



Centre of Excellence
for Decarbonising Roads



STYRELF BIO-PMB LIVE TRIAL EVALUATION REPORT

Live Labs 2 North Campus

This report evaluates Styrelf Bio-PMB, a bio-based binder substitute to virgin bitumen binder, as a sustainable alternative to Hot Rolled Asphalt (HRA). Styrelf Bio-PMB demonstrated overall lower carbon emissions (A1-A5) than HRA and offers potential further carbon savings if the materials carbon sink claims can be substantiated. Recommendations drawn from this trial include implementing a robust monitoring period, and verification of carbon sequestration and end-of-life processes.

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Executive Summary

This report evaluates a live trial conducted as part of the Live Labs 2 project, which aims to test innovative highway solutions to reduce carbon emissions, improve road performance, reduce maintenance needs, and enhance safety. This trial focused on Styrelf® Bio-PMB X70, described by the manufacturer as a binder substitute replacing petroleum-based bitumen binder with bitumen's modified with elastomeric polymers as well as biobased binders to create a theoretical carbon sink.

Styrelf® Bio-PMB X70 was trialled as part of the Supersite Trial (a single stretch of highway trialling several materials and techniques) along Hirst Road in North Lanarkshire. Styrelf® Bio-PMB X70 was trialled as a surface course within section 2 of the supersite at a depth of 50mm, a control section of Hot-Rolled Asphalt (HRA) surface course was also applied to the supersite at a depth of 50mm to allow for direct comparisons to the business as usual (BAU) approach to surfacing for North Lanarkshire Council. The findings, limitations, and recommendations presented in this report aim to inform the potential rollout of Styrelf® Bio-PMB X70 across UK local councils.

This report assesses carbon emissions across cradle to construction lifecycle stages in accordance with EN 15804, covering product stages A1-A3 of this standard (raw material extraction, transportation to processing facilities and manufacturing) and construction stages A4 to A5 (transportation of the finished material to site and installation). EN 15804 classifies carbon and establishes a modular, transparent approach to lifecycle assessment that assigns emissions to defined stages. Using EN 15804 ensures that this live trial is in line with the recognised European standard, follows accepted boundaries and allocation rules, and enables results that are comparable, auditable and consistent across products and projects.

Styrelf® Bio-PMB X70's primary carbon advantages arise through materially lower emissions through the replacement of a portion of virgin bitumen with biogenic binder. The materials biogenic component is claimed to act as a temporary carbon store within the binder. This along with lower manufacturing and installation temperatures reduce fuel consumption during production and laying, highlighting Styrelf® Bio-PMB X70 as having a high carbon saving potential.

The findings from the trial have shown that Styrelf® Bio-PMB X70 has high potential in reducing carbon emissions when compared with conventional HRA, with the trial showing 8.74 kgCO₂e/m² versus 9.19kgCO₂e/m² for benchmarked HRA (both applied at a depth of 50mm), indicating a 5% reduction under this trial's conditions. This reduction is predominantly due to lower material-stage (A1-A3) and construction stage (A5) emissions associated with the partial replacement of bitumen with bio-derived binder. While these results are positive, the trial cannot comment on the certainty around the permanence and the accounting of biogenic carbon. The trial did not receive a detailed methodology to substantiate carbon-sink claims. Potential biogenic benefits depend on feedstock provenance and end-of-life pathways. Confirmed, transparent evidence on feedstock sourcing and end-of-life handling is required to validate sequestration assertions.

Nonetheless, Styrelf® Bio-PMB X70 does show carbon savings and is production ready and compatible with standard asphalt plant and laying practices, lowering potential barriers to contractor adoption. To convert these trial-level results into network scale gains, multi-year monitoring, verified end-of-life processes and supply-chain optimisation is recommended.

Introduction

This Evaluation Report provides a high-level assessment of Styrelf® Bio-PMB X70, an emerging sustainable material in highways, construction and maintenance, focusing on its environmental impact, product viability, and alignment with future infrastructure needs. Styrelf Bio-PMB is described by the manufacturer as a binder substitute replacing petroleum-based bitumen binder with bitumen's modified with elastomeric polymers as well as biobased binders to reduce the carbon emissions typically associated with Hot Mix Asphalt (HMA).

Live Labs 2 is a three-year UK-wide programme funded by the Department of Transport (DfT), with a five-year monitoring and evaluation period, focusing on how to decarbonise local highways infrastructure and assets. As part of this initiative, North Lanarkshire Council (NLC) are working alongside Transport for West Midlands (TfWM), to establish the UK Centre of Excellence for Materials Decarbonisation in Local Roads.

The Centre of Excellence will act as a central hub within Live Labs 2, supporting research, innovation, and best practices to accelerate low-carbon solutions in road construction and maintenance. By integrating findings from Live Labs 2 trials, the centre will drive sustainable advancements, enabling Local Authority Highway sectors across the UK to adopt more efficient and environmentally responsible materials and methodologies.

The purpose of these reports is to present key findings from a comprehensive evaluation of sustainable materials, including their carbon intensity, potential application, and overall benefits by examining carbon appraisals, lifecycle benchmarks, and various factors such as scalability, compliance, durability and supply chain viability. The report aims to provide decision-makers with valuable insights into the material's capacity to meet sustainability goals while maintaining construction quality and durability. The evaluation will inform ongoing efforts to balance environmental considerations with operational efficiency in infrastructure development.

The carbon profiles of materials have been calculated using the Future Highways Research Group (FHRG) tool Carbon Leadership Profiler Toolkit (previously known as Carbon Analyser), a excel-based tool developed in collaboration with local highway authorities to provide a simple, standardised method for quantifying carbon emissions associated with transport and highways activities, and the OneClickLCA database where embodied carbon data is otherwise unavailable. All carbon profiles have incorporated a local and sector-wide baseline material to benchmark carbon savings. The Styrelf Bio-PMB trial has been evaluated against conventional HRA.

The carbon evaluations for Styrelf Bio-PMB incorporate whole lifecycle assessments which consider:

- Embodied Carbon;
- Transportation emissions of materials and people;
- Operation of plant and equipment during construction period;
- Operational electricity, fuel and water emissions;
- End of life emissions including deconstruction and waste processing.

Feature	Description	Carbon Intensity	Product Prospects
Material Summary	Description of material	Specific emissions data (CO ₂ e per unit of material)	Brief product potential overview
<p>Styrelf® Bio-PMB X70– Total Energies</p>	<p>Styrelf® Bio-PMB X70 is a biogenic/bio-based binder substitute for petroleum bitumen used in asphalt mixes for road surfacing. Styrelf also contains bitumen modified with elastomeric polymers to increase the asphalt's durability.</p> <p>A proportion of the conventional bitumen in hot mix asphalt is replaced by a bio-derived binder that contains carbon originally absorbed from the atmosphere during biomass growth, effectively making the asphalt a carbon sink.</p>	<p>Initial carbon analysis of A1-A5 carbon emissions from this trial has shown that Styrelf® Bio-PMB X70 produces 8.74 kgCO₂e/m². When applied on the same stretch of road conventional HRA produced 9.19 kgCO₂e/m². Both surface course materials were applied at a depth of 50mm.</p> <p>Comparative carbon analysis in this trial showed a 5% reduction in A1-A5 lifecycle stage carbon emissions per square metre.</p> <p>However, the baseline HRA on the supersite contained 15% Reclaimed Asphalt Pavement (RAP) while Styrelf® Bio-PMB X70 contained 10%. To allow for a more complete comparison, carbon modelling of Styrelf® Bio-PMB X70 and HRA 0% RAP has been completed. This modelling demonstrated a 16% reduction.</p>	<p>It is considered that this product has a potential in the road construction and maintenance industry, particularly in projects prioritising sustainability and the use of bio-based materials.</p> <p>Styrelf® Bio-PMB X70 has shown 2.68% material stage carbon savings and 35.36% construction stage carbon savings when compared to HRA within this trial, proving it has potential to deliver reduced-carbon surfacing in live environments.</p> <p>These results support Styrelf® Bio-PMB X70's low carbon claims however, further empirical evidence is required to verify whether the material sequesters carbon as claimed.</p>

Methodology

Trial Design

The Styrelf® Bio-PMB X70 trial was designed to evaluate the performance, durability, and environmental impact of this innovative material. The trial was conducted as part of the larger Supersite trial (a single stretch of highway trialling several materials and techniques) which focussed on testing innovative low-carbon surfacing materials and in-situ recycling techniques to evaluate their carbon savings and long-term performance under real-life road conditions. Styrelf Bio-PMB was applied to section 2 of Hirst Road which had previously undergone cold in-situ recycling by Colas Regen, to assess the materials high durability claims.

Carbon emissions have been assessed based on the whole lifecycle stages A1-A5 (cradle to construction) in accordance with EN 15804. EN 15804 is the European standard that defines the rules and reporting format for Environmental Product Declarations (EPD) for construction products, providing a consistent, audible framework for quantifying carbon impacts across a products lifecycle. These stages cover raw material extraction, transport to and manufacture at the factory, delivery to site and on-site installation, see [Figure 1](#). This clear separation of stages enables precise attribution of emissions to each segment of the supply chain, helping to identify areas for potential reduction measures and ensuring comparability across all trials.

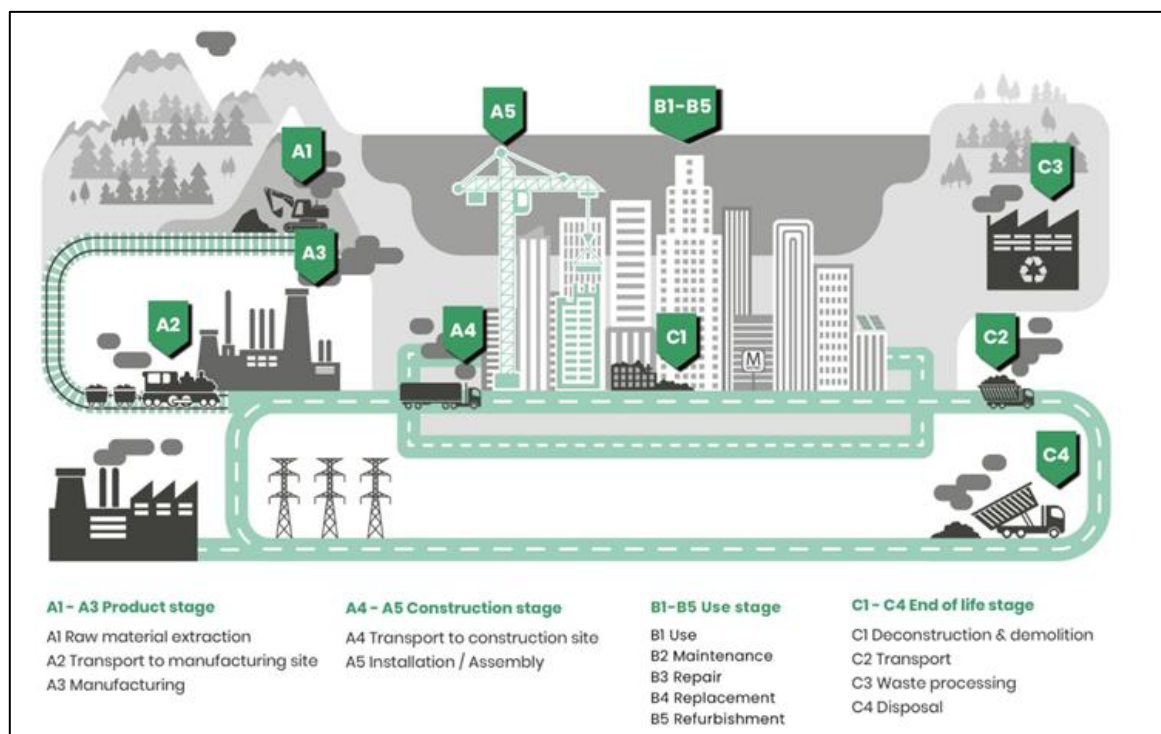


Figure 1: Carbon Lifecycle Stages¹

¹ <https://help.oneclicklca.com/en/articles/275901-life-cycle-stages>

Site Selection

The trial sites were chosen based on the following criteria:

- **Traffic Volume:** The site was chosen as it experiences high numbers of both light and heavy vehicles allowing for the assessment of the material's performance under differing stress conditions.
- **Environmental Conditions:** The Supersite site was selected due to its varying weather conditions (e.g., temperature, humidity) to evaluate the surfacing material's resilience.
- **Surface Type:** Sites were all originally surfaced with hot-rolled asphalt (HRA) and had severely deteriorated since, requiring urgent maintenance.

Data Collection Plan

The following data items were collected to ensure a thorough evaluation of Styrelf® Bio-PMB X70 during site trials:

DATA ITEM	UNIT(S)	RESPONSIBLE	LOCATION OF DATA	PURPOSE
Trial Location	Road name, Road Type (A, B, C), Coordinates of location of Bio-PMB	Operational Staff	Site Diary	Technical comparisons
Conditions at the time of lay	Temperature (°C) Conditions (rain, dry, etc)	Operational Staff	Site Diary	Operational considerations and technical comparisons
Coring	Pen Softening Point DSR	University of Nottingham	Site Diary	Technical Evaluation
Road Surface Temperature	Temperature (°C)	Inspector	Site Diary	Technical Evaluation
Quantity	m ² of Bio-PMB used	Operational staff & Carbon Lead	Site Diary	Cost and Carbon Evaluations
Cost	£ for Bio-PMB £ for conventional resurfacing	Amey Procurement and Suppliers	SAP	Purchase cost and whole lifecycle cost evaluation
Surface Characteristics	Length and Width (cm)	Carbon and/or Technical Lead	Site Diary	Technical and Carbon Evaluation
Operational Experience – ease of installation	Subjective – any concerns or benefits experienced by Operations Team	Project Manager to collect on-site data with Operations Team	Case Study in knowledge bank	Scalability Evaluation
Health & Safety	Ease of installation on-site Temperature required for installation	Operational staff and supplier information	Site Diary	Health and Safety Assessment
Operational Data	Time to complete (hh:mm)	Operational Staff	Site Diary	Operational considerations and carbon evaluation
Fuel Usage	Litres of petrol used Type of plant/fleet used (electric, diesel, model)	Operational Staff	Site Diary	Carbon evaluation

Table 1: Data collection plan

Trial Location Plan

The primary aim of the Supersite trials is to undertake a comparison analysis of surface courses with the current benchmark used by North Lanarkshire Council, traditional HRA. There were a total of eight trial sections along one site (Hirst Road), with six surface courses and two binder courses on the main straight stretch of the carriageway and a further two surface course sections at junctions – Styrelf® Bio-PMB X70 was tested on section 2 of the trial sections. All trial sites were completed on one B classification of road (Hirst Road).

TRIAL SECTION	BINDER COURSE			SURFACE COURSE			
	MATERIAL/METHOD	DEPTH (MM)	SUPPLIER	PRIMARY MATERIAL	INNOVATION	DEPTH (MM)	SUPPLIER
1	In-situ Recycling	110	Colas	HRA	GiPave®	50	Iterchemica/ Holcim
2	In-situ Recycling	110	Colas	HRA	Styrelf Bio-PMB	50	Total /Holcim
3	In-situ Recycling	110	Colas	HRA (warm mix)	HRA 35/14 Warm Mix	50	Holcim
4	In-situ Recycling	110	Colas	HRA	Traditional Surface HRA 35/14	50	Holcim
5	In-situ Recycling	4% CEM II and 4% calcined clay binder (150mm HBM recycled layer)	SPL	HRA	UltiPave Bio	50	Tarmac/ Holcim
6	In-situ Recycling	4% CEM II and 4% calcined clay binder (150mm HBM recycled layer)	SPL	HRA (warm mix)	HRA 35/14 Warm Mix	50	Holcim
Junction 1	Traditional Binder	60	Hochtief	14mm HardiPave	HardiPave®	40	Miles Macadam
Junction 2	Traditional Binder	60	Hochtief	14mm MilePave PMB	MilePave®	50	Miles Macadam

Table 2: Supersite trial information

Procedure

Site Preparation: The selected sites were cleaned, prepared and planed for the application of Styrelf® Bio-PMB X70. Loose debris and water were removed to ensure proper adhesion.

Material Application: Roads were prepped as per manufacturer's instructions prior to the products application. Styrelf® Bio-PMB X70 was applied by Holcim via a paver following conventional HRA processes.

Monitoring and Data Collection: The trial sites will be monitored over a period of 12 months. Data on surface condition, material performance, and environmental impact were collected at regular intervals.

Performance analysis: The performance of Styrelf® Bio-PMB X70 was evaluated based on criteria such as durability, resistance to traffic stress, and environmental impact. Comparisons were made versus traditional resurfacing to benchmark performance.

Data Analysis

The collected data was analysed to determine the effectiveness of Styrelf® Bio-PMB X70 as a surfacing material as an alternative to conventional HRA. Data analysis methods were used to evaluate the performance of Styrelf® Bio-PMB X70 versus a control section (HRA) along the same road. The analysis focused on:

- **Durability:** Assessing the longevity of the treated site and resistance to traffic and environmental stress;
- **Environmental Impact:** Evaluating the reduction in carbon emissions and use of recycled materials; and
- **Cost- Effectiveness:** Comparing the costs associated with Styrelf® Bio-PMB X70, including material, application, and maintenance costs.

The embodied carbon factors for trialled materials have been built based on supplier product data and supported from carbon factors sourced from OneClick LCA where required. An Environmental Product Declaration (EPD) has been produced for Styrelf® Bio-PMB X70 produced by Total Energies and provided to Holcim. Holcim have provided A1-A3 carbon values for the manufacturing of Styrelf® Bio-PMB X70 from Duntilland Quarry. Holcim's internal carbon tool was used to calculate these values. This tool follows the principles of EN 15804 and has been third party verified by Circular Ecology Ltd. The tool uses primary activity data from Holcim operations, secondary data coming primarily from the UK Government GHG emission factors and Inventory of Carbon and Energy v4.0 by Circular Ecology and University of Bath, with additional data supplied by Carbon Trust.

Circular Ecology Ltd verifies to recognised frameworks and standards used in lifecycle assessments, including ISO 14064, PAS 2050, ISO 14067, ISO 14040/44 and EN 15804.

This existence of a third party verified carbon tool provides objective verification that Holcim's carbon claims are transparent and can be independently validated. This positions Styrelf® Bio-PMB X70 as a credible alternative to conventional asphalt.

This live trial is unable to validate Total Energie's carbon sink claims of Styrelf Bio-PMB as no methodology or calculations to support these claims has been shared with Live Labs 2 CEDR team.

Carbon Appraisal

Carbon appraisal

Drawing on data collected through trials; a carbon assessment has been undertaken. [Table 3](#) establishes the parameters of the model, defines assumptions and outlines product specifications.

ASSUMPTIONS	JUSTIFICATION
All transportation is undertaken via diesel HGV.	Based on standard modelling assumptions from similar schemes.
Design life of pavement surface is 40 years.	Based on PAS 2080 guidance ² . At 40 years the binder course of HRA requires replacing.
Unit of measurement used is 'kgCO ₂ e/ m ² '.	Based on the best available data used to conduct carbon appraisals.
Traffic management activities were not included within this carbon assessment.	Traffic management differs between sites and local authorities so requires separate capturing, as a part of standard practice.
Government emission factor transport, HGV, diesel 2025 was used to calculate A5 for plant when a specific emission factor is unknown.	Based on the best available data at the time of this carbon appraisal.
This carbon analysis does not incorporate planing out activities within this assessment.	This is a BAU activity therefore is not influenced by this innovative process.
Where specific machine hour carbon emission factors were unavailable emission factors have been selected based on average kW power, sourced from OneClick LCA.	Based on the best information available at the time of the carbon appraisal.
To calculate the CO ₂ e emissions per tonne of aggregate from each quarry, Holcim utilised the total energy consumption for each quarry (Duntilland and Leven seat) over the previous 12 months. Each quarry's energy use was converted to an equivalent CO ₂ emission value then divided by the total tonnage of aggregate sold in that same period.	Based on the most up to date information the contractor (Holcim) had available at the time of this carbon analysis.
Holcim utilised Eurobitume's 2025 carbon emission factor for bitumen, 530kgCO ₂ e/ tonne ³ .	This figure is the most recent bitumen emission factor and is considered the industry standard.
Fuel consumption of dryers has been calculated by the amount of fuel used divided by the tonnage of asphalt supplied. Giving the CO ₂ e value per tonne of asphalt mixed can vary plant to plant based on tonnage supplied. Fuel type, efficiency etc.	Based on the best available data at the time of this carbon appraisal.
The emission factor used for fibre pellets used as standard in conventional asphalt production were sourced from ASPECT.	Based on the most recent emission factors available to the contractor (Holcim) for emission factor calculation. Holcim's internal carbon calculation tool has been externally verified by Circular Ecology and follow the principles of EN 15804.
The default emission factor used for RAP (reclaimed asphalt pavement) was sourced from ASPECT.	Based on the most recent emission factors available to the contractor (Holcim) for emission factor calculation. Holcim's internal carbon calculation tool has been externally verified by Circular Ecology and follow the principles of EN 15804.
The emission factor used for limestone filler was sourced from ICE v.3 2020.	Based on the most recent emission factors available to the contractor (Holcim) for emission factor calculation. Holcim's internal carbon calculation tool has been externally verified by Circular Ecology and follow the principles of EN 15804.
The EPD for Styrelf Bio-PMB has not been provided to Amey but has been supplied to Holcim.	Holcim has an NDA in place to receive the EPD. The EPD was used by Holcim to calculate the A1-A3 emission values and to populate its internal carbon calculation tool, which has been

² [2023-03-29-pas_2080_guidance_document_april_2023.pdf](#)

³ <https://eurobitume.eu/wp-content/uploads/2025/03/EB-GWP-Report-to-LCA-4.0-2025.pdf>

ASSUMPTIONS	JUSTIFICATION
	externally verified by Circular Ecology in accordance with EN 15804.
The carbon modelling for HRA with 0% RAP assumes equivalent material quantities and construction activities to those recorded for the supersite's HRA control section, ensuring a like for like comparison.	This approach controls key variables, reducing modelling uncertainty and making the carbon impact of RAP omissions directly attributable.
Carbon emission factor for HRA containing no RAP was sourced via One Click LCA from an EPD for Hot Rolled Asphalt surface course mixture (HRA 35/14) manufactured by Roadstone Limited and awarded an EPD by Eco Platform in 2025 (EPD-IES-0020174).	EPDs are prepared and verified to EN15804 and ISO 14025 standards, which makes this emission factor suitable for lifecycle modelling. One Click LCA is widely used within the industry to source and apply verified EPD data in construction carbon models.

Table 3: Carbon appraisal matrix

Carbon Modelling

The carbon modelling for the trials was conducted using the Future Highways Research Group (FHRG) Carbon Leadership Profiler Toolkit to collect and analyse primary carbon data from the trials, detailing emissions from materials, transport, construction activities and equipment use. Using this information the tool generated carbon profiles that identified emission hotspots and using the toolkit's emission database providing verified emissions factors to improve data accuracy.

One Click LCA was also utilised in modelling to support the FHRG Carbon Leadership Profiler Toolkit due to its large database of emission factors supported by Environmental Product Declaration (EPD).

Indicative results from carbon modelling for the Styrelf® Bio-PMB X70 works along section 2 of the Supersite on Hirst Road are presented graphically in [Figure 2](#), [Figure 3](#) and [Figure 4](#):

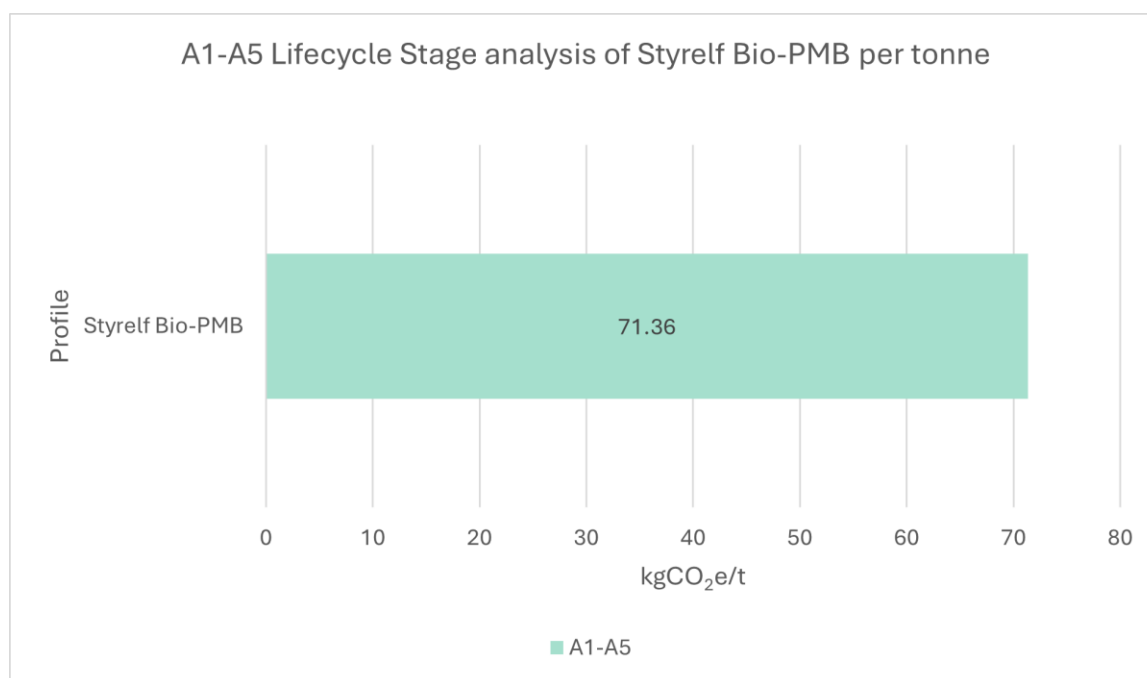


Figure 2: Carbon analysis of Styrelf® Bio-PMB X70 per tonne (50mm depth)

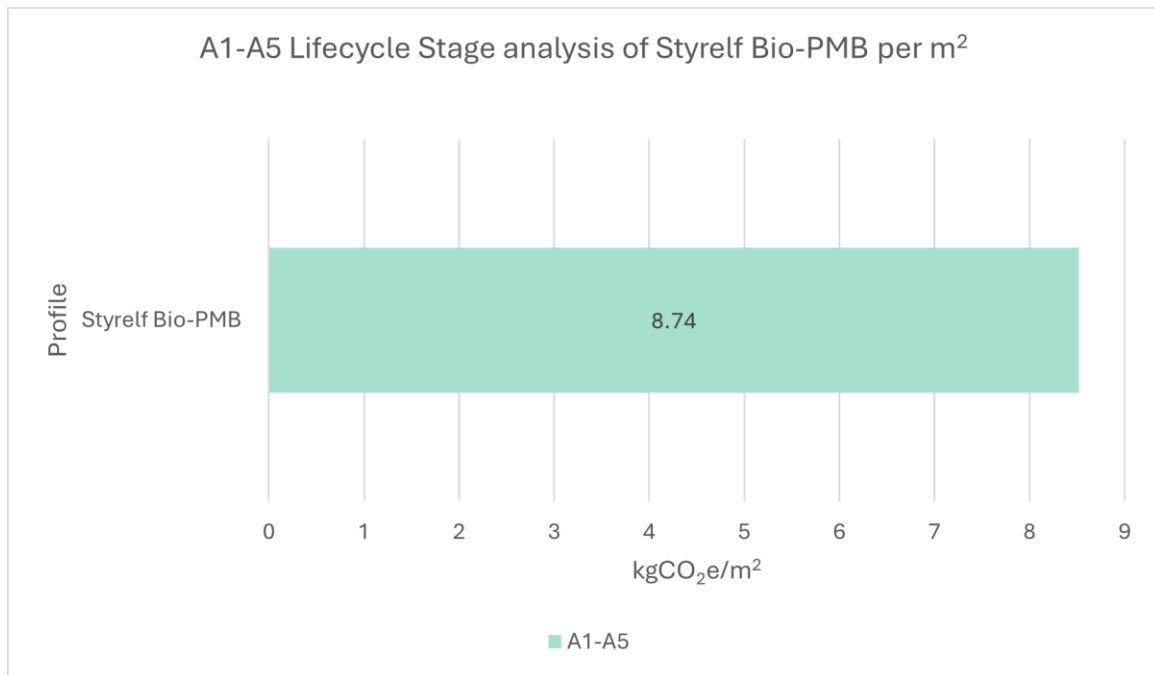


Figure 3: Carbon Analysis of Styrelf® Bio-PMB X70 per meter squared (50mm depth)

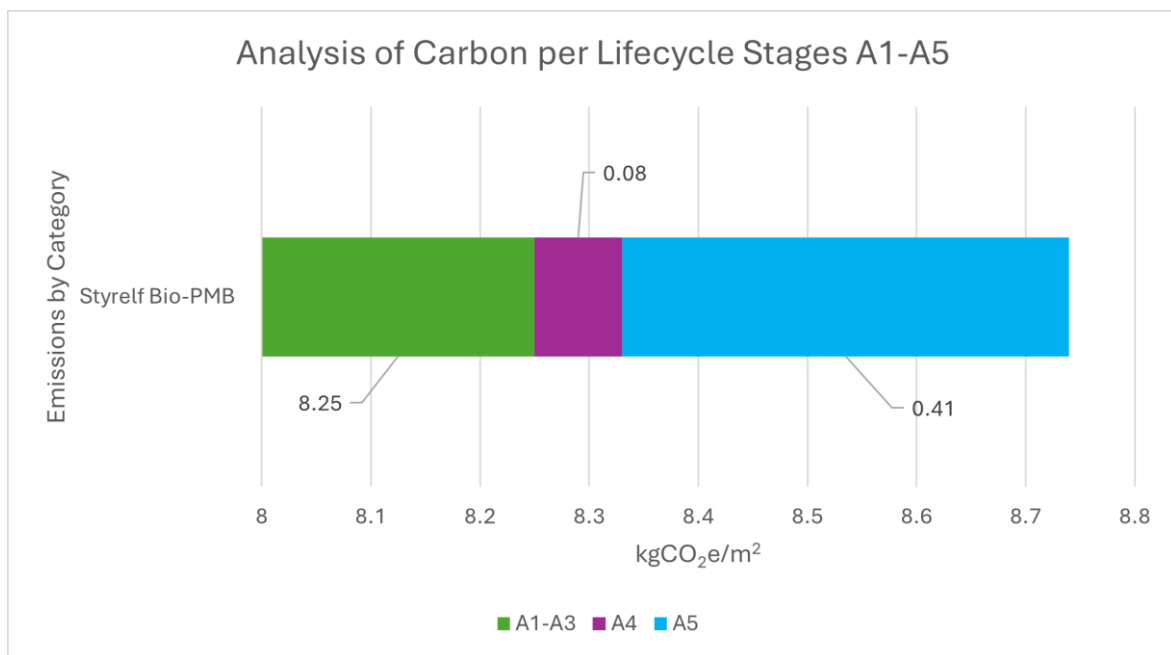


Figure 4: Lifecycle analysis A1-A5 of Styrelf® Bio-PMB X70 per m² (50mm depth)

Benchmarking

Styrelf® Bio-PMB X70 is yet to be used in North Lanarkshire. These trials are to allow for an analysis of the performance of Styrelf® Bio-PMB X70 in comparison to conventional HRA on the same road of the same traffic loads. This would be the traditional option for re-surfacing if Styrelf® Bio-PMB X70 was not used. This allows for comparisons between Styrelf® Bio-PMB X70 versus BAU surfacing within the carbon analysis.

Comparative analysis results are presented graphically in [Figure 5](#) and [Figure 6](#):

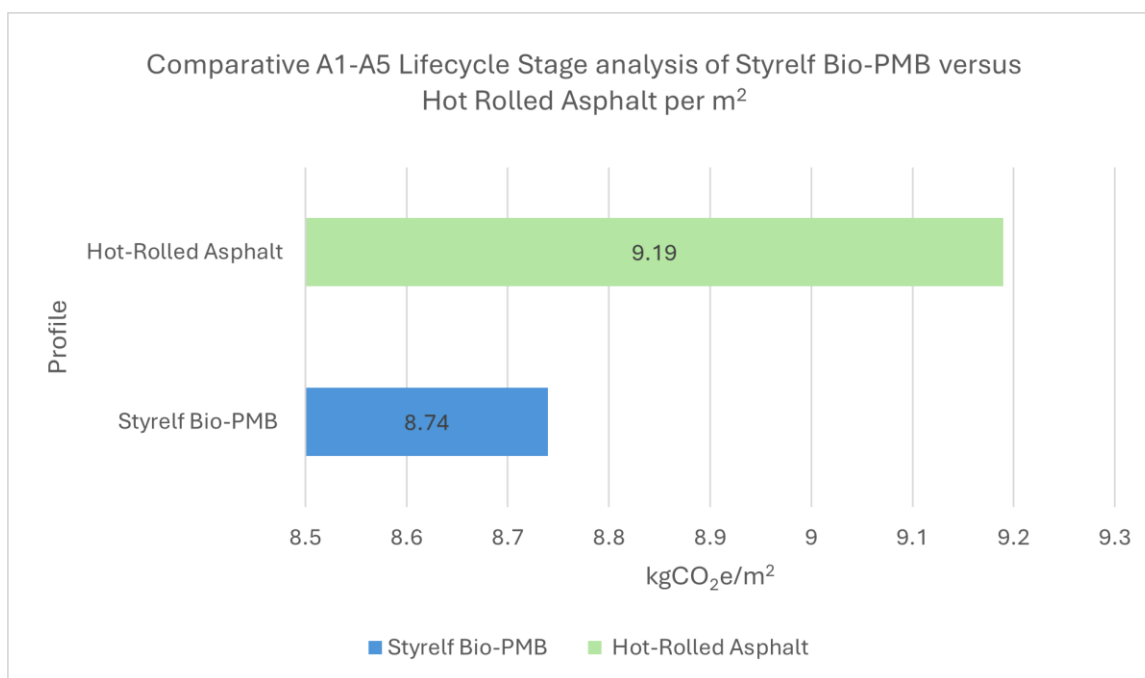


Figure 5: Comparative carbon analysis Styrelf® Bio-PMB X70 versus HRA per m² (50mm depth).

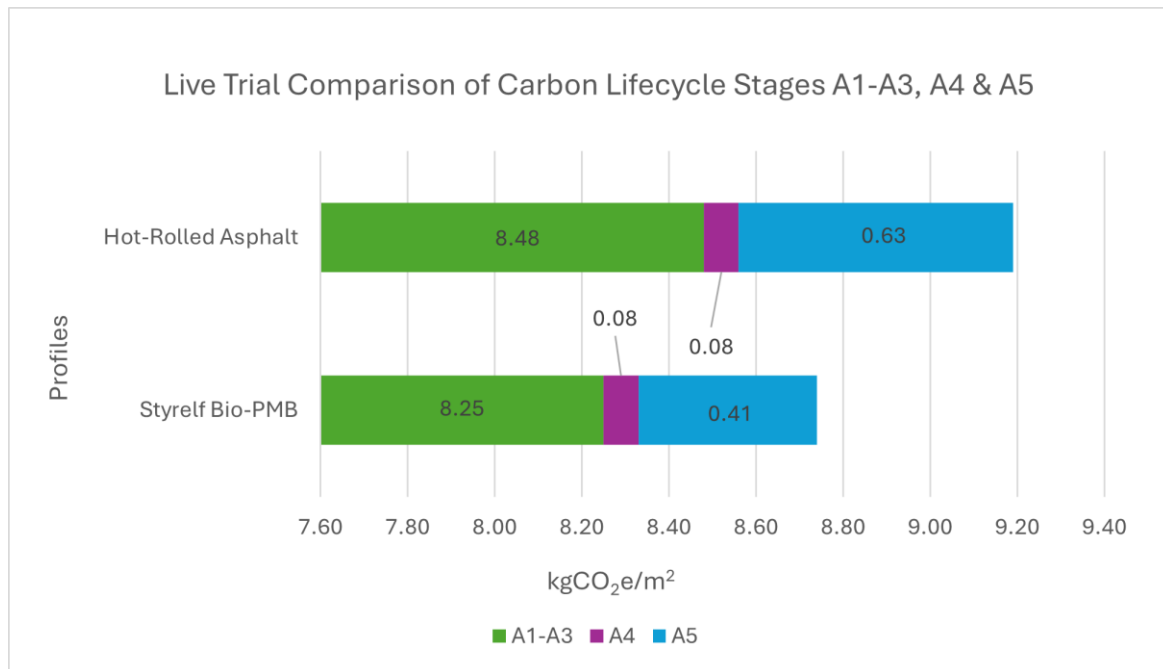


Figure 6: Comparative carbon analysis of Styrelf® Bio-PMB X70 versus HRA, lifecycle stages A1-A5.

The benchmark HRA control section on the supersite contained 15% RAP while the Styrelf Bio-PMB X70 mix included 10% RAP. RAP content varies by Local Authority, due to specification and design. To provide a conservative, like-for-like comparison, Styrelf Bio-PMB X70 has been modelled against an HRA baseline with no RAP content to demonstrate further potential carbon savings. Results from this modelling are represented graphically below in [Figure 7](#):

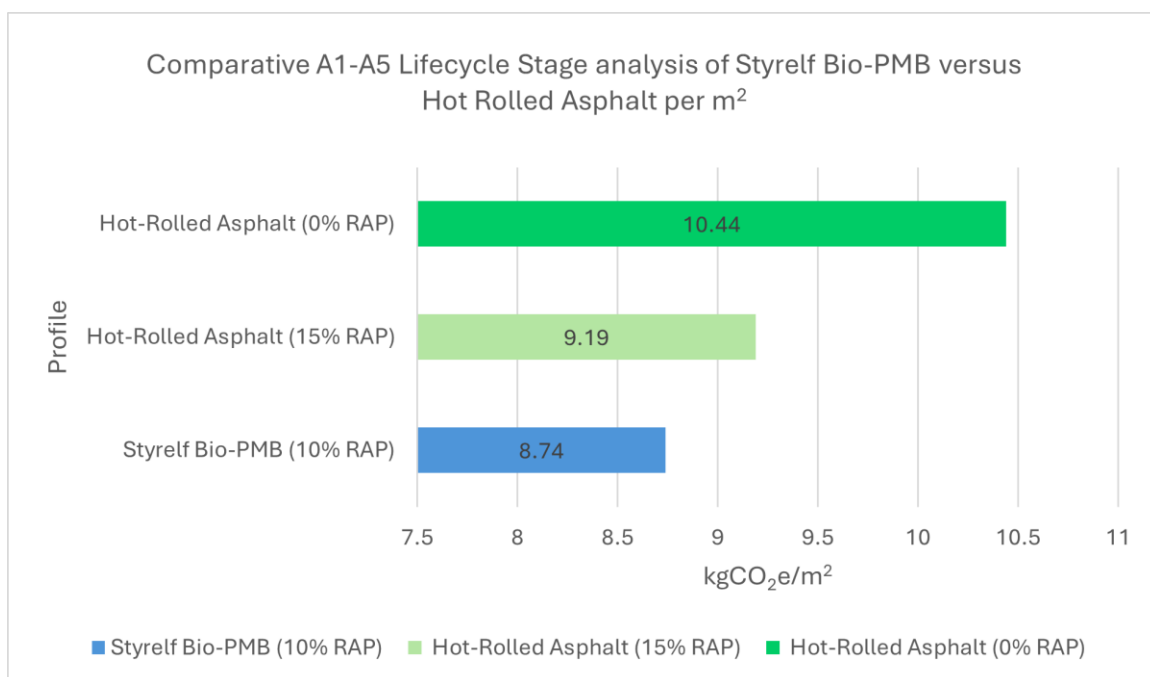


Figure 7: Comparative carbon analysis Styrelf Bio-PMB X70 versus HRA with no RAP content per m² (50mm depth)

MATERIAL	COMPOSITION	APPLICATIONS	PERFORMANCE	INSTALLATION	SUSTAINABILITY
HRA	HRA is a dense, gap-graded bituminous mix comprising of a mortar of fine aggregate (sand), filler and bitumen. It is hot applied via a paver. Immediately after paving, the pre-coated high-PSV chippings are rolled into the hot mix to lock in a positive texture for skid resistance.	HRA is predominately used on high-speed and heavily trafficked roads where durable, dense, low-void wearing course is required such as motorways, A-roads, bus lanes, roundabouts etc.	The densely mortared matrix makes HRA impermeable and resistant to rutting and deformation under heavy loads. Its sharp chippings protruding from the surface maximises adhesion and increases skid resistance at even at speed. HRA can be susceptible to rutting if the mix or compaction is incorrect under heavy traffic but is the proven baseline with well-understanding of mix suitability.	HRA is supplied and laid on site at approximately 160-180 degrees – at the Hirst Road site WMA was applied at approximately 155-156 °C. Laid using standard hot-mixing plant and standard paving/rolling practices for HRA. After initial compaction, pre-coated chippings are spread at a controlled rate and rolled in immediately to embed them into the mortar. HRA has well-established specifications on procedures across the industry.	Traditional HRA can incorporate reclaimed asphalt pavement (RAP) percentages, though high fines and virgin bitumen grades often limit RAP rates to maintain mortar cohesion.
Styrelf® Bio-PMB *	Styrelf Bio-PMB is a polymer-modified bitumen designed to combine the mechanical benefits of elastomeric PMBs with biogenic material to create a carbon sink.	Styrelf PMBs are used for high stress, heavy loading and specialist applications such as airfields where high durability and resistance to rutting is a high priority.	PMB performance is similar to conventional hot mix asphalt. The inclusion of bio-binder and polymer helps to reduce ageing and improving whole life durability. Long term performance data for Bio-PMBs is still being accumulated.	Bio-PMB follows the established specifications and procedures of hot mix asphalt. Modified polymers and biogenic material is added into the composition during production at the plant with installation following conventional hot mix asphalt/ warm mix asphalt procedures.	Bio-binder PMBs have potential to reduce embodied carbon emissions as the biogenic material acts as a carbon sink, 'locking in' carbon. Bio-binder PMBs can also be used in warm mix asphalt which requires reduced fuel consumption due to lower temperatures during manufacturing and installation. Asphalt containing bio-binder PMBs can incorporate RAP percentages within its composition. However, the use of biogenic material within road construction raises questions to whether this can be considered to be a true carbon saving. There have also been concerns whether the stored biogenic carbon may be re-released at the surface materials end of life.

Table 4: Styrelf® Bio-PMB Appraisal

*All factors assessed as part of the appraisal of Styrelf® Bio-PMB X70 has been built on supplier provided material and are not drawn from the live Supersite trial.

Life Cycle Stage	Baseline Carbon Emissions (HRA) (kgCO ₂ e)	Styrelf® Bio-PMB X70 Carbon Emissions (kgCO ₂ e)	Difference (%) (Increase/ Reduction)
A1 – A3	17,799.73	17,323.54	2.68%
A4	163.98	170.04	3.7%
A5	1,326.71	857.62	35.36%

Table 5: Lifecycle Stage Comparison to BAU

Carbon Benefits and Considerations (Matrix)

Table 6 presents the findings of the carbon benefits and considerations matrix for Styrelf Bio PMB X70 application. **All scoring is bold and underlined.**

Technical data used during benchmarking and the carbon benefits and considerations matrix were supplied by the manufacturer and are not derived from the Supersite live trial in North Lanarkshire. While reliance on supplier-provided information may introduce uncertainty in confidence levels, the information and data represent the best available evidence at the time of the appraisal. Data quality has been considered when selecting supplier information and, where possible, supplier values were chosen from manufacturers' standard test reports, specifications and product datasheets that reference recognised test methods and certification.

BENEFIT/LOAD UNDER REVIEW	CONSIDERATIONS	SCORING SYSTEM	JUSTIFICATION
Costs	Transport, operational, material procurement	1 - Significant additional costs <u>2 - Costs approximate baseline</u> 3 - Costs significantly lower than baseline	Polymer modification and bio-content add material cost when compared to conventional standard bitumen. However, the reduced maintenance requirements and potential increased longevity have potential to bring whole-life cost is close to the baseline hot mix asphalt.
Maintenance	Design life, maintenance burden, on time for plant	1 – Significantly more maintenance/lower longevity 2- Approximately same maintenance/similar longevity <u>3 – Significantly less maintenance/higher longevity</u>	Using modified bitumen binders with elastomeric polymers improves rutting and fatigue resistance, storage stability, cohesiveness, elongation capacity and resistance to ageing. This helps to support longer resurfacing intervals and lower routine maintenance demands.
Scalability	Manufacturing facilities	1 - Lab testing only 2 - In process of commercialisation w. small scale manufacture <u>3 - Already has market presence with developed supply chain</u>	Bio-PMB's have market presence with an established supply chain within the UK.
Compliance with specifications	Requirements for standards departures	1 - Requires significant departure(s) from standard and has not been used before by end client 2 - Requires some departure from standard, but has been used before by end client <u>3 - Does not require any departure from standard.</u>	Styrelf Bio-PMB uses standard paving equipment and can meet existing HAPAS/National Highways requirements with minor specification notes rather than wholesale departures.
Environmental	Nature-based solution	1 - Would have significant net disbenefit for environmental factors (noise, AQ, biodiversity, landscape etc) <u>2 - Would have negligible net</u>	Environmental benefits arise from reduced interventions and lower embodied carbon due to the presence of less plant on site, reducing fuel consumption, odour and dust related with maintenance activities. Issues arise from the sourcing of biomass as this may drive land-use change or

BENEFIT/LOAD UNDER REVIEW	CONSIDERATIONS	SCORING SYSTEM	JUSTIFICATION
		<p><u>benefit/disbenefit or no overall change regarding environmental factors</u></p> <p>3 - Would have significant net benefit/disbenefit for environmental factors.</p>	<p>biodiversity loss, it is important that the source of the biomass is declared. There are also issues over whether stored biogenic carbon may be re-released at surfaces end of life.</p>
	Road noise	<p>1 - Would have significant net disbenefit</p> <p><u>2 - Would have negligible net benefit/disbenefit or no overall change regarding</u></p> <p>3 - Would have a significant net benefit</p>	<p>The binder choice within asphalt will have limited direct effect on operational noise levels.</p> <p>By increasing maintenance intervals, Bio-PMB has potential to reduce construction noise through reducing the requirement of plant on site.</p>
	Climate resilience/future proofing	<p>1 - Would have significant net disbenefit</p> <p>2 - Would have negligible net benefit/disbenefit or no overall change regarding</p> <p><u>3 - Would have a significant net benefit</u></p>	<p>Styrelf Bio-PMB's improved binder elasticity and reduced ageing, provides greater resistance to thermal cracking and rutting. Supporting climate resilience.</p>
Risk and safety	H&S impacts, safety testing data	<p>1 - Would present increased risk or safety versus BAU option</p> <p><u>2 - Would present no overall risk increase or safety impact versus BAU option</u></p> <p>3 - Would present lower risk or safety impact versus BAU option.</p>	<p>No overall increase in H&S risk versus conventional hot mix asphalt when installed by trained contractors.</p>
Technology Readiness Level	Is it commercially available, is there enough R&D?	<p>1 - Not yet commercially available</p> <p>2 - Commercially available from worldwide suppliers</p> <p>3 - Commercially available from European suppliers</p> <p><u>4 - Commercially available from UK suppliers</u></p> <p>5 - Commercially available from local suppliers</p>	<p>Bio – PMBs are commercially available from UK suppliers.</p>
Constructability	How easy is it to handle on site, install, recover, curing time, specialist equipment/training, storage?	<p>1 - Specialist contractors, time on site and/or equipment required</p> <p><u>2 - No considerations required above and beyond baseline solution</u></p> <p>3 - Significant benefits to on-site activity / ease of installation</p>	<p>Largely compatible with existing plant and paving practices. Bio-PMBs do not require any specialist installation methods.</p>

BENEFIT/LOAD UNDER REVIEW	CONSIDERATIONS	SCORING SYSTEM	JUSTIFICATION
Supply Chain	Material availability	1 - Novel materials used with limited supply 2 - Materials are available with some supply restrictions 3 - Materials are readily available	Questions arising over the availability and variability of biomass would - constrain large-scale rollout.
Circular Economy	Recycled content	1 - Virgin materials are used with little or no recycled content 2 - Materials contain a level of recycled content 3 - Materials are predominantly recycled and/or use novel sources of recycled content that would otherwise be discarded as waste	The binder modified asphalt can include the corporation of RAP (reclaimed asphalt pavement), however concerns may be raised over the source of biomass, ideally feedstocks will be residues however, the source of biomass is often not given.
	Ease of recycling	1 - Minimal recycling of material possible upon removal 2 - Limited recycling is possible and/or significant reprocessing required 3 - Reuse/recycling is easy and convenient	There are issues over whether stored biogenic carbon may be re-released at surfaces end of life.

Table 6: Carbon benefits and considerations matrix

Long-Term Performance Analysis

The carbon analysis within this report do not contain lifespan analysis. This will be finalised dependent upon the publishing of longevity test results in partnership with the University of Nottingham.

These tests will focus on the following:

- Durability and Aging Resistance,
- Skid Resistance and Surface Integrity,
- Lifecycle Carbon Savings,
- Traffic and Environmental Stress Testing,
- Optimal Reapplication Intervals.

Conclusion & Recommendations

Conclusions

The live trial of Styrelf Bio-PMB has demonstrated some promising results in advancing sustainable road surfacing practices. Styrelf Bio-PMB's integration of biogenic/bio-based binder as a substitute for petroleum bitumen within the asphalt's composition, offers a significantly lower embodied carbon when compared to conventional Hot Rolled Asphalt (HRA). This trial has validated carbon reduction claims for lifecycle stages A1-A5 (raw materials, distribution transport, manufacturing, transportation to site and construction). Carbon analysis demonstrated a 5% reduction in carbon emissions, with most savings being experienced in construction related emissions (A5).

Analysis did highlight an 3.7% increase in carbon emissions during transport stage (A4); however, these emissions are site specific and will vary for each Local Authority. Authorities situated closer to the Total Energies storage depot are likely to incur lower A4 emissions. Consequently, the observed increase is not considered significant and does not materially affect the embodied carbon results from this trial.

Styrelf Bio-PMB also holds potential to offer further carbon savings when compared with HRA not containing any Reclaimed Asphalt Pavement (RAP). RAP usage varies depending on the HRA mix specification and Local Authority requirements. To allow for a more conservative comparison Styrelf Bio-PMB has been modelled against HRA containing no RAP. This modelling demonstrated a potential to equate for 16% carbon savings across cradle to construction emissions.

Styrelf Bio-PMB does not change standard HRA production, laying and compaction processes, and requires no specialist plant or unusual installation. This indicates that Styrelf Bio-PMB has potential to be integrated into existing delivery practices without major changes to site workflow, training or equipment, supporting more straightforward trial scaling where material supply permits.

While Styrelf Bio-PMB has shown reduced carbon emissions in this trial when compared to conventional HRA, issues arise with the use of bio-genic materials on whether these results constitute a genuine, permanent carbon saving. Biogenic carbon accounting is highly sensitive to feedback origin, allocation rules and the timescale over which biomass regrows; if feedstock is sourced from dedicated crops or cause indirect land-use change, the net climate benefit can be overstated. There have also been concerns whether biogenic carbon stored in binders is not necessarily permanent. Processes during high-temperature recycling processes, incineration or degradation at end of life and re-release carbon, reducing or reversing the sequestration claim. Evidence of sustainable feedstock sourcing and monitored end-of-life processes are essential to substantiate any carbon savings.

Recommendations

It is recommended that a robust long-term monitoring (over 5+ years) is implemented at re-surfaced sites to comprehensively evaluate performance and verify lifecycle carbon savings. This further long-term monitoring will allow for more expansive carbon modelling to assess end-of-life scenarios to provide a more comprehensive understanding of whole life carbon emissions.

It is recommended that Total provide the biogenic carbon methodology and feedstock certification that demonstrate origin and sustainability credentials. Total should also define and require explicit end-of-life for the material, including likely carbon re-release routes and associated mitigation measures.

Total holds a verified EPD for Styrelf® Bio-PMB X70, however it is not currently publicly accessible to Local Authorities. It is advised that Total should publish the full EN 15804 Environmental Product Declaration (EPD) publicly. If immediate full release is not feasible, an alternative a third-party-verified, non-confidential one-page EPD summary is recommended to be issued with commitment to a clear, time-bound plan for making the complete EPD available. Public access will remove procurement barriers, enable independent verification, and reduce reputational risk, while a verified summary preserves legitimate commercial sensitivities during the transition.