

Route maps to UK net zero: construction materials governance, at a glance

Pete Gates, Arthur Coates, Eva Gaal and Kaloyana Kostova – all members of the IStructE Structural Futures Committee – examine the carbon-reduction route maps of the UK steel, concrete and timber industries, considering the role structural engineers can play to reduce an apparent gap between the net-zero target and the speed of decarbonisation actually envisaged.

Target 2050

It is legislation within the UK that net-zero carbon must be achieved by 2050¹. As structural engineers, we contribute to one of the most carbon-intensive industries in the UK and therefore have a significant challenge to fulfil our obligation in achieving the 2050 target.

We know from analysis of precedent projects that structures can account for up to two-thirds of the total embodied carbon of a building², emitting a total 33Mt of carbon emissions annually across the UK in their construction³.

Although the scale of the challenge is vast, the primary material industry bodies in the UK have published route maps to achieve net zero, essentially summarising how they plan for the ‘embodied carbon factors’ (the carbon intensity of producing their materials) to reach zero. (Equation 1).

This article provides an overview, analysis and comparison of the various route maps towards net zero of the UK’s main material industries. The key assumptions for the route maps are highlighted. Criteria where external influences are of critical importance to the decarbonisation of the construction industry are also highlighted. Through this analysis, it is evident that the manufacturers of materials are predicting that they will not decarbonise at a pace aligned with a 1.5°C future. As such, structural engineers need to find additional routes to reduce carbon in their designs, namely through tackling the other half of Equation 1 and reducing the quantity of material used.

$$\text{Embodied carbon} = (\text{quantity of material}) \times (\text{carbon intensity factor}) \quad (1)$$

While UK law dictates that we must reach net zero by 2050, it also includes

several shorter-term targets, as speed of decarbonisation (and thus total emissions) is as important as the end goal of ‘net zero’. Figure 1 shows an Intergovernmental Panel on Climate Change (IPCC) decarbonisation curve that would limit carbon emissions to levels aligned with a 1.5°C future⁴. In this figure, the vertical axis is equivalent to a rate of carbon emission, so it is the area below the curve which is therefore equivalent to the total volume of emissions released into the atmosphere. This is why the shape of the curve is significant, and why the target for 2030 is just as important as 2050. If a linear route to net zero was achieved by 2050, this would still mean too much carbon would be released to limit climate change to the target 1.5°C.

The IStructE proposed the Structural Carbon Rating Scheme (SCORS)⁵ as a response to the IPCC curve in Figure 1, to best capture the targeted decarbonisation required by the construction of structures up to 2050.

A response from materials governance organisations

Since targets for carbon reduction have been established and agreed, ‘route maps to net zero’ are commonplace. Practically every large company in the construction industry has one. However, there is great variation in these plans and how comprehensive they are. Naturally, they look very different depending on the role of the relevant party: contractor, consultant or material supplier, for instance.

As practitioners and specifiers, it is extremely important to understand the implications and impact of using the principal construction materials: steel, concrete and timber.

This article is intended to serve as an ‘at a glance’ guide to understand the task ahead, the approaches proposed from a material supplier’s perspective, and ultimately how engineers must adapt to the challenges that net-zero-carbon legislation brings.

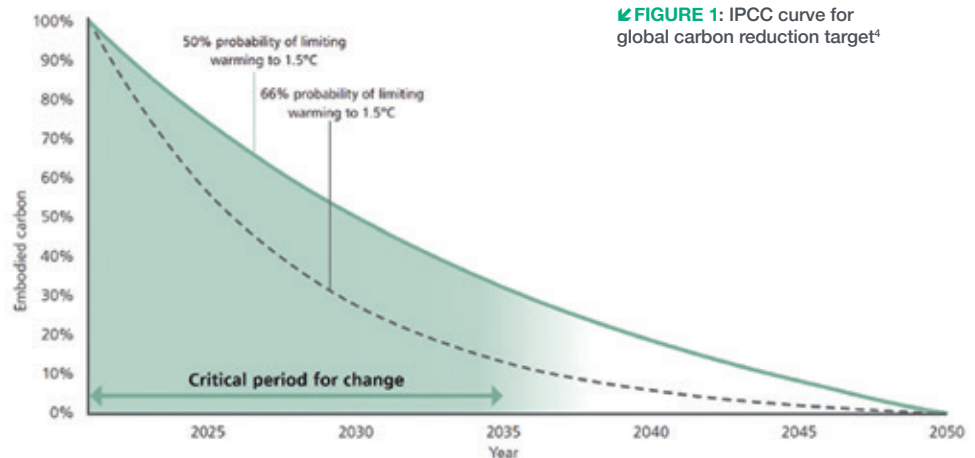


FIGURE 1: IPCC curve for global carbon reduction target⁴

Route map summaries

The following sections examine the three principal construction materials in turn.

Table 1 provides a brief of overview.

Steel

While the British Constructional Steelwork Association (BCSA) roadmap⁶ emphasises the need to decarbonise primary steelmaking (i.e. mostly from iron ore, with only a small amount of scrap), the UK appears instead to be prioritising the use of electric arc furnaces (EAF) to reduce its overall carbon emissions, by increasing the recycling of UK-generated scrap steel from the current figure of 30% to as close to 100% as possible.

If the UK increases its EAF capacity, this would simply reduce other countries' ability to use scrap and EAF capability. Given that 85% of scrap steel is already recycled (and the maximum will be well below 100% for practical and economic reasons), moving the UK towards increased recycling would not result in a reduction of global carbon emissions, and more virgin steel would need to be produced elsewhere to meet global demand. As industry bodies predict, around half of global steel consumed in 2040 will be virgin material⁶. A potentially more accurate way of tracking the decarbonisation of steel production is through the Responsible Steel Decarbonisation Levels⁷, which set embodied carbon targets depending on the level of scrap input.

To achieve the full 100% reduction of carbon emissions as targeted, the roadmap places a reliance on future technology, notably through hydrogen injection and direct reduction methods, as well as carbon capture and storage (CCS), which requires expensive and costly upgrades of UK infrastructure. Estimates highlight a need for over £20bn in investment in CCS technology over the next 20 years; however, only £1bn has been committed so far by the UK government by 2030⁶.

Importantly for engineers, 30% of the reduction is assumed to come from material efficiency and circularity. This is achievable by enhancing design utilisations, which is possible right now, or reusing existing steelwork. The reuse of existing steelwork is currently a prevalent topic of discussion⁸ but requires a substantial change in the 'norms' of how structure is procured, designed and insured.

Concrete

In the MPA UK Concrete route map⁹, the full 100% reduction of carbon emissions is targeted by 2050, though notably no prediction is given for 2030, where the IPCC target is 50%⁴. While no reliance



30% OF THE REDUCTION IS ASSUMED TO COME FROM MATERIAL EFFICIENCY AND CIRCULARITY

on offsetting or offshoring is articulated by the roadmap, a very large reliance is placed on CCS (to the order of 60%), and decarbonisation of the energy grid and transport networks⁹.

For the 12% reduction proposed to come from use of low-carbon cements, no detail is given. The Green Construction Board's Low Carbon Concrete Group (LCCG)¹⁰ does give more detail, however, on where this might come from.

Enabling the specification of low-carbon concrete by introducing a performance-based code of practice, BSI Flex 350 v2.0:2024-09, developed with the intention to improve from PAS 8820:2016 and to increase the uptake of low-carbon concrete¹¹. This is because BSI Flex is intended for emerging areas, where good practice evolves through iterations, while PAS is more applicable to widely accepted new concepts, where minimal change is expected.

Reducing the reliance on declining resources, including ground granulated blast-furnace slag (GGBS) and pulverised fuel ash (PFA), by introducing new binders/ supplementary cementitious materials (SCMs). For example, calcined clays are already permitted in BS EN 197-5. Future activation of calcined waste products is also anticipated. Outside the UK, there has been more widespread adoption of SCMs formed from calcined clays. In France, there are already two large plants producing calcined clays, which provide a codified substitute to ordinary Portland cement¹².

Efficient use of GGBS and PFA in reducing global emissions. GGBS is already highly utilised and is not recommended to be used solely for CO₂ reduction, but where it is technically required as well, e.g. for sulphate resistance¹³. PFA is believed to have some spare 'capacity' in some countries, but is only really appropriate for use near coal power stations where it is made, even in the short term.

Carbonation of concrete is a natural mechanism of carbon capture occurring throughout the life cycle of concrete products. While enhancing carbonation is not an option, as carbonation is

associated with a deterioration of the material, it may form part of end-of-life strategies, e.g. crushed concrete for speeding carbonation and reuse. The MPA route map suggests carbonation could take emission intensity *beyond* net zero by -12%. While it is not clear what design life this -12% would be attributed to, it would not seem appropriate to consider when the objective is to limit the rate of emissions by 2050.

A further 44% reduction beyond net zero is claimed as possible too, attributed to the use of thermal mass in whole-life carbon savings⁹. However, this has been disputed by academics specialising in embodied carbon, stating that 'for housing and the majority of other buildings there is little evidence that using more concrete will reduce the operational energy, let alone the operational carbon, and considerable evidence that using concrete rather than, say, timber is likely to substantially increase the embodied carbon'¹⁴.

Timber

Timber needs around a 10th of the heat required to produce steel or concrete, and none of the equivalent chemical reactions, meaning that the upfront carbon emissions are much less significant for timber than for such manufactured materials. The emissions for non-engineered timber are mostly from drying and transporting it¹⁵. Engineered timber products have a higher embodied carbon, as they undergo additional processes, though this adds only a small proportion. At current emission intensities, board products carry about an extra 12% embodied carbon per unit volume, and engineered timber products, like cross-laminated timber (CLT) and glued laminated timber (glulam), only carry about 5% extra embodied carbon, compared with sawn softwood¹⁵.

The UK consumes 16.6M cubic metres of timber annually; however, only a third of this timber is produced in the UK. The remaining two-thirds comes mostly from Europe (although plywood is exclusively from the wider world, associated with a significant CO₂e/kg). Construction represents only 12% of UK consumption (or 45% of that which is UK produced)¹⁵.

The timber route map is perhaps slightly more realistic in the anticipated rate of decarbonisation of the transport network, compared with attributed reductions outlined in the steel and concrete route maps to net zero, seeking to reduce road transport emissions intensity by 25%. Processing and manufacturing are proposed to be reduced by 50% by 2030, and forestry



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Table 1. Material decarbonisation route maps at a glance

CATEGORY/CRITERIA	ROUTE MAP		
	STEEL	CONCRETE	TIMBER
	BSCA [7] unless otherwise ref.	MPA UK Concrete [9] unless otherwise ref.	TDUK [15] unless otherwise ref.
Current mass of carbon emitted annually within UK from material production through to use	12.0MT CO ₂ e (UK production) – 2.5% of UK emissions (UK consumption much higher)	7.3MT CO ₂ e (in 2018 in UK) – 1.5% of UK emissions	1.58MT CO ₂ e (UK production – excluding paper, cardboard, pulp, imported biomass) – 0.35% of UK emissions (2019 data)
Proportion of above figure associated with construction	~50%	100%	~45%
Mass of material produced annually in UK	7.2MT (in 2021)	22MT (in 2022)	~5.8M m ³ (in 2020) so ~2.9MT
Current proportion of material used in UK that is made in UK	48%	95%	~33%
Reduction in carbon proposed by 2050 (for UK consumed material u.n.o.)	100%	100%	For UK-produced timber 100% 'emissions intensity target' Aim for UK consumption, 100% is also targeted [TDUK carbon paper] but not explicitly presented in route map
Reduction in carbon proposed by 2030	30%	Not provided in MPA route map. The LCCG route map ¹⁰ does, however, suggest 30–40% would be possible	30%
Stated reliance on offset	0%	0%	0%
Stated reliance on offshoring to achieve noted reduction	0%	0%	0%
Stated reliance on CCS	25%	61%	0% outside of sector (though inherent carbon sequestration is considered in product)
Anticipated/planned change in tonnage (material use) in UK	32.5% reduction	0%	Increase is anticipated, but with uncertain percentage. New homes in timber frame will increase from 12–50%. This has a much smaller impact on overall increase in timber, however, because so much timber is already used in refurb. market [via discussion with TDUK]

emissions by 50% by 2040. Overall, it is intended to reduce the emissions intensity of the industry by 90% by 2050.

The remainder of the 100% net reduction is envisaged to be attained through offsetting by tree planting. The land-use change and forestry sector provides a way of offsetting emissions. As this 'offset' is within the timber industry, the figure is still shown as zero in **Table 1**; however, in terms of actual carbon intensity reduction by 2050, and the growing time required for trees, further clarification on how the offset is quantified is needed.

The UK is already relatively good at 'using all the tree', relative to other countries. The UK only has approx. 12–13% forest coverage (compared with 70% in Sweden, as somewhere the UK

imports from), so we can only use so much homegrown timber. In 2020, the UK was the second largest net importer of forest products. As two-thirds of UK-consumed timber is imported, the CO₂e of imported materials is critical. Reduction in CO₂e from this proportion (associated with imported timber) is targeted at approx. 70% by 2050 (inferred from a particular figure in the route map)¹⁵. This sounds feasible, given that imported timber (which is mostly from Scandinavian countries) is already lower carbon. Potentially even when making allowance for the crucial transport element¹⁶.

Carbon capture and storage

Referenced in all the materials route maps, CCS is clearly expected to

be key in the reduction in CO₂ from industrial processes. As the technology is in its infancy, the authors have examined the scale of CCS development in more depth.

In October 2024, government confirmed funding to launch the UK's first carbon capture sites in in Teesside and Merseyside, hoping to create thousands of jobs, attract £8bn of private investment, and accelerate the UK towards net zero in 2050¹⁷.

At present, the removal of CO₂ (2Gt CO₂/year, compared with the 40Gt CO₂/year emitted by humanity, and the 1,500Gt CO₂ since the industrial revolution⁴) happens almost entirely via afforestation, reforestation and management of existing forests. A tiny percentage (less than 0.1%) of CCS

Table 1 continued...

CATEGORY/CRITERIA	ROUTE MAP		
	STEEL	CONCRETE	TIMBER
	BSCA [7] unless otherwise ref.	MPA UK Concrete [9] unless otherwise ref.	TDUK [15] unless otherwise ref.
Carbon reduction planned, attributed to material production methods	28%	12%, from low-carbon cements	13–15%. Moving away from gas in kilning, CHPS instead. Plant on site (currently diesel) going to electric or large plant to hydrogen
Stated carbon reduction attributed to other industries decarbonising	6.5% (from national grid being decarbonised)	11% from national grid and transport being completely decarbonised and 16% from zero-carbon fuel being available (e.g. biomass)	50% from transport
Designer toolkit comments; how will specification and design need to change (pertinent points)?	Member utilisation and reuse to improve. 17.5% reduction in steel weights due to design efficiency. 15% reduction due to retaining steel <i>in situ</i> or reusing Easy wins for engineers now: S460 columns, section optimisation, testing, reuse more, both <i>in situ</i> and in circular market	BSI Flex 350 published recently is a testing specification for low-carbon cements. BS 8500 and EN 197, part 5 give designers more immediate practical guidance on specification	Specify OSB instead of ply; UK produced with used waste timber, lower carbon, and lower formaldehyde than ply
Reduction stated to have already occurred in industry	20% since 1990	53% since 1990	Not recorded in the past for the industry
What are the main areas the ambition detailed in the route maps rely on the government for?	Decarbonisation of the grid, decarbonising transport, hydrogen injection or direct reduction methods for steel production	Carbon-free electricity, carbon-free solid fuel and carbon-free transport; not anticipated to have financial incentive tax benefit to using more concrete. Clean grid and CCS technology advancement	Increase woodland cover from 13% to 17–19% by 2050. Relies a lot on decarbonisation of transport. e.g. 18t lorries running on hydrogen Warranty issue on reuse must be dealt with to meet targets for 2050 The UK government committed to increasing the use of timber in construction

is attributed to novel technologies. However, such technologies are being explored as a future alternative to using low-carbon material, further reducing and utilising CO₂¹⁸.

The primary novel CCS technologies that exist today involve direct separation, post-combustion or oxyfuel carbon capture. No carbon capture systems capture 100% of the CO₂ produced in place, but efficiencies of about 90% capture are possible¹⁹. Carbon capture technologies are currently energy intensive, and this energy must also come from a renewable source to avoid further emissions¹⁹.

Several technologies are being developed that use the concrete material for the 'storage' part of CCS. Such concrete-based CCS can be 'upfront', whereby CO₂ is injected in ordinary Portland cement (OPC) mixes

(or used as a curing agent in non-OPC), or considered 'long-term', such as CO₂ storage through carbonation of concrete, as discussed above.

Other capture technologies include strategies such as 'direct air capture', or 'geological sequestration' for permanent storage of CO₂ in deep underground rock formations. 'Injection wells' are used to inject CO₂ into deep rock formations.

Captured CO₂ can also be used as a feedstock to produce products such as low-carbon fuels, cement or plastics. The UK government is also invested in building 'carbon sequestration hubs'¹⁷.

In summary, there is a multitude of ways in which novel CCS technologies are trying to prevent carbon emissions to the atmosphere or draw down on existing levels of emissions. However, this amounts to less than 0.1% of

all carbon capture currently, so less than 0.005% of all global emissions. While novel CCS technologies are accelerating, they have a long way to go before they start to significantly impact carbon emission levels.

Will we get a 'clean grid'?

The materials governance route maps presented above also each rely on decarbonisation of the energy network. The National Energy System Operator Limited (NESO), formerly the 'National Grid', has also published a route map to net zero by 2050²⁰.

Published after the other materials route maps presented, the NESO route map gives details on several differing 'future energy scenarios', though generally notes that a 'large-scale deployment of CCS is needed within the next 10 years'. A 'counterfactual' scenario is pragmatically

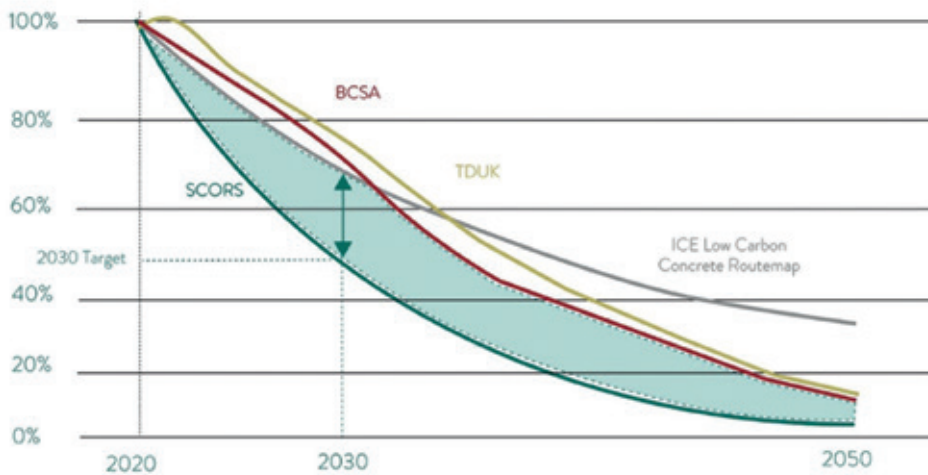


FIGURE 2: Indicative overview of various materials’ net-zero trajectories if CCS is ignored, plotted against SCORS industry scheme

included in the set, to illustrate a scenario where actions and timings do not achieve net zero by 2050. This sets out a trajectory if critical deadlines are missed.

To develop the infrastructure needed for the massive increase in electrical generation and distribution, a recent update report by NESO states: ‘Network expansion must proceed at more than four times the rate of the last decade, delivering twice as much in half the time.’²¹

Conclusions

The route maps examined in this article all seek to achieve net zero by 2050. The 2030 target for 50% reduction (the significance of which is discussed in the opening section) is not demonstrated as being met by the steel and timber route maps. The concrete route map does not comment on a 2030 target, but we cannot see how this could be met, given that there is a 63% reliance on CCUS, none of which is likely to be ready by 2030.

Reassuringly, there is no reliance

cited in any maps for offshoring or offset by another sector or industry. While concrete is practically all within UK control, steel and timber have the challenge of embodied carbon governance where a significant proportion of materials are imported to the UK.

Reliance on developing technologies enabling CCUS for steel and concrete is, however, of concern. Given the current state of research in low-carbon cements and cement-replacement technologies, compared with the level of knowledge of CCUS, one might ask whether there is more scope to progress with low-carbon cements or low-carbon steel technologies now.

Decarbonisation of the grid and of transport networks is of relevance across the board. For timber, this affects around half of all emissions, so is critical. Steel has a notably smaller reduction attributed, with performance towards targets within these industries, though it is not completely clear exactly how the

BCSA has defined the scope of activities within the ‘material production’.

There is an observation that the construction industry is delegating much responsibility, or ‘passing the buck’, to the power-generation industry, the transport and fuel-production industries, and to those developing both novel CCS technologies and green hydrogen. This is not necessarily a criticism, and it is valuable to understand the impact that those sectors have on carbon emissions associated with construction. It is, however, very sobering to quantify the reductions envisaged that are associated with improved production technologies, especially where the technology already exists today.

There are numerous criteria in all route maps relying on government action. Partly where relating to power and transport sectors, but also to permit new manufacturing infrastructure for steel and concrete and to increase woodland cover for timber targets. Testing and warrantee issues for steel and timber must both be resolved without further delay to meet targets for 2050.

What can designers do?

Clearly, there is a significant gap that engineers are expected to fill between material roadmaps and science-based decarbonisation targets in buildings, best captured by the 1.5° emissions curves, such as that replicated in the SCORS proposal (Figure 2).

Ultimately, engineers will need to ‘use less stuff’ and they can achieve a good proportion of reduction immediately. ‘Easy wins’ are highlighted as by the IStructE within its ‘Hierarchy for net-zero design’²², e.g. more reuse, shorter spans, eliminating transfer structures, avoiding basements, prioritising low-carbon materials, designing to 100% utilisation and minimising waste through construction. However, there are more fundamental changes needed, as it’s clear that carbon intensity factors will never reach absolute zero.

The focus on reducing the ‘quantity of material’ part of the equation should be by increasing reuse. This will require a broadening of our understanding of retrofitting existing structures and justification of their long-term durability for changes in use and environmental conditions. One of these routes could be through developing smarter surveys and performance-based techniques to severely reduce (or even eliminate) new material usage²³. It is well within the capability of an engineer to test or even challenge their client’s brief if it goes against reuse.

Maximising the utilisation of existing material will also require a better

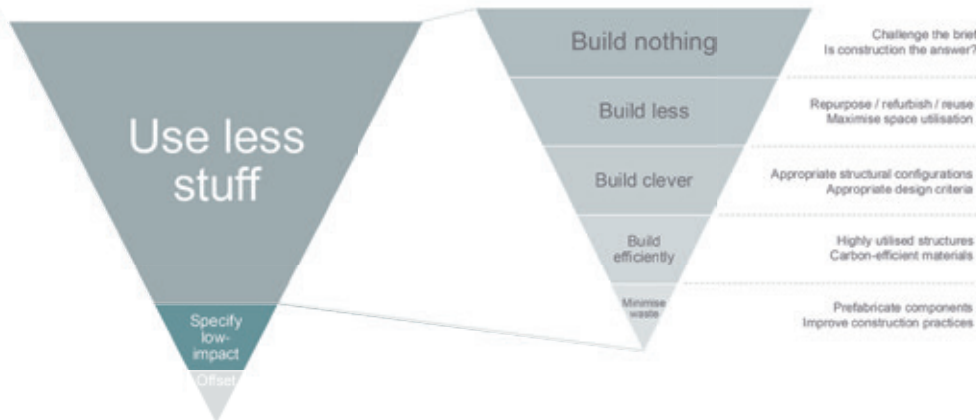


FIGURE 3: Specifying low-carbon materials remains much less important in hierarchy of net-zero design than designing efficiently

understanding of how structures perform in reality. Better data collection and the development of true statistical models will ensure more realistic utilisations and resultant factors of safety, meaning more efficient use of material in the future²⁴.

What is also key is developing specifications that avoid minimum levels of scrap and instead set appropriate carbon limits that are based upon percentages of scrap, like a sliding scale. Each project and client will be unique.

Overall, the target of 2050 appears feasible on paper, but a dramatic recasting of an engineer's skillset is necessary to fill the gap that industry is generating. Critically, none of the materials industries are claiming they will decarbonise quickly enough by 2030 to enable engineers to just continue 'business as usual' in the meantime. As designers and specifiers, we need to close the gap by 2030 by using materials more efficiently (Figure 3). Much more efficiently.

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