Options for incorporating embodied and sequestered carbon into the building standards framework

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Quality information

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1. Summary of options identified

Historically, the building regulations framework has focused on setting standards around operational energy and related carbon emissions from new buildings. There is potential to reduce carbon emissions further, by expanding the framework to address and drive down the lifecycle carbon associated with buildings. In addition to considering operational emissions, this requires consideration of the embodied carbon associated with the manufacture, transport, maintenance and disposal of building materials and components, and the potential to increase the amount of sequestered or stored carbon in buildings[1]. There is a growing interest in lifecycle carbon associated with new buildings, with relevant policies being introduced or under consideration in Germany, Netherlands and France among other countries.

In early 2018, the Committee on Climate Change (CCC) commissioned research on the costs and benefits of introducing tighter standards for new buildings,[2] and as part of this commissioned AECOM to investigate options for incorporating embodied and sequestered carbon into the standards framework for new buildings in the UK. This paper sets out the findings of AECOM's options study, which involved literature review and selective stakeholder engagement. It sets out the current context, drivers and approaches for addressing embodied and sequestered carbon in the planning and design of new buildings in the UK and internationally (whether through a lifecycle approach or through assessing embodied and sequestration impacts separately). This is followed by a rationale for and summary of options to drive reductions in lifecycle carbon in new buildings in the UK.

The paper does not per se focus on the merits of using certain materials, such as timber.[3] The paper focuses on how lifecycle emissions can be addressed through the building standards framework or voluntary codes with a view to inform the upcoming review of regulatory standards (and ongoing work through the Construction Sector Deal and Transforming Construction Challenge Fund). This is not withstanding the range of other policy measures that could, or already do, deliver some or part of the intended outcomes, e.g., carbon pricing, Climate Change Levy and Climate Change Agreements etc. A range of factors including resource/material availability / scarcity, cross-sector competition for resources, relative cost-effectiveness, and trade issues should influence the overall policy mix for addressing lifecycle carbon in UK buildings.

The three alternative policy options for addressing embodied and sequestered carbon (as part of an overall approach to reducing lifecycle carbon) identified through this work are presented below, and a summary with indicative timescales is shown in Figure 1.

- **Option 1 – Voluntary action & Government leads by example through procurement**: This involves a number of parallel streams including promoting action to address lifecycle carbon in the construction sector (e.g. by setting non-binding sector targets and monitoring changes in the lifecycle carbon impact of new buildings over time) and requiring government-funded building projects to quantify and reduce this impact (e.g. by specifying a number of the relevant BREEAM and Home Quality Mark (HQM) credits to be achieved where assessments are already mandatory) alongside maximising sequestration. Voluntary action could also include lobbying for embodied and sequestered carbon assessment to become a mandatory issue in BREEAM and HQM.

- **Option 2 – Whole-life elemental carbon intensity targets**: Elements, product types and material substitutions with the highest lifecycle carbon savings are identified, accounting for supply chain dependencies (construction sector capacity, domestic capacity, effect of materials source, etc.). Whole-life carbon intensity limits are set in building regulations for these elements, product types and materials, initially near levels met by incumbent options, along with a trajectory for progressive tightening of standards. The targets would need to consider the thermal performance of the building elements (including heat loss and thermal mass impact) to ensure that trade-offs between embodied and operational carbon are accounted for. A shift to Option 3 can be made if and when necessary to drive further savings.

- **Option 3 –Whole building lifecycle carbon intensity targets**: A scheduled introduction of whole building lifecycle carbon intensity targets in building regulations could be considered. This will involve working with the construction sector and professionals to develop the corresponding regulatory tools and calculation method as well as capacity building for building control officers. Targets can be progressively tightened to drive increased carbon savings.

1 See appendix for definitions of embodied and sequestered carbon.
2 Currie Brown and AECOM (2019) *The costs and benefits of tighter standards for new buildings*
3 The importance of timber in construction as a route to sequestering more carbon in the built environment is discussed in the CCC's 2018 report *Biomass in a low-carbon economy*.

Some groundwork to enable assessment and benchmarking will be required in parallel or preceding each of these options and is common across all of the policy options discussed. This includes establishing a standardised approach to carbon quantification of new buildings, a national LCA/EPD database, along with steps to bridge the skills gap in this area.

Broadly mandatory targets are likely to be more effective in addressing lifecycle carbon and encourage innovation in the sector compared to voluntary action, though this is dependent on the level of ambition for mandatory targets and, on the other hand, the wider policy drivers and/or actions taken to promote voluntary action. Overall there is limited evidence currently to draw robust conclusions on the most effective approach. There are a series of low-regret actions that can however be progressed to lay the groundwork for a future policy intervention, with a decision point indicatively in 2020 on the long-term regulatory framework. Option 1 could be implemented in parallel to the groundwork with a view to encouraging early action, and facilitating project level data and learning. An increase in the number of assessments, driven by voluntary codes and/or planning requirements, along with standardised approaches to assessment can be used to establish carbon intensity benchmarks and targets across new building archetypes. The ambition for the voluntary action could also be revised with time to reflect the policy development under Options 2 & 3.

Figure 1: Summary of options and indicative timeframes for driving down lifecycle carbon (including embodied and sequestered carbon) in new buildings

Time-scale	Common	Voluntary action led by Government procurement	Building regulations whole- life carbon intensity targets	
			Elemental	Whole building
	Groundwork	**Option 1**	**Option 2**	**Option 3**
Decision -point	**Commence groundwork and Option 1 as low-regret actions**			
2019	National product/material & building LCA/EPD database Standard, simplified LCA for new buildings	Develop overall and sectoral strategies Monitor sectoral carbon intensity targets Lobby for mandatory LCA in BREEAM & HQM		
Decision -point			**Opt for Option 2 or Option 3 as the preferred option**	
2020	Build professional & industry capacity	Require government funded projects to consider and minimise the contribution of embodied and sequestered carbon to lifecycle carbon impacts (e.g. by making relevant BREEAM & HQM credits mandatory)	Establish targeted elemental method Develop regulatory methods and tools Develop regulatory (e.g. building control) capacity	Establish whole building method and scope
2021	Expand building LCA database & benchmark across archetypes		Introduce elemental carbon intensity targets	
2022			Progressively tighten intensity targets	Develop regulatory methods and tools Develop regulatory (e.g. building control) capacity Introduce whole building carbon intensity targets
2023	Maintain LCA / EPD			
Onwards			Potentially introduce whole building targets	Progressively tighten intensity targets

Legend: LCA = lifecycle analysis; EPD = Environmental Product Declaration; BREEAM = BRE Environmental Assessment Method; HQM = BRE Home Quality Mark; Element = e.g. structure, façade, roof, etc.

2. Introduction

2.1 Purpose

Historically, the building regulations framework has focused on setting standards for the operational energy and carbon savings from new buildings achieved through a combination of energy efficient design of building fabric and services, and integration of renewable energy technologies. There is potential to reduce carbon emissions further, by expanding the framework to address and drive down the lifecycle carbon associated with buildings incorporating both embodied and sequestered carbon. The embodied carbon emissions of buildings can be as much as two-thirds to three-quarters of the total whole life emissions (RICS, 2017[4]). Actions that reduce whole-life embodied carbon – without increasing operational carbon emissions – could represent a substantial carbon abatement opportunity that remains largely untapped by the UK policy agenda to date. There is also potential to increase the amount of sequestered or stored carbon in buildings (also referred to as 'embedded carbon'; see definitions in Section 2.2), e.g. through the use of wood in construction.

This paper sets out the findings of an investigation into how embodied and sequestered carbon could be incorporated into building standards or voluntary codes. It forms part of a wider programme of research on the potential for using wood and bioenergy resources for construction (published alongside this work) and on the costs associated with setting tighter standards for new build properties (due to be published early 2019).

2.2 Terminology

The term 'embodied carbon' is straightforward to define in concept, e.g. as "emissions aris[ing] from producing, procuring and installing the materials and components that make up a structure… includ[ing] the lifetime emissions from maintenance, repair, replacement and ultimately demolition and disposal" (RICS 2017). However, in practice an operative definition of the term depends on the precise scope (or 'system boundaries') of a particular carbon accounting exercise. This has led to the use of qualifications on the general term 'embodied carbon', the most common being 'cradle to gate' and 'cradle to grave', that aim to give a clearer idea of the assessment boundaries.

EN 15978 establishes a standardised framework for defining and presenting lifecycle or whole-life carbon information applicable to environmental impacts including embodied and sequestered carbon (see Figure 2, page 8). Under this framework (which is currently under review), sequestered carbon is part of module A1 –A3 (Product stage) and C1-C4 (End of Life stage).

Other key terms are defined in Appendix A - Terminology.

The global warming potential (GWP) associated with embodied carbon is one of a number of environmental impacts[5] addressed in lifecycle analysis (LCA), which can be applied at a material, product, elemental, or whole building level. As such, this paper often treats embodied carbon as a subset of LCA and assumes drivers, standards, tools, etc. for LCA indirectly serve the same role for embodied carbon.

2.3 Methodology and structure of the paper

The paper is based on a literature review and selective stakeholder engagement. Key documents that have influenced the paper are listed in the Bibliography and stakeholders interviewed are listed in Appendix A. The following sections summarise:

- the current context, drivers and approaches for considering embodied and sequestered carbon in the planning and design of new buildings in the UK and internationally; and
- a rationale for and summary of options for addressing embodied and sequestered carbon (as part of an overall approach to reducing lifecycle carbon) in new buildings in the UK.

4 RICS, Whole life carbon assessment for the build environment, Nov 2017, Figure 1
5 Environmental impacts in LCA are considered under impact categories. Information is most commonly presented for at least the following 5 impacts: climate change (GWP), acidification, eutrophication, stratospheric ozone depletion, and photochemical ozone creation. Other impacts include: abiotic resource depletion (covers primary energy and water resources), human toxicity, ecotoxicity, land use, ionising radiation, and (rarely) particulates.

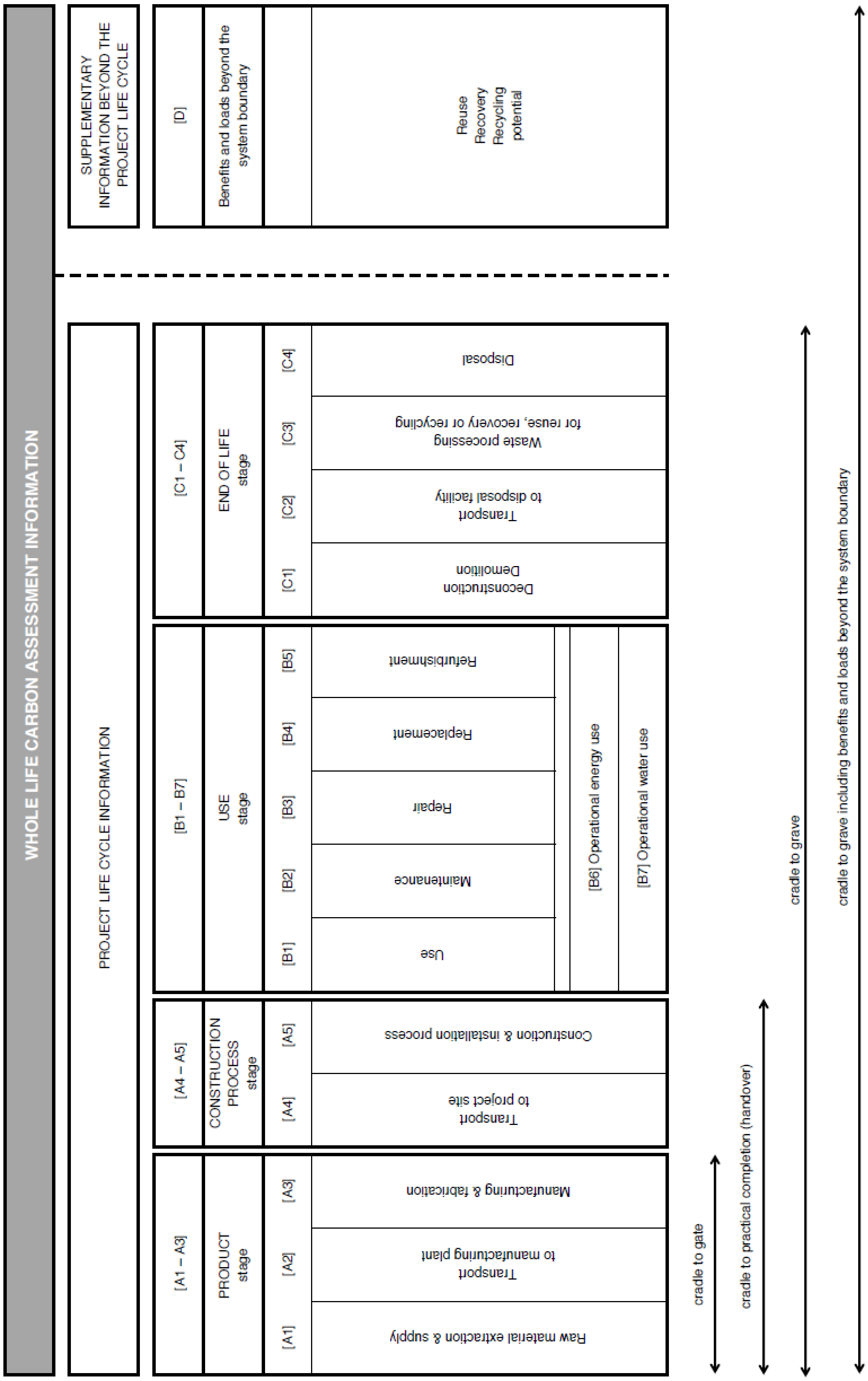

Figure 2: Modular information for lifecycle assessment as per EN 15978 including typical system boundaries [source: RICS 2017 Figure 2].

3. Context, drivers & approaches to addressing embodied and sequestered carbon in buildings

This section examines the context, drivers and approaches to addressing embodied and sequestered carbon in buildings, whether through a life cycle approach or through assessing embodied and sequestration impacts separately from consideration of operational emissions.

3.1 UK context, drivers & approaches to date

The construction and housebuilding sectors are currently subject to a range of existing drivers to quantify and reduce the lifecycle carbon emissions in new buildings taking into account the embodied and sequestered carbon in the building materials. These come from:

1. The planning system – Lifecycle Green House Gas (GHG) emissions need to be considered under current Environmental Impact Assessment (EIA) Regulations; planning authorities also have the option to address lifecycle GHG emissions associated with buildings through local planning policy including any local offsetting schemes.
2. Central Government – The use of BREEAM[6] is required for government-funded new non-domestic buildings but achieving credits based on LCA are not mandatory in the scheme. See section 3.1.2 below for more details on BREEAM requirements. (Embodied and sequestered carbon is not considered under current Building Regulations.)
3. Corporate bodies (voluntary action) – Commitments to address lifecycle GHG emissions may be made by developers and construction clients (including national and local government, other public sector organisations and large companies), with targets based on voluntary codes such as BREEAM or on bespoke metrics. Under carbon reporting frameworks – including UK mandatory reporting regulations, and voluntary frameworks such as CDP (formerly the Carbon Disclosure Project), GRI (Global Reporting Initiative) and others – participants have the option to report embodied and sequestered carbon in goods and services under 'scope 3' emissions.

The planning system, voluntary environmental assessment methods, and underpinning LCA standards and tools are the main things currently shaping how embodied and sequestered carbon is addressed in the UK, and each is discussed further below.

Addressing embodied and sequestered carbon through planning

Lifecycle analysis of new buildings (incorporating embodied and sequestered carbon) is not currently covered by national standards. Planning authorities may however choose to address them to suit local circumstances, subject to policies being based on sound evidence tested through the plan-making process.

The Embodied Carbon Industry Task Force (2014) recognised a number of ways that embodied carbon could be addressed at the planning stage of new developments, which remain valid today under an essentially unchanged planning system. In general, planning provides the following levers that can be used to ensure that developers consider embodied carbon (and where relevant sequestered carbon) as they are preparing development proposals:

- Environmental Impact Assessment – specifically the transposition into UK regulations of the revised EU directive on Environmental Impact Assessment gives greater prominence to addressing lifecycle greenhouse gas emissions associated with new development. Good practice in this regard is set out by IEMA (2017). As a result, where planning authorities require an Environmental Impact Assessment of a new development (depending on type and scale of development), the assessment should now include consideration of lifecycle greenhouse gas emissions.
- Planning policy – The scope and rigour of how planning policy addresses lifecycle GHG emissions from buildings varies by local authority. The Task Force report listed examples[7] of planning authorities with policies addressing embodied carbon (whether independently or as part of a lifecycle approach). These are

6 BREEAM is the BRE Environmental Assessment Method, which can be used to assess the environmental performance of non-domestic buildings based on assessment criteria covering nine environmental topics:
7 Brighton and Hove, Huntingdonshire, Eastleigh, and Dundee County Councils, Leeds City Council, and the London Borough of Wandsworth.

generally broad requirements for developers to demonstrate that embodied carbon has been addressed, which can be satisfied by anything from very general statements (e.g. a tick-box on the Brighton & Hove Sustainability Checklist) to voluntary submission of a whole building LCA study as supporting evidence within a planning application. The GLA (Greater London Authority) Draft London Plan (2018) recently introduced a requirement for whole lifecycle carbon emissions assessments for developments referable to the Mayor. This covers operational emissions and embodied emissions including emissions associated with maintenance and end of life disposal.

- Carbon offset schemes – a major focus of the Task Force recommendations was the potential for embodied carbon to be an 'Allowable Solution[8]' under zero carbon building regulations that at the time were expected to be introduced in 2016 for homes and in 2019 for non-domestic buildings. Note that sequestered carbon is not specifically mentioned in the Task Force recommendations. Reference is however made to EN16449 for calculating the emissions factor for timber which allows for sequestered carbon to be taken into account for wood and wood-based products. Although the Government did not take this policy agenda forward, local planning authorities retain the scope to introduce similar 'carbon offset schemes', as demonstrated in London in response to London Plan policies. The offset scheme instituted by the London Legacy Development Corporation, for example, includes embodied carbon savings as an eligible measure that can be used to offset the residual on-site carbon emissions from new developments.

Some advantages of promoting activity through planning are that action can be taken before there is nationwide agreement on standards and benchmarks. Indeed, the data generated through planning-related actions can contribute to the evidence base required for subsequent national regulations and standards. The planning system (alongside corporate commitments and government targets applied to publicly-funded construction) also remains one of the main mechanisms for setting targets under voluntary sustainability codes (e.g. BREEAM and HQM).

BREEAM and the Home Quality Mark

BREEAM is the main sustainability assessment method used in the UK for voluntary assessment and labelling of the sustainable design and construction of new non-domestic buildings. Following the withdrawal of the Code for Sustainable Homes[9], the BRE Home Quality Mark (HQM) is likely to emerge in an equivalent role for new homes.

BREEAM and HQM adopt similar approaches to rewarding actions (by awarding credits or points) to reduce the lifecycle environmental impact of materials based on:

1. The application of LCA, which addresses a wide range of lifecycle impacts[10] of materials including embodied carbon; and
2. The procurement of products with recognised environmental product declarations (EPDs) and procurement policy (HQM only).

The relevant issue headings and references to the sections setting out criteria and assessment guidance covering embodied carbon in BREEAM and HQM are set out in Table 1. Note that neither of the criteria is mandatory to achieve a particular BREEAM or HQM rating.

Table 1: Materials credits available in BREEAM 2018 and the Home Quality Mark Beta

Issue heading	Issue ID / Criteria	
	BREEAM 2018[11]	**HQM Beta**
Building lifecycle assessment	Mat 01	19.02 crit 5 & 6
Procurement policy and product environmental information	Mat 02	19.01 crit 1 – 4

8 Allowable solutions was the name given to the prospective offsetting mechanism proposed in relation to the withdrawn zero carbon homes policy to address residual carbon emissions after all on-site saving measures had been taken.
9Treatment of embodied carbon in the Code for Sustainable Homes was similar to contemporary treatment in BREEAM (i.e. as an aspect of wider LCA and using the Green Guide to Materials Specification).
10 BRE environmental profiles use a total of 13 categories with resource depletion split into minerals, fossil fuels and water, ecotoxicity split into 'to water' and 'to land' components, waste added as a distinct category, and particulates and land use omitted.
11 SD5078: BREEAM UK New Construction 2018

Important features of the way that BREEAM and HQM currently address lifecycle carbon are:

1. Embodied carbon is addressed as part of LCA and criteria align with a range of LCA standards underpinned by European, international and some UK-specific standards.
2. The minimum scope of the LCA in terms of lifecycle stages to be covered is set in terms of the lifecycle stages defined in BS EN 15978:2011 (see Figure 2) as Stage A: A1 – A3 (cradle to gate). Stages B (use) and C (end of life). These stages must be covered to the extent enabled by the BRE-recognised LCA tool used (i.e. the scope for the use and end of life stages is flexible). LCA analysis could be expanded to include Stage D but is not essential.
3. The scope of building works included and excluded from the assessment is clearly defined based on the RICS New Rules of Measurement classification system. The scope of the LCA to achieve credits that involve benchmarking the performance of the design is limited to defined elements of the superstructure. The substructure and hard landscaping elements are assessed separately to avoid benchmarking being skewed by site-specific factors (sloping sites, buildings with / without basements and external parking, etc.) Building services are also assessed separately
4. The majority of credits in BREEAM (for the main non-domestic building types: offices, retail, and industrial) can be achieved on submitting quantitative LCA data, which is converted into Ecopoints[12] and compared with benchmarks.
5. The majority of credits in HQM (beta) are based on calculated performance, again in terms of Ecopoints, with distinct benchmark[13] performance scales for houses (detached or terraced / semi / clustered) and apartments (low or high rise).
6. Both BREEAM and HQM reward procuring more than a certain number of products with EPDs based on the rationale that this encourages more construction product manufacturers to produce and register EPDs for their products, which increases the amount of product-specific LCA data available.
7. BRE provides simplified calculation tools, to ensure that most credits are attainable by design teams without the need for potentially costly expert LCA support, while also maintaining a system to recognise expert tools suitable for more advanced LCA that is generally necessary to achieve more demanding credits, including what are referred to as 'innovation' credits.

LCA standards, tools and practice guidance

Most approaches to addressing lifecycle impacts of buildings (including embodied and sequestered carbon) are underpinned by a number of standards defining LCA practice. A range of tools and databases are available that enable standards-compliant calculations to be undertaken based on design information and construction bills of materials. A list of relevant standards is included in Appendix A and explanatory documents (e.g. RICS (2017), GLA (2013)) are listed in the Bibliography. The main thing to note is that there is a comprehensive range of emerging standards and a broadening competitive market for LCA calculation tools suitable for both LCA professionals and less expert users, such as building design team members. The remaining practical difficulties for LCA relate less to the availability of procedural standards and calculation tools and more to standardising their application, particularly the required scope of LCAs in terms of the lifecycle stages and the parts of the building covered, to enable effective benchmarking and target setting.

A lack of standardisation can be seen in the variations in scope suggested or required for LCAs in different sources of practice guidance, most notably from:

1. The Institute of Environmental Management & Assessment (IEMA) guidance for environmental impact assessment of GHGs – gives advice on "key common components" but "does not recommend a particular approach" or scope;
2. RICS professional standards and guidance – requires that LCAs cover as a minimum A1 – A5, B4 Replacement (for facades) and B6 Operational energy, for a defined subset of substructure and superstructure elements; the guidance encourages that assessments where possible, account for all components relating to the project across all life stages.

12 "A UK Ecopoint is a single score that measures total environmental impact as a proportion of overall impact occurring in the UK. It is calculated by taking [normalised impact data], applying a weighting factor to each impact and then adding all the weighted impacts to give a total – The Ecopoints". BRE Green Guide FAQ https://www.bre.co.uk/greenguide/page.jsp?id=2089.
13 "The home's impact benchmark is a reference of average environmental impact for a home in the UK as calculated using an IMPACT compliant tool and average construction data for homes built since 2006. The unit used for comparison is BRE Ecopoints (based on a range of EN 15804 indicators) and national average occupancy for the type of home being assessed." BRE. HQM Beta Manual.

3. BRE for BREEAM and HQM – requires that LCAs cover the ‘product’ (A1 – A3), ‘use’ (B) and ‘end of life’ (C) stages (see Figure 2) to the extent enabled by the LCA tool used, for a defined subset of superstructure element; additional credits can be achieved if LCAs also cover substructure and some core building services elements.

The lack of standardisation makes it harder to assemble LCA data suitable for comparison and benchmarking of embodied carbon performance of buildings.

3.2 International approaches

The study looked internationally for examples of the use of regulation and voluntary mechanisms to address lifecycle carbon in construction with a view to identifying advanced approaches or potential alternatives to those currently in place in the UK.

Embodied and sequestered carbon in regulations

The study looked for policy instruments that are in force or in prospect[14] addressing embodied and/or sequestered carbon separately or as part of lifecycle analysis, in the EU, North America, and Australia. Whilst not a comprehensive list, the following regulations were identified:

1. Germany, BNB assessment for new federal buildings – This assessment and rating system developed in partnership with the German Sustainable Building Council (DGNB, based on their voluntary scheme known by the same abbreviation) became mandatory in 2011, initially for office buildings. Like DGNB (discussed below), parts of BNB are fundamentally based on a whole building LCA, which is therefore integral to obtaining certification. DGNB and BNB are enabled by a national LCA /EPD database and bespoke calculation rules, including weighting of scores for different environmental impacts to produce a single overall environment impact score for benchmarking and comparison against performance limits. The system boundary for the LCA covers the ‘product’ (A1 – A3), ‘use’ including operational energy use (B1 – B4 and B6), and ‘end of life’ (C3 and C4) stages, plus ‘benefits and detriments beyond the system boundary’ (D). Refer to Figure 2 for a description of LCA stages.
2. Netherlands, Building Decree 2012 – Article 5.9 on sustainable construction has required LCA calculations covering GHGs and resource depletion for new homes and non-domestic buildings over 100m^2 since 2013. Calculations are enabled by a national calculation methodology and LCA / EPD database. The system boundary covers all stages from A to D excluding operational energy and water use (B6 and B7).
3. California, Buy Clean California Act – Requires the Department of General Services: by January 2019, to set maximum global warming potential limits (carbon intensity limits) for the following materials in public works contracts: (1) Carbon steel rebar. (2) Flat glass. (3) Mineral wool board insulation. (4) Structural steel; from July 2019, to set facility-specific upper limits on the carbon intensity of eligible materials (at or below the previously determined maxima) and require successful bidders to submit a current, ISO 14025-compliant (or similarly robust) Type III Environmental Product Declaration to show that the limits are not exceeded. Prohibits the installation of non-compliant materials. Requires review of the carbon intensity limits by January 2022 and every three years thereafter.
4. France, future regulation of lifecycle carbon – As follow-up to the commitments made at the COP21 meeting in Paris, the French government drew up a law, the French Energy Transition for Green Growth Act, which among other things enables “by 2018…the implementation of an ambitious environmental standard for new buildings”[15]. The government partnered with industry and expert bodies to develop and launch a trial scheme in 2016 named E+C- (energy positive, low carbon) to test the feasibility of new performance targets and related assessment methods. E+C- establishes two levels of performance for lifecycle GHG emissions. The evaluation includes the ‘product’ and ‘construction process’ (A), ‘use’ (B) and ‘end of life’ (C) 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.
5. Finland, prospective regulation of embodied carbon of building materials – Finland has set out a roadmap to integrate embodied carbon emissions of building materials into building regulations, with limits for all buildings from 2025. Calculations would be based around EN 15978 but further details of the methodology are still to be developed. 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 towers before being extended to all building types.

14 Only includes policy instruments with a definite timetable or steps taken toward implementation; broad commitments to work towards greater use of LCA, e.g. for government procurement, are not included.
15 http://www.batiment-energiecarbone.fr/en/trial-scheme/background/

6. Switzerland, municipal requirements for carbon footprinting – A number of Swiss municipalities require developers to calculate the carbon footprint of new developments. Targets are established based on consistency with the vision of the 2000-Watt Society as reflected in Standards published by the Swiss Society of Engineers and Architects: SIA 2031 Energy Certificate of Buildings (2009), SIA 2032 Grey Energy of Buildings (2010), SIA 2039 Induced Mobility (2011) and SIA 2040 SIA Energy Efficiency Path (2011). The lifecycle assessment data that underpins these calculations in based on ecoinvent[16] database and accounts for sequestered carbon in materials.

Given the limited number of examples identified, our conclusion is that while interest in embodied and sequestered carbon in new buildings is growing, few countries are currently addressing it in their building regulations, mirroring the current position in the UK. Where progress is being made, the focus has been on approaches underpinned by European and global standards and (in Europe) by an enabling framework usually including a national LCA database and calculation methodology. In both Germany and the Netherlands, the LCA calculation methodology for national use has been adopted from the dominant voluntary environmental assessment method.

The California example stands out in not taking a whole building approach. The legislation is intended to drive decisions on materials sourcing with limits set to exclude the use of high embodied carbon sources of bulk construction materials, likely to include Chinese materials that currently have relatively high cradle-to-gate embodied carbon. This example clearly shows that the use of performance limits, particularly at material and product levels, has potential direct trade implications. Similarly, lifecycle carbon limits (after accounting for sequestered carbon) at the elemental scale could have direct implications for competition between alternative design solutions (e.g. timber vs. steel or concrete frame). Such effects need to be carefully considered.

Embodied and sequestered carbon in voluntary codes

Voluntary building sustainability assessment and labelling systems with international applicability or influence include the UK's BREEAM, US's LEED, Germany's DGNB, France's HQE, and Australia's Greenstar schemes. There is a lot of similarity in the way that these national schemes currently address embodied, sequestered or lifecycle carbon, and also some notable differences.

All of the schemes reward the undertaking of a whole-building LCA (addressing embodied carbon as one aspect of broader lifecycle impacts of materials), but only DGNB makes LCA mandatory. DGNB and BREEAM award points based on pre-established LCA performance benchmarks. BREEAM sets benchmarks based on overall ecopoints[12]. DGNB addresses 5 of the 9 LCA impact areas including global warming potential (which is broken down into separate embodied and operational emissions components) and sets a minimum performance backstop and a points scale relative to absolute reference performance benchmarks for each impact. The other schemes reward a mixture of process, indirect indicators of performance improvement, and auto-benchmarking; for example awarding points for:

- quantifying impacts using LCA one or more times during design and construction;
- selecting a minimum number or proportion of products with Environmental Product Declarations, i.e. with quantified lifecycle impacts;
- studying options for reducing lifecycle impacts and showing that impacts have been reduced through the design process relative to baseline impacts established for a baseline design.

It is also worth mentioning that the Dutch localisation of BREEAM, BREEAM-NL, uses shadow prices to convert LCA impacts in a range of different units into a single quantity for benchmarking (by contrast with weightings based on expert opinion, as used for UK ecopoints). This shadow price approach is made possible by the existence of a national dataset on shadow prices for a wide range of environmental impacts.

These national schemes take a variety of approaches, though there is no evidence of relative effectiveness of these in driving reductions in lifecycle carbon for the buildings assessed.

In addition to these national schemes the EU has developed Level(s)

> *a voluntary reporting framework that provides a common "sustainable" language for the buildings sector: a set of simple metrics for measuring the sustainability performance of buildings throughout their life cycle. Level(s) encourages life cycle thinking at a whole building*

16 Ecoinvent is an international lifecycle inventory database used in Life Cycle Assessment (LCA) and Environmental Product Declarations (EPDs)

level… and covers energy, materials, water, health and comfort, climate change and life cycle cost and value.

Within the ‘Thematic Area’ of Life cycle environmental performance and under ‘Macro-objective 1: Greenhouse gas emissions along a buildings life cycle’, Level(s) includes the calculation of the ‘Life cycle Global Warming Potential’ of a building. Level(s) establishes the methodology for calculation and reporting of sustainability indicators for buildings but does not set performance limits, benchmarks, or characterise or label overall performance. Level(s) has been developed with broad input from the developers of national voluntary building environmental assessment methods such as BREEAM, HQE & E+/C-, DGNB, etc., with the aim of developing a common set of building sustainability metrics across Europe. The methodology was developed in 2017 and is currently under test phase.

3.3 Classification of approaches and relevant precedents

As well as reviewing the range of past and current approaches summarised above, the study considered past and current approaches to addressing other issues including operational energy and carbon, water, ozone depletion, health impacts, etc. There are potential parallels between the challenges initially faced in tackling other environmental issues and those facing embodied and sequestered carbon now, e.g. variability in building and construction product supply chains; initial lack of universally accessible but robust whole building calculation methods and benchmarks; and so on. The study considered the applicability of these past approaches to addressing lifecycle carbon, and in particular the lessons that could be learned from the history of regulation covering the energy efficient design of buildings.

Classification and examples of environmental improvement approaches

Looking at the approaches that have been used to drive performance improvement in relation to buildings on a range of environmental issues to date, a typology of approaches emerges:

- Exclusion – Banning ‘things’ with unacceptably poor performance / impact;
- Preference – Preferring ‘things’ with better performance / lower negative impact; and
- Quantified performance (and limits) – Setting explicit, quantified limits that determine which ‘things’ are acceptable / unacceptable.

The ‘things’ in question depend on the scale at which the performance improvement approach is applied and are generally one of the following:

- Material / ingredient – e.g. glass, steel;
- Product – e.g. a glazed façade panel, a steel beam, a boiler;
- Element / system – e.g. a building façade, a heating system; or
- The whole building.

LCA can be applied at each of these scales in buildings. Examples of each type of environmental performance improvement approach at each scale of application are set out in Table 2. Examples that address embodied and/ or sequestered carbon directly or via LCA are shown in bold.

Table 2: Examples of environmental improvement approaches at different scales

Environmental Improvement Approach	Scale at which approach is applied			
	Material / ingredient	**Product**	**Element / system / sub-system**	**Whole building**
Exclusion	CFCs & HCFCs Deleterious (e.g. asbestos) Unsustainable timber C2C banned chemicals GM foods	Incandescent light bulbs	PU backed aluminium cladding systems	
Preference	**Materials preference method** Scarcity index Non-PVC	**Reward for choice of materials with an EPD (BREEAM, LEED, C2C, Ska)** Green product lists (Greenbook live, Greenscreen)	**Green Guide to Specification** Waste hierarchy GLA heating and cooling hierarchies	Passive design Naturally ventilated
Quantified performance (and limits)	**Recycled content (materials)** BREEAM refrigerants	**Recycled content (products)** Window U-values Boiler efficiency BREEAM appliance labelling, fan SFP, lamp efficacy, paint VOC, etc. Enhanced Capital Allowances lists	**BREEAM 2018 Simplified Building Assessment Tool** Wall/façade, roof, and floor U-values Heating system efficiency Lighting efficiency	**Whole building LCA (BREEAM etc.)** Bldg. Regs. Part L TER, TFEE Air permeability Bldg. Regs. Part G water use limit Private Rented Sector Regs.

Exclusions – Pros and cons

The clearest examples of the use of exclusions for improving environmental performance are the banning (via regulations) of refrigerants with high ozone depletion potential and of incandescent light bulbs, and restrictions on the use of unsustainable timber (driven by planning and corporate policy and foreshadowed by criteria in BREEAM and other voluntary assessment methods).

- **Pros** – simple; relatively easy to apply and control; involves specifying what cannot be used, leaving scope for innovation on lower impact alternatives.
- **Cons** – potentially simplistic; potential for real or perceived perversities – some things allowed are / appear more carbon intensive than some things excluded, or embodied carbon is / appears less critical than other issues not considered; limited scope to reduce overall embodied carbon in buildings given the number and diversity of construction materials, of which few (only the worst) things can be excluded; hard to justify and implement if attempting to restrict a pervasive material (e.g. some uses of concrete).

The acceptability of using exclusions to drive improvement is likely to depend on the strength of the evidence for the exclusion based primarily on:

1. The criticality of the negative impacts avoided, e.g. ozone depleting substances; or
2. The existence of cost-effective alternatives making the impacts of an obsolete product intolerable, e.g. incandescent light bulbs.

The regulatory precedents show that it is possible to exclude materials and product types on environmental grounds. Any trade-offs between embodied/sequestered carbon and carbon associated with operational energy use and/or other environmental impacts would need to be considered upfront when determining any exclusions. Exclusions aimed at reducing lifecycle carbon are likely to rely heavily on the existence of cost-effective alternatives that make the impacts of incumbent products hard to justify.

Preferences – Pros and cons

Many of the early approaches to addressing the embodied/ lifecycle impacts of materials were based on the idea of materials preferences, which mainly work at the scale of materials, products, or building elements. The Green Guide to Specification is a long-standing example of an elemental materials preference method, and ranks elements such as window types, wall and roof constructions, etc. from 'A+' to 'E' based on overall impact expressed in terms of ecopoints. BREEAM and many other voluntary schemes reward the selection of products with EPDs (regardless of the actual impacts quantified), which is a form of preference at product level.

- **Pros** – more scope to address embodied and lifecycle carbon impacts (compared to exclusions) as preferences can be identified for as many materials, products, and elements as desired; effective way to drive specific things, such as the use of wood for particular building elements such as superstructure or wall / facade. [17]
- **Cons** – complex to set targets / compliance criteria as preferences for enumerated materials, products and elements do not translate obviously into aggregate performance thresholds, (although the previous BREEAM 2014 Mat 01 credit calculator – based on ecopoints – showed it is possible); requiring that specific preferred materials / products / elements be used (prescription) makes for easy criteria but runs against the grain of most current regulatory approaches; may be a barrier to innovation unless there are mechanisms to quickly assess and add new products / elements to the preference system; and the same materials from different sources can have different embodied, and therefore lifecycle, carbon impacts, so may get perversities with complex, shifting supply chains.

Preference methods are potentially flexible. They could be used to broadly drive the use of preferred (in this case low lifecycle carbon) materials / products / elements, as demonstrated by the use of the Green Guide to Specification across multiple building elements in BREEAM prior to the 2018 scheme. However, the Green Guide also shows that a lot of up-front analysis is required to rank the options to enable a preference method approach, and application can be cumbersome as designers need to equate available products to the closest archetypes in the preference method database to inform their decisions. As is the case for using exclusions, there would need to be strong evidence on the relative performance of materials / products / elements on a lifecycle basis to justify the use of preference methods in building regulations (ensuring that underpinning data is comprehensive and unbiased). This study did not identify any examples of the use of such methods in regulations to date. However, preference methods and hierarchies are commonly used in planning policy, where developers can be required to justify in their applications any decision not to integrate preferred approaches in development proposals. Examples include references to the waste hierarchy in local plans, and the GLA heating and cooling hierarchies in the London Plan.

Quantified performance (and limits) – Pros and cons

Most of the current UK and international approaches to addressing embodied/ lifecycle carbon identified in sections 3.1 and 3.2 involve the quantification of carbon based on LCA at whole building scale (Dutch Building regulations, BNB/DGNB, E+C-, BREEAM, LEED) or at the material level (Buy Clean California Act). Voluntary codes, which often foreshadow potential regulatory options, appear to be converging on whole building LCA as the basis for driving reductions in embodied impacts. Only DGNB currently sets limits on embodied impacts at building level. However, the Buy Clean California example shows that performance limits at a material level could also work to drive improvement, and it is easy to imagine a similar approach applied at the product level (based on EPD information, for example) and at the building element level (in a manner analogous to U-values).

- **Pros** – quantification as part of every design should enable evidence-based, project-specific decision-making; encourages optimisation and provides a framework for driving continuous lifecycle carbon reduction towards a discoverable theoretical minimum; compatible with and potentially drives innovation; whole-building calculations are flexible allowing trade-offs driven by e.g. overall cost-effectiveness.
- **Cons** – currently requires expensive expert tools and expertise (although the BREEAM 2018 simple building assessment and new third party tools such as One Click LCA are pitched to be usable by design team members); time intensive; benchmarks are currently poor and / or not transparent and hence a weak basis for baseline target setting (particularly at the level of products and building elements); difficult

17 The importance of timber in construction as a route to sequestering more carbon in the built environment is discussed in the CCC's 2018 report *Biomass in a low carbon economy* as well as the recent report by the Royal Society on *Greenhouse gas removals*. Using timber in construction to both sequester carbon and displace high embodied carbon materials is one of the best uses of sustainable biomass identified through the CCC's analysis. The work concluded that up to 3 MtCO2e per year could be stored if high levels of new residential units are built using timber frame systems. Comparable quantities may also be stored through the use of engineered wood products such as cross-laminated timber (CLT), particularly in the non-residential sector, although current levels of deployment of these systems are very low.

to undertake analyses to a consistent scope and to validate this based on reported results, so could be susceptible to 'gaming'; risk that the focus is on the LCA process that requires activity but may not lead to improvement (e.g. identification but not selection of lower embodied carbon options); current carbon savings achieved through the LCA-based approach are not assessed for cost-effectiveness; identifying cost-effective solutions would require assessment of a range of scenarios at the project level taking into account the direct and consequential cost impacts (e.g. on choice of materials for other components, or maintenance costs).

There are substantive differences in the merits and practicalities of applying quantified lifecycle impact limits at the different scales (material, product, element, whole building). Below the whole building scale, it is fair to argue that within a given category, different materials, products and elemental constructions are not drop-in substitutes for each other. For example, using a wooden glue-lam vs. a concrete structure for a building is likely to have knock-on design effects on other elements that would not be reflected in a narrow comparison of the embodied carbon of the superstructure. As such, the construction products supply chain is likely to favour LCA at whole building scale over material, product or elemental approaches. Conversely the potential to make large reductions in lifecycle carbon) may be concentrated in relatively few substitution options at material, product or elemental level. The Green Construction Board (2013) found that six "key material industries [represent] over 90% of total supply chain GHG emissions: 1. Metals (steel); 2. Concrete and cement; 3. Timber; 4. Brick and ceramics; 5. Glass; [and] 6. Plastics". If so, it could be more efficient (in terms of analysis effort vs. carbon reduction) and more effective (greater verifiable reductions from regulation) to apply limits to the materials, product types, and elements that offer the greatest scope for lifetime carbon savings. The costs of administering any standards are also a consideration. Whole building LCAs could be undertaken at individual building level, or at a project level, with different approaches having different implications for the regulatory cost burden. In comparison, the use of material, product or elemental embodied carbon limits would tend to incur initial and periodic costs in assembling and updating the evidence base and setting performance thresholds, plus costs on the supply chain to establish the performance of materials and products. There is potential for the ongoing costs to developers for assessments on each building to be reduced for this type of standard. While there are pros and cons of both approaches, a detailed cost benefit analysis may help inform the most effective route. Again different approaches may be considered depending on size of project/ development.

Irrespective of whether the targets are set at product, elemental or whole building level, they would need to take into consideration the relative thermal performance of alternatives (including heat loss and thermal mass impact) to ensure that trade-offs between embodied and operational carbon are accounted for.

Learning from regulating operational carbon emissions at design stage

Introduced in 1985 (under the 1984 Building Act), Part L of the Building Regulations is the main regulatory instrument for improving the energy efficiency of new buildings and reducing operational carbon emissions. One of the routes for compliance under all versions of Part L up to 2006 was called the 'elemental method' and involved meeting U-value limits for each building element: walls, windows, roof, ground floor, etc. alongside some other limits on design such as the proportion of glazed area of the façade. Minimum boiler efficiency standards were introduced in 2002, along with a switch from energy to carbon as the focus of the regulations, and in 2005 it was effectively made compulsory for boilers to be of the more efficient 'condensing' type.

For homes, whole-house energy use calculations using SAP were cited as a compliance method as early as 1994, but only became the primary basis for demonstrating compliance with a limiting Target Emission Rate (TER) in 2006, when Part L was radically updated, along with the introduction of a 'notional building' baseline. At the same time, equivalent compliance criteria were introduced for non-domestic buildings with calculations defined in a non-domestic simplified building energy model, SBEM. Since 2006, percentage changes to the TER have become the main way of understanding the scale of improvement sought, in terms of reductions in carbon emissions in Part L updates. Nevertheless, elemental performance limits have continued to play a role in Part L, in the form of design 'backstops' for elemental U-values, boiler efficiency, etc.

Since 2010, one of the main issues when considering updates to Part L has been addressing the so-called 'performance gap' between design and as-built performance. In broad terms and on average, buildings once constructed and in use have higher energy use and carbon emissions than expected based on design stage calculations. Design changes during construction, poor construction quality, and shortcomings in the energy models are likely to be contributory factors to the observed performance gap.

Linked to Part L was the ultimately cancelled Zero Carbon Homes agenda, which included allowable solutions – essentially carbon offsetting. The Embodied Carbon Industry Task Force promoted embodied carbon as a potential allowable solution. Among the issues they recognised needed to be resolved was that of 'additionality'.

Apparent carbon savings may not be additional if they simply move savings that would have happened anyway, e.g. from one building project to another if a material substitution measure (e.g. use of PFA for cement in concrete) is already using all the low carbon material available.

Considering the history of regulating operational carbon at design stage through Part L (where relevant expressed in the terms introduced in Table 2 – exclusions, preference, quantified performance), the following progression can be observed:

1. Use of elemental method (i.e. elemental performance (walls, roofs, etc.) and product (windows) and U-value limits, etc.) as main compliance route;
2. Introduction of whole-building calculation methods as an alternative compliance route;
3. Use of product and elemental performance limits to effectively exclude existing options with poor performance (e.g. non-condensing boilers);
4. Switch to a whole-building calculation as the main compliance route, retaining elemental performance backstops; and
5. Focus on improving the robustness of the compliance calculation to close any gap between as-built outcomes and design assumptions (addressing the quality of both the calculation and the construction process).

The approaches used and the progression from elemental to whole building calculations for regulating operational energy use and carbon emissions could hold relevant lessons for considering how lifecycle carbon might be effectively regulated.

3.4 Summary of mechanisms to address lifecycle carbon in buildings

Reviewing the past and current UK and international landscape of voluntary incentives and regulations, and considering parallels with regulation in other areas such as operational energy and carbon, the broad picture that emerges is that:

1. Drivers for addressing lifecycle carbon, including embodied and sequestered carbon, in buildings in the UK can come from: government, through regulations and mandatory rules on government procurement; the planning system, including EIA, planning policy, and through offsetting schemes; and from voluntary corporate commitments, which may relate to the use of any mix of corporate reporting standards, voluntary building environmental assessment methods, and bespoke guidelines and targets.
2. Almost all approaches addressing lifecycle carbon in buildings at any scale are likely to rely on or refer to underpinning standards on LCA and EPDs and make use of related calculation resources (e.g. LCA and EPD databases) and tools.
3. Voluntary building environmental assessment schemes such as BREEAM and LEED are based on ‘whole building’ LCAs. The schemes are converging on requiring design teams to undertake standards-based assessments using dedicated calculation tools enabled by national and international LCA and EPD databases.
4. The rare examples of regulations in Europe (Netherlands and prospectively France and Finland) are following the lead of the voluntary schemes, adopting approaches based on LCA standards, calculation methods and supporting LCA / EPD tools. In addition, Germany has demonstrated the co-option of a voluntary scheme for government use (with the development of BNB from DGNB).
5. The California regulation example stands out as a different type of approach. It is focused at the materials / product level on a narrow range of high embodied carbon materials.
6. Voluntary schemes retain non-LCA approaches to drive sustainable materials selection at the product and building element levels. For example, BREEAM, LEED and some of the other schemes reviewed reward the use of products with standards-compliant EPDs.
7. Voluntary schemes also retain vestiges of alternative approaches to comparing the embodied or lifecycle impacts of materials, for example the BREEAM Simplified Building LCA tool is based on the Green Guide to Specification used in previous versions of BREEAM, which labels construction types for building elements (walls, roofs, floors, etc.) on a scale of A+ to E based on ecopoints[12].
8. Looking generally at precedents for driving environmental performance improvements in buildings, three broad types of approach can be identified: exclusion of specific things with the worst environmental impacts; preference for specific things with better impacts; and the use of quantified limits as the basis

for selection on performance. These approaches can be applied at the material, product, elemental, or whole building scale, and the combination of approach and scale of application provides a useful framework for mapping out the full range of options available for driving the reduction of lifecycle carbon in buildings.

9. Exclusions are unlikely to be a practical way of driving significant carbon reductions, given the number and diversity of construction materials and the weight of evidence needed to justify banning some material uses outright. Preference methods and hierarchies have been used in planning policy and voluntary building assessment methods, but it is not clear how such a mechanism, lacking clear compliance criteria (e.g. in the absence of limits or targets on quantity or proportion of preferred materials), would work in building regulations. This suggests that performance limits at material, product, elemental or whole building scale are likely to be the practical options for driving significant carbon reductions through building regulations.

10. The coverage of operational energy and carbon in building regulations shows a progression from elemental performance limits (U-values, boiler efficiency, etc.), through the introduction of whole-building calculations as an alternative compliance route, finally a shift to whole-building performance limits, retaining elemental performance backstops, and a current focus on data / calculation and construction quality and hence the robustness of calculated performance vs. outturn.

While the review identified a range of approaches to incorporating assessments of embodied and sequestered carbon in voluntary or mandatory frameworks, it found no evidence about the individual or relative effectiveness of either the regulatory approaches or the use of voluntary codes (based on the examples and assessment methods discussed in Section 3) in actually reducing lifecycle carbon emissions in new buildings.

4. Options for driving down lifecycle carbon through regulations and voluntary codes

4.1 Options identification and rationale

There is broad agreement that standards, supporting technical and professional resources and hence current practice in the areas of embodied and sequestered carbon in UK construction[18] are relatively immature, compared to those available to address operational energy and carbon. Commentators in the literature suggest that the next steps in addressing lifecycle carbon in UK construction need to focus on developing the evidence base, calculation resources, professional experience, and a convincing narrative framework as groundwork to enable the introduction of regulations. Much of this commentary is based on the assumption that this should and eventually will be addressed in regulations at a whole building scale[19] and it is recognised that standardised approaches to LCA would be needed for this. Much of the research and commentary starts at a whole building scale and assumes, often implicitly, that whole building quantification is a necessary part of reducing lifecycle carbon associated with buildings. This perspective is reflected in the approaches being taken in voluntary building environmental assessment methods such as BREEAM, assessment of federal buildings in Germany, building regulations in the Netherlands, and the potential regulation being trialled in France.

In this context, one option for driving lifecycle carbon savings in new UK buildings would be to take steps towards the introduction of **regulations requiring whole building carbon calculations**. Regulations could cover carbon alone (including embodied and sequestered carbon) or as part of LCA. Taking this route would not necessarily mean introducing such regulations immediately. In fact there would likely be a need for certain groundwork before regulations would be practicable. Addressing lifecycle carbon in the planning system, and government collaboration with industry on the development of calculation tools and resources (following the French E+C- model) could be part of laying the necessary groundwork.

The framework of LCA standards, guidance on professional practice, and to some extent even environmental assessment methods like BREEAM focus more on the consistent quantification of environmental impacts than on the potential to reduce impacts. There appears to have been little or no study to date of the effectiveness of a whole building approach in saving carbon, the cost-effectiveness of savings driven at a whole building level, or comparisons in these terms of a range of alternative approaches for addressing lifecycle carbon in buildings. The literature typically focuses on the immaturity of LCA and limitations of data, tools, standardisation, established

18 E.g. Giesekam, J. et. al., 2016; De Wolf, C. et. al., 2017
19 Albeit with a constrained scope in terms of the parts and level of detail in the building covered

benchmarks and skills as barriers to wider uptake of whole-building approaches. A limited review of buildings subject to whole building carbon analysis or broader LCA showed that only modest actions were taken on materials substitution, increased use of recycled materials, etc. achieving modest reductions in embodied carbon. This suggests that the requirement to carry out an LCA itself may not deliver the intended benefits though whole building analysis inherently allows for more flexibility in choosing options to reduce lifecycle carbon. It is also not clear exactly how benchmarking of the range of outcomes for current design practice should be translated into carbon intensity targets for new buildings in a way that would drive significant design and construction changes, for instance the substitution of wood for high-carbon alternatives such as steel, bricks or concrete.

An alternative to starting with whole building carbon regulations is illustrated by the progression of regulations addressing operational energy and carbon, particularly in Building Regulations Part L. Part L began by driving achievable improvements in elemental efficiency standards for new buildings through the setting and periodic tightening of elemental performance limits (U-values, boiler efficiency). This produced some notable changes in the types of products and elements that could be used, e.g. from unfilled to filled cavity walls, single to double glazing, and from standard to condensing boilers. After these major shifts in construction practice, as the absolute improvements between Building Regulations iterations became smaller and the cost curve for further savings became steeper, Part L moved to a whole building calculation method[20], which provides greater flexibility to designers and developers to achieve increasingly stringent emission targets in the way they find most cost-effective and otherwise acceptable in terms of design, construction and supply chain considerations, etc.

Regulations to reduce lifecycle carbon could similarly begin by **setting elemental carbon intensity targets and successively tightening these to achieve major changes in construction practice**, either through material substitutions (e.g. from high-carbon steel, bricks, and concrete to wood, etc.), or through material efficiency improvements that deliver equivalent elemental performance improvements, where possible. If the largest and most cost effective lifecycle carbon savings options can be clearly identified and related to building elements, this approach could be a relatively simple and cost-effective way to deliver them. The carbon intensity limits could be set such that trade-offs are allowed between elements and with operational targets, as long as the overall lifecycle emissions are lower. This approach allows efforts to be focussed on the most carbon intensive elements/ materials in buildings, while allowing flexibility to expand the remit to include other less carbon intensive building elements/ components over time. Further carbon savings could then be driven by shifting to a whole building calculation later if necessary, and once the enabling groundwork is in place. This represents a second option for introducing regulations addressing lifecycle carbon. A detailed cost benefit analysis may help inform the most effective option for various scales of projects/ development.

Based on the evidence reviewed as part of this study, it is not clear whether a whole building approach, an elemental approach, or some combination of the two offers a better mandatory route to incentivise uptake of the largest or most cost-effective lifecycle carbon savings that can be addressed through building design and construction. Further work and engagement would need to be undertaken to determine this.

A final broad option would be an approach that does not involve regulation but relies on other direct and indirect levers for promoting changes in construction practice. This could include **strengthening and consolidating the existing voluntary framework, coupled with public sector leadership in procurement.** The Government could lead the construction sector by example, following the example of Germany, which effectively requires LCA for the main types of federal buildings, which must be assessed under the federal equivalent (BNB) of the voluntary DGNB assessment method. The UK Government could achieve a similar outcome by requiring buildings procured with public money and already subject to mandatory BREEAM targets to achieve a specified number of credits under BREEAM issue Mat 01, and could require lifecycle carbon (including embodied and sequestered carbon) to be addressed when funding national infrastructure. The Government could promote the use of voluntary building environmental assessment methods by the construction sector to address lifecycle carbon, and make the case for the relevant Mat 01 credits in BREEAM and issue 19 in HQM to be made mandatory. The scale of savings achieved would then depend on the uptake of voluntary schemes such as BREEAM & HQM and the performance benchmarks they adopt.

Common to all of the options identified here, is the need for the Government to work with the construction sector and professions on the groundwork to enable effective project-level carbon assessment and benchmarking.

One reason for going down a route that does not involve regulation addressing lifecycle carbon in building design, could be a finding that greater (or sufficient) reductions in lifecycle carbon can be achieved more cost

20 The change to whole building target setting was driven by the European Performance of Building Directive so it is coincidental that major changes in energy efficient design happened before the change.

effectively at other points in the construction product supply chain or the wider economy. A range of factors including material capacity / scarcity, cross-sector competition for resources, relative cost-effectiveness, and trade issues should influence the overall policy mix for addressing lifecycle carbon in UK buildings.

4.2 Summary of options

Groundwork to enable lifecycle carbon assessment and benchmarking

Enhance the evidence and complementary narrative for addressing lifecycle carbon in the design of new buildings. Establish a national LCA / EPD database for generic and manufacturer specific construction materials and products. Consider how the databases would be maintained and updated regularly. Establish a standardised approach to carbon quantification (and broader LCA) of new buildings. Increase the number of professionals capable of using LCA tools to produce high quality, standardised assessment data for new buildings through relevant accreditation schemes. Increase the number of assessments of new buildings undertaken, driven by planning requirements, voluntary building environmental assessment methods, and standards of professional practice for building design team members. Collate lifecycle carbon assessment data for new buildings, ideally standardised, and use this to establish carbon intensity benchmarks and targets for new building archetypes.

Indicative timescale: minimum 3 years to have all groundwork in place (LCA / EPD database, simplified method, industry skills depth, standardised benchmarks).

Option 1 – Voluntary action & Government lead by example through procurement

Promote action addressing lifecycle carbon in the construction sector, e.g. by setting non-binding sector targets and monitoring changes in the lifecycle carbon in new buildings over time. Require government-funded building projects to quantify and reduce lifecycle carbon e.g. by specifying a number of the relevant BREEAM and HQM credits to be achieved where assessments are already mandatory. Lobby for LCA/ carbon accounting to become a mandatory issue in BREEAM and HQM.

Indicative timescale: minimum 6 months to study, develop strategy and launch.

Option 2 – Whole-life elemental carbon intensity targets

Identify elements, product types and material substitutions with the highest lifecycle carbon savings (taking into account embodied, sequestered and operational carbon), accounting for supply chain dependencies (construction sector capacity, domestic capacity, effect of materials source, etc.). Set carbon intensity limits for these elements, product types and materials, initially near levels met by incumbent options. Set a trajectory to reduce the limits for each element and hence drive progressive changes in design choices, such as substitution of wood for steel / bricks / concrete, and innovation in the construction products supply chain. Shift to regulation based on whole building carbon intensity targets if and when necessary to drive further savings after industry-wide changes in design and materials selection corresponding to the main cost-effective carbon savings have been made.

Indicative timescale: minimum 2 years to research, develop, consult and introduce new regulations.

Option 3 –Whole building lifecycle carbon intensity targets

Set a timetable for putting in place the necessary groundwork (above) to enable the introduction of whole building carbon intensity targets in building regulations. Work with the construction sector and professionals to develop the corresponding regulatory tools including a standardised calculation method. Develop the capacity of building control officers to assess compliance with the proposed regulations. Introduce regulations based on whole building carbon intensity targets. Progressively tighten targets to drive lifecycle carbon savings.

Indicative timescale: 3 year groundwork + minimum 2 years to develop, consult and introduce new regulations.

5. Bibliography

Bundesministerium des Innern, fur Bau und Heimat. *Bewertungssystem Nachhaltiges Bauen (BNB)*. Accessed 2 May 2018. https://www.bnb-nachhaltigesbauen.de/

Committee on Climate Change. *Bioenergy Review*. December 2011. https://www.theccc.org.uk/publication/bioenergy-review/

Committee on Climate Change. *Biomass in a low-carbon economy,* December 2018.

https://www.theccc.org.uk/publication/biomass-in-a-low-carbon-economy/

De Wolf, C, Pomponi, F, Moncaster, A. *Measuring embodied carbon dioxide equivalent of buildings: A review and critique of current industry practice*. April 2017. Energy and Buildings 140 (2017) 68–80. https://www.sciencedirect.com/science/article/pii/S0378778817302815

Embodied Carbon Industry Task Force. *Proposals for Standardised Measurement Method and Recommendations for Zero Carbon Building Regulations and Allowable Solutions*. June 2014. https://asbp.org.uk/wp-content/uploads/2016/01/Embodied-Carbon-Industry-Task-Force-Proposals_June-2014_Final.pdf

European Insulation Manufacturers Association (Eurima). *Life Cycle Assessment of Buildings – A Future-proofed Solution in the Digitalised World of Tomorrow. The Use of LCA for Environmental Building Assessment: A Vision of the Future*. White Paper. September 2017. https://www.eurima.org/uploads/ModuleXtender/Publications/170/Eurima_LCA_WhitePaper_Final_20170915.pdf

Green Construction Board. Low Carbon Routemap for the Built Environment. March 2013. https://www.greenconstructionboard.org/index.php/resources/routemap

Giesekam, J, Densley Tingley, D and Barrett, J. *Building on the Paris Agreement: making the case for embodied carbon intensity targets in construction.* September 2016. http://eprints.whiterose.ac.uk/103278/1/p35v2.pdf

GLA & Best Foot Forward Ltd. *Construction Scope 3 (Embodied) – Greenhouse Gas Accounting and Reporting Guidance*. GLA. March 2013. https://www.london.gov.uk/sites/default/files/gla_construction_scope_3_embodied_greenhouse_gas_accounting_and_reporting_guidance_vfinal_1.pdf

IEMA & ARUP. Environmental Impact Assessment Guide to: Assessing Greenhouse Gas Emissions and Evaluating their Significance. IEMA. 2017. https://www.iema.net/assets/newbuild/documents/IEMA%20GHG%20in%20EIA%20Guidance%20Document%20V4.pdf

Ministerie van Binnenlandse Zaken en Koninkrijksrelaties. *Bouwbesluit [Building Decree] 2012*. July 2013. https://rijksoverheid.bouwbesluit.com/Inhoud/docs/wet/bb2012/hfd5

Poyry. *Alternative Uses of Biomass in Decarbonising Industry – A report to the Committee on Climate Change*. CCC. December 2011. https://www.theccc.org.uk/archive/aws/Poyry%20(2011)%20alternative%20uses%20of%20biomass%20in%20decarbonising%20industry.pdf

State of California Legislative Council Bureau. *Buy Clean California Act. Assembly Bill No. 262. Chapter 816.* October 2017. https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180AB262

Stichting Bouwkwaliteit. *Nationale Milieudatabase*. Accessed 2 May 2018. https://www.milieudatabase.nl/

Brockmann, T. Sustainability and Building Materials within BNB. 2014. http://www.oekobaudat.de/fileadmin/downloads/SB14_SustainabilityandBuildingMaterialswithinBNB.pdf

The Parliamentary Under-Secretary of State for Communities and Local Government (Stephen Williams). Written ministerial statement on Communities and Local Government – Building Regulations. March 2014. https://publications.parliament.uk/pa/cm201314/cmhansrd/cm140313/wmstext/140313m0001.htm#14031363000005

WRAP. *Embodied carbon database*. Accessed 2 May 2018. http://ecdb.wrap.org.uk/Default.aspxZizzo Strategy Inc., Brantwood Consulting. *Embodied Carbon of Buildings and Infrastructure – International Policy Review*. Forestry Innovation Investment Ltd. September 2017. https://www.naturallywood.com/resources/embodied-carbon-buildings-and-infrastructure

Appendix A

Terminology

Embodied carbon

Embodied carbon is the impact on global warming due to the emissions of greenhouse gases associated with a product or process. These emissions can be related to direct processing, transportation, generation of electricity, processing of resources to make fuels. Embodied carbon is normally reported in terms of global warming potential in units of kg carbon dioxide equivalents (kg CO_2e). The term should not be confused with embedded carbon.

Global Warming Potential (GWP)

Global Warming Potential is a measure of the atmospheric radiative forcing caused by the emission of greenhouse gases (GHGs) associated with a production or process. Different GHGs exhibit different amounts of radiative forcing and this can change depending on the time period considered. The most common way of reporting GWP is over a 100 year period and this is often labelled as GWP_{100}. The reporting units are kg carbon dioxide equivalents (kg CO_2e) or higher units of mass, such as tonnes, megatonnes, etc.

Sequestered carbon

Sequestered carbon refers to the quantity of carbon that is physically stored in a material. This carbon can be biogenic or abiogenic in origin. In this report, sequestered carbon refers to biogenic carbon only. Sequestered carbon can be reported directly in terms of carbon (kg C) or in terms of carbon dioxide equivalents (kg CO_2e). One kg of embedded carbon is equivalent to 3.67 kg of carbon dioxide equivalents. Sequestered carbon is also referred to as stored or embedded carbon, which can also be biogenic or abiogenic in origin.

Biogenic carbon storage

In the process of photosynthesis, the carbon atoms from atmospheric carbon dioxide are stored in the plant material. This material can then be used in products in the economy. The biogenic carbon atoms are stored for the lifetime of the products. This biogenic storage period can be lengthened by re-using or recycling the products. If the products are finally incinerated at the end of life (or multiple lives) the carbon is oxidised to carbon dioxide and returned to the atmosphere. Stored biogenic carbon can be reported as kg of carbon, or kg of carbon dioxide equivalents.

Life cycle assessment (LCA)

Life cycle assessment (LCA) is a technique for calculating and reporting on the environmental impact (including carbon emissions) associated with the production, use, re-use/and or disposal of a product. Different life cycle stages can be included in such an analysis and this must be explicitly stated when the system boundaries of such an analysis are declared.

LCA standards

The landscape of key standards relevant to addressing embodied carbon assessment and LCA in buildings is outlined in Table 3.

Table 3: Standards landscape for embodied carbon assessment (source GLA et. al. 2013 & RICS 2017)

	European	International	UK
Framework	EN 15643-2	ISO 14025: 2006 ISO 14040: 2006 ISO 14044: 2006	-
Building	EN 15978: 2011	-	Voluntary building codes: e.g. BREEAM 2018; Home Quality Mark (Beta) Professional codes: e.g. RICS professional statement 2017
Product	EN 15804: 2012 + A1: 2013 (under review) EN 16449: 2014 EN 16485: 2014 EN 16757: 2017	ISO 21930: 2017 ISO/TS 14067: 2013	PAS 2050: 2011 Voluntary product codes: e.g. C2C

Legend

EN 15643-2	Framework for Environmental Performance
EN 15978: 2011	Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method
EN 15804: 2012 + A1: 2013	Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products
EN 16449: 2014	Wood and wood-based products. Calculation of the biogenic carbon content of wood and conversion to carbon dioxide
EN 16485: 2014	Round and sawn timber. Environmental Product Declarations. Product category rules for wood and wood-based products for use in construction
EN 16757: 2017	Sustainability of construction works. Environmental product declarations. Product Category Rules for concrete and concrete elements
ISO 14025: 2006	Environmental labels and declarations – Type III environmental declarations – Principles and procedures
ISO 14040: 2006	Environmental management – Lifecycle assessment – Principles and framework
ISO 14044: 2006	Environmental management – Life cycle assessment – Requirements and guidelines
ISO 21930: 2017	Sustainability in buildings and civil engineering works – Core rules for environmental product declarations of construction products and services
ISO/TS 14067: 2013	Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification
RICS professional statement 2017	Whole life carbon assessment for the built environment
PAS 2050: 2011	Specification for the assessment of the life cycle greenhouse gas emissions of goods and services

Stakeholder interviews

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