Regulating Embodied Carbon in Scotland's Buildings

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A report for Zero Waste Scotland, prepared by JH Sustainability Ltd.

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Contents

1 Introduction

As progress is made on building energy efficiency and associated greenhouse gas emissions, the relative significance of upfront emissions associated with the construction of buildings is increasingly recognised worldwide, and is becoming a target for regulation. This document provides an overview of progress in regulation and associated initiatives around the world, and draws out lessons for the development of regulation in Scotland. The final section indicates a possible way forward.

1.1 Terminology

Key terms representing the scope of building greenhouse gas (GHG) emissions assessment relate to the definitions in EN 15978:2011, where A1-3 is the product stage, A4-5 the construction stage, B1-7 the use stage, C1-4 the end of life stage, and D benefits and loads beyond the system boundary (Figure 1.1). These definitions are worth stating, as the regulations and initiatives discussed in this paper have different scopes. Further details are in WLCN/LETI/RIBA guidance on terminology (2021) [1], but key points are as follows:

- **Upfront carbon**, in relation to a building, refers to the GHG emissions (as mass of carbon dioxide equivalents: $kgCO_2e$) associated with the extraction, processing and transport of building materials and their eventual construction (A1-A5 inclusive).
- **Whole-life carbon** includes GHG emissions associated with stages A-C inclusive. D can be reported additionally and separately as it helps to provide the complete picture, but is outside of the system.
- **Embodied carbon** is whole-life carbon *excluding* the emissions associated with operational energy and water use (B6 & B7): the main point being that the carbon emissions associated with in-use heating, cooling, lighting etc. are B6 and therefore excluded from embodied carbon.

In practice, the term 'embodied carbon' tends to be used quite loosely: sometimes synonymously with 'upfront carbon', and at other times can mean A1-A5 plus whatever other stages can conveniently or usefully be included (with the exception of B6 & B7). This is the case in the more general parts of the following text, although precise terminology is aimed for when discussing particular cases.

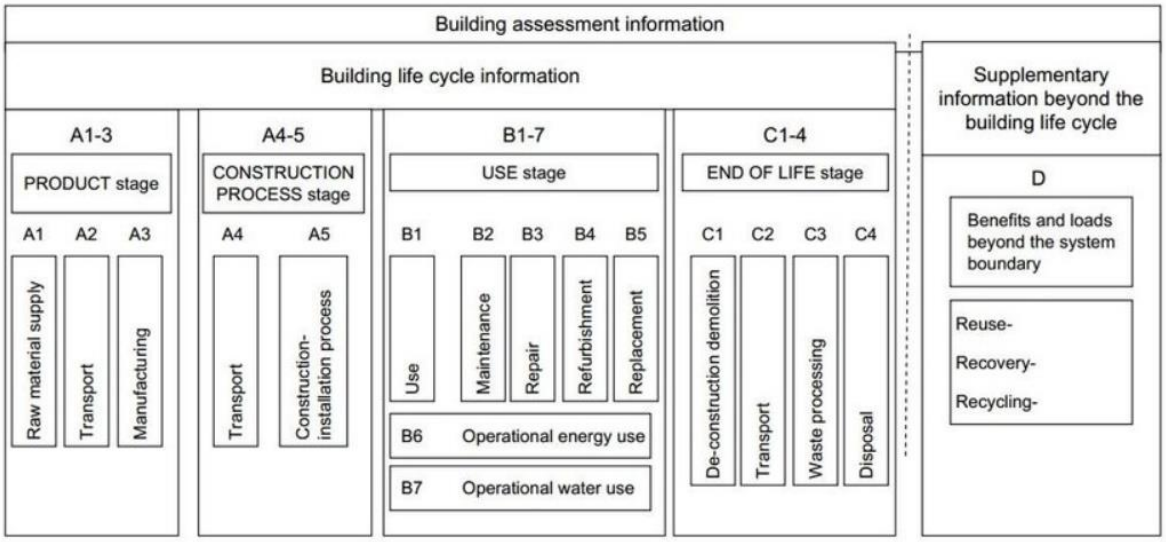

Figure 1.1. EN 15978:2011 building life cycle stages.

1.2 Regulating Embodied Carbon in Scotland

An overview of the development of embodied carbon discourse and its applicability in Scotland is provided in the Zero Waste Scotland report on embodied carbon (2020) [2], which observed that emissions from the Scottish construction sector – a major component of embodied carbon in Scottish buildings – have amounted to between approximately 4 and 5 $MtCO_2e$ per year (around 10% of the current annual quantity of Scotland's total GHG emissions) for around 20 years. Whilst annual carbon emissions from the energy used in buildings is even greater, the fact that this is already regulated means that this can be expected to decrease as older buildings are replaced with more energy-efficient buildings. Therefore, without action, the construction-related emissions will take an increasing share of the GHG budget. As things stand, there is little incentive for developers to drive down the embodied carbon of their projects, or even to measure and share data on the subject.

If and when embodied carbon is regulated in Scotland, this is likely to be through the Building Standards. Indeed, Section 7 (Sustainability) of the Technical Handbooks – both Domestic and Non-Domestic (2021) – states that whilst embodied carbon is beyond the scope of the Building Standards, the *"standard can respond in due course to the growing relative importance of embodied energy as the performance of new buildings improves further".* The operational CO_2 emissions associated with energy consumption in new buildings is regulated through Section 6 (Energy), and Section 7 provides a voluntary awards system for improvements over the minimum thresholds, along with achievements in other aspects of sustainability. For instance, the gold level requires that the dwelling emission rate (DER) is 27% lower than the 2015 target emission rate; and the platinum level requires that the DER is zero or less.

Clearly, the introduction of obligatory assessment of embodied or whole-life carbon together with minimum performance levels would significantly extend Section 7's mission and scope. Given the progress being made on regulation in Europe generally, particularly with the proposed revision of the Energy Performance in Buidlings Directive – the EPBD Recast (2021) – potentially forcing the issue across the EU, and also the momentum on voluntary initiatives more broadly, it is clear that – if it is ever going to happen – the time has now come for the standard to respond "*to the growing relative importance of embodied energy"* noted in the Building Standards*.* Even if the process of revising Section 7 begins in 2022 Q2, several European countries will already have limits on embodied carbon in force by the time the regulation development process is complete.

Other relevant initiatives and areas of policy development include the Scottish Futures Trust's Net Zero Public Sector Buildings Standard (NZPSB); a forthcoming consultation on a Sustainable Construction Procurement Policy; and – more remotely – a Compliance Plan approach that may, in future iterations, become relevant to this topic. Embodied and whole-life carbon are also increasingly becoming a target for reporting and minimisation in Scotland City Region Deals and Regional Growth Deals, with joint guidance to project owners coming from the UK and Scottish Governments. All new projects are required to include analysis of whole-life carbon in the economic case, and existing projects will also be expected to address carbon management, as noted, for instance, by a recent City Region Deal Committee paper (2022) [3].

The Climate Change Committee's (CCC) current recommendation to the Scottish Government (CCC: Dec 2021) [4] is to move towards minimum whole-life standards for all buildings. They advise that a plan is required "*for phasing in mandatory whole-life reporting followed by minimum whole-life standards for all buildings, roads and infrastructure by 2025, with differentiated targets by function, scale, and public/private construction."*

Additionally, Scotland's Climate Assembly's recommendations for action (2021) include the implementation of *"clear and future-proofed quality standards for assessing the carbon impacts of all buildings public and private using EnerPhit/Passivhaus standards (as a minimum) and integrating whole life carbon costs, environmental impact and operational carbon emissions."* The Scottish Government response [5] shows a degree of commitment on energy, but its comments on whole life carbon are open to much interpretation: it commits to reporting back on the opportunities for *"whole life emission reporting"* by the end of 2022.

1.3 Embodied Carbon Landscape in the UK

Embodied carbon has been part of government and industry discourse around the environmental impact of buildings for well over ten years: for instance, the 2007 Sullivan Report (*A low carbon strategy for Scotland*) first raised this issue for Scottish standards (still referenced in Section 7 of the Standards), and – although it used the term 'embodied energy' – embodied carbon was evidently part of the report's ambition for net-zero carbon new buildings (from construction all the way through to demolition) by 2030. But it is in the last 10 years or so that embodied carbon has gained significant traction in the UK, from being a niche term for academics and industry pioneers to being a commonly understood concept and cause for concern. This section provides a very brief, non-exhaustive, overview of some of the key developments on that timeline.

From 2012 onwards, Dr Alice Moncaster at the University of Cambridge was spearheading the importance of the topic in UK's academia with two publications that resonated internationally: one on a comparison of existing methodologies [6], and another on a national method for cradle to grave assessments to comply with the then new TC350 standards [7].

Concomitantly, the Green Construction Board released in March 2013 a Low Carbon Routemap for the Built Environment that showed the relevance of embodied carbon (then referred to as capital carbon), and broke it down into non-domestic, domestic, and infrastructure clusters. Momentum grew with the Embodied Carbon Week in 2014 [8], under the umbrella of the UK Green Building Council (UKGBC). In the 'next steps' section, there was already clarity that embodied carbon had to be incorporated into the planning system, an outcome we are still waiting for today - eight years on. Another key point that emerged was the need and demand for a harmonised calculation methodology.

This was also picked up in an industry task force recommendation on embodied carbon in 2014 [9] which sought to introduce embodied carbon as an 'allowable solution', but the subsequent scrapping of zero carbon homes in 2015 (due to come in force the following year) resulted in a loss of momentum at the policy level.

Effectively, the European standard for the sustainability of construction works (EN 15978 – first published in 2011) had been around for a few years already but was not used at sufficiently large scale. One of the issues seemed to be the difficulty of translating a European standard on such a new topic into the different national contexts. For this reason, in 2015, academia and industry worked to address this issue through an Innovate UK funded project Implementing Whole Life Carbon in Buildings. In the same year, WRAP published its guidance on reducing embodied carbon in construction.

Led by Dr Moncaster at Cambridge University for the academic side and Simon Sturgis for the industrial side, and with big industry names such as Arup and Laing O'Rourke, this project also strategically involved the Royal Institution of Chartered Surveyors (RICS) and produced as its main outcome in 2017 the RICS professional statement (PS) Whole life carbon assessment for the built environment [10], the *de facto* national methodology for the UK for embodied and whole life carbon analysis. The UKGBC also published an embodied carbon guidance for clients in 2017, a Net Zero Framework in 2019, and a net zero whole life carbon roadmap in 2021.

Things began to move very quickly after the release of the RICS PS, particularly as a PS is the highest form of mandatory guidance from RICS. Other professional bodies did not want to be seen as lagging behind, and in 2018 the Royal Institute of British Architects (RIBA) produced its own dedicated guidance Embodied and whole life carbon for architects. Some other institutions took a little longer to identify the needs of the professional members and produce guidance that was tailored to them. This was, for instance, the case for the Institution of Structural Engineers (IStructE) which released a 'how to' guide in 2020 and a wide range of subsequent resources. The Chartered Institution of Building Services Engineers (CIBSE) also followed suit with a Technical Memorandum on embodied carbon in building services (TM65) in 2021.

The 2017 publication of the RICS PS contributed to and coincided with a cross-profession mobilisation, with the set-up of the London Energy Transformation Initiative (LETI). LETI was

established to support the transition of the London's built environment to meet Net Zero Carbon, and worked collaboratively across built environment disciplines to put together evidence-based recommendations for two pieces of policy: the new London Environment Strategy and the rewrite of the London Plan.

However, LETI did not stop with that and it now counts more than 1000 professionals and has produced excellent guides that are supporting common knowledge and language in the UK's built environment, such as the Climate Emergency Design and Retrofit guides, the Embodied Carbon Primer, a Client Guide for Net Zero Carbon Buildings, and an Embodied Carbon Target Alignment guide among others. The latter includes a proposal for a rating badge, similar in appearance to energy performance certificates etc., and these are being used as a basis for voluntary reporting, e.g. Bennetts Associates.

In parallel, but with slightly different scope, another voluntary collective emerged a couple of years later, the Whole Life Carbon Network (WLCN). WLCN wishes to promote consistent and robust whole life carbon assessment and reporting within the built environment and therefore - compared to LETI – has a stronger focus on methodological accuracy, definitions, calculations and reporting. A further voluntary collective, The Embodied Carbon Group (TECG), emerged specifically to provide advice to government departments on implementation of whole life carbon assessment and management.

The last year or so has seen a significant ramping up of activity in the whole-life carbon arena. WLCN and LETI collaborated with RIBA in producing a joint document on "Improving Consistency in Whole Life Carbon Assessment and Reporting" scoped around Carbon Definitions for the Built Environment, Buildings and Infrastructure, referred to above. WLCN also began work in 2021 on the update of the RICS methodology and has received funding from BEIS for a 'consistency project' due to report later in 2022.

2021 saw the development and publication of Part Z: an industry-led proposal for amending the building regulations in England and Wales to include embodied carbon. The Part Z campaign has received support from over 140 construction firms and a majority of the UK's professional institutions – including Royal London Asset Management, Grosvenor Great Britain & Ireland, Stanhope PLC, Landsec, British Land, Willmott Dixon, Multiplex Europe, BAM Construct UK Ltd, Laing O'Rourke, Morgan Sindall Group, Arup, WSP, SOM, Atkins Limited, Mott Macdonald, The Institution of Civil Engineers, IStructE, RIBA, and the Royal Town Planning Institute alongside many others. In February 2022, Duncan Baker MP introduced a private members bill to the UK Parliament proposing implementation of the Part Z proposals (discussed further in Section 2.1.4).

Linking the UK to the global space, in November 2021 the International Cost Management Standard (ICMS) 3 was released [11], "a world first for cost and carbon management in construction, from concept to completion and beyond" according to RICS, which is one of the 49 international organisations behind it. At the moment a WLCN working group led by Jane Anderson is providing comments on the ICMS3 as it currently does not align with EN standards and the Modular Life Cycle Structure.

Whilst Part Z is not a government-backed initiative, the UK Government is not silent on embodied carbon. Also in 2021, the UK Government's response to the CCC's recommendations [12] (which were informed by commissioned research considering options for incorporating embodied and sequestered carbon into the building standards framework in England and Wales [13]) stated *"We are working across Government and Industry to develop and test Whole Life Carbon methodologies for major built assets. We intend to carry out some longer-term work to consider the future of energy efficient buildings beyond the Future Homes Standard and the Future Buildings Standard…We expect this work to consider embodied carbon".*

The Environmental Audit Committee's inquiry into Sustainability of the Built Environment recently concluded the evidence gathering phase, which made reference to low carbon construction materials and the potential regulation of embodied carbon. The resultant report and recommendations are currently at draft stage with publication anticipated around Easter.

The UK Government's Net Zero Strategy, published in October 2021, included a commitment that the *"Government aims to support action in the construction sector by improving reporting on embodied carbon in buildings and infrastructure with a view to exploring a maximum level for new builds in the future".* This commitment was already visible in relation to public procurement through The Construction Playbook, published by the UK Government in December 2020, which introduced the requirement that *"contracting authorities should adopt the use of whole life carbon assessments to understand and minimise the GHG emissions footprint of projects and programmes throughout their lifecycle.. . Contracting authorities should require that solutions put forward by potential suppliers are accompanied by a whole life carbon assessment."* This requirement for reporting on social and economic infrastructure is currently being rolled out across UK Government departments with the support of the Infrastructure and Projects Authority.

The Welsh Government also has special requirements for some aspects of construction procurement: in particular, a recent announcement that new educational buildings (and extensions / major refurbishments) must now be net zero in operation, with a 20% reduction (and more to come) in embodied carbon.

Collectively these recent developments are leading to a significantly wider uptake of embodied carbon assessment in the public sector. Meanwhile a small but growing minority of private sector projects are undertaking assessments on a voluntary basis. Some assessments are driven by corporate commitments from designers (e.g. Arup are undertaking WLC assessments on all projects from April 2022) through schemes such as Built Environment Declares. Others are driven by client demands, which in turn are driven by growing requirements for carbon disclosure from the financial sector. A small number of private sector clients, such as Landsec, are now actively managing embodied carbon across their portfolio and investment pipelines (and reporting emissions from upcoming projects as a KPI).

1.4 Embodied Carbon Landscape Internationally

This section offers a brief overview of international embodied carbon regulation: further detail is provided in Section 2.

Throughout the world, regulation of embodied carbon in buildings is a long way behind the regulation of operational energy and carbon. That said, the picture is changing, with pioneering initiatives in the Netherlands, Scandinavia and France in particular paving the way for stirrings at the EU level. The Netherlands has required assessment of new buildings since 2012, with limits imposed from 2018. In France, limits on upfront carbon have applied since the beginning of 2022, and in Finland, Denmark and Sweden, limits are expected to come into force in the near future. Within this group of countries, a range of approaches is being taken. For most, a whole-life perspective is taken, with emissions averaged over a standard time period (usually 50 years) to create an annual figure; France, for instance, is an exception as it regulates upfront emissions.

Meanwhile, the European Commission has recently published a proposal for a revision of the Energy Performance in Buildings Directive, the EPBD Recast (2021). Although the primary focus here is still energy performance, life cycle global warming potential (GWP) makes its first appearance. Under this proposal, member states would be required to submit their implementation proposals by the middle of 2023, which would require whole-life carbon to be calculated in accordance with the Level(s) framework and potentially disclosed through Energy Performance Certificates (EPCs) from 2027 for larger buildings and 2030 for all buildings. The EPBD recast would also require that Member States' building renovation plans consider whole-life carbon. However, as noted by BPIE (2022) [14], a requirement to measure and report does not necessarily translate into action: the failure to require action on embodied carbon and to factor embodied emissions into the vision and definition of zero carbon buildings for 2050 is a significant weakness. The level of ambition here (in terms of setting limits before ~2030) is clearly well below that of the countries mentioned earlier, but the proposal has to recognise that many member states will be starting from close to square one.

In addition to the EPBD recast, the recent EU Taxonomy climate delegated act (regarding sustainable finance) notes that *"for buildings larger than 5000 m^2, the life-cycle Global Warming Potential (GWP) of the building resulting from the construction has been calculated for each stage in the life cycle and is disclosed to investors and clients on demand"*. The GWP being over all life cycle stages and averaged over a reference period of 50 years in accordance with the Level(s) framework. In effect, this inclusion in the Taxonomy, introduces a more immediate assessment requirement, driven by investors, on the largest building schemes throughout Europe.

In several jurisdictions, embodied carbon is addressed either through public procurement (e.g. the 'buy clean' regulations in North America), through building eco-labelling schemes that include embodied carbon in their scoring system, or both. Some of the procurement initiatives set minimum standards for construction materials (through the medium of Environmental Product Declarations - EPD), whilst others assess the building.

2 Examples of Regulation and Initiatives

Regulation of upfront carbon, embodied carbon, and whole-life carbon is in its infancy, but there are several examples which have significant traction, and many examples of voluntary initiatives and public sector procurement requirements. This section extracts and discusses details of some of the most advanced and interesting cases.

2.1 Approaches Taken by Regulations and Incentives

The primary focus of this section is those jurisdictions that have regulated embodied or whole-life carbon, or have committed to the development and implementation of such regulations. Regulations are reviewed in terms of what types of building are regulated, the scope of the life cycle assessment required (e.g. upfront carbon or whole-life carbon), the timetable for introducing and tightening the regulation, and information on how compliance is demonstrated. Section 2.2 covers the process (where such information is available) followed in the development of the regulations: gathering of evidence, consultation, impact assessments, etc., and also how the impact and success of the regulation will be (or might be) reviewed and reported.

The most ambitious regulatory initiatives will target all buildings (and infrastructure) above a relatively low significance threshold, at the first opportunity. Other possibilities for regulation and incentives include:

- Focus on embodied carbon in public procurement of buildings before – potentially – expanding the reach to all buildings.
- Ecolabelling of buildings with mandatory minimum levels. In these cases, embodied carbon may be tradeable against other sustainability criteria.
- Incentivisation. Whilst hard limits on embodied carbon or ecolabel scores may not be set, good performance can unlock incentives such as subsidies and soft loans for environmental costs, or increased leeway in the planning system (e.g. extra floorspace).

Whilst embodied carbon regulation in some jurisdictions has emerged from a top-down process, in other cases industry players are unifying to ask for regulation, for a range of reasons. For instance, regulation would mean that they can confidently target the embodied carbon of their projects without the risk of putting themselves at a competitive disadvantage. Regulation would also involve a degree of harmonisation around assessment methodologies, tools, and data sources, whilst also improving the availability and quality of life cycle data on construction materials and products. Together, these changes can both reduce the cost of evaluating the embodied carbon of buildings and increase the credibility – and therefore the value – of the reported results.

Leaving aside questions around process (discussed below), some key technical questions must be resolved. For instance, the question of what should actually be regulated is key. Should it be construction materials, products or buildings? And upfront carbon, embodied carbon (across the whole

life cycle) or whole-life carbon including emissions due to operational energy demand? It is apparent from the initiatives discussed in this section that a range of options are followed here, including:

- Key building materials – upfront carbon A1-3
- Whole buildings – upfront carbon A1-5
- Whole buildings – embodied carbon (with some stages omitted)
- Whole buildings – whole-life carbon (with some stages omitted).

Upfront carbon (A1-5) and operational carbon (B6) are the stages that are, firstly, likely to have significant GWP and, secondly, are within the control of the building development team and supply chain. Furthermore, they are, to an extent 'set in stone' when the building is commissioned, so are an obvious focus point for some. A great deal of uncertainty will always surround the GWP of maintenance, refurbishment and eventual disposal of buildings (and parts there-of) with decades-long lifespans, potentially undermining the credibility of regulation overall. Therefore, the remaining building use stages, along with the end of life might reasonably be aspects that building proposals are required to consider and report, but not actually be restricted in terms of carbon limits.

Where an integrated whole-life carbon assessment is regulated (i.e. including B6, operational energy/carbon), the typical approach is to provide the assessment over a set reference period: for instance 50 years, with all emissions over the period totalled and divided by that period. Scenarios can be used to consider the gradual decarbonisation of operational energy. There are, however, alternative ways of looking at this which assign a greater importance to emissions in the short term than emissions in the more distant future. The standard simplification used by almost everybody (rightly or wrongly) is to add up the GWP100 values for all emissions within the reference period[1], irrespective of when they occur. France (RE2020) has opted for a highly simplified dynamic approach[2] to the assessment which – ultimately – produces a GWP value that reports the climate change impact 100 years after the start of the project taking account of the fact that emissions later in the period have less time to impact the climate. In RE2020 though the purpose is not to tilt the balance between upfront and operational carbon, as these are regulated separately: instead, it is to tilt the balance in favour of bio-based construction products, as the dynamic method rewards them for the temporary carbon storage function performed. It does not, however, take account of forest carbon losses that might be linked to increased timber use.

Regulation of upfront carbon associated with the whole building, along with operational carbon would cover much more of the construction sector's emissions than regulation of selected building materials alone. However, the option exists to work from both ends at once, meaning that the industry supply chain will feel pressure to decarbonise their production from regulators and from customers.

Another key technical question is the actual level at which any limit is set, and how and if different limits are set for different building types. Again, there is no universality in the conclusions reached by the different regulations seen so far (although a relatively small number of limits is generally the norm). In deciding on the number of different building types to regulate for, there are trade-offs to be considered. For instance, if just one challenging limit is set for domestic buildings then developers may gravitate towards the most efficient built forms: this might make carbon sense, but may push against any number of other priorities such as place-making.

A final observation is that some important LCA considerations are generally neglected by the regulations. A well-known example is that the use of a given value for the embodied carbon of a material or product (e.g. from an EPD) obscures the uncertainties and sources of variability that together mean the value may be a long way from the mark: it is easier to account for this in academic work, where ranges of possibilities can be discussed, data quality rated, and uncertainties quantified – to some extent. Another is that the form of 'process LCA' that underpins embodied carbon work

[1] And – for completeness – the GWP100 of all associated emissions (e.g. around end of life) that occur beyond the reference period but within 100 years.
[2] i.e. one in which the life cycle inventory includes a time dimension.

systematically understates[3] and biases the GWP associated with the subject of analysis, because of truncated product system boundaries. Crawford et al. (2022) [15] calculate that for a range of construction materials, an average of approximately 50% of the GWP is missed in process analysis, with some variation between materials. Such issues are unlikely to be resolved in the near future, and – as with the various inconsistencies associated with EPD – nothing useful is likely to be achieved by waiting for improvements before regulating. Indeed, in the case of EPD the reverse might be the case in that regulation might spur additional production of EPD and add pressure to harmonise the associated methods and data. Despite the 'issues' with LCAs of buildings, there is little doubt that driving down embodied carbon as measured with current methods and data will push emissions firmly in the right direction. Operational energy and associated carbon provides a parallel in that the many uncertainties involved (for instance, about how successfully design intent and energy modelling can transfer through to construction / installation / commissioning, and then to occupation) have not prevented regulation.

Key examples of regulations are shown in Table 2.1 (below). Notes on items in Table 2.1 are:

- The Danish regulation has different requirements for the two LCAs that must be submitted, given that differing levels of information are available at the planning stage and at completion. For instance, A5 (construction process) is omitted from the planning stage LCA, but is included in detail in the completion LCA (with meter readings etc.). It is not immediately clear what the sanction is (if any) for exceeding limits at the completion stage: presumably the developers are not required to rebuild!
- Variability in the building model is evident. For instance, Finland and Denmark's regulations are interested in building services and other aspects of internal fit-out that are not covered by Sweden and Norway.
- In the Netherlands, embodied carbon forms only a part of the overall assessment, as a full LCA is required covering 19 midpoint indicators (three of which are GWP) covering the gamut of environmental impacts. A weighted sum is then used to derive the score for a single environmental indicator (expressed in financial terms, as €/m^2/yr). The LCA is in accordance with EN 15804+A2. The guide to environmental performance calculation (2020) differs from other European cases, also, in that the whole-life assessment is based on default service lives (75 years for homes, 50 years for offices) or justified alternatives, rather than the standard reference period specified in other cases. Thus the Netherlands, as well as being a trailblazer with regard to regulating the embodied environmental impacts of buildings, is also an outlier in terms of approach.
- The French approach to dynamic LCA in RE2020 is discussed above. Also of interest is its decision to focus on upfront emissions: this may be due in part to the very low emission factor of grid electricity in France (although operational energy is, nevertheless, regulated separately). According to Carbon Footprint's grid factors report (2020), the emission factor for French electricity is below 0.04 kgCO_2e/kWh, which is less than a fifth of the EU average (and the UK grid). That said, the same applies to Scandinavian nations too in general, with Sweden and Iceland having even lower grid emission factors than France, and Finland and Denmark sitting between France and the EU average.
- The RIBA target (level B) for life cycle embodied carbon in 2030 would equate to approximately 11 to 15 kgCO_2e/m^2 if averaged over a 50-year reference period, as used in some of the European cases presented in the table.

[3] And therefore underestimates the benefit of regulation if this is calculated from a bottom-up perspective.

Case	Scope	Threshold	Aggregation	Compliance	Timetable – introduced	Timetable – ratchet	Novel Variations
			Regulations				
EU (EPBD recast)	A1-5, B	>2000 m^2 before 2030, all buildings thereafter	Up to member state	EPCs	2027 X $kgCO_2e/m^2/yr$ over 50 yr		
Denmark	A1-3, B4&6, C3-4, D	>1000 m^2 for limits. All must report.	One category	LCA at planning and on completion	2023: 12 $kgCO_2e/m^2/yr$ over 50 yr	2025 & 2029 with 2 years warning	'voluntary class' for surpassing more challenging limits.
Finland	A1-5, B3,4 & 6, C1-4, D		5: resi, offices, service (care), educ, commercial.		2025. Illustrative limits of 10 – 14 $kgCO_2e/m^2/yr$ over 50 yr		Carbon handprint
France	A1-5 + carbon storage		2 categories of housing – individual and collective		2022: 640 – 740 $kgCO_2e/m^2$	2025, 2028 & 2031, when limits will be down by ~35%	Bio-based focus
The Netherlands	A1-5, B1-5, C1-4, D		2: housing & offices		Since 2018: Not GWP-specific: limits as €/m^2/yr	Limit value to be halved by 2030.	Enviro f.print – sum of 19 weighted indicators
Sweden	A1-5 (& WLC to be declared from 2027)		2 housing, 1 non-dom (from 2027)	LCA on completion	2022. Limits from 2027 (Boverket proposal)	2035 & 2042	
			Proposals, campaigns, initiatives				
Part Z – UK prop	A-C (report) A1-5 (limits)	>1000m^2 or 10 homes		Report/data to Govt portal	2023 non-dom 2025 dom WLC report. 2027 for A1-5 limits	Review need for limits	
LETI (Upfront carbon)	A1-5		4: domestic, retail, offices, education		2030 target – level A 300-350 $kgCO_2e/m^2$		
LETI/RIBA (WLEC)	A1-5, B1-5, C1-4		4		2030 RIBA target – level B 535-750 $kgCO_2e/m^2$		

Table 2.1. Regulations on upfront, embodied, and life cycle carbon: enacted; in pipeline; proposed/campaigns/initiatives. Note that direct comparison between limits should be avoided, as scopes and building elements assessed may differ. Information presented here should also not be taken as definitive, as – especially in regulations in development – contradictions are occasionally apparent within and between documents.

Further links/references applicable to Table 2.1 and surrounding discussion:

- Denmark
  - Denmark sets out phased embodied carbon targets for buildings (PassivHausPlus news item)
  - Denmark – Life cycle assessment - the overall climate impact of the building (Danish Government Website)
- Finland
  - Carbon Footprint Limits for Common Building Types - Ministry of Environment, Finland [16]
  - VTT Finland – Carbon Handprint Guide [17]
  - Reduced carbon footprints of buildings: new Finnish standards and assessments [18] (Journal paper from the Environment Ministry)
- Netherlands
  - Netherlands Guide to Environmental Performance Calculations [19]
  - Netherlands – Determination Method – Environmental Performance Buildings and Civil Engineering Works [20]
- Sweden
  - Boverket - Regulation on climate declarations for buildings proposal for a roadmap and limit values [21]

2.1.1 Further Embodied Carbon Regulation Routemaps

An inventory of all relevant regulatory manoeuvres around the world is beyond the scope of this document. Others exist outside Europe: for instance the **New Zealand** government has published a Whole-life carbon framework (2020) [22], which suggests that in due course such emissions will need to be reported as part of the building consent process, with a gradually tightening mandatory cap following behind. There are also numerous examples of municipal action on the subject too, some of which are identified below.

The **City of Vancouver** has set a target that by 2030 embodied carbon from new construction will be 40% lower than it was in 2018, and that operational emissions will be zero. An indicative roadmap envisages the setting of caps for different building types alongside the development of incentive programmes (5% extra floorspace is allowed for zero-emission buildings). Some details of the scope of assessment are given, including the parts of the building to be assessed, the inclusion of B2-B4, and assumed service life of 60 years.

Oslo has a climate strategy aiming for a 95% reduction in GHG emissions by 2030 (on a 2009 baseline). Although a full account of embodied carbon is out of the target's scope, as it is concerned with direct emissions from within the city, construction site emissions (stage A5) are very much included. There as an expectation of zero fossil fuel use on sites and, by 2030, zero carbon construction sites. Also, embodied carbon is targeted more generally by the objective to reduce "*Oslo's impact on greenhouse gas emissions outside the City"* to significantly below the 2020 level by 2030, and that Oslo will *"limit emissions related to the consumption of materials for buildings*".

In **Stockholm**, an LCA tool is being developed / piloted, and procurement from 2023 will face LCA requirements [23]. The LCA requirements will apply "*in connection with land tenure agreements for new production on the City's land and agreements on development".* This is separate from the national regulation already discussed.

These examples highlight the potential for action at municipal level to dial up national requirements, thus leveraging more impact from the regulation. In Scotland, with a fifth of the population living in two council areas, supporting local government in pushing further than any national regulation is worth considering – but some degree of national regulation would probably be needed to catalyse this.

2.1.2 Public Sector Procurement Obligations

An Executive Order signed by President Biden in December 2021 aims to put **US federal buildings** on a path to net zero carbon emissions by 2045, with 50% reductions by 2032, with a 'buy clean' policy to promote reductions in embodied carbon in construction. The Executive Order notes the importance of federal purchasing of materials with low carbon footprints, and commits to launching a 'buy-clean' initiative for such materials. The US Clean Future Bill (introduced in 2021) outlines a potential way forward: within 6 months, working with the Secretary of Energy and others, the Environmental Protection Agency would be expected to *"establish a program to enhance the transparency, quality, and availability of life cycle assessment data, and harmonize life-cycle assessment approaches to calculating greenhouse gas emissions and other environmental factors"* for a specified list of construction materials. This will either be through EPD or a similar mechanism, with a full review of the "quality and efficacy" of EPD etc. with the possibility of extending the process to other impact categories.

Canada has its own 'Buy-Clean Roadmap' (2021). The initial focus is on infrastructure (with targets for federal infrastructure by 2025), and improvements in embodied carbon tracking and transparency. But the expectation is that this will permeate into building codes for private sector construction by 2030, all supported by a centralised, publicly available Canadian LCI database. In turn, this will be supported by the LCA^2 initiative (or LCA-squared - low carbon assets through life cycle assessment) which is expected to improve data availability, management and use by 2023. Roles and responsibilities for various federal departments and agencies are detailed.

Germany and **Switzerland** are both identified as countries that have introduced requirements around LCA for some public sector buildings and projects, according to a 2021 BPIE report [24].

At the sub-national level, a number of US states are developing their own approaches. For instance, from January 2024, **Colorado** will impose limits on GWP for a defined list of 'eligible materials' used in public projects. Limits will be reviewed and revised two years later and then every four years, and will be published along with a general progress review and details as to how the limits are derived. From July 2022, tenders to public projects must include EPD for all eligible materials (to include various forms of steel, cement and concrete mixtures, asphalt, glass, and structural timber). A similar approach was taken earlier through the Buy Clean **California** Act. As of January 2022, GWP limits apply to a set of seven material categories (a more limited range than the Colorado set: various forms of structural and reinforcing steel, glass and mineral insulation) used in public projects. Limits will be revised on a 3-year cycle. A legislative report details the process by which the limits are defined, which essentially involves identifying and using an industry average of EPD for each material: these have each been based on industry-wide EPD, rather than an analysis of facility-specific EPD.[4] Note that the Act only focuses on production emissions, with the effect (whether intentionally or not) that remote suppliers are not automatically disadvantaged. Exclusion of the steel fabrication step (A3) is permitted, on the grounds that this is less than 10% of the total emissions for steel, and the diversity of products would make compliance burdensome for small fabricators. Further details, and information on such measures in other states, are included in a critical review of this usage of EPD by the Carbon Leadership Forum (2021) [25].

2.1.3 Ecolabels

Singapore's Building and Construction Authority has a mandatory (for all buildings and major retrofits of > 5000 m^2) green building certification scheme BCA Green Mark 2021 (GM2021), which succeeded earlier versions in November 2021. Whole-life carbon has been introduced to the assessment, and measurement contributes to the overall Green Mark score for a building, with further points for

[4] As an aside, it will be interesting to monitor the impact of this approach: will it just mean, for instance, that materials from more carbon-intensive facilities will be used in greater quantities in non-federal projects?

substantial improvements on reference values (A1-4: 1000 $kgCO_2e/m^2$ for non-residential, 1500 $kgCO_2e/m^2$ for residential, and 2500 $kgCO_2e/m^2$ for industrial).

Austria's Oekoindex provides an environmental score for building materials, assemblies and buildings. This is on a 100-point scale A-E label, combining and weighting scores for GWP, non-renewable energy depletion, and acidification into a single indicator. According to Sattler & Österreicher (2019) [26], the GWP element of this includes carbon storage. The score achieved by a building design can be the key to unlocking environmental subsidies and loans – which vary by region.

2.1.4 Voluntary Initiatives & Campaigns

In the context of UK regulation, the Part Z proposal for the inclusion of upfront and whole-life carbon in building regulations carries much weight, as, firstly, it has wide industry support and involvement and, secondly, it has growing support in Westminster, where the Carbon Emissions (Buildings) Bill was recently due for its second reading with signatories from four political parties. Whilst most private members bills fail to make it into legislation,they can play an important role in refining proposals that are eventually adopted by government. The bill's sponsor, Duncan Baker MP, was recently made a Permanent Private Secretary in the Department for Levelling Up, Housing and Communities (DLUHC, supporting the Under Secretary of State with responsibility for Building Regulations in England and Wales. As a consequence the bill was withdrawn (as a PPS cannot bring forward private member bills in their area of Government competence) but a new sponsor for a revived bill in the next Parliamentary session has already been identified (within the governing party but outside Government). Duncan Baker MP remains supportive of the agenda in his new role, recently attending the parliamentary launch of Part Z in the House of Lords. DLUHC's most recently publicly stated position in relation to Part Z is that "*Government has closely followed the Part Z work and noted its suggested approach. There is active work across Government to consider the issues and most appropriate actions, particularly as they relate to new build, and as part of that work officials in the Department are engaging a range of wider industry experts and stakeholders, including authors of the Part Z proposal*" with the intent of "*exploring the potential for a maximum level of embodied carbon for new buildings in the future*". With respect to upfront carbon limits, the philosophy of Part Z is that easily achievable limits are set initially (but still useful in filtering out the most egregious climate offenders), and then tightened every 3 years.

The Architects Climate Action Network (ACAN 2021) [27] also advocates for a Part Z regulation to be included in building regulations, with limits set by building type. Other (additional) suggestions include revising Regulation 7 (England and Wales) to include limits on embodied carbon on specific materials, and incorporating a requirement for whole-life cycle carbon assessments in the National Planning Policy Framework. ACAN argues that the methods, tool and evidence are already in place for this – through EN 15978, the RICS professional statement, and EPD databases, and if governments see deficiencies in any of these, they should exert their influence to address them.

The UKGBC NZWLC Roadmap (2021) identifies areas needing a bit more work prior to introducing mandatory reporting in 2023 and phasing in limits in 2025. These include:

- Development of a free national embodied carbon assessment tool, and a product carbon database, building on existing efforts (see the Built Environment Carbon Database, since launch in November 2021, pulling various industry efforts together on product data and building data).
- Publish embodied carbon benchmarks that have been produced using the approved method and data
- Work with industry on skills and quality assurance
- A range of support measures to improve the quantity and quality of verified EPD to EN 15804
- Give local planning authorities the freedom to go further in limit setting.

The London Energy Transformation Initiative (LETI) has drawn attention to the absence of consistent measurement protocols leading to misaligned benchmarks, also commenting on how inconsistent

inputs into LCAs result in reduced credibility around the reported results. This last point is also one of many raised in BPIE's factsheet (2021) [28] discussing some of the problems with EPD.

2.2 Regulation Development and Revision Process

Section 2.1 outlined the scope of various regulatory initiatives. This section moves on to the processes involved in developing the regulations, where these have been revealed, with particular focus on the development of the evidence base, and on those jurisdictions that are making significant progress with regulating embodied carbon at the building level.

2.2.1 Precursors to Full or Transitional Implementation of Regulations

2.2.1.1 Methods and Data

In general, implementation of the regulations identified in Section 2.1 has been – or is being – preceded by necessary groundwork relating to matters such as data, methods, tools, and skills. There is a sense of the various jurisdictions around Europe doing their own thing on environmental data of building products, when a more harmonised approach would be beneficial – e.g. through a single database. Regulators in Scotland may not wish to support the development and maintenance of a Scotland-specific window into EPD for instance, and should consider working with neighbouring countries (specifically, immediately to the south) on a harmonised approach.

Whilst a satisfactory level of data quality is a requirement for regulation, there does seem to be an acceptance that perfection can be the enemy of progress. For instance, the **Danish** regulation recognises that for some construction products, in the absence of specific data, generic data can be used – in which case it should be from Ökobaudat (a free German national database). Environmental data (in accordance with EN 15804 and independently verified) must represent the construction products used *"in the best possible way",* bearing in mind geographical and temporal considerations. And the selection of environmental data set must be justified.

Finland also has a free-to-access database, developed with Swedish partners, with an English language interface option. In this case, the database houses generic / typical data for products used in Finland, which have been manipulated with a 'conservative value conversion factor' - essentially a penalty for using generic data, but it provides a good option for estimating emissions in earlier stages of the design process. Other relevant information such as waste factors and recycling data is also included. Emission factors for a range of transport modes is also provided, along with emission factors (per floor area) for the embodied carbon of various building services, and for construction and demolition processes.

In the **Netherlands**, the Buildings Decree is supported by the National Environmental Database (NMD) which has been established "*to ensure the verifiability of the environmental data submitted by producers and to ensure a uniform use of the data when calculating the environmental performance".* The NMD houses data on environmental profiles of products and standard design details to support mass calculations; it also includes information relating to circular economy objectives – regarding recyclability, reuse, etc. The NMD Foundation is responsible for data quality assurance, and filling in gaps where EPD are unavailable, although the industry is expected to provide the verified environmental data as required. As a safeguard to prevent the Decree being an obstacle, where a product is missing from the NMD, it is permissible to consider the constituent materials of the product separately or – failing that – use data for a near-equivalent.

France's RE2020 regulation uses a free-to-access database – Inies – which houses life cycle data on construction products and building services equipment. The data is from EPD or FDES (French environmental and health declaration sheet) which is, in effect, an EPD supplemented with health information. This database is well populated on account of the very strong uptake for FDES (nearly 3500 registered to date). France's leadership in this sphere is in large part due to a regulation which requires any product environmental claims to be backed up with evidence (Decree No. 2013-1264, 23

December 2013 on the environmental declaration of certain construction products intended for use in building works): which, for construction products, essentially means production of an FDES / EPD.

In **Sweden**, Boverket (the National Board of Housing, Building & Planning) has plans for a range of initiatives planned to support the move towards WLC reporting and the imposition of limit values in 2027. These include a methods review and work on harmonisation across the Nordic region; expansion of databases to ensure that WLC is well covered (not just product stage carbon); national scenarios to support in-use and end-of-life carbon assessment (covering issues such as service life and maintenance intervals, energy emission factors, and waste management scenarios); and development of default values for categories such as internal finishes and fittings.

Denmark's National Strategy for Sustainable Construction (2021) identifies a number of initiatives put in place to support the introduction of limits in 2023 and subsequent developments [29]. These include the development of LCA and Life Cycle Cost tools; cooperation and harmonisation with other Nordic countries, and also with the EU regarding Construction Products Regulation[5]; and various initiatives to make lower embodied carbon buildings more easily achievable by the industry. The latter potentially include consideration of support schemes, increased digitalisation, facilitation of transport of large 3D offsite constructions, promotion of fossil-free construction sites, inclusion of LCA in tender material, and improved documentation on recycled materials and components.

Part of the National Strategy is that the Danish Agency for Housing and Planning has a coordination committee to ensure that such initiatives are well-founded and compatible with existing industry activity. This committee – with members drawn from industry – has formal communication channels back to the Agency. According to written evidence to the UK parliament from the Danish Energy Agency, via the Danish Embassy in London (2021), since 2019 'climate partnerships' between government and business have been operating in 13 sectors, and the construction sector climate partnership actually came up with recommendations for (amongst other things) incorporating carbon accounting of new buildings through building regulations, saving 1.1 $MtCO_2e$ per year. The speed of developments from then through to regulation taking effect in 2023 is striking. The partnership also recommended some of the initiatives that subsequently appeared in the National Strategy.

2.2.2 Risk Assessment

In general, details of how risks and costs were considered in regulation – on both sides of the regulatory divide – is relatively hard to discover.

Boverket (**Sweden**) notes a number of potential negative impacts associated with regulation. It mentions (but does not quantify) costs for the government in terms of monitoring compliance and managing the associated IT infrastructure. Costs to the developer are implied to be initially around 50,000 SEK (~£4000) per project, but with an expectation of a reduction over time as systems and competencies develop. The cost of obtaining EPD in the supply chain is also noted, along with a suggestion that support may be necessary to ensure the flow of certified, innovative low-carbon products that will be needed. It also notes that in the absence of checks and balances, there are potentially many aspects of the building design that might be negatively impacted by a relentless focus on embodied carbon (including durability, fire protection, damp-proofing, noise), and that poorly tested innovations in the past have led to problems.

With regard to setting the proposed length of the reference study period for the whole-life carbon assessments that are likely to be expected from 2027, the associated risks were also considered by Boverket. An initial concern was that a reference period (50 years) shorter than the likely lifetime of the building might discourage the use of more durable products. However they found no evidence that the use of LCA had ever led to such an outcome.

[5] Stop press. Proposal for revision of the CPR issued by the EC on 30th March 2022. Background information here. Regulation proposal here.

Denmark's National Strategy for Sustainable Construction refers to an expectation that analysis of the climate and socio-economic effects of LCA reporting and CO_2 thresholds will be required.

2.2.3 Setting and Revising Limits – Process and Evidence

The process of setting and revision of embodied carbon limits may have reactive and anticipatory elements. Reactive in that, following regulation, a continuous supply of data facilitates analysis of progress in reducing embodied carbon in buildings: this enables limits to be revised to cut off the worst performers and to pressurise the middling performers to go further. An anticipatory way forward is illustrated by the UKGBC's whole life carbon roadmap technical report, which has presented decarbonisation scenarios – with sensitivity analyses – through to 2050 for the factors that contribute to embodied carbon. These are material efficiency in design, construction site efficiency, transport, and carbon intensity of material manufacture. Although material efficiency in design is only anticipated to improve by ~20%, bigger improvements in the other aspects mean that the collective effect can be dramatic. UKGBC includes analysis of these scenarios alongside the UK's carbon budget through to 2050 and construction projections, including housing retrofit, and shows that potential exists for buildings to reduce their share of the much smaller carbon 'pie' in 2050.

Finland's Ministry of the Environment commissioned Bionova Ltd (OneClick LCA) to develop the evidence base to support the development of benchmark values and limits. It approached this using the combination of methods discussed above, i.e.

- A top-down statistical review of nearly 500 projects (and much more for those looking at operational energy).
- A bottom-up review of reference buildings covering the five categories of interest (residential, offices, health, education, and commercial).
- Sensitivity / scenarios analysis regarding decarbonisation (e.g. material switching – alternative binders in concrete, timber frame, etc.) and local zoning requirements (which might, for instance, restrict construction material options).

The scope of the building elements assessed in the statistical review of Finnish cases was said to be inconsistent, and the assessment method (2019) [30] was correspondingly being updated in 2021.[6] That said, the statistical review and the reference review appear to produce results of approximately similar magnitude. In the statistical analysis, the 95% confidence intervals vary significantly by building type: for instance, for A1-3, the interval is just 8 $kgCO_2e/m^2$ for a substantial sample of residential buildings (perhaps indicating that – in effect – the same LCA is repeated many times), but 82 $kgCO_2e/m^2$ for healthcare and 335 $kgCO_2e/m^2$ for commercial and cultural buildings (a much smaller sample, but potentially with a wider range of design possibilities).

Sweden's National Board of Housing Building & Planning (Boverket) presents an interesting example of a conservative approach to limit imposition, as its proposals expand the scope of the 'climate declarations for buildings' regulation after a 5-year warm-up period following a limited introduction in 2022. The regulation starts with declarations only, and for upfront carbon alone. It is proposed that from 2027 limits will apply, and the scope expands to whole-life carbon, and the building model is expanded to include 'installations', which is understood to imply building services, etc. The 2027 limit values will be based on a forthcoming study of at least ten reference buildings across the three building categories of interest, and a review in 2024-5 will take place to ensure that the whole process looks sufficiently robust to justify the imposition of limits.

Boverket sets out its own evidentiary requirements for limit-setting, and states that the reason for waiting until 2027 before applying limits is to allow time for "*the development of skills and capacity for*

[6] A foreign language PDF file covering the consultation on the methodology in 2021. In general, most of the foreign language web pages referred to here will succumb to in-browser translation tools, but PDF files may require more commitment.

carrying out calculations with quality", which will also be supported by improved digitalisation.[7] And thus, when limit values are introduced, it is possible for them to set a genuine challenge. Boverket also cautions against frequent regulatory change, and suggests that each revision should be preceded by evaluation starting three years beforehand.

Boverket argues that limit values should be *"stringent from the outset"*, and 20–30% lower than a calculated reference value obtained from registered climate declarations in the run up to 2027. It argues there is evidence that it is usually possible to reduce climate impacts by up to 30% with existing technology, and the construction and civil engineering sector's roadmap makes this especially feasible, as said organisations have already committed to a *"50 per cent reduction of the climate impact from the construction stage between 2015 and 2030",* with further promises from the concrete industry, which envisioned a 50% reduction in the climate impact of concrete already by 2023. However, this last point was predicated on the Slite cement plant in Sweden (which satisfies around three quarters of the country's needs) being equipped with bioenergy with carbon capture and storage (BECCS), which now looks highly unlikely in the near term, with the very future of the plant apparently in doubt (2021).

The **Netherlands** Guide to Environmental Performance Calculations (2020) includes a discussion of the relationship between the environmental indicator score and key design parameters (gross floor area, number of floors, floor height, façade area, and glazing ratio), which implies a degree of ongoing analysis of incoming data related to the regulation in order to support best practice and also to support future tightening of limits. A verbal response from a national representative on Annex 72 suggests that the initial limit was intentionally set at a very soft level (MPG = €1/m^2/yr, with MPG being the Dutch abbreviation for the indicator), and although now revised down to €0.9, compliance is still straightforward: the fact that the requirement only applies to domestic buildings and offices (with their relatively uniform requirements compared to some other building types) may suggest that if it is easy for one building it should be easy for all. A further reduction to €0.6/m^2/yr is reportedly overdue (so coming soon), and the intention is to reach €0.5 (€0.4 in some reports) by 2030. These revisions may challenge developers, but published case studies are already available on the MilieuDatabase website with an MPG of well below €0.6/m^2/yr: for instance a 45-home development in Eindhoven with timber frame, locally sourced poplar facades, and various recycled materials has an MPG of less than €0.5. This presents a good case study in starting early and gently to raise awareness, gain industry acceptance and get systems in order before tightening the screw. However, the option of a truly early start in the UK is no longer available, meaning more ambition will be needed when a regulation is introduced, but this should be feasible given the wide industry support (a situation not replicated in the Netherlands in the many years leading up to the implementation of their regulation).

In **France**, the introduction of upfront carbon requirements in RE2020 followed an experimental stage of the E+/C- approach (positive energy and carbon reduction) from 2017 onwards and extensive industry consultations in 2019. And then, according to the Ministère de la Transition Écologique, a 'simulation phase' was used to clarify the choice of indicators and performance levels. These simulations (or scenarios) were based on a gradual transformation of construction techniques, industrial sectors and energy solutions, in order to control construction costs and guarantee the development of professional skills. These simulations were followed by further consultation to assess the impacts of RE2020 on materials, construction methods and building sectors, allowing emissions limits to be set at sufficiently ambitious levels. A system for retaining and assessing the data collected[8] by the administration on newly constructed buildings was planned[9] in order to monitor the impacts of the regulations and to inform future changes.

[7] An interesting question would be whether similar considerations applied to the development and implementation of operational energy limits...
[8] This document is another foreign language PDF file (see footnote #6).
[9] ...and is presumably in place. As with many of the cases discussed in this paper, the rate of development is high, and the boundary between stated intentions and what has actually occurred is blurry, especially when viewed through the prism of online translation tools.

In **Denmark**, a pilot phase runs until mid-2022[10], with participation on a voluntary basis, which involves the industry testing the 'sustainability class' on live building projects for the mutual benefit of the industry and the regulator, continuously accumulating experience and data. Project experience will be shared on the theme page, along with questionnaires and interviews, to encourage ownership of the process in the industry whilst bringing to light any aspects that might need revision in due course (e.g. limits, documentation, and data systems). The Denmark Energy Agency's written evidence to the UK Parliament also refers to projects receiving funding to participate in the trial, covering the associated professional fees. A test panel with representatives across the construction value chain is reviewing progress and making recommendations for adjustments to the building regulations. Previous research completed in 2019 and published in 2021 has included a WLC study of 60 building projects (including 34 domestic and 22 office buildings dating from 2013 onwards), commissioned by The Danish Transport, Construction and Housing Authority [31]. Benchmarks for WLC over 50 years are shown as lower quartile, median, and upper quartile: 8.5, 9.5, and 10.6 $kgCO_2e/m^2/yr$ respectively. Therefore, the 2023 limit (12 $kgCO_2e/m^2/yr$) is comfortably in the upper quartile. Nevertheless, 7 buildings out of the 60 were above the limit, including three which were more than 13 $kgCO_2e/m^2/yr$ – so the limit should have some influence in requiring improvements from a number of buildings. The illustrative timeline is for the limit in 2025 to be around the upper quartile mark (10.5), and going below the median level in 2027.

3 Options for Regulation in Scotland

In this section, an overview of some of the key questions concerning embodied carbon regulation in Scotland is presented.

Notwithstanding the various inconsistencies, challenges and complexities surrounding methods, data, and evidence, it is clear that many jurisdictions have seen enough to convince them that embodied carbon can – and must – be regulated in some way. Even if Scotland moves quickly, by the time it establishes its own regulations it is likely that many other countries will be doing the same, with some already having regulations in force for several years.

The assumption made here is that emissions will be regulated at the building level through building standards, rather than the planning system. Note that this does not preclude separate regulations or procurement obligations around the environmental qualities of construction products. An opportunity clearly exists to regulate through Section 7 (Sustainability) of the building standards, as this is due for an update, and – in the face of the unfolding climate emergency – the time has come to move it on from its voluntary and somewhat neglected status.

During the regulation development process, from the initial engagements leading to formal consultation all the way through to implementation and potential future revisions, a range of questions need to be asked and answered. These questions generally fall into one of the following categories:

- Why? The aim of the regulation, and how its success might be determined.
- What? Temporal and physical scope of the regulation.
- When? Urgency and ambition.
- How? The regulatory instrument, compliance, etc. Practical and political considerations also.
- Who? Implications for the regulator and the regulated in terms of skills and resources.

Within these categories, key questions are identified and briefly discussed below. Each question is given a star rating to indicate its urgency:

- Three-star questions (***) are on the critical path, and it may be difficult to engage coherently with stakeholders before a reasonably clear view of the way forward has been developed.
- Two-star questions (**) must be resolved at some point during the regulation development process (e.g. during the consultation cycle).

[10] Bolig og Plansyrelsen – Housing and Planning Agency website

- One-star questions (*) might potentially be ‘parked’ for possible consideration in future revisions, unless there is an urge to include them in the first iteration.

3.1 Why Regulate?

As discussed, the need to regulate is clear, but the case will need to be restated and possibly refined as the process unfolds.

Another facet of the question is to ask what success would look like, and how it would be measured (**).

The straightforward answer is that the average embodied carbon of new buildings will reduce more than would have been the case in the absence of regulation. But demonstrating this to be the case will require some planning from the start. In particular, a robust data-gathering and analysis process will need to be in place to record the results for buildings as they come in along with the date of the assessment and other details that might be required. A declining trend in embodied carbon can be expected as a result of decarbonisation of the wider economy, and reductions in the emission factors of construction materials generally: this must be factored into the analysis. The impact of the regulation in indirectly driving down the emission factors of those construction materials would be more difficult to model.

The ‘bigger picture’ answer to the question of what success would look like is that the regulation will cause a reduction in the overall GHG emissions of the construction industry, including those emissions associated with consumption of products and materials produced outside Scotland.

3.2 What to Regulate?

3.2.1 (**)Physical Scope

- A decision is needed about which building elements to include: grey areas can include building services such as heating and lighting systems; fixtures, fittings and finishes; external landscaping and parking; and – even outside the building curtilage – associated infrastructure. Some of these elements will be more significant than is generally realised, but at the same time some may be difficult to quantify without resorting to generic data.
- A decision on how to normalise the results – e.g. by gross floor area, or by heated floor area.
- Similarly, a decision is needed about which buildings to include:
    - Should this include, for instance, domestic, commercial, public buildings, etc., or even all buildings?
    - Include a minimum floor area threshold: and if so, (a) what will it be? And (b) what would be the justification, given that individual small buildings are subject to regulation of energy demand?
- Include building refurbishment and retrofit? If a whole-life carbon perspective is taken, then this would be a good intervention point to test the trade-off between added materials and energy efficiency. But setting limits for upfront carbon that are significantly lower than the limits for new buildings may have unintended and unwanted consequences. Setting a reporting requirement alone may be a safer option.

3.2.2 (***)Temporal Scope

A decision is needed on the stages of the building life cycle that are assessed and subject to limits. A strong case can be made for requiring assessment and reporting to cover everything, but setting limits only for those elements that are truly assessable upon completion (primarily that is upfront carbon and operational energy).

- Upfront carbon (A1-A5 only) is the most straightforward option, and it has the advantage that when a building is ready for its completion certificate the carbon account is effectively settled, with no future uncertainties and scenarios to consider.
- Embodied carbon, potentially including everything except emissions associated with operational energy and water (the former being regulated separately already) gives a more comprehensive picture. If so, will the regulation:
    - set a fixed reference period: e.g. 50 years? Whatever period is chosen would be generous to buildings specified (or likely to endure) for less than that period, so an adjustment mechanism would be needed for such buildings, or
    - allow developers to specify a building lifetime? This is potentially the more 'correct' option, but clearly opens a loophole for 'gaming the system'.
- Whole-life carbon (where operational energy carbon is included and is therefore tradeable against – mainly – upfront carbon). An integrated limit for A1-A5 + B6, divided by the reference period allows the value of adding embodied carbon (in the form of insulation and energy systems for instance) to be explored and – in theory – an optimum found.[11]
    - Whilst this is the option chosen in several jurisdictions, a significant flaw is that it assumes a kg of carbon dioxide emitted now is no different from a kg emitted in 25 or 50 years time. To address this, either a dynamic assessment would be needed or three separate limits would be required, one for A1-A5, one for B6, and an integrated limit that requires a level of over-performance with respect to the other limits.
    - Scenarios need to be considered for operational carbon reduction associated with – primarily – the decarbonisation of the electrical grid, but also potentially with non-electrical heating systems.

3.2.3 (**)Variations

- (**)If limits are set for embodied carbon (i.e. including end of life), should they include consideration of biogenic carbon storage? Or is biogenic carbon storage a matter for separate reporting alone?
- (*)Whilst on the subject of reducing the climate impact of construction, should the scope be extended beyond carbon and climate? There are a number of pros and cons to this, but possibly more of the latter at the moment, which is why this is not a popular approach. Of particular concern is that it moves the focus on from carbon and climate at a time when the public, industry and regulators are finally warming to the task of dealing with it.
    - Other environmental impacts that might be included are, for instance, energy depletion (as a proxy for energy security), and a suite of pollution-related impacts.
    - If so, the choice would be whether to integrate the environmental impacts into a single indicator, as the Netherlands has done(which would sacrifice focus and transparency regarding carbon impact), or to regulate each indicator of interest separately (which may be asking a lot in terms of both regulation and compliance).

3.3 When to Regulate?

This question is addressed here in terms of the urgency and ambition around regulation, rather than the timetable as such.

3.3.1 (***)Tactics

Should evidence precede regulation, or should regulation be enacted in order to secure the evidence? The answer will need to be 'yes and yes' if regulation is to be implemented before even 2030. A robust body of evidence on the true whole life cycle carbon of buildings is of course desirable in order to

[11] A case can be made for also including B4 – replacement – to cover elements that have fairly predictable lifespans that are lower than the reference period.

inform regulation and limit-setting. But regulation may be necessary to secure the evidence needed for robust limit-setting.

A realistic approach would be:

- With the minimum delay possible, require measurement and reporting, along with an indicative timetable for introduction of limits. In the meantime, support pilot projects to show how this can be done, and how improvements can be achieved.
- Allow, say, an extra year for evidence-gathering and consultation before imposing a 'soft' limit alongside a requirement to measure and report, with an indicative timetable for tightening the limits.

3.3.2 (**)Building categorisation

Should different limits be set for different types of building – e.g. retail, offices, and different domestic archetypes?

- If reporting requirements and limits are introduced contemporaneously, then this might be done with the lowest number of categories deemed to be useful, and soft limits to push only the poorest proposals towards improvements (initially).
- As evidence accumulates about performance in different categories, the limits can be tightened at different rates.
- For new domestic buildings, the decision on whether to set different limits for different archetypes (e.g. detached homes, low-rise flats, mid-rise flats) is fundamentally important, as it should steer developers towards certain built forms: these should be optimal in carbon terms, but may have other qualities that are less desirable.

3.4 How to Regulate?

The critical question (***) is the choice of regulatory instrument. As discussed, this is assumed here to be building standards, which might be Section 7 or some form of cross-over between Sections 6 and 7 if whole-life carbon is the focus. A wider review of sustainability throughout the building standards may be needed here, but there is a case for moving on embodied carbon regardless. The questions of compliance and sanctions will be linked to the choice made. It is noted that the Building Standards Division is in the process of developing a Compliance Plan approach to improve the transfer of intentions from design to building completion, but initially the focus is on health and safety issues surrounding high risk buildings.

If failure to comply all the way through to completion results in only modest financial penalties (e.g. through setting a price per tonne of excess carbon emitted, and/or requiring that it be offset: to be reviewed), then an additional option may be to use the carrot of publicising best practice and providing certification that a given level has been reached. Or offer a tangible financial or planning reward for full compliance (or going beyond), such as soft loans for measures that were needed for the good result.

Other issues within this section are both philosophical and practical.

3.4.1 Political Alignment.

(***)The degree to which Scotland's approach should resemble that of neighbours – especially England and Wales, and EU / European trailblazers – should be considered. This is both for practical reasons (common methodologies and data sources can limit the burdens on both regulators and industry) and in order to keep up with best practice.

Thus, it is very unlikely that a uniquely Scottish approach to the challenge will be desirable. Instead, the methods, tools and data sources should align closely with neighbouring jurisdictions, as with the new proposals for developments to the EU Construction Product Regulation. However, some differences which do not place significant burdens on the industry may not create any particular problems, for instance:

- Relatively minor additions to, or removals from, the scope.
- Differences in the limits set, and the categorisation of buildings that limits apply to.

3.4.2 (**)Methods and Data

Bearing in mind the view taken on political alignment and on the temporal scope of assessment, decisions are needed on the methods, tools and data to be used, and whether and how they should be supported by the government. For instance:

- For product environmental data, should there be a Scottish database developed and maintained for the purpose? Or is reliance on commercial systems acceptable? Or free, philanthropically funded systems (e.g. EC3 / openEPD)?
- Should a penalty be applied for use of generic data (a 'conservative factor': automatically applied in the Danish database for instance, and also applicable in Sweden and Finland)? And if so, what should the factor be? Using a tool such as EC3 this penalty could be for instance imposing the higher value in the range offered for a specific class of product/material.
- A platform or platforms is/are needed for the sharing of project embodied carbon data, for two main purposes:
    - Compulsory and confidential data submissions for compliance purposes, and to allow analysis and the production of statistical summaries for publication, to show progress in each building category. The Scottish Government would require a plan for this.
    - A forum for sharing carbon reduction ideas, asking and answering questions, and publishing detailed case studies. This is something that the Government might lead on, or it could look at how it can (if necessary) support industry in developing its own initiatives.

3.4.3 (**)Setting limits

Alternative options exist for how limits are set, telegraphed in advance, presented and revised.

- For each building category (or even for all buildings together) a single pass-fail threshold might be set, and revised periodically as an increasing body of evidence shows that further improvements are possible.
- Or an A^{++} to G banding system might be used, as in the LETI target alignment document, with a banding set for each building category. An initial limit might be set at a relatively easily achievable level (for the sake of argument, level D), with an indicative timetable for moving the limit up through the levels, subject to evidence on progress and achievability.
- Pilot studies may be needed, using the approved methods and data, to demonstrate the suitability of proposed limits.
- An alternative option (and a more radical one, but effectively guaranteed to result in the carbon reductions sought) is to set an annual budget for embodied carbon in construction in Scotland, and work out how to share it amongst all projects. This might be through a combination of limit-setting in the sense discussed above, along with limiting the actual amount of new floorspace being added. The embodied carbon implications of the retrofit projects required to achieve net zero operational carbon will also need to form part of this conversation, as it does in the modelling being undertaken for the EU's Whole-Life Carbon Reduction Roadmap (project launched in March 2022).

3.5 Who will be Involved?

The question in this section (***) is about the human resources (and the associated financial cost) that would be required, both for the Government in terms of implementing and managing the regulation, and for industry in terms of compliance. This is a critical question, as if the resource requirement turns out to be excessively burdensome, then implementation is likely to fail.

On the part of the Government, an analysis would be required of the data systems (and the human resources behind developing, maintaining and using them) that will be needed to interface with building developers, review and approve their data submissions, and to gather and report statistics.

On the part of the industry, for those companies already invested in embodied carbon measurement, regulation may actually enable their human resources to go further, on account of the benefits associated with a standardised approach, approved data sources in one place, etc. Overall, however, there is likely to be an increase in the number of people the industry needs, and some analysis of the number of person-days per project or per 1000m^2 of project may be useful. For developers of smaller projects, the costs of compliance need some consideration, which may inform on whether there is a need to set a floor area threshold below which the regulation does not apply.

4 Indicative Routemap

The purpose of the indicative routemap presented in this section is to outline a possible way forward towards regulation, with a phased introduction of requirements and gradually tightening limits, leading to challenging limits on upfront GHG emissions in place no later than 2030. The philosophy is to present a trajectory that is realistic whilst being reasonably ambitious. Potential may exist for the process to be accelerated beyond the rate presented, through a combination of political ambition and industry willingness to participate, along with the capacity and resources required by the regulator.

4.1 Routemap Overview

A very high-level overview of the process is as follows:

1. Begin all necessary preparations to regulate upfront GHG emissions (A1-A5) without delay, leading to:
    a. A requirement to report – at least – A1-A5 emissions and probably B6 emissions (from 2026, although consideration of the potential for bringing this forward by a year is recommended).
    b. The imposition of a limit on A1-A5 emissions (from 2027).
    c. The imposition of a more challenging limit(s) by 2030. Depending on results of reviews leading up to this point, such limits might still have the same scope, or the scope might be revised to cover whole-life carbon, so that operational carbon and embodied carbon can be traded off to optimise design.
2. Undertake a review of where sustainability and energy should sit within the building regulations. The assumption here is that a revised Section 7 will initially be the vehicle for the regulation of upfront carbon emissions, but this review will open up the possibility of developing a holistic approach to regulating whole-life cycle carbon through future revisions of the regulations. Note that this document does not argue the relative merits of regulating upfront carbon and operational carbon separately or together: it is just observed that this is a choice that should be actively made, as opposed to setting off on the path of least resistance and then sticking to it by default.
3. Working with the industry as necessary, develop the systems and capabilities required to implement the regulation.
4. Amass evidence for setting limits, through a number of processes, including – before the regulation takes effect – the implementation of a pilot programme along with an associated data analysis plan.

4.2 European Routemap Milestones Comparison

Figure 4.1 shows the timelines for the development of regulations concerning embodied carbon in buildings in the key national cases identified in Section 2, along with the indicative timeline for Scotland discussed in Section 4.3 below.

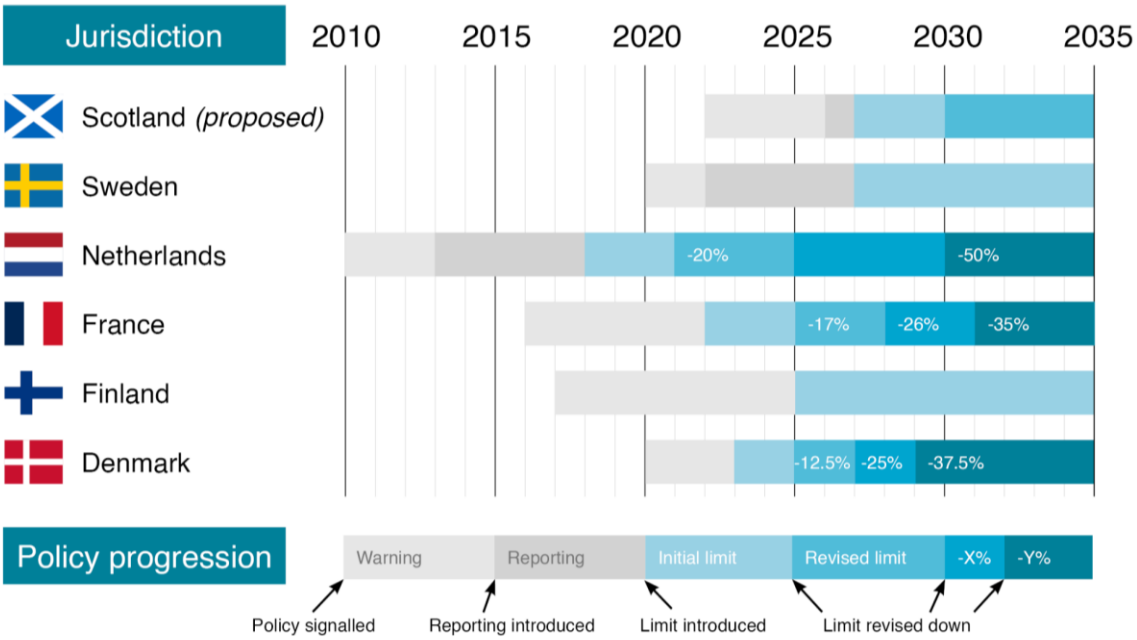

Figure 4.1. Regulation timelines in Europe, including that for Scotland proposed in this section. Increased shading as limits are tightened.

Notes for Figure 4.1:

- The dates when limits are introduced and tightened are indicative in some cases and some have not actually projected beyond 2030.
- The relative challenge of the limits in different countries cannot be compared using this plot.
- The left-hand end of each bar is the first date identified when there seems to have been a clear signal of impending regulation.
- Absence of darker grey block means reporting requirement and limits are introduced simultaneously (e.g. France).
- Sweden – first limit tightening proposed is in 2035 (-25%).
- The Netherlands – environmental footprint: there are some uncertainties around the limit tightening timetable.

There are some striking differences between the timelines indicated, suggesting that if Scotland does decide to start relatively promptly, it should be possible to act on a timeline that would not look out of place in this context. The case of the Netherlands exhibits first-mover advantage and disadvantage: advantageous in that the regulation is the first to begin having an impact (by several years), but disadvantageous in the drawn-out development and implementation, without mutual support from parallel work in neighbouring jurisdictions. The Netherlands has also ended up taking a different path to that taken by the other countries.

In the context of the other countries illustrated, Sweden appears to be on a conservative path, in that a 5-year reporting-only period is indicated before any limit is applied, which then sticks until 2035. In contrast, Denmark is setting an ambitious pace, with little obvious indication that this was coming before approximately 2020 (the test phase start for the voluntary standard) or 2021 (the National Strategy for Sustainable Construction), and yet a limit is expected to apply in building regulations as

early as 2023 – already stringent enough to require improvements in some buildings – with tightening just two years later. Such an approach is not without risk, as France has found in needing to twice postpone implementation of its requirements – though this was in the context of a global pandemic. This is a concern unlikely to be lost on Scotland's regulators who will remember, for instance, the substantial delay to the landfill ban on biodegradable municipal solid waste when it turned out that the shortage of infrastructure might lead to negative consequences.

Therefore, there is a strong case for opting for the route taken by Sweden and the Netherlands in imposing a requirement to report from the earliest feasible date, and in the meantime developing the evidence base required to support the selection and imposition of limits, rather than requiring all evidence and systems to be in place before demanding anything from the industry. Even though low embodied carbon design will be optional to begin with, the requirement to engage with the topic, together with the knowledge that limits are coming, should yield some improved buildings right away, and will support a smoother introduction of limits when the time comes. This transitional phase may include the submission of many low-quality assessments using poorly sourced data, but it should prove to be a useful learning phase for the industry while also providing an evidence-base for limit-setting training data for verification processes and systems.

4.3 Detailed Indicative Routemap

The indicative routemap is shown in Table 4.1, below (spread across 3 pages), and summarised subsequently in Figure 4.2. Abbreviations: EC – embodied carbon (generally); UFC – upfront carbon; WLEC – whole-life embodied carbon; WLC – Whole-life carbon (including operational energy).

M	**Milestones**	
M1	Publish provisional limit tables through to 2030.	2024 Q4
M2	Following a pilot phase (see item D3), introduce a requirement to report WLC design intent and as built. Scope to be confirmed through items B1-3.	2026 Q1
M3	Soft limit – UFC.	2027
M4	Optional intermediate limit tightening.	2028
M5	Tighten limit further. If indicated by results of item E1, then transition to WLC limits.	2030
A	**Regulation Development**	
A1	Review of where in the regulations EC should sit, along with how sustainability is considered, and future of Section 7 [N.B. The rest of the routemap assumes Section 7 is the initial home for EC].	2022 Q2-4
A1(i) *A1(ii)*	*Consideration of legislative competence* *Map out legislative process.*	...
A2	Industry engagement – regulation development.	2022-23
A2(i)	*Convene industry advisory group and working groups in order to both gain the confidence of the industry, to highlight key challenges, suggest initiatives to address them, and recruit wider industry support for them.*	2022-23
A2(ii)	*Working groups to provide input for draft consultation papers.*	2022-23
A3	Cross-border regulatory engagement process. Convene an ongoing dialogue with neighbouring jurisdictions – particularly with the UK Government departments DLUHC and BEIS.	2022-23

A4		Regulation risk assessment. Include identification and mitigation of the potential negative impacts on building design / quality / safety in the context of Scotland's regulations.	2022-23
A5		Formal consultation process.	2024 Q1
A6		Regulation process complete.	2024 Q3
B		**Scope Definition**	
B1		Temporal scope – starting assumption would be report WLC in full, but limit UFC and B6 separately (at least to begin with). Review this.	2022 Q2-3
B2		Physical scope (whether to include fit-out, building services, landscaping, and even associated infrastructure). Link to item D1(ii).	2023
	B2(i)	*Review of scope and plans for regulations in neighbouring jurisdictions. Pros and cons of options chosen.*	...
	B2(ii)	*Determine whether same scope should be used for obtaining a building warrant and getting a completion certificate (default would be yes).*	
B3		Carbon storage and sequestration. The initial default is that this will be a reporting requirement / suggestion only. If not, bring forward the relevant piece in the regulation review (item E2). A similar point applies to including environmental impacts other than climate.	2022 Q2-3
C		**Systems & Methods**	
C1		Carry out SWOT analysis of methods, tools, data sources, and skills.	2022-2023 Q1
C2		Develop compliance systems for the submission and review of data at building warrant stage and at completion. Trial these during the pilot phase (item D3).	2023-24
C3		With partners (construction industry and knowledge brokers), develop embodied carbon platform for publishing best practice, and for knowledge sharing (links to item A2).	2023-25
C4		Conceive and begin development of programmes to address the WOTs of the SWOT analysis. For instance, making the EPD process more accessible to SMEs; and awareness-raising and training (links to item A2).	2024-25
C5		Industry engagement regarding the SWOT findings (links to item A2).	2023-24
C6		Detailed approach defined regarding approved methods, tools, data, and quality control.	2024 Q3
D		**Evidence Gathering**	
D1		Bottom-up commissioned studies – LCA of building archetypes	2023-24
	D1(i)	*Analysis of building warrant applications to identify representative archetypes*	...
	D1(ii)	*'BAU' LCA study of each archetype – including results for separate building layers to inform choices around physical scope*	
	D1(iii)	*Best practice options LCA for each archetype*	
	D1(iv)	*Publish and present results.*	
D2		Develop or adopt construction industry / buildings decarbonisation scenarios through to 2030.	2023-24
	D2(i)	*Trajectories for materials scope A1-3. Key materials such as concrete, steel, timber, and typical mix.*	...
	D2(ii)	*Trajectory for freight transport*	

D2(iii)	*Trajectory for construction site (bearing in mind electrification for instance)*	
D2(iv)	*Overall trajectory for typical building A1-5*	
D2(v)	*Trajectories for operational energy carbon B6 from new buildings.*	
D3	Pilot reporting requirement with and by selected industry partners, using settled methodology.	2024-25
D3(i)	*Write up / publish case studies*	...
D3(ii)	*Analyse data and set provisional limits for 2026 onwards (link to item M2).*	
D4	Define metrics to track and report the overall success of the policy.	2024
E	**Regulation Review**	
E1	Statistical/evidence reviews, and wider reviews of progress leading to further planning. Compare results with anticipated scenarios, considering decarbonisation, material switching, and design efficiency. Link to item D3.	2025 onwards
E2	Carbon storage and sequestration. Given that building standards are functional rather than prescriptive, any special treatment for biogenic carbon would have to be on a strictly objective basis. Default assumption is that biogenic carbon would be reported separately in WLC account, but not included in any limits. Review of approaches to giving credit to biogenic carbon storage in buildings – dynamic assessment. Consider inclusion of concrete carbonation.	2025
E3	Other environmental impacts. Review pros and cons of expansion of the regulation to cover other environmental impacts, in terms of reporting and – potentially – limits (as in the Netherlands).	2025
E4	Investigate case for defining more building categories (with their own limits), based on evidence to date, from pilot studies and initial data submissions.	2025 Q3 – 2026 Q1
E5	Revise future limits trajectory accordingly – for 2027 and 2030.	2026

Table 4.1 Detailed Routemap

It is recognised that this routemap gives an outline of just one of many possible ways forward, and even the essential activities might conceivably be ordered and arranged differently. Given the choice to aim for a balance between ambition and realism, it is to be hoped that the general form of the routemap, and many of its features, will eventually be embodied in the path taken towards regulation. The routemap is further summarised in Figure 4.2 over the page.

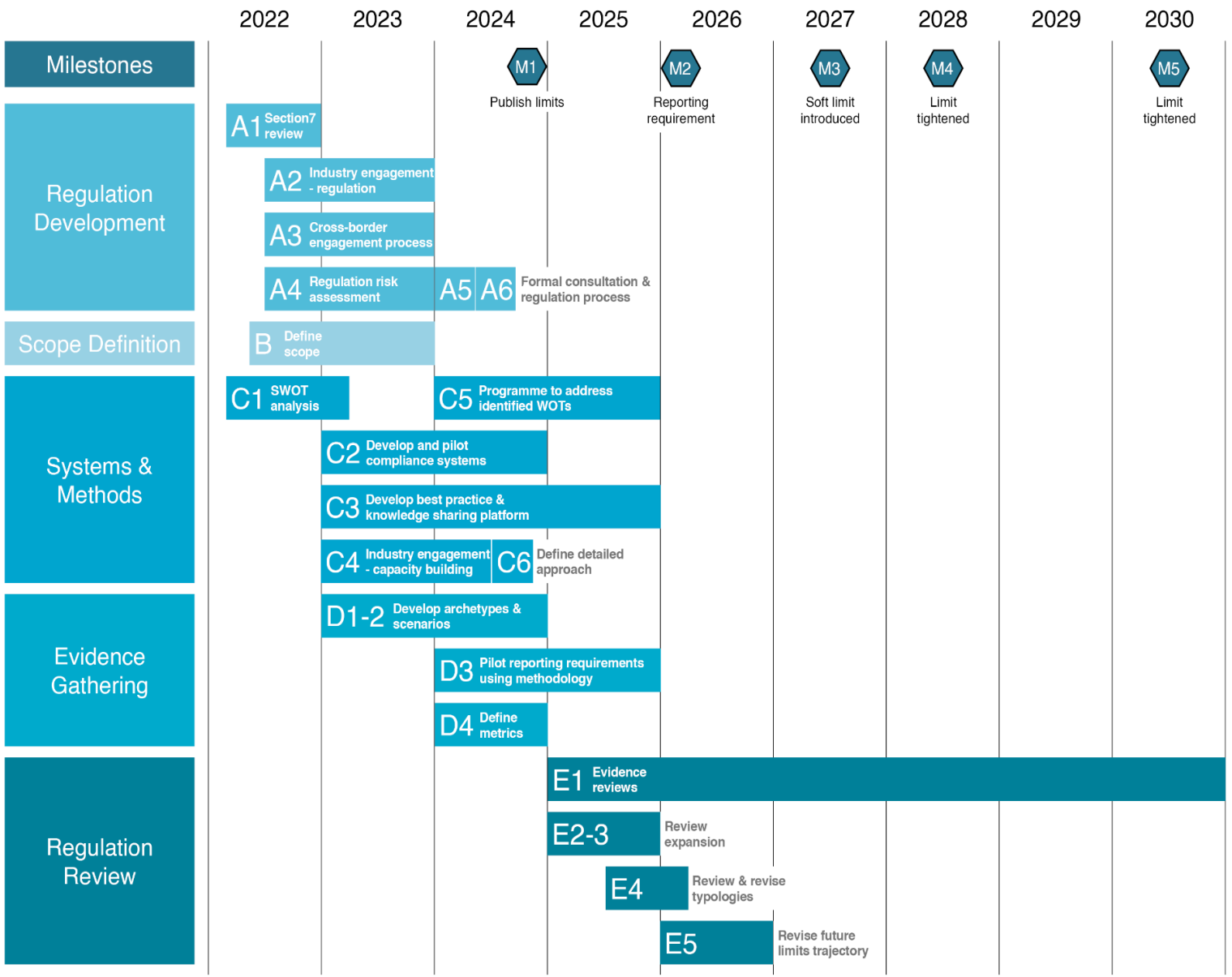

Figure 4.2. Indicative Routemap Summary

5 Selected References

This document contains a large number of hyperlinks to online resources, not all of which are included in this list of references. The intention is that sufficient information is included in the contextual text and in the hyperlinks themselves to allow the relevant document to be located even if the URL is changed. In some cases where more information might be needed however, a reference number in square brackets is used to refer the reader to this section.

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