Classification methodology for embodied carbon of concrete

July 2024

Executive summary

Assessing the embodied carbon of concrete and specifying limits or targets is increasingly important for the United Kingdom's construction sector.

This note describes three tools for assessing the embodied carbon of concrete which are or are expected to become important in the UK. The Market Benchmark developed by the UK Low Carbon Concrete Group (LCCG) and the Universal Classification developed by Arup for Innovate UK are already in use. The Global Banding proposed by the Global Cement and Concrete Association (GCCA) is currently in draft and significant time may be required before this system is ready for general use.

The Market Benchmark assesses embodied carbon relative to all concrete recently available in a market. The benchmark is dynamic. It changes as the embodied carbon of concrete sold on the market changes. The Market Benchmark is only applicable to the market from which the data is sourced. The LCCG Market Benchmark applies to all normal weight concrete produced in the UK. There are variations in embodied carbon of concrete produced in different parts of the UK and, particularly, for different uses. Assessment against the Market Benchmark should be cognisant of this. The LCCG intends to report on variations in the embodied carbon of concrete between uses and UK regions in September 2024, subject to receipt of sufficient data.

The static and dynamic benchmarks form a powerful combination. The static benchmarks can be used to define a pathway to net zero.

The Universal Classification and the Global Banding are static rating systems. The rating boundaries remain the same over time and between markets, regions and uses. Static rating systems are required to define the target for the average embodied carbon of concrete on a pathway to net zero. Methods of calculating embodied carbon vary between countries. The Universal Classification is entirely static and makes no provisions for variations in calculation method. Care is therefore required when comparing Universal Classification ratings derived using different calculation methods. The Global Banding will include national modifications to take account of different calculation methods.

National policy needs to be developed so that across the nation the average embodied carbon of concrete follows the pathway defined in the UK government's Industrial Decarbonisation Strategy

Therefore, the values assigned to the Global Banding boundaries between ratings will vary between countries.

The static and dynamic benchmarks form a powerful combination. The static benchmarks can be used to define a pathway to net zero. The pathway can be used in conjunction with the dynamic Market Benchmark to specify concrete that meets the pathway and is commercially available for the proposed use. Section 3 illustrates how the static and dynamic benchmarks can be used in combination.

There is a wide spread in the embodied carbon of concrete produced for different uses. This is not expected to change. Further work is required to determine principles for procuring concrete so that the average embodied carbon across a portfolio aligns with a pathway to net zero. Similarly, national policy needs to be developed so that across the nation the average embodied carbon of concrete follows the pathway defined in the UK government's Industrial Decarbonisation Strategy [8].

At project level, clients and designers will usually specify an upper bound on the embodied carbon rating for concrete for each type of use. The rating may be set using any of the Market Benchmark, Universal Classification, or Global Banding tools. In time, specification practice is expected to develop towards use of a static scheme with reference to Market Benchmarks to confirm availability of concrete of the specified rating.

Embodied carbon must be correctly calculated. Methods of calculating embodied carbon vary. Section 1.3 summaries how the embodied carbon of concrete should be calculated in the UK. During design development, it is usually appropriate to use industry database values for embodied carbon. Once the mix design, batching plant, and sources of constituents are known, the embodied carbon can and should be calculated to reflect the true embodied carbon of the constituents and production processes.

Contents

Executive summary 02

1.0 Context 08

1.1 Introduction 09

1.2 Scope 10

1.3 Methods of calculating embodied carbon 12

2.0 The classification schemes 14

2.1 The LCCG Market Benchmark 14

2.2 Universal Classification 18

2.3 The draft IDDI/GCCA Global Banding 20

3.0 Application of the classification systems 22

3.1 The current market assessed on Universal Classification or Global Banding 22

3.2 Definition of a pathway to net zero 24

3.3 Achieving a pathway to net zero 26

Abbreviations used in the text

CCU	Carbon Capture and Use
CCS	Carbon Capture and Storage
EC	Embodied Carbon
EPD	Environmental Product Declaration
ETS	Emissions Trading Scheme
GCCA	Global Cement and Concrete Association
GHG	Greenhouse Gas
GWP	Global Warming Potential
ICG	Infrastructure Client Group
IDDI	Industrial Deep Decarbonisation Initiative coordinated by the United Nations Industrial Development Organisation (UNIDO)
LCA	Life Cycle Analysis
LCCG	Low Carbon Concrete Group
MPA	Mineral Products Association
PCR	Product Category Rules (Rules and requirements that guide how to measure and report the life cycle impact of a specific type of product when conducting an EPD)
SCM	Supplementary Cementitious Material or Secondary Cementitious Material

1.0

Context

1.1 Introduction

Assessing the embodied carbon of concrete and specifying limits or targets for the carbon footprint of concrete is increasingly relevant for the UK construction sector. In this context, two embodied carbon classification tools have been developed and established in the UK: i) the **Market Benchmark,** published by The UK Low Carbon Concrete Group in 2022 and ii) the **Universal Classification** embodied carbon scheme for concrete published by Arup for Innovate UK (UKRI) in 2023.

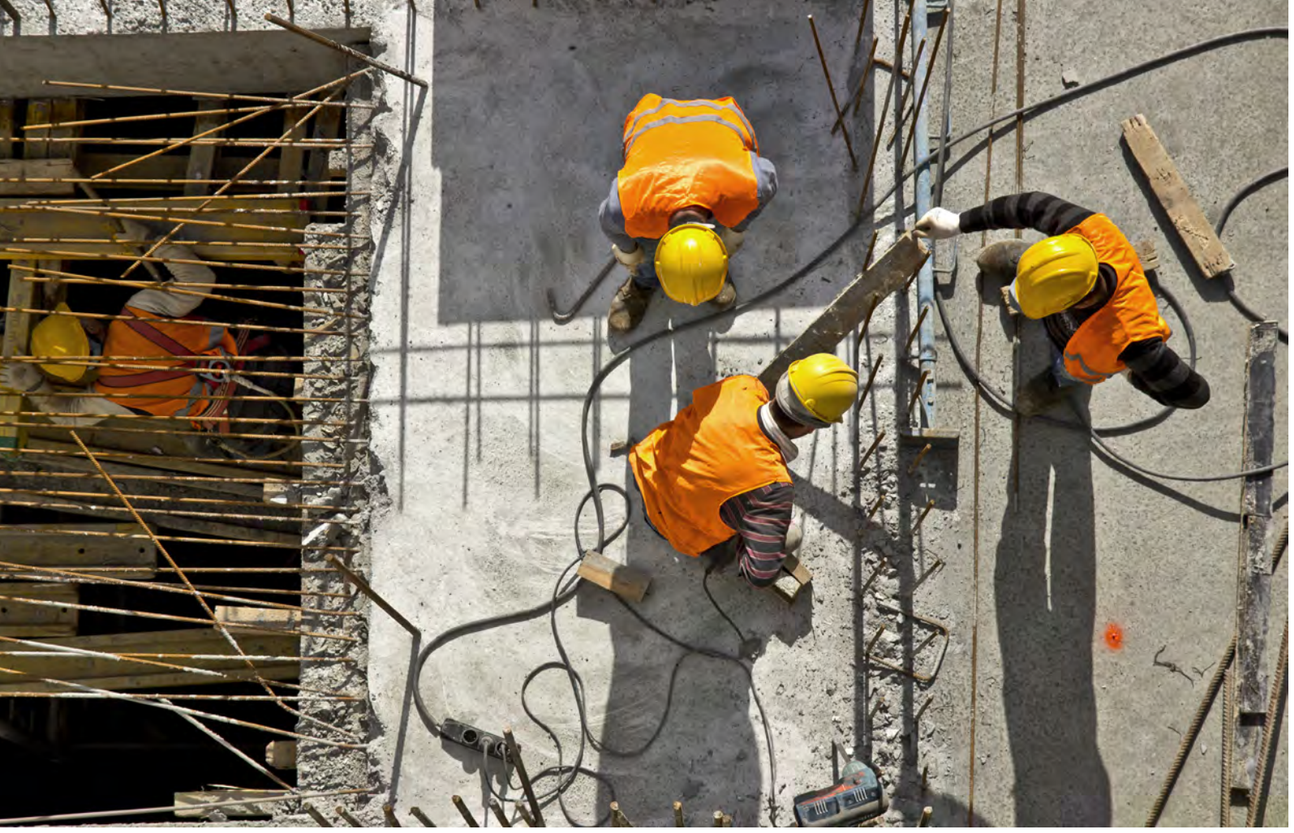
These two embodied carbon assessment tools are based around the same method of calculating embodied carbon. However, they adopt fundamentally different approaches to assessing the embodied carbon. The tools are complementary and together provide a powerful tool for planning, specifying, and reporting the embodied carbon of concrete in the short and long term.

In January 2024 the GCCA published a white paper on **Global Banding** of the embodied carbon of concrete. The Global Banding is similar to the Universal Classification. The GCCA intention is that, once finalised, the Global Banding will be adopted by concrete producers in all countries.

This guidance note describes the three tools and illustrates how they may be applied. For detailed characteristics of the three tools, the reader is referred to the corresponding references [1, 2, 3, 4].

A steering group consisting of end users of the classification tools, including designers, contractors, industry bodies and clients was assembled to provide feedback on the development of this guidance note.

This guidance note has been prepared by the LCCG. The scope was determined following conversations with the ICG, the MPA (The Concrete Centre), Concrete Zero, LCCG and Innovate UK. Funding was provided by The Infrastructure Client Group concrete decarbonisation accelerator programme.



1.2 Scope

This note summarises three methods of assessing the embodied carbon of concrete. The note shows how the methods can be used in combination to set policy for, specify, or assess the embodied carbon of concrete. The guidance is targeted at concrete use in the UK; however, aspects of the guidance may be relevant in other markets.

In this note the embodied carbon of concrete refers to GHG emissions attributable to Life Cycle Stages A1 to A3 (for ready mix concrete: from cradle to batching plant gate, and for precast concrete: from cradle to mould). Emissions arising from transport to site (A4) and site works (A5) are not included. This approach allows concrete to be compared on a like for like basis.

This note only considers the embodied carbon of concrete. It does not consider the whole life emissions of the complete works. Similarly, the note is agnostic on the embodied carbon of the cement and other constituents used to make the concrete.

The Market Benchmark, the Universal Classification, and the Global Banding are tools to rate the embodied carbon of concrete. The tools must be used in the context of reducing overall project and global GHG emissions. Sometimes concrete with higher embodied carbon will result in lower project and/or global GHG emissions. In particular, if concrete uses a high GGBS content to reduce embodied carbon, this may be an inefficient use of GGBS and may lead to an increase in global GHG emissions [5]. In such cases particular care is required to consider the impact on global GHG emissions.

The Market Benchmark is specific to the UK market for all normal weight concrete. The distribution of the embodied carbon of concrete available in other markets varies.

The Universal Classification has been developed based on data for concrete produced in the UK, EU and elsewhere.

The Universal Classification has been developed based on data for concrete produced in the UK, EU and elsewhere. Concrete produced in other countries can be assessed against the Universal Classification. However, methods of calculating embodied carbon vary between countries and so do the carbon factors of different constituent materials. As such, the different methods may report different embodied carbon for the same concrete. Therefore, care should be taken when comparing Universal Classification ratings of concrete produced in different countries.

The Global Banding has been developed for global application. Modification factors will be applied nationally to take account of differences in methods of calculating embodied carbon.

1.3 Methods of calculating embodied carbon

The embodied carbon of concrete should be calculated in accordance with the requirements of BS EN 15804 [6] for LCA Stages A1 to A3.

Alternative calculation methods may be used to assess embodied carbon using the Universal Classification. However, an alternative calculation method may result in a different rating relative to calculations in accordance with the requirements of BS EN 15804.

Embodied carbon calculations should be transparent and either independently verified or available for independent audit.

The embodied carbon of concrete should be calculated as accurately as possible. Industry database values of embodied carbon may be used during the development of the design.
The embodied carbon of cast concrete should be based on the mix design and supply chain data for the embodied carbon of the constituents. Supply chain EPDs are a good source of data for the embodied carbon of the constituents.

EPDs can be provided for concrete. EPDs for concrete are sometimes based around the concept of concrete families as used in conformity testing of concrete. EPDs usually remain valid for 5 years. If an EPD is provided for concrete, the supplier should verify that the EPD accurately reflects the particular concrete supplied and that the embodied carbon of the constituents remains as reported in the EPD.

For calculation of the embodied carbon of concrete, the embodied carbon of cement should be reported gross of emissions arising from burning fossil waste-derived fuels in the kiln. Fossil waste-derived fuels are also referred to as “alternative” or “secondary” fuels. Calculating gross emissions is consistent with the MPA guidance for concrete produced in the UK and aligns with the treatment of carbon emissions in UK ETS. When referencing EPDs it is important to obtain gross rather than net GWP values.

Embodied carbon calculations should be transparent and either independently verified or available for independent audit.

Current UK guidance is that any biomass portion of fuels is classified as carbon neutral. This guidance however reportedly varies between countries.

Carbon dioxide which has been permanently incorporated into the concrete during LCA stages A1 to A3, and which would otherwise have been released into or remained in the atmosphere should be considered and used to reduce the calculated embodied carbon. For example, certain cement and concrete technologies manufactured with sequestered carbon qualify for the above.

Carbon dioxide generated during the manufacturing process which has been captured and permanently sequestered (i.e. CCS) should be considered as waste processed to the “end of waste state” as defined in BS 15804 . This carbon dioxide does not contribute to the embodied carbon of the concrete.

Other forms of carbon offsetting should be reported under LCA Stage D “Benefits and loads beyond the system boundary”. They should not be used to reduce the embodied carbon reported in LCA stages A1 to A3.

Reductions in GHG emissions elsewhere in industry enabled by the production or use of concrete should be reported under LCA Stage D and should not be used to reduce the embodied carbon calculated in LCA stages A1 to A3.

2.0

The classification schemes

2.1 The LCCG Market Benchmark

The LCCG Market Benchmark summarises the distribution of the embodied carbon of normal weight concrete recently produced in the UK. The benchmark covers LCA stages A1 to A3 (“cradle to batching plant gate”, or “cradle to precasting mould”).

The Market Benchmark is of particular use for comparing concrete relative to alternative available products, for specification to ensure good practice relative to the market, and to ensure availability of concrete that is specified using the Universal Classification or GCCA Global Banding.

The LCCG aims to provide an annual update of the Market Benchmark for normal weight concrete used in the UK.

Since the embodied carbon of concrete varies between regions, uses, and concrete types, the Market Benchmark varies between markets. The LCCG aims to report on variations in the embodied carbon of normal weight concrete between the UK regions and between different uses .

An anonymised version of the data underlying the LCCG Market Benchmark that updates and reports on variations in embodied carbon of concrete between regions and uses will be publicly available.

Figure 1: The LCCG Market Benchmark, 2023 update.*

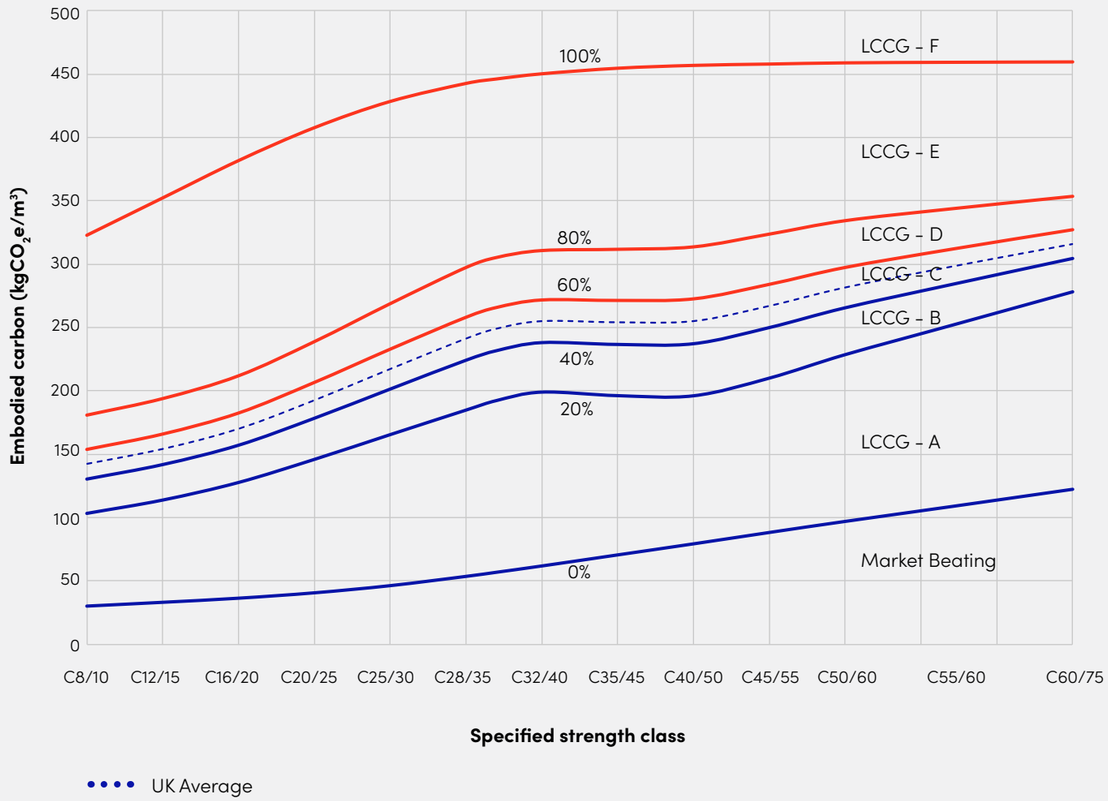


Table 1: The LCCG Market Benchmark Ratings.

Embodied carbon fraction of the market	LCCG Market Benchmark Rating for the 2023 update	LCCG Market Benchmark Rating for the 2024 & subsequent updates
Lower carbon than data submitted to the LCCG	Market Beating	Market Beating
> 0 to 20%	LCCG - A	LCCG - 1
> 20% to 40%	LCCG -B	LCCG - 2
> 40% to 60%	LCCG -C	LCCG - 3
> 60% to 80%	LCCG -D	LCCG - 4
> 80% to 100%	LCCG -E	LCCG - 5
Higher carbon than data submitted to the LCCG	LCCG - F	Outlier mixes

Table 1 summarises the LCCG Market Benchmark ratings. To avoid confusion with the Universal Classification and Global Banding ratings, the 2024 update and subsequent updates will use numerical ratings instead of alphabetical ratings. Each rating can be further refined by four subdivisions (1, 2, 3, 4) which each represent a nominal 5% fractile of concrete recently available in the market. For example, LCCG rating 1.1 represents concrete in the lowest 5% of the market while rating 5.4 represents concrete in the highest 5% of the market.

* The benchmark ratings are based on embodied carbon of normal weight concrete mixes used recently in the UK

* Performance requirements may make it impractical to achieve some ratings for a particular application

* Achieving a rating of A through use of a high proportion of GGBS may not be an effective method of reducing global GHG emissions

* Opportunities for reducing the carbon rating may typically be achieved by adjusting: specified strength class; type and % of SCM; requirements for early strength gain; consistence; environment (e.g. by use of protective barrier layers); minimum cement content (kg/m3); w/c ratio; use of admixtures; type, and grading of aggregates; age at which the specified strength must be achieved; sources of constituents

To avoid confusion between rating systems, references to the LCCG Market Benchmark should explicitly specify the reference as the LCCG Market Benchmark and indicate the version referenced. For example: LCCG - C.2 [2023] or LCCG - 3.2 [2024]. The Market Benchmark is based principally on the embodied carbon of concrete produced in the UK by MPA members. Additional data is received from industry, which includes data relating to concrete not produced by MPA members.

The method of generating the Market Benchmark is described in more detail in the annual updates.

The Market Benchmark is based principally on the embodied carbon of concrete produced in the UK by MPA members.

Figure 2: The Universal Classification for embodied carbon of concrete.

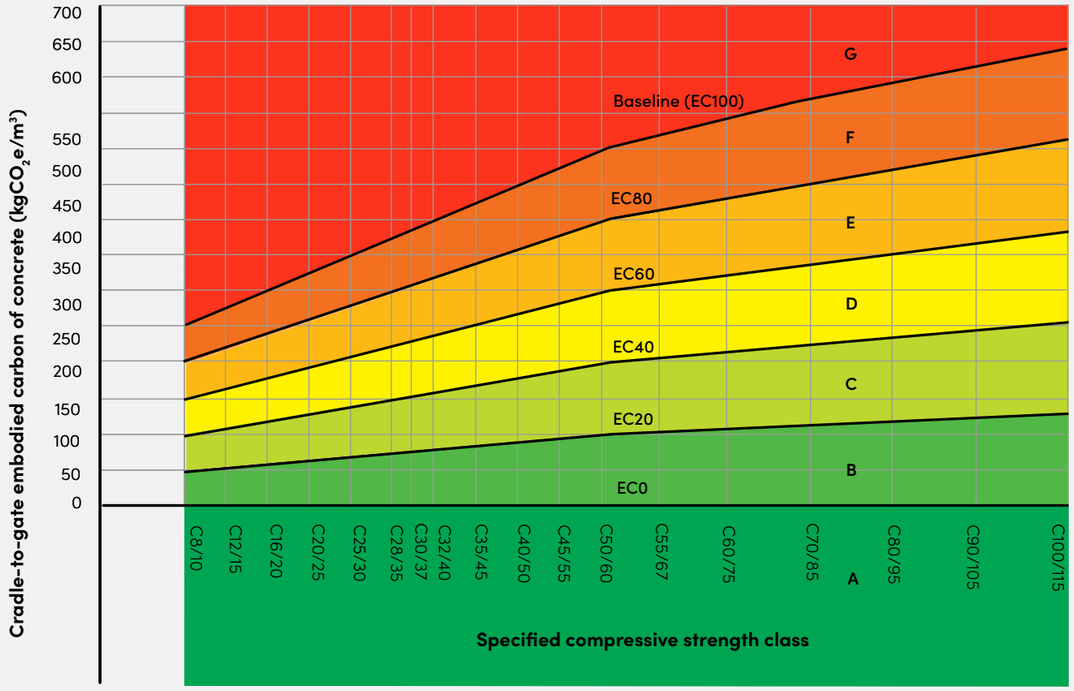
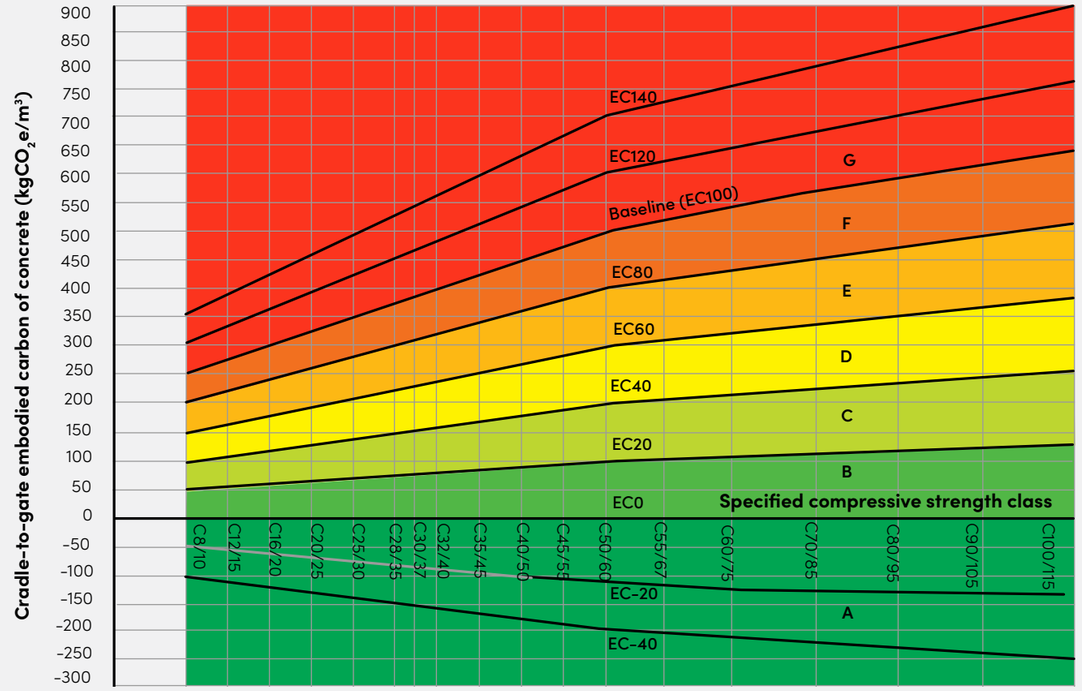


Figure 3: The Universal Classification for embodied carbon of concrete with extended bands to account for more carbon-intensive and carbon-negative concrete.



2.2 Universal Classification

The Universal Classification for embodied carbon of concrete assesses embodied carbon of concrete relative to ratings that are unchanged over time or between markets. The Universal Classification is therefore better suited than the dynamic Market Benchmark for defining how the average embodied carbon of concrete should change over time, for example to define a pathway to net zero and setting long-term targets. The Universal Classification is of particular relevance for market transformation policies, standardised guidance documents, and for formulating long-term embodied carbon targets for multi-year construction projects.

Arup was appointed by Innovate UK (UKRI) to develop a classification system with fixed embodied carbon rating bands for concrete, labelled A–G, as shown in **Figure 2.** The rating bands are set between embodied carbon (EC) reference curves at 0, 20, 40, 60, 80 and 100% of the baseline. The EC100 baseline was generated by Arup based on the embodied carbon of notional mixes for normal weight concrete made in the UK and elsewhere using CEM I (Portland cement) with no use of SCMs. Points on the EC reference curves are defined for each of the concrete strength classes included within Eurocode 2 [7].

The Universal Classification is accompanied by user notes [3] which define terms such as “baseline” and ”EC rating”.

The mean embodied carbon of concrete used in the UK in 2022 approximately corresponds to the Universal Classification reference curve EC60 (see **figures 5**&**6**).

In the Universal Classification as originally developed, the embodied carbon reference curves range from EC100 to EC0. This reflects concrete availability in the current and near future market. However, within the Universal Classification the EC reference curves can be extended upwards or downwards depending on regional and market needs.

For example, to enable use in regions where concrete is more carbon intensive than the baseline (EC100), the EC reference curves can be extended upwards, as EC120, EC140, etc. Similarly, as technologies around concrete decarbonisation mature, carbon negative concretes might emerge, the EC reference curves can be extended downwards into the carbon negative “A” rating band as EC-20, EC-40 etc. An extended version of the Universal Classification for embodied carbon of concrete is shown in **Figure 3.**

2.3 The draft IDDI/GCCA Global Banding

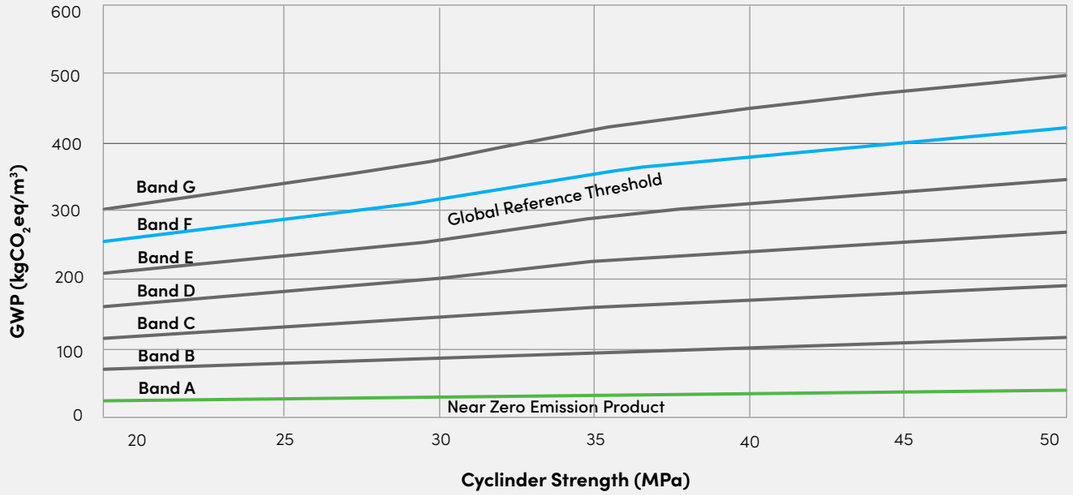
In January 2024 the Global Cement and Concrete Association (GCCA) published a white paper "Definitions for low carbon and near zero emissions concrete for IDDI Low Carbon Product Procurement Initiative, Part 1 Methodology". This was followed in March 2024 by Part 2, "Numerical Definitions".

The white paper proposes a Global Banding for Concrete that is somewhat similar to the Universal Classification discussed above but less developed.

In the IDDI/GCCA proposal the top of Band E defines "global threshold value" concrete. The top of Band E is calculated assuming:

- Use of CEM I cement.
- The cement carbon footprint is taken as the mean minus one standard deviation of the carbon footprint of CEM I production in 2020 in the principal concrete producing countries.
- The cement content is the least weight of cement required to meet each strength class.
- The carbon footprint of all other constituents, transport, and manufacturing processes are the 2020 average values in the country where the concrete is produced.

Figure 4: Draft GCCA Global Banding, before national normalisation.



In the IDDI / GCCA proposal the bottom of Band A defines a "near zero emission" concrete. The bottom of Band A is calculated assuming:

- The clinker content of the cement is reduced to 52%.
- The cement carbon footprint is taken as the "IEA near zero cement value". This IEA value assumes the use of CCS to permanently sequester carbon dioxide generated during manufacture of the clinker. However, it is not restricted to this technology to achieve this level of emissions.
- The cement weight is reduced by around 14% relative to the weight used to calculate the carbon footprint for the top of band E.
- All other constituents, transport, and manufacturing processes have a carbon footprint of zero.

Following the GCCA having determined values for the vertical axis, there will be a process of normalisation to determine national values for those countries where EPDs are determined to different PCRs, or where there are other variations in methods of calculating embodied carbon. This would be valid for countries which decide to use GCCA's banding over other systems.

Once the GWP values have been determined, the IDDI/GCCA Global Banding may replace the Universal Classification if providing a more coherent approach to classifying embodied carbon of concrete.

The LCCG welcomes the IDDI/GCCA Global Banding proposal. We believe that the system would benefit by extension to accommodate the potential for carbon neutral and carbon negative concrete, similarly with the Universal Classification, should these prove to become viable for use at scale. Such an extension would be simple to implement.

As of now, GCCA's Global Banding is the least developed system amongst those discussed in this note. Significant time may be required to finalise the normalisation of national values.

3.0

Application of the classification systems

3.1 The current market assessed on Universal Classification or Global Banding

Recent market data can be overlaid on the Universal Classification or Global Banding rating systems.

Figures 5 and **6** overlay the data used to generate the 2023 update of the LCCG Market Benchmark on the Universal Classification. The figures demonstrate that the average embodied carbon of concrete used in the UK in 2022 broadly corresponds to the Universal Classification embodied carbon reference curve EC60.

The figures also illustrate the wide spread in the embodied carbon of concrete that is used to meet the varied requirements of concrete used across the UK. Note that it is not possible to immediately transform the market so that all concrete has embodied carbon levels close to the 2022 lower bound. It is highly likely that for the foreseeable future there will continue to be a large spread in the embodied carbon of concrete within each strength class.

Figure 5: The 2023 LCCG Market Benchmark overlaid on the Universal Classification (strength classes up to C60/75 only).

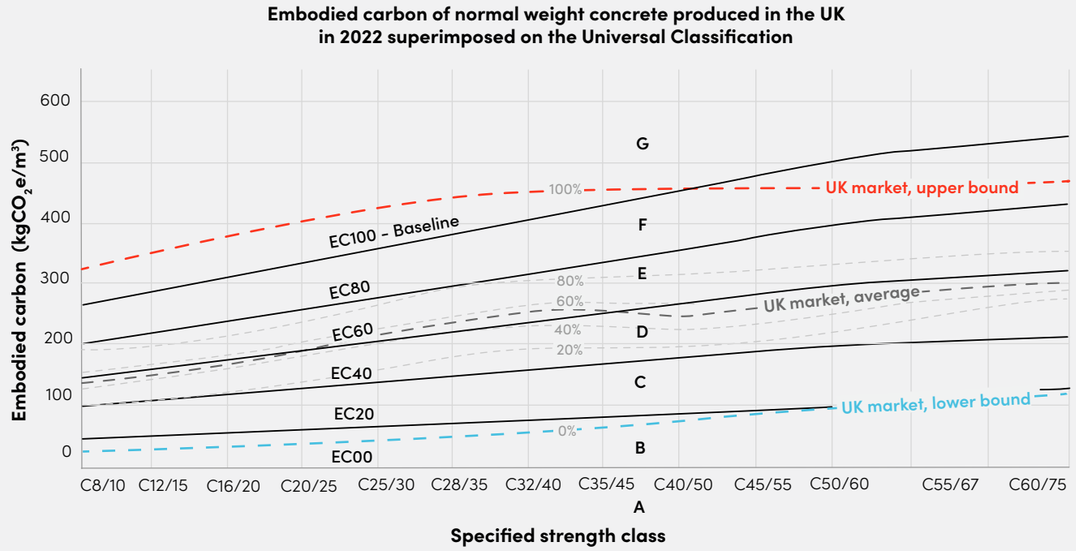
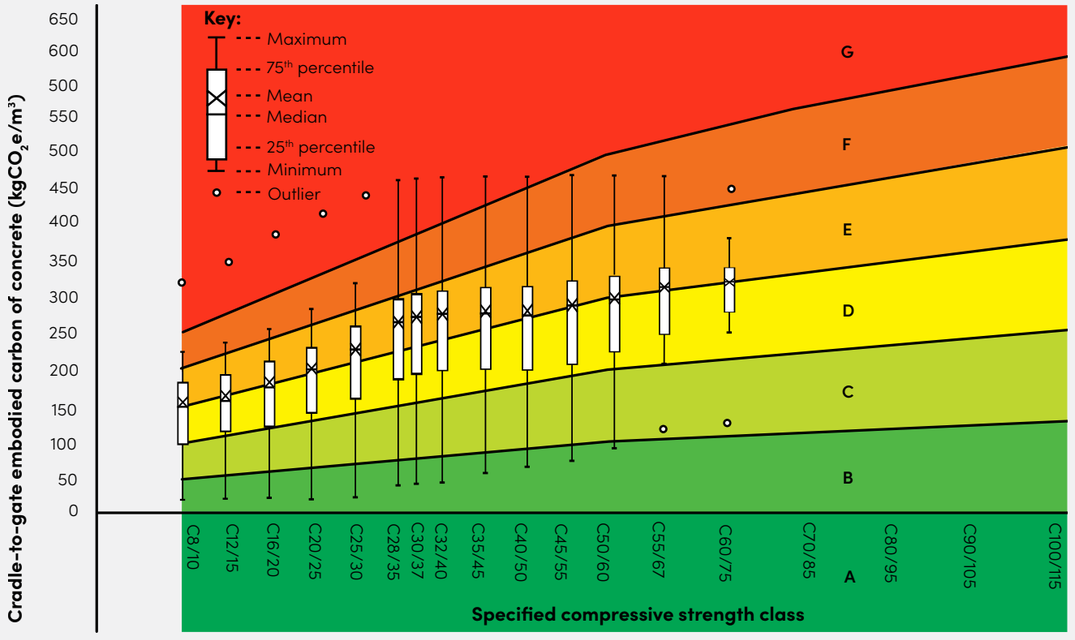


Figure 6: Box and whisker plot of data used to generate 2023 LCCG Market Benchmark overlaid on the Universal Classification (strength classes up to C60/75 only).



3.2 Definition of a pathway to net zero

Setting targets for the embodied carbon of concrete is critical for industry to plan and install the infrastructure required to deliver carbon reductions in line with these targets.

A pathway to net zero can be defined at the national level, for a particular market sector, by an individual client, or by a group of clients.

The **Universal Classification** or **Global Banding** systems should be used to define a pathway to net zero. The requirement for the average embodied carbon of concrete should be defined.

Table 2 and **Figure 7** illustrate how the Universal Classification might be used to set targets for the average embodied carbon of concrete to meet the Industrial Decarbonisation Strategy of the UK Government [8]. **Table 2** and **figure 7** are extracted from LCCG workstream 12 which assesses how the various methods for reducing the embodied carbon of new concrete may be used to meet a planned pathway to net zero.

Use of a pathway to define the average embodied carbon of concrete is compatible with the wide spread in embodied carbon within each strength class. This enables concrete with higher embodied carbon to continue to be used where performance requirements or construction constraints require it, while concrete with lower embodied carbon is used elsewhere to achieve the target average embodied carbon.

The approach provides scope for higher carbon "legacy" concrete to be used where a long history of successful use is required. Guidance will be required on which uses require concrete with a long history of successful use, and which uses are appropriate for concrete with a shorter track record.

Figure 7: A pathway to net zero based on the UK Industrial Decarbonisation Strategy [8] with allowance for the rate of growth in concrete production at 50% of the rate of GDP growth.

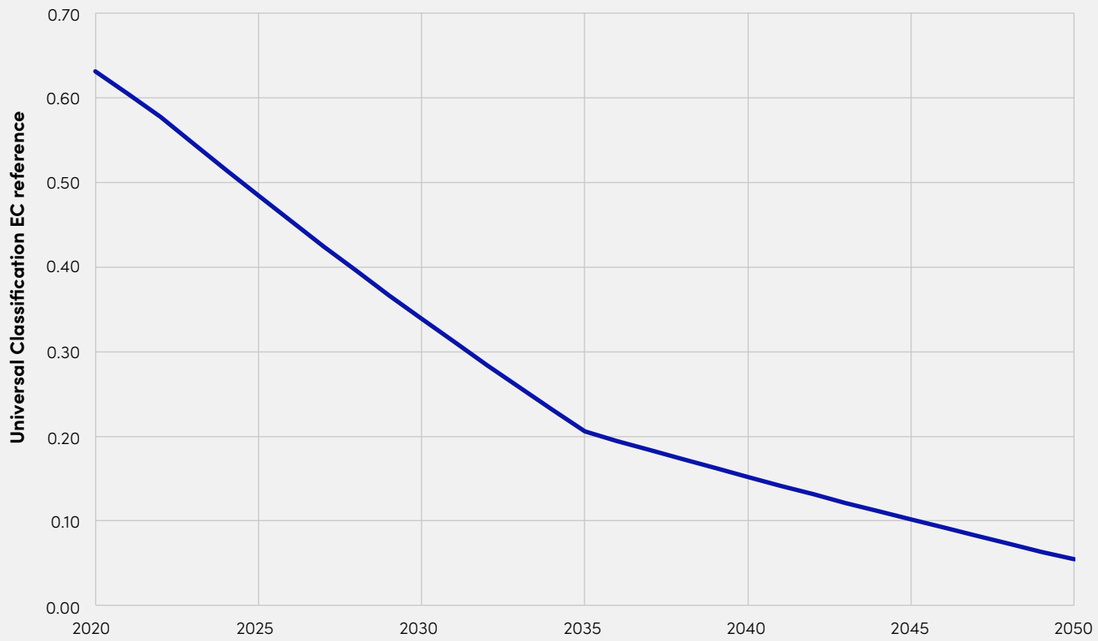


Table 2: Example: Setting the Universal Classification targets for the average embodied carbon of concrete used in the UK.

		2018	2025	2030	2035	2040	2045	2050
Projected GDP relative to 2018 (2018 prices) [9]		100%	101%	111%	122%	131%	140%	150%
Assumed rate of concrete production growth relative to GDP growth		Record data to 2022	50%	50%	50%	50%	50%	50%
Projected concrete production	Million m^3 /year	37.5	37.0	38.8	40.7	42.1	43.6	45.2
HMG Industrial Decarbonisation Strategy	GHG emissions	100%	73%	53%	34%	26%	18%	10%
Target embodied carbon of new concrete	$Mt.CO_2e$ /year	9.7	7.1	5.2	3.3	2.5	1.7	1.0
Target average embodied carbon of new concrete	$kgCO_2e/m^3$	258	191	133	81	60	40	21
Universal Classification for the average embodied carbon of new concrete	EC Reference Curve	0.66	0.48	0.34	0.21	0.15	0.10	0.05
	Rating	E	D	C	C	B	B	B

3.3 Achieving a pathway to net zero

At project level, clients and designers will usually specify an upper bound on the embodied carbon rating for concrete. The rating may be set using any of the Market Benchmark, Universal Classification, or Global Banding tools. In time, specification practice is expected to develop towards using the Global Banding ratings, with reference to Market Benchmark to confirm availability of concrete of the specified rating.

To meet varying performance requirements and make efficient use of the available "carbon budget", the specified upper bound will usually vary between uses (e.g. piles typically have lower embodied carbon than suspended slabs). Further work is required to develop guidance for the upper limit on the embodied carbon ratings for different uses (and regions) to ensure that the average embodied carbon of all concrete used across a portfolio, or nation, will be in accordance with the selected pathway to net zero.

Further work is required to develop guidance for the upper limit on the embodied carbon ratings for different uses (and regions) to ensure that the average embodied carbon of all concrete used across a portfolio, or nation, will be in accordance with the selected pathway to net zero.

References

1. Low Carbon Concrete Routemap, ICE & GCB, April 2022
2. 2023 update to the Market Benchmark, prepared by the LCCG and published by the MPA, September 2023
3. Embodied Carbon Classification Scheme for Concrete, Arup and Innovate UK, September 2023
4. White paper: Definitions for low carbon and near zero emissions concrete for IDDI Low Carbon Product Procurement Initiative, Part 1 Methodology, GCCA, January 2024
5. Arnold et al., The efficient use of GGBS in reducing global emissions, The Institution of Structural Engineers, September 2023
6. BS EN 15804:2012+A2:2019 Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products.
7. BS EN 1992-1-1:2004+A1:2014 Eurocode 2: Design of concrete structures - General rules and rules for buildings
8. Industrial Decarbonisation Strategy CP339, UK Government, March 2021
9. Global Trade Outlook, UK Government, February 2023

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