



Centre of Excellence
for Decarbonising Roads

GIPAVE LIVE TRIAL EVALUATION REPORT

Live Labs 2 North Campus

This report presents the findings of a live trial evaluating GiPave®, a graphene-enhanced polymeric binder additive, as a sustainable alternative to Hot Rolled Asphalt (HRA). GiPave® demonstrated overall lower carbon emissions (A1-A5) than HRA and offers potential further carbon savings due to high resistance claims, extending service life. Recommendations drawn from this trial include implementing a robust monitoring period to verify these claims and highlight whole-life carbon savings.

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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 GiPave[®], described by the manufacturer as a graphene-enhanced polymeric super modifier containing recycled plastics. GiPave[®] is an asphalt additive which increases the materials durability leading to lifetime extensions of the surface.

GiPave was trialled as part of the Supersite Trial (a single stretch of highway trialling a number of materials and techniques) along Hirst Road in North Lanarkshire. GiPave was trialled as a surface course within section 1 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 GiPave 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.

GiPave[®]'s primary carbon advantage arises from materially lower A1–A3 embodied emissions and the additive's capacity to extend surface life, which reduces the frequency of maintenance over a pavement's life. Lower maintenance frequency reduces repeated construction stage emissions and user sector disruption. The presence of recycled plastic in the modifier further reduces reliance on virgin materials. The verified EPD and third-party carbon calculation for GiPave[®] provide transparent inputs for robust lifecycle comparison and procurement.

The findings from the trial show that GiPave demonstrated a reduction in carbon intensity when compared with conventional HRA, with trial results showing 8.57 kgCO₂e/m² versus 8.87 kgCO₂e/m² for baseline HRA (both applied at a depth of 50mm), indicating strong carbon efficiency when applied under the conditions tested. The primary driver of the carbon savings is the materially lower A1–A3 embodied emissions associated with the GiPave[®] binder and the inclusion of recycled plastic in the modifier. These material stage advantages, coupled with the product's potential to extend service life, reduce the need for repeated maintenance interventions and therefore lower cumulative construction stage and user sector emissions over time.

The presence of a third-party verified A1–A3 calculation and an independently verified EPD increases confidence in the reported embodied carbon inputs and enables reliable benchmarking across local authorities.

Introduction

This Evaluation Report provides a high-level assessment of GiPave, an emerging sustainable material in highways, construction and maintenance, focusing on its environmental impact, product viability, and alignment with future infrastructure needs. GiPave is a graphene additive which is added to conventional hot-rolled asphalt (HRA) to create a graphene enhanced asphalt which offers increased durability and reducing maintenance requirements.

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 GiPave trial has been evaluated against conventional HRA.

The carbon evaluations for GiPave 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>GiPave® - Iterchimica</p> | <p>GiPave® is a graphene enhanced polymeric super modifier added to asphalt to increase the durability of the surface material.</p> <p>GiPave® contains a percentage of recycled plastic within its content.</p> | <p>This product produced 8.81 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 4% 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 GiPave contained 3%. To allow for a more complete comparison, carbon modelling of GiPave and HRA 0% RAP has been completed. This modelling demonstrated a 16% reduction.</p> <p>A core marketing feature of GiPave is its enhanced durability, attributed to the graphene additive. Carbon modelling extending GiPave®'s service life by five years compared to a conventional HRA mix results in a 54.69% reduction in emissions.</p> | <p>It is considered that, this product has a potential in the road construction and maintenance industry, particularly in projects prioritising sustainability.</p> <p>GiPave® has shown material stage carbon savings when compared to HRA within this trial, proving it can deliver reduced-carbon surfacing in live environments.</p> <p>These results support GiPave®'s durability claims and its inclusion in surfacing programmes, demonstrating its applicability and potential for widescale carbon savings across local authority networks. A monitoring programme of at least five years is required to verify long-term durability and quantify additional carbon savings from any extended asset service life.</p> |

Methodology

Trial Design

The GiPave trail was designed to evaluate the performance, durability, and environmental impact of the material. The trial was conducted as part of the larger Supersite trial (a single stretch of highway trialling a number of 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.

GiPave® was applied to section 1 of Hirst Road which had previously undergone cold insitu 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.

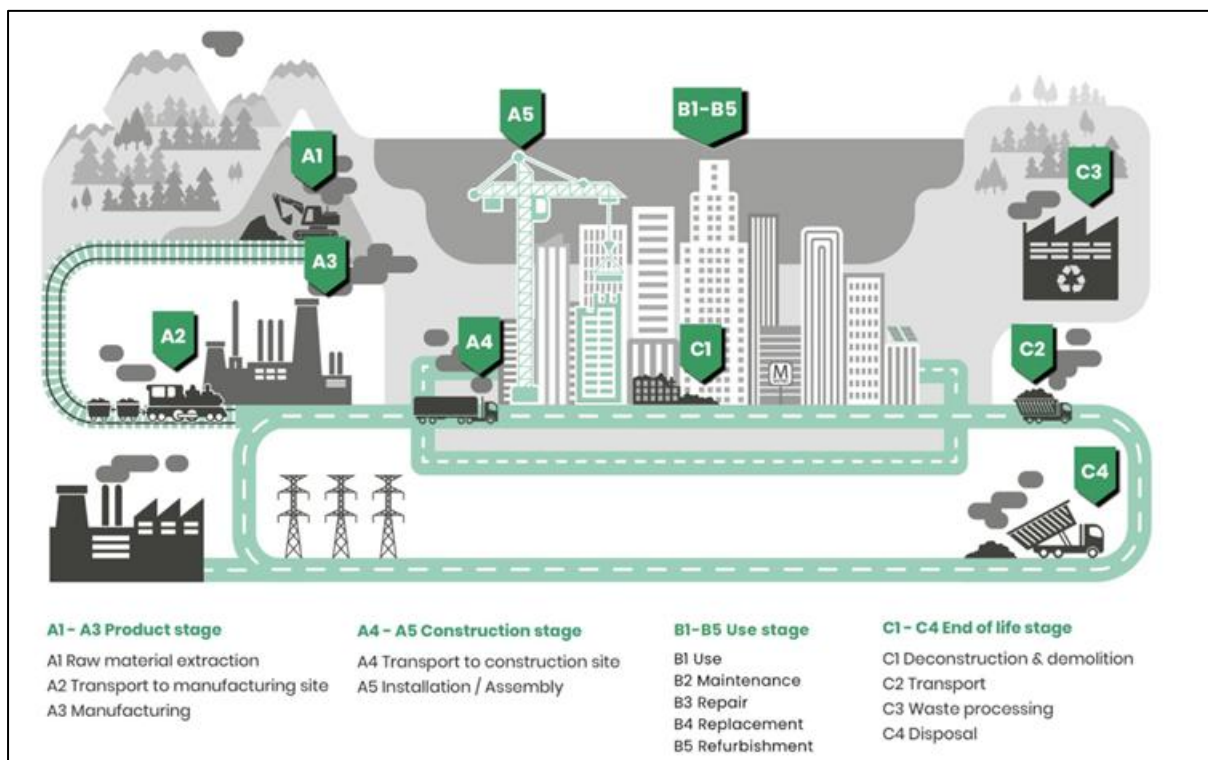


Figure 1: Carbon Lifecycle Stages¹

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 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 with hot-rolled asphalt (HRA) and had severely deteriorated, requiring urgent maintenance.

Data Collection Plan

The following data items were collected to ensure a thorough evaluation of GiPave® 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 GiPave | 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 GiPave used | Operational staff & Carbon Lead | Site Diary | Cost and Carbon Evaluations |
| Cost | £ for GiPave £ 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 NLC, 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 – GiPave® was tested on section one of these 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 planned for the application of GiPave®. 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. GiPave® 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 GiPave® 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 GiPave® as a surfacing material as an alternative to conventional HRA. Data analysis methods were used to evaluate the performance of GiPave® 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 GiPave, 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 and third party verified for GiPave®. The EPD has been completed by Eco Platform in accordance with ISO 14025:2006 and EN 15804:2012+A2:2019/AC:2021 and third party verified by ACCREDIA.

Holcim have provided A1-A3 carbon values for the manufacturing of GiPave at 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.

The existence of an EPD and the use of a third party verified carbon calculation tool provides objective verification that GiPave®'s carbon reduction claims are based on transparent, independently validated, and whole-life carbon data. This positions GiPave® as a credible alternative to conventional asphalt.

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 part of standard practice. |
| Government emission factor transport, HGV, diesel 2025 was used to calculate A5 for plant when a specific emission factor was unavailable. | 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 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 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 EN 15804 principles. |
| 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 EN 15804. |
| The comparative carbon modelling for GiPave and HRA assumes a standard 20-year service life for HRA and models a scenario in which GiPave extends the surface material's service life by an additional five years. Modelling assumes after 20 years HRA requires planing and re-installing. | Based on PAS 2080 guidance. |

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>

| | |
|---|--|
| <p>The service-life scenario modelling does not include emissions or impacts from lifecycle stages B1–B9.</p> | <p>This information was not available at the time of this carbon analysis. Therefore, these stages have been excluded to ensure service-life scenario modelling to maintain a clear, auditable scope focused on construction-phase and embodied impacts where robust, project-specific data are available.</p> |
| <p>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.</p> | <p>This approach controls key variables, reducing modelling uncertainty and making the carbon impact of RAP omissions directly attributable.</p> |
| <p>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).</p> | <p>EPDs are prepared and verified to EN15804 and ISO 14025 standards, which makes this emission factor suitable for lifecycle modelling.</p> <p>One Click LCA is widely used within the industry to source and apply verified EPD data in construction carbon models.</p> |

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 highlighted key emission hotspots, drawing on the toolkit's verified emissions-factor database to improve overall 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 Declarations (EPD). The carbon emission factor for GiPave has been supplied by Holcim. This value was calculated using a combination of the EPD as well as third-party verified carbon calculators.

Indicative results from carbon modelling for the GiPave® works along section 1 of the Supersite on Hirst Road, expressed in kgCO₂e/t and kgCO₂/m². This presentation of emissions enables direct comparison across different surfacing materials, to highlight carbon-efficient options and to support data-driven decision making for reduction strategies. Results are presented graphically in [Figure 2](#), [Figure 3](#) and [Figure 4](#):

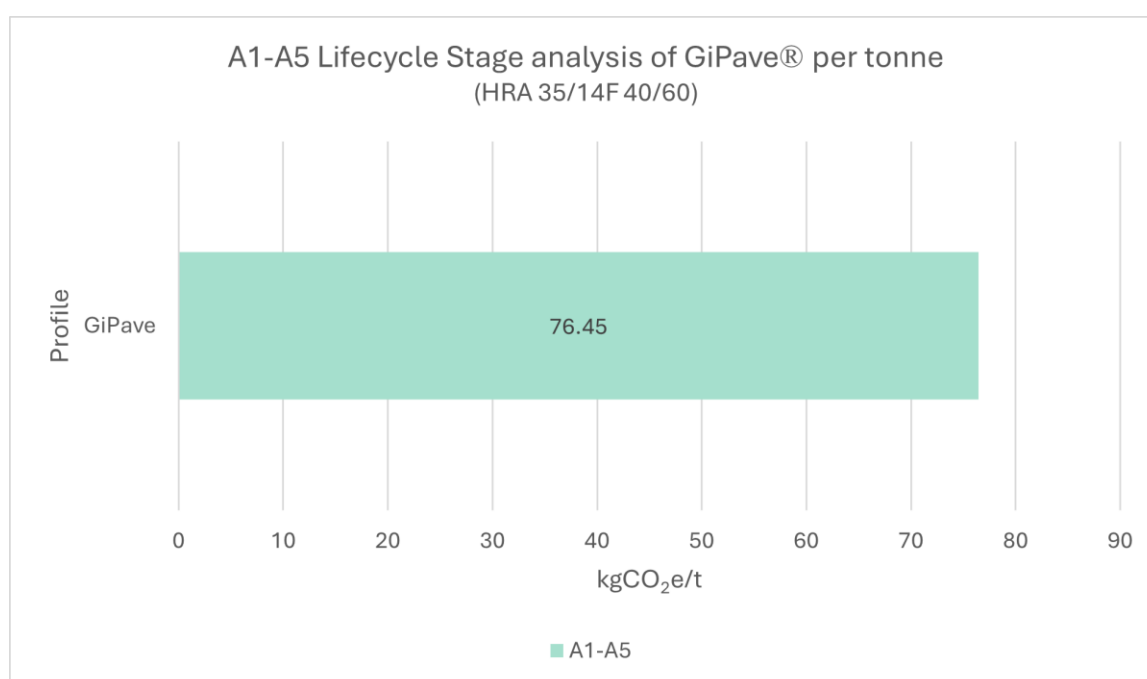


Figure 2: Carbon analysis of GiPave per tonne (50mm depth)

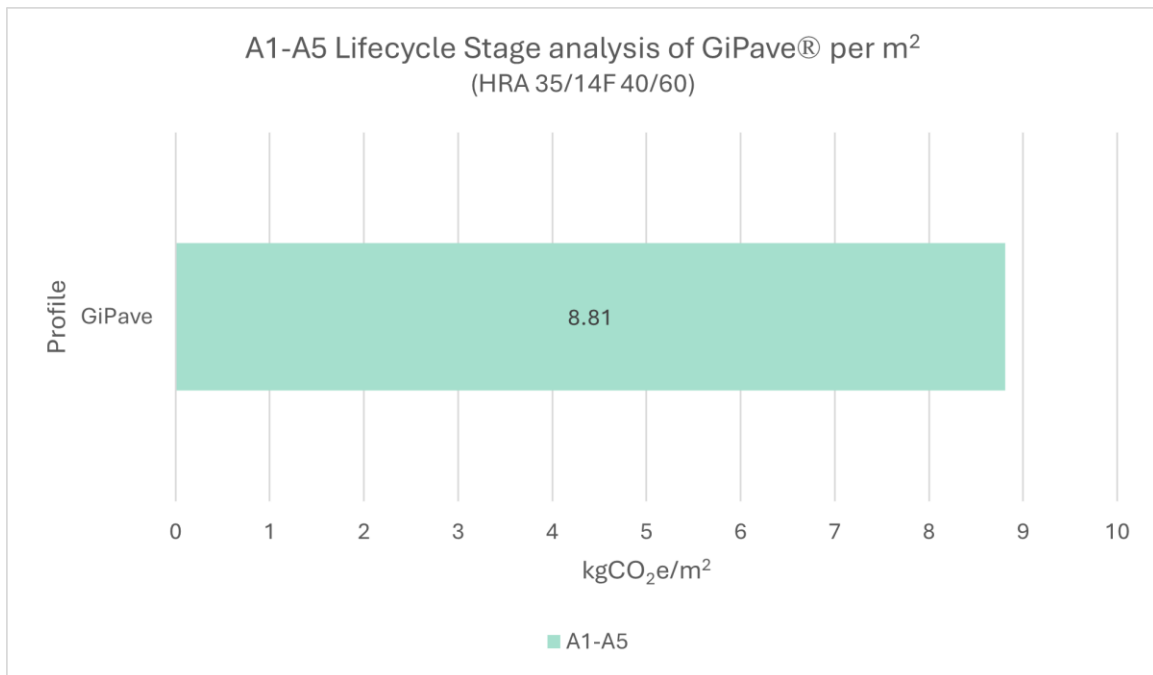


Figure 3: Carbon Analysis of GiPave per meter squared (50mm depth)

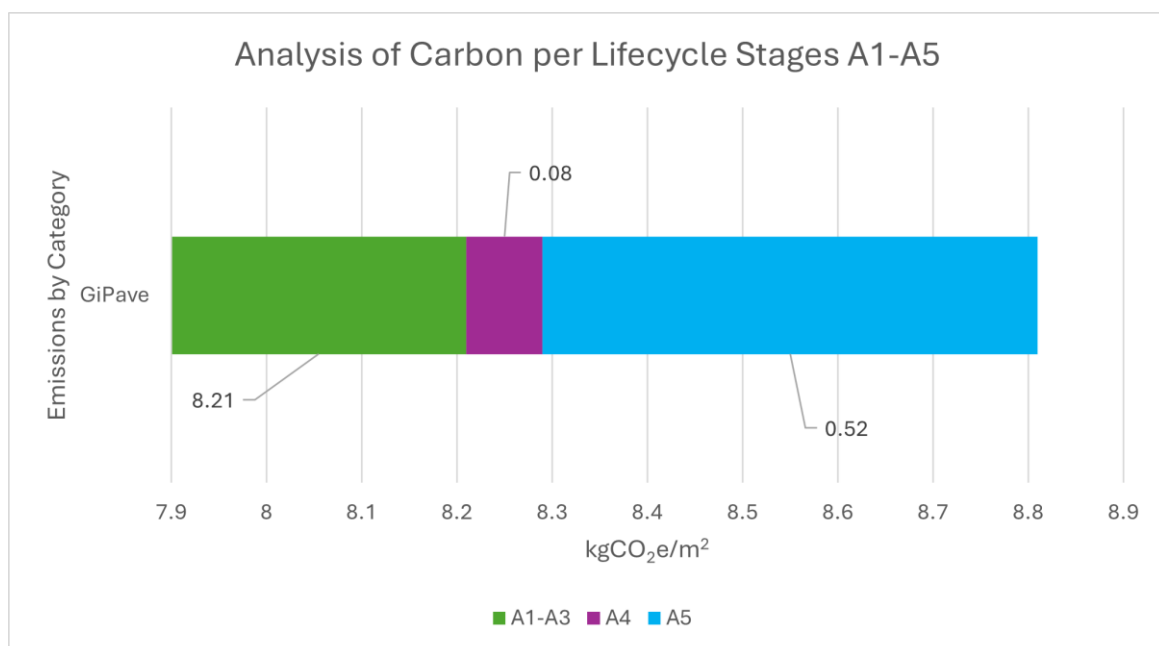


Figure 4: Lifecycle analysis stages A1-A5 of GiPave per m² (50mm depth)

Benchmarking

Until this trial, GiPave was yet to be used by North Lanarkshire Council. These trials are to allow for an analysis of the performance of GiPave in comparison to conventional HRA on the same road of the same traffic loads. This would be the traditional option for re-surfacing if GiPave was not used. This allows for comparisons between GiPave versus BAU surfacing within the carbon analysis.

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

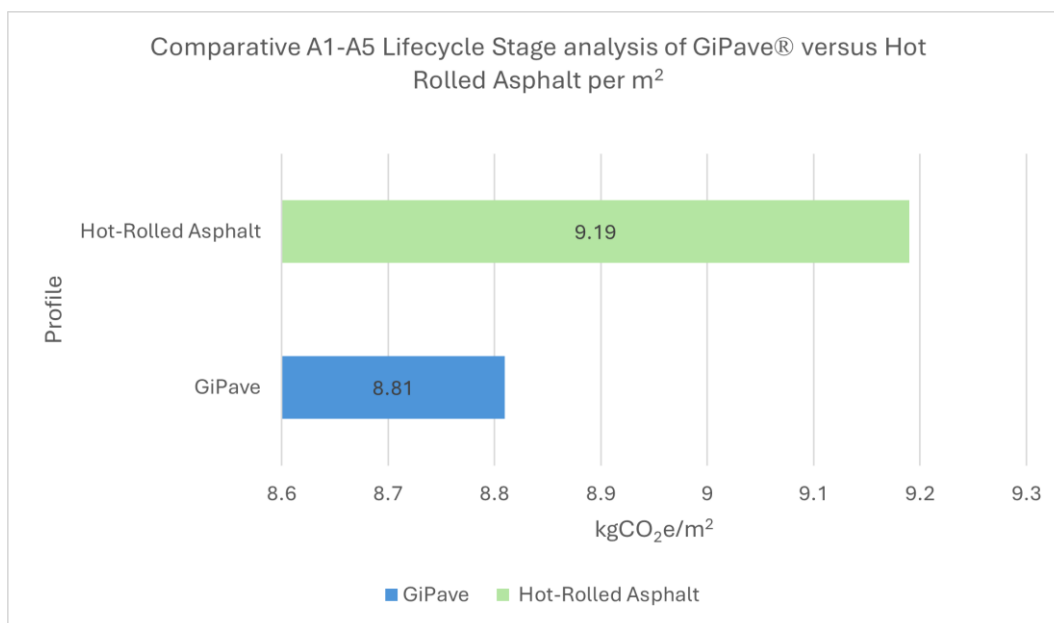


Figure 5: Comparative carbon analysis GiPave versus HRA per m² (50mm depth).

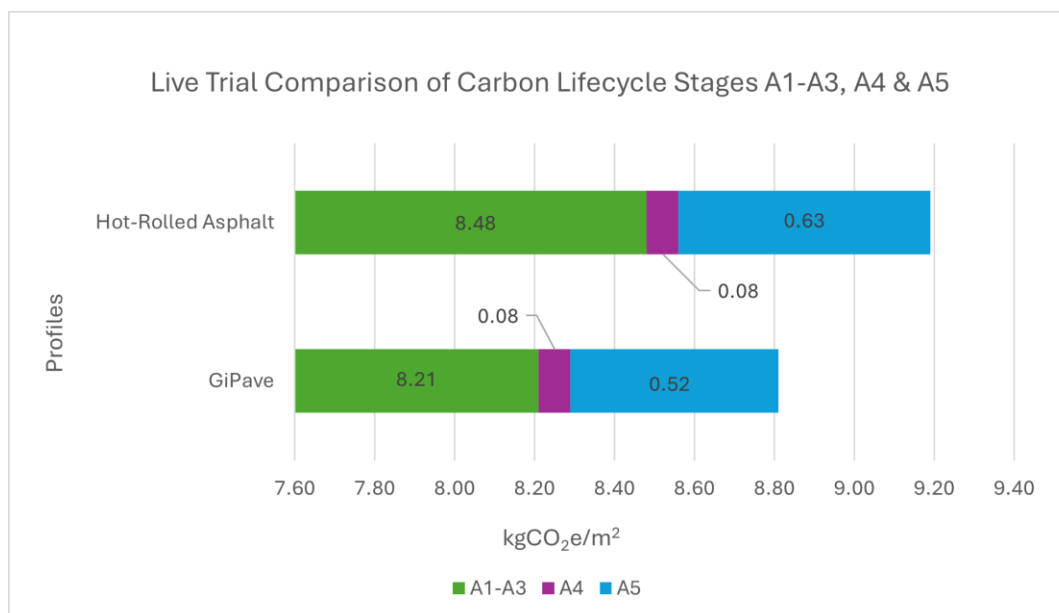


Figure 6: Comparative carbon analysis of GiPave versus HRA, lifecycle stages A1-A5.

Comparative carbon modelling of GiPave under the scenario that the graphene additive increases service life by 5 years. Results from this modelling are represented graphically below in [Figure 7](#):

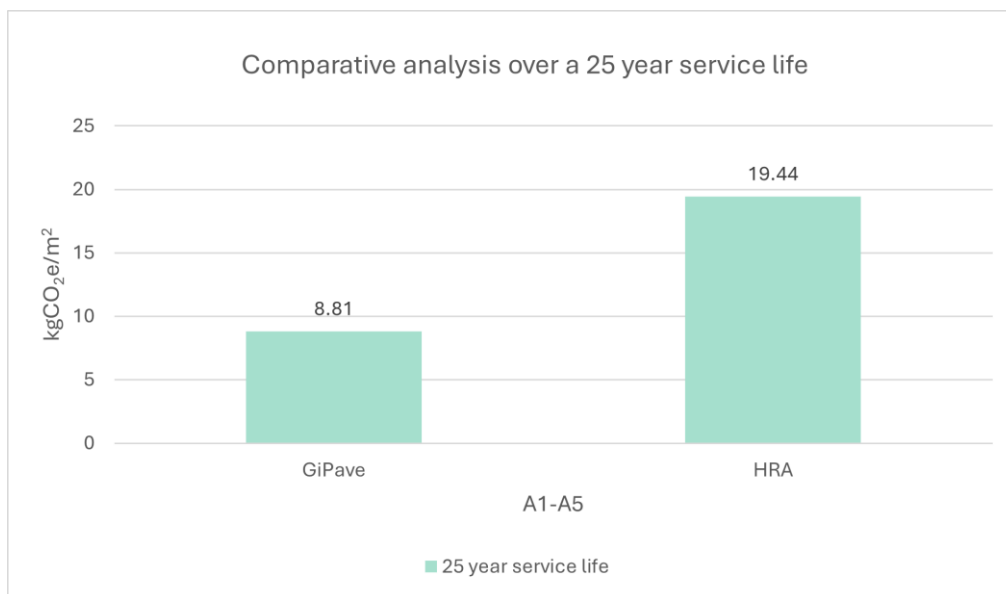


Figure 7: Comparative carbon analysis GiPave versus HRA per m² (50mm depth) over a service life of 25 years

The benchmark HRA control section on the supersite contained 15% RAP while the GiPave mix included 3% RAP. RAP content varies in HRA mixes by Local Authority; this is dependent on specifications and design. To provide a conservative, like-for-like comparison, GiPave 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 8](#):

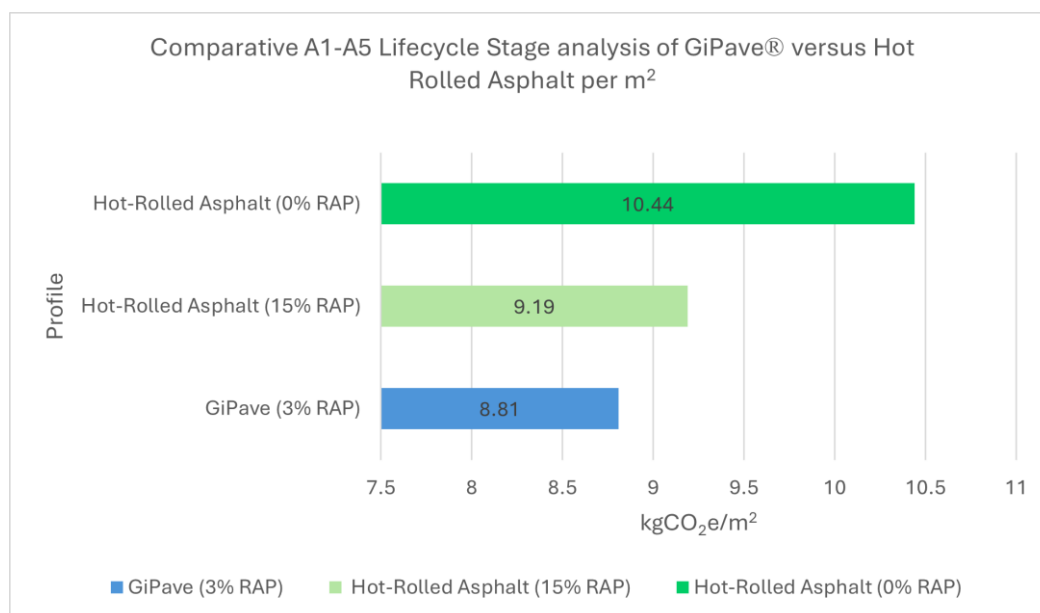


Figure 8: Comparative carbon analysis GiPave versus HRA with no RAP content per m² (50mm depth)

| 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 Celsius. 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. |
| GiPave®* | GiPave® is a polymeric super-modifier which is added to the binder at varying percentages dependent on design. The modifier is blended into conventional bitumen to produce a graphene enhanced polymer-modified binder which is used within asphalt mixes. | Typically used as an additive in binder for surface courses where improved structural performance and longer life are required – e.g. motorways, strategic roads etc. | The GiPave® additive improves resistance, reduces deformations and improves fatigue performance under repeated heavy loads. It does this by increased stiffness and resistance to rutting, leading to potential increased service life. Performance varies depending on the percentage mix. | It is installed through normal asphalt laying using asphalt plant. It is hot applied like conventional HRA. | GiPave® contains recycled waste plastic within its content. The modified asphalt is claimed to be 100% recyclable. The additive helps to extend the service life, reducing maintenance requirements and potentially reducing whole lifecycle carbon emissions. |

Table 4 GiPave® Appraisal

*All factors assessed as part of the appraisal of UltiPave Bio, as a biogenic additive for HRA 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) | GiPave Carbon Emissions (kgCO ₂ e) | Difference (%) (Increase/ Reduction) |
|------------------|---|---|--------------------------------------|
| A1 – A3 | 17,799.73 | 17,243.94 | 3.12% |
| A4 | 163.98 | 163.98 | 0% |
| A5 | 1,326.71 | 1,092.65 | 17.64% |

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 GiPave application as a surfacing material. **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 represents 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 | The addition of the modifier into the material formation adds costs when compared to conventional HRA however, reduced maintenance requirements have potential to offset this added cost when comparing whole-life cost. |
| 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> | The GiPave® additive improves resistance, reduces deformations and improves fatigue, reducing maintenance requirements. |
| 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> | GiPave has 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> | GiPave 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, | Environmental benefits arise from reduced interventions and lower embodied carbon due to the presence of less plant on site, reducing fuel |

| BENEFIT/LOAD UNDER REVIEW | CONSIDERATIONS | SCORING SYSTEM | JUSTIFICATION |
|----------------------------|--|--|--|
| | | <p>biodiversity, landscape etc)</p> <p>2 - Would have negligible net benefit/disbenefit or no overall change regarding environmental factors</p> <p>3 - Would have significant net benefit/disbenefit for environmental factors.</p> | consumption, odour and dust related with maintenance activities. |
| | Road noise | <p>1 - Would have significant net disbenefit</p> <p>2 - Would have negligible net benefit/disbenefit or no overall change regarding</p> <p>3 - Would have a significant net benefit</p> | Typical noise performance is anticipated to be close to the baseline. However, there is potential that specific texture adjustments may provide marginal improvements. |
| | 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>3 - Would have a significant net benefit</p> | GiPave improves resilience due to the higher durability of the graphene additives. The material contains recycled resources. Reducing the dependency on virgin resources. |
| Risk and safety | H&S impacts, safety testing data | <p>1 - Would present increased risk or safety versus BAU option</p> <p>2 - Would present no overall risk increase or safety impact versus BAU option</p> <p>3 - Would present lower risk or safety impact versus BAU option.</p> | No overall increase in H&S risk versus conventional HRA when installed by trained contractors. |
| 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>4 - Commercially available from UK suppliers</p> <p>5 - Commercially available from local suppliers</p> | <p>Commercially available from UK suppliers and has been utilised in multiple projects.</p> <p>GiPave has the readiness for widespread adoption for maintaining road infrastructure within the UK.</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>2 - No considerations required above and</p> | Installation mimics conventional HRA therefore, does not require major additional equipment or specialist training. |

| BENEFIT/LOAD UNDER REVIEW | CONSIDERATIONS | SCORING SYSTEM | JUSTIFICATION |
|---------------------------|-----------------------|---|--|
| | | <p><u>beyond baseline solution</u></p> <p>3 - Significant benefits to on-site activity / ease of installation</p> | |
| Supply Chain | Material availability | <p>1 - Novel materials used with limited supply</p> <p>2 - Materials are available with some supply restrictions</p> <p>3 - Materials are readily available</p> | Materials are readily available through existing recycled material suppliers and asphalt producers. |
| Circular Economy | Recycled content | <p>1 - Virgin materials are used with little or no recycled content</p> <p>2 - Materials contain a level of recycled content</p> <p>3 - Materials are predominantly recycled and/or use novel sources of recycled content that would otherwise be discarded as waste</p> | GiPave® contains recycled waste plastic within its content, diverting waste from landfill. |
| | Ease of recycling | <p>1 - Minimal recycling of material possible upon removal</p> <p>2 - Limited recycling is possible and/or significant reprocessing required</p> <p>3 - Reuse/recycling is easy and convenient</p> | The modified asphalt is claimed to be 100% recyclable. Using existing road material recycling systems. |

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 GiPave live trial demonstrated positive results for sustainable road surfacing when compared to conventional HRA and provides positive evidence that a graphene-enhanced polymeric modifier can reduce carbon emissions. GiPave recorded 8.81kgCO₂e/m² versus 9.19kgCO₂e/m² for HRA at 50mm depth, a 4% reduction across A1-A5 lifecycle stages (raw materials, distribution transport and manufacturing) per square meter. These savings can be attributed to 3.18% lower A1-A3 lifecycle stages and 17.45% lower A5 lifecycle stage carbon emissions. The results from this trial can be further supported by carbon modelling assuming GiPave®'s graphene additive increase the service life by 5 years, reducing carbon emissions by 54.69%, demonstrating the additive holds potential to create whole lifecycle emission savings.

GiPave 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 design requirements. To allow for a more conservative comparison GiPave has been modelled against HRA containing no RAP. This modelling demonstrated a potential to equate for 16% carbon savings across cradle to construction emissions.

The existence of an EPD and independently verified A1-A3 carbon calculation process increases confidence in the reported figures and helps to position GiPave as a credible low-carbon alternative for road surfacing. To translate trial-level gains into reliable, deployable benefits at scale, further long-term monitoring and supply chain optimisation will be required.

Despite these positive outcomes, the trial outcomes are bounded by site-specific factors and the limited monitoring window to date. The extent of lifecycle benefit at network scale will depend on demonstrable long-term performance under varied traffic loads, confirmed durability gains in multi-year monitoring and real-world recyclability at end of life. Extended monitoring would be particularly valuable for validating GiPave®'s durability claims and quantifying whether an extended service life can deliver additional lifecycle carbon savings compared to conventional HRA.

Overall, GiPave presents a high-potential, low-carbon surfacing solution for roads where extended service life and reduced maintenance are priorities. When supported by verified product data, optimised regional supply, and decarbonisation objectives while reducing whole-life cost and disruption associated with routine surfacing.

Recommendations

It is recommended that robust long-term monitoring (over 5+ years) be implemented at treated 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 a structured end-of-life validation programme is established that demonstrates the recyclability of GiPave® under real-world recovery and reprocessing flows. Commission recycling trials through typical UK recycling routes, capture material recovery rates, characterise the quality of returned RAP, and document any reprocessing steps required to meet specification for reuse.