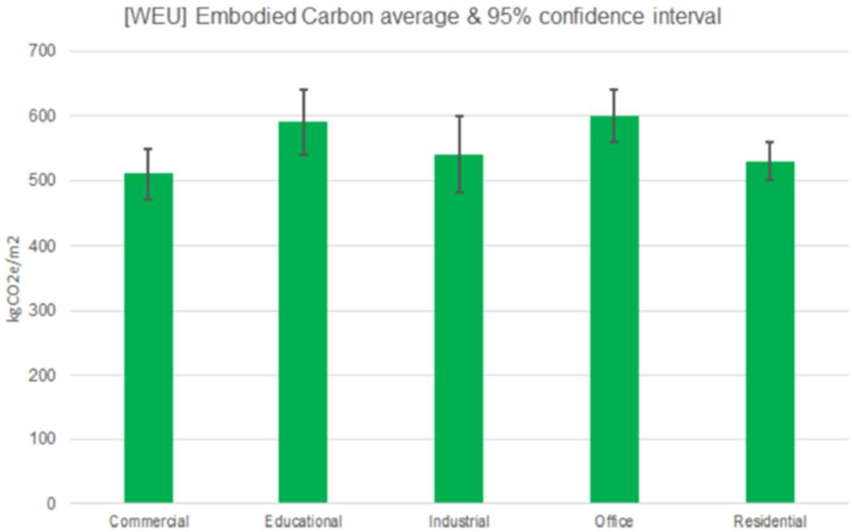
Apartment building

	Apartment/hotel WLC benchmarks - Carbon at Completion (A1-A5)	Apartment/hotel WLC benchmarks - Carbon Over Life Cycle	Apartment/hotel aspirational WLC benchmarks - Carbon at Completion (A1-A5)	Apartment/hotel aspirational WLC benchmarks - Carbon Over Life Cycle
Substructure	-	-	-	-
Superstructure	-	-	-	-
Finishes	-	-	-	-
FFE	-	-	-	-
Services	-	-	-	-
External works	-	-	-	-
Total	750 to 850 kg CO2e/m2 GIA	300 to 400 kg CO2e/m2 GIA	450 to 500 kg CO2e/m2 GIA	180 to 240 kg CO2e/m2 GIA

One Click embodied carbon reporting

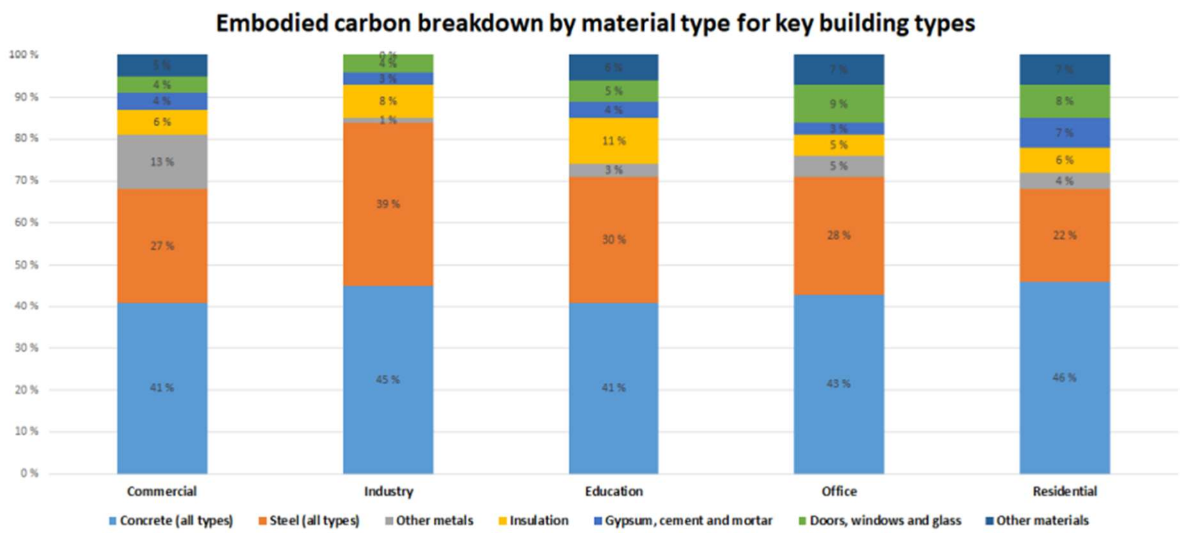
One Click is the one of the most commonly used LCA tool providers in the UK and Europe and has access to the world's largest generic and EPD database.

One Click recently published some research findings, sharing embodied carbon data for a range of building types, located in different parts of the world. Embodied carbon averages for the sample of projects from Western European countries and the embodied carbon breakdown by material type, was reported as follows:



The completeness of reporting for these scopes by building types is summarized below.

Building element	Foundation / substructure	Super-structure	Enclosure	Interior finishes	Building services	External areas
Commercial	100 %	100 %	100 %	33 %	30 %	35 %
Educational	100 %	100 %	100 %	35 %	35 %	23 %
Industrial	100 %	100 %	100 %	27 %	32 %	44 %
Office	100 %	100 %	100 %	55 %	30 %	21 %
Residential	100 %	100 %	100 %	42 %	57 %	19 %
Total	**100 %**	**100 %**	**100 %**	**42 %**	**40 %**	**25 %**



6 Establishing good practice

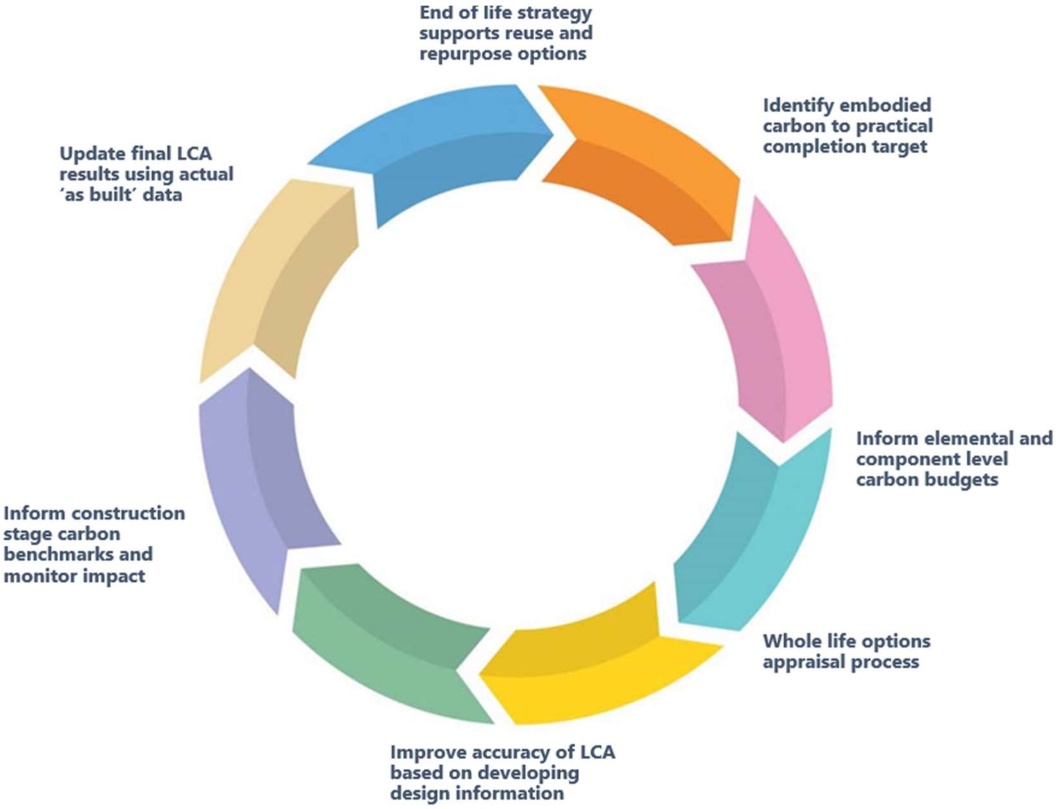
All projects considering embodied carbon will benefit from a carbon mitigation strategy. This should:

- clearly define scope and boundary
- identify aspirational target
- adopt robust methodology and make use of a reliable LCA tool
- prepare early-stage indicative baseline LCA results and carbon budgets
- identify biggest contributors
- apply circular practices
- reduce material intensity
- optimise and report reused content (per element / sub-element)
- optimise and report recycled content
- ensure early supply chain viability testing – assess opportunity and risk
- optimise the use of natural materials
- optimise recycled content
- design for longevity, robustness and resilience (embodied carbon impact associated with replacement is typically significant)
- design for ease of maintenance in operation
- design for adaptability / flexibility (user informed)
- align Life Cycle Costing and Life Cycle Analysis, to account for cost and carbon during options appraisals
- plan for reuse, recovery and recycling
- prepare a 'Future Bill of Materials', plan for improvement in respect of repair and replacement quantities of materials (per element / sub-element)
- source locally (mitigate transport impacts)
- adopt responsible construction practices (avoid waste to landfill and mitigate site impacts)
- engage a suitably trained and qualified delivery team
- obtain third party verification
- support data disclosure

Life cycle planning and reliable data

The most significant opportunity to influence and mitigate embodied carbon impacts is during the early life cycle stages. To encourage good practice and maximise the opportunity for embodied carbon reduction, high-level actions / principles must be identified to support projects during the planning, development and implementation stages.

The use of data during different life cycle stages is summarised below (using RIBA plan of work stages as a reference):



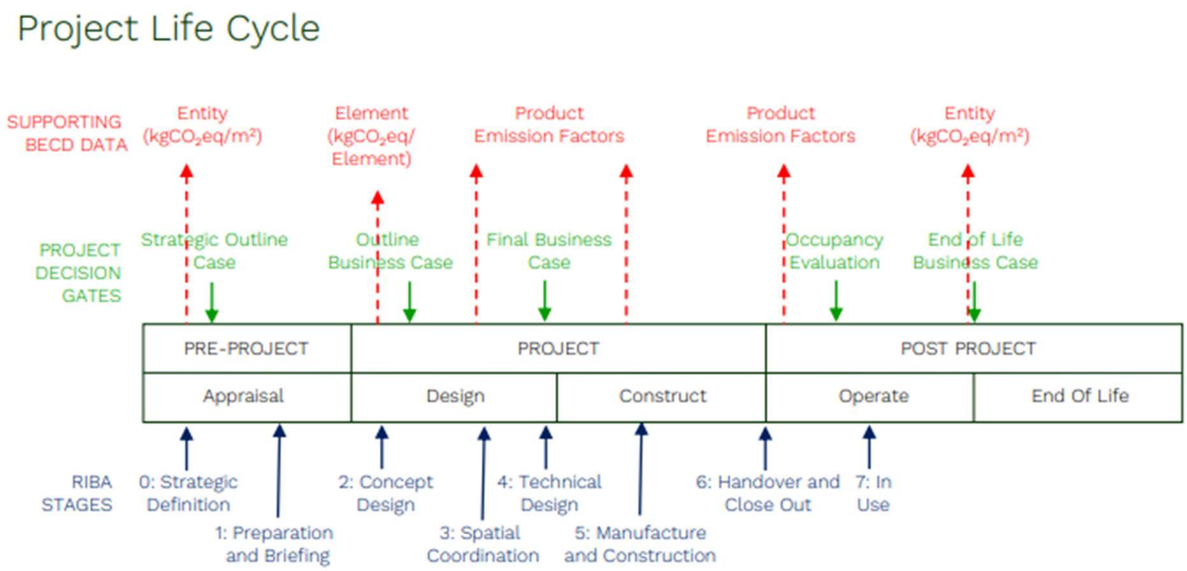
Life Cycle Assessment (LCA) is used to calculate embodied carbon and should be an iterative process for a project. LCA analysis and embodied carbon reporting should be reported during key review stages to support options appraisal and inform decision making.

Environmental Product Declarations (EPDs) are third-party issued certificates that quantify environmental information on the life cycle of a product to enable reliable comparisons between products that can fulfil the same function. Prioritising the use of EPDs can help to improve the accuracy of the LCA analysis and embodied carbon calculation.

The use of reliable and robust carbon databases can also be helpful for projects to aid some early-stage decision making and may also help to inform target setting.

BEIS is currently funding an initiative which will launch an open source 'built environment carbon database'. The database is being developed to enable the collection and support the supply of product data and entity level data to industry, through its own dedicated portal and by interacting with existing databases and software solutions.

The ‘built environment carbon database’ working group has shared the image below to help demonstrate how a project could utilise and / or provide data during different life cycle stages.



Inter-connected policy

When considering embodied carbon, recognition must also be given to inter-connected policies, including building technical standards, circular economy and the sustainable construction procurement policy and a number of socio-economic and environmental outcomes must be considered and prioritised.

7 Materials and manufacture

When considering embodied carbon and the adoption of an aspirational yet realistic target, it is important to consider not only the impact of material specification but the opportunity for optimisation, the level of innovation taking place within industry and the available capacity through the supply chain.

If we consider the product life cycle stage i.e. modules A1 – A3, the most significant carbon influences to embodied carbon will most likely result from the substructure and superstructure building elements and is likely to include the use of timber, concrete, steel and insulation material. The following comparisons have utilised data that is referenced in the ICE database for embodied carbon.

Timber

The way in which timber is now being manufactured is more efficient and cleaner than, for example, compared with 10 years ago. This means:

- Less energy is typically being used by each manufacturer to produce 1m^3 of mass timber
- Less non-renewable energy is typically being used by each manufacturer to produce 1m^3 of mass timber

Recent research undertaken by IStructE reports:

- Current recommendation is 0.25 $kgCO_2e/kg$ for CLT (compared with the current widely adopted factor of 0.437 $kgCO_2e/kg$)
- Current recommendation is 0.28 $kgCO_2e/kg$ for glulam (compared with the current widely adopted factor of 0.512 $kgCO_2e/kg$)
- Softwood value recognised as 0.263 $kgCO_2e/kg$ (consistent with the ICE database)

IStructE has shared the following recent research findings in relation to the production and embodied carbon of European timber:

Figure 1 CLT annual European production

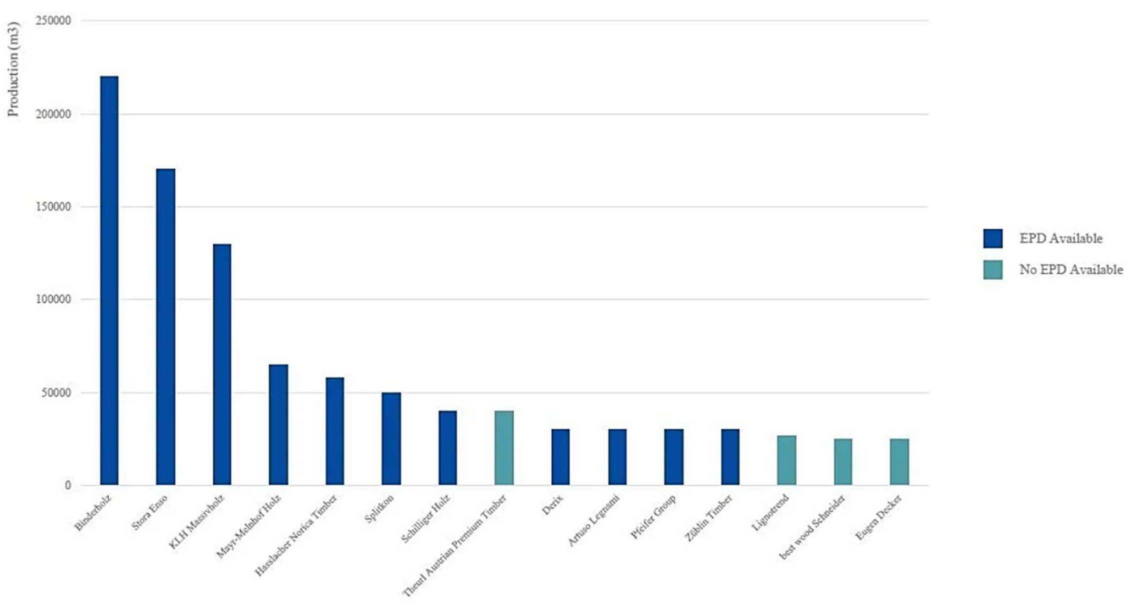


Figure 2 Glulam annual European production

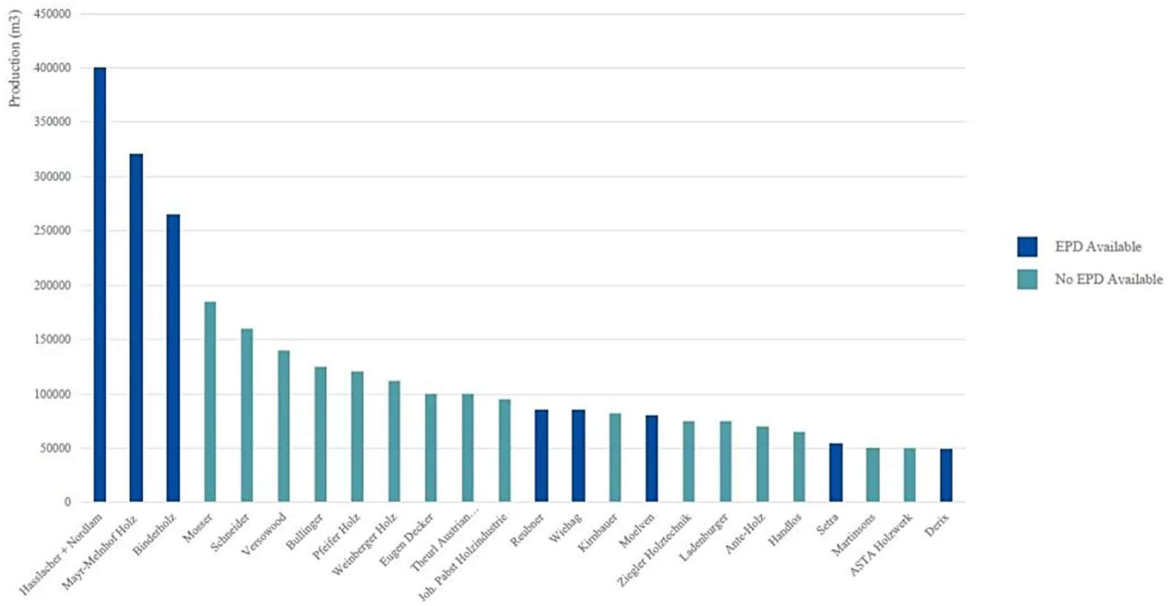


Figure 3 CLT embodied carbon A1-A3 without sequestration

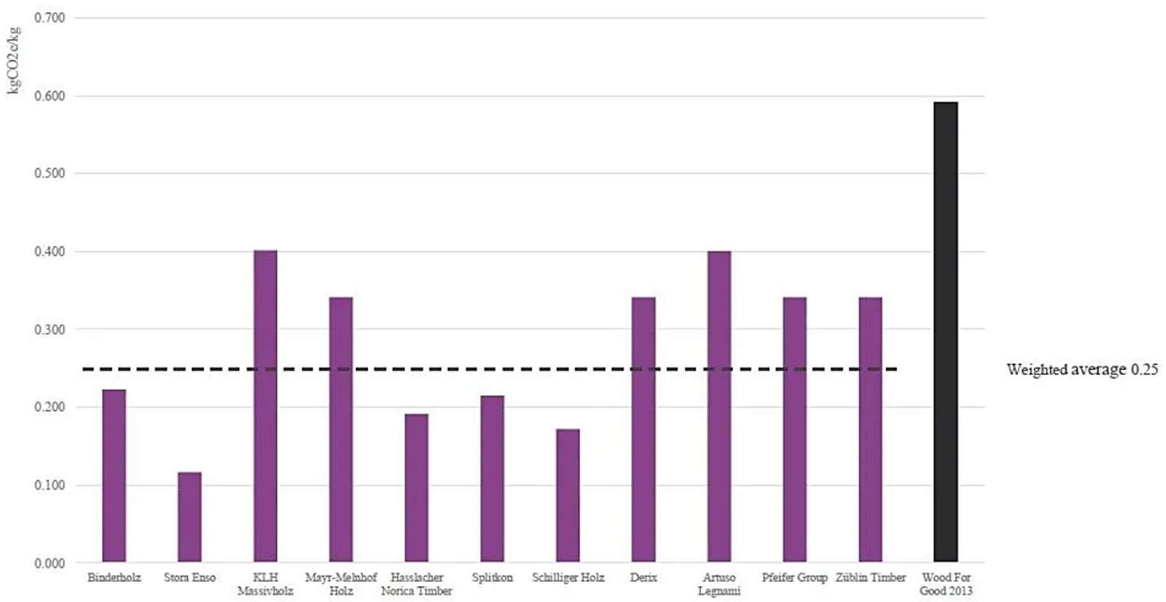
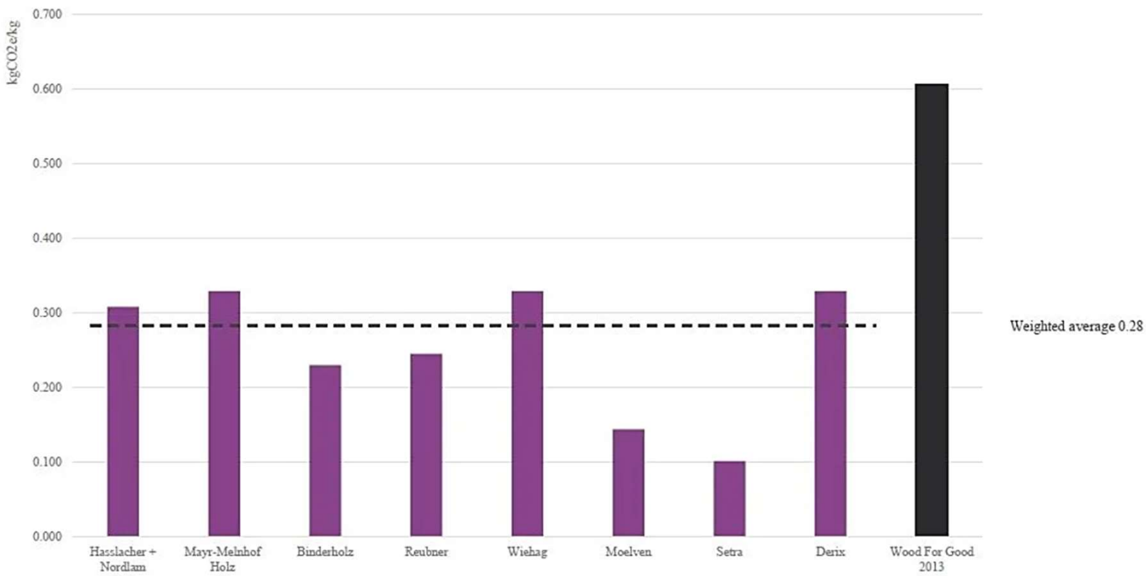


Figure 4 Glulam embodied carbon A1-A3 without sequestration



When exploring the use of timber on a project, it is also important to consider:

- Sequestered carbon – the benefits of this can be recognised as part of a whole life carbon assessment
- Circularity – how best to support repurpose and end of life scenarios
- Locally manufactured – local manufacture is encouraged and is being supported by organisations such as Construction Scotland Innovation Centre, however at present local supply is not able to meet local demand
- Costs – local sourcing and manufacture are significantly higher than European suppliers, also timber costs compared with steel and concrete structural options significantly higher (the current market is described volatile, a whole life cost and carbon appraisal is required)
- Wellbeing – natural materials and recognised wellbeing benefits should be recognised and the benefit of healthier internal environments (e.g. exposed finishing and less VOCs etc.)
- Fire risk – early planning and consideration required, early consultation with building control required
- Insurance premiums – demands and premiums can act in a prohibitive way, early conversations with insurers required

Concrete

Concrete is made from aggregate, cement and water and is the second most consumed material globally. Therefore, there is significant opportunity to reduce overall embodied carbon emissions by reducing the embodied carbon emissions from concrete.

Early considerations for reducing embodied carbon will typically include:

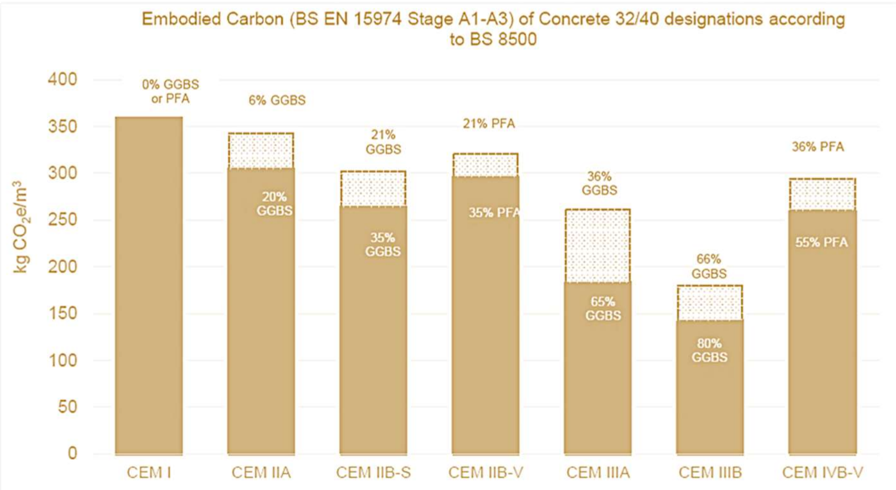
- Consider impact scenarios e.g. typically, concrete has 50% higher embodied carbon than timber and potentially higher quantities required for use in substructure (when compared with lighter weight / timber frame options)

- Identify opportunity for cement substitutes

- Optimise recycled mixes e.g. up to 80% GGBS mix in substructure and >50% in superstructure can significantly reduce embodied impact – this will require advance consideration and programme planning (curing time and strength)

- Consider local sourcing opportunities to reduce associated emissions from transporting materials to site

- Introducing GGBS replacement mixes could be cost comparable and depending on source of supply, could offer marginal net savings when compared with e.g. typical CEM1 mixes



Source: BS 8500

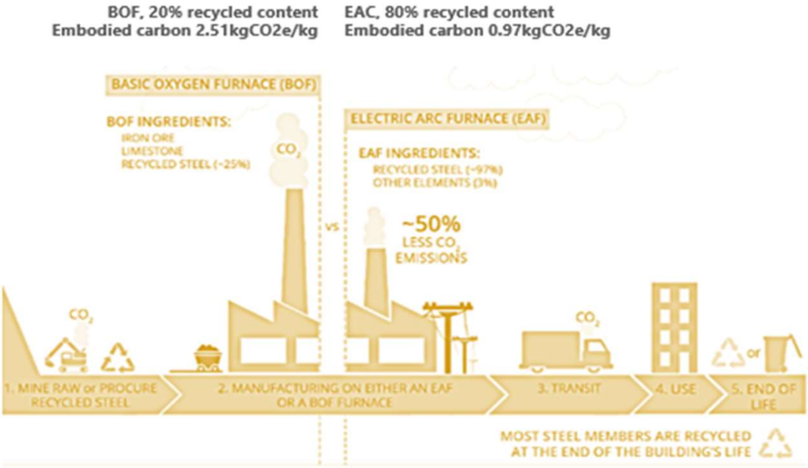
Steel

Steel can be one of the most carbon intensive materials utilised in the delivery of a new building.

Early considerations for reducing embodied carbon will typically include:

- Consider impact scenarios e.g. steel can have up to 70% higher embodied carbon than timber, consider timber as alternative where design supports this or use of hybrid options such as steel with timber infill which may be less impactful
- Maximise recycled content, as close to 100% as possible (all uses)
- Consider the manufacture process, for example preference given to Electric Arc Furnace (EAF) as opposed to Basic Oxygen Furnace (BAF or BOS)
- Factor in transport emissions – EAC steel not yet manufactured in UK (British Steel estimating that this is likely to be 4 – 5 years away) and any shipping emissions (although note that these are comparably quite small for EAC steel sourced from Europe) do need to be accounted for
- Consider choice of finish e.g. powder coating could be 30% less carbon intense than anodised and use of intumescent paint can have significant impact on carbon

- Recycled EAF steel could increase costs by up to 5% when compared with UK BOS steel, however on larger scale projects there may be an opportunity to take advantage of products that have increased structural strength, resulting in reduced quantities being required



Source: Architecture 2030

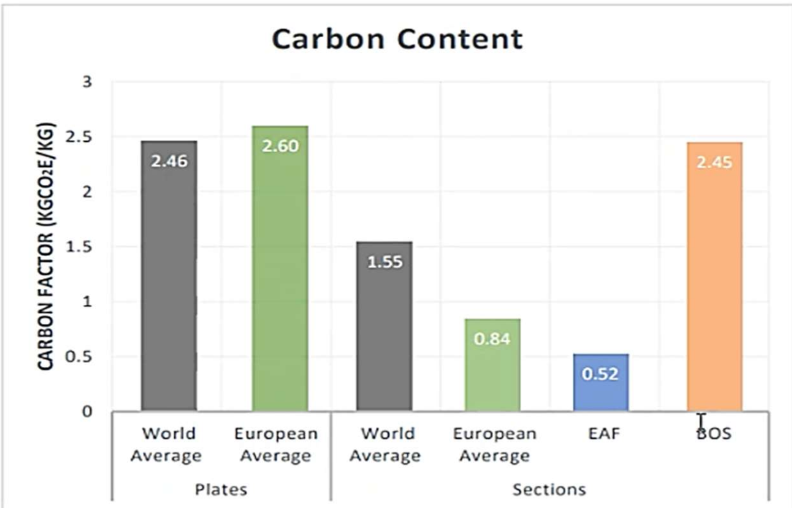


Figure 1: The variations in the carbon intensity of steel by location and process.
Source: ICE 2019 database, ArcelorMittal EPDs and British Steel EDP

Insulation

Materials that are specified in large quantities can also significantly contribute to the total embodied carbon of a new building. Insulation products are an example of this.

Early considerations for reducing embodied carbon will typically include:

- Consider impact scenarios e.g. typically EPS can have an embodied carbon content of double that of rock wool
- Identify opportunity for use of more natural or recycled materials that are now being manufactured locally e.g. hemp based or jute insulation for flooring could have an embodied carbon content as low as $6kgCO_2/m^2$

- Identify opportunity for recycled materials e.g. cellulose fibre insulation could have an embodied carbon content as low as $3kgCO_2/m^2$
- Compare Environmental Product Declarations (EPDs) to make informed choices e.g. some rock wool insulation has an embodied carbon of less than $4kgCO_2/m^2$

Gypsum

The volume of gypsum specified for use on a building could be significant.

Early considerations for reducing embodied carbon will typically include:

- Consider impact scenarios e.g. compare fibre boards with traditional plasterboards and alternative timber and recycled options

- Typical gypsum plasterboard embodied carbon levels could be in excess of $3kgCO_2/m^2$. Options that are closer to $1kgCO_2/m^2$ could be considered

Flooring

The volume of internal floor finishes specified for use on a building could be significant.

Early considerations for reducing embodied carbon will typically include:

- Consider impact scenarios e.g. synthetic carpets are likely to have embodied carbon. A number of flooring manufacturers are promoting more circular and carbon neutral alternatives, including carpet tiles and hard finishes. The environmental and health benefits (e.g. elimination of VOCs) should also be considered.

Building services

The embodied carbon of building services products over the whole life of the building can be significant.

Early considerations for reducing embodied carbon will typically include:

- Eliminate use of refrigerants with a Global Warming Potential >1 where possible

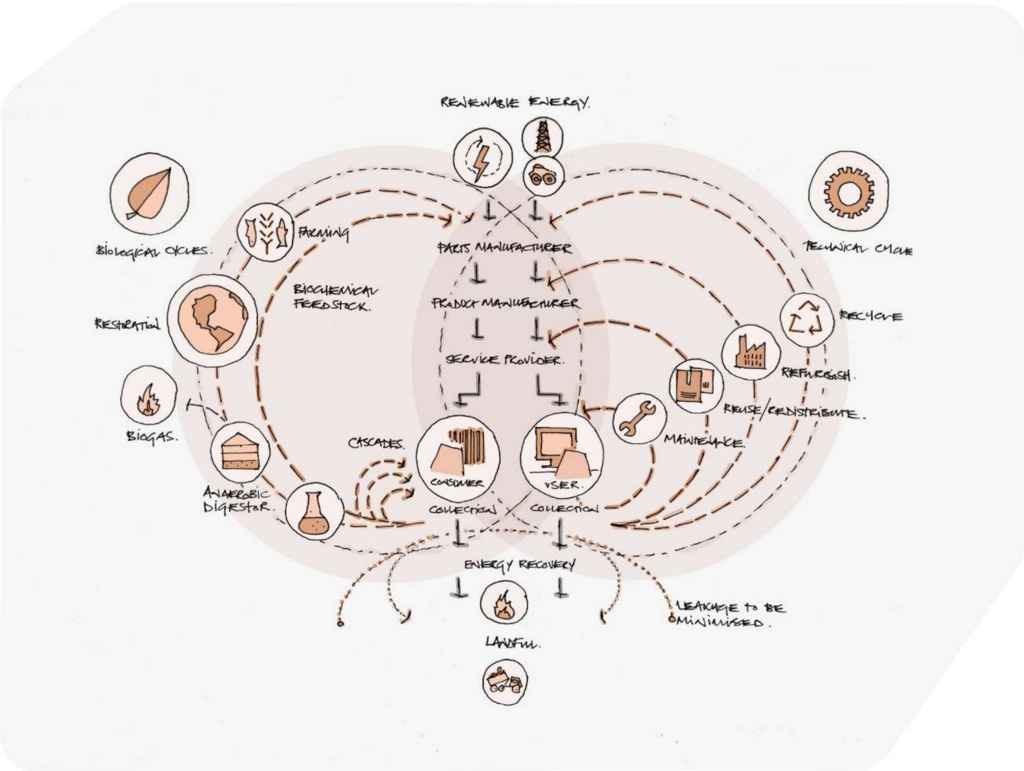
- Where small amounts of refrigerant are used, GWP should be as close to zero as possible e.g. manufacturers now offer a range of heat pump technology with low GWPs (R1234ze has a GWP of 7 and CO_2 has a GWP of 1)
- System design should mitigate risk of refrigerant leakage
- Design for longevity, reducing need for replacement over life cycle
- Where EPDs are not readily available to assist decision making, CIBSE TM65 resource suite and methodology should be used
- Resource efficiency e.g. consider use of metals and steel for services suspension system (wire rope as opposed to typical thread rod)

Material co-benefit analysis

When considering material and product selection and associated embodied carbon contributions, it is important to also consider how circular and healthy the materials are and if they can be responsibility sourced.

Early supply chain viability testing should consider:

- Embodied carbon and impacts – preference given to products with EPDs / credible data sources.
- Health impacts – prioritise the use of non-toxic products with low levels of Volatile Organic Compounds and extremely low levels of formaldehyde.
- Circular benefits – consider the circularity, optimise recycled content and the opportunity for future reuse, recyclability or recoverability potential must be considered for all products.
- Responsible sourcing – evidence of responsible should be sought, ethical and legal sourcing of materials.



8 Recommendations

The regulation of embodied carbon will require a credible and consistent approach to assessment, the use of a robust methodology and the use of calculation tools that generate reliable results. The introduction of clear benchmarking data will also be required to allow applicants to demonstrate compliance with performance targets.

In recognition of this, the following recommendations have been made:

Definition

- provide a clear definition for embodied carbon:
    - embodied carbon is the total Greenhouse Gas (GHG) emissions generated to produce a built asset
    - this includes emissions associated with the Product, Construction Process, Use and End of Life stages, as detailed in BS EN 15978
    - it excludes operational emissions of the asset (which are considered when reporting whole life carbon)

Target setting

- identify any target(s) for embodied carbon:
    - embodied carbon to practical completion (i.e. for modules A1 – A5) targets identified for different building types
    - individual projects required to set whole life objectives (bespoke to each project and demonstrating a carbon reduction for modules B1 – B5 'Use stage' and modules C1 – C4 'End of Life stage')

Boundary

- define the assessment boundary:
    - a whole life carbon assessment will include consideration of modules A1 – A5, B1 – B5 and C1 – C4, following the modular structure of BS EN 15978
    - an embodied carbon to practical completion target will consider modules A1 – A5 only

Scope

- detail the required scope of the assessment:
    - a whole life carbon assessment will consider all building components and works relating to the project
    - reference study years for building's should be assumed to be 60 years

  - all applicable building elements will be based on the RICS New Rules of Measurement classification system
  - a minimum of 95 per cent of the cost allocated to each building element category should be accounted for in the assessment
  - where applicable, external works will be included in the assessment, however these can be excluded from the embodied carbon target
  - non-fixed fittings, furnishings and equipment can be excluded from the assessment

Methodology

- standardise the assessment process:
  - the methodology described in the RICS PS whole life carbon assessment for the built environment must be used

Use of LCA tools

- require the use of credible and reliable LCA tools:
  - LCA tools used to generate calculates must be IMPACT compliant or equivalent

Data sources

- determine the carbon data sources that are allowable for use:
  - environmental declarations and datasets delivered in accordance with the required ISO, PAS or EN standards will be allowable, as detailed in the RICS PS for whole life carbon assessment for the built environment

Reporting

- require consistency of data reporting:
  - whole life and embodied carbon assessment results must be reported using consistent units, for example total kgCO_2e

Verification

- require a level of quality assurance:
  - third-party verification must be provided by a suitably qualified and experienced person or via the LCA tool provider, confirming that the required methodology has been followed and compliance demonstrated

In addition to following the recommendations set out in the previous section of this report, it is further recommended that the aspirational embodied carbon to practical completion benchmarks that are listed below are introduced for a sample selection of projects and that data is collected and analysed over the next 12 to 24 month period to help review, sense-check and where required, refine these targets.

Building type	Aspirational target
Education	450 – 500kgCO_2e/m^2
Office	550 – 600kgCO_2e/m^2
Health centre	550 – 600kgCO_2e/m^2
Industrial	450 – 500kgCO_2e/m^2
Other non-domestic	550 – 600kgCO_2e/m^2
Residential	tba (different building types would need to be considered - is this within the scope of this commission?)

9 Building an evidence base

To ensure rigour and an appropriate level of market testing, it is recommended that the proposed methodology and recommendations described within this report are introduced to and adopted by a number of live projects, enabling a period of testing and data collection to take place over the next couple of few.

It is recommended that data is collated over at least a 12-month period, ideally stretching up to 24 months, allowing for a period of analysis and refinement to any proposal and recommendations that are to be put forward for consideration by Scottish Government.

A representative sample of building types e.g. health, education, commercial, industrial, domestic etc. should be identified and encouraged to take part in this exercise. It is recommended that projects registering under the Scottish Government Net Zero Public Sector Building Standard should be encouraged to participate. Public sector delivery organisations, such as the hub network and key sector representatives (e.g. from health, education, prison sector etc.) should also be encouraged to engage with and take part in this initiative.

To provide a layer of quality assurance, it is recommended that data is reviewed and third-party verified prior to any analysis taking place. All results should be analysed and sense checked against proposed targets and prescribed methodology.

Findings must be used to inform any required amendments or updates to the proposals being prepared for Scottish Government considering the regulation of embodied carbon.

Options to consider for data gather should include:	Consideration to be given to:
• central data depository and open participation call to all interested parties	○ can start to collate data immediately ○ can accept and collate potentially large quantities of data ○ requirement to verify data may be resource intensive ○ quality of data samples may vary ○ unsure if representative building samples will be provided
• hand-select a sample number of projects to participate and mentor through process	○ quantity of projects and volume of data likely to be less ○ quality of usable data more assured

	○ greater level of assurance that representative building types and / or sectors will be included
• train individual project 'champions' to participate	○ data gathering will not be immediate - time and resource requirement to prepare for and train individuals ○ select number of projects would benefit from in-depth support ○ an element of mentoring will most likely still be required during the duration of the project
• hybrid approach, where sample selection of projects is identified to participate and are mentored through the process, in addition to an open call for participation (with perhaps limited number of participants so to manage quality assurance aspect effectively)	○ greater levels of assurance with regards to quality of data and representative sample