Road to net zero – asphalt

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Foreword

Asphalt is used as the surface for 95% of our roads as well as for playgrounds, footways, parking areas and airport runways, with around 25 million tonnes produced each year in Great Britain.

It is already one of the most sustainable construction materials available as it is extremely durable and 100% recyclable: worn out surfaces can be reused back into new asphalt, which can also contain other recycled content as well as secondary materials.

In addition, innovation within the sector is continuing apace to develop lower carbon asphalts as we seek to help the UK government, National Highways and local authorities meet their net zero ambitions.

The inclusion of biogenic materials, recycled content and additives to improve durability, as well as using lower production temperatures, are just some of the innovations already being used.

Department for Transport (DfT) road length statistics show that there are almost 250,000 miles of road in Great Britain, so the scope for these developments to have a significant impact on reducing the UK's carbon emissions is huge.

This document aims to summarise the sources of carbon emissions in asphalt production and laying and investigate the innovative developments taking place as well as the benefits these could provide when applied to the whole-life carbon impact of asphalt. I hope you find it useful and interesting.

Gareth Day
Asphalt and Contracting Managing Director
Heidelberg Materials UK

Introduction

The highways sector is increasingly focused on carbon reduction as it looks to the future and commits to playing its part in meeting the Government's net zero target by 2050.

Around 80% of local authorities in England and Wales have declared a climate emergency and the Annual Local Authority Road Maintenance (ALARM) survey 2023, produced by the Asphalt Industry Alliance, reports that over 90% of local authorities have a net zero pledge – with 60% pledging to reach their target by 2030. National Highways has also set out its commitment for all road construction and maintenance activities to be net zero by 2040.

It's a challenging target and commitment is needed from industry, local authorities and the Government to achieve this goal.

Around half of the carbon emissions associated with asphalt production and laying come from the fuel used in manufacture, so reducing the temperature at which asphalt is produced is an important consideration. In addition, using longer-life products to increase the durability of the asphalt reduces the number of maintenance interventions, lowering whole-life carbon emissions and supporting the circular economy.

Over 90%
of local authorities have a net zero pledge

Carbon emissions from asphalt today

The embodied carbon per tonne of asphalt is typically between 40kg and 75kg, dependent on the type of asphalt, raw materials used, transportation and the production process used.

Carbon emissions are categorised into three sources: direct scope 1 emissions and indirect scope 2 and 3 emissions:

Typical carbon emissions by tonne of asphalt (A1-A3 product stage of asphalt lifecycle assessment: cradle-to-gate, excluding laying)

Product Category	Total $kgCO_2e/t$	Scope 1	Scope 2	Scope 3
Base Course	47	30	2	15
Binder Course	48	30	2	16
Surface Course	60	31	2	27

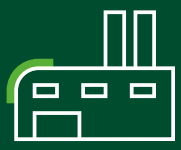
Source: asPECT database

The emissions associated with the production of asphalt (the energy and raw materials used) is by far the largest contributor, with emissions associated with laying the asphalt relatively small at around 2-3kg/tonne or 4-6% of the total embodied carbon of the finished material.

There are several areas that can be tackled to help cut the CO_2emissions associated with asphalt production including:

- Optimising the supply chain by, for example, delivering aggregates by rail rather than road.
- Using electric/hydrogen trucks.
- Upgrading to modern, efficient burners.
- Switching to lower/zero carbon fuel sources, including hydrogen.
- Producing asphalt at lower temperatures.
- Eliminating waste in the asphalt production process.
- Increasing the percentage of recycled asphalt planings (RAP) within the mix.
- Using lower-carbon bitumen or bitumen substitutes.
- Designing asphalt with long term durability in mind.

Carbon emissions are categorised into three sources:



Scope 1

Direct production emissions from company owned or controlled sources, primarily from the asphalt plant itself.

Scope 2

Indirect emissions from electricity consumption.

Scope 3

Indirect emissions from purchased goods and services such as raw materials like bitumen, aggregates and recycled asphalt planings (RAP), as well as distribution to site.

Scope 1 emissions

Direct scope 1 emissions account for between 45% and 65% of the total embodied CO_2 of asphalt, with the largest source being the dryer/burner within the asphalt plant. As a result, replacing older burners with modern ones, for example, can improve burner efficiency by 10%. This could lower scope 1 emissions by approximately 3-4kgCO_2e/t of asphalt.

In the future, as hydrogen becomes economically available in sufficient quantities, switching the fuel used in the burner and the mobile plant to a net zero fuel mix by using hydrogen could save around 30kgCO_2e/t – close to 100% of emissions from this area.

Other plant improvements that can cut carbon emissions include:

- Covering recycled asphalt planings (RAP) that are being stored for use. This can reduce RAP moisture content from 5% to 3%, resulting in less fuel needed to produce the asphalt and reducing scope 1 emissions by up to 1kgCO_2e/t.
- Reducing production waste at an asphalt plant by 1% can reduce scope 1 emissions by approximately 0.5kgCO_2e/t.

A cement kiln at Heidelberg Materials' Ribblesdale works in Lancashire has successfully been operated using a net zero fuel mix which includes hydrogen. It was a world-first demonstration and established a pathway to moving away from using fossil fuels and has the potential to be replicated in other industries, including asphalt production.

In a separate collaboration with EDF and the Department for Energy Security and Net Zero, a demonstrator project using nuclear-derived hydrogen to decarbonise asphalt production is being trialled at Heidelberg Materials' Criggion asphalt plant in mid Wales. Hydrogen created at EDF's Heysham 2 power station in Lancashire will be used to fuel the industrial processes at the plant in place of the existing mix of liquid fossil fuel. This is likely to be the first time hydrogen has been used to produce asphalt on an industrial scale in the UK.

World's first

net zero fuel mix

including hydrogen in a kiln

Warm mix asphalts

Reducing the temperature at which asphalt is produced can have a meaningful impact on scope 1 emissions as around half of the carbon emissions associated with asphalt production and laying come from the fuel used in manufacture.

Warm mix asphalts (WMAs) are produced using special techniques and/or additives to reduce the production temperature of the asphalt to between 100°C and 160°C. This compares with conventional hot mix asphalt products which are generally produced at temperatures of up to 200°C.

Reduced production temperatures result in lower energy consumption, cutting scope 1 carbon emissions. In addition, WMAs offer various other advantages such as improved worker safety, quicker reopening times and improved surfacing operation efficiencies. These benefits have been clearly outlined in the **Working for better roads** report produced by the All Party Parliamentary Group for Better Roads.

The use of WMAs is gathering pace, helped by the announcement from National Highways in 2019 encouraging its use as standard on its network.

The 2023 ALARM survey reports that 82% of local authorities in England and Wales include WMAs on their specification list – up from 60% cited in the 2022 report – and that more are looking to adopt it in the future. But the reality is that only a small proportion of total asphalt production volumes are WMAs, which presents a sizeable opportunity for carbon reduction from a technology that is already proven and readily available.

In addition to WMAs, half WMAs and cold mix asphalts are also available and offer the potential for significant carbon reduction. Half WMAs typically reduce manufacturing temperatures to around 100°C through the use of micro-foaming techniques. Cold mix asphalts are produced using emulsion-based binders which do not require heating but have more limited applications.

Typical carbon reduction figures are:

Warm mix asphalts can cut 2-4kgCO_2e/t – up to 15% of scope 1 emissions.
Half warm mix asphalts can cut 12-14kgCO_2e/t – up to 50% of scope 1 emissions.
Cold mix asphalts can cut 24-26kgCO_2e/t (when liquid fuels are used) – up to 90% of scope 1 emissions.

More than 22,000 tonnes of Heidelberg Materials' ERA WMA has been used on eight schemes across Areas 6 & 8 in the East of England, reducing CO_2e emissions by 44,000kg and helping to meet National Highways carbon reduction objectives.

Rob Barron, Supplier Relationship Manager for Operations East at National Highways, said: "The team at Heidelberg Materials has continually demonstrated its commitment to supporting both National Highways' carbon reduction strategy and net zero targets through the promotion and use wherever possible of warm mix asphalt.

"Heidelberg Materials' continued commitment to best practice is greatly appreciated and will assist hugely in helping to shape the type of materials utilised on future projects with, not only environment benefits, but also enhancing health and safety, as well as improving longevity of network life."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Lower carbon plant/vehicles

In addition to the emissions from the fuel used in asphalt production, there are also those generated in the transportation of raw materials to asphalt plants, delivery of asphalt to site and the plant used for laying.

Rail distribution can reduce carbon emissions versus road transport by 76%. A typical rail transport distance for aggregates in the UK is 92 miles. Switching the mode of transport from road to rail for this distance can reduce carbon emissions by 8.5kgCO_2e/t.

Switching to lower-carbon fuel sources – such as using electric or hydrogen trucks – can also remove almost all transportation emissions, while the use of hydrotreated vegetable oil (HVO) and gas-to-liquids (GTL) fuels can significantly reduce those generated from pavers and rollers used for laying asphalt.

Heidelberg Materials operates a network of seven rail connected quarries and 22 rail depots located close to market centres. Each year the company transports more than 5mt of aggregates by rail, saving over 40,000tCO_2e.

Heidelberg Materials' pavers and rollers are using GD45+, supplied by GB Fuels Ltd, which reduces CO_2 emissions by more than 40% as well as cutting NOx by 14% and releasing 18% fewer fine particles when compared to traditional diesel.

GD45+ is a mix of sustainably sourced HVO and a GTL fuel developed in conjunction with Shell and is classed as readily biodegradable under Defra definition. As a result of using this alternative fuel source, the contracting division has cut its Scope 1 emissions by 40%.


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Scope 2 emissions

Indirect scope 2 emissions (primarily from electricity consumption) typically represent less than 5% of the CO_2 emissions associated with asphalt but are one of the easiest to remove completely from the process.

This can be achieved by using a carbon neutral supplier and/or local renewable energy generation, such as solar, wind or nuclear power.

Scope 3 emissions

Scope 3 emissions come predominantly from the production and transportation of the raw materials used in asphalt and account for 30-50% of its embodied CO_2.

The majority of surface course asphalts have a much higher proportion of carbon embodied in scope 3 – approximately double that of a typical base course – due to the raw materials used. This is because surface courses have higher bitumen contents, a greater use of polymer modified bitumen (PMB) and often contain high polished stone value (PSV) aggregates, which have generally travelled further to reach the asphalt plant.

PMB has higher embodied carbon than standard bitumen but offers benefits such as enhanced durability through increased fatigue resistance, which extends the life of the asphalt and reduces whole-life emissions.

Surface course asphalts also often use aggregates with a higher PSV to aid skid resistance and improve the safety of roads. These materials are less readily available and often have to be transported from further afield, increasing their carbon impact.

National Highways specified the use of locally sourced aggregates to resurface the A30 near Exeter, Devon. The project was the first formal trial of Heidelberg Material's CarbonLock asphalt containing PMB bio-binders on the strategic road network. Sourcing the aggregates and producing the asphalt at Hingston Down nearby, minimised transportation-based emissions, saving around 20kgCO_2e/t compared with importing high PSV aggregates, helping to reduce the project's overall carbon footprint while still meeting National Highways' specification requirements.


RAMP
AHEAD
RAMP

Materials innovation

Materials innovation has an important role to play in reducing scope 3 carbon emissions and creating a more resilient road network. Over the years, collaboration between asphalt manufacturers and their supply chain have driven a wide range of process and product innovation including:

‘Biogenic’ asphalt

‘Biogenic’ asphalts contain natural, responsibly sourced, biogenic materials within the bitumen content of the asphalt, which absorb and store CO_2 throughout their life. This CO_2 is then ‘locked’ within the asphalt and not released back into the atmosphere – even when the asphalt is recycled.

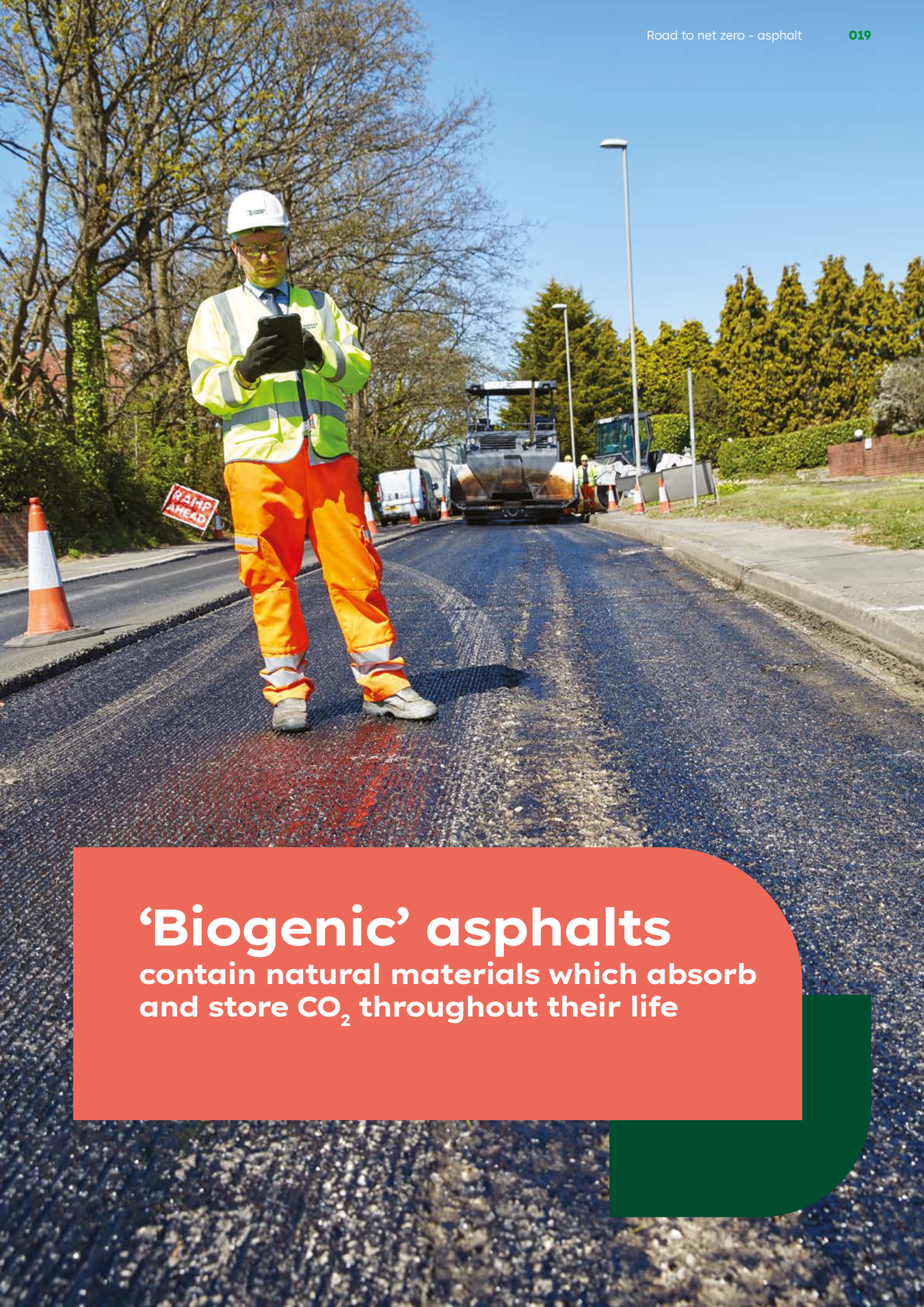
Heidelberg Materials’ CarbonLock ‘biogenic’ asphalt has been used to resurface both rural and urban roads as part of the company’s longstanding strategic partnership with Dorset Council.

CarbonLock includes biogenic materials within the binder and is estimated to ‘lock in’ six tonnes of CO_2 in every kilometre of road. It can be produced using Heidelberg Materials’ ERA WMA technology and can also include a PMB, which provides additional durability benefits, to further extend the life of the asphalt and reduce the need for maintenance interventions, lowering whole-life carbon impacts.

Jack Wiltshire, Head of Highways at Dorset Council, said: “In 2019 we declared a climate and ecological emergency in Dorset, and we have since committed to being net zero by 2040.

“The highways team is playing its part and our strategic partnership with Heidelberg Materials allows us to collaborate closely to minimise the environmental impact of our highways works.

“We have already introduced a range of measures to reduce our carbon footprint, which include how we can reduce the embodied carbon of the asphalt laid in the Dorset Council area. Heidelberg Materials’ CarbonLock is an excellent example of this, and we hope it will become an important addition to our specification list.“



‘Biogenic’ asphalts

contain natural materials which absorb and store CO_2 throughout their life

Recycled glass and plastic

The construction industry is moving towards a circular economy with new products containing more recycled content, while still being fully recyclable at the end of their life.

Asphalt containing waste glass or plastic can provide a beneficial use for the materials at the end of their life and, when produced as a WMA, can also lower carbon emissions.

Heidelberg Materials' RecyclePlast asphalt contains waste plastic that has been chemically converted into a more usable component. This makes it compatible with bitumen without impacting performance and ensures the asphalt remains 100% recyclable at the end of its life.

The product is being trialled in Cumbria where each kilometre of road resurfaced with RecyclePlast contains the equivalent of 25,000 500ml plastic bottles, or approximately 600 full wheelie bins. It was also produced as a WMA, reducing scope 1 emissions at the asphalt plant by around 15%.

RecyclePlast asphalt has been laid in different locations to allow the performance of the material to be assessed under different load and climate conditions. Trials are ongoing.

Heidelberg Materials also regularly uses recycled crushed or ground glass in asphalt mixes as a sand substitute.

Recycled asphalt planings (RAP)

Asphalt is 100% recyclable at its end of life and can be incorporated back into new asphalt. Using these recycled asphalt planings (RAP) in the production process avoids using primary aggregates, protecting natural resources for future generations.

Increasing the use of RAP in asphalt mixes can reduce scope 3 emissions by using recycled aggregates and bitumen recovered from old road planings. For each tonne of RAP used, the saved aggregates and bitumen carbon emissions are typically 5.5kgCO_2e, including the increase in scope 1 emissions from the additional heating required. As a result, increasing RAP content in asphalt by 10% can result in a 0.55kgCO_2e/t saving.

The industry has successfully introduced the widespread use of RAP in asphalt products. In 2022 total UK annual asphalt production was 25mt (Source: BDS Market Intelligence), with RAP usage estimated to be 5mt. Based on a saving of 5.5kgCO_2e/t of RAP used, this represents a total saving of 27,500 tonnes of CO_2 – the equivalent of removing 14,700 cars from the roads each year.

Clause 942 surface course materials are expected to be updated by Q4 2023 to increase the addition of 10% RAP as standard to 20% – effectively doubling the potential CO_2 that could be saved.

In situ recycling/ cold recycled bound material (CRBM)

CRBM allows a high percentage of recycled content to be used in the mix – up to 100% in some case – and, as the name suggests, is produced cold, minimising production emissions. These materials are usually produced onsite, removing any carbon impact from transportation, and are laid by conventional paving equipment.

CRBM can also include tar-bound planings, which are classed as a hazardous waste, removing the cost and carbon implications of sending them for processing or to landfill.

CRMB was used by Heidelberg Materials to create the new base course of the A338 Bournemouth Spur Road in Dorset.
The decision allowed 100% of the old road materials to be incorporated, preventing 70,000 tonnes of material going to waste or landfill. The planings were removed and then crushed, screened and processed on site, reducing carbon emissions. They were then combined with cement and foamed bitumen to produce the new B3 QVE asphalt in accordance with the specifications TRL 611 and MCHW Clause 948.

The bigger picture: whole-life carbon emissions

Considering the embodied carbon of asphalt at the point of production and laying only tells one part of the story.

Department for Transport (DfT) road length statistics show that there are 247,800 miles of road in Great Britain that need to be maintained, as well as a small percentage of new roads constructed each year to service new residential and commercial developments, bypass towns and so on.

These roads – as well as asphalt used to surface car parks, runways, playgrounds and driveways – all need to be maintained and it is estimated that maintenance (as opposed to full depth reconstruction) is responsible for around 90% of all emissions generated by the asphalt industry.

As a result, reducing the number of maintenance interventions becomes an important driver as this will lead to the use of less materials, cut waste and reduce whole-life carbon emissions.

Lifecycle carbon analysis

The DfT road length data is split by type with the strategic road network (motorways and the majority of 'A' roads) managed by National Highways and the 'B', 'C' and 'U' roads managed and maintained by local authorities:

- **31,900 miles of motorway and 'A' roads**
- **18,900 miles of 'B' road and**
- **197,100 miles of 'C' and 'U' roads**

These types of roads have different design life and intervention expectations, which allow an analysis of whole-life carbon impacts to be undertaken.

For example, National Highways typically works on a 40-year design life for the asphalt used on its roads with an expectation for a surface course maintenance intervention after 15 years, intervention 2 at 30 years and intervention 3 (resurfacing) at 40 years.

However, it is important to consider the impacts of using lower carbon asphalt solutions in the specification of materials. Using environmental product declarations to take the lifecycle of the roads – including the frequency of interventions – into consideration can have a significant impact on the overall carbon footprint of a project.

Extending the life of asphalt

The asphalt industry recognises the importance of enhanced material durability to reduce the number of maintenance interventions and minimise whole-life carbon emissions.

Polymer modified bitumens (PMBs) are key in this area as they prevent the premature hardening of bitumen that occurs through its chemical reaction with the oxygen in the atmosphere. PMBs improve flexibility, strength and resistance to fatigue and deformation to extend the life of the asphalt. They can also include biogenic material and other additives that can help further reduce embodied CO_2.

Heidelberg Materials' AgeLast asphalt has been laid on the eastbound carriageway of the A414 in Hertfordshire to help meet National Highways' lower carbon ambitions. AgeLast contains Shell's Cariphalte AgeSafe binder, which reduces the rate of bitumen ageing to delay the onset of embrittlement and prolong the life of the asphalt surfacing by up to 25% (demonstrated under laboratory conditions), reducing the need for intervention and cutting carbon emissions.

Puru Loganathan, Senior Pavements Advisor at National Highways, said: "Reducing carbon emissions is a key priority for us, as is delivering long lasting smooth roads which connect the country. If we are going to achieve net zero in a timely fashion, we need to collaborate with our supply chain to explore the innovative solutions they are developing to reduce carbon emissions and create more resilient and sustainable roads. We are excited about the results this new trial will bring, and hope the technology used can extend the life of our road surfaces across the country."

Smoother roads

Smooth road surfaces reduce friction with tyres, which improves fuel consumption and consequently cuts CO_2 emissions.

To meet National Highways' smoother roads criteria, the asphalt industry is increasing investment in innovation and digitalisation that can be used to further enhance the laying of asphalt.

As part of National Highways' project to resurface the A414 near St Albans in Hertfordshire, a shuttle buggy was used to provide a constant supply of asphalt to the paver, in combination with the latest levelling technology, to enhance the smoothness of the road. This approach has been successfully used internationally, but the A414 represented one of the first applications to a maintenance scheme in the UK.

The smoother surface, installed without joints, creates less friction with tyres, reducing fuel consumption and ongoing CO_2 emissions throughout the life of the road. The finished surfacing has also improved ride quality for road users which helps extend life to the next intervention as well as reducing noise.

In a separate project on the A12 Margaretting Bypass in Essex, Heidelberg Materials has integrated Leica Geosystems' 3D machine control solution onto its pavers to ensure each layer of the new asphalt surface meets National Highways' smoother roads criteria.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Creating a pathway to net zero asphalt

The asphalt industry is committed to reducing its carbon footprint and a number of different levers are already available to help producers and their clients reduce emissions now. But to maximise the benefits, industry, national government and local authorities need to work together to share successes and champion innovative new methods of road design and construction.

Industry is already implementing a range of carbon reduction measures, as outlined in this paper, that reduce scope 1, 2 and 3 emissions. But, in the longer term, it will need to adapt to the changing energy environment and embrace new lower, or zero, carbon fuels like hydrogen as they become available. Heidelberg Materials is at the forefront of that transition having entered into a collaboration with EDF and the Department for Energy Security and Net Zero to demonstrate the use of hydrogen in asphalt production.

The industry will also need to continue to inform its customers of the lower carbon options available and bust some longstanding myths about the durability and workability of some lower carbon/high recycled content products. It will need to become more sophisticated in the way it recycles asphalt planings of different bitumen types and PSV value, and that will require improved data on what is contained in existing roads. To support the increase in use of lower carbon/high recycled products, asphalt suppliers will need to continually improve product quality management and assurance.

In addition, clients will need to evaluate trade-offs between carbon emissions and cost – for example where innovative lower carbon materials cost more to produce – and between source and lifecycle emissions, for example where the time between interventions can be extended for a smaller up-front increase in carbon emissions using long life or PMB bitumen.


VOLVO
FM

Next steps

Increase the use of WMAs

The **Working for better roads** report produced by the All Party Parliamentary Group For Better Roads states: 'If all asphalt production in Great Britain in 2017 (the last year for which data is available) had been switched to WMA, it would have saved at least 61,000 tonnes of CO_2 – the equivalent of cutting almost 300 million miles of car journeys.'

While it may not be realistic to switch to 100% WMAs, increasing its use from an estimated 5% of total asphalt production to 20% would save an additional 9,150 tonnes of CO_2 annually while also reducing binder ageing, extending the service life of the asphalt and providing whole-life carbon benefits. Wider adoption of WMA would also lead to enhanced asphalt plant efficiencies as production could permanently switch to this method, lowering the carbon impact of plants.

Update material specifications

Clients should carefully consider whole-life carbon emissions at the early stages of a project. They should also consider the specification of materials to minimise the impact of transportation emissions, particularly where high PSV aggregates are unnecessary for the application. This will have the combined benefit of reducing carbon and providing better value for clients.

Proposed changes to Clause 942 thin surface course systems are expected to see an increase from 10% reclaimed asphalt to 20% in the next revision. The change is welcomed to support the circular economy, reducing high PSV aggregate demand and further supporting carbon reductions of circa 1.5kgCO_2e/t.

Supply chain collaboration

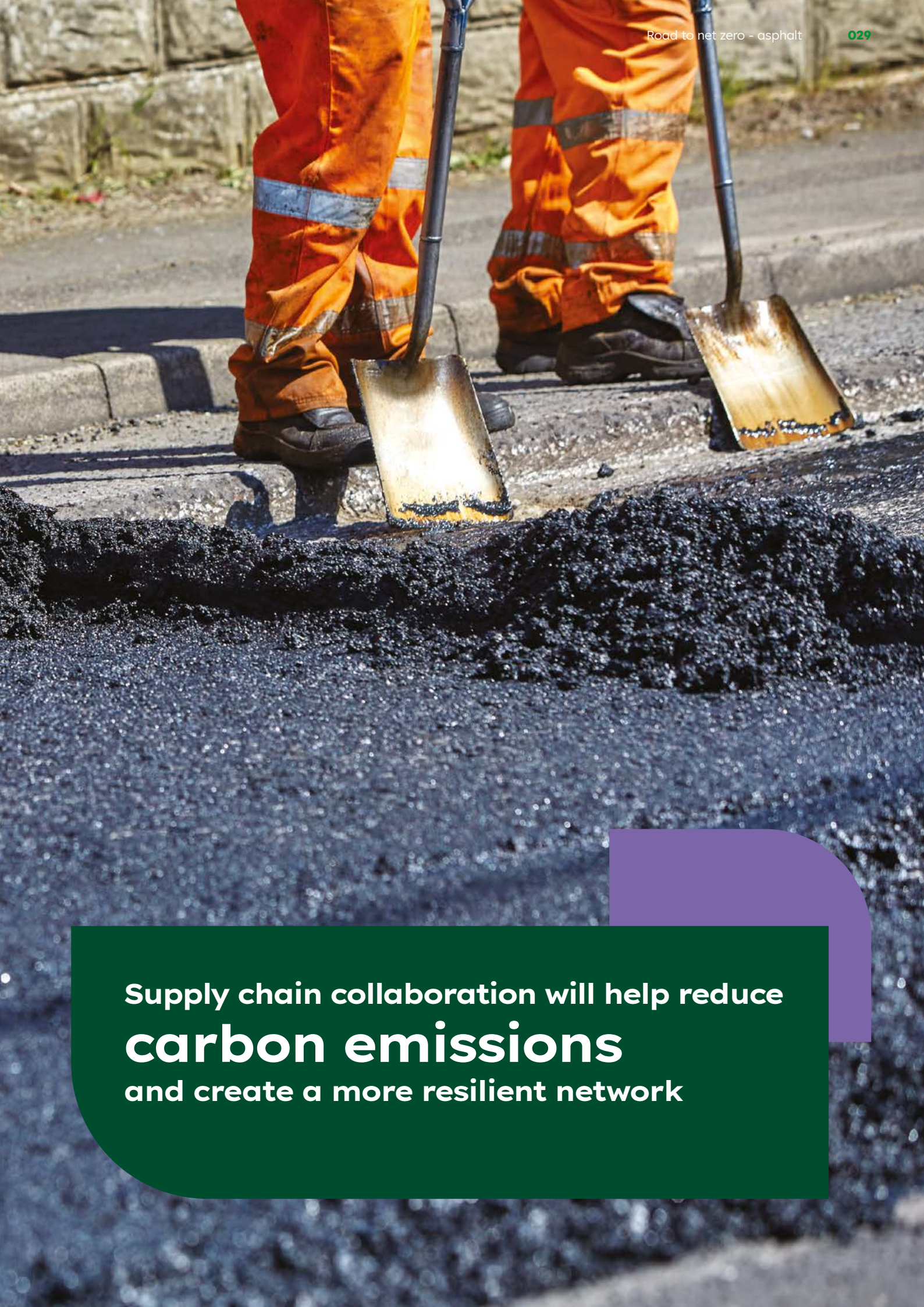
Early involvement and collaboration on projects with the supply chain will help to reduce carbon emissions and create a more resilient network. Projects can be designed to use lower carbon and recycled materials, but only with the early involvement of clients, contractors and the broader supply chain. Also, with careful planning at an early stage, planings can be back-hauled on the lorries used to deliver asphalt, reducing road miles and saving carbon emissions.

Bitumen innovation

The bitumen content of asphalt has a significant impact on whole-life carbon emissions and the industry is actively pursuing a number of strategies to help meet net zero objectives.

PMB increases the durability of asphalt, extending its life and reducing the number of maintenance interventions, cutting carbon emissions further. The development and increasing use of bio-binders and anti-ageing binder technology will continue to support the industry in its journey to net zero carbon while ensuring the long-term durability of asphalt.

The bitumen industry is now looking at other new innovations, many of which can also be produced as PMB and at a lower temperature, to maximise carbon reduction. Synthetic binders, for example, which include carbon neutral/carbon negative material, are in early development.



Supply chain collaboration will help reduce **carbon emissions** and create a more resilient network

Abbreviations:

$kgCO_2e/t$: kg of carbon dioxide equivalent/tonne

mt: million tonnes

PMB: polymer modified bitumen

PSV: polished stone value

RAP: recycled asphalt planings

WMAs: warm mix asphalts

Sources:

Greenhouse Gas Protocol (ghgprotocol.org)

CAPE: tracking the UK's journey towards carbon zero (cape.mysociety.org)

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BDS Market Intelligence (bdsmarketing.co.uk)

Road lengths in Great Britain: 2021 - GOV.UK (www.gov.uk)

APPG for Better Roads WMA report (appg-betterroads.org/wp-content/uploads/2019/09/aia-warm-mix-document-Fl.pdf)

Mineral Products Association (www.mineralproducts.org)

Rail Freight and Mineral Products Working together to build Britain (https://mineralproducts.org/MPA/media/root/Publications/2019/Rail_Freight_Mineral_Products_Working_Together_to_Build_Britain.pdf)

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