CO_2 2.Low carbon

Seeing the bigger picture – industry emissions, your project and the performance gap

Ian Poole, Marika Gabbianelli, Will Arnold and John Orr encourage engineers aspiring to low-carbon outcomes to consider how their design decisions impact wider industry carbon emissions, ensuring that the benefits for one project are not detrimental to others.

Introduction

The construction industry's response to the climate emergency is moving at an unprecedented pace, with engineers increasingly embracing carbon calculations, and a growing number of projects aspiring to net-zero goals and low-carbon solutions.

The manner in which we pursue these solutions is important. Decisions that achieve a low-carbon project may not always yield an absolute reduction in emissions across the construction industry, but it is the latter that is our collective end goal. The Intergovernmental Panel on Climate Change (IPCC) has set out a carbon budget **(Figure 1)**, which we must not exceed if we are to avoid the most destructive consequences of climate change.

Achieving this requires engineers to have an appreciation of how their project decisions impact industry emissions.

This article outlines how to:

- →|use materials responsibly to reduce industry emissions through appropriate application of carbon factors and demand reduction
- →|increase the likelihood of as-designed carbon emissions being similar to as-constructed carbon emissions, avoiding a performance gap
- →|minimise the unintended consequences of over-specifying low-carbon alternatives to standard construction materials.

Material options

High-carbon, lower-carbon and zero-carbon supply of materials

This article will focus solely on steel and concrete, as these structural materials represent the majority of those used in UK construction, and therefore cause the most emissions.

For simplicity, we will categorise versions of these materials as either high-carbon, lower-carbon alternatives, or zero-carbon **(Table 1)**. The reality is clearly less distinct than this, but simplifying the situation helps us to understand how our reliance on each type of material should change over time.

Using these three categories, **Figure 2** demonstrates one way that the use of these materials may change over time as our industry

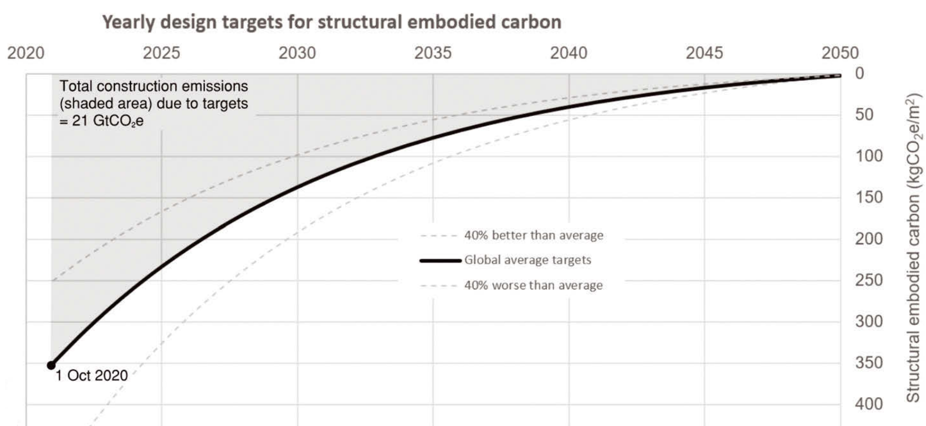


FIGURE 1: IPCC carbon budget as apportioned for building structures[1]

TABLE 1: Carbon category assumptions for steel and concrete

Material supply carbon category	Definition	Examples
High-carbon	→|The primary way in which the majority of construction materials are currently supplied →|Manufactured using fossil fuel energy sources	→|**Primary steel**[2] – blast furnace-basic oxygen furnace (BF-BOF) steel →|Portland cement
Lower-carbon alternatives*	→|Short-term helpers enabling reduced carbon emissions →|Often by-products of other processes; hence, material supply is limited	→|**Secondary steel**[2] – recycled electric-arc furnace steel →|Cement blend with high replacement of (current) **supplementary cementing materials:** ground granulated blast-furnace slag, fly ash
Zero-carbon	→|Materials manufactured using renewable energy or taking advantage of carbon-capture technologies →|This is the end goal, requiring significant advances in technology and cost investment	→|**Primary steel** produced using 100% renewable power and carbon capture →|**Portland cement** using decarbonised heat and carbon capture →|Novel material alternatives and production routes

* As the article focuses on steel and concrete, this category refers to current lower-carbon material alternatives to BF-BOF steel and Portland cement. It does not refer to novel/natural low-carbon materials

moves towards net zero, with use of high-carbon materials slowly reducing, and resource-constrained lower-carbon alternatives starting to be replaced by zero-carbon supply (starting at Point B).

Looking further into the future, as the UK grid decarbonises and zero-carbon materials become cheaper and more common, the use of high-carbon materials and low-carbon alternatives will shrink to zero (Point D). In principle, reaching this point will be enabled and accelerated through the reduction of virgin material use due to an increasingly circular economy.

Figure 3 looks at the carbon emissions associated with the material use and supply outlined in **Fig. 2**, showing that eventually this trajectory would result in zero emissions.

The use of current lower-carbon alternatives such as secondary steel (recycled electric-arc furnace) and secondary cementitious materials (SCMs) may be seen as 'easy wins' to drive reductions in an individual project's carbon emissions – but their supply is finite and locked into existing supply chains. These materials are already used in full by the supply chain, and so high-carbon materials currently supply the remaining demand.

Fig. 2 is simplistic in assuming that the supply of lower-carbon alternatives cannot expand (which we know isn't entirely true, e.g. the discovery of a new, widely available cement replacement would increase supply), but the same fact still emerges – we cannot depend on finite supplies of existing lower-carbon alternatives to reduce industry emissions.

In the future, as decarbonisation technologies develop and emerge, zero-carbon production methods will enable carbon-intensive production to be phased out. However, relative to the timescale of an average building project, these changes will occur slowly; hence, it is critical for designers to make decisions based on current, available supplies.

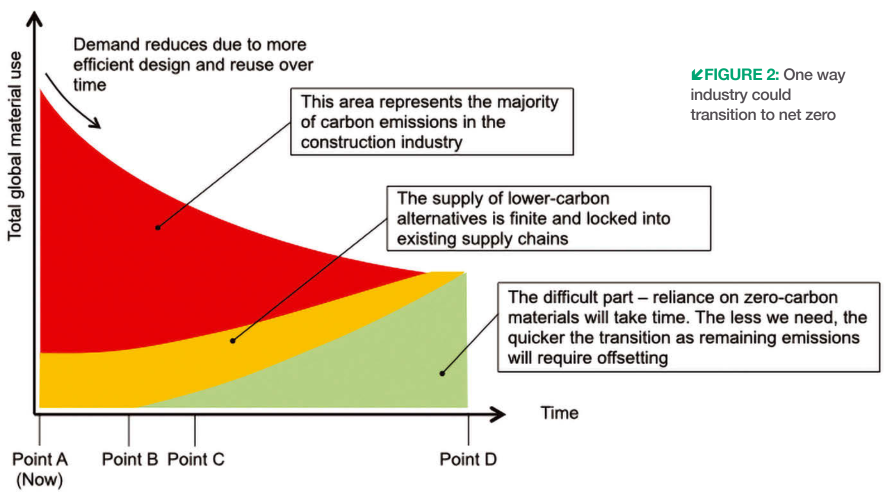


FIGURE 2: One way industry could transition to net zero

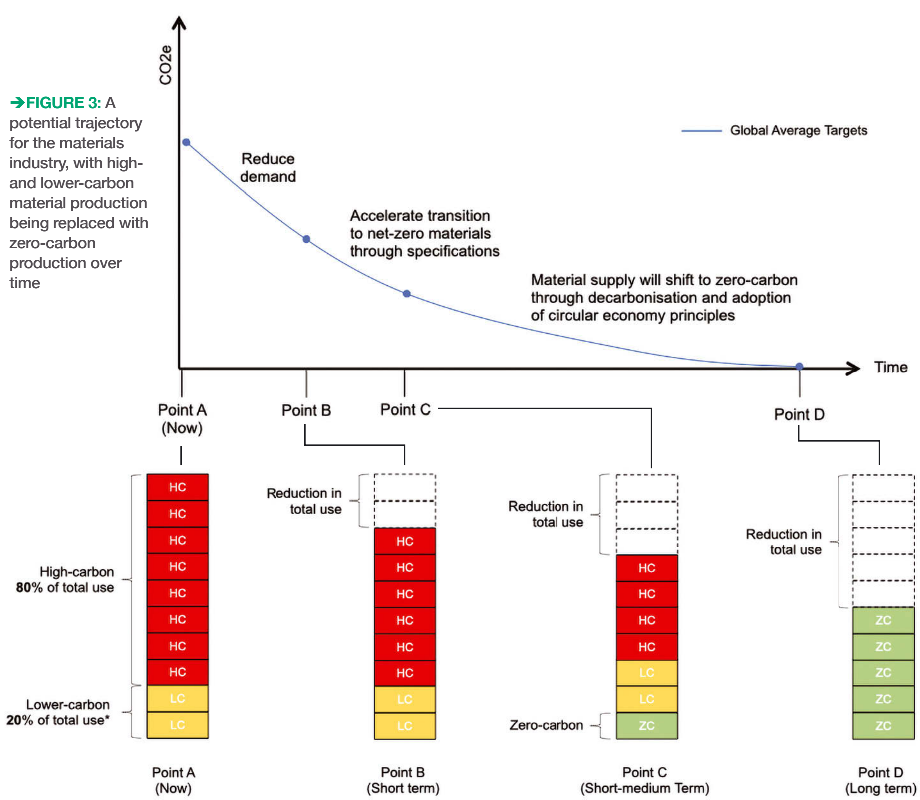


FIGURE 3: A potential trajectory for the materials industry, with high- and lower-carbon material production being replaced with zero-carbon production over time

* Global quantity of fly ash and GGBS limited to 15–25% of cement consumption and values are unlikely to increase in the future, or may even decrease as coal-fired power and primary steel production are phased out

The risk in assuming lower-carbon alternatives – the 'performance gap'

Following the fact that lower-carbon alternatives for primary steel and Portland cement are limited[3,4], we see that using 'lower-bound' carbon factors representing unrealistic contributions of lower-carbon production (e.g. high-percentage cement replacement or secondary steel) throughout design can lead to a performance gap, whereby predicted emissions are considerably lower than the actual as-built emissions (similar to the often-discussed performance gap for operational energy use[5]). These assumptions have real-world implications, such as steering towards wrong decision making, missed carbon targets, and increased offsetting costs.

The risk in specifying lower-carbon alternatives

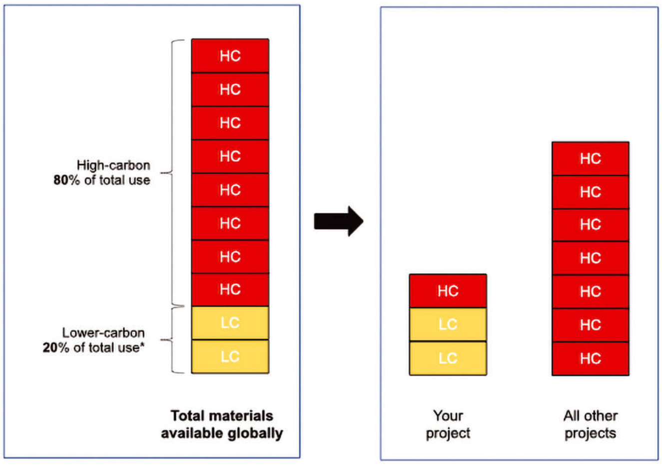
A common response to the previous point is that you can ensure that low-carbon alternatives are delivered to site by writing them into the specification. While this may be true in some instances, the limited supply of low-carbon alternatives means that specifying something lower-carbon than what is typically available will not reduce industry emissions. Rather, other projects will be left with a higher proportion of high-carbon materials, and overall industry emissions will remain the same.

Specifying lower-carbon steel or concrete on one project simply means that it cannot be used elsewhere, as there is not enough supply to meet demand **(Figure 4)**.

The overspecification of lower-carbon alternatives may even lead to increased overall industry transport emissions. For example, in the UK, ground granulated blast-furnace slag (GGBS) is often sourced from abroad (e.g. Turkey and China), and the majority of secondary steel sections are sourced from Europe and further afield[4].

Needlessly transporting materials around the world to help individual projects or countries realise low-carbon ambitions doesn't help the global problem.

It is also important to highlight that certain materials have benefits beyond carbon, and so their use should be concentrated where these can be maximised. In large infrastructure projects, GGBS as an SCM is a valuable commodity, with its durability benefits enabling



←FIGURE 4: Procuring higher than average proportions of lower carbon supply has no overall benefit to the industry

* Global quantity of fly ash and GGBS limited to 15–25% of cement consumption and values are unlikely to increase in the future[3,6]

reduced reinforcement requirements (to control cracks), and further reducing emissions. Therefore, to limit the global warming potential (GWP) of the concrete industry, GGBS use should be prioritised for projects where it is able to offer significant performance benefits.

The added benefits of using less material

Reducing the total quantity of materials required is critical in phasing out high-carbon production and achieving net zero in the timeframe written into UK law. The difference between Points A and B in **Fig. 3** highlights how reducing overall demand would lead to an increase in share for lower-carbon materials, which in turn would reduce average carbon factors across the industry.

Further, Point C emphasises that an overall reduction in demand will facilitate and expedite the future transition to zero-carbon production. Initially, zero-carbon materials are likely to be expensive and difficult to produce, so the fewer we need the better.

Things to do during design

Use less stuff

It is critical to develop an appreciation of how individual decisions affect industry emissions; to understand that there is little to be gained from the overspecification of current lower-carbon alternatives to reduce one project's emissions. This is why, in the carbon hierarchy principles, using less material is always prioritised. A significant library of resources is available on the IStructE climate emergency webpage (www.istructe.org/resources/climate-emergency/) to enable all members to use less in their designs.

Mind the performance gap – use consumption-average carbon factors

When using carbon calculations to inform design decisions – a process that all engineers should now be following[8] – it is recommended that national consumption-average carbon factors are used to define which structural solution will have the least damaging carbon impact. If time allows, it can also be beneficial to consider what would change if the materials delivered to site were nearer to the upper and lower end of the range of carbon factors for the material, to sense-check any decisions made.

The Structural Carbon Tool[9] enables this, and the next edition of *How to calculate embodied carbon*[10] will highlight suggested carbon factors based on consumption-average figures, as well as setting out a range for the most common materials.

This approach ensures that design-stage carbon calculations have the highest chance of being representative of what is built, and that decisions made across the industry will collectively leave us in a better place once the net positives and negatives across all projects are accounted for.

Specifying materials well

We can have a significant influence on the market and nudge the industry towards a faster decarbonisation through our specification and procurement process. Once the use of materials on our projects has been minimised as far as reasonably possible, other guidance notes[2,11–13] can be followed to help find additional carbon savings in the final specification, and ensure suppliers have committed to sustainable sourcing schemes[14].

Specifying materials to drive innovation

Further, to enable change to be accelerated, all specifications should shift their focus beyond simply resource-constrained lower-carbon alternatives, to supporting suppliers who have defined science-based emission-reduction pathways (e.g. approved by the SBTi[15]) aligned with industry decarbonation needs.

Engaging with suppliers, such as those who have committed to initiatives like SteelZero[16] and Race to Zero[17], and encouraging innovation and development of additional low-carbon and zero-carbon material supply will have a longer-lasting impact than would be gained by simply asking them to use considerable amounts of our current, limited lower-carbon alternatives.

Measure and record

To continue industry learning and development, it is important to ensure contractors are recording and sharing final as-constructed carbon data, and that environmental product declarations are provided for all materials and products used on site (this should be a requirement in the specification).

Measuring and recording the actual emissions is vital for future benchmarking and policy setting, as well as enabling us to compare these figures with those estimated in design to understand the performance gap. This is aligned with the wider industry need for accurate as-built records – the 'Golden Thread' of information set out in the Hackitt Report[18].

Summary

The fact engineers are now pursuing low-carbon solutions on projects is both encouraging and imperative for the sustainable future of our habitat. However, we must take caution in single-minded approaches that prioritise an individual project over the wider industry benefit.

Using consumption-average carbon factors for our principal materials gives the highest chance of estimating site emissions accurately and making the most appropriate decisions at early stages of design. While using less material is still the priority, knowing what to use less of and how to help decarbonise the material supply are necessary steps to having the most positive impact.

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