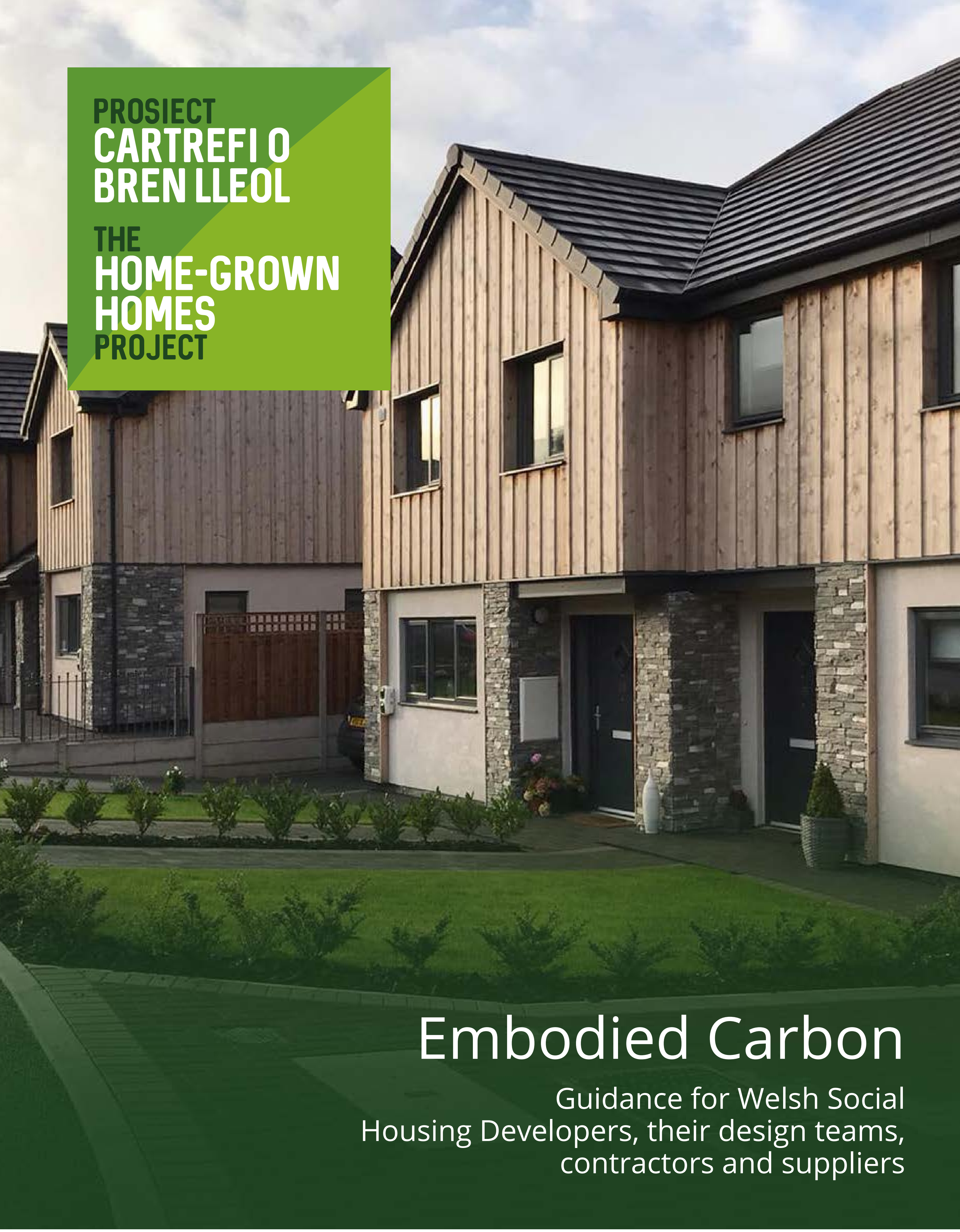

PROSIECT CARTREFI O BREN LLEOL

THE HOME-GROWN HOMES PROJECT

Embodied Carbon

Guidance for Welsh Social Housing Developers, their design teams, contractors and suppliers

Cefnogir y prosiect hwn gan Gronfa Amaethyddol Ewrop ar gyfer Datblygu Gwledig
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Embodied Carbon

Guidance for Welsh Social Housing Developers, their design teams, contractors and suppliers

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FOREWORD

Halting and then reversing global man-made temperature rise is the big challenge of our time. Having worked in and around the area of sustainability in the built environment for nigh-on 25 years, I'm confident that it can be done and there are lots of reasons to be optimistic. But there is no time to lose. Every opportunity for carbon emissions reduction needs to be grasped and every policy lever that can be pulled should be pulled.

Currently, around 50% of carbon emissions from new build housing is caused by the building materials, the build process, maintenance and end of life - known as the Embodied Carbon emissions. These carbon emissions currently fall largely outside the scope of current regulation, although we do hope and expect regulations to be introduced over the coming months and years.

In any case, my experience of working with Welsh social housing clients, architects and the wider supply chain over the past 5 years, has convinced me that many organisations and individuals do not intend to wait for regulation. They want to do what they can to reduce carbon emissions now. The barrier is not willingness to act, but simply an incomplete understanding of what to do. If you're one of them, then this guidance is for you.

The guidance is primarily written for providers of new build social housing, their consultants and contractors, but it is relevant to everyone operating in the built environment sector, including retrofit.

Over the past few decades a huge amount of work has been done to develop construction product data and the internationally agreed standards that are required to underpin consistent measurement. There are now 1000's of construction product Environmental Product Declarations (EPDs) which provide much of the hard data. There are many assessment tools that make embodied carbon analysis and reduction easy to assimilate into the design process, many of which are described in this guidance. Now in 2020, there is no technical reason not to embark on your embodied carbon reduction journey and this guidance is designed to support you.

That said, reducing embodied carbon does require us to confront the short-termism of the dominant models of house delivery. In particular, the manner in which materials and systems are put together with little thought given to their environmental impact or future resource needs. In that sense, embodied carbon reduction provides both the context and a measurement method to enable a profound re-framing of construction for the substantial benefit of current and future generations.

Gary Newman,
CEO of Woodknowledge Wales

GLOSSARY

Carbon terms

Biogenic Carbon: carbon derived from biomass

Carbon dioxide equivalent / CO_2 equivalent (CO_2e): unit for comparing the radiative forcing of a greenhouse gas to that of carbon dioxide

Carbon Footprint: sum of greenhouse gas (GHG) emissions and GHG removals in a product system, expressed as CO_2 equivalents (CO_2e) and based on a life cycle assessment using the single impact category of climate change. The carbon footprint of a house is equivalent to its Whole Life Carbon. The carbon footprint of a brick is equivalent to its Embodied Carbon

Carbon negative: an activity that goes beyond achieving net zero carbon emissions to actually create an environmental benefit by removing additional carbon dioxide from the atmosphere. The same thing as “climate positive”

Carbon Offset: mechanism for compensating embodied or Operational Carbon through the prevention of the release of, reduction in, or removal of an amount of greenhouse gas emissions in a process outside the product system under study Carbon positive is how organizations sometimes describe Climate Positive or Carbon Negative. As it is confusing, we don’t recommend its use

Embodied Carbon: Embodied Carbon emissions are the GHG emissions associated with materials and construction processes throughout the whole life cycle of an asset (Modules A1-A5, B1-B5, C1-C4)

Upfront Carbon: Upfront Carbon emissions are those GHG emissions associated with materials and construction processes up to practical completion (so product manufacture, transport and construction) (Modules A1-A5)

Operational Carbon: Operational Carbon emissions are those GHG emissions arising from all energy and water consumed by an asset in use, as projected or measured, over its life cycle (Modules B6-B7)

Operational Energy Carbon: Operational energy carbon emissions (Module B6) are those GHG emissions arising from all energy consumed by an asset in use, as projected or measured, over its life cycle

Operational Water Use Carbon: Operational water emissions (Module B7) are those GHG emissions arising from water supply and wastewater treatment for an asset, as projected or measured, over its life cycle

Whole Life Carbon: Whole Life Carbon emissions are the sum total of all asset related GHG emissions, both operational and embodied over the life cycle of an asset including its disposal. Overall Whole Life Carbon asset performance includes separately reporting the potential benefit from future energy recovery, reuse, and recycling (Module D). Whole Life Carbon = Operational Carbon + Embodied Carbon and Module D (Modules A1-A5, B1-B7, C1-C4 & Module D)

Net Zero Terms

Net Zero Embodied Carbon: A ‘Net Zero Embodied Carbon emissions’ asset is one where the sum of Embodied Carbon (Modules A1-A5, B1-B7 & C1-C4) and offsets equals zero

Net Zero Upfront Carbon: A ‘Net Zero Upfront Carbon’ Asset is one where the sum total of GHG emissions from material sourcing, transport, manufacture and construction (Modules A1-A5) plus offsets equals zero

Net Zero Operational Carbon: A ‘Net Zero Operational Carbon’ asset is achieved when those GHG emissions arising from all energy and water consumed by an asset in use (B6, B7), as projected or measured over its life cycle, plus offsets, equals zero

Net Zero Whole Life Carbon: A ‘Net Zero Whole Life Carbon’ Asset is one where the sum total of all asset related GHG emissions, both operational and embodied, over its life cycle including disposal (Modules A1-A5, B1-B7, C1-C4) plus offsets equals zero

Net Zero Carbon Asset: A ‘Net Zero Carbon Asset’ is one where the sum total of all asset related GHG emissions, both operational and embodied, over its life cycle including disposal (Modules A1-A5, B1-B7, C1-C4) plus offsets equals zero

Net Zero - Carbon Neutral: For simplicity and consistency, ‘Net Zero’ and ‘Carbon Neutral’ are considered to be interchangeable.

Energy terms

Embodied energy: total of all the energy consumed in the processes associated with the production of materials and products

Zero energy: where a building produces as much energy from onsite renewables as it consumes. The same thing as “energy neutral”

Energy neutral: where a building produces as much energy from onsite renewables as it consumes. The same thing as “zero energy”

Energy positive: where a building produces more energy from onsite renewables than it consumes

Other terms

Biomass: material of biological origin excluding material embedded in geological and/or fossilized formations

Circular economy: an economy that is restorative and regenerative by design, and which aims to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles

Climate positive: an activity that goes beyond achieving net zero carbon emissions to actually create an environmental benefit by removing additional carbon dioxide from the atmosphere. The same thing as “carbon negative”

GLOSSARY (cont.)

Design team: architects, engineers and technology specialists responsible for the conceptual design aspects and their development into drawings, specifications and instructions required for construction of the building or facility and associated processes. The design team is a part of the project team

Element unit quantity (EUQ): a unit of measurement that relates solely to the quantity of the element or sub-element itself (e.g. the area of the external walls, the area of windows and external doors and the number of internal doors)

Element: part of a construction containing a defined combination of construction products (e.g. ground floor, roof, external wall)

Environmental Product Declaration (EPD): An EPD provides environmental information about a product in a standardised format using an consistent methodology. For construction products in Europe, the European standard EN 15804 provides the format and methodology

Global warming: a gradual increase in the overall temperature of the earth's atmosphere generally attributed to the greenhouse effect caused by increased levels of carbon dioxide, CFCs, and other pollutants

Greenhouse gas (GHG): gaseous constituent of the atmosphere, both natural and anthropogenic, that absorbs and emits radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds

Gross internal area (GIA): Gross internal area is the area of a building measured to the internal face of the perimeter walls at each floor level

Life Cycle Assessment (LCA): compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle

Mechanical, Electrical and Plumbing (MEP): MEP is a term for the equipment to provide services such heating, ventilation, lighting, and water. Also known as "building services" or M&E (mechanical and electrical)

Mixed-mode ventilation: mixed-mode ventilation refers to a hybrid approach to space conditioning that uses a combination of natural ventilation from operable windows (either manually or automatically controlled), and mechanical systems that include air distribution equipment and refrigeration equipment for cooling.

Passive ventilation: passive ventilation is the process of supplying air to and removing air from an indoor space without using mechanical systems

Passivhaus: Passivhaus buildings provide a high level of occupant comfort while using very little energy for heating and cooling. They are built with meticulous attention to detail and rigorous design and construction according to principles developed by the Passivhaus Institute in Germany, and can be certified through an exacting quality assurance process

Radiative forcing: an externally imposed perturbation in the radiative energy budget of the Earth's climate system – causes global warming

EXECUTIVE SUMMARY

This guidance has been written for those wanting to both increase their knowledge of Embodied Carbon in the housing sector and to understand how to reduce it. The target audience encompasses key stakeholders within Welsh social housing organisations including development and asset managers, their design teams, contractors and suppliers. Clear and authoritative guidance is provided on how to procure and undertake an Embodied Carbon assessment, what benchmarks can be set, tools that can be used and how Embodied Carbon can be reduced. Examples are provided to show how others have tackled Embodied Carbon within their organisations and projects, with a focus on housing. Where relevant, other guidance and useful information is signposted.

Key points to note are:

- Embodied Carbon can be up to 50-70% of the emissions of a building over its life cycle and is growing in importance due to the decarbonisation of the grid and the resulting reduction of Operational Carbon.
- Embodied Carbon savings made during the design and construction stage are delivered immediately, helping to reduce CO_2 levels in the atmosphere.
- There are multiple benefits for addressing Embodied Carbon including reduction in capital and operational costs, mitigating risk and environmental impact.
- Undertaking Embodied Carbon assessments will help to understand the overall carbon footprint of an organisation and those that have declared a climate emergency.
- Everyone has a responsibility and role to play in reducing Embodied Carbon.
- There needs to be united commitment across the housing association/local authority to addressing Embodied Carbon.
- At an organisational level, a carbon policy should be set, encompassing Embodied and Operational Carbon from housing activities and requirements for Embodied Carbon should be included in the project brief.
- Embodied Carbon should be considered as early as possible in the process to maximise the ability to reduce impact.
- There are opportunities to reduce Embodied Carbon throughout the design process. Changing building form and construction type can significantly reduce Embodied Carbon.
- Various tools are available to undertake an Embodied Carbon assessment, and most suitable tool should be chosen dependent on the type of project and scope of assessment. The RICS Professional Statement on Whole Life Carbon should be followed.
- Biomass based building materials such as timber contain sequestered carbon and during the life of the building, this sequestered carbon is stored and kept out of the atmosphere.
- Benchmarks at either building or element level are a useful way to check performance.
- Providing context for the mass of carbon provided in Embodied Carbon calculations can help people to understand the numbers.
- There are examples in the UK, across Europe and North America, where policy and legislative requirements for measuring and limiting Embodied Carbon have been set.

EXECUTIVE SUMMARY (cont.)

Woodknowledge Wales has developed targets for Upfront Carbon, Embodied Carbon and Energy Use Intensity which it recommends that developments should aim to achieve. This guidance will help organisations in meeting these targets.

Woodknowledge WalesTargets	Low-Rise Housing	Medium and High-Rise Housing
Upfront Carbon	**300 kg CO_2e/m²**	**450 kg CO_2e/m²**
Embodied Carbon	**400 kg CO_2e/m²**	**750 kg CO_2e/m²**
Energy Use Intensity for Space Heating	**15 kWh/m² per year**	
Total Energy Use Intensity	**35 kWh/m² per year**	

The structure of this guidance

This guidance is divided into 12 chapters. For each chapter, a summary and a description of the intended audience is provided.

Chapter 1: Introduction – *This chapter introduces the topic of Embodied Carbon and will be of interest to all readers.* Details are provided on what is meant by Embodied Carbon, its increasing importance and why we need to act now. The relationship between Embodied and Operational Carbon is described, together with a summary of how it is measured across a product's lifecycle and its relationship with life cycle assessment.

Chapter 2: Drivers and benefits of Embodied Carbon/ Whole Life Carbon – *This chapter explains why you should address Embodied Carbon and is aimed at all readers.* Information is provided on the benefits of addressing Embodied Carbon including the reduction in capital and operational costs, mitigating risk and environmental impact. Our climate obligations and the share of carbon including Embodied Carbon from the built environment are provided. Linkages to climate emergencies and declarations, green finance, carbon pricing and circular economy are described.

Chapter 3: Why me – your role and what you can do – *This chapter is aimed at all readers and explains, for different roles, what you can do address Embodied Carbon.* The roles covered within a social housing organisation include politicians/elected members, head of services/CEO/housing association board members/ directors and development or asset managers. For asset managers, the Embodied Carbon impacts of refurbishing compared to demolishing and building new is presented. Also presented are the roles of architects, consultants, and others such as quantity surveyors, manufacturers and suppliers, contractors, clerk of works and warranty providers and insurances.

Chapter 4: Procuring low Embodied Carbon – *This chapter is aimed at those that procure design services, construction services or construction products and explains how you can procure low Embodied Carbon housing.* It commences with the need for a policy for Embodied Carbon, how to develop an Embodied Carbon Brief and considerations on appointing a project team. Good practice in procuring an Embodied Carbon assessment is provided together with an example of how an assessment has been specified in a Welsh housing project. Other sections include procuring low Embodied Carbon products and asking for Environmental Product Declarations (EPDs), construction, monitoring and practical completion.

Chapter 5: Tools and approaches to measure Embodied Carbon – *This chapter is aimed at designers, clients, engineers or consultants that may wish to measure Embodied Carbon.* It explains how you can measure Embodied Carbon and the tools that are available. Measurement strategies are aligned with the RIBA Plan of Work Stages and include a checklist, simple analysis and whole building LCA. The importance of standards is presented, such as the RICS Professional Statement on Whole Life Carbon and details on the tools that are available to undertake an assessment, together with the criteria on selecting the most suitable tool for

EXECUTIVE SUMMARY (cont.)

your circumstances (7 from the UK and 4 from overseas) and practical tips to get the most out of them. Feedback from undertaking assessments is also provided.

Chapter 6: Biomass, biogenic carbon sequestration and carbon storage – *This chapter is aimed at those with an interest in using timber and biobased products and explains how these products can contribute to low Embodied Carbon solutions and the benefits they bring. Note: Chapter 12 on Timber Policy and Regulation may also be of interest.* It provides technical details on biogenic carbon and sequestration and the benefit of carbon storage and how much is typically stored in housing, which can be substantial for both masonry and timber framed buildings. Guidance on calculating sequestered carbon is provided and how it should be considered in target setting. Reporting biogenic carbon and using it to mitigate and offset emissions is also presented.

Chapter 7: Approaches to reducing Embodied Carbon – *This chapter is aimed at all who are interested in reducing embodied carbon, but particularly designers and explains the different approaches to reducing Embodied Carbon.* Design strategies which can reduced Embodied Carbon are related to the RIBA Plan of Work Stages, which include retrofit and refurbishment, building form, material efficiency, the choice of materials including using timber to reduce impact, and consideration of elements. Other aspects include the transportation of materials, construction choices and the use and end of life stages. The balance between Upfront Carbon, Embodied Carbon and Operational Carbon is also discussed.

Chapter 8: Benchmarking Embodied Carbon – *This chapter is aimed at those who want to understand how their project compares to others and explains how you can benchmark Embodied Carbon and the benchmarks that are available.* Details are provided on the types and range of benchmarks including cradle to grave and Upfront Carbon along with their potential benefits. An analysis has been undertaken from literature to show the range of benchmarks for Upfront Carbon. There is also an analysis for Upfront Carbon, Embodied Carbon, Whole Life Carbon and Stored Carbon benchmarks from Wood Knowledge Wales Case Studies. Elemental benchmarks are also presented and recommendations on providing results to WoodKnowledge Wales and RICS to be able to develop robust benchmarks.

Chapter 9: Woodknowledge Wales' recommendations for assessment, reporting and benchmarking of Embodied Carbon – *This chapter is aimed at clients and their design teams working on social housing and explains how you can consistently measure and report Embodied Carbon and Woodknowledge Wales' recommended target values*. This includes the recommendations of the timing of assessments including for detailed design and as-built stages and the elements that should be assessed. Recommendations on the assessment and reporting of Upfront Carbon, Embodied Carbon, Operational (In-Use) and Whole Life Carbon are provided. Perhaps most importantly is the presentation of Upfront Carbon and Embodied Carbon targets for low rise and medium and high-rise housing; an Energy Use Intensity for Space Heating target and Total Energy Use Intensity target have also been set.

Chapter 10: Communicating Embodied Carbon – *This chapter is aimed at those who would like to communicate their work on Embodied Carbon and provides some different ways of communicating which others have used.* This includes providing some context for the mass of carbon such as a UK citizens impact, monetary use or relating it to car usage. Visual examples are also presented for projects including for biogenic carbon storage.

Chapter 11: Embodied Carbon policy and regulation – *This chapter is aimed at those who may be interested in policy and regulation and provides an overview of the different ways in which Embodied Carbon has been considered for regulation in Wales and integrated into policy and regulation across the UK and overseas.* Examples of previous UK policy on Embodied Carbon are provided including for local authorities through planning. Specific reference is made to Wales and the proposed requirements for Quality Requirements in Housing and other relevant policy and legislation and funding programs such as the Innovative Housing Programme. Examples are given across Europe and North America where national and local governments have set Embodied Carbon or related requirements

Chapter 12: Timber policy and regulation – *This chapter is aimed at those with an interest in policy and regulation, and the benefits of using timber and explains different approaches to policy and regulation in Wales and elsewhere.* This includes information on the EU Timber Certification, Sustainable Timber Certification and examples of policies that encourage the use of wood. In Wales, an example of a wood encouragement policy from Powys County Council is provided and finally recommendations for policy.

CHAPTER

01

INTRODUCTION

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CHAPTER 1 - SUMMARY

- **Embodied carbon is defined as the greenhouse gas emissions (and removals) associated with materials and construction processes throughout the whole life cycle of a building.**
- **Embodied carbon can be up to 50-70% of the emissions of a building over the life cycle and is growing in importance due to the decarbonisation of the grid and the resulting reduction of Operational Carbon.**
- **Embodied Carbon savings made during the design and construction stage are delivered now, helping to reduce CO_2 levels in the atmosphere.**
- **It is important to understand the relationship between Embodied Carbon and Operational Carbon, to determine the best carbon reductions opportunities across a building's life cycle.**

What is Embodied Carbon?

Embodied Carbon is the total greenhouse gas (GHG) emissions (often simplified to 'carbon') generated to produce a building or home. It covers the emissions that arise from the energy and industrial processes used in the processing, manufacture and transportation of the materials, products and components required to construct, maintain and refurbish a building such as a house. It also includes deconstruction, disposal and end of life aspects. It does not include Operational Carbon (emissions that arise from the energy used to operate the house e.g. the heating, cooling etc).

The Embodied Carbon which relates to emissions from the material production and construction phases before the building has been completed is known as 'upfront carbon'. These emissions have already been released into the atmosphere before the building is occupied. This is shown in Figure 1.

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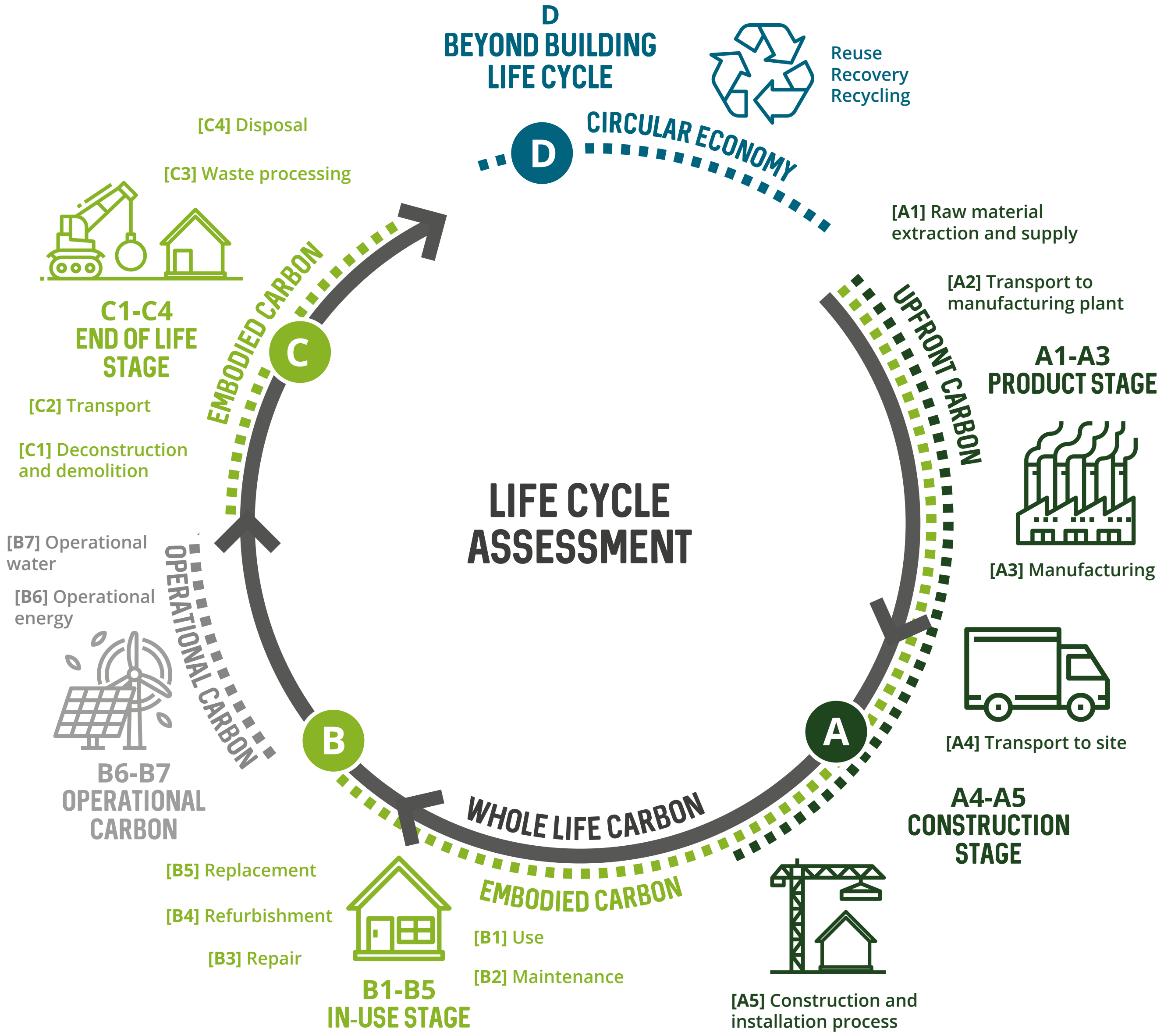

Figure 1
Embodied Carbon Relationships

Why is it important?

Embodied Carbon emissions from construction and the service life of buildings (usually a 60-year life) are significant and can represent more than 50-70% of the lifetime emissions of a new building (see figure 2).

Evidence gathered for a recent Historic England study, for example, demonstrates that if Embodied Carbon emissions are not included, the carbon emissions of a new buildings are underestimated by up to 31% over 60 years[1].

[1] Historic England (2020) There's No Place Like Old Homes. Reuse and Recycle to Reduce Carbon. Prepared as part of Heritage Counts 2019. Project Code: HE0031. https://historicengland.org.uk/content/heritage-counts/pub/2019/hc2019-re-use-recycle-to-reduce-carbon/

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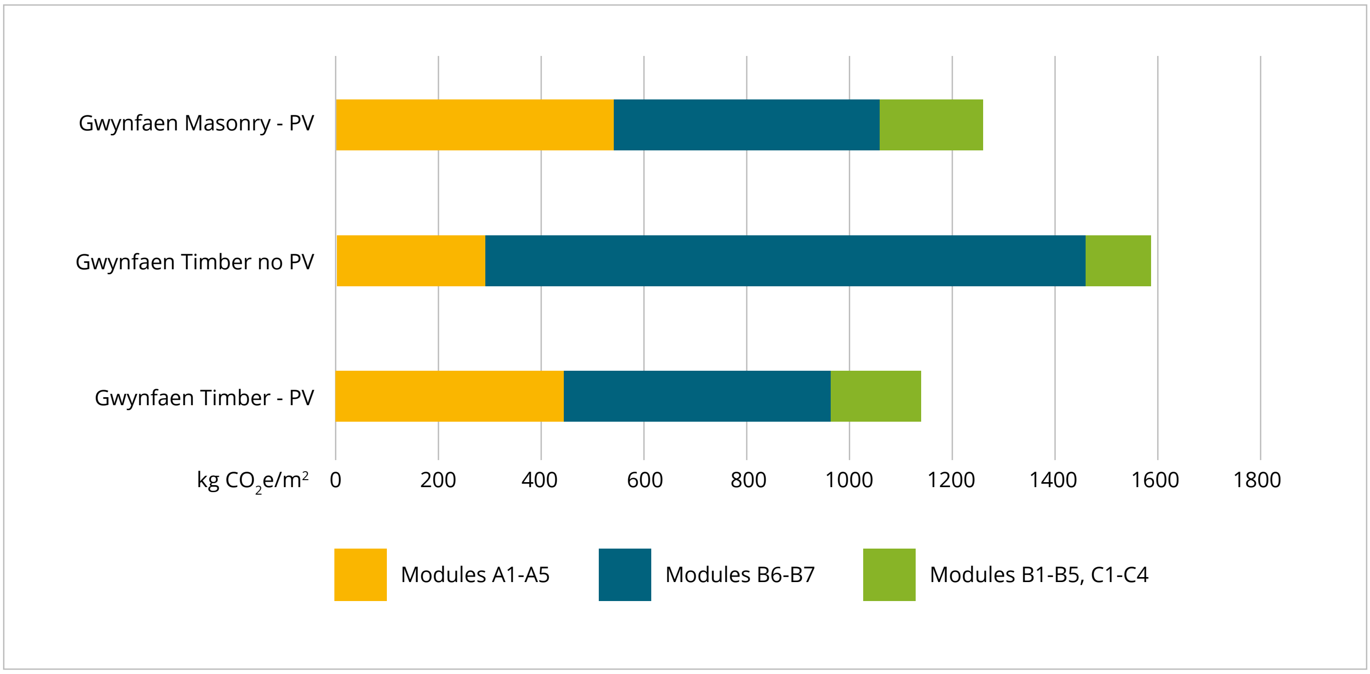

Figure 2
Breakdown of the impacts for 3 versions of Gwynfaen House type 24. Gwynfaen Timber has timber structure, cladding and insulation, Gwynfaen Masonry has masonry structure, PIR insulation and brick cladding. No PV uses heat pump. PV has 20 m2 PV and battery storage together with heat pump. The size of the "pie" reflects the Whole Life Carbon of the house. The yellow slice is upfront carbon, the yellow and green slices are together the Embodied Carbon, and the blue is the Operational Carbon. Data courtesy of Stride Treglown

The relative significance of Embodied Carbon is likely to increase as the UK grid is decarbonised and Operational Carbon emissions reduce. At the same time, if the number of additional homes per year matches the estimates of housing need we will see between 6,700 and 9,700 new homes built in Wales[2], which will increase Embodied Carbon emissions due to the material needs. This is despite any increase in construction efficiency.

Therefore, it could be argued that even greater action is required to reduce Embodied Carbon. Embodied Carbon emissions are "locked in" when the building is built – they can never be reduced, and their impact will be felt for the life of the building. Embodied Carbon savings made during the design and construction stage are delivered now, not in the years to come. This contrasts with operational emission savings which are delivered over time in the future.

The importance of acting on Embodied Carbon

- DEFRA data shows that a kg of CO_2 saved over the next 5 years has a greater environmental value than a kg saved in say 10 or more years' time[3].
- The Stern Review estimated that the cost of mitigating the harmful impacts of climate change would be 10 times the cost of acting now to reduce it[4].

[2] https://gov.wales/sites/default/files/statistics-and-research/2019-06/new-house-building-april-2018-to-march-2019-995.pdf
[3] UKGBC & Crown Estate (2015). Tackling Embodied Carbon in Buildings. London, UKGBC. www.ukgbc.org/sites/default/files/Tackling%20embodied%20carbon%20in%20buildings.pdf
[4] Stern, N. H. (2007). The economics of climate change: the Stern review. Cambridge, UK, Cambridge University Press. www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_index.cfm

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How is it measured?

Embodied Carbon is usually expressed in units of CO_2. This usually includes a number of greenhouse gases (GHGs) including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6). Each GHG has a different warming effect on the earth's atmosphere. In order to aggregate the total effect of all gases, each is converted into its equivalent CO_2 warming effect (global warming potential - GWP) and all CO_2-equivalents (CO_2e) are then added. The GWP of the GHGs assigned by the IPCC over a 100 year timeframe (Stocker *et al*., 2013) are summarised in Table 1.

Table 1: Global warming potentials (GWP) of key Greenhouse Gases over 100 years

Carbon dioxide (CO_2)	1 kg CO_2eq
Methane (CH_4)	36.75 kg CO_2eq
Nitrous oxide (N_2O)	298 kg CO_2eq
Hydrofluorocarbons (HFCs)	0-13900 kg CO_2eq
Perfluorocarbons (PFCs)	0-12300 kg CO_2eq
Sulphur hexafluoride	26100 kg CO_2eq

The boundaries of Embodied Carbon studies can vary. In terms of life cycle stages, some only consider the embodied emissions in the manufacturing supply chain (extraction, manufacturing, transport), i.e. "cradle-to-gate". Others include transport to site and installation as well, that is "upfront carbon". Some also include replacements over the life cycle of the building and the disposal of products, and even the demolition/deconstruction of the building , taking account of landfill or incineration (with or without energy recovery) and the benefits of recycling and reuse ("cradle to grave" studies).

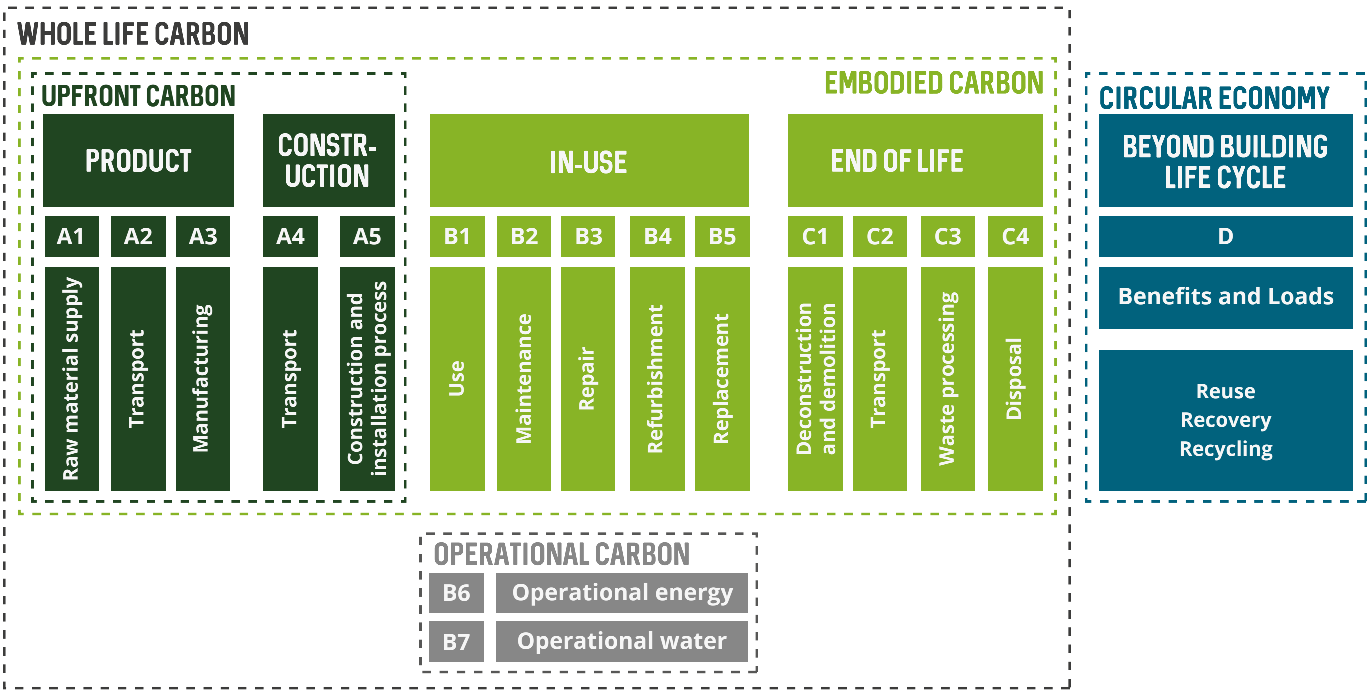

Figure 3
Diagram showing the different life cycle stages according to CEN/TC350 and how they relate to Embodied Carbon

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The modules, life cycle stages and boundaries applied are shown in Figure 3 which is aligned to CEN/TC350 Standards EN 15978 and EN 15804 (see **Role of standards – EPD, LCA and Embodied Carbon**). Throughout the document you will see references to the Modules used in this diagram to describe the different life cycle stages – for example Modules A1-A3 to cover the impacts of product manufacture, Module A4 to cover transport to the construction site, Module B6 to cover Operation, or Module C1-C4 to cover end of life.

The Royal Institute of Chartered Surveyors (RICS) has also published guidance on *Whole Life Carbon assessment for the built environment professional statement*[5] uses exactly the same modular approach, and advises that an assessment should consider all resources and emissions produced over the entire life of the building, from sourcing through construction and use to disposal (cradle to grave).

Embodied Carbon emissions are affected by many factors. These range from the type and volume of structure installed, the materials used and the associated carbon intensity of their manufacturing processes, to the modes and distances by which materials are transported and the processes by which these materials are constructed, maintained and finally removed and treated at the end of life.

LCA and Embodied Carbon – what's the difference?

The measurement of the environmental impact of a product at all stages of the life cycle is called Life Cycle Assessment (LCA). LCA can be used to measure the environmental impact of a construction product, component or building. Impact categories are recorded within an LCA, of which climate change is one. Therefore, when undertaking an LCA, Embodied Carbon will be calculated using the GWP from the emissions generated throughout a product, component or building lifecycle. Other impacts measured include acidification, eutrophication, toxicity, ozone depletion and resource depletion. Both LCAs and Embodied Carbon assessments should be carried out by following recognised standards (see **Tools and approaches to measure Embodied Carbon**).

LCAs can be undertaken at a building level, which will assess the potential environmental impact of a building over its complete life cycle, from the production of materials to the end-of-life and management of waste. There are a number of tools that can be used to undertake a building LCA which can be complex depending on the number and type of materials used, the building form and its intended use. LCAs can also be undertaken at product level, which should be based on common set of rules 'Product Category Rules (PCRs)'. These are in the form of Environmental Product Declarations (EPDs) which are a standardised set of environmental information for products. These are increasingly being produced for construction products by manufacturers in the UK, EU and elsewhere, with more than 7000 available globally. There is a suite of European Standards produced by CEN Technical Committee 350 (CEN/TC 350) standards that underpin LCAs for construction products and buildings.

Embodied v Operational Carbon, Whole Life Carbon and Net-Zero Carbon

The Whole Life Carbon of a building such as a house includes both the Embodied Carbon and the Operational Carbon over its lifetime. This can also sometimes be known as the Whole Life Carbon footprint. It is important to understand the relationship between Embodied Carbon and Operational Carbon, to determine the best way to reduce it across the lifecycle; that is why Whole Life Carbon is being increasingly measured. Whilst minimising Embodied Carbon is vitally important, it is important not to risk creating adverse or negative outcomes over the whole building life cycle. A low carbon house is one that optimises the use of resources to build it **and** to use it over its lifetime.

The term 'net zero' is now becomingly commonly used and generally means that the building is highly energy-efficient with the operational energy use provided by renewable energy (preferably on-site but also off-site production), to achieve net zero carbon emissions annually in operation. Some also use 'zero energy' or 'energy neutral' or even 'energy positive' where a building produces more energy from onsite renewables than it consumes. More recently, Embodied Carbon is beginning to be considered in the context of a 'net zero carbon' building. At present, this can cover upfront carbon (excluding biogenic carbon), Embodied Carbon, Operational Carbon or Whole Life Carbon. For example, the World Green Building Council defines a 'net zero Embodied Carbon building' (new or renovated) as highly resource efficient with upfront carbon minimised to the greatest extent possible and all remaining carbon reduced or, as a last resort, offset in order to achieve net zero across the life cycle. A full list of terms and their definitions is provided in the **Glossary** at the front of this Guidance.

[5] www.rics.org/globalassets/rics-website/media/upholding-professional-standards/sector-standards/building-surveying/whole-life-carbon-assessment-for-the-built-environment-1st-edition-rics.pdf

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DRIVERS AND BENEFITS OF LOW EMBODIED CARBON/ WHOLE LIFE CARBON

CHAPTER

02

DRIVERS AND BENEFITS OF LOW EMBODIED CARBON/WHOLE LIFE CARBON

CHAPTER 2 SUMMARY – DRIVERS AND BENEFITS

- **There are multiple benefits from addressing embodied carbon including reduction in capital and operation costs, mitigating risk and environmental impact**
- **Undertaking embodied carbon assessments will help an organisation to understand the carbon footprint of its projects, and of the organisation as a whole, which is particularly relevant to those that have declared a climate emergency**
- **Lower embodied carbon may also help in obtaining green finance such as green bonds**
- **There is a direct relationship between embodied carbon and circular economy**

Embodied Carbon and whole life costs

Targeting Embodied Carbon can help address the whole life costs of a building, especially when, for local authorities and housing associations for example, future running costs may be more of a concern than initial build costs. For instance, by investing in more durable materials, will mean fewer replacements over time and less Embodied Carbon. This also equates to a reduction in lower life cycle costs and less tenant disruption. Reducing Embodied Carbon through a fabric first approach, which maximises the performance of the building fabric and reduces the need for mechanical and electrical building systems, will reduce capital and operational costs and the need for maintenance.

The business case

There are many benefits in addressing Embodied Carbon. Capital and operational costs (repair, maintenance and refurbishment) can be reduced though the reduction of Embodied Carbon. From a cost perspective, reducing Embodied Carbon can be relatively low cost when compared to solutions for saving Operational Carbon. Significant savings from addressing Embodied Carbon can often be achieved over a shorter period of time compared to a longer period for Operational Carbon savings. It can also encourage efficiency, through the optimisation of materials, leaner design and less wastage, which will all reduce cost. Embodied Carbon can be, in fact, often be viewed as a proxy for cost management, providing an additional means of value engineering at early design stage.

DRIVERS AND BENEFITS

Cost savings from addressing Embodied Carbon

- Anglian Water's Covenham to Boston water transfer scheme achieved a £13 million cost saving (25%) by building less and building clever which equated to 2,000 tonnes (57%) reduction in capital carbon[6].
- Connect Plus, a joint venture between Skanska, Balfour Beatty, Atkins and Egis Projects, realised a 115,000 tonnes reduction in capital carbon and cut the outturn cost of the £1 billion project by 5% through building clever and building efficiently during the widening of a 63km length of the M25 motorway[7].
- WWF Living Planet Centre in Woking: a 'whole life' carbon assessment showed that, for this building, double glazing was more carbon efficient than triple. This was because the lifetime capital carbon costs outweighed the Operational Carbon savings over the anticipated life. This choice also significantly reduced initial capital expenditure, with only a small operational increase[8].
- Westgate shopping centre is a major shopping centre in Oxford that was extensively remodelled and extended between 2016–17. Embodied Carbon savings were 30,000 tonnes CO_2e that were cost neutral which included high levels of recycled content for certain products and local sourcing of concrete[9].

Note: Capital Carbon (CapCarb) is a term used within the infrastructure sector and refers to the emissions associated with the creation of an asset. Capital carbon is being adopted within the infrastructure sector because it accords with the concept of capital cost.

Addressing Embodied Carbon can also assist in identifying risks in the supply and use of materials and related resource price increases. Managing the Embodied Carbon of projects mitigates this risk by ensuring that building materials are used efficiently throughout the building life and that the manufacturing, transportation and construction processes are energy efficient and clean. It can also drive innovation in the manufacture and design of products and buildings.

Increasing material prices

- RICS predict that over the next five years, construction materials prices are expected to rise by between 3% and 4% per year[10].
- The average construction price has increased since 2015 for aggregates, cement and concrete, timber and joinery, metal and plastic products and insulation[11].
- The Federation of Master Builders (FMB) reported that costs of building materials have risen due to supply chain issues with brick prices up by an average of 9%, timber and roof tiles up by 8% and insulation increasing by 16%[12].

[6] HM Treasury (2013) Infrastructure Carbon Review. https://www.gov.uk/government/publications/infrastructure-carbon-review
[7] HM Treasury (2013) Infrastructure Carbon Review. https://www.gov.uk/government/publications/infrastructure-carbon-review
[8] www.ukgbc.org/sites/default/files/Tackling%20embodied%20carbon%20in%20buildings.pdf
[9] www.ukgbc.org/ukgbc-work/case-study-westgate-oxford/
[10] www.rics.org/uk/news-insight/latest-news/news-opinion/building-tender-prices-forecast/
[11] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/906248/20-cs8_-_Construction_Building_Materials_-_Bulletin_July_2020.pdf
[12] www.independent.co.uk/news/business/news/brick-shortage-supply-building-firms-raw-material-costs-a8312746.html

DRIVERS AND BENEFITS

Meeting our Paris obligations and 1.5 degrees

The UK has a legally binding commitment to achieve a zero-carbon emission target by 2050. This will enable the UK to deliver the Paris Agreement[13] by "reducing carbon emissions by at least 100% below 1990 levels (termed as Net Zero) by 2050". The Paris Agreement signed- in 2015, within the United Nations Framework Convention on Climate Change, aims to combat climate change and to accelerate and intensify the actions and investments needed for a sustainable low carbon future. It has the long-term goal of:

"Holding the increase in the global average temperature to well below 2°C above preindustrial levels and pursuing efforts to limit the temperature increase to 1.5°C above preindustrial levels, recognizing that this would significantly reduce the risks and impacts of climate change;"

(Article 2.1.a).

Buildings need to play a vital role in meeting these climate change obligations, with their construction and operation accounting for 36% of global final energy use and nearly 40% of energy-related CO_2 emissions in 2017. The global average building energy intensity per unit of floor area needs to be at least 30% lower than current levels. Whilst energy efficiency improvements are having a gradual impact, the final energy demand in buildings globally has increased by 5% since 2010, largely from a growth in floor area and population[14]. In the UK, it is predicted that final energy demand for the residential sector will increase by 19% between 2018 and 2040; this is due to a number of assumptions including the growth in the number of households, changes in household income and future weather[15] .

Buildings sector global contribution to CO_2[16]

- The buildings sector produced 9.5 gigatons (Gt) of CO_2 annually in 2015-17, 28% of the global energy-related CO_2 emissions.
- 70% of this is from indirect emissions (i.e. emissions from power generation for the consumption of electricity and commercial heat).
- Total buildings-related CO_2 emissions amounted to more than 11 $GtCO_2$ when material use is included.
- As such, CO_2 emissions resulting from material use in buildings account for 28% of the annual buildings related CO_2 emissions.
- Most of these emissions are a result of cement and steel manufacturing, which have high process emissions and are used in large quantities. Aluminium, glass, plastics and bricks are secondary contributors.

[13] https://unfccc.int/process-and-meetings/the-paris-agreement/what-is-the-paris-agreement
[14] IEA (2018) Global Status Report. www.iea.org/reports/2018-global-status-report
[15] BEIS (2019) Updated energy and emissions projections 2019. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment data/file/931323/updated-energy-and-emissions-projections-2019.pdf
[16] IEA (2018) Global Status Report. www.iea.org/reports/2018-global-status-report

DRIVERS AND BENEFITS

Figure 4 shows the CO_2 emissions from the built environment from a global, UK and Welsh perspective. Whilst the datasets are slightly different it shows that Embodied Carbon accounts for 6% of the overall CO_2 emissions in Wales, 7% in the UK and 11% globally.

Fuel use and electricity in the residential sector accounts for 23% of overall CO_2 emissions in Wales, 27% in the UK and 17% globally.

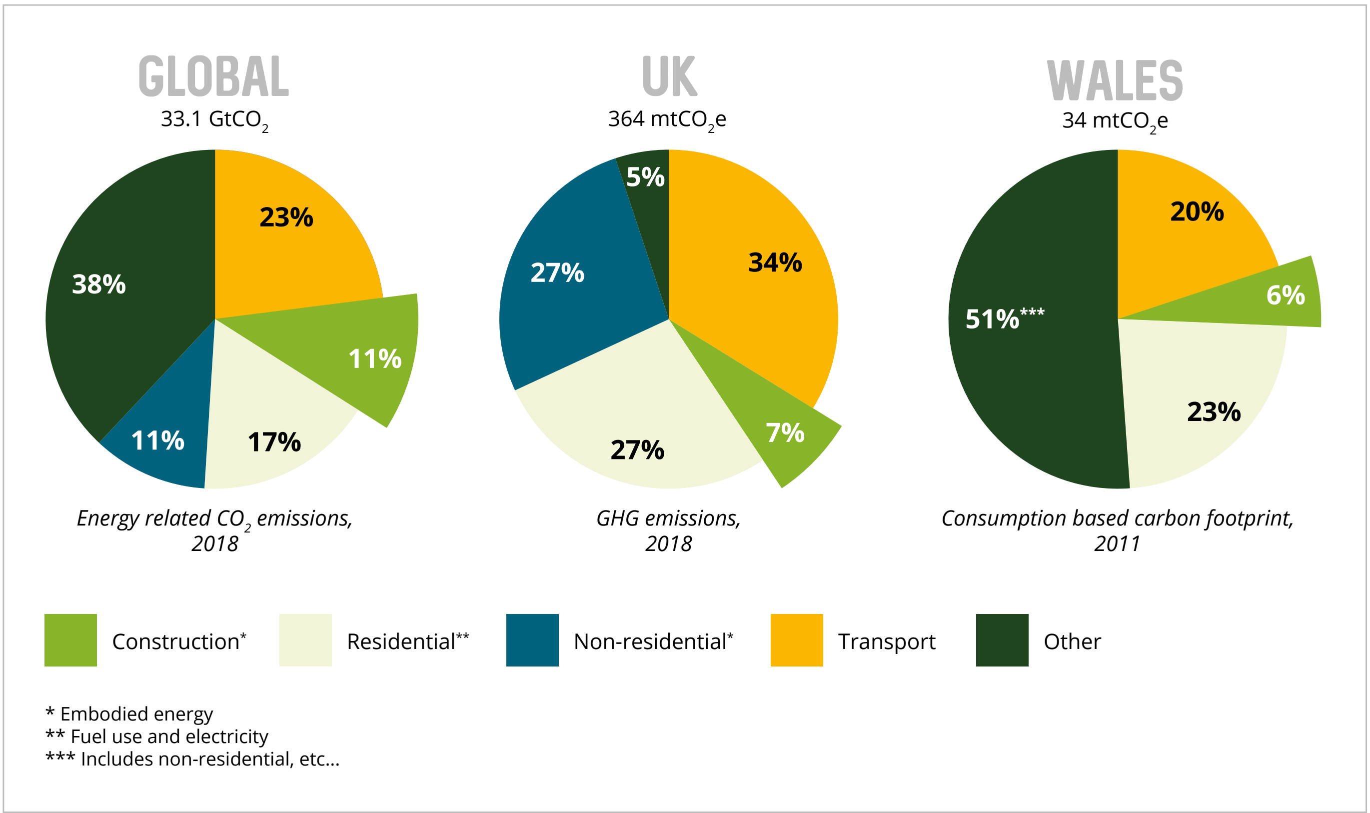

Figure 4
Built Environment Impacts globally, for the UK and for Wales[17]

The UK Green Building Council (UKGBC) established that the built environment contributed 42% of the UK's total carbon footprint (in 2014)[18]. This included:

- the direct emissions (operational energy) from buildings (17%) – 138MtCO_2e
- the embodied emissions from buildings through new construction (6%) – 48MtCO_2e
- electricity grid emissions (plug loads and cooking) (5%) – 44MtCO_2e
- the emissions generated from transport (14%) – 199MtCO_2e.

[17] Sources: Global: International Energy Agency (IEA), Global Alliance for Buildings and Construction and United Nations Environment Programme, 2019; UK: DUKES, 2018; National Statistics, 2019 Wales: Stockholm Environment Institute and GHD, 2015
[18] www.ukgbc.org/climate-change/

DRIVERS AND BENEFITS

Climate Emergency and Declarations

Organisations that have declared a climate emergency include 16 out of 22 Welsh local authorities[19] and the Welsh Government want all public bodies to be carbon neutral by 2030. Undertaking Embodied Carbon assessments will help to understand the overall carbon footprint of these organisations.

Other organisations are producing their own targets, route maps, and pathways aimed at reducing their carbon emissions, including Embodied Carbon. Examples in the construction sector include developers, designers, consultants and contractors, such as:

Developers

- Derwent London[20] has set a target to achieve net zero carbon by 2030 and a pathway for how they will do this by driving down energy demand across their portfolio, investing in renewable energy and offsetting the residual emissions. For Embodied Carbon, actions include setting reduction targets, carbon accounting and exploring the use of low Embodied Carbon materials and processes.
- British Land[21] has committed to a net zero carbon portfolio by 2030. This includes 50% less Embodied Carbon by 2030, equivalent to less than 500CO_2e/m² and 100% of developments to be net zero Embodied Carbon, delivered after April 2020. They are also financing retrofit by applying a £60/tonne levy on their developments.
- LandSec[22] are committed to become a net zero carbon company by 2030. This includes setting Embodied Carbon targets for all major developments and assessing them through a recognised methodology, to understand where to focus their efforts for maximum impact. They are simplifying their designs in order to buy less materials and reduce carbon.

Designers and Consultants

- Architects have come together to declare a climate and biodiversity emergency[23]. This includes commitments to raise awareness, advocate for change, share knowledge and research, include whole life costing and Whole Life Carbon to reduce embodied and operational resource use and accelerate the shift to low embodied carbon materials in all their work. As of October 2020, there are over 1000 signatories.
- RIBA has developed sustainability outcomes guidance[24] and RIBA 2030 Climate Challenge targets[25] with an aggressive timeline of delivery by 2030 for new and refurbished buildings, and an absolute backstop of 2050 for most existing buildings; this includes a target for Embodied Carbon (see **Benchmarking Embodied Carbon**).
- Grimshaw, an architecture practice, for all their operations their international operations and studios will operate on a net zero carbon basis, and all of its design work will be net zero carbon ready by 2030[26].
- Cundall, an engineering consultancy, has committed to be a carbon neutral business by 2020 and climate positive by 2025[27]. They are also developing solutions for climate positive buildings and infrastructure for their clients.
- Arup has committed to achieving net zero emissions across its entire operations by 2030, covering everything from the energy used in offices to goods and services purchased[28]. Arup has developed a Zero Carbon strategy and set up an Arup Carbon Fund, funded by a levy on flights.

[19] www.climateemergency.uk/blog/list-of-councils/ (16 councils as at 25 October 2020)
[20] www.derwentlondon.com/responsibility/environmental/net-zero
[21] www.britishland.com/sustainability/environment/net-zero
[22] https://landsec.com/sustainability/efficient-use-natural-resources/climate-change-carbon
[23] www.architectsdeclare.com/
[24] www.architecture.com/-/media/GatherContent/Test-resources-page/Additional-Documents/RIBASustainableOutcomesGuide2019pdf.pdf
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[26] https://grimshaw.global/assets/uploads/FINAL2_GrimshawEnvironmentalStrategyPR_191204_1.pdf
[27] https://cundall.com/Services/Net-zero-carbon.aspx
[28] www.arup.com/news-and-events/arup-commits-to-net-zero-across-global-operations-by-2030

DRIVERS AND BENEFITS

Contractors

- Mace[29] has committed to being net zero carbon in 2020. Within their strategy are commitments to measure and report Embodied Carbon in all their development and construction projects, reduce Embodied Carbon in their development projects by 50% and in their construction projects by 20% by 2030.
- Skanska[30] will become carbon neutral by 2045, which includes its supply chain, without using offsetting schemes. Actions include setting Whole Life Carbon reduction targets where they are responsible for design with reductions being required, offering low or zero carbon emissions to customers and key suppliers to provide costed low carbon alternatives for consideration.
- UK contractors have declared a climate and biodiversity emergency[31]. This includes committing to raising awareness of the issues, advocating for faster change, setting targets, sharing knowledge and research, supporting the upgrading of existing buildings, promoting the use of whole life cycle costing and Whole Life Carbon modelling including to reduce both embodied and operational resource use and to *'Accelerate the shift to low embodied carbon materials in all our work and promote meaningful actions that will lead to reducing embodied carbon by at least 40% by 2030'.* As of October 2020, there are 36 signatories.

The World Building Green Council has developed the Net Zero Carbon Buildings Commitment which challenges business, organisations, cities, states and regions to reach net zero carbon in operation for all assets under their direct control by 2030, and to advocate for all buildings to be net zero carbon in operation by 2050[32]. As of October 2020, 76 business and organisations have signed up, 28 cities and 6 states and regions.

Green finance

Green investment is increasing with companies looking to actively divest from fossil fuel activities. As such some of the investor rating and measurement schemes are including embodied carbon, for example:

- The Dow Jones Sustainability Index[34] includes a section about the life cycle assessment of building materials
- The FTSE4Good Index[35] asks questions on lifecycle studies and related carbon emissions reductions
- The GRESB (assesses and benchmarks the Environmental, Social and Governance (ESG) performance of real assets) survey[36] has a number of questions on new construction and major renovations.
- The CDP[37], which runs a global environmental disclosure system includes voluntary reporting of Scope 3 emissions[38]

[29] www.macegroup.com/about-us/a-responsible-business/sustainability
[30] www.skanska.co.uk/about-skanska/sustainability/green/carbon/carbon-reduction-targets2/
[31] http://contractorsdeclare.co.uk/
[32] www.worldgbc.org/thecommitment
[33] As of Autumn 2020; source: https://climateemergencydeclaration.org/ and https://www.climateemergency.uk/blog/list-of-councils/
[34] www.spglobal.com/esg/csa/indices/
[35] www.ftserussell.com/products/indices/ftse4good
[36] https://gresb.com/
[37] www.cdp.net/en
[38] Scope 3 emissions are results of activities from assets not owned or controlled by the reporting organization

DRIVERS AND BENEFITS

Green bonds are an increasingly attractive funding route. The London-based housing association, Clarion Housing, has attracted bonds worth £350M which their commitment to environmental, social and governance issues (ESG) played an important part in obtaining them. In November 2019, this commitment was recognised when Clarion became the first housing association in the UK to be accredited with the pan-European Certified Sustainable Housing Label[39].

Optivo is the first housing association in the UK to publish an 'ESG Report for Investor'[40]. Optivo, Peabody and Clarion have published a white paper that identified 10 themes and 45 metrics which can help housing associations and private finance align to achieve social value. This includes items such as housing associations environmental strategy, responsible sourcing and waste management for building materials[41] .

The Energy Efficiency Mortgage Action Plan (EeMAP) initiative is exploring the link between energy efficiency and borrower's reduced probability of default and the increase in value of energy efficient properties. For banks and investors, this could lead to loans that represent a lower risk on the balance sheet and could therefore qualify for a better capital treatment. In June 2018, 37 major European banks launched a new energy efficiency mortgage pilot scheme. The banks and financial institutions involved in the scheme represent a combined lending power of over €3 trillion, equal to around 20% of the EU's GDP[42].

Carbon Pricing

There is growing interest in carbon pricing, which puts a price on carbon and makes those that produce it pay a price. Therefore, there is a financial incentive for companies to reduce their carbon emissions. It can be in the form of a carbon tax or an emission trading system (ETS), which caps the total level of greenhouse gas emissions and allows those industries with low emissions to sell their extra allowances to larger emitters. The EU ETS is the world's first major carbon market and remains the biggest one targeting industry sectors such as iron and steel, cement and lime, paper, glass, ceramics and chemicals. Whilst carbon pricing has not been used in construction, studies have indicated the potential for influencing construction design, where emissions are locked in for the duration of an asset's life[43].

[39] www.clarionhg.com/news-research/2019/november/clarion-to-adopt-sustainable-housing-label/
[40] www.insidehousing.co.uk/news/news/g15-landlord-publishes-esg-report-for-investors-67395
[41] https://thegoodeconomy.co.uk/resources/reports/UK-Social-Housing-Building-a-Sector-Standard-Approach-to-ESG-Reporting-May-2020.pdf
[42] www.worldgbc.org/green-mortgages
[43] For example, www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/climate+business/resources/greening-construction

DRIVERS AND BENEFITS

Embodied Carbon and the circular economy

The circular economy is defined by the Ellen MacArthur Foundation[44] as an economy "*based on the principles of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems*". Reducing Embodied Carbon emissions is directly related to circular economy and resource efficiency in several ways. These include:

- Being more efficient in the way we use our resources. The construction industry uses more than 50% of all resources extracted in the EU each year[45]. A reduction in the amount of materials used, for example through better design and material optimisation, will lead to a reduction in Embodied Carbon.
- Evaluating the long-term impact and use of a building or space, designing for flexibility and adaptability will minimise the environmental and material impact throughout the life of the structure.
- Repurposing of buildings will extend the lifetime of the building and the components within; this is particularly important for the structure which should be designed to be long-lasting.
- Designing for deconstruction at end of life will increase the longevity of the products and materials through higher levels of reuse, negating the need for primary materials.
- By designing more for less, through for example material optimisation and light weighting, less materials are used which results in a direct cost saving. A study by the University of Cambridge found that steel framed buildings could be produced with around 30% less steel than at present by optimization[46]. The use of reclaimed and recycled materials reduces the need for primary materials and the associated carbon emissions involved in their extraction and processing.
- The increased durability of products leads to a longer life with less replacement and therefore less materials being used.
- The reduction of waste during construction, for example through the better management of materials, less ordering and the use of offsite manufacturing will save materials and reduce waste arisings and the associated impacts of its disposal. Some structures such as CLT can be prefabricated and cut to size before being delivered to site, generating less waste.
- Not using waste management routes such as energy recovery and landfill will also reduce carbon emissions.
- Designing and using buildings more efficiently through multi-functionality, and higher utilisation, such as using empty office space at night-time for community activities can also lead to less demand for resources.

From an organisation's point of view, assessing Embodied Carbon can contribute to other sustainability objectives and targets such as the use of recycled content, recyclability of building materials and zero waste targets.

There are a number of case studies that illustrate the reuse of wood, which range from salvage items such as wooden flooring, structural joists and beams and offcuts from timber from construction[47].

Visual strength grading can be undertaken on structural joists and beams to establish grade, disease, infestation and straightness. Historic and listed buildings will often use reclaimed timber in their renovation.

Bron Afon Housing Association in Torfaen generates waste wood. For example, furniture, fencing and garden sheds from house clearances, kitchen cabinets from kitchen refurbishments, timber offcuts, surplus timber, plywood shuttering, site hoardings, pallets and cable reels from its construction sites. They send this waste wood to Reseiclo Community Wood Recycling in Newport which recovers it selling reclaimed wood to the construction trade and the general public. Through Reseiclo Training, adults with learning disabilities learn basic woodworking skills whilst producing furniture and other products like chopping boards from the waste.

[44] www.ellenmacarthurfoundation.org/
[45] European Commission. Roadmap to a Resource Efficient Europe. Brussels; 2011. http://ec.europa.eu/environment/waste/construction_demolition.htm
[46] Carruth, M.A., Allwood, J.M. and Moynihan, M.C., 2011. The technical potential for reducing metal requirements through lightweight product design. *Resources, Conservation and Recycling, 57, pp.48-60*.
[47] For example: www.trada.co.uk/case-studies/command-of-the-oceans-the-historic-dockyard-chatham-kent/ and www.ellenmacarthurfoundation.org/assets/downloads/Built-Env-Co.Project.pdf and www.wrap.org.uk/sites/files/wrap/Reclaimed%20building%20products%20guide.pdf

DRIVERS AND BENEFITS

Clarion Housing Group is aiming to have circular principles written into every procurement contract for the Merton Regeneration Project, which is providing 3000 new homes along with 9,000 $m^2$of retail, leisure, office, work and community space. This includes looking at the materials that are used and if they can be re-used at end of life, and the take back of kitchen and bathrooms.

There are a number of studies that show the Embodied Carbon benefits of applying circular economy principles including:

- A circular scenario for the built environment could reduce global CO_2 emissions from building materials by 38% or 2.0 billion tonnes CO_2 in 2050, due to a reduced demand for steel, aluminium, cement, and plastic[49]. This is based on having durable, mixed use buildings designed in a modular way and constructed with reused and non-toxic materials. They would be highly utilised, thanks to shared and flexible office spaces and flexible, smart, and modular homes.
- According to a study by Deloitte, the circular economy has the potential to take us at least 60% of the way to mitigating emissions related to the production of material goods through product reuse and recycling[50] .
- Resource efficiency in the construction sector offers the greatest opportunity (more than vehicles, food and drink, textiles and electronics and appliances combined) to cut carbon emissions, with potential to reduce them by 79. 14 $MtCO_2e$ between 2023 and 2032 as shown in Figure 5. This includes optimal design practices, light-weighting, use of lower carbon materials and an increase in reuse[51].

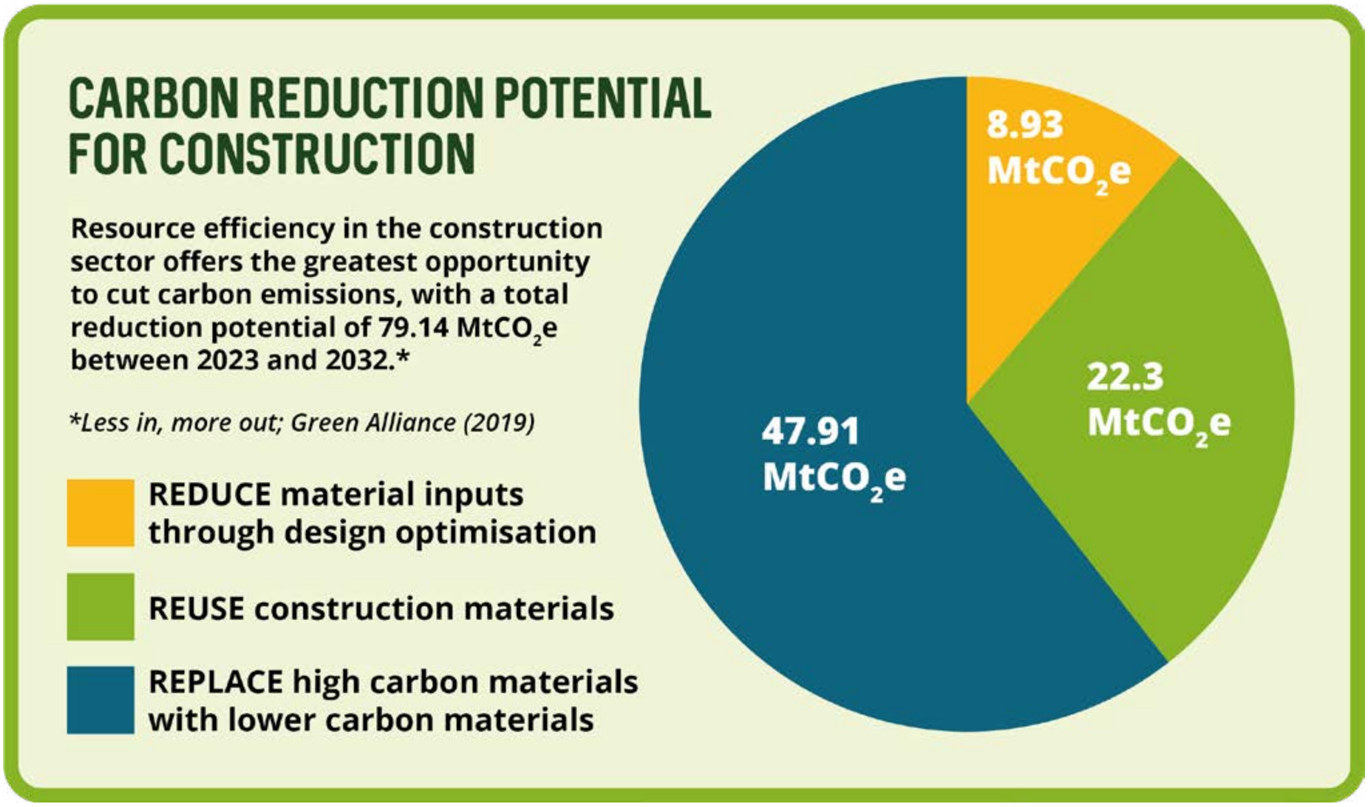

Figure 5
Opportunities from increasing resource efficiency in construction

[49] www.ellenmacarthurfoundation.org/assets/downloads/Completing_The_Picture_How_The_Circular_Economy-_Tackles_Climate_Change_V3_26_September.pdf
[50] www.deloitte.com/content/dam/Deloitte/fi/Documents/risk/Deloitte%20-%20Circular%20economy%20and%20Global%20Warming.pdf
[51] www.green-alliance.org.uk/resources/Less_in_more_out.pdf

DRIVERS AND BENEFITS

Between December 2019 and April 2020, the Welsh Government consulted on a new circular economy strategy, Beyond Recycling[52]. This includes moving towards zero waste by 2050, encouraging the reuse, repair and remanufacture of products and materials and maximising the economic and social opportunities of a more circular economy. Consultation responses highlighted the need for the focus on the construction sector as it is a primary producer of waste and has a large carbon footprint associated with the production of new materials.

Benefits of assessing Embodied Carbon

The main benefits of undertaking an Embodied Carbon assessment are:

- It allows organisations to understand the environmental impact of their decisions and guide them to reduce Embodied Carbon in the design and construction of new buildings
- It will help to identify elements that are carbon-intensive and promote alternative options
- It can be used to compare the environmental impacts of different building materials, designs and construction processes.
- It assists in providing environmental information for making decisions for various scenarios, for example:
    - Comparing refurbishment and demolition of buildings
    - Comparing Operational Carbon and Embodied Carbon
    - Comparing options for reusing, reprocessing and recycling waste materials
    - Comparing different sources and supply chains for materials
    - Quantifying the carbon impacts of procurement choices and construction methods (e.g. off-site vs on-site)
- It provides a greater understanding of in-use considerations such as maintenance, durability, adaptability
- It can assist in obtaining credits in schemes such as BRE's Home Quality Mark (HQM) standard
- It helps to understand the overall carbon footprint of an organisation
- It provides evidence of addressing impacts for organisations that have declared a climate emergency.

[52] https://gov.wales/circular-economy-strategy

DRIVERS AND BENEFITS

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UK Government Green Finance www.gov.uk/guidance/green-finance

World Green Building Council. The Net Zero Building Commitment www.worldgbc.org/thecommitment

WRAP Reclaimed Building Product Guide www.wrap.org.uk/sites/files/wrap/Reclaimed%20building%20products%20guide.pdf

CHAPTER

03

WHY ME - YOUR ROLE & WHAT YOU CAN DO

WHY ME - YOUR ROLE & WHAT YOU CAN DO

CHAPTER 3 SUMMARY – WHY ME?

- Everyone has a responsibility and role to play in reducing embodied carbon
- There needs to be united commitment across the housing association/local authority to addressing embodied carbon
- When considering the management of assets and the role of the asset manager, less embodied carbon will be produced from refurbishment than demolishing and building new
- Heads of Service/CEOs and politician/elected members should lead and facilitate the reduction of embodied carbon in buildings

A co-operative/integrative and united effort is required in assessing, identifying and implementing strategies for reducing Embodied Carbon and should involve the whole of the project team, with associated drivers and benefits defined for each role. Architects, structural engineers and quantity surveyors all need to be involved in initial discussions about Embodied Carbon. As with other value-based decisions, the ultimate decision to choose one design over the other usually rests with the client. However, the architect and contractor (especially in a design and build procurement) are instrumental in designing, specifying and procuring lower Embodied Carbon products.

Politicians/Elected Members

In local authorities, it is important that elected members have enough knowledge in order to communicate and lead local responses to the climate emergency, and within that the role Embodied Carbon must play. This will also be important when setting the overall strategic direction and providing strategic oversight for carbon, including articulating and achieving priorities and targets. Therefore, elected members should contribute to the development of polices and strategies including those for Embodied Carbon and how that interacts with the provision of housing or other buildings.

Heads of Service/CEO/Housing Association Board members/Directors

There is an important leadership role within an organisation, to drive through the need to reduce carbon within the organisation and have an understanding on the importance of Embodied Carbon within an organisation's carbon footprint and the related benefits. It is also important for local authorities and other public bodies to respond to their climate emergency declarations (see **Climate Emergency and Declarations**). A key part of addressing carbon is ensuring that the underlying processes are in place which include the need for data and evidence, greater collaboration across supply chains and encouraging innovation. Clear leadership will also enhance an organisation's reputation and provide assurance and credibility to stakeholders internally and externally, together with the wider public, that the organisation is committed to reducing its carbon.

Development managers

Measuring, managing and reducing Embodied Carbon should be part of the decision-making process for different development opportunities, both new build and refurbishment. Assessing the costs and benefits of addressing Whole Life Carbon throughout the lifecycle of a new build development can identify where carbon and cost savings can be made (both often going hand in hand). It can also identify related efficiencies. There are many factors that need to be considered when developing schemes, such as the price, maintenance, longevity and quality of products, as well as sustainability aspects including Embodied Carbon. As such, it is important to establish how designing and procuring lower Embodied Carbon infrastructure fits into these existing decision-making processes and the value-added aspects that it may bring.

Managing Embodied Carbon may also assist in obtaining funding. For example, through the Welsh Government Innovative Housing Fund and the increasing use of green finance such as green bonds (see **Green finance**). It may also help with planning consent, for example, the draft London Plan introduces a requirement for all new referable development to calculate and reduce whole life-cycle carbon - both operational and embodied emissions[53].

[53] Referable schemes are those which due to their size or use of greenbelt land for example, the Mayor needs to check meet the requirements of the London Plan. www.london.gov.uk/decisions/add2363-london-plan-whole-life-cycle-carbon-assessments

WHY ME - YOUR ROLE & WHAT YOU CAN DO

Asset managers

Assessing Embodied Carbon can help asset managers in demonstrating improvements over the lifetime of an asset and the effectiveness of solutions for Whole Life Carbon, such as specifying lower Embodied Carbon products which require less maintenance. Savings in Embodied Carbon are not subject to ongoing building user behaviour in the way that Operational Carbon savings are. As a result, Embodied Carbon reductions can be more accurate and identifiable than predicted Operational Carbon reductions. When undertaking an Embodied Carbon assessment, scenarios should be developed for the maintenance, repair, replacement, refurbishment and operation of the building. This should include the lifecycle and the related costs of the building. This ensures that Embodied Carbon is considered within future running costs, which are of potentially more concern that the initial building costs.

In terms of managing existing assets, refurbishment of buildings can improve energy efficiency by adding insulation or replacing old systems with more energy-efficient systems, such as more efficient boilers. This will reduce the operational energy and associated costs for residents or occupiers, but there will also be more Embodied Carbon as more materials are added to the building and the older systems are disposed of. However, by undertaking refurbishments, the lifespan of the building is likely to be extended and therefore Embodied Carbon is avoided by delaying the replacement of an old building with a new one.

A decision that may have to be taken, is whether to refurbish or demolish. There is a debate of the costs of refurbishment verses demolition and new build, although studies tend to show that it is usually lower to do the former. For example, it is potentially cheaper to adapt than to demolish and rebuild, in as much as the structural components already exist and the cost of borrowing is reduced, as contract periods are typically shorter. When a building is demolished, energy is used to deconstruct it, and remove, process and dispose of the waste. However, reusing or recycling the materials from demolition can reduce Embodied Carbon. Building a new replacement requires more materials and energy, creating more Embodied Carbon.

Several case studies have estimated Embodied Carbon from demolition

- The demolition of the London Borough of Lambeth's Central Hill Estate of 450 houses is estimated at 7000 tonnes of CO_2e; which equates to the annual domestic emissions of over 4,000 Lambeth residents, or heating 600 detached homes for a year using electric heating[54]
- For the 15 semi-detached homes in Borough Grove estate in Hampshire, managed by Drum Housing Association, the new build cost was a third more expensive than retrofit; the new build life time CO_2e emissions were 6% more than retrofit and the life time CO_2e emissions savings were 9% higher for retrofit[55]
- A study of a Victorian terrace refurbishment showed that the construction-related Embodied Carbon emissions were estimated to be 1.2 tonnes of CO_2e (2% of the building's total emissions over 60 years). The construction of a new home of the same size produces up to 13 times more Embodied Carbon than refurbishment. Demolition emissions alone accounted for 4% of the total carbon emissions from the new build over the 60-year reference study period[56].

Gaspar and Santos (2015) assessed the potential saving for a detached house in Portugal built in the late 1960s, concluding that refurbishment would be 22% more efficient than demolition and rebuild[57]. A strong case for refurbishment can be also found in the work of Power (2008), who demonstrated that the case for large scale demolitions "is greatly weakened" when considering Embodied Carbon as well as operational figures, for the Embodied Carbon of an average refurbishment project to bring an existing house up to modern standards is around one third of that of a new house[58].

[54] https://architectsforsocialhousing.co.uk/2017/02/02/embodied-carbon-estimation-for-central-hill-estate-report-by-model-environments/
[55] www.engineering.ucl.ac.uk/engineering-exchange/files/2014/10/Fact-Sheet-Embodied-Carbon-Social-Housing.pdf
[56] https://historicengland.org.uk/content/heritage-counts/pub/2019/hc2019-re-use-recycle-to-reduce-carbon/
[57] Gaspar, P.L. and Santos, A.L., 2015. Embodied energy on refurbishment vs. demolition: A southern Europe case study. Energy and Buildings, 87, pp.386-394.
[58] Power, A., 2008. Does demolition or refurbishment of old and inefficient homes help to increase our environmental, social and economic viability? Energy policy, 36(12), pp.4487-4501.

WHY ME - YOUR ROLE & WHAT YOU CAN DO

Architects

Architects have a vital role in both assessing and reducing Embodied Carbon. For housing projects, they are ideally positioned to undertake an Embodied Carbon/Whole Life Carbon assessment at different stages of the design process based on various scenarios, and can make design decisions that will directly affect the amount of Embodied Carbon. They are also likely to inform the client of Embodied Carbon requirements within the tender process for the building contractor and related specifications. Many architects are now declaring a climate and biodiversity emergency and have committed to reduce Embodied Carbon and undertake Whole Life Carbon assessments (see **Climate Emergency and Declarations**). Architects need to consult with engineers in the early design stages, where decisions such as the choice of the foundation, floor slab and structure will all have a significant impact on the amount of Embodied Carbon (see Approaches to reducing Embodied Carbon).

Consultants

Structural engineers and building services engineers are responsible for numerous elements of the building design – the sub- and super-structure, and the mechanical, electrical and plumbing installations (MEP or building services), which can have significant Embodied Carbon impacts. It is important to ensure that these embodied impacts are considered, either by the engineers themselves or in conjunction with the architect, whilst providing a building that meets the client's requirements. As demand for zero carbon homes and buildings grows, and as technologies evolve, such as ground source heat pumps, there is likely to be an increased need to involve building services engineers early in the design process and to undertake building performance modelling such as dynamic thermal flows. The MEP should take into account the Embodied Carbon aspects of specified systems in relation to the Whole Life Carbon performance (see **Balancing Upfront, Embodied and Operational Carbon**).

Other roles including QS

Quantity surveyors normally undertake cost plans and whole life costing exercises. Some may also undertake Whole Life Carbon assessments with RICS (the professional body) who have developed a professional statement that specifies mandatory requirements and provides guidance on assessing the carbon emissions arising from built projects throughout their lifecycle[59] (see **Role of standards – EPD, LCA and Embodied Carbon**). Any potential costs associated with Embodied Carbon assessment and projected savings from carbon reduction measures should be identified within the project cost plan and associated budgets. The identification of these costs and savings should be undertaken in conjunction with the architect during their design process. Moreover, potential scenarios for financial costs and savings should be modelled through whole life costing models addressing the construction and operational costs from both an Embodied and Operational Carbon perspective. This will feed into the development manager's decision making process.

Manufacturers and suppliers

Low carbon products need to be made available within the construction marketplace. This may require innovation in the materials that are used, the manufacturing process, their durability and transportation. Anticipated benefits for manufacturers addressing Embodied Carbon include cost savings and the development of products for a growing market as well as meeting their own carbon obligations. Manufacturers and suppliers need be able to communicate their low carbon products to designers who specify them and the contractors who will procure them. It is important that information on the embodied emissions of construction products is readily available and understandable, preferably in the form of EPDs[60], and comparable, wherever possible.

[59] www.rics.org/globalassets/rics-website/media/news/whole-life-carbon-assessment-for-the--built-environment-november-2017.pdf
[60] See the ASBP's briefing papers on EPD at https://asbp.org.uk/all-resources?tx_category=briefing-paper

WHY ME - YOUR ROLE & WHAT YOU CAN DO

Contractors

Contractors play an important role in specifying and procuring low Embodied Carbon products, with the type of transportation and distances involved impacting Embodied Carbon considerably. It is vital that lower carbon products that are specified by an architect or client are not 'value-engineered' out, due to financial decisions. Financial savings can be made elsewhere with the help of Embodied Carbon measurement. During the construction phase, Embodied Carbon will be generated through the construction waste that is being generated on site. The same is true for any demolition waste. Measuring Embodied Carbon can assist contractors in reducing waste and ensuring higher levels of recovery, which should result in financial savings. The contractor also has a major influence on the management of the site, in terms of the type of fuel and power used and the energy efficiency of temporary offices and other facilities. A reduction in energy/fuel use can lead directly to financial savings.

According to Imperial College London[61], inefficient generator use is common across construction sites in the UK. Traditionally the same generator that supplies high daytime loads is also left running to supply lower overnight loads. Generators run less efficiently at very low loads which burns litres of fuel unnecessarily. Hybrid power generators (HPG) has an on-board intelligent management system which automatically manages the supply of power during lower loads; they have onboard battery capacity and can switch off the main diesel generator when higher loads are not required. Use of HPG's can reduce fuel consumption by up to 50%, reduce diesel carbon emissions by up to 50% and also reduce maintenance costs due to the reduced running time. Additionally, HPGs are capable of using a range of renewable technologies such as solar, wind, battery and biodiesel.

In 2018 PYC contractors built a 220m² timber frame office in Welshpool to the Passive House Standard, using their own timber system, costing £350,000[62]. This incorporated elements such as triple glazed timber windows and doors, recycled newspaper insulation, woodfibre board and Welsh Douglas fir horizontal cladding. An Embodied Carbon assessment showed that the building had an impact of approximately 52 tonnes of CO_2e, and stored – around 30 tonnes of sequestered CO_2 over the life of the building.

Clerk of Works

By utilising a Clerk of Works, whose responsibility is likely to include the inspection and quality control of the contractor's work and materials, implementation of client requirements and industry standards (including those related to environmental concerns) can be monitored. This can include any commitments to Embodied Carbon targets and checking what products have been installed against what was specified. They may potentially identify issues early, allowing for solutions to be actioned without delaying the overall construction programme.

Warranty providers and Insurers

Any innovative process or product will require warranty providers and insurers such as NHBC which are willing to accept it. This means that the project team, especially the contractor, needs to work closely with these bodies, providing robust information on the products and systems that are being used. This could include technical and environmental performance information, including EPDs.

[61] https://clec.uk/advice/smart-generators
[62] https://passivehouseplus.ie/magazine/new-build/office-romance-passive-house-supplier-walks-the-walk-with-new-office-factory

WHY ME - YOUR ROLE & WHAT YOU CAN DO

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CHAPTER 04

PROCURING LOW EMBODIED CARBON

PROCURING LOW EMBODIED CARBON

CHAPTER 4 SUMMARY – PROCUREMENT

- **At an organisational level, a carbon policy should be set, encompassing Embodied and Operational Carbon from housing activities**
- **Requirements for Embodied Carbon should be included in the project brief, ensuring that the documentation is in line with the organisation's carbon policy and the development's ambitions.**
- **Define the performance outcomes that are required to meet the policy and target which can be used in the procurement documentation**
- **Ensure that someone is responsible for monitoring/measuring of Embodied Carbon at every stage of a building's lifecycle.**
- **Ensure that a robust and systematic approach is taken to assess the Embodied Carbon of different design options throughout the building's lifecycle.**

Procurement presents an important opportunity for measuring, reducing and managing Embodied Carbon. There is various guidance available on construction procurement and sustainability, including references to Embodied Carbon. (See **References and Further Information**). This section focusses on the procurement process for social housing and signposts to other guidance where relevant.

Policy for Low Embodied Carbon

At an organisational level, a carbon policy should be set, encompassing Embodied and Operational Carbon from housing activities. Other organisational activities should also be included. It should be clear how this policy links with other requirements and its relationship with strategic objectives. This may be in reference to declared climate emergencies and overall organisational goals for the reduction in carbon. There is standard wording from WRAP[63] that can be incorporated into a policy and amended as appropriate. This also includes Operational Carbon as follows:

"As part of our commitment to having a low environmental impact in [our business/ buildings/ operations], we aim to reduce our Operational and Embodied Carbon emissions. We will:

- *set a target for improving the carbon efficiency and reducing energy consumption of our new and existing buildings;*
- *embed the target within corporate policy and processes;*
- *set corresponding requirements in project procurement and engage with our supply chain;*
- *measure performance at a building level; and report annually on overall carbon emissions and savings made*

Objectives

To increase the carbon efficiency of [our new buildings; buildings we occupy; buildings we manage and maintain] we will: [delete as appropriate]

- *require a Whole Life Carbon assessment for each building/ project (or equivalent); for construction or refurbishment projects:*
- *define and achieve project-specific targets for as-designed / in-use] Operational Carbon efficiency [and savings in embodied carbon, taking into account corporate and regulatory requirements, potential outcomes and cost-effectiveness.*

[63] www.wrap.org.uk/sites/files/wrap/Procurement%20Requirements%20for%20carbon%20efficiency%20FINAL.pdf

PROCUREMENT

Developing an Embodied Carbon Brief

Requirements for Embodied Carbon should be included in the project brief, ensuring that the documentation is in line with the overall policy and the development's ambitions. This could be to a commitment of measurement and assessment; to reach a specific target in kg CO_2e/m^2 (See **Woodknowledge Wales Targets for Upfront Carbon and Embodied Carbon**) and/or a specified reduction of Embodied Carbon. Architects and consultants can have an important role in helping to set the Embodied Carbon ambitions of a development by providing independent and expert advice, particularly when the client has little experience in this area. Dialogue can also be undertaken with the supply chain to understand what low Embodied Carbon products and processes are available.

Figure 6
Processes to be considered when developing an Embodied Carbon Brief from UKGBC guidance (same ref as [64])

UKGBC[64] has produced detailed guidance on incorporating Embodied Carbon in a project brief; Figure 6 shows some of the key considerations, including:

- Who should be involved – it is recommended that there is someone responsible for ensuring an Embodied Carbon assessment is undertaken (from the client team) and that members of the project team are aware of their roles and responsibilities.
- When it should be undertaken – a decision needs to be made on when measurement should start, how many times and when in the RIBA stages. Clients can outline their intent to measure and reduce Embodied Carbon before conceptual design begins. An early assessment can be used to compare design options during the conceptual design stage (RIBA Stage 2), and it is valuable to repeat the assessment through to technical design RIBA Stage 4) in order to compare the detailed design options, and finally to assess the as-built product.
- Where in the process – this is to align the Embodied Carbon assessment and potential for reduction with key decision points, ensuring that reductions are locked in as design progresses. Clients can review where these decision points are in advance, ensure that any decisions are taken according to the Embodied Carbon brief, and capture data as required.
- How it should be incorporated – consider how the Embodied Carbon requirements are to be communicated to the project team and associated reduction strategies resulting from the assessments.

  The requirements can be embedded in a wide range of documents such as:
  - o scope of service
  - o Employer's Requirements
  - o specifications
  - o requests for proposal/tender documents
  - o construction contracts.
- Why include Embodied Carbon – place Embodied Carbon within the overall sustainability drivers of the organisation, providing the full context and linking to relevant policies.
- What – understand what the Embodied Carbon brief should contain and what decisions are needed for each aspect.

Within this guidance, is an example of a project brief for undertaking an Embodied Carbon assessment, which can be used and adjusted accordingly. Sections in the example brief include:

- o Context and company objectives
- o Boundary of the study
- o Scope of the assessment
- o Assessment standards and calculation methodology
- o Data and tools
- o Starting points, iterations and frequency
- o Presentation of the results

[64] www.ukgbc.org/wp-content/uploads/2017/09/UK-GBC-EC-Developing-Client-Brief.pdf

PROCUREMENT

In some circumstances, clients will instruct a third-party consultant to undertake an Embodied Carbon assessment. In design and build contracts this responsibility can sometimes be passed directly to the contractor, who in turn may employ a consultant to undertake the Embodied Carbon assessment.

Previous experience in Welsh housing projects has shown that it is important to have a sustainability target in relation to the development, which can include Embodied Carbon. This provides a level of consistency if the project team changes.

The Gywnfaen project, which involves the construction of 133 houses has prioritised the sourcing materials and products from Welsh/UK supply chains. Moreover, timber for all loadbearing wall framework, internal stud partitions and roof members is to be sourced locally, in Wales, a maximum 100 miles travel distance from the site location. There is a requirement to undertake an embodied carbon assessment to practical completion. The specification used in the Gwynfaen Development for carbon reporting and LCA requirements is provided below.

The client will appoint a life cycle assessment (LCA) practitioner to undertake an 'Embodied carbon to practical completion' carbon Assessment of the project using 'RICS professional standards and guidance, for UK 'Whole Life Carbon assessment for the built environment' 1st edition, November, 2017'. Specific information and/or site monitoring data should be provided by the project contractor and primary subcontractors as these become available. The requirements are detailed below.

Reporting of emissions [A1–A3] Product stage

The product stage deals with the carbon emissions attributable to the cradle to gate processes - raw material supply, transport and manufacturing. These are calculated by assigning suitable embodied carbon factors to the given elemental material quantities. Product specific evidence from proposed manufacturers in the form of relevant Environmental Product declarations (EPDs) based on ISO 14025 and EN 15804 are to be made available to the LCA practitioner. Cost data or mass or area of elements measurements as appropriate will be required to determine quantities.

Reporting of emissions [A4 and A5] Construction process stage

Modules [A4] and [A5] below respectively capture the emissions associated with the transportation of the materials and components from the factory gate to the project site and their assembly into a building to completion.

[A4] Transport emissions. Transport emissions must include all stages of the journey of the products following their departure from the final manufacturing plant to the project site, taking into account any interim stops at storage depots and/or distribution centres. Evidence from the main contractor and subcontractors will be required. Transport distance and number of lorry loads should be calculated based on the distance between the manufacturing location and the project site, and is subject to the anticipated supply chain route of each item or alternatively this can be evidenced with appropriate daily records.

Note: The transport of people and commuting of employees is excluded from the calculations as the emissions associated with these activities are not attributable to the project but to the individual employees.

PROCUREMENT

[A5] Construction – installation process Emissions

The carbon emissions arising from any on- or off-site construction-related activities must be considered in [A5]. This includes any energy consumption for site accommodation, plant use and the impacts associated with any waste generated through the construction process, its treatment and disposal.

Evidence from the main contractor and subcontractors will be required for electrical energy consumption relating to site emissions and fuel usage.

Waste recording and reporting should be undertaken in accordance with WRAP guidelines, now transferred to CIRIA, with specific information and/or site monitoring data provided by the project contractor and primary subcontractors as these become available.

Appointment of the project team

Embodied Carbon should be included within the project procurement process. There are different procurement processes that are used to commission a project which will use differing approaches to producing and issuing tender information and communicating client requirements. Therefore, it is important to discuss the best route with the project management team to ensure that the Embodied Carbon requirements are understood and clearly set out. The appointment of the design and project team should reflect the ethos and policies of the housing association or organisation and share the ambitions of lowering carbon, including Embodied Carbon.

Sample wording has been taken from WRAP[65] for various documentation which can be amended as follows:

PQQ

"As part of our commitment to reducing resource use and carbon in all of our developments and cutting the associated costs, we require all new build and [refurbishment projects] to pursue carbon efficiency. This involves reducing as designed and as-built Operational Carbon impacts and the Embodied Carbon associated with the selected construction materials. Specific targets for this project are to [insert relevant targets from Project Brief]. Further detail is provided in the Project Brief.

1. *Detail your understanding and experience in cost-effectively designing out Embodied Carbon.*
2. *Detail your experience of undertaking life cycle assessment and Embodied Carbon assessments.*
3. *Detail your understanding and experience in developing carbon reduction strategies (or equivalent) that provide a robust forecast of carbon emissions together with defined and costed proposals for achieving improved standards of carbon efficiency without compromising value for money.*

ITT

"As part of our commitment to reducing resource use in all of our developments and cutting the associated costs, we require all new build [and refurbishment projects] to pursue carbon reduction. This involves reducing as designed and as-built Operational Carbon impacts and the Embodied Carbon associated with the selected construction materials. Specific targets for this project are to [insert relevant targets from Project Brief]. Further detail is provided in the Project Brief. Please describe your approach to:

1 *achieving our minimum requirements; and*
2. *preparing a reduction strategy (or equivalent) in line with the requirements set out in the Project Brief.*
3. *Please identify any factors you believe to be significant to the cost-effective achievement of Operational and Embodied Carbon targets set for this project.*

Employer's Requirements

Employer's Requirements can be issued for either the designer team or when tendering for a design and build (D&B) contractor. The clauses below ensure that D&B contractors and their design teams will systematically consider carbon reduction as part of the design development process.

[65] www.wrap.org.uk/sites/files/wrap/Procurement%20Requirements%20for%20carbon%20efficiency%20FINAL.pdf

PROCUREMENT

As part of our commitment to reducing resource use in all of our developments and cutting the associated costs, we require all new build [and refurbishment projects] to pursue carbon reduction. This involves reducing as designed and as-built Operational Carbon impacts and the Embodied Carbon associated with the selected construction materials. The design team must:

- *identify the [5-10] most significant and cost-effective opportunities to reduce the Embodied Carbon emissions associated with the project (e.g. through leaner design, designing out waste, reusing materials, and selecting materials with lower Embodied Carbon over the project life-cycle);*
- *quantify the savings made through individual design changes;*
- *report actions and outcomes;*
- *report against targets within the project brief;*
- *Assist and/or undertake the Embodied Carbon assessment throughout the design stages.*

These sample clauses and wording can be amended depending on whether the contract is with the designer or contractor and the type of procurement. The WRAP guidance has more clauses for the contractor and subcontractor appointment.

Procuring Embodied Carbon assessments

Assessing Embodied Carbon can be done in-house using the tools described in **Tools and approaches to measure Embodied Carbon**. When the assessment is done by the person working on the design then it is easy to consider the implications of different options, integrate findings into the design and communicate the results to the rest of the design team. It is also common to employ a consultant to do the assessments. This can limit the benefits because they are less able to assess new design options as the designer considers them, and to be able integrate into the design team unless they are providing other services. London Energy Transformation Initiative (LETI), (2020) provides guidance on Embodied Carbon and suggest that if employing a consultant to assess Embodied Carbon or LCA for a development, they should be able to demonstrate they have recently completed at least three different building LCAs and/or Embodied Carbon reduction strategies for clients. A typical fee for appointing an LCA consultant is in the range of £80-£120/hour. The early involvement of a sustainability/LCA consultant (or architect providing these services) can help define the client's aspirations. They should if possible, be part of the design team and follow the design, stage by stage.

Procuring low Embodied Carbon products

Only the exact building components specified as a result of any carbon reduction strategies should be procured and used during the construction process. If there are any product substitutions, then these should have a similar impact to those specified. Co-ordination between design team and contractor is standard practice, but the input of those who undertook the Embodied Carbon assessment is recommended.

To meet Embodied Carbon goals or targets, there will be a need to procure low Embodied Carbon products. This is likely to be part of the responsibility of the contractor in most cases, particularly for the fabric of the building. One way of doing this is by asking for an Environmental Product Declaration (EPD)[66]. Having an EPD does not mean that a product has low Embodied Carbon, but EPDs will give the information to be able to assess it. For products where lots of manufacturers have an EPD, for example in insulation and plasterboard, it might be possible to specify products on the basis of their Embodied Carbon. Other information that might be useful is biobased content and recycled content. If manufacturers are not able to provide an EPD, then it could be useful to understand what they are doing to reduce their environmental impacts. The provision of EPDs or similar information could be a requirement within the contract.

If substitutions are to be made from the specification, then it is important that evidence is provided that it is equivalent to the original specification or better.

Example wording for tenders for the provision of products are:

Submit an EPD for each product specified:

1. Impact Categories
   a) *Global Warming Potential (GWP): All GWP information submitted shall be in the form of kgCO_2eq/kg. for A1-A3 and other modules.*
   b) *Manufacturer-specific GWP information will be one of the decision criteria when awarding this scope. GWP information will be evaluated against both industry average impact category datasets, as well as the GWP information reported within manufacturer-specific EPDs from competing bidders. If manufacturer-specific GWP information is not provided, industry average EPDs will be used.*

[66] See the ASBP's briefing papers on EPD at https://asbp.org.uk/all-resources?tx_category=briefing-paper

PROCUREMENT

c) *If the primary goal when using this specification language is to measure total building carbon footprints and to incentivise suppliers to provide product specific EPDs that meet or beat the industry average, the specifier may choose to use a penalty factor to generic EPD. This penalty would apply to the suppliers that don't provide product specific EPDs compared to those that do provide product specific EPDs.*

d) *Where relevant and proportionate to the goods or services being procured as part of this tender, please describe how you will measure & monitor the carbon footprint of those goods or services using accredited methodology such as ISO 14067 and/or PAS 2050.*

2. Please provide the biogenic content (or mass of biogenic carbon) for the product.
3. Please provide the recycled content of any material within the products
4. Please describe your approach to environmental sustainability, including details of any specific steps taken in the design and manufacture of services to reduce Embodied Carbon and any other relevant detrimental environmental impacts, and detail how this will be applied to this tender.'

Specification clause used in the Gwynfaen Development for product substitution

Any proposed product substitutions should evidence the products Global Warming Potential (GWP) in $kgCO_2eq$/declared unit using an EPD to EN15804 (minimum scope stages A1:A3) for the product to be considered. Products and materials which exceed the Global warming potential (GWP) measured in $kgCO_2e$ per declared unit by 10% or more compared to the baseline specification will be deemed not equal unless the contractor can demonstrate by calculation the substitution will result in fewer emissions.

Construction

The contractor should also be required to record the energy used on site, the water and types and quantities of waste generated and their management routes. This data could be used in the as-built assessment if the contractor provides these numbers, which will be preferable to using default numbers. For large developments, targets could be set, for example using the BRE HQM criteria for waste generated (see Figure 26) or aiming for zero avoidable waste to landfill (Green Construction Board, 2020).

Monitoring and practical completion

Ongoing improvement throughout the contract can be achieved by building requirements into the contract and managing the contract appropriately once awarded. This could be by putting targets into the contract, although it is important that any targets or performance outcomes should be realistic and achievable. They must also be quantifiable and measurable, otherwise there is a risk that enforcement may be impossible.

There could be an obligation on the contractor to undertake a practical completion carbon assessment and report. This is to see if the actual building(s) did encompass the reduction strategy and any carbon reduction targets that were set.

PROCUREMENT

RIBA STAGES	PROCUREMENT STRATEGIES
0 STRATEGIC DEFINITION	• Client to ensure low embodied carbon is part of the overall strategy and there are links to organisational polices • Appoint a person who has responsibility for carbon; this could be a 'Carbon Champion' • Consider who will assess embodied carbon (in-house, architect, consultant)
1 PREPARATION AND BRIEF	• Client to ensure requirements for embodied measurement and reporting are included in the brief and any targets/goals for embodied carbon and reduction
2 CONCEPT DESIGN	• Client to require assessment and reporting of the Stage 2 design and provide opportunities for carbon reduction
3 DEVELOPED DESIGN	• Engage with supply chain to provide embodied carbon data from EPDs, and to explain how their products can address the net-zero whole life carbon agenda • Continue to develop designs that reduce embodied carbon (within the context of whole life carbon)
4 TECHNICAL DESIGN	• Client to require assessment and reporting of the Stage 4 design • Client to require specifications take into account low embodied carbon requirements
5 CONSTRUCTION	• Client to require measurement of site energy, water and waste • Client to require embodied carbon assessments for all contract variations • Contractor to procure low embodied carbon products as per the specification and require • Client to ensure monitoring of contract and correct implementation of embodied carbon requirements
6 HANDOVER/ CLOSE OUT	• Require as built practical completion assessment
7 IN USE	• Require embodied carbon assessment and reporting during major refurbishments
END OF LIFE	• At end of life consider undertaking pre-demolition audits to maximise reuse and recycling and record the embodied carbon results

Figure 7
Key Procurement steps by RIBA Design Stage

PROCUREMENT

References and Further Information

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CHAPTER 05

TOOLS AND APPROACHES TO MEASURE EMBODIED CARBON

TOOLS AND APPROACHES TO MEASURE EMBODIED CARBON

CHAPTER 5 SUMMARY – MEASUREMENT AND TOOLS

- Embodied carbon should be considered as early as possible in the process to maximise the ability to reduce impact
- If you are assessing embodied carbon in-house, then you need to use a tool
- Decide on the appropriate scope for the assessment
- Choose the most suitable tool to use for the type of projects and scope of assessment
- Follow the approach of the RICS Professional Statement on Whole Life Carbon

The importance of considering Embodied Carbon as early as possible

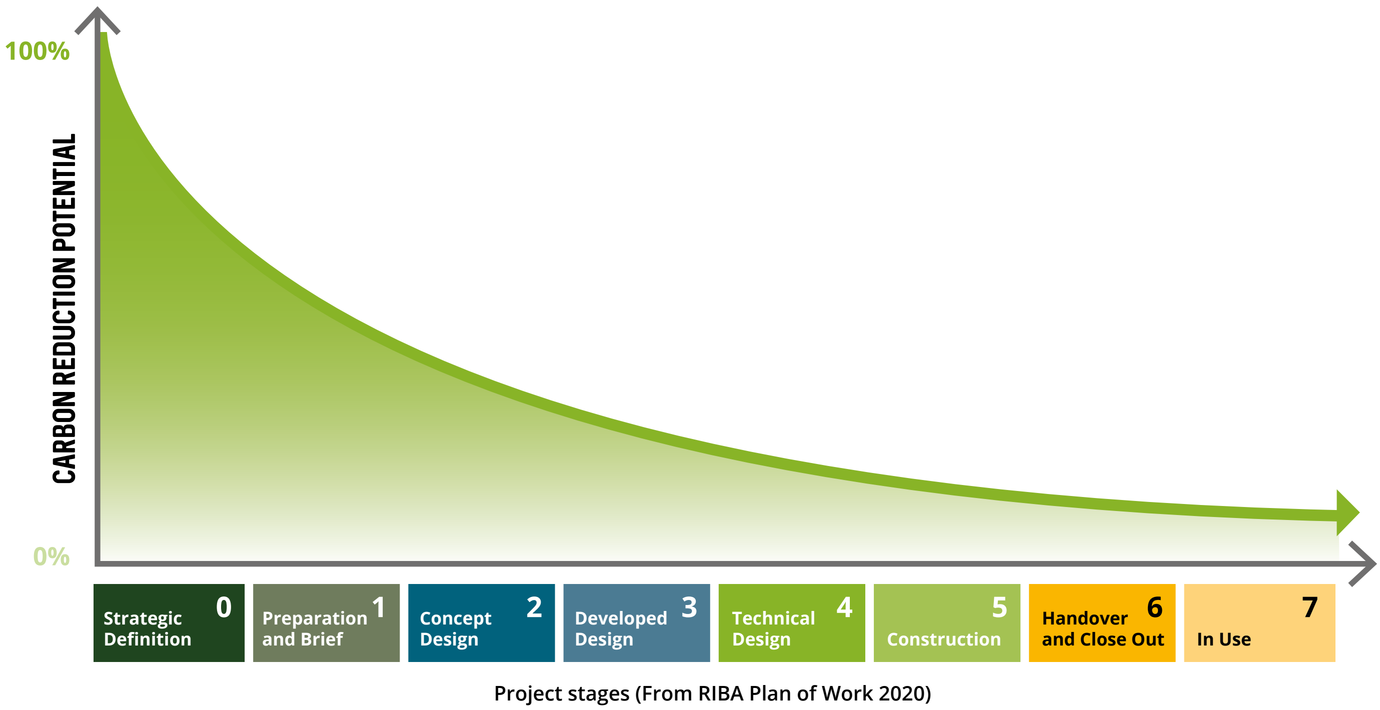

Figure 8
How the ability to influence Embodied Carbon decreases as the project progresses

The earlier you consider Embodied Carbon, the greater your ability to reduce it, as shown in Figure 8 above. Ideally Embodied Carbon should be included in the development of the brief, throughout the design process, the construction process and through the life of the building to its eventual end of life.

MEASUREMENT AND TOOLS

RIBA STAGES	PROCUREMENT STRATEGIES
0 STRATEGIC DEFINITION	• N/A
1 PREPARATION AND BRIEF	• Check what requirements are included in the brief • Choose a tool or appoint an Embodied Carbon Consultant
2 CONCEPT DESIGN	• Assess the different options using standard specifications to identify the influence of form • Assess chosen form with different structure and fabric options • Assess final design and identify hotspots and reduction strategies
3 DEVELOPED DESIGN	• For the hotspots, assess different design options for elements and components • Consider the impacts of potential internal walls and finishes • Assess final design and identify hotspots and reduction strategies
4 TECHNICAL DESIGN	• For the hotspots, assess different materials and manufacturers • Assess the final Stage 4 design
5 CONSTRUCTION	• Monitor and meter energy and water use • Monitor and measure waste by type and destination • Assess the impact of any changes in specification or design
6 HANDOVER/ CLOSE OUT	• Re-evaluate as built embodied carbon • Offset residual embodied carbon
7 IN USE	• Measure embodied carbon for ongoing maintenance, replacement and retrofit and compare to the as built assessment
END OF LIFE	• Undertake demolition audits • Measure impact of end of life and benefit of materials recovery

Figure 9
Embodied Carbon Measurement Strategies by RIBA Stage

MEASUREMENT AND TOOLS

Levels of assessment (checklist, simple analysis, whole building LCA)

At its simplest, Embodied Carbon is measured in a similar way to providing cost estimates of a building. For a material like brick, the volume of the material is assessed from the area and thickness. For bricks, Embodied Carbon is normally given per tonne, so the volume needs to be converted to mass using the brick's density. The Embodied Carbon for the product is then taken from databases or an Environmental Product Declaration (EPD). Embodied Carbon tools make this process a little simpler – and in BIM integrated tools, quantities such as volume can be taken directly from a BIM model. When using tools, you normally have to identify the materials used, either by linking each material in the model with a material in the tool database, or by linking an element such as a wall to an element catalogue, which includes a build-up of the material. In the case of a wall, this can include plasterboard, timber studs and acoustic insulation in an internal wall partition, for example.

Savings are typically calculated by multiplying a reduction in a material quantity by its carbon emission factor or by multiplying the material quantity by the reduction in carbon emission factor. Material quantities can be derived from cost plan data, bill of quantities or BIM models. A standard material comparison on a kg CO_2e/kg of material basis should be avoided as different materials have different densities and are not used in the same quantities within a building to deliver equivalent performance. As a minimum a kg CO_2e/m^2 assessment should be used for different options to consider the effects of material intensity in the 'as built' condition.

Using a consistent approach is important to ensure that results are meaningful and can be used for benchmarking. Some older studies may have used kg CO_2 rather than kg CO_2e – which means they did not take into account emissions of other greenhouse gases like methane. The result of this can be a 10% difference on the figures, although this will vary by material.

The level of detail for the study is also relevant. Some studies are based on a full bill of quantities and will include foundations, external works, staircases, boilers, doors, skirting boards and gutters for example, whilst others might focus on only the main elements such as walls, roof, floors and windows, which can potentially capture less than half the total Embodied Carbon for some buildings.

Using consistent data for assessment is also important, although the now more common use of EN 15804 and EN 15978 to measure the embodied impacts of construction products and buildings means this is much less likely to occur. Data to these standards is provided using the modules shown in Figure 3.

- Cradle to gate data (Modules A1-A3) are most easily available at product level, from databases such as the Inventory of Carbon and Energy (ICE)[67] or from Environmental Product Declarations (EPD)[68]. Using cradle to gate data at this level will ignore any differences over the life of the building. For example, two windows may have different expected lives in the building or different maintenance schedules.
- Including the impacts of transport (Module A4) is most important for high tonnage materials with relatively low impact per tonne. These include aggregates and timber, where transport can have as much impact as the material itself. For more processed materials, transport impacts are generally less significant relative to the impact of the product, especially when more efficient shipping is used for trans-continental transport.
- Considering site wastage and installation (Module A5) is also relevant, particularly when comparing onsite construction with prefabricated solutions, which should have little waste on site (onsite solutions might have wastage rates of 10% or more). But if using prefabricated solutions, you should ask for factory energy and waste data so that you can accurately model them.

[67] ICE Database: www.circularecology.com/embodied-energy-and-carbon-footprint-database.html
[68] https://asbp.org.uk/briefing-paper/epd-where-to-find

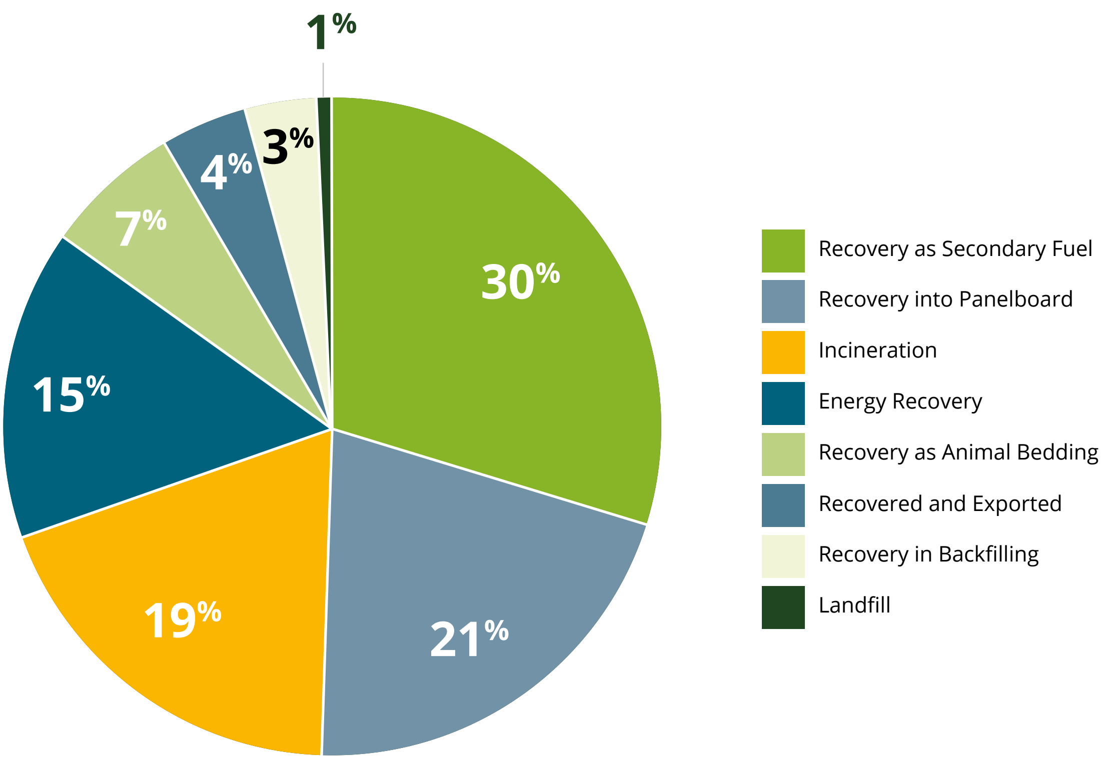

Figure 10
Estimatwd Final Waste Treatment Routes for UK Wood Waste in 2016
(Source DEFRA (2020), WRA (2020), Doherty (2019)

- Taking into account disposal at end of life (Modules C1-C4) is a key decision for biomass, as it addresses the biogenic carbon stored in products such as timber (known as Sequestered Carbon) which is associated with this choice. In the UK, as shown in Figure 10, most timber is recovered or recycled at end of life – chipped or pelletised for use as a secondary fuel, chipped for use in wood panel products, or shredded for animal bedding or exported or it is used in Energy from Waste (EfW) plants to generate energy. A decreasing amount is incinerated with no or little energy recovery as EfW becomes more popular in the UK, though this is not as common as it is elsewhere in Europe. Disposing of timber in landfill has decreased significantly to less than 1% of wood waste in 2016, but the behaviour of timber products in landfill is an aspect which is still relatively unresearched. Recent studies have suggested most timber will stay intact (e.g. Ximenes, Gardner and Cowie, 2008) , and landfill gas collection rates in the UK are increasing – a report for DEFRA calculated 50% of methane from all UK landfills in 2011 was captured and burnt to form CO_2, and for the most modern landfills, suggested capture rates of 68% (Gregory *et al.,* 2014).
- For all materials, including timber, end of life offers opportunities for materials to be reused, recycled or used for energy recovery, which will all have benefits in future product life cycles. The impact of any recovery are included in Module C, and for outputs which are not “looped” back to match inputs of secondary material, the loads of any further processing and the benefits of recovery in terms of avoided production can be shown in Module D.

MEASUREMENT AND TOOLS

Building elements are, of course, interdependent. For example, naturally ventilated solutions may require exposed high mass floor slabs but no materials for ducts and fans. Solutions requiring high levels of natural daylight may require greater floor to ceiling height and narrow floor plans hence more building envelope. Lightweight solutions will affect the foundation design as well as thermal performance. It is important for all these that all relevant aspects of the building are assessed when considering an alternative design option. It is also important that Embodied Carbon is considered alongside Operational Carbon.

To ensure all these aspects are considered, a "cradle to grave" assessment is the best approach. At early design stages, it is fine to focus on the key elements and to use generic data (average data for products and scenarios). This early stage assessment will provide information on the impacts for each life cycle stage, by element and by material, and will help ensure the building form and basic structural system are optimised. As you progress through the design stage, it is important to ensure the detailed design is modelled, and that where relevant, manufacturer specific data (from Environmental Product Declarations (EPD)) is used. Modelled energy consumption during the use stage should also be considered. This will allow you to see the trade-offs, for example between increased energy efficiency or using renewables, and the Embodied and Operational Carbon.

Figure 11 shows that for typical low-rise housing, most of the impact is in the foundations, external walls, windows and doors and roof. There is some variation by type: for bungalows, more impact will be attributed to the foundations and roof; for terraced housing, less impact will come from external walls and more from other walls; and for detached housing, more impact will come from external walls. For low-rise housing, assessing just these four major elements at early design stage can give a good idea of the embodied impact of the building: defaults can be used for other elements (like MEP/building services and finishes) or they can be considered out of the scope.

Typical Low-Rise Dwelling:
Embodied Carbon Breakdown

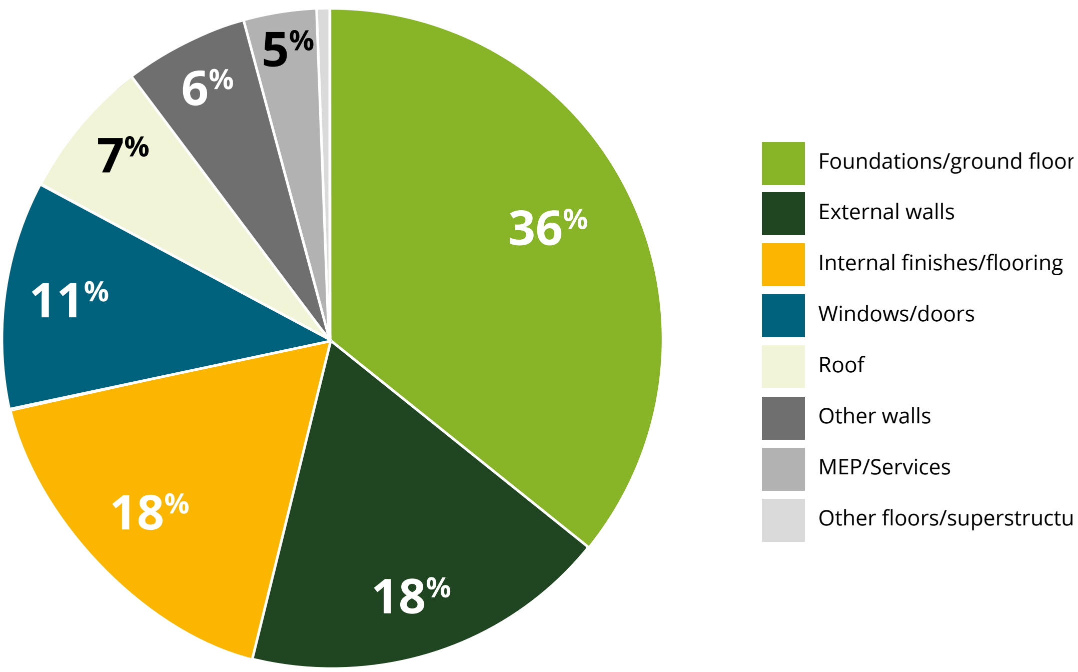

Figure 11
Embodied Carbon breakdown by element over 60 years, based on new build terraced and detached masonry and timber frame houses in Balson, Lowres and Johnson (2011).

MEASUREMENT AND TOOLS

As the number of storeys increases, particularly for medium and high-rise buildings, the impact of the foundations and other floors and superstructure will increase. Building services relating to mechanical, electrical and plumbing installations (MEP) may also increase in impact as these types of residential building are often more highly serviced. For these high-rise buildings, it would therefore be sensible to also include superstructure and MEP/services in early design assessments.

As there are various tools available to undertake Embodied Carbon assessments and LCAs (see **Table 3**) but there is not one standard industry tool. There can be variation between the answers produced which is largely due to the databases that are used to underpin the tools, the boundaries of their assessment, and the assumptions that the tools use for transport, waste, service life and end of life disposal. However, the RICS Professional Statement (RICS, 2017) attempts to provide a common format for the assessment of Whole Life Carbon.

Role of standards – EPD, LCA and Embodied Carbon

As mentioned above, the European Standard, EN 15978:2011 and the RICS Professional Statement on Whole Life Carbon both try to ensure consistency of embodied impact assessments. EN 15804:2012 covers the assessment of embodied impact at product level to produce Environmental Product Declarations (EPD) and with EN 15978 – the building level assessment standard - is part of the CEN/TC 350 suite of standards, with a common format and set of indicators. EN 15804:2012+A2:2020 has recently been updated with new indicators and some additional reporting requirements – and EN 15978 has just started the process of revision. Until this has been completed, EPD will commonly provide results to both standards. For more information on EPD, see the ASBP's briefing papers.

The RICS Professional Statement on Whole Life Carbon provides guidance on how to assess Embodied Carbon according to EN 15978 in a way that will bring about more consistency for UK assessments. For example, it provides guidance on default assumptions for transport to site, reference service lives and end of life, which can be used during the early design stages.

Table 2
Default transport scenarios for UK projects from RICS Professional Statement

Transport scenario	km by road*	km by sea**	Example
Locally manufactured e.g. concrete, aggregate, earth	50[69]		Welsh timber
Nationally manufactured e.g. plasterboard, blockwork, insulation	300[1]		Scottish timber
European manufactured e.g. CLT, façade modules, carpet	1,500[70]		Austrian CLT
Globally manufactured e.g. specialist stone cladding	200[71]	10,000[3]	Canadian timber

* Means of transport assumed as average rigid HGV with average laden – average laden as per BEIS carbon conversion factors.
** Means of transport assumed as average container ship.

[69] EeB Guidance Document, Part B: Buildings – Operational guidance for life cycle assessment studies of the Energy-Efficient Buildings Initiative, p.199.
[70] Generic distance for items assumed to be sourced from continental Europe, e.g. Austria.
[71] Generic distance for items assumed to be sourced from Eastern Asia.

MEASUREMENT AND TOOLS

Using these defaults will highlight which aspects are particularly important for the overall impact – and this means that more specific data can be found during the later design stages. For example, during early design stages the Professional Statement gives default distances that should be used. If the modelling with default data highlights that the transport impact is significant, then during the detailed design stages, the actual transport route and distance from the supplier should be used.

At present, the Whole Life Carbon Network, a group of UK professionals working on Embodied Carbon, is producing further guidance to improve the consistency in Whole Life Carbon assessment and reporting. We recommend checking this when it is published as an appendix to the RICS Professional Statement, when it is also intended to be made available through professional bodies such as RIBA, CIBSE, IStructE, RICS, Architects Declare, Architects Climate Action Network, British Council for Offices, LETI and UKGBC.

Tools to assess Embodied Carbon

Table 2 provides information on the tools most commonly used to assess Embodied Carbon which have been developed to cover the UK market. In addition, many structural engineering and building services engineers will have their own in-house tools.

Some tools only work as plug-ins, for example within Revit or PHPP – so if you do not already use the host tool, they may not be appropriate. Some tools have added functionality which may be useful, and the costs of tools also varies widely with some available free and others for a monthly subscription. Tools also come with different templates, for example for different wall constructions or building typologies – it is worth checking how useful these may be for your work. Tool providers often provide videos of their products in action – there are also a webinar provided by ASBP[72] which may be useful to give you an overview of the tools.

In Table 3 overleaf, we provide an overview of the tools commonly used in the UK market to assess upfront and Embodied Carbon. In addition, the following free tools may be of interest:

Beacon: Thornton Thomasetti's in-house Embodied Carbon for building structures has been made available free and open source (Revit plug-in).

FCBS Carbon: FCB Studios in-house Embodied Carbon tool for early design has been made available free as a beta version (excel based).

EC3: Developed by the Carbon Leadership Forum in North America, this Embodied Carbon tool links with the EC3 database of Environmental Product Declarations (EPD). Although most EPD are for the US, increasing numbers of European EPD are being added (online tool).

Criteria for selecting an Embodied Carbon or Building LCA tool

The following questions may be useful in selecting a tool.

- During which life cycle stages will you be doing the assessment? This will influence the level of detail available. Some tools are better dealing with early design stage, others with detailed design and post-completion assessments.
- Does it cover refurbishment, retrofit and fitout, if these are relevant to your practice?
- What type of input data for the building does the tool need, and are you able to obtain/generate data with this level of detail for your projects?
- Does the tool integrate with your design processes (e.g. use of Revit or BIM)?
- Do you only need to assess Embodied Carbon, or do you want to do LCA, e.g. for BREEAM/LEED?
- Is the data from the tool third party verified? Does it reflect the geographical location of the project? How much data is there in the tool? Does it cover all the materials and services you specify? Does it include manufacturer specific and generic data? If there are EPDs in the database, how often are they added and updated?
- Do you need the tool to be IMPACT compliant (for BREEAM)? Does the tool comply with EN 15978? Does it comply with the RICS Professional Statement on Whole Life Carbon? If so, how has this been checked?
- Does it allow you to change defaults (e.g. service lives, ransport scenarios, etc) if relevant?
- How much time will it take to learn to use the tool, to set up "build-ups" or "templates" and to model a project?
- How much skill is required to use the tool? Is training required? What training is available?
- Does the tool help you to reduce Embodied Carbon?
- Are the outputs flexible enough for you to use in client reports, publicity etc?

If you are considering investing in software, will the software be kept up to date?

[72] https://asbp.org.uk/video/webinar-embodied-carbon-building-design-tools and https://asbp.org.uk/video/webinar-life-cycle-analysis-tools-and-datasets

Table 3 Tools to assess Embodied Carbon

Tool name	Carbon Designer by OneClickLCA	ECCOlab by Rapiere Software Ltd	eToolLCD by eTool	H\B:ERT by Hawkins Brown	PHRibbon by Tim Martel for AECB	One Click LCA Planetary	One Click LCA
Cost for users?	Yes, costs on request	Starts at £27pm	Between $50 USD and $500 USD per month	Free beta version ICE database	£105 + Passivhaus Planning Package (PHPP)	Free in UK through UKGBC partnership	Yes, costs on request[73]
Where does it source its data for materials?	One Click LCA Database - Generic Data (EN15804 compliant and 3rd party verified) EPD data	EPD data ICE database	- Default eTool Datasets (ecoinvent) - EPD data - BRE IMPACT*	Users can enter data from EPDs etc.	EPD data ICE database	Only includes ten most important construction materials and selected essential assemblies. Global generic (average) data, as well as manufacturer specific, 3rd party verified EPDs	One Click LCA Database - Generic Data (EN15804 compliant and 3rd party verified) - EPD data - BRE IMPACT*
Life cycle modules included?	A1-A5, B1- B7, C1-C4 + Module D Users can add A5, B1, B3, B6, B7.	A1-A4, B4, B6, C4 Further stages in development.	A1-A5, B1- B7, C1-4 + Module D	A1-A5, B4, C1-C4	A1-A5, B1-B7, C1-C4 + Module D Users can add B3 and B5.	A1-A3	A1-A5, B1, B3- B7, C1- C4 + Module D
Which environmental indicators does it include?	Embodied Carbon	Embodied Carbon	Embodied Carbon EN15804+A1 Material Efficiency Metrics	Embodied Carbon	Embodied Carbon	Embodied Carbon	Embodied Carbon BREEAM LCA categories EN 15804+A1 and A2
Where is scenario data sourced from?	One Click LCA Database which has UK localised data or User input	RICS Professional Statement, CIBSE, Insurance data, EPDs. Assumes incineration at End of Life. User input for Transport Plugin for Sketchup IFC from Revit	Industry average eTool defaults User input	RICS Professional Statement	RICS Professional Statement EPD data	n/a	Industry average localised One Click LCA Database EPD data User input
Links with CAD/BIM tools and other tools	Can upgrade to full OneClickLCA tool	Can import .gbxml	Revit Excel	Must use Revit 2017, 2018, 2019 as a Revit Plugin	Must be used in Passivhaus Planning Package (PHPP)*	No	REVIT, IES-VE, IFC etc see website
Results export?	Excel	Excel, Word	Excel, Word, PDF	Excel, PDF	Excel	No	Excel, Word
Additional features	Add-ons: Whole life costing, Circularity Statements, LCA for BREEEAM	Included: Whole life costing, Energy Plus energy modeller, BREEAM Credits Report	Included: Life Cycle Costing		Included: PHRibbon functionality Add-on: Costing module gives capital and 30-year heating cost.	No	Add-ons: LCC, Building circularity, Carbon Designer, Carbon benchmarking, EPD Generator
What help is available to users?	Customer support centre / Email / Helpfiles / Online tutorials / Webchat	Email / Manual / Online tutorials / Webchat	Email / Online Training / Online Tutorials,	Email / Online Training / Online Tutorials,	Manual / Online tutorials / Online monthly Q&A / Telephone	Online resources only	Customer support centre / Email / Helpfiles / Online tutorials/ Webchat
Checking or auditing service?	Yes on request.	On agreement	Third Party Verification by eTool is included.		Yes on request.	No	Yes on request.

*Building does not have to be a Passivhaus. AECB compliant buildings are also modelled in PHPP and can use this tool

[73] One architecture practice told us their annual business licence was over £5,000 to include BREEAM IMPACT assessments.

MEASUREMENT AND TOOLS

Undertaking assessments with tools

With many tools, calculations can be carried out with minimal data requirements (for example using concept design drawings or simple specifications such as building footprint, structure type, number of floors etc.) to compare different early design concepts (e.g. terraces vs semi-detached, different form factors, different areas per occupant, different structural materials or facade finishes). Assumptions can be made for any unknown design specifications at each stage. Then as the design progresses, levels of detail and accuracy can be increased.

Material specifications and quantities can be extracted from architect's drawings, bills of quantities and BIM as they become available, and carbon data can be sourced from generic Environmental Product Declarations (EPD) and databases such as ICE, moving to manufacturer and product specific EPD[74] as the project progresses. Similarly, it may be best to use the default sources in the RICS Professional Statement for scenarios such as transport, waste, replacement intervals and end of life, but as the project progresses, actual data such as transport distances from the supplier to site, the contractor's wastage rates and realistic replacement intervals and end of life scenarios (e.g. taking account of design for deconstruction) can be used.

When using BIM based LCA tools, it is important to keep the data from the final BIM model in order to compare the reality to the proposed design. The BIM model can also be used to aid maintenance and replacement, as well as compare to the assumed replacement cycles established in the LCA. The tool should also be able to recognise most elements of the 3D model to make sure nothing is left behind ('take-up methodology'). Great care and precision must be given to the 3D model and the way it is linked with the LCA tool as it will directly impact on the LCA. The resulting LCA will only be as accurate as the model itself - **rubbish in equals rubbish out!**

It is particularly important to check how the tool is interpreting elements such as windows, profiled panels, stud partitions or hollow elements such as mullions for example as they may have been modelled as monolithic, solid materials. These types of elements may need to be created as new materials or elements in the tool, based the real combinations of materials, often including air, with the correct masses of each material used.

For more detail on how to undertake assessments, we recommend the detailed case study for Gwynfaen produced by Stride Treglown, and Section 9 and Appendix 3 of the LETI Embodied Carbon Primer.

Overseas Tools to assess Embodied Carbon

There are also other tools developed for overseas markets, some of which have been produced by National Governments for use in regulation or to encourage uptake and which are free to use. All those below are available in English and are Life Cycle Assessment tools covering all the EN 15978 indicators, rather than just Embodied Carbon (the Global Warming Potential Indicator used in EN 15978).

- eLCA (German Government)- full LCA, free) - www.bauteileditor.de/
- TOTEM (Belgian Government – full LCA, free) - www.totem-building.be/
- Eco2Soft (Austria – full LCA, euro 120) - www.baubook.info/eco2soft/?SW=27&lng=2
- Generis (Germany – full LCA – free for basic assessments) - www.generis.live/#/signin; https://generis-solution.eu produkte/

Case studies of tool use

A number of case studies will be made available on the Woodknowledge Wales website. https://woodknowledge.wales

Feedback from undertaking assessments

As part of the development of this guidance, we have worked with a number of stakeholders who have been using tools to assess Embodied Carbon. Feedback from these assessments is included below.

"Although specialist LCA knowledge is not required, good knowledge of building design and construction is needed. Indeed, for the tool to provide maximum benefit, building designers should be using this tool from project conception and prior to submitting planning permission, at which point a design becomes largely fixed. The tool should be used while key design decisions can still be influenced (without incurring significant additional cost or project delay, as may be the case later in the process)."

[74] See the ASBP's briefing papers on EPD at https://asbp.org.uk/all-resources?tx_category=briefing-paper

MEASUREMENT AND TOOLS

"The more accurate the data input into the software, the more accurate the results."

"When we do our Embodied Carbon analysis, because these Embodied Carbon tools link to our Revit model, obviously the measure is only as good as the level of detail in the Revit model."

"This is where the use of tools … is invaluable. A project can compete against itself and give designers insight into which aspects of design achieve the best environmental results, driving best practice and continuous improvement in the sector."

"The strength of tools … is not so much the absolute Embodied Carbon value calculated for a structure but the relative Embodied Carbon values of design alternatives being considered within a project at each stage of the design process. This is what drives down Embodied Carbon for that project."

"Different tools may use different data sources and may make slightly different data assumptions (e.g. relating to transport of materials, wastage on site, recycling at end of life and replacement intervals etc.) so consideration should be given to this when comparing your design to a benchmark that has been calculated by others and/or using a different tool."

eToolLCD

"There are a growing number of design tools available on the market that are designed to simplify the calculation of Whole Life Carbon of buildings so that specialist knowledge of life cycle assessment (LCA) is not required. We trialled EtoolLCD and we found this to be true for the main purpose of reducing Embodied Carbon in design – expert LCA knowledge was not needed to use the software or to understand and utilise the results to improve design. The trade-off of a simplified system is loss of data transparency. However, this is not considered to be an issue for most users. "

"Buildings that use standard materials and design specifications can be modelled very quickly but if your project uses non-standard materials or specifications then modification of library templates or even creation of new library templates may be required. This can be time consuming, especially for novice users. However, when familiar with the software and after you have created/ modified templates once, you can reuse them in future projects. This makes modelling of new projects extremely quick and easy – a project could be modelled in as little as an hour or two if minimal modifications are needed."

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"A significant investment in time (perhaps a week or more) is required for the user to familiarise themselves with the software and its functionality. The software is free (though a subscription is payable to access additional features and user support) and its interface was not found to be particularly intuitive or slick."

"We found the first project took a number of days because the library of materials and modules within the software are not named using standard convention (and some of them use Australian terminology, which can differ from British terminology) so it is not always easy to identify the materials you are looking for."

"Results presented in eToolLCD allow the user to identify materials that are contributing most to the Embodied Carbon impact and enables them to compare the impacts of alternative specifications. It also enables comparison with benchmark designs (for example a previous structure designed by the user)."

"Etool doesn't explicitly separate Embodied Carbon from Operational Carbon in its results reports but they can be calculated manually by adding up the emissions from relevant life cycle modules. In its reporting, EtoolLCD currently (Summer 2020) amalgamates some impacts from some life stages (C3 and D) when presenting results. This can be a problem for users since Embodied Carbon targets are set for Modules A-C."

H\B:ERT tool
"The Hawkins Brown one [H\B:ERT tool] is very useful for early stage concept stuff I find. You can quite quickly get some outputs with that."

One Click LCA tool
"What OneClick does, it makes the output very easy. So if you're doing a BREEAM assessment it will split it into the various scopes, the different stages that were required. And it makes that workflow really easy. And the other tools don't really do that. So that was the main reason why we purchased this software over other tools."

"We purchased [OneClickLCA] because it's European centric, as opposed to something like eTool or others which are may be focussed on other parts of the world. We felt this is more relevant to the U.K. And then secondly because of the BREEAM element. And we felt that the amount of EPDs or the size of the database was, I think, one of the best around. And we felt that because we are paying for the software and that the database would be kept up to date, you'd get decent product support, which we have."

"It's got a rather clever little learning function on [OneClick-LCA], that basically remembers your previous selections. So as you do another assessment, it will remember the kind of materials that they used."

"...after a while, it pre-populates stuff. There's a disadvantage in that, you still need to go through and check it, and not assume that it's all okay."

"...it is a big time saver, but it's not 'one click' and I'm sure, compared to older ways, it's a lot quicker than it used to be."

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CHAPTER 06

BIOMASS, BIOGENIC CARBON SEQUESTRATION & CARBON STORAGE

BIOMASS, BIOGENIC CARBON SEQUESTRATION & CARBON STORAGE

CHAPTER 6 SUMMARY – BIOMASS, CARBON SEQUESTRATION AND STORAGE

- Biomass based building materials such as timber contain sequestered carbon
- During the life of the building, this sequestered carbon is stored out of the atmosphere. This carbon storage can be substantial for both masonry and timber framed buildings
- This long-term carbon storage in buildings has a benefit in reducing global warming
- At end of life, timber reuse and recycling are likely to result in further carbon storage

Biomass

Biomass is material of biological origin such as timber, paper, wool, leather, linseed oil used in linoleum and hemp used in hempcrete. Biomass however excludes biological material embedded in geological and/or fossilized formations such as limestone or peat, or fossil fuels.

Biogenic carbon and sequestration

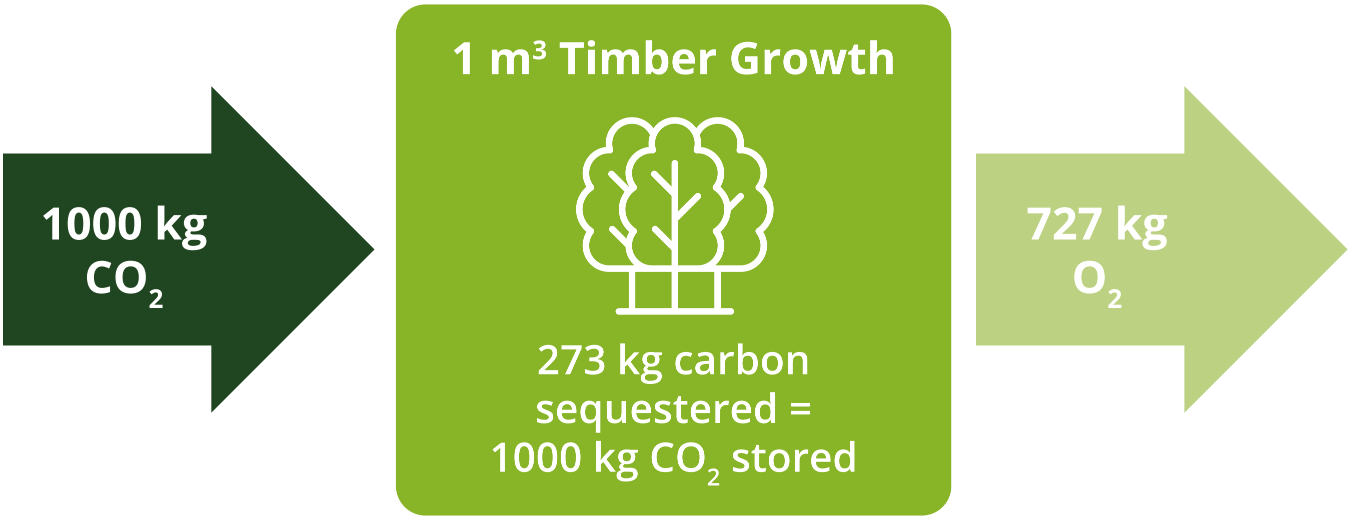

Figure 12
On average, a typical tree absorbs, through photosynthesis, the equivalent of 1 tonne of carbon dioxide for every cubic metre's growth, whilst producing the equivalent of 727 kg Oxygen.

Biomass contains biogenic carbon, which is CO_2 removed from the atmosphere and incorporated as carbon into biomass through photosynthesis and other processes associated with the carbon cycle – this process is called sequestration and biogenic carbon incorporated in products is called Sequestered Carbon. The amount of biogenic carbon within each product will vary, depending on its chemical composition, but for a tree, 1 m³ of timber growth removes 1 tonne of CO_2 to sequester 273 kg of biogenic carbon and "stores" it out of the atmosphere. If the tree is harvested, the Sequestered Carbon within the timber stays as biogenic carbon content. For most timber, half the dry mass of the timber is biogenic carbon, for example 1 m³ of UK grown kiln dried timber[75] contains 208 kg of biogenic carbon having sequestered 763 kg of CO_2 which it then stores out the atmosphere. 1 m³ of spruce or pine timber from Sweden[76] contains 195 kg biogenic carbon having sequestered and stored 715 kg CO_2 out the atmosphere.

[75] EPD for 1 m³ UK sourced and produced kiln dried planed or machined sawn timber. Available from http://woodforgood.com/assets/Downloads/EPD/BREGENEPD000124.pdf
[76] EPD for Swedish sawn dried timber of spruce or pine. Available at https://www.environdec.com/Detail/?Epd=14140

BIOMASS, BIOGENIC CARBON SEQUESTRATION & CARBON STORAGE

The Benefit of Carbon Storage

Using biomass based products such as timber within buildings with their long lives has a benefit – every tonne of CO_2 sequestered into biomass and then stored for many years in the building reduces the amount of atmospheric CO_2 - in the same was as reducing greenhouse gas emission. This means that global warming is reduced, and the rate of global temperature change will not be as high, so climate change will be somewhat mitigated. The UN National Emissions Inventory reporting under the Paris Agreement reflects this by allowing countries to use the biogenic carbon sequestered in forestry and CO_2 stored in long life harvested wood products such as structural timber to mitigate their greenhouse gas emissions.

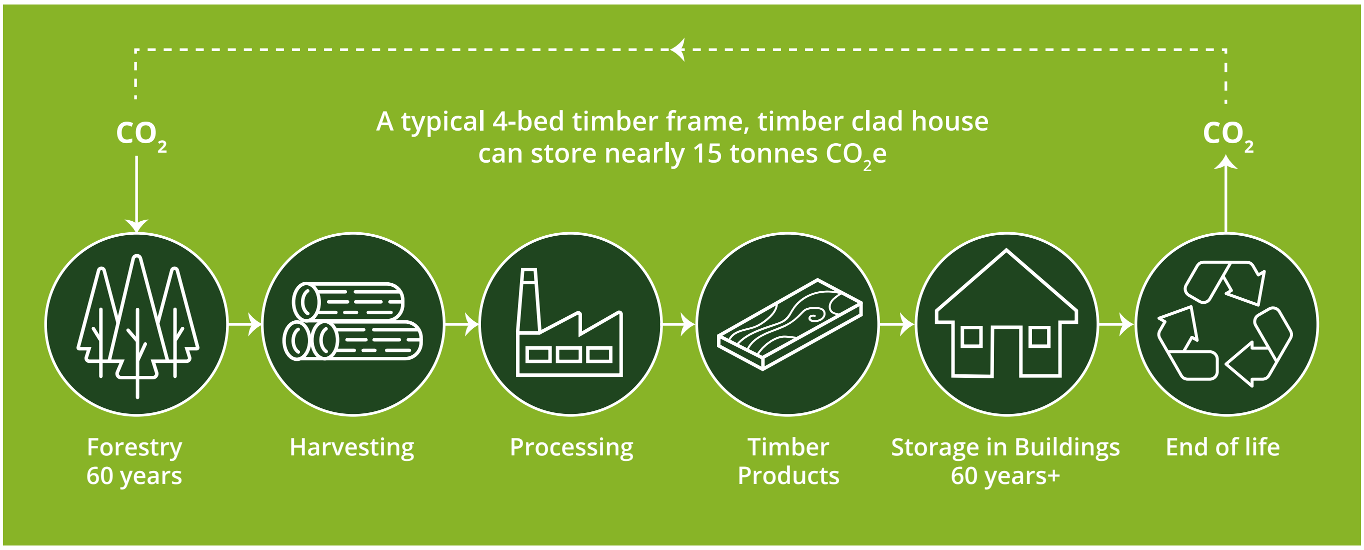

Figure 13
The benefits of carbon storage for a house (Timber framed timber clad house designed for Gwynfaen. Data from Stride Treglown (2020)

This benefit of biogenic carbon storage from using timber in buildings can be substantial. The Biocomposites Centre, in their report to the Committee on Climate Change (Spear *et al*., 2019) estimated that the carbon storage within residential new build in 2018 was 1.25 million tonnes of CO_2 and that if timber frame and cladding were used more, then this could increase to over 3 million tonnes of CO_2 stored per annum. At the level of a house, Stride Treglown calculated that a 4-bed house with timber frame and cladding at Gwynfaen would store nearly 15 tonnes of CO_2, and this is in addition to the reduced Upfront Carbon associated with using timber in housing. The Biocomposites Centre (Spear *et al*., 2019) estimated that a 4 bed detached house with a timber frame and timber cladding would have a 40% reduction in Upfront Carbon for the structure and fabric, and a timber framed 3 bed mid-terraced house a 15% reduction in Upfront Carbon.

Sustainable Sourcing of Timber and other biomass

To consider biogenic carbon sequestration and storage, as a minimum, biomass must be legally harvested, as defined by the exporting and receiving country. Timber must be able to demonstrate sustainable sourcing, for example using FSC or PEFC certification or similar. Bio-based products from tropical regions could use the Rainforest Alliance's Sustainable Agriculture Standard .

We need to recognise that timber and biomass are still limited resources, even if they are sustainably harvested and renewable. Although using these products has a benefit because of their carbon storage, we should only use what we need to efficiently deliver the required function. In doing so, we ensure that the maximum number of buildings can benefit from carbon storage, without depleting a valuable resource for future generations.

BIOMASS, BIOGENIC CARBON SEQUESTRATION & CARBON STORAGE

How much biogenic carbon is stored in housing?

The UK Committee on Climate Change estimates that based on the current rates of use of timber frame in UK housing (15-28%) that 1 million tonnes of CO_2 is stored in UK housing each year (Committee on Climate Change, 2018). This is based on research by the Biocomposites Centre at Bangor University (Spear *et al.*, 2019), which estimate that a typical masonry 4 bed detached house will store 8.5 tonnes of CO_2. Using a timber frame will increase this to 12.7 tonnes of CO_2, and a 4-bed detached house using both timber frame and cladding could store nearly 15 tonnes of CO_2 (around 125 kg CO_2/m²). The Centre estimated that a masonry mid-terraced 3 bed house will store 5.6 tonnes of CO_2 – meaning even masonry housing generally has biogenic carbon storage of about 65-75 kg CO_2/m².

Upfront CarbonCalculating Sequestered Carbon

Biogenic carbon content can be calculated using stoichiometry (the study of the relationship between the relative quantities of substances taking part in a reaction or forming a compound) or by testing.

For timber, biogenic carbon sequestration can be taken into account if the timber has been sustainably sourced, for example if it has FSC or PEFC certification, and the forest has been replanted or allowed to regenerate. In this case, according to EN 16449, then half the dry mass of timber can be assumed to be carbon, and this can be converted to CO_2 by multiplying by 44/12 (the mass of carbon dioxide compared to carbon).

For other biomass, the Phyllis 2 database provides details of the biogenic carbon content of a wide range of biomass materials, or EN 16640:2017 provides a method based on mass spectroscopy and ASTM Test Method D6866 provides a method based on radio carbon dating.

Reporting Biogenic Carbon

Biogenic carbon sequestration can be claimed in A1 when the timber used is sourced from forests which are operating under established certification schemes for sustainable forest management, according to EN 16485:2014 – unsustainably harvested timber will have impacts at end of life from the emission or transfer of biogenic carbon but cannot claim its removal in A1.

When reporting Embodied Carbon or Whole Life Carbon across the full life cycle of a building (Modules A-C) according to EN 15978, the Sequestered Carbon – the biogenic carbon contained within biomass such as timber within the building – should be considered as use of CO_2 as a resource from nature with a negative GWP in A1 when the biomass is sustainably sourced, and at the end of life, as an emission to nature when the carbon is emitted through c ombustion or release from degradation in landfill, as a transfer to another product system through reuse, recycling, recovery as a fuel or as a transfer to nature if it remains undegraded in landfill after 100 years – all with a positive GWP. Unless some of the biogenic carbon is released as methane from landfill, or the biomass such as timber is not sustainably sourced, then there will normally be a biogenic carbon balance and zero GWP from biogenic sources over the full life cycle. For transparency, the biogenic carbon stored within the building can additionally be reported as a separate figure, normally as the mass of Sequestered CO_2 in the building.

> By increasing the proportion of housing that is built using timber, the Committee on Climate Change estimate that 3 million tonnes of CO_2 could be stored in UK housing each year.

Inclusion of Sequestered Carbon in Upfront, Embodied and Whole Life Carbon Targets

Because there is normally a biogenic carbon balance over Modules A-C, it makes little difference whether sequestered carbon is included in targets for Embodied and Whole Life Carbon. However it is important for Upfront Carbon. The RICS Professional Statement says that:

"Carbon sequestration must only be taken into account when the following criteria are met:

1.The Whole Life Carbon assessment of the project includes the impacts of the EoL stage [C]
and
2.The timber originates from sustainable sources (certified by FSC, PEFC or equivalent).

Carbon sequestration figures should be reported separately, but should be included in the total product stage figures [A1–A3] provided the specified conditions above are met. ***Upfront Carbon targets or benchmarks, covering only A1-A5, should therefore exclude sequestered carbon****, as Module C is not included in the target of benchmark."*

BIOMASS, BIOGENIC CARBON SEQUESTRATION & CARBON STORAGE

For clarity, the total sequestered carbon should always be reported separately for a building whether it has been excluded from an Upfront Carbon assessment, or included in an Embodied Carbon or Whole Life Carbon assessment. This is also the recommendation of the RICS Professional Statement.

Using Biogenic Carbon Storage to mitigate and offset emissions

At a national level, carbon storage within both forestry and harvested wood products is used to balance greenhouse gas emissions using the methodology provided by IPCC (2006). At a building level, once Embodied and Operational Carbon have been reduced, then the long-term carbon storage within a building can be considered as a further mitigation measure for the building's Whole Life Carbon before offsetting. For example, the UKGBC study, Building the Case for Net Zero, provides the costs of offsetting the Upfront Carbon for a Net-Zero Upfront Carbon residential scheme both accounting for the benefit of biogenic carbon storage and for Upfront Carbon alone.

Achieving net zero Whole Life Carbon will require some form of offsetting. Offsets should be verified and traceable, to ensure that they are achieving additional carbon mitigation or removal. Recognised organisations in offsetting include the Gold Standard, the UN Carbon Offset Platform and the UK Woodland Carbon Code. Types of Carbon Offsets include:

- Afforestation and reforestation
- Renewables
- Community projects, for example clean cookstoves.

As can be seen below in Figure 14, afforestation and reforestation provide the greatest additional value for every tonne of CO_2 offset. The cost of offsetting 1 tonne typically varies from £1 to over £20. The World Bank's High Level Commission on Carbon Pricing[77] concluded that the explicit carbon price level consistent with achieving the Paris temperature target was between $40 and $80 per tonne. The Greater London Authority requires offsetting of residual regulated Operational Carbon emissions through Carbon Offsetting funds. This included a minimum price for offsets of £60 per tonne in 2018 which will be updated upon publication of the New London Plan to £95 per tonne[78]. UKGBC's Building the case for net zero provides more information on offsetting and uses a price of £64 per tonne.

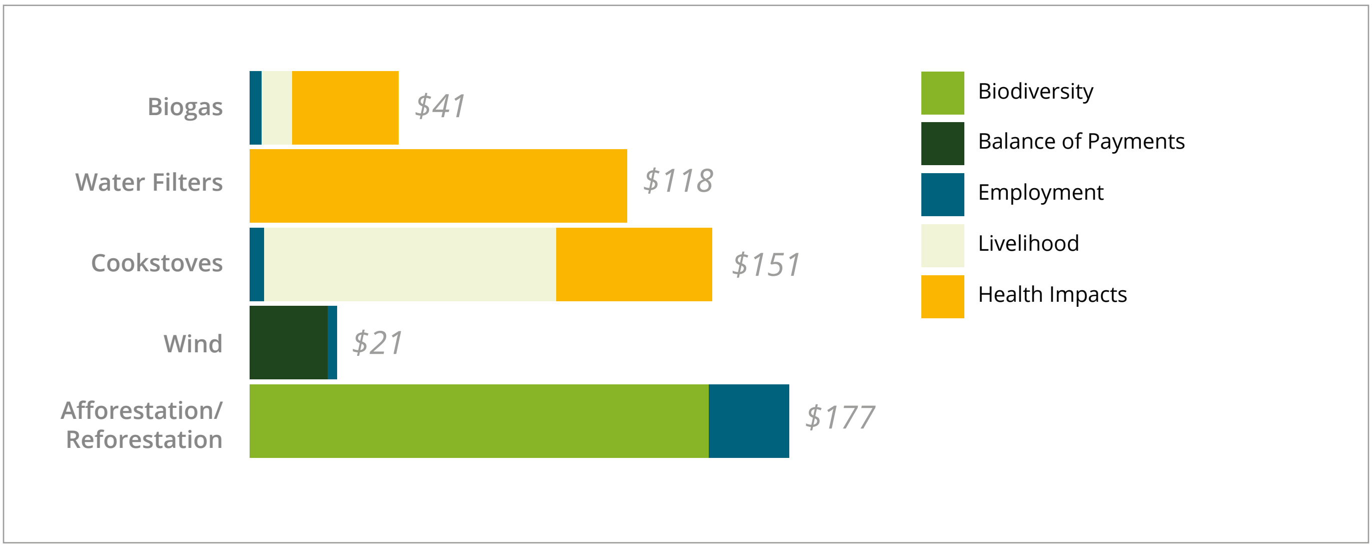

Figure 14
Financial benefits of different types of offset. Source https://www.goldstandard.org/articles/gold-standard-global-goals

[77] openknowledge.worldbank.org/handle/10986/32419
[78] www.london.gov.uk/what-we-do/planning/planning-applications-and-decisions/pre-planning-application-meeting-service-0

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* European Standards are often available in English to download at a very reasonable price from www.evs.ee/en/search

CHAPTER

07

APPROACHES TO REDUCING EMBODIED CARBON

APPROACHES TO REDUCING EMBODIED CARBON

CHAPTER 7 SUMMARY – REDUCING EMBODIED CARBON

- There are opportunities to reduce Embodied Carbon throughout the design process
- The earlier Embodied Carbon is considered, the easier it is to reduce
- Changing building form and construction type can significantly reduce Embodied Carbon
- Focus on the "hotspots" with the highest Embodied Carbon first

2013, the Green Construction Board provided an estimate of the Embodied Carbon of the UK construction industry in 2010 at 34 million tonnes CO_2e – over 50% of this impact was from materials extraction and production. Around 6% was from design services – the offices and business of architects, engineers and surveyors. 21% was from the operation of construction sites for both buildings and infrastructure - including use of site offices, heavy equipment and tools, and the production and transport of materials that are wasted. Around 9% was from the transport of construction products and of people to construction sites (The Green Construction Board *et al*., 2013).

There are various approaches to reduce Embodied Carbon dependent upon the stage of the project. Typically, those that will have the most effect will relate to very early decisions during the strategic planning stage and as the design progresses, the opportunity to reduce impact also reduces, as shown in Figure 15.

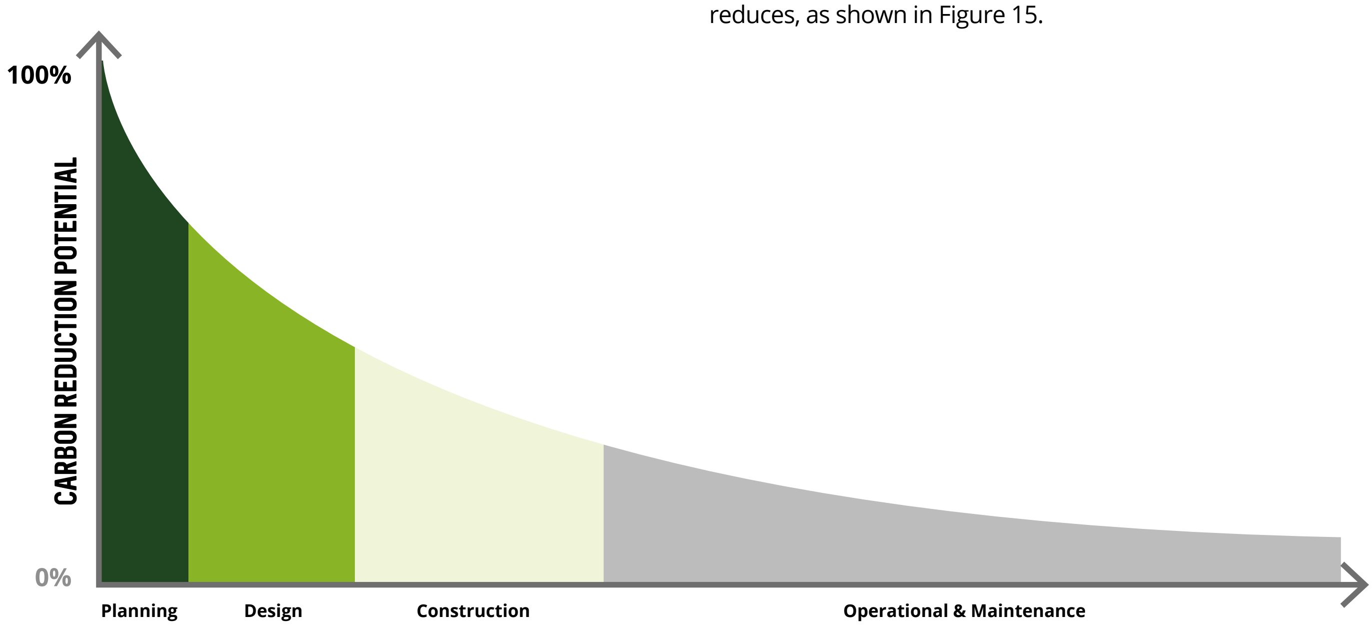

Figure 15
Carbon reduction curve

Design strategies to reduce Embodied Carbon

There are various design strategies that can affect the Embodied Carbon of a building across its entire lifecycle. Designing leaner structures by minimising the quantity of materials will reduce the energy used to make the building in the first place. Designing for future use, adaptability and flexibility, will increase a building's lifespan and minimise the need for new buildings in future. Building with deconstruction in mind will enhance the reuse of construction materials, effectively increasing their lifespan. Embodied Carbon can also be addressed by including features from the outset rather than retrofitting.

REDUCING EMBODIED CARBON

RIBA STAGES	EMBODIED CARBON REDUCTION STRATEGIES
0 STRATEGIC DEFINITION	• Consider the need for a new building • Consider reuse and retrofit of existing buildings • Reduce land used by built environment (intensification) and minimise need for infrastructure • Intensify the use of buildings – share space and uses
1 PREPARATION AND BRIEF	• Ensure embodied carbon measurement, targets and outcomes are included in the brief • Identify a carbon champion to drive carbon reduction • Consider designing for adaptability and extending building life
2 CONCEPT DESIGN	• Optimise building form and layout • Consider simple, repetitive structural solutions • Consider prefabrication/off-site manufacuring • Compare whole life carbon impacts of different building services and energy supply options • Use resource efficient construction approaches • Use resource efficient construction approaches • Consider lightweight construction • Increase biogenic carbon storage within the building • Design for deconstruction and disassembly • Report on upfront and embodied carbon at design stage
3 DEVELOPED DESIGN	• Increase use of reused and recycled materials • Use materials with lower impacts • Design out waste • Use materials which can be reused or recycled
4 TECHNICAL DESIGN	• Use products with lower impacts • Increase material efficiency • Minimise any over-specification • Design for low maintenance and easy access to shorter life or critical components • Optimise service life and durability • Ensure the tender documents clearly state the embodied carbon goals • Report on upfront & embodied carbon and justify any increase from design stage assessment
5 CONSTRUCTION	• Communicate the embodied carbon intent during tender and appointment to ensure cooperation from contractors and the supply chain • Use local materials, especially aggregate, concretes and timber • Use efficient construction processes • Monitor and reduce energy and water usage • Monitor and reduce waste arising and maximise reuse and recovery, minimise downcycling • Report on the embodied carbon impacts of any variations
6 HANDOVER/ CLOSE OUT	• Evaluate the as-built upfront and embodied carbon and include in the O&M Manual • Compare to initial assessments and identify lessons learnt • Offset whole life carbon • Ensure guidance on the operation and maintenance of the building is provided at handover • Ensure information on how to repair and replace components is provided in the O&M manual
7 IN USE	• Maintain components to optimise service life • Review actual service life data against predicted impacts • Consider embodied carbon when specifying replacements and refurbishment • Include embodied carbon in any post occupancy evaluation
END OF LIFE	• Consider retaining structure and fabric where possible • Deconstruct rather than demolish • Increase reuse and recovery of waste at end of life • Minimise downcycling of waste

Figure 16
Embodied Carbon Reduction Strategies by RIBA Stage

REDUCING EMBODIED CARBON

Changes in the building form can reduce the demand for materials - WRAP estimated that adjusting the building form to be more compact or efficient can reduce cradle to gate Embodied Carbon by up to 5%[79]. Specifying passive or mixed-mode ventilation for buildings will reduce the Embodied and operational carbon arising from MEP equipment. Designing for durability will make buildings easier to maintain and reduce the need for new construction materials. This include ensuring easy replacements of assets and designing to allow for easy reconfiguration to meet changing needs. Detailing should be life long and robust, using systems and products that have long life spans. Offsite modular systems can also be considered, but they may not always minimise Embodied Carbon.

Figure 16 summarises a wide range of reduction strategies gathered from the literature, grouped by the RIBA stage where they are most relevant.

Retrofit and Refurbishment

The previously mentioned study commissioned by Historic England (Historic England, 2019) estimated the carbon emissions associated with the retrofit of a Victorian terraced house and a comparable new build house. For the Victorian Terrace, the construction-related Embodied Carbon emissions from the retrofit works were estimated to be 1.2tCO_2e (2% of the building's total emissions over 60 years). On the other hand, the construction of a new home of the same size produces up to 13 times more Embodied Carbon than retrofit. For the New Build, 16.35 tCO_2e or 28% of building's total carbon emissions were Embodied Carbon. The retrofit also resulted in a significant reduction in Whole Life Carbon emissions compared to base case of leaving the building unchanged. Given the fact that the government policy has set carbon reduction targets for 2030 and 2050 it is worth noting the emissions on these dates. In 2030, the life cycle carbon emissions for the base-case, refurbishment and new build are 38, 16 and 27 tonnes CO_2e respectively; the equivalent figures in 2050 are 89, 36 and 42 tonnes CO_2e. Based on these figures, retrofitting existing housing would best help reach UK government policy targets.

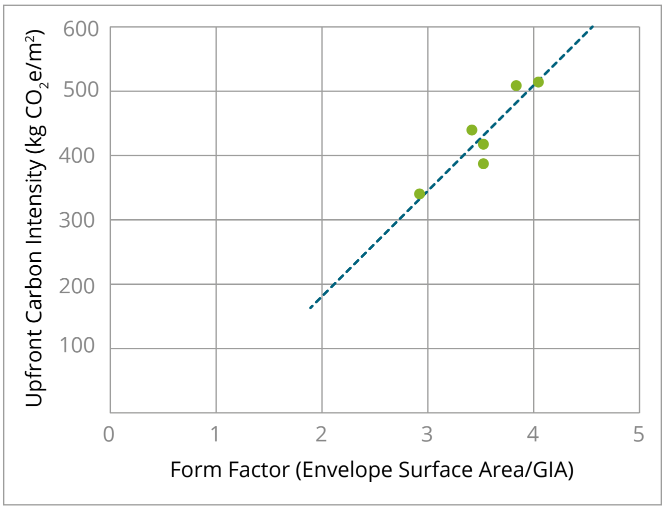

Figure 17
Form Factor v Upfront Carbon for the most common dwelling types - Gwynfaen Development. Data courtesy Stride Treglown.

"The greenest building is... one that is already built"
Carl Elefante, AIA

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

REDUCING EMBODIED CARBON

Using building form to reduce Embodied Carbon

The building form can strongly influence Embodied Carbon. Form factor compares the enclosing outer envelope area to the gross internal area (GIA)[80]. A lower number indicates a more compact building shape. In Figure 17 party walls have been included (form factor calculated as if they were detached dwellings). For Embodied Carbon, party walls and party floors, where the structure is shared with another dwelling, are more material efficient than each dwelling having its own floor or wall. The proposed dwellings at Gwynfaen have broadly similar structure and fabric, and as can be seen, as form factor increases, so does Upfront Carbon per m² - an increase in form factor of 0.5 is associated with an approximate increase in Upfront Carbon of 100 kg CO_2e/m^2. This relationship between form factor and Embodied Carbon is very similar to that of form factor and operational energy, so minimising form factor will be advantageous for both Embodied and Operational Carbon. Terraced housing and low-rise apartments generally have the lowest upfront and Embodied Carbon and detached houses and especially bungalows have the highest upfront and Embodied Carbon. High rise apartments, although having a low form factor, will often have high upfront and Embodied Carbon due to the greater structural requirements.

Material efficiency to reduce Embodied Carbon

One strategy that may be key to achieving emissions reductions is to use materials as efficiently as possible. Yet research has shown that real buildings use structural material inefficiently: Moynihan and Allwood, (2014) considered 23 buildings and 10,000 structural steel beams, and showed average utilization was 50% below their capacity. A survey of 129 engineering practitioners revealed that there is habitual over-design resulting in more expensive buildings that consume more material resource than necessary (Orr *et al*., 2019). However, this overdesign also often has the advantage that buildings can be adapted by adding more storeys or mezzanine floors, or allowing change of use.

Material choices to reduce Embodied Carbon

Building elements such as the foundations and structure represent the biggest contribution to Embodied Carbon, largely due to the amount of materials they use. Therefore, consideration of low Embodied Carbon materials, such as timber or increasing the recycled content of materials will have a positive impact. Material choice for both structure and façade are considered from very early on in the project process, from concept design. A study by Arup and WBCSD, (2012), found in the UK, material choice for the structure has been finalised during the concept stage in 40% of cases and during scheme design in 50% of cases.

Using as few materials as possible will also have an impact, and obviously save on costs. This means not over-specifying and if possible, reducing finishing details related to the aesthetics. This is where timber may have more of an appeal due to its inherent biophilic properties. Using fewer building materials can also improve the health of a space by improving indoor air quality through reduced off-gassing from volatile organic compounds or other chemicals used in common building materials.

Selecting materials with high levels of durability and low through-life maintenance (e.g. facades and fixing components which last as long as the building frame) will also aid in reducing Embodied Carbon as the likelihood of them being replaced is lower. Using reclaimed and recycled materials (for example reclaimed bricks, recycled fill, plastic drainage products with high recycled content) is also a good strategy for reducing Embodied Carbon.

WRAP[81] estimates that cradle to gate Embodied Carbon can be reduced by up to 20% by changing the specification of building elements to reduce mass and Embodied Carbon; by up to 20% by changing individual materials to lower carbon alternatives (e.g. to concrete using cement replacements such as Ground Granulated Blastfurnace Slag (GGBS), sustainably sourced timber etc); and by up to 10% by specifying materials with increased recycled content. Circular Ecology's Concrete Embodied Carbon Footprint Calculator[82] allows you to model the Embodied Carbon of up to three concrete mixtures so you can explore the impact of mix design or assess the mixes proposed by your concrete supplier. Concrete suppliers may be happy to discuss low carbon concrete solutions for your project, and larger suppliers can provide on-demand EPD or carbon footprints.

[80] www.rics.org/globalassets/rics-website/media/upholding-professional-standards/sector-standards/valuation/code-of-measuring-practice-6th-edition-rics.pdf
[81] www.wrap.org.uk/sites/files/wrap/FINAL%20PRO095-009%20Embodied%20Carbon%20Annex.pdf
[82] https://circularecology.com/concrete-embodied-carbon-footprint-calculator.html

REDUCING EMBODIED CARBON

Using timber to reduce impact

A study conducted for the Committee on Climate Change (Spear *et al*., 2019) compared the embodied impacts of the structural elements (floor, walls, roof structure) of four 4-bedroom detached houses. These were a) timber framed with brick cladding, b) timber framed with timber cladding, c) timber framed with fibre cement rainscreen cladding and d) masonry with brick cladding. d) used PU insulation and a), b), and c) used glass fibre insulation in the timber frame and PU elsewhere. Figure 18 shows that the timber framed, timber clad option has around 10 tonnes less Embodied Carbon than the masonry option, with the timber framed brick cladding option saving around 3 tonnes Embodied Carbon over a masonry option. The authors say across all housing types, 1.7-3.2 tonnes of Embodied Carbon are typically saved by using a timber structure rather than a masonry structure.

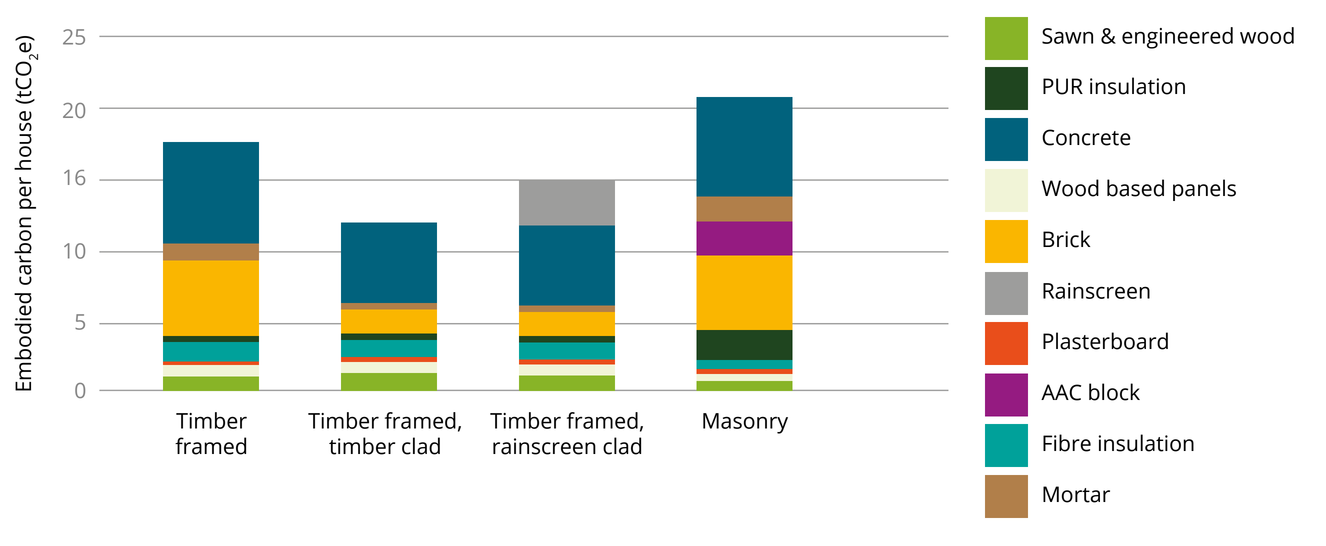

Figure 18
Comparison of Embodied Carbon for detached house with different cladding systems and structure. Source Spear et al., (2019)

In addition, the timber framed, timber clad option will store 6 tonnes more CO_2 in the building than the masonry option, with timber framed houses storing 2-4.2 tonnes more CO_2 than masonry framed houses. For Gwynfaen, Stride Treglown compared the Embodied Carbon and amount of carbon for masonry and timber alternative. The timber alternative used timber structure, cladding and wood fibre insulation; the masonry alternative used brick cladding, PIR insulation and in this study, the assessment covered the whole building (including finishes).

REDUCING EMBODIED CARBON

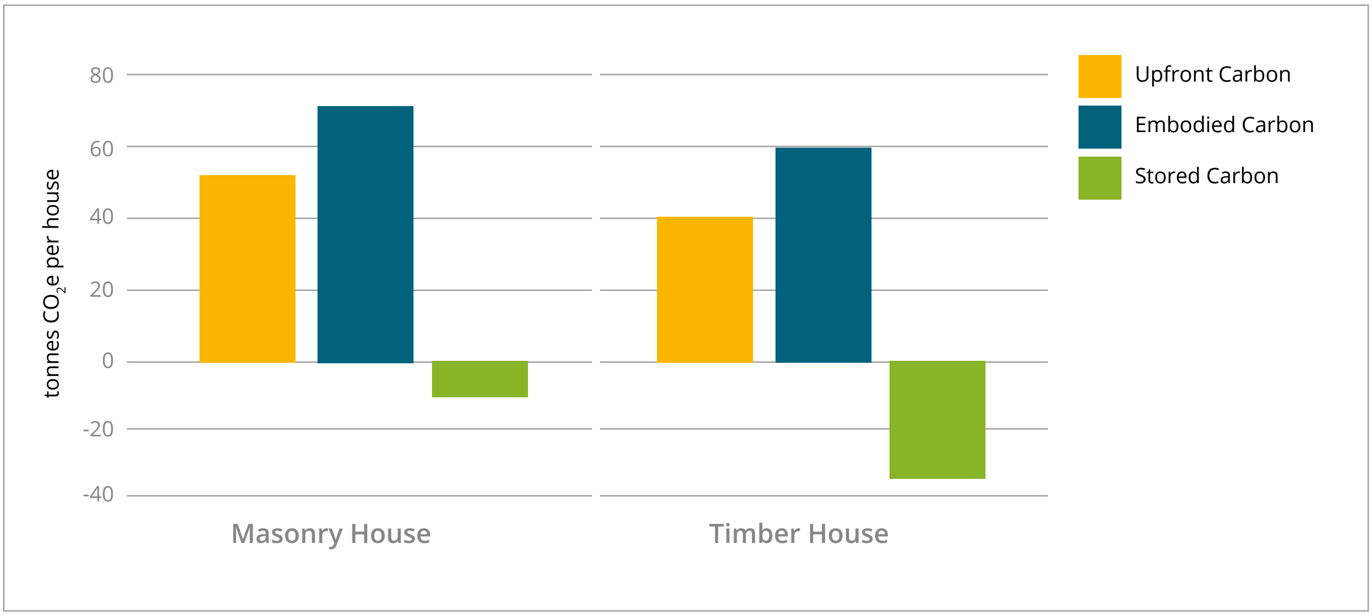

Figure 19
Comparison of masonry and timber versions of 3-bed 7-person semi-detached (Type 4) dwelling at Gwynfaen. Source Stride Treglown, (2020).

Figure 19 shows that the masonry option still includes enough timber to store 10 tonnes of Sequestered CO_2 over the life of the building – enough to compensate for 15% of its Embodied Carbon. However, the timber option stores 36 tonnes of Sequestered CO_2 – enough to compensate for 90% of its Embodied Carbon, and has a 22% reduction in Upfront Carbon and a 15% reduction in Embodied Carbon.

Reducing Embodied Carbon by element

London Energy Transformation Initiative (LETI), (2020) provide a very useful overview of approaches to reducing Embodied Carbon by element in their Embodied Carbon Primer. For sub- and super-structure, this includes comparing options at an early stage to identify an optimum solution, and specifying maximum Embodied Carbon quantities for structural components. For the envelope, they recommend considering Embodied Carbon comparisons for a typical façade bay during early design stage and using benchmarks to guide the design. For Mechanical, Electrical and Plumbing (MEP), they recommend doing detailed load assessments to ensure plant is not over-specified. For finishes, they recommend self-finishing materials such as timber to eliminate unnecessary materials. For Design for Manufacturing and Assembly (DfMA) and offsite fabrication, they recommend comparing the Embodied Carbon with traditional options, and ensuring the solutions are designed for deconstruction.

WRAP (Connaughton *et al.*, 2015) estimated the *cradle to gate* Upfront Carbon for a typical house and then looked at simple changes in material specification to reduce impact. This shows that reductions of up to 50% for some elements are easily possible, and a reduction in overall upfront impact of 25% was achieved.

REDUCING EMBODIED CARBON

Element	Base Specification	kg CO_2e/m^2	Improved Specification	kg CO_2e/m^2	Reduction
Foundations	OPC concrete	135	40% PFA concrete	115	15%
Upper floors		10		10	
Roof	Clay roof tiles	40	Concrete roof tiles	25	37.5%
External walls	Brick and block	135	Reclaimed brick PFA in blocks	65	52%
Windows & ex doors	u-PVC	43	Alu-clad timber	38	11.6%
Internal walls		13		13	
Internal doors & finishes		59		59	
M&E		40		40	
External works	Asphalt (virgin)	125	Asphalt (50% recycled planings)	120	4%
Reduced waste		0	50% reduction in waste*	-35	50%
TOTAL		**600**		**450**	**25%**

*Additional production due to wastage should be considered in A5 but has been considered in A1-A3 in this study.

Figure 20
Approaches to reducing Upfront Carbon for a typical house

Balancing Upfront, Embodied and Operational Carbon

Figure 21 shows an evaluation of differences in Embodied and Operational Carbon for housing classified by performance level (Chastas, Theodosiou and Bikas, 2016). As expected, Operational Carbon is lowest for passive houses and low energy dwellings, and highest for conventional housing, and you can see that for passive house and low energy dwellings, operational and Embodied Carbon are fairly well balanced over the building lifetime. Embodied Carbon is similar for both passive and conventional housing, but is a little higher for low energy housing. This may be due to the increased use of natural materials in passive houses due to the focus on indoor air quality.

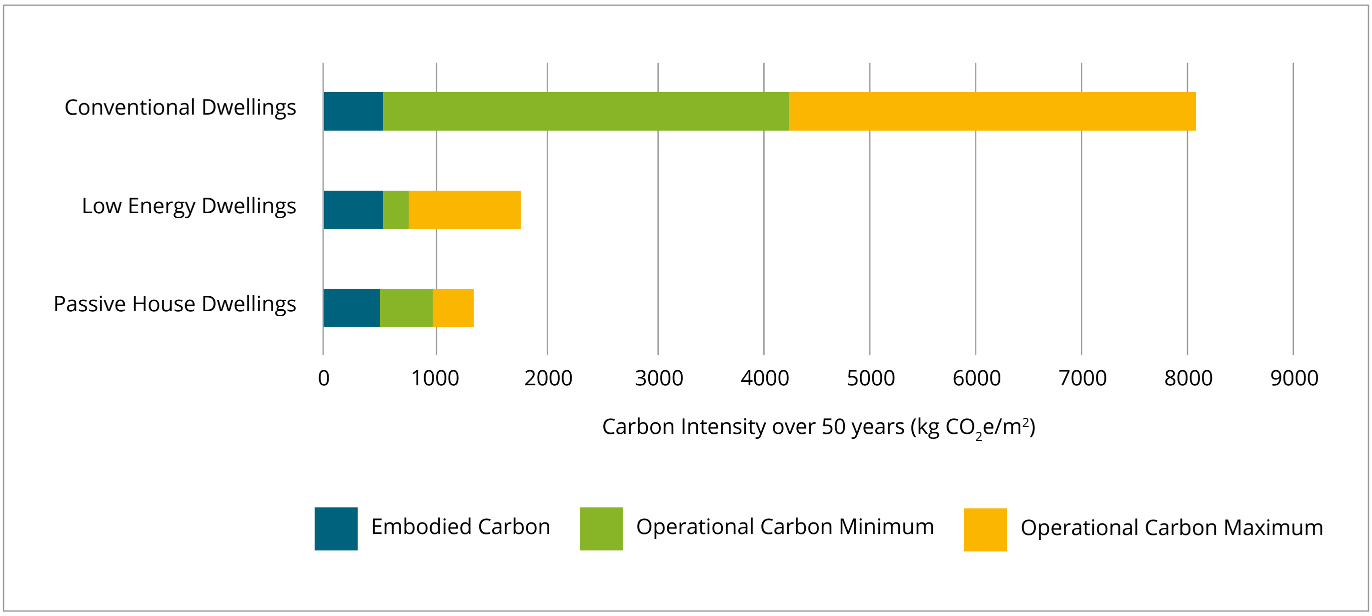

Figure 21
Range of impact over 50 years for 20 buildings classified by building performance level from Chastas et al, 2018.

REDUCING EMBODIED CARBON

Greenhouse Gas conversion factors[83]) and using the value for grid carbon provided in SAP 10.1 as representative of future grid carbon, to compare the Whole Life Carbon impact of different operational options.

At Gwynfaen, 20 m² of mono-crystalline PV and 13.5 kWh battery storage was considered. Both systems have high Upfront Carbon, and it is assumed the PV will need replacing after 30 years, and the battery after 20 and 40 years, meaning that embodied impacts over 60 years are around 200 kg CO_2e/m^2 higher. However, the PV generates electricity amounting to 56% of calculated annual energy demand, reducing the need for grid electricity, and the battery can be used to store PV electricity when the house does not need what is generated.

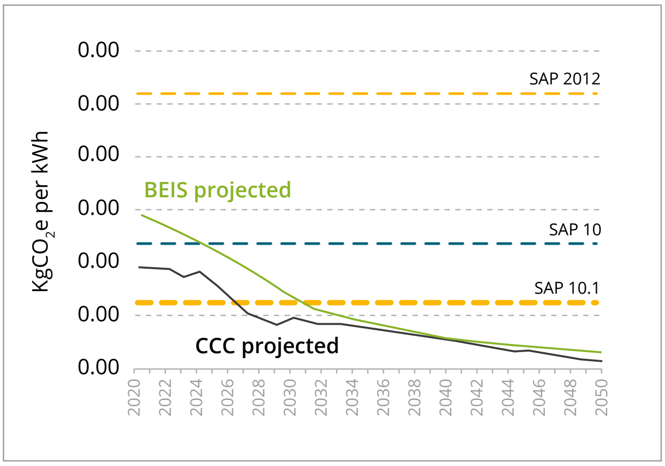

Figure 22 UK Grid Electricity emissions from various sources

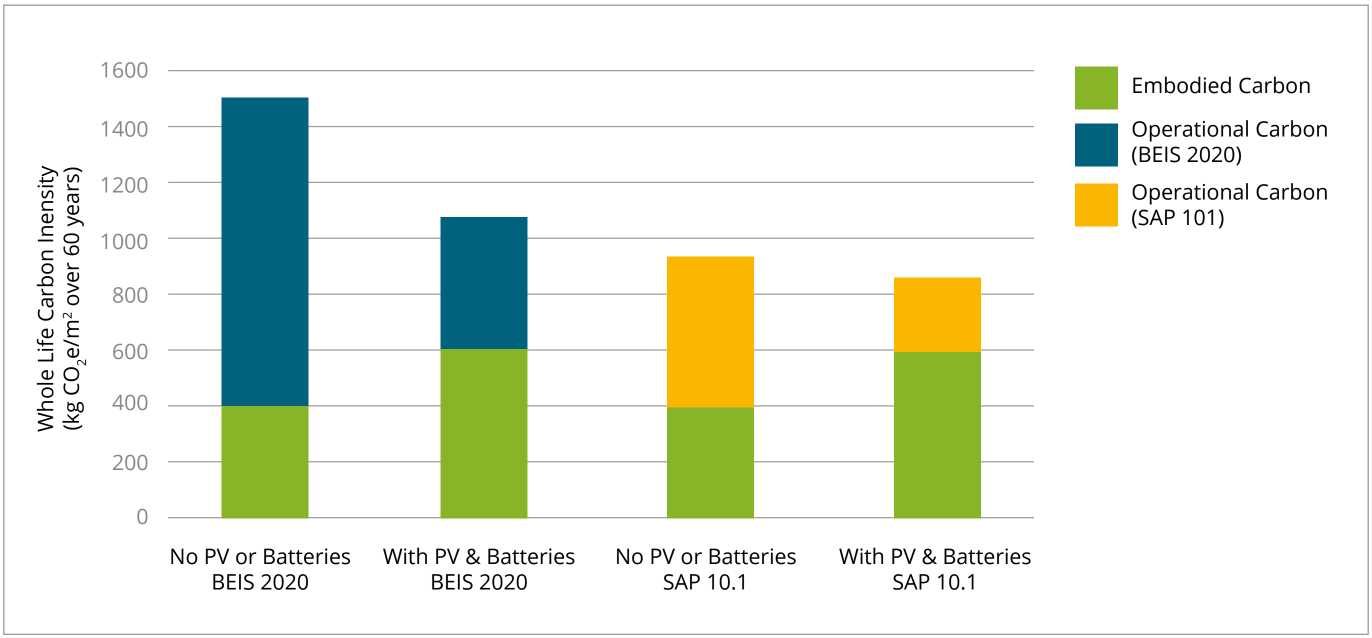

Figure 23
Comparison of Whole Life Carbon for different options for a 3-bed 7-person semi-detached (Type 4) Dwelling at Gwynfaen. Data courtesy of Stride Treglown

It can be seen that with both grid carbon factors, the option with PV and batteries saves Whole Life Carbon, though the savings using the SAP 10.1 factor are lower.

Reducing Embodied Carbon from transport

The type of transportation can also have an effect on the Embodied Carbon particularly if it is being transported long distances and coming from overseas – long haul air freight is 79 times more impactful than container shipping (see Figure 24) though construction products are very rarely moved by air. But moving a tonne of goods in an articulated lorry has almost one kg CO_2 impact per 10 km travelled – a tonne of goods would need to travel 50 km in a container ship to have the same impact.

[83] www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2020

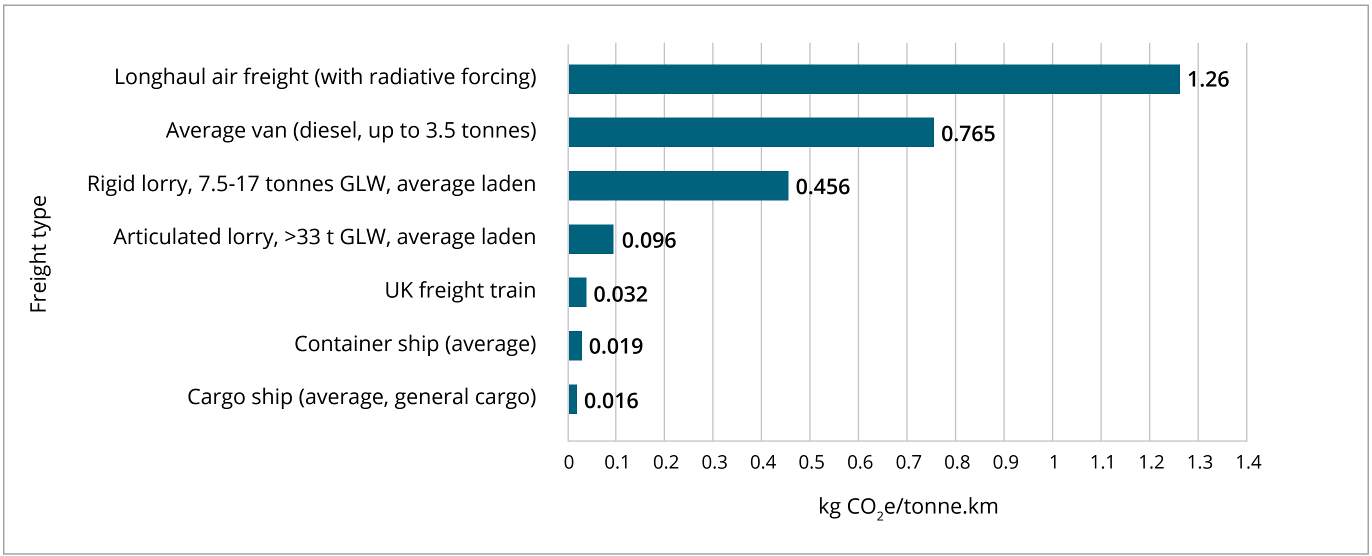

Figure 24
Relative carbon intensity of different transport types (BEIS & DEFRA, (2020))

Manufacturing impacts are generally much higher than transport impacts, other than for very low impact materials like aggregates and concrete. For recycled or reused materials, it is especially important not to transport them too far otherwise they will have more impact than the virgin material (see Figure 25). Sourcing locally where feasible will therefore have a positive effect on the transportation impacts but it is sensible to try to compare the manufacturing impacts (Modules A1-A3) for products, alongside the impact of transport to site (Module A4) to ensure that the optimal solution is selected. Experience on BedZED showed that by simply choosing the most local supplier for standard products, haulage of materials can be reduced significantly compared with national average haulage distances recorded by BRE. At BedZED, the total Embodied Carbon of all construction materials was reduced by 2% through local sourcing (Lazarus, 2005).

Maximum transport distances for reclaimed materials to have environmental benefits over new

Material	Distance (miles)
Tiles	100
Slate	300
Bricks	250
Aggregates	150
Timber	1000
Steel products	2500
Aluminium products	7500

Figure 25
Maximum transport distances for reclaimed materials from The BRE Green Guide to Specification

REDUCING EMBODIED CARBON

Reducing Embodied Carbon through Construction Practices

During construction it is important to work as efficiently as possible to reduce material and energy usage and wastage (see Table 4). This can include specifying work procedures and methods that avoid waste such as implementing Just-in-Time delivery to avoid over-ordering, using appropriately sized vehicles to avoid half full deliveries. Energy efficient site offices can be used and ensure that lights and energy consuming equipment are switched off when not in use and consider supplying the construction site with renewable energy. Surplus products could be returned to the supplier or reused on other projects or given to the community. Offcuts depending on their size and shape could also be reused or donated to other projects and groups. Waste should be segregated to ensure high levels of recovery, with minimal waste being landfilled. Prefabricating components off site can reduce waste and transport emissions.

Use energy efficient site offices and ensure that lights and energy consuming equipment are switched off when not in use, and consider supplying the construction site with renewable energy.

Waste generated per 100m² (project wide gross internal floor area (GIFA) for new build residential projects

m³ per 100m²	Tonnes per 100m²	Credits
≤ 13.9	≤ 8.5	2
≤ 8.1	≤ 4.9	4
≤ 4.8	≤ 2.9	6
≤ 3.5	≤ 1.9	8

Note - Volume (m³) is actual volume of waste (not bult volume)

Type of waste	% diverted from landfill (by Volume)	% diverted from landfill (by Tonnage)	Credits
Construction	70%	80%	2
Demolition	80%	90%	
Construction	85%	90%	4
Demolition	85%	95%	

Figure 26
HQM credits for site waste (BRE, 2015)

The following figure can be used as an average for building construction site emissions, in the absence of more specific information[84]: 1400 kg CO_2e/£100k of project value or 50 kg CO_2e/m². The cost figure is based on the date of the publication, March 2015, and should be adjusted to current value in accordance with CPI. Average data from contractors' site emissions monitoring suggest similar levels of construction emissions. This rate should be refined by substitution with site monitoring data provided by the project contractor as these become available.

WRAP estimate that reducing wastage from baseline to good practice levels for 10 key materials can reduce building impact by up to 10%.

[84] Wrap Net Waste Tool Retrieved May 1, 2016, from nwtool.wrap.org.uk taken from (De Wolf, Pomponi and Moncaster, 2017)

REDUCING EMBODIED CARBON

Good Practice Wastage from WRAP NetWaste Tool 2008	
15%	Plasterboard
10%	Bricks, rolled soft flooring
5.5%	Sand and Gravel
5%	Blocks, tiles and ceramics, stone, rebar, timber, insulation, structural waterproofing, boarding, tiled cladding
4%	Precast beam and block
2.5%	Surfacing materials, in-situ concrete and screed, aluminium, glass, gypsum products, doors, windows and curtain walling
2%	Soft floor tiles, plastic
0%	Precast concrete, structural and roofing frames, piling

Table 4
Good Practice Wastage Rates for common construction products

Reducing Embodied Carbon during the use stage

Many of the design and material choice decisions will affect Embodied Carbon in-use, which is largely minimised by ensuring that products last as long as intended, and replacement is kept to the minimum. A proactive maintenance, servicing and repair strategy will assist with this. Systems with high maintenance requirements or which need frequent replacement should be avoided. Ultra-high-tech equipment that offers only marginal energy savings in use may not warrant the savings when including Embodied Carbon.

A Danish study by Rasmussen, Birkved and Birgisdóttir, (2020) compared a reference house with three alternatives over a 120 year building life. The Upcycle house, which focussed on reused materials and materials with high recycled content with a timber structure, saved 40% Embodied Carbon over the building lifetime.

The Maintenance Free House with long life components which will need few or no replacements over the building lifetime, saved 30% Embodied Carbon.

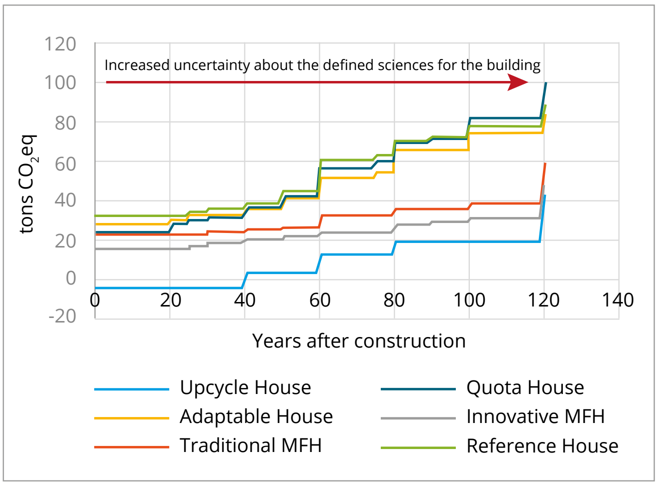

Figure 27
Case Study from (Rasmussen, Birkved and Birgisdóttir, 2020)

The Adaptability House which is easy to rearrange and extend, and is designed for disassembly, had a 17% saving in Embodied Carbon.

Reducing Embodied Carbon at end of life

Whilst end of life should be a long way into the future for buildings that are built today, this is not always the case. Buildings may also need to be demolished to make way for new housing. Therefore, consideration should be given at this stage for demolition materials to be reused into new construction, preferably in the same site or reused and recycled off site. Efficient demolition equipment should also be used.

REDUCING EMBODIED CARBON

Cost implications of reducing upfront and Embodied Carbon

Building the Case for Net Zero (UK Green Building Council, 2020) investigated how new buildings can be designed to reach performance targets covering both operational energy and Upfront Carbon and the effect this has on cost. A "business as usual" design for a 18-storey residential block providing 208 apartments was redesigned to meet intermediate targets (energy intensity of 70 kWh/m2/year and Upfront Carbon of 500 $kgCO_2e/m2$ based on the LETI/RIBA 2025 targets) and stretch targets (35 kWh/m2/year and Embodied Carbon of 350 $kgCO_2e/m2$ based on the LETI/RIBA 2030 targets).

The changes to address both operational and Upfront Carbon targets resulted in an increased cost of 3.5% to meet the intermediate target and 5.2% to meet the stretch targets. Of this, changes to specifically address the Upfront Carbon impact increased costs by 0.7% to meet the intermediate target and 2.1% to meet the stretch target.

One Brighton was a residential development which aimed to meet ten One Planet Living principles. The development had an Embodied Carbon of 382 $kgCO_2e/m^2$, a 25% reduction in their benchmark performance for new housing and reduced Operational Carbon emissions by 60%. Although there were increased costs for aspects such as PV and biomass boilers, the car-free development was able to increase the number of apartments from 80 to 172 because of this, and the costs were considered mainstream, with better yields and sale values than similar apartment buildings in Brighton due to the sustainability features provided[85].

Outside the residential sector, Anglian Water has demonstrated between 30%-50% capital cost savings by tracking Embodied Carbon[86], and SusCon, a training and research centre for Prologis in Kent, had 30% lower Embodied Carbon than similar buildings, and 87% lower Operational Carbon emissions, without significant extra cost[87].

[85] One Brighton One Planet Annual Review 2007-2014 Available from https://storage.googleapis.com/www.bioregional.com/downloads/One-Brighton-Impact-Report-2014-17.pdf
[86] UKGBC & Crown Estate (2015), Tackling embodied carbon in buildings, available from www.ukgbc.org/sites/default/files/Tackling%20embodied%20carbon%20in%20buildings.pdf
[87] www.theguardian.com/sustainable-business/best-practice-exchange/prologis-inspiring-low-carbon-buildings

REDUCING EMBODIED CARBON

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CHAPTER 08

BENCHMARKING EMBODIED CARBON

BENCHMARKING EMBODIED CARBON

CHAPTER 8 SUMMARY – BENCHMARKING EMBODIED CARBON

- **Benchmarks at either building or element level are a useful way to check performance**
- **Elemental benchmarks can be used to estimate impact at early design stages**
- **Check the scope and type of benchmarks – they can vary**

Types of benchmarks

Benchmarks for Embodied Carbon are provided in various ways: most are 'per m²' of floor area (normally measured as gross internal area (GIA), though some for housing may be 'per dwelling' or 'per occupant', and occasionally they are provided per m² per year. The scope of benchmarks is also relevant, some cover the full life cycle of a building (Whole Life Carbon) or exclude operation (Embodied Carbon), others may just be for the materials production (cradle to gate) or through to completion on site (Upfront Carbon). It is also important to check how much of the building is included in the benchmark – some may cover all elements of the building and its site, but others may only include the superstructure and fabric for example.

Some benchmarks show the range of Embodied Carbon for a particular building type such as housing, sometimes split into quartiles; some set a maximum - 'limit' – value; some set a 'target' value, that you should aim to achieve; and some set a 'reference" value – the average, which you should aim to beat. Benchmarks can be developed by reviewing a wide group of buildings, or by assessing an archetypal building or buildings.

Benefits of different types of benchmarks

Per m² benchmarks provide the overall performance of the construction; for housing per occupant or per dwelling benchmarks mean that an efficient use of space is also considered alongside construction, but per dwelling benchmarks need to be used cautiously as 4 bedroom houses will have more impact than 2 bedroom houses due to their increased floor area for example.

Upfront Carbon benchmarks focus on the impacts that are occurring currently, and which have a direct effect on our ability to keep within our emissions budget and limit climate change to 1.5° - Upfront Carbon targets and reported values should normally exclude sequestered carbon (as required by the RICS Professional Statement on Whole Life Carbon). Embodied and Whole Life Carbon benchmarks will account for Embodied Carbon over the full life cycle, so can account for durability and low maintenance designs, at impacts at the end of life. In Embodied and Whole Life Carbon assessments, carbon sequestration for biomass based products in the production stage should be balanced by emissions and transfers of biogenic carbon at end of life.

Benchmarks given for different archetypes such as bungalows, detached houses and terraced houses show the reduced impacts per m² of terraced houses, where the construction of the separating walls is shared with the adjacent houses, reducing impact; and the higher impacts for bungalows due to their increased share of ground floor and roof fabric per m² of floor area. This is described more in the section on *Using building form to reduce Embodied Carbon*.

BENCHMARKING EMBODIED CARBON

Cradle to Grave Embodied Carbon Benchmarks

For the UK, the Movement for Innovation (M4i) provided an 'environmental performance indicator' for the cradle to grave Embodied Carbon of UK domestic dwellings (both apartments and houses) in 2001[88]. This provided four colour coded ranges as shown in Figure 28, 'green' representing the range for best 25% (quartile) from the data set, 'red' representing the range for the 'worst' 25%, yellow and amber representing the middle quartiles. The measure was the total greenhouse gas that has been emitted of a 60-year life of the building, and was estimated based on calculations using specifications from the Green Guide to Housing. From this you can see that an Embodied Carbon impact below 400 kg CO_2/m² would put you in the top 25% of performance, and below 650 kg CO_2/m² would put you in the best 50% of performance for residential construction generally.

RIBA used this M4i document as the basis for its 2030 Climate Challenge Targets for residential buildings, which are <600 kg CO_2e/m² for 2020 reducing to <450 kg CO_2e/m² in 2025 and <300 kg CO_2e/m² by 2030 covering Embodied Carbon, Modules A-C.

A number of countries such as France and Switzerland have set benchmarks for Embodied Carbon of housing. Targets have also been included in sustainable building certification schemes such as DGNB, and in planning guidance for London proposed by GLA. Studies have also reviewed the Embodied Carbon of large numbers of dwellings. These are shown in Figure 30.

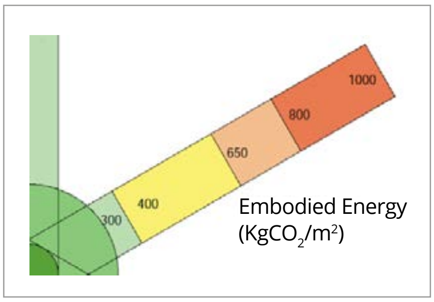

Figure 28
M4i windrose for Embodied Carbon of residential construction

This shows the range of existing benchmarks (of various types, and for different types of residential building) for Embodied Carbon over the whole life cycle. From this you can see that most existing benchmarks for low-rise housing are already well below the RIBA 2020 benchmark of 600 kg CO_2e/m². The aspirational benchmark provided by the GLA, and the benchmarks in France and Denmark for apartments are all 800 kg CO_2e/m² or less.

As part of the development of this guidance, we have reviewed Embodied Carbon assessments of a number of Welsh housing projects currently in design stage, shown in Figure 29. These are undertaken, as recommended in the RICS Professional Statement on Whole Life Carbon, per m² gross internal area (GIA), which is the area of the building measured to the internal face of the perimeter walls at each floor level[89]. Note that using different measurement metrics for the building area will result in different values.

[88] Movement for Innovation, 2001. Sustainable Working Group Report: Environmental performance indicators for Sustainable Construction. M4i, London. http://158.132.155.107/posh97/private/research/references-construction-safety/EPI-sustainable-construction.pdf
[89] www.rics.org/globalassets/rics-website/media/upholding-professional-standards/sector-standards/valuation/code-of-measuring-practice-6th-edition-rics.pdf

BENCHMARKING EMBODIED CARBON

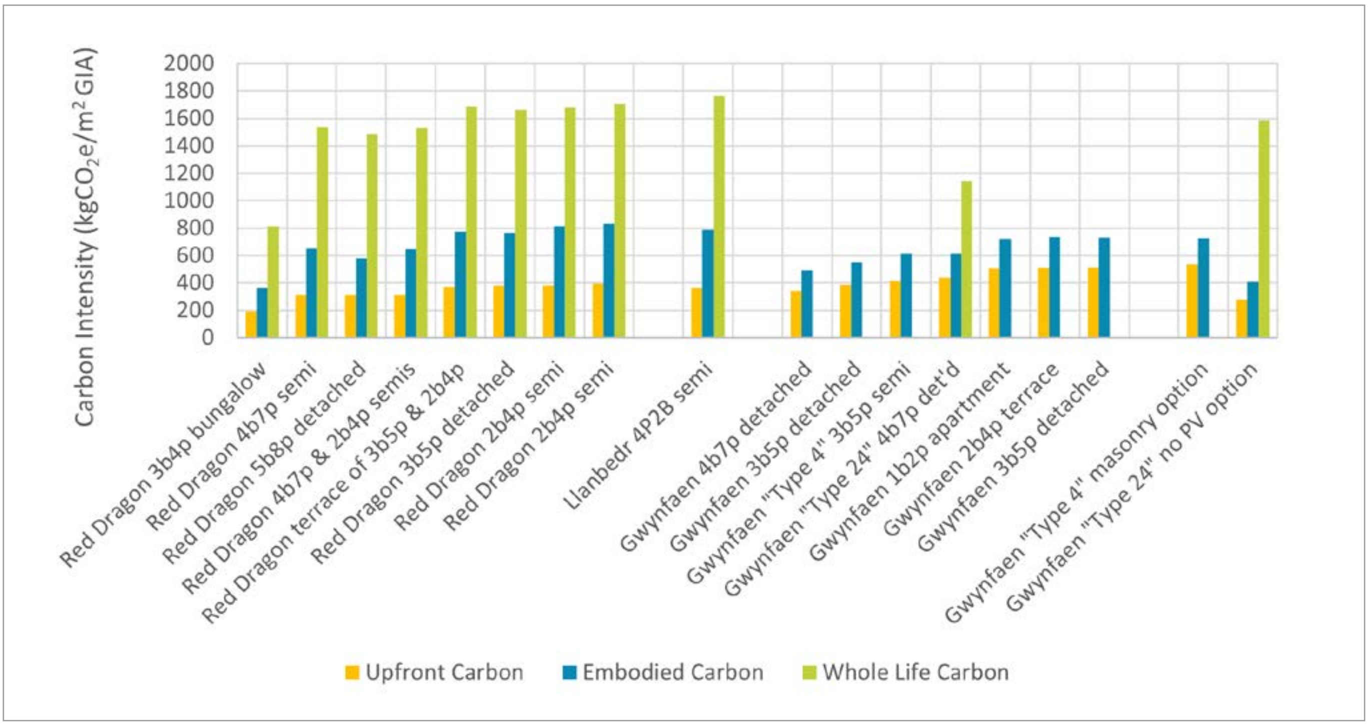

Figure 29
Upfront, Embodied and Whole Life Carbon Intensity for the Welsh Case Study dwellings, Red Dragon, Llanbedr and Gwynfaen.
Data for Gwynfaen courtesy of Stride Treglown.

BENCHMARKING EMBODIED CARBON

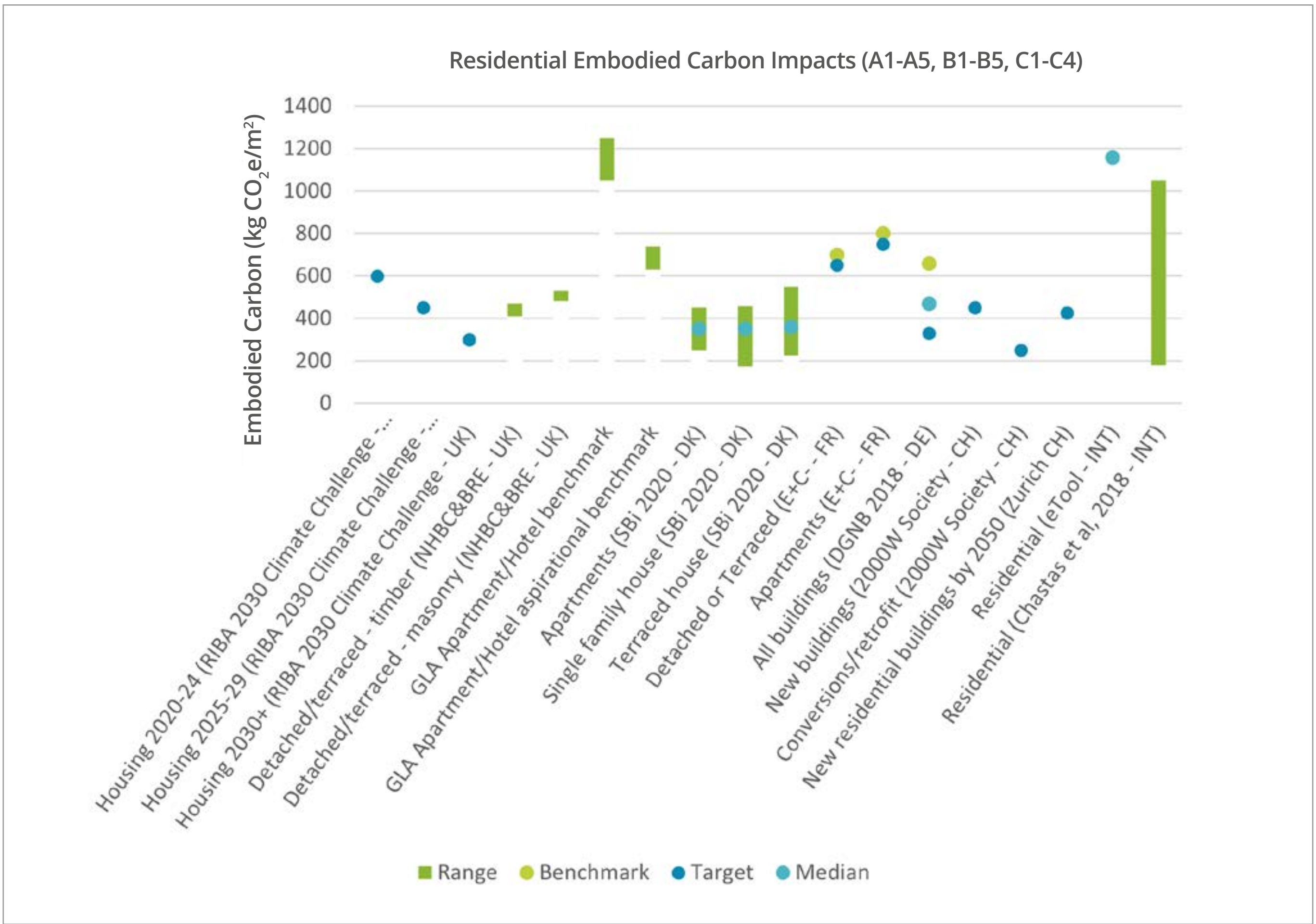

Figure 30
Embodied Carbon benchmarks from literature. For sources, see footnote[90]

[90] RIBA (2019) RIBA 2030 Climate Challenge. London.
NHBC/BRE study, 2011 www.nhbcfoundation.org/publication/operational-embodied-carbon/
GLA 2020, Draft whole lifecycle carbon assessments guidance, GLA. www.london.gov.uk/sites/default/files/wlc_guidance_april_2020.pdf
SBi 2020: Chastas, P., Theodosiou, T. and Bikas, D. (2016) 'Embodied energy in residential buildings-towards the nearly zero energy building: A literature review', Building and Environment. Pergamon, 105, pp. 267–282. doi: 10.1016/J.BUILDENV.2016.05.040.
DGNB (2020) ENV1.1 Building Life Cycle Assessment Software. Stuttgart. Available at:
https://static.dgnb.de/fileadmin/dgnb-system/en/buildings/new-construction/criteria/02_ENV1.1_Building-life-cycle-assessment.pdf

BENCHMARKING EMBODIED CARBON

Upfront Carbon Benchmarks

In 2010, Geoff Hammond and Craig Jones estimated the cradle to site “upfront” carbon impact of typical new build UK house types based on their typical floor areas from the English House Condition Survey of 2001, as shown in Table 5 below (Hammond and Jones, 2010). This measure of Upfront Carbon excludes Sequestered Carbon. These estimates exclude any external works (conservatories, driveways, paths, garages etc) for which they give estimate of impact per m² habitable floor area.

Building type	Typical Floor Area (m²)	ECO_2e (tonnes)	ECO_2e/m² habitable floor area
Apartment 3 storey	50	24	480
Apartment 4 storey	50	23	460
Terraced house	68	25	370
Semi-detached house	73	31	425
Bungalow (detached)	76	47	620
Detached house	125	51	410
External works	n/a	n/a	135-177

Table 5:
Upfront Carbon for UK new build house types, sourced from Hammond & Jones, 2010

LETI provided Upfront Carbon targets for residential buildings of 500 kg CO_2e/m² (excluding Sequestered Carbon) and 400 kg CO_2/m² including Sequestered Carbon for 2020, reducing to 300 kg CO_2e/m² and 200kg CO_2e/m² respectively by 2030 (London Energy Transformation Initiative (LETI), 2020).

Republique Francaise (2018) Bâtiment à Énergie Positive et Reduction Carbone. Available at: www.batiment-energiecarbone.fr/fr/
Zimmermann, R. K. et al. (2020) SBi 2020:04 Klimapåvirkning fra 60 bygninger Muligheder for udformning af referencevaerdier til LCA for bygninger. Kongens Lyngby: Polyteknisk Boghandel og Forlag ApS.
2000W see above,
Zurich
https://etoolglobal.com/eblog/engineering/etool-international-residential-benchmark-methodology-summary/
Chastas, P., Theodosiou, T. and Bikas, D. (2016) ‘Embodied energy in residential buildings-towards the nearly zero energy building: A literature review’, Building and Environment. Pergamon, 105, pp. 267–282. doi: 10.1016/J.BUILDENV.2016.05.040.

BENCHMARKING EMBODIED CARBON

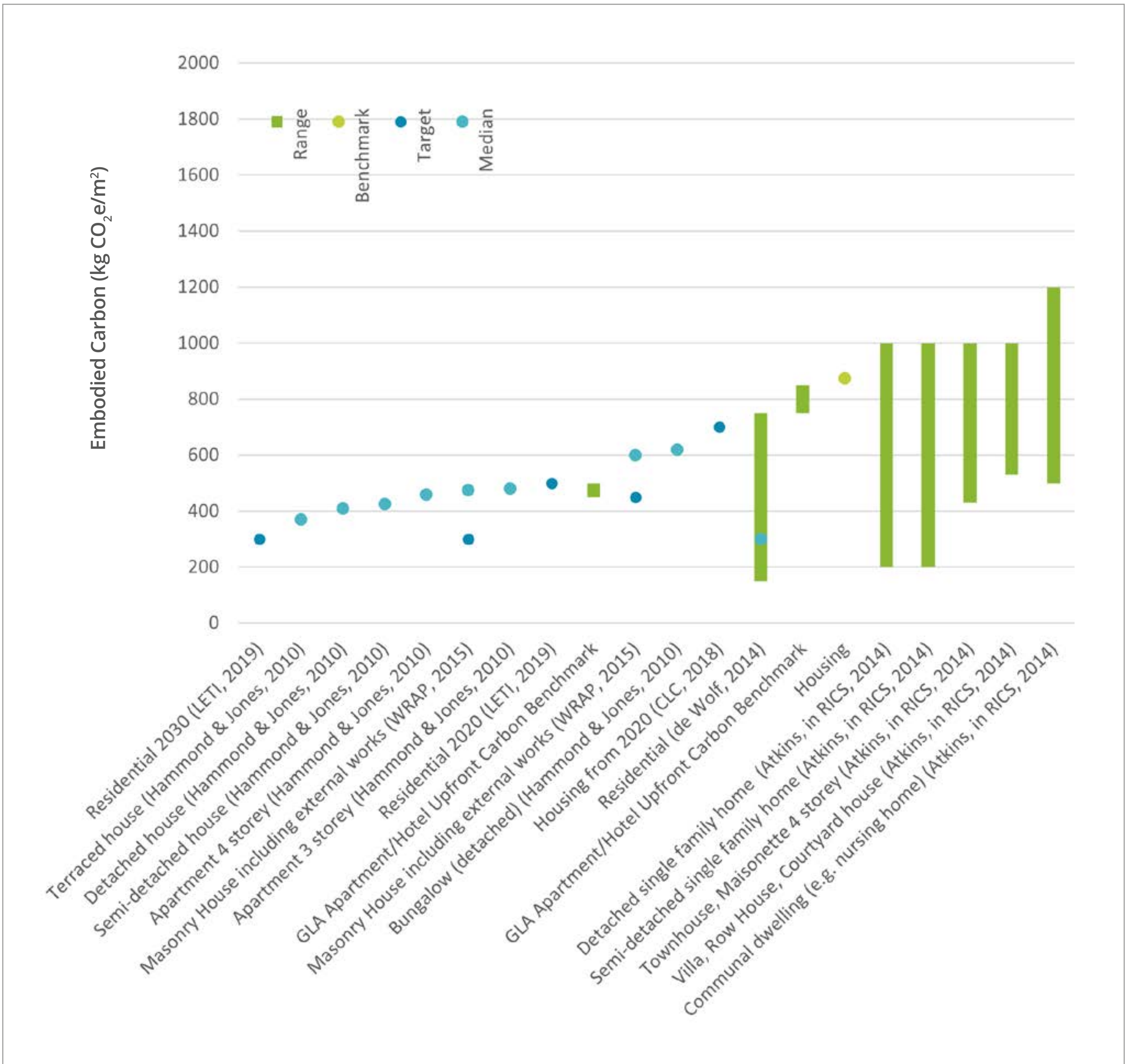

Figure 31
Upfront benchmarks from literature. For sources, see footnote[91]

[91] LETI, 2019. Embodied Carbon Primer.
Wrap, 2015: WRAP, Cutting embodied carbon in construction project, 2015.
www.wrap.org.uk/sites/files/wrap/FINAL%20PRO095-009%20Embodied%20Carbon%20Annex.pdf
CLC, 2018: Construction Leadership Council Smart Construction Dashboard (2018) www.constructionleadershipcouncil.co.uk/building-metrics/
C. De Wolf, 2014, Material Quantities in Building Structures and Their Environmental Impact, Department of Architecture, Massachusetts
Atkins in RICS, 2012: Atkins Carbon Critical Masterplanning Tool, 2010. Reproduced with permission from Atkins, in RICS, Methodology to calculate the embodied carbon of materials, RICS Information Paper IP 32/2012, 2012.
www.igbc.ie/wp-content/uploads/2015/02/RICS-Methodology_embodied_carbon_materials_final-1st-edition.pdf

BENCHMARKING EMBODIED CARBON

Benchmarks by building type (detached/terraced/bungalow/apartment etc).

As Figure 32 shows, the impact of high-rise residential buildings is generally higher than that of low-rise housing. Detached housing also has higher impacts than semi-detached housing, with terraced housing and low-rise apartments having the lowest impacts, as much of the building fabric and structure is shared between dwellings.

Woodknowledge Wales Case Study performance

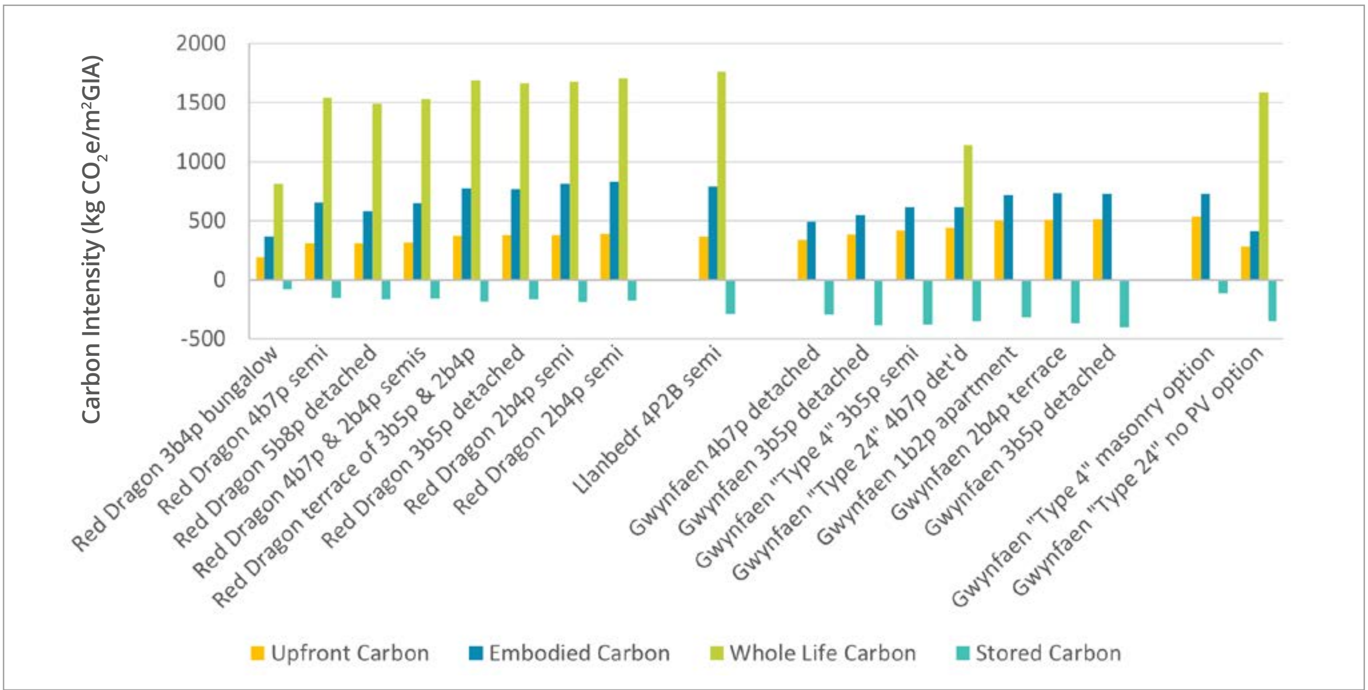

Figure 32
Upfront, Embodied and Whole Life Carbon and Stored Carbon over 60 years, per m², for the Woodknowledge Wales Case Studies, Red Dragon, Llanbedr and Gwynfaen. Data for Gwynfaen courtesy of Stride Treglown.

Figure 32 shows the impacts of the various houses which have been assessed and reviewed as part of this project for Woodknowledge Wales[92]. All the houses have been funded through the Innovative Housing Programme and use a timber structure. The facades vary from timber to render or masonry. They have been designed to have a high thermal performance and use PV to provide energy. The PV (and battery storage in the case of Gwynfaen) increase the upfront and embodied impact of the houses. The house types include bungalows, low-rise apartments, terraced, semi-detached and detached houses.

The assessments have been carried out at RIBA stages 3 and 4 (the developments were being tendered at the time of writing) using eTool (Red Dragon and Llanbedr) and One Click LCA (Gwynfaen). For all developments, the design and specification of the main elements was largely complete when the assessments were undertaken, and no attempt to reduce impact was made due to the lack of time before tendering for Design and Build contractors. The assessments cover all elements of the building apart from external works, and generally use RICS defaults. Module D has not been reported here. For Red Dragon and Llanbedr, the end of life of timber has been assumed to be incineration so there is a biogenic carbon balance over the life cycle.

The Upfront Carbon (excluding biogenic carbon) is generally at or below 500 kg CO_2e/m², and the Embodied Carbon at or below 800 kg CO_2e/m² for all options. Removing the PV and batteries for Gwynfaen reduces Embodied Carbon for the Type 4 dwelling from just over 600 kg CO_2e/m² to 400 kg CO_2e, but the Operational Carbon increases considerably and the Whole Life Carbon for the "No PV" option is nearly 400 kg CO_2e/m² higher over the 60-year lifetime (using the SAP 10.1 emission factor for electricity).

[92] https://woodknowledge.wales/special-feature/google-map-highlights-some-timber-frame-projects-in-wales

BENCHMARKING EMBODIED CARBON

Element Benchmarks

Figure 33 shows the expected range of Embodied Carbon impact per m² over 60 years for different external wall options for residential buildings, derived from data on Embodied Carbon per m² for different specifications provided in the Green Guide to Specification (Anderson *et al.*, 2009).

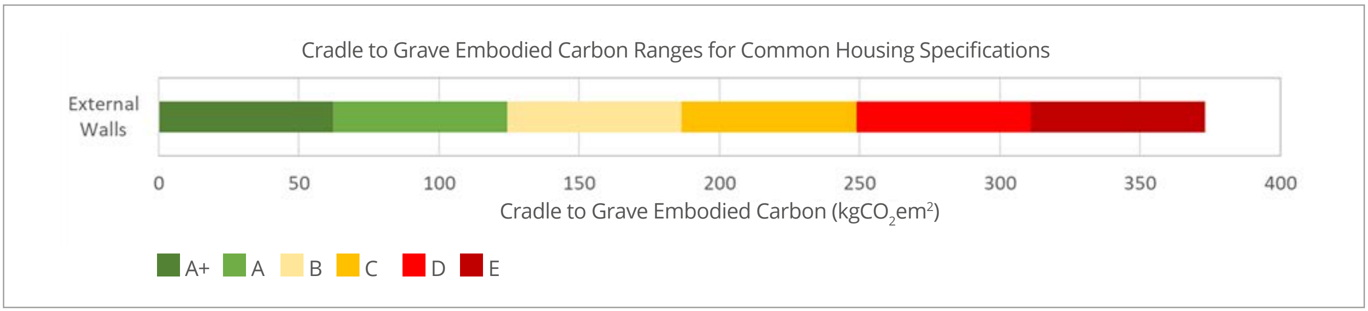

Figure 33
Green Guide to Specification range for Residential External Walls (derived from Anderson et al, 2009).

Figure 34 provides similar element benchmarks calculated cradle to grave for residential buildings in Switzerland over a 60-year life. This study also includes an additional range for building technical equipment (MEP or building services) of 1.18-3.15 kg CO_2e/m² of floor area per year.

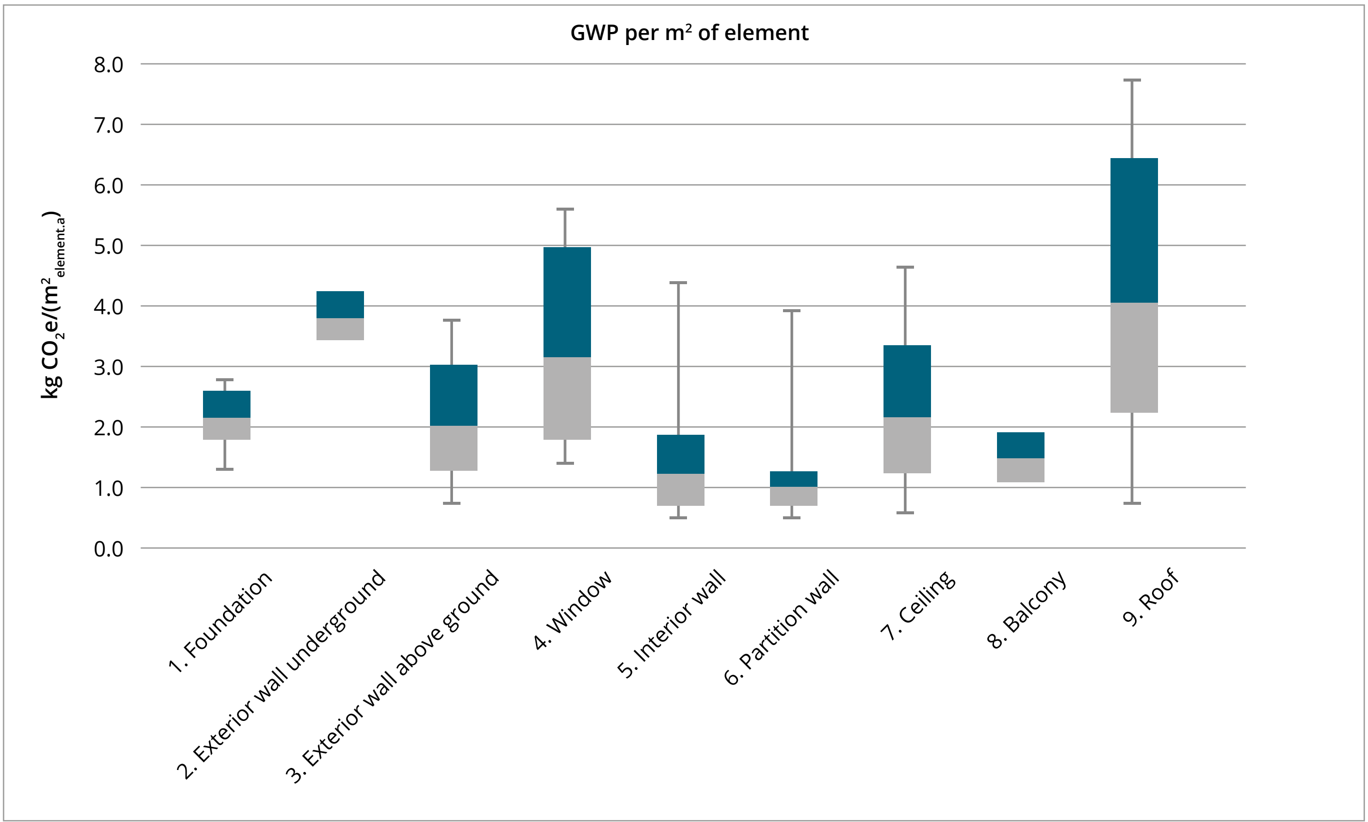

Figure 34
Swiss Cradle to Grave Benchmarks per m² of element from Hollberg et al, 2019, assuming a 60-year building life. Building technical equipment 1.18-3.16kg CO_2e/m²(GIA).

BENCHMARKING EMBODIED CARBON

Case Study
Elemental Analysis

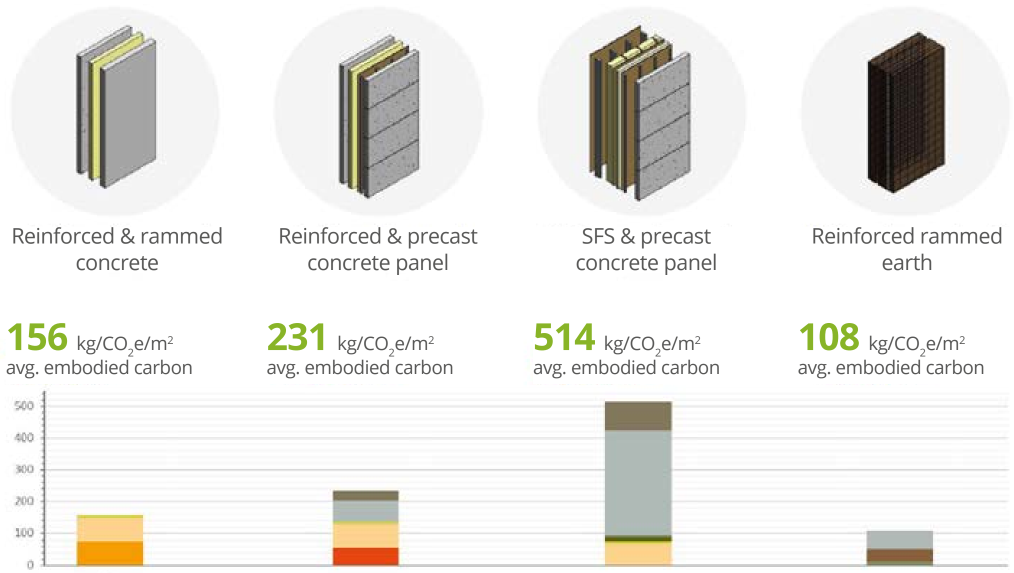

Figure 35
Examples of facades with similar aesthetics and functionality but very different embodied carbon, from H\B:ERT presentation, 2019

Figure 35 shows the calculated embodied impacts made by Hawkins Brown using their H\B:ERT tool. The assessment covers four different façade options with similar appearance and functionality, but very different Embodied Carbon per m². Comparing impacts to a benchmark range like the Green Guide, or to different options provides an easy way to see how the detailed designs for different elements are performing.

Providing results of assessments to WKW and RICS to improve benchmarking

If you are able to share the results of future assessments with WKW, it will enable the provision of more accurate benchmarks for different housing archetypes in Wales in the future.

The RICS also manages the RICS Building Carbon Database https://wlcarbon.rics.org/Default.aspx (previously known as the WRAP Embodied Carbon Database) which anonymises Embodied Carbon data submitted by users to enable benchmarking. Adding assessments to the RICS Building Carbon Database will increase the population of Embodied Carbon data with which to produce robust benchmarks for all building types in the UK.

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WOODKNOWLEDGE WALES' RECOMMENDATIONS FOR ASSESSMENT, REPORTING AND BENCHMARKING OF EMBODIED CARBON

CHAPTER

09

WKW RECOMMENDATIONS FOR ASSESSMENT

CHAPTER 9 SUMMARY – WKW RECOMMENDATIONS FOR ASSESSMENT

- **Developments should aim to achieve the WoodKnowledge Wales targets for Upfront Carbon, Embodied Carbon and Energy Use Intensity**
- **Upfront, Embodied and Whole Life Carbon should be reported for at least one representative dwelling, using a metric of per m² of Gross Internal Area, over 60 years**
- **WoodKnowledge Wales recommend that RIBA Stage 4 assessments should be added to the RICS Building Carbon Database and shared with WoodKnowledge Wales to enable benchmarking.**
- **At handover, the as-built Upfront, Embodied and Whole Life Carbon should be updated with the actual materials and design, and we recommend the updated assessment should be shared with WoodKnowledge Wales and the RIBA Stage 4 assessment should be updated in the RICS Building Carbon Database.**

Timing of assessments

WoodKnowledge Wales recommend that assessments are undertaken during RIBA Stage 2 and RIBA Stage 3 to inform the design process and reduce Whole Life Carbon. These assessments can cover different scopes in terms of the modules to be assessed and the elements to be included depending on the aim of the assessment. It is important to ensure that the scope aims to include relevant aspects. WoodKnowledge Wales recommend that these assessments are shared with the client and design team, but they do not need to be reported externally.

At RIBA Stage 4, a full assessment of Whole Life Carbon using the WoodKnowledge Wales recommended approach should be undertaken.

During construction, any changes to the design or specification should be assessed in terms of their impact on Upfront, Embodied and Whole Life Carbon and the results shared with the client and design team.

On handover, an 'as built' assessment should be made based on the actual materials and design, updating the RIBA Stage 4 assessment.

Recommended Approach for RIBA Stage 4 (Detailed design) and RIBA Stage 5 (As Built) assessments

Upfront Carbon, Embodied Carbon and Whole Life Carbon should be assessed for at least one representative dwelling in each development. To ensure the greatest level of consistency in assessments, Woodknowledge Wales recommends the following criteria for undertaking RIBA Stage 4 and as-built assessments. These are in addition to the requirements of the RICS Professional Statement. The modules mentioned (e.g. A1-A5) are drawn from the CEN/TC350 standards and are shown in Figure 36.

Elements of the building to be assessed for Upfront, Embodied and Whole Life Carbon

Include all fixed elements of the building (so fitted kitchens, cupboards, fixed flooring and paint). Exclude loose fixtures, fittings and finishes (e.g. curtains, furniture, rugs).

For the site, assess Demolition, Enabling Works and External Works but provide separately outside the benchmark of the dwelling.

As in the RICS Professional Statement, include at least 95% of each element by cost. Any item excluded should account for less than 1 per cent of the total element cost. In case the coverage is lower than recommended, the impact for the element should be multiplied by the following adjustment factor to account for the impacts of the items not quantified and the actual percentage of coverage stated alongside the results:

Coverage adjustment factor = (100% / % of cost covered in the given element)

If cost data is unavailable, the same principles apply to the mass or area of elements as appropriate.

WKW RECOMMENDATIONS FOR ASSESSMENT

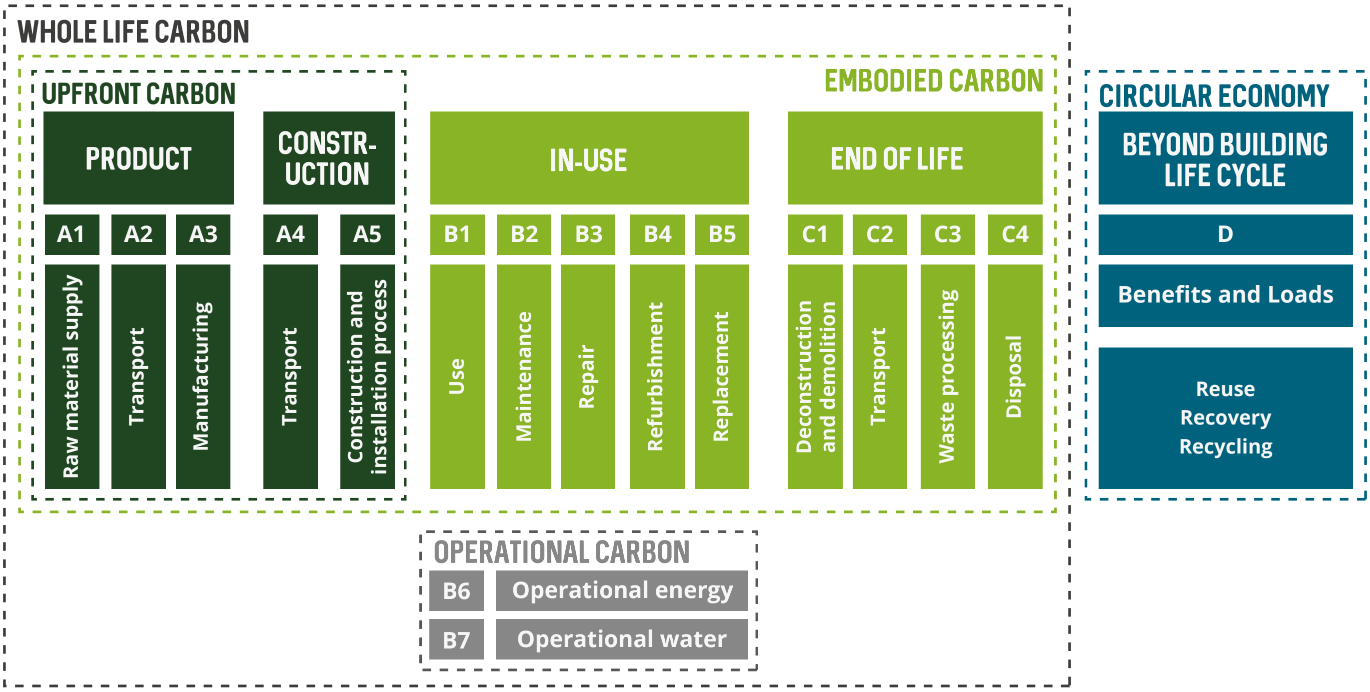

Figure 36
Diagram showing the different life cycle stages according to CEN/TC350 and how they relate to Embodied Carbon

Assessing Upfront Carbon

For Upfront Carbon, include Modules A1-A5 according to EN 15978, but exclude biogenic carbon, which should be separately reported as the amount of Sequestered Carbon in kg CO_2e.

Assessing Embodied Carbon

For Embodied Carbon, include Modules A1-A5, B1-B5 and C1-C4 according to EN 15978. Biogenic carbon removals and emissions should be included in the modules where they occur as in EN 15978. Use a 60 year service life and RICS specified defaults for service lives unless you have manufacturer specific data. Use the RICS specified defaults for scenarios for transport and construction unless you have manufacturer-specific or site-specific data. Use the RICS specified defaults for scenarios at end of life, except for timber which should be assumed to be recovered, used for energy recovery or incinerated, rather than landfilled (see Figure 10). The assessment should report Sequestered Carbon separately as kg CO_2e and should ensure that there is a carbon balance for all timber and that timber end of life is correctly accounted for. Module D should also be separately reported to inform circular economy thinking.

Assessing Operation: Module B6

The scope for Operation (B6) should include space heating, domestic hot water, ventilation, cooling (if installed) and lighting energy consumption, based on the latest version of SAP, currently SAP 10.1 (BRE, 2019). On-site renewables should be considered as required in SAP to calculate the net energy consumption. The SAP 10.1 Emission Factor for electricity (136 g CO_2e/kg) is close to the average of 30 years for the UK decarbonisation scenario to 2050, so it is useful to consider this impact and consumption over a 30 year timeframe (assuming that after 2050 the impact of electricity will be 0 kg CO_2e), particularly when looking at options for on-site renewable energy generation. However in line with the RICS Professional Statement, to calculate Whole Life Carbon, the Operational Carbon (B6) should use the net energy consumption data from SAP over a 60 year timeframe with the latest BEIS and Defra GHG Emissions factor including Transmission and Distribution losses (T&D) and the Well to tank (WTT) emissions (BEIS & DEFRA, 2020).

WKW RECOMMENDATIONS FOR ASSESSMENT

Assessing Operation: Module B7

The scope for Operation (Module B7) should include the impact of water supply and treatment considered over a 60-year timeframe. Estimates on anticipated water consumption should be made based on the values provided in Table 22 of the BSRIA Rules of thumb – Guidelines for the building services, 5th edition for the respective building type, in the absence of project specific information at early design stages. Assume that the same volume of water used is sent for wastewater treatment.

The emission factors for water should be the local water supplier's (given as carbon intensity or carbon footprint per m³) for water supply and treatment if this is available. For example, carbon intensity figures are given per m³ of water supplied and treated in Welsh Water's Annual Report (Welsh Water, 2020). If no supplier specific data is available, the latest DEFRA BEIS GHG Emissions factors should be used (BEIS & DEFRA, 2020).

Assessing Whole Life Carbon

For Whole Life Carbon, assess Modules A1-C4 including Embodied and Operational Carbon as above. Separately report Module D to inform circular economy thinking.

Reporting Upfront, Embodied, Operational and Whole Life Carbon

Upfront, Embodied and Whole Life Carbon should be reported for at least one representative dwelling, using a metric of per m² of Gross Internal Area, over 60 years. It may also be useful to also report per dwelling, per occupant figures, and for the overall development, which would also include external works and infrastructure.

WoodKnowledge Wales recommend that RIBA Stage 4 assessments should be added to the RICS Building Carbon Database and shared with WoodKnowledge Wales to enable benchmarking.

At handover, the as-built Upfront, Embodied and Whole Life Carbon should be updated with the actual materials and design, and we recommend the updated assessment should be shared with WoodKnowledge Wales and the RIBA Stage 4 assessment should be updated in the RICS Building Carbon Database.

Woodknowledge Wales Targets for Upfront Carbon and Embodied Carbon

Providing aspirational targets for upfront and Embodied Carbon alongside performance targets for operational energy gives clients, architects and contractors the motivation to achieve significant reductions in Upfront, Embodied and Whole Life Carbon. WoodKnowledge Wales targets are shown in Table 6 below.

Woodknowledge WalesTargets	Low-Rise Housing	Medium and High-Rise Housing
Upfront Carbon	**300 kg CO_2e/m²**	**450 kg CO_2e/m²**
Embodied Carbon	**400 kg CO_2e/m²**	**750 kg CO_2e/m²**
Energy Use Intensity for Space Heating	**15 kWh/m² per year**	
Total Energy Use Intensity	**35 kWh/m2 per year**	

Table 6
Woodknowledge Wales Upfront and Embodied Carbon Targets

WKW RECOMMENDATIONS FOR ASSESSMENT

For Upfront Carbon (excluding biogenic carbon), we recommend that low-rise housing aims to achieve a target of 300 kg CO_2e/m² (equivalent to the LETI 2030 Upfront Carbon target), and 450 kg CO_2e for medium and high-rise housing (equivalent to the GLA aspirational target for apartments). For Embodied Carbon, we recommend that low-rise housing aims to achieve a target of 400 kg CO_2e/m² (a little below the RIBA climate challenge figure for 2025), and medium- and high-rise housing 750 kg CO_2e/m² (equivalent to the French E+C- target for apartments).

To ensure that assessments are consistent, we recommend following the approach provided in this section.

Operational Carbon Emissions

For Operational Carbon considered in B6 (Operational energy use), Woodknowledge Wales has set an **Energy Use Intensity target of 15 kWh/m² per year for space heating**, and **a total energy use intensity of 35 kWh/m²/year including regulated and unregulated loads**. This follows the guidance of LETI. Using the greenhouse gas emissions factors for UK grid electricity and mains natural gas provided by BEIS and DEFRA and by SAP 10.1, we have calculated the expected impact per m² for Operational Carbon emissions (B6) over 60 years.

Operational Carbon[93]	Consumption/year	Emission Factor used[94]	Impact: 60 years
B6 Operational Energy Use	35 kWh/m² electricity	Only on-site renewables	0 kg CO_2e/m²
B6 Operational Energy Use	35 kWh/m² electricity	BEIS & DEFRA 2020	600 kg CO_2e/m²
B6 Operational Energy Use	35 kWh/m² electricity	SAP 10.1	286 kg CO_2e/m²
B6 Operational Energy Use	35 kWh/m² electricity	Residual mix 2019/20	890 kg CO_2e/m²
B6 Operational Energy Use	15 kWh/m² gas 20 kWh/m² electricity	BEIS & DEFRA 2020	554 kg CO_2e/m²
B6 Operational Energy Use	15 kWh/m² gas 20 kWh/m² electricity	SAP 10.1	352 kg CO_2e/m²

Table 7
Operational Carbon from Operational Energy Use (B6) using different emission factors

For B7 (operational water use) we have taken the target consumption of 125 litres/person/day as considered in Building Regulations and assumed that this water is returned to sewer. We have taken the minimum sizes of a 3 to 6 person dwellings given in the current consultation, Beautiful Homes and Spaces, to calculate the approximate amount of water used per m² (2.5 litres/m²). We have used the greenhouse gas emissions factors for UK mains water and water treatment provided by BEIS and DEFRA, and the carbon intensity factors provided by Welsh Water for 2019/20[95] .

Operational Carbon[96]	Consumption/day	Emission Factor used[97]	Indicative Impact: 60 years
B7 Operational Water Use	125 litres/person	BEIS & DEFRA 2020	150 kg CO_2e/m²
B7 Operational Water Use	125 litres/person	Welsh Water 2019/20	11.8 kg CO_2e/m²

Table 8
Operational Carbon from Operational Water Use (B7) using different emission factors

[93] Whole life carbon is a combination of embodied carbon and Operational Carbon.
[94] Includes Transmission and Distribution and Well to tank (WTT) factors.
[95] Welsh Water Report and Accounts 2019 to 2020, available from https://corporate.dwrcymru.com/en/library/group-annual-report-and-accounts/glas-cymru-cyfyngedig
[96] Whole life carbon is a combination of embodied carbon and Operational Carbon.
[97] Includes Transmission and Distribution and Well to tank (WTT) factors.

CHAPTER

10

COMMUNICATING EMBODIED CARBON

COMMUNICATING EMBODIED CARBON

CHAPTER 10 SUMMARY – Communicating Embodied Carbon

- **Providing context for the mass of carbon provided in Embodied Carbon calculations can help people to understand the numbers**
- **Common approaches include comparing to the impact of driving a certain number of miles, or stating the amount of forestry that would be required to offset the emission**

Communicating Embodied Carbon

Providing figures for Embodied Carbon can be difficult for people to understand without context. Below we provide some examples of how Embodied Carbon can be made more meaningful by comparing it to more understandable concepts, such as a typical UK citizen's impact, or the impacts of a common material, or the distance travelled by car or plane which would have the same impact, or by considering it in terms of the forest that would be required to offset the emission, or by visualising the actual quantity of carbon dioxide.

In 2017, the UK's consumption-based carbon footprint was 772 million tonnes[98] which means a UK citizen footprint of 11.7 tonnes of CO_2e per year[99] .

The Treasury's 2013 Infrastructure Carbon Review said that "developing a 'currency of carbon' is important for giving people a feel for what carbon is and what it is worth".

Using data they provided, a UK citizen's annual impact of 11.7 tonnes of CO_2e is equivalent to

- 3 return flights from London to Sydney
- 7.5 tonnes of mild steel or 80 tonnes of reinforced concrete

And in monetary terms, 11.7 tonnes of CO_2e would be worth between £240 and £320 based on the European Union Carbon Trading price in August 2020 of between 25-30 euros per tonne[100].

In Figure 37, the Embodied Carbon of a building is compared to the impact of petrol and car use, and the carbon sequestered by oak woodland. In Figure 38, it is compared to car use.

Design Option	Carbon (tCO_2e)	Petrol (litres)	Oak Woodland (m^2)	Car Use (miles)
Base-case	151	34,811	5,600	607,840
Refurbish	59	13,589	2,186	237,288
New-build	59	13,479	2,186	235,350

Figure 37
Alternative measures of life cycle carbon emissions for a Victorian Terrace Refurbishment assuming a 21°internal temperature and a 60-year reference study period. Example sourced from Duffy et al. (2019)

[98] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/ 882939/Consumption_emissions_March_20_v9.pdf
[99] www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/bulletins/annualmidyearpopulationestimates/mid2017
[100] https://ember-climate.org/carbon-price-viewer/

COMMUNICATING EMBODIED CARBON

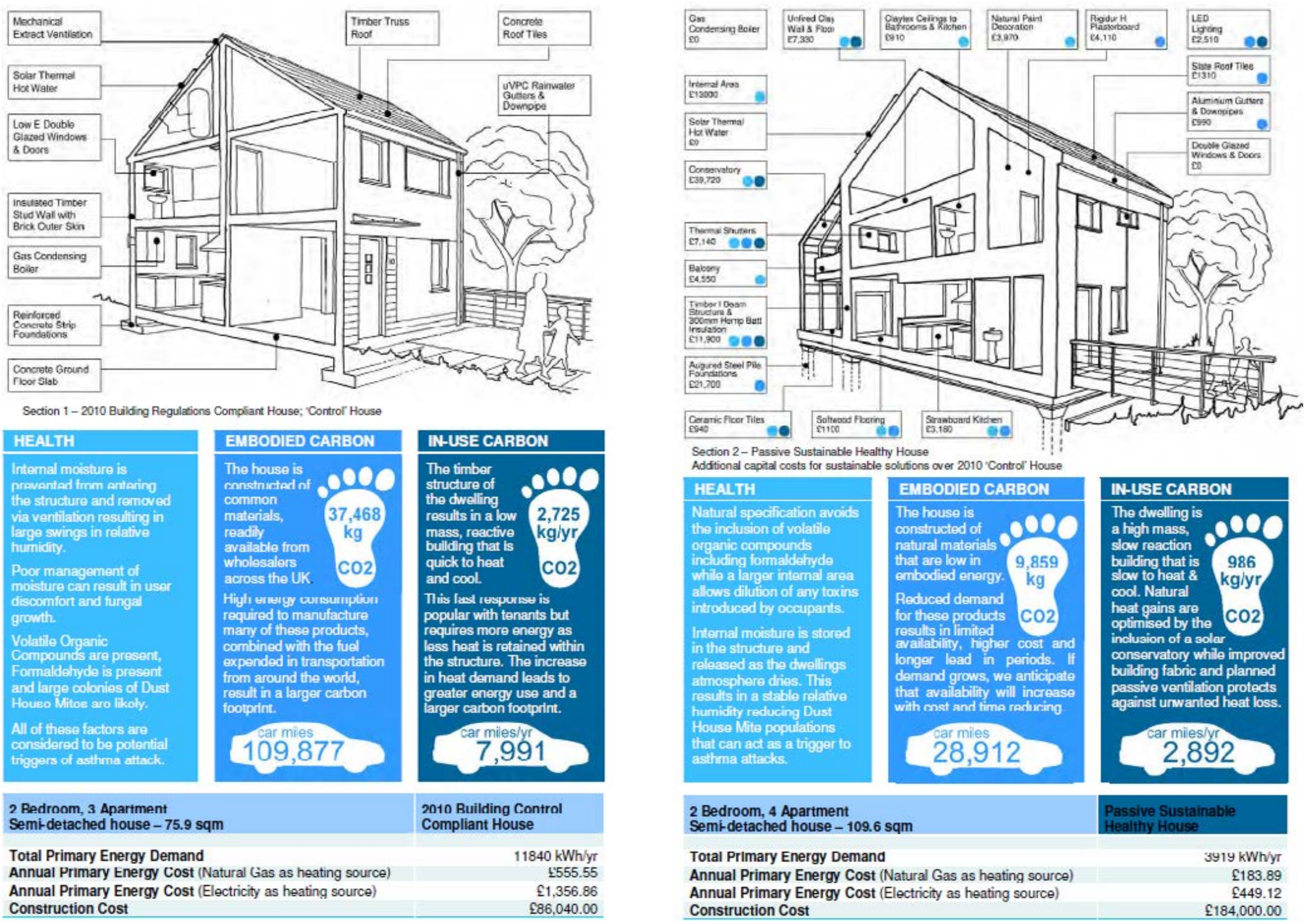

Figure 38
illustration of Embodied and Operational Carbon for Tarryholme project comparing a typical new build house, a passively ventilated sustainable healthy house, and a mechanically ventilated sustainable healthy house. Example from Tarryholme Sustainable Healthy House Study: Project Summary (2011). Availalble from http://www.cicstart.org/userfiles/file/FS-11-REPORT.PDF

In Figure 39, Heritage England compare a building's impact to the area of conifer forest that would be required to offset the emissions within 10 years.

> ■ This year's Heritage Counts research shows that the refurbishment and retrofit of two case study historic buildings resulted in a dramatic reductions in carbon emissions. **Carbon emissions are reduced by 60% in the Victorian Terrace case study as a result of energy efficiency interventions and by 62% in the Chapel Conversion case study by 2050.** In the Victorian retrofit, carbon emissions are reduced by 53tCO_2e by 2050 – it would take 10 years for a forest of 12,594 conifer trees to offset this carbon, this represents an area of approximately 5 ha or 7 football pitches. In the case of the Chapel Conversion, 98tCO_2e of carbon emissions are saved by 2050 – it would take ten years for a forest of 23,288 conifer trees to offset this carbon, this represents an area of approximately 9.3 ha or 13 football pitches.

Figure 39
Comparing carbon saved to carbon sequestration of a forest. Example sourced from Historic England (2019)

COMMUNICATING EMBODIED CARBON

And in Figure 40, WoodforGood visualise the carbon stored within a tree and a house, with each bubble representing 1 kg CO_2e.

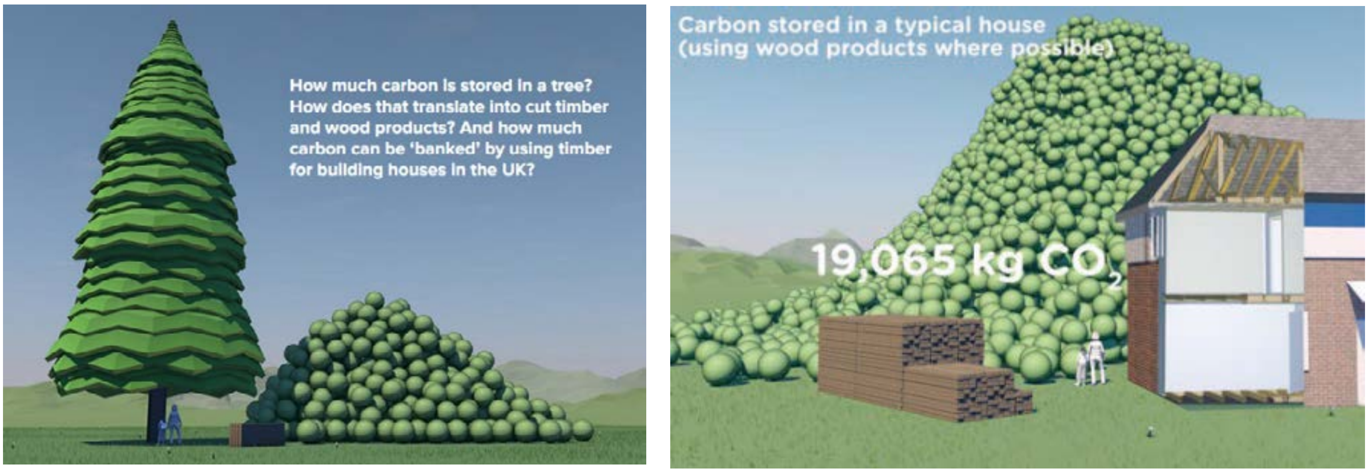

Figure 40
Wood for Good Images by Carbon Visuals showing the biogenic carbon stored in a tree, and in a typical house using wood products where possible. Each bubble is 1 kg CO_2e. Examples sourced from https://woodforgood.com/assets/Downloads/Growing%20Our%20Low-Carbon%20Economy.pdf and https://woodforgood.com/news-and-views/2014/10/27/climate-talks-yield-new-opportunities-for-timber/.

For a project in Hackney, Dalston Lane, built using CLT panels produced using certified timber from sustainably managed forests in Germany and Austria, Waugh Thistleton explain that the equivalent of 2325 trees were used, and that the Austrian and German forests from which the trees were sourced can create the equivalent woody biomass in just 3 hours.

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CHAPTER 11

EMBODIED CARBON POLICY AND REGULATION

EMBODIED CARBON POLICY AND REGULATION

CHAPTER SUMMARY – Embodied Carbon Policy and Regulation

- **Local Authorities in the UK, for example the Greater London Authority and Brighton & Hove City Council, have included requirements to measure embodied carbon as part of planning requirements**
- **Other countries and regions have regulated to measure and limit embodied carbon and embodied impacts. This has been done through various mechanisms, including planning, building regulations and control on advertising**

Policy and Regulation in the UK

Existing policy and regulation for carbon and buildings across the UK has largely been aimed at improving building energy performance to be able to get towards very low energy buildings and targeting "zero" energy or emissions buildings. There is currently no regulation in the UK for Embodied Carbon in the building sector, though there have been previous attempts.

- The Code for Sustainable Homes, which became mandatory for publicly funded housing in England and Wales in 2007 and Northern Ireland in 2008, introduced a link to embodied impacts through the Green Guide to Specification 4th Edition. However, the Code was wit drawn in 2015 following the Housing Standards Review[101].
- In Scotland, the Scottish Government instituted an evaluation of approaches to regulation of Embodied Carbon (Scottish Building Standards Agency, 2007) and the Panel's recommendations included an ambition of "total-life zero carbon buildings by 2030" and considered the possibility of covering embodied energy in building products but it was decided to wait until requirements to consider embodied impact were proposed in European Regulations – this didn't happen and no action was taken when the Panel was reconvened in 2013. More recently, a study has been produced for Zero Waste Scotland (ZWS) to help it determine the state of the art in Scotland and beyond, the direction the sector should take in regard to Embodied Carbon, and the support that might be needed from ZWS (Pomponi *et al*., 2020).
- In 2019, a report to the Committee on Climate Change[102] showed how Embodied and Sequestered Carbon could be considered in the new build standards framework. It provided three options – 1) that Government could monitor Embodied Carbon and lead with mandatory reporting and reduction through its own procurement, 2) that "Whole Life Carbon intensity limits" could be set in Building Regulations for relevant elements, product types and materials, or 3) that a "scheduled introduction of whole building lifecycle carbon intensity targets in building regulations could be considered".
- The Low Carbon Route Map[103] produced by the Green Construction Board in 2013 suggested that from 2017, declarations of Embodied Carbon for construction products should become mandatory (using EPD), alongside he measurement and reporting of Embodied Carbon for public buildings, with mandatory reporting for all buildings from 2022, however no action towards this has been taken.

At a more local level, there have been other policies which require the consideration of Embodied and Whole Life Carbon within buildings. These include:

- Local planning policy
  - o The Greater London Authority (GLA) Draft London Plan (2018) introduced a policy requirement (SI 2)[104] for whole life cycle carbon emissions assessments for developments referable to the Mayor and encouraged for all major applications. This covers Operational Carbon and Embodied Carbon including carbon associated with maintenance and end of life disposal.
  - o Oxford City Council had policies in the adopted Local Plan 2001 to 2016 which included recycled materials and natural resource impact analysis (NRIA). As part of the NRIA, there are a number of questions related to Embodied Carbon and a simple scoring system dependent upon usage of aggregate, timber, insulation materials and local sourcing.

[101] www.gov.uk/government/consultations/housing-standards-review-technical-consultation
[102] www.theccc.org.uk/publication/options-for-incorporating-embodied-and-sequestered-carbon-into-the-building-standards-framework-aecom/
[103] https://d7.ciob.org/sites/default/files/GCB_Carbon_ROUTEMAP_1.pdf
[104] www.london.gov.uk/what-we-do/planning/implementing-london-plan/planning-guidance/whole-life-cycle-carbon-assessments-guidance-pre-consultation-draft

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- o Brighton & Hove City Council had policy SU2 on the sustainability of materials proposed in planning applications from 2005 to 2015. This expected the use of construction materials with low embodied carbon; reduction of raw material inputs; and use of recyclable and/or recycled materials and provided an Embodied Carbon tool to be used to assess schemes prior to submission.

- The planning system – Environmental Impact Assessments (EIAs) are currently required where more than 150 dwellings are to be built or if the area of the development is greater than 5 hectares. Planning authorities can ask for Embodied and Operational Carbon to be considered as part of this assessment although this is uncommon.
- Home Quality Mark (HQM) – BRE's HQM scheme includes optional credits for reducing the environmental impact associated with construction products. These are detailed in Table 9.

HQM Materials Criteria Detail	**Credits available (% of final HQM score)**
Criteria 01: By the end of RIBA stage 2 (or equivalent), the Client/Developer has a documented policy and procedure that sets out procurement requirements for all suppliers and trades to adhere to relating to the sourcing of construction products with lower environmental impact.	1 credit (0.2%)
Criteria 02: The documented policy and procedure must be disseminated to all relevant internal and external personnel and included within the construction contract to ensure that they are enforceable on the assessed project.	1 credit if Crit01 achieved (0.2%)
Criteria 03: The documented policy and procedure must encourage the specification of products with EPD over similar products without EPD.	1 credit if Crit02 achieved (0.2%
Criteria 04: Where a range of products specified at the Design Stage (DS) and installed by the Post Construction Stage (PCS) are covered by verified EPD.	Up to 5 credits (1%)
Criteria 05: The dwelling is assessed using the HQM materials tool in accordance with the methodology. This route is suitable for the assessment of standard, simple dwellings/ buildings.	Crit05 up to 8 credits (1.6%) or
Criteria 06: The dwelling has been assessed using an IMPACT compliant tool in accordance with the methodology.	Crit06 up to 23 credits (4.6%)
Materials Section Total	31 credits (6.2%)

Table 9
Credits available in HQM for addressing reduced environmental impact from construction products

Voluntary commitments – some companies and public sector organisations may make commitments with associated targets. As part of voluntary frameworks such as Global Reporting Initiative (GRI), Carbon Disclosure Project (CDP) and GRESB[105]; Embodied Carbon can be recorded in these schemes as a Scope 3 emission.

[105] https://gresb.com/

EMBODIED CARBON POLICY AND REGULATION

Policy and Regulation in Wales

At the time of writing, the Welsh Government was consulting on its revision of the Development Quality Requirements for Housing[106]. It was proposed that these will be mandatory for all affordable homes in Wales. It stated that "Homes should be of high quality, innovative and sustainable" and *"Homes should be flexible, responsive to the changing needs of the occupant, meet the changing needs of a variety of households who will occupy the building over its life and be of sufficient size.*

This means, in relation to the issues considered in this report, that:

- *Homes should demonstrate that they represent value for money and "whole life cost" analysis should be a material consideration when assessing future maintenance costs against initial capital cost*
- *Considering best practice in utilising a "circular economy" process, for example by;*
- ***Choosing materials that are capable of being recycled and maximising the use of timber in construction to help Wales meet its carbon reduction targets***
- ***Reducing Embodied Carbon by utilising carbon sink and low carbon materials, processes and products in buildings.***
- *Where practicable make internal walls non load bearing to enable future flexibility / adaptability and consider providing space in "one bedroom" homes for potential "sleep over"*
- *Consideration should be given to MMC techniques and innovation that can maximise flexibility for adaptations and allow homes to respond to occupants needs over a building / occupant's lifetime."*

In 2016, the Welsh Government consulted on the possible consideration of embodied impacts in a replacement for the Code for Sustainable Homes in Wales, but concluded in 2017 that the subject "lacks maturity and presents significant issues that preclude a regulatory approach at this moment in time"[107].

In Wales, there is policy and legislation related to sustainable development and wellbeing (see *Well-being of Future Generations (Wales) Act opposite*) and a low carbon delivery plan[108] which includes decarbonisation of the building stock. Embodied Carbon is considered within applications to the Welsh Government's Innovative Housing Programme (IHP) as is the use of sustainable materials such as timber.

"The IHP would be interested in submissions that further the evidence base and understanding of the levels embodied energy in new homes, and consequential Embodied Carbon. Schemes may not be able to offer comprehensive embodied energy assessments for all materials used and/or running from raw material to installed component, but are encouraged to innovate around scalable methods to record and evidence primary construction materials. Schemes may wish to consider opportunities for Circular Economy under this category as part of a low embodied energy model, where there will be a need to demonstrate a probable reuse rather than just potential for reuse" (from IHP Guidance).

Bodies such as Woodknowledge Wales (WKW) have provided recommendations to the Welsh Government to address Embodied Carbon emissions for homes. This includes bringing Embodied Carbon emissions into the regulatory framework by developing targets for homes by 2023 and mandating the reduction for projects over £2 million through building regulation, planning policy and/or other levers e.g. a carbon tax. They also recommend the adoption of the UKGBC Net Zero Carbon Definition throughout all levels of policy and recommendation.

Well-being of Future Generations (Wales) Act

In 2015, the National Assembly for Wales (now the Welsh Parliament) made a historic decision to change the course of Wales to a more sustainable path by passing the Well-being of Future Generations (Wales) Act 2015[109]. This requires Welsh Ministers and Local Authorities, along with other public bodies to improve the economic, social, environmental and cultural well-being of Wales by taking action, in accordance with the sustainable development principle, aimed at achieving well-being goals.

The act defines **seven well-being goals:** i) a prosperous Wales, ii) a resilient Wales, iii) a healthier Wales, iv) a more equal Wales, v) a Wales of cohesive communities, vi) a Wales of vibrant culture and thriving Welsh language and vii) a globally responsible Wales. The **sustainable development principle** means that bodies must act in a manner which seeks to ensure that the needs of the present are met without compromising the ability of future generations to meet their own needs.

[106] https://gov.wales/mandatory-quality-standards-new-homes
[107] https://gov.wales/building-regulations-sustainability-review
[108] https://gov.wales/sites/default/files/publications/2019-06/low-carbon-delivery-plan_1.pdf
[109] www.legislation.gov.uk/anaw/2015/2/contents/enacted

EMBODIED CARBON POLICY AND REGULATION

The Act also established the world's first statutory independent Future Generations Commissioner, to be an advocate for the long term and to support decision-makers in Wales.

The Innovative Housing Programme (IHP), as a programme developed and funded by the Welsh Government at the request of the Cabinet Secretary for Children and Communities, is required to address the Act, and Figure 41 shows how the construction and operation of new housing funded by the programme, together with the wider benefit that the new housing brings, relate to the WFGA goals. Those benefits outlined in black directly related to upfront and Embodied Carbon and the reduction strategies for Embodied Carbon set out in this guide.

Potential benefits associated with housing, as they relate to WFGA

	during construction	benefits in use	wider benefits	
WFGA goal:	**short term benefit:**	**medium term benefit:**	**long term benefit:**	**focus:**
globally responsible	low embodied CO_2 locking in carbon	reduced carbon footprint potential for carbon negative	decarbonising communities meeting international targets	CO_2
prosperous	addressing cost and value local resource use	more affordable housing supporting Welsh suppy chain	affordability, local economy skills and community building	capital
resilient	robust, low maintenance changeable by the community	resilient to climate change acessible construction	adaptability and resilience reskilling and empowering	change
healthy	natural resource use breathable construction	healthy internal environment reduced impact on environment	positive health benefits reduced strain on public services	health
more equal	low embodied energy reduced heating bills	energy generation offsetting rental costs	affordable warmth for all energy positive homes	energy
cohesive communities	flexibility in layout constructable by end user	long life loose fit 'other' procurement pathways	meeting specific housing need flexible, high quality homes	space
thriving culture	variety in form and materials suitability to different contexts	building strong neighbourhoods creating places with character	supporting people, communities and distinctive places	place

Figure 41
Showing how the Innovative Housing Programme relates to the Well-being of Future Generations Act (source IHP Technical Specification, v3, 2019).

EMBODIED CARBON POLICY AND REGULATION

International Policies and Regulation addressing Embodied Carbon

There are a growing number of examples of international policy and regulation for Embodied Carbon and construction material impacts. These include:

European Regulation

- Netherlands - Building Decree 2012 has required LCA calculations covering greenhouse gas emissions and a basket of other environmental impacts for all new dwellings, and for any non-domestic buildings over 100m² since 2013. Calculations are enabled by a national calculation methodology where the impacts over a 50-year building life are converted into a mitigation cost (or shadow-price) in €/m²; for carbon the price of €67/tonne is used[110]. Since January 2018, there is a cap of 1€/m²/year.
- France - developed a pilot regulation E+C- (energy positive, low carbon) to test the feasibility of new performance targets and related assessment methods and the Government approved eight commercial Building LCA tools for the evaluation. E+C-establishes two levels of performance for lifecycle GHG emissions. The evaluation includes the 'product' and 'construction process', 'use' and 'end of life' stages. France also has a national LCA/EPD database, and it is against the law to make environmental claims about construction products in the absence of a published EPD registered in the Government EPD programme, inies.
- Belgium - has developed national methodologies to undertake Building LCA, the Milieugerelateerde Materiaalprestatie van Gebouwelementen (MMG) and the Government has piloted the MMG approach and is currently encouraging the construction industry raise awareness by using the Totem tool, whilst also researching benchmarks to support policy makers in the definition of environmental targets for buildings. Belgium has also established a national LCA/EPD database, and it is against the law to make environmental claims about construction products in the absence of a published EPD.
- Finland - has set out a roadmap to integrate Embodied Carbon emissions of building materials into building regulations, with limits for all buildings from 2025. The prospective methodology would first be tested on publicly procured building projects on a voluntary basis. Embodied Carbon requirements would then be introduced for residential buildings before being extended to all building types.
- Switzerland - the city of Zurich has set a 2050 target for life-cycle Embodied Carbon of 425 kg CO_2e/m² (over a 50-year building life) for residential buildings, as part of a pledge to reduce energy usage and Embodied Carbon
- Italy - Green Public Procurement criteria have been set for buildings, for example that buildings must have 15% recycled content by mass, all concrete must have 5% recycled content, EAF steel must have 70% recycled content and integrated steel 10% recycled content. EN 15804 EPD are highlighted in the criteria as the means to demonstrate this.
- Sweden – Climate Declarations are proposed initially from January 2022 for all multi-dwelling buildings to report the cradle to gate Embodied Carbon emissions associated with the structural frame, building enclosure and basement and garage. Climate declarations for all residential buildings, covering the full specification and life cycle will follow.

North American Regulation

- California, USA - the Buy Clean California Act is targeting the Embodied Carbon of steel (structural and rebar), flat glass and insulation used in public works contracts. EPDs are being used to identify the GWP for the materials. From the 1st July 2021, contracts will be required to use products with a GWP equal or lower than the levels established by the State.
- Minnesota, USA B3 Guidelines passed July 2017 require whole building LCA for state funded new buildings and major renovations.
- Oregon, USA Executive Order 17-20, which was signed in November 2017 states new state buildings will need to be carbon neutral in operation and will need to analyse feasible options that will lower Embodied Carbon impacts from 2022.
- Vancouver, Canada – the Zero Emissions Building Plan has been formulated to establish how zero emissions in all new buildings by 2030 can be achieved. A target of reducing Embodied Carbon by 40% by 2030 has been set. A whole building LCA is required as part of planning for 'rezoning' projects.

[110] From Environmental Prices Handbook 2017: Methods and numbers for valuation of environmental impacts, Authors: Sander the Bruyn, Saliha Ahdour, Marijn Bijleveld, Lonneke de Graaff, Ellen Schep, Arno Schroten, Robert Vergeer. Delft, CE Delft, May 2018. The value for greenhouse gas emissions of 0.057 euro/kg CO_2 includes VAT and increases by 3.5% per annum relative to the 2015 values.

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CHAPTER

12

TIMBER POLICY AND REGULATION

TIMBER POLICY AND REGULATION

CHAPTER 12 SUMMARY – Timber Policy and Regulation

- **The use of sustainably grown and harvested timber is essential**
- **"Wood Encouragement" policies are being used in Powys, and in other countries to encourage the use of timber in buildings due to its positive effect on climate change. These policies are also aimed at stimulating local forestry and timber industries**
- **Forestry and long-life harvested wood products such as timber used in construction can mitigate against climate change, and are therefore included in national emissions inventories**

The EU Timber Regulation

The EU Timber Regulation was passed in 2010 , and counters the trade in illegally harvested timber and timber products through three key obligations:

- It prohibits the placing on the EU[111] market for the first time of illegally harvested timber and products derived from such timber;
- It requires EU traders who place timber products on the EU market for the first time to exercise 'due diligence'; Once on the market, timber and timber products may be sold and/or transformed before they reach the final consumer. To facilitate the traceability of timber products, economic operators in this part of the supply chain (referred to as traders in the regulation) have an obligation to
- Keep records of their suppliers and customers.

The Regulation covers a wide range of timber products listed in its Annex, using EU Customs code nomenclature.

Sustainable Timber Certification

Timber Certification schemes provide third party assurance attesting to the origin of the wood material and its qualification as a sustainably harvested product, and ensure traceability of sustainable timber through the supply chain. The most well-established certification schemes are FSC and PEFC.

Currently, only certain sources of timber are allowed to take account of timber sequestration in A1 during life cycle assessment to EN 15804+A1. These only cover wood that comes from countries that account for increasing forest carbon pools under Article 3.4 of the Kyoto Protocol or wood originating from forests which are operating under established certification schemes for sustainable forest management. Timber which cannot meet these requirements must still report the release of biogenic carbon at end of life (i.e. only sustainable timber is biogenic carbon neutral over the life cycle).

EN 15804+A2 will widen the types of timber that can account for sequestration – any timber which is not sourced from "native forests" will be allowed to account for the s equestration over the life cycle. The standard states, "Native forests exclude short term forests, degraded forests, managed forest, and forests with short-term or long-term rotations."

Policies encouraging the use of wood

One of the first countries to adopt a Wood Resource Policy was Switzerland in 2005[112]. Their policy aimed to increase the amount of wood used in housing by 2020, from 11.4% to 17% for single family dwellings and 3.6% to 8% for multi-family dwellings; other measures included:

- Using efficient forestry practices, to fully utilize the potential of producing sustainable wood products from Swiss forests
- Increasing domestic demand for wood and wood products, especially for products from domestic forests.
- Developing bio-fuel energy generation potential, ensuring that wood is sourced and used sustainably, cleanly and efficiently.
- Strengthening the innovation capacity of the forestry and timber products industries.
- Through close coordination, ensure that the Wood esource Policy contributes significantly to the success of other sectoral policies.

[111] https://ec.europa.eu/environment/forests/timber_regulation.htm
[112] www.bundespublikationen.admin.ch/cshop_mimes_bbl/8C/8CDCD4590EE41EE787B92ADE90017262.pdf

TIMBER POLICY AND REGULATION

In France, President Macron has stated that the French government will require 50% timber in all new public buildings from 2022[113]. This builds on their "Action plan for the development of timber in the building sector" which came into effect in 2009 and was applicable to all types of buildings, aiming to lift the barriers to the development of timber and more generally bio-sourced materials in the building sector.

In 2009, British Columbia (BC) in Canada introduced the Wood First Act, which positioned wood as the material of choice for publicly funded building projects[114]. In 2011, the Government of British Columbia's market development agency for forest products tool over the management of the Wood First Initiative, whose strategic objectives are:

- Growing the culture of living and building with wood in BC and beyond
- Maximising the appropriate use of wood in public and private projects
- Strengthening BC's capacity to produce high quality wood-based products and building systems
- Accelerating adoption of existing and emerging wood-based products and building systems
- Positioning BC as a world leader in the design, production and application of sustainable and innovative wood-based products and building systems.

Timber Policy in Wales

The Plan has outcome indicators including:

***D3** Area of woodland in England*
***E5** Percentage of the annual growth of trees in English woodlands that is harvested (headline 8)*
***E6** Volume of timber brought to market per annum from English sources*

In 2018, Wales harvested 1.6 million m³ of timber. Whilst most of this timber would be of suitable quality to be used for construction, most is currently used in other markets such as packaging and fencing. According to estimates from Woodknowledge Wales in a study for Welsh Government[115] , Welsh housing would require up to 200,000 m³ of harvested logs to meet the current housing target of 8,300 new homes each year if they followed a low carbon strategy based on using timber.

In January 2017, Powys County Council adopted a Wood Encouragement Policy with the purpose of providing a stimulus to the local timber industry. This was a first such policy in the UK, although Hackney Council was the first local authority in England "to promote timber construction in its planning policy" in 2012, aiming to stimulate timber construction as a climate change mitigation strategy.

Powys County Council's policy aims to stimulate sustainable economic development within the timber/wood products industry and encourage development of added value products. The Council advocates any timber use advocates the utilisation of wood products that are certified by: Forest Stewardship Council, (FSC); PEFC; Grown in Britain (GiB), or are from local well managed sources; and using wood only when it is the right material for the selected application.

The implementation of the policy means the Council will

- "ensure that all briefs for new Council housing projects (subject to any grant constraints) incorporate the requirement to use wood as the preferred material for both construction and fit out purposes, where wood is deemed a suitable and cost effective material for the proposed application
- seek those who can find, practical, efficient, versatile and cost-effective building and design solutions using wood when sourcing design and architectural expertise for such projects
- ensure that all comparisons to the cost of building with other materials will take into account all long-term and life cycle benefits of using wood
- where possible, source locally and home-produced wood products for construction and fit out purposes
- use development, planning and procurement processes to maximise opportunities for targeted recruitment and training in the timber industries
- be a champion of the forest and wood products industry, by establishing a Wood Encouragement Policy and demonstrating commitment to the further development of the local forest and wood products industry
- actively seek demonstration projects that showcase the use of wood within the County and Wales
- actively work to support existing and attract new, innovative wood products manufacturers to Powys"

[113] www.thetimes.co.uk/article/macron-use-more-wood-in-our-buildings-wmlrf2f3g
[114] www2.gov.bc.ca/gov/content/industry/forestry/supporting-innovation/wood-first-initiative
[115] https://woodknowledge.wales/wp-content/uploads/2019/06/zero-carbon-homes-from-wood-2019-English.pdf

TIMBER POLICY AND REGULATION

Timber Policy in England

In England, the Government's 2018 Environment Plan for England (Defra, 2018) states, "We will ensure that resources from nature, such as food, fish and timber, are used more sustainably and efficiently." The Government will do this by maximising the value and benefits from resources, doubling resource productivity by 2050, and increasing timber supplies. They state, "We will increase tree planting by creating new forests, and incentivising extra planting on private and the least productive agricultural land, where appropriate. This will support our ambition to plant 11m trees." "We want our continuing promotion of large scale woodland creation to give investors the confidence to renew and expand wood-processing capacity, thereby securing the supply of current wood products and stimulating further innovation with new products such as cross-laminated timber used in construction." "We will also work with industry and support Grown in Britain to increase the amount of home grown timber used in England in construction, creating a conveyor belt of locked-in carbon in our homes and buildings. A wide range of economic and environmental benefits will flow from commercial afforestation to meet the growing demand for timber. "

Using Forestry and Harvested wood products to mitigate climate change

The UN National Emissions Inventory reporting under the Paris Agreement allows countries to use the biogenic carbon stored in both forestry and harvested wood products (HWP) to mitigate their other greenhouse gas emissions. The 2006 IPCC guidelines provide guidance on how to estimate and report the contribution of these harvested wood products to annual CO_2 emissions/ removals. harvested wood products are normally reported by product categories with different life cycles such as paper, wood panels and sawn wood and include emissions from the decay of existing harvested wood products and the increase in carbon stocks through addition of new harvested wood products.

In 2018, Wales reported 1.2 million tonnes of CO_2 removals from Welsh forestry, and 0.3 million tonnes of CO_2 stored in harvested wood products in Wales, which together were used to reduce Wales' overall reported annual Greenhouse Gas emissions by 4%.

> "It's also about the wider benefit, not just the Embodied Carbon, but the economic benefit to the Welsh area, about doing any processing of the timber to create higher value products which will benefit the local economy."
>
> WKW Embodied Carbon workshop attendee

> "It's timber first, Welsh manufacturing second, home-grown timber third, but all three if possible and practical."
>
> Gary Newman, CEO, WoodKnowledge Wales

Recommendations for Policy

The Timber Accord – a partnership of UK timber industry organisations - has a long term aim to improve the competitiveness and performance of the UK timber industry by working together to promote timber and wood products to the Government, other commercial organisations and everyday customers, by putting wood at the heart of the UK's environmental policy and popular thinking.

In 2014, it made twelve recommendations to Government in the UK (Timber Accord, 2014), of which three are highly relevant to Embodied Carbon:

- Recognition and reward for low-energy manufacturing
- Ensure all buildings projects consider full carbon impact
- Set and enforce strong carbon reduction targets.

TIMBER POLICY AND REGULATION

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FURTHER GUIDANCE AND INITIATIVES

We highlight below the main sources of guidance, resources and initiatives in the Embodied Carbon field.

Alliance for Sustainable Building Products
https://asbp.org.uk/

The ASBP is looking to increase knowledge sharing around Embodied Carbon across the construction industry. It runs a series of webinars and masterclasses covering Embodied Carbon which are available to listen to after the event, and has provided a number of detailed briefing papers around Embodied Carbon and Environmental Product Declarations (EPD).

Architects Climate Action Network (ACAN)
www.architectscan.org/about

ACAN is a network of individuals within architecture and related built environment professions taking action to address the twin crises of climate and ecological breakdown, and focusses on political campaigning and lobbying, direct action and public engagement, and research and knowledge sharing. ACAN has a thematic group looking at Embodied Carbon, working to drive down carbon emissions from the construction sector by calling for new regulations and policies to control Embodied Carbon.

Architecture 2030 https://architecture2030.org/

Architecture 2030's mission is to rapidly transform the global built environment from the major contributor of greenhouse gas (GHG) emissions to a central part of the solution to the climate crisis. It provides a number of resources for Embodied Carbon, and hosts the 2030 challenge for Embodied Carbon.

BRE

BRE provides a number of resources related to Embodied Carbon: The BRE Green Guide offers free registration to access an online resource which provides Embodied Carbon data for common construction specifications for different building types. The BRE EPD Verification Scheme provides free online access to all BRE EPD. BRE IMPACT® is a database and methodology which can be used by approved tools to calculate Embodied Carbon and LCA for use in BREEAM.

Building Transparency https://buildingtransparency.org

Building Transparency's core mission is to provide the open access data and tools necessary to enable broad and swift action across the building industry in addressing Embodied Carbon's role in climate change. It hosts the free, open source Embodied Carbon Calculator for Construction (EC3) tool that helps measure Embodied Carbon and track the impact of individual materials. Currently focussed on North American EPD, EC3 makes it easier to perform comparisons between specific materials and see potential reductions based just on which cement, or steel, or insulation choice is made.

Carbon Leadership Forum
https://carbonleadershipforum.org/

The forum is based in the US, but has chapters in the UK. Its aim is to decarbonise the built environment, and it provides a wide range of resources and research on Embodied Carbon as well as supporting a number of initiatives such as EC3. It also hosts the Carbon Leadership Forum Community (previously the Embodied Carbon Network) which is available to full members of the Forum.

Carbon Neutral Cities Alliance
https://carbonneutralcities.org/

The Carbon Neutral Cities Alliance (CNCA) is a collaboration of leading global cities aiming to achieve carbon neutrality before 2050 - the most aggressive GHG reduction targets undertaken anywhere by any city involved in the Embodied Carbon Policies initiative below.

Centre of Industrial Energy, Materials and Products (CIE-MAP)
http://ciemap.leeds.ac.uk/

CIE-MAP conducts research to identify all the opportunities along the product supply chain that ultimately deliver a reduction in industrial energy use, and provides a number of useful briefings on Embodied Carbon.

CIRIA

CIRIA now hosts many of the older WRAP publications for construction. Free registration is required to access them.

Circular Ecology https://circularecology.com/resources.html

Craig Jones provides lots of resources including his Inventory of Carbon and Energy (ICE Database), an Embodied Carbon calculator for concrete and webinars and videos.

FURTHER GUIDANCE AND INITIATIVES

Construction Declares

Construction Declares allows the construction industry to sign agreed declarations to address climate change. Started in the UK with Architects Declare groups are now active around the world, and covering Architects, Building Services Engineers, Civil Engineers, Contractors, Landscape Architects, Project Managers and Structural Engineers.

Some presentations from an Architects Declare event in February 2020 are provided at www.architectsdeclare.com/resources#architects-declare-resources

Construction Products Association

For a simple guide to life cycle assessment of products and the presentation of data through EPD see the Construction Product Associations' Guide to understanding the environmental impacts of construction products.

Embodied Carbon Policies

Developed by the Carbon Neutral Cities Alliance, One Click LCA and Architecture 2030, this website provides detailed resources on embodied carbon policies, including publications and webinars. www.embodiedcarbonpolicies.com/

Endeavour Centre

This organisation based in Ontario, Canada, has some useful resources including videos introducing Embodied Carbon. http://endeavourcentre.org/videos/

Greater London Authority (GLA)

The Draft London Plan Policy SI 2 sets out a requirement for developments to calculate and reduce Whole Life-cycle Carbon (WLC) emissions. This requirement applies to planning applications which are referred to the Mayor, but WLC assessments are encouraged for all major applications. Guidance has been published here to explain how the assessment of these carbon emissions should be approached and presented. A WLC assessment template has also been produced which applicants will be expected to use.

Institute of Structural Engineers (IStructE)

The Institute has recently published How to calculate Embodied Carbon, a set of Embodied Carbon calculation principles for the structural engineering community to follow to calculate Embodied Carbon in the same rigorous way across all designs, which will allow meaningful comparisons to be made between structural schemes, developing the understanding of Embodied Carbon as well as how the industry can most effectively reach net zero carbon.

The Inventory of Carbon and Energy (ICE) Database

The ICE database is an Embodied Carbon database for building materials which is available for free from Circular Ecology. Their founder, Dr Craig Jones, created the ICE database in his former role as a researcher at the University of Bath whilst working for Professor Geoff Hammond, at the Sustainable Energy Research Team (SERT). The ICE database original contained embodied energy and Embodied Carbon factors. However, since 2019 embodied energy factors are no longer included. The major data source for the ICE v.3 database is now EN 15804 Environmental Product Declarations (EPD).

London Energy Transformation Network (LETI)

LETI is a network of over 1000 built environment professionals that are working together to put London on the path to a zero carbon future. The voluntary group is made up of developers, engineers, housing associations, architects, planners, academics, sustainability professionals, contractors and facilities managers. LETI has provided an Embodied Carbon Primer for those interested in exploring Embodied Carbon in more detail and to support project teams to design buildings that deliver ambitious Embodied Carbon reduction.

materialsCAN www.materialsCAN.org

MaterialsCAN includes members of the global building industry that are ready to act on the smart prioritization of Embodied Carbon in building materials.

RIBA

In June 2019, the RIBA joined the global declaration of an environmental and climate emergency. The RIBA Sustainability Outcomes guide complements the RIBA Plan of Work 2020 Sustainability Strategy and the RIBA Plan for Use Guide. It provides targets with a timeline to delivery by 2030 for new and refurbished buildings as part of the RIBA 2030 Climate Challenge, and an absolute backstop of 2050 for most existing buildings. These include:

- Reducing operational energy demand and carbon by at least 75%, before offsetting
- Reducing Embodied Carbon by 50-70% before offsite renewables offsetting

FURTHER GUIDANCE AND INITIATIVES

RIBA Whole Life Carbon Guidance introduces architects to carbon assessment in the built environment and its application through the RIBA work stages. It makes the case for architects' role in reducing carbon emissions to mitigate climate change, explains the key concepts of Embodied and Whole Life Carbon and recommends the use of the Royal Institution of Chartered Surveyors (RICS) methodology for undertaking detailed carbon assessments.

RICS

In November 2017, RICS published "Whole Life Carbon assessment for the built environment" – a Professional Statement (the highest form of RICS guidance, both mandatory and regulated by the RICS). It is the recommended methodology for undertaking carbon assessments, brings increased consistency to reporting, aligns with BS EN 15978 (though only measuring global warming potential, not the full range of EN 15978 indicators) and provides a reporting structure and practical guidance for calculating lifetime Embodied and Operational Carbon emissions. It can be applied to all types of built assets, including buildings and infrastructure and covers new and existing assets including refurbishment, retrofit and fit-out projects.

RICS Building Carbon Database. Use the RICS database to explore Embodied Carbon calculations for buildings at each project stage. Register your completed carbon calculations and help build a detailed comparative dataset that will aid building design benchmarking.

Targeting Zero

Simon Sturgis provides links to his many articles and publications on Embodied Carbon, including his book, Targeting Zero: Embodied and Whole Life Carbon explained. www.targetingzero.co.uk/publications.html

UK Green Building Council

The UK Green Building Council has produced several guidance documents which cover Embodied Carbon.

Embodied Carbon: Developing a Client Brief and an Example Embodied Carbon Brief provide practical guidance to enable built environment clients to begin requesting Embodied Carbon measurements and how to act on the results.

UKGBC: Tackling Embodied Carbon in Buildings is designed for clients and developers who want to begin to consider and to reduce the Embodied Carbon impacts of their developments.

Practical How-To Guide: Measuring Embodied Carbon on a project: UKGBC partnered with BRE to provide a short guidance note on how to get started measuring Embodied Carbon on a project.

Net Zero Carbon Buildings: A Framework Definition: UKGBC has developed a framework definition for net zero carbon buildings to provide the industry with clarity on how to achieve net zero in both construction and operation (in-use energy consumption), whilst beginning to provide direction for addressing Whole Life Carbon in the industry.

In July 2019, UKGBC published a 'Guide to Scope 3 Reporting in Commercial Real Estate' to support commercial real estate companies with reporting their complete carbon footprint, including value chain (scope 3) emissions. The guide is intended to improve the overall understanding of value chain emissions and provide consistent approaches to reporting activities specific to commercial real estate.

They have recently published Building the case for Net Zero which provides the findings of a feasibility study that shines a light on the real-world implications for achieving new net zero buildings. The study looked at two real-life buildings at design stage, one residential block and one office building. The team considered the base designs and produced two further design iterations for each, one 'intermediate' scenario, looking to meet 2025 net zero performance targets and one 'stretch' scenario with 2030 targets in mind. The targets used were drawn from work undertaken by RIBA, LETI and UKGBC, covering Embodied and Operational Carbon.

WoodKnowledge Wales (WKW)
https://woodknowledge.wales/

WKW, a not-for-profit, for-public-good membership organisation, champions the development of wood-based industries for increased prosperity and well-being in Wales. Its ambition is to increase the market for wood, find ways to use wood better and to increase the supply and value of the homegrown resource.

FURTHER GUIDANCE AND INITIATIVES

World Green Building Council

The World Green Building Council's Net Zero Carbon Buildings Commitment invites developers, landlords, occupiers and regional authorities to commit to all buildings in their direct control achieving net zero carbon for operational energy by 2030. They call on UK business to sign up to the Commitment and use this framework to achieve net zero carbon for operational energy, and to go even further by reducing embodied impacts from construction. It's pioneering report, Bringing Embodied Carbon Upfront: Coordinated action for the building and construction sector to tackle Embodied Carbon, demands radical cross-sector coordination to revolutionise the buildings and construction sector towards a net zero future, and tackle Embodied Carbon emissions.

The Use Less Group www.uselessgroup.org/

The Use Less Group is based in the Department of Engineering at the University of Cambridge. The group is pursuing world leading research into the sustainable use of materials, energy and resources, including the book, Sustainable Materials: with both eyes open.

WRAP

Wrap no longer works in the built environment sector, but has provided a number of useful documents on Embodied Carbon – some links are provided below. Other documents are now available through CIRIA (see above).

Cutting Embodied Carbon in construction projects

The Business Case for Managing and Reducing Embodied Carbon in Building Projects

Procurement requirements for carbon efficiency

PROSIECT
CARTREFI O
BREN LLEOL

THE
HOME-GROWN
HOMES
PROJECT

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