RSTA CARBON EMISSIONS FOR ROAD SURFACE AND OTHER MAINTENANCE TREATMENTS FOR ASSET MANAGEMENT PURPOSES

Written by PYE-Management Ltd

On behalf of RSTA

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RSTA is the Road Surface Treatments Association
www.rsta-uk.org

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1. Introduction

Road surface treatments are methods or materials for extending the lifetime of road pavements, delaying the need for major maintenance or rehabilitation. This process means that surface treatment contractors believe the treatment processes against conventional methods have a lower impact on the Greenhouse Gas (GHG) emissions produced. These claims are not usually made based on robust, standards led assessments as there is currently a lack of standardisation and consistency in producing carbon footprint. The purpose of this report is to follow a required methodology for producing a carbon footprint and apply this to the different treatments as well as the conventional methods of resurfacing or patching, to determine which approach has a lower carbon footprint.

This report will be reviewed and updated no less than every 3 years, to ensure that figures are accurate and appropriate to the current methods and working practices.

1.1. What is a Carbon Footprint?

A carbon footprint is a calculation of the amount of greenhouse gases (GHG) produced from using resources to make products or provide services and is expressed as a carbon dioxide equivalent (CO_2e), and accounts for the following GHG emissions (Carbon Trust, 2020):

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulphur hexafluoride (SF_6)

The Greenhouse Gas Protocol is a widely used set of standards that set out how to account for a companies' GHG emissions. Greenhouse gas emissions are categorised into three groups or 'Scopes' (as shown in Figure 1) by the most widely used international accounting tool, the GHG Protocol.

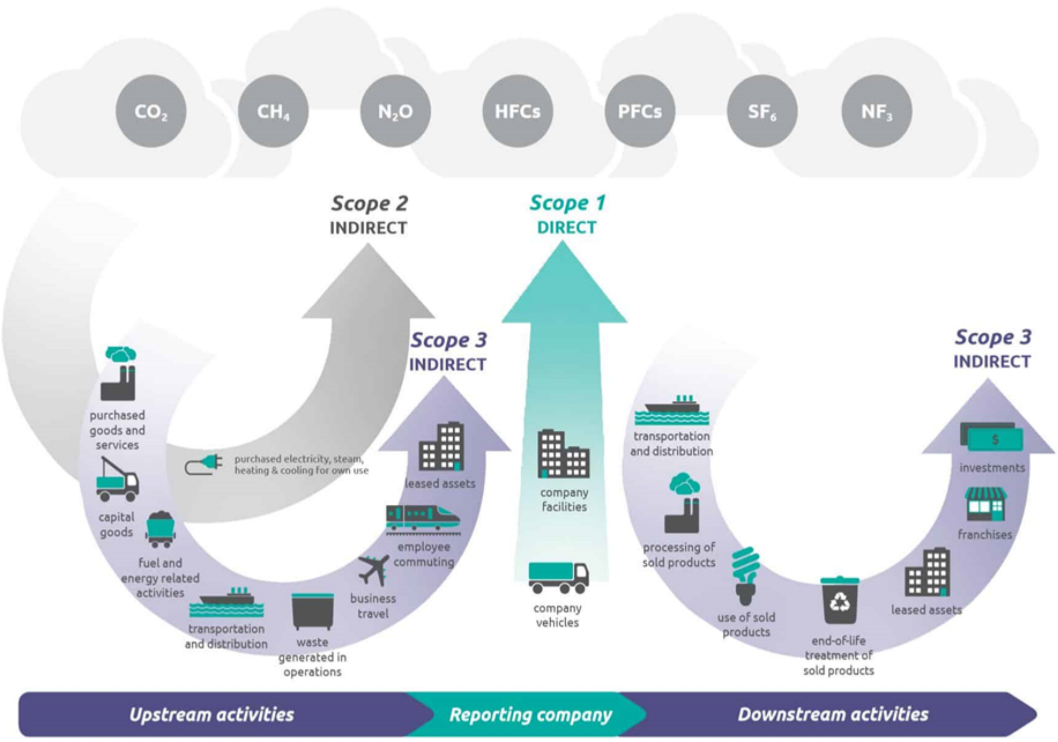

Figure 1: Scope 1, 2 and 3 (Compare your footprint, 2021)

To report the greenhouse gas emissions associated with an organisation's activities, the emissions need to be converted into 'activity data' such as:

- Distance travelled.
- Litres of fuel used.
- Tonnes of waste disposed.

A conversion factor is then applied to the activity data, which enables the emissions to be converted to a common unit of KgCO2e (kilogram of carbon dioxide equivalent). (Gov, 2022)

1.2. What is embodied carbon?

Embodied carbon is the carbon dioxide (CO_2) emissions associated with materials and construction processes throughout the whole lifecycle of a building or infrastructure.

It includes any CO_2 created during the manufacturing of building materials (material extraction, transport to manufacturer, manufacturing), the transport of those materials to the job site, and the construction practices used.

Put simply, embodied carbon is the carbon footprint of a building or infrastructure project before it becomes operational. It also refers to the CO_2 produced maintaining the building and eventually demolishing it, transporting the waste, and recycling it. It does not include the operational carbon emissions i.e., the heating of the building. (CarbonCure, 2022).

Figure 2 shows the life cycle stages and identifies which are embodied carbon and which are operational. These are discussed in more detail further in the report.

The fundamental principle of an embodied carbon calculation is typically to multiply the quantity of each material or product by a carbon factor (normally measured in $kgCO^2e$ per kg of material) for each lifecycle module being considered:

$$\text{Embodied carbon} = \text{quantity} \times \text{carbon factor}$$

The carbon factors are split up by lifecycle module and are estimates that improve in accuracy as more is known about the procurement process for the project.

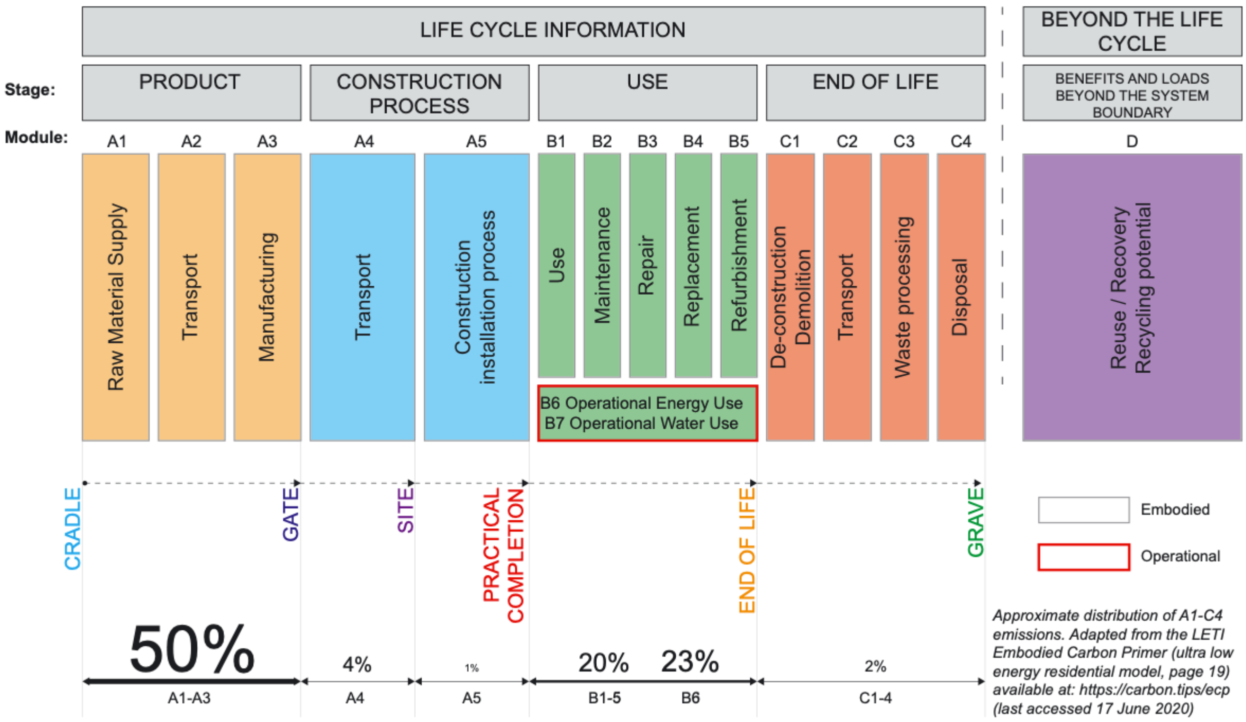

Figure 2: Lifecycle stages and modules (thestructuralengineer.org,2020)

1.3. Why look at embodied carbon?

There is a pressing need to dramatically cut carbon emissions across the world. There is a need to calculate the embodied carbon of work at every design stage, giving engineers the ability to target carbon reductions through material selection, specification, efficiency, and reuse.

It is recommended that the minimum life cycle scope of embodied carbon assessments for structural elements is to include life cycle Modules A1–A5 (embodied carbon to practical completion). There are several reasons for this:

- A1–A5 are the first emissions to be released. They are therefore the emissions that most urgently need to be understood to help minimise global warming.
- There is certainty over A1–A5 emissions data.
- Typically, the majority of the embodied carbon of structures is associated with Modules A1–A5, therefore this should be the focus of the carbon reduction efforts (thestructuralengineer.org,2020)

1.4. Treatments

Road surface treatments are methods or materials for extending the lifetime of road pavements when they deteriorate, delaying the need for major maintenance or rehabilitation. (Spray, no date).

1.4.1. Surface Dressing

Surface Dressing is a long-established proven highway maintenance technique. In simple terms it involves the even spray application of a bituminous emulsion through a purpose built spray tanker onto the existing road surface followed immediately by the even application of aggregate chippings to ‘dress’ the binder. (RSTAa, no date).

1.4.2. Slurry Microsurfacing

These materials are cold-applied, thin bituminous surface courses incorporating bitumen emulsion and fine graded aggregate with fillers. Micro-surfacing incorporates a polymer modified bitumen emulsion and is often a two-coat application and can be laid mechanically or manually to a maximum dried film thickness of 20mm. These materials are usually referred to as Micro-Asphalts (RSTAa, no date).

1.4.3. Spray Injection Patching

Spray Injection Patching (SIP) is a unique process that provides a quick and effective solution for pothole repair. The system applies a blended bitumen emulsion and aggregate mix to potholes for a permanent repair solution.

1.4.4. High Friction Surfacing

High Friction Surfacing (HFS) has a long history of proven use in saving lives by imparting the highest level of skid resistance onto a road surface. High Friction Surfacing is available as hot or cold applied systems. The cold applied technique involves the even application of a tough polymeric liquid binder onto the road surface followed by the application of calcined bauxite aggregate. The hot applied systems involve the application of a hot pre-mixed material consisting of binder and calcined bauxite.

The concept was first investigated in the USA during the 1950’s using epoxy resin binders and was first known as “Anti-skid Surfacing” (RSTAa, no date).

1.4.5. Geosynthetics

Geosynthetics are industry recognised for extending the life of pavements. When placed between bituminous bound layers these products retard the initiation and propagation of reflective cracking which leads to premature pavement failure (Highways Magazine, 2014).

Key products include:

- Steel meshes.
- Polymer grids.
- Non-woven textiles.
- Glass grids.
- Composites.

1.4.6. Ironworks

Ironworks Reinstatement Systems are a long-lasting mastic asphalt system designed to reinstate failing surfaces surrounding manholes, drainage gullies and other public utilities ironworks.

1.4.7. Preservation

Asphalt preservation involves the spray application of a sealant treatment onto bituminous-bound road surfaces that consequently restricts water ingress, inhibits binder oxidation and consequently binder ageing. By providing a protective seal, the treatment can significantly extend the resilience and performance life of an asphalt road surface. The technique can be used as part of an asset management strategy designed to maintain network condition by delaying the need for reactive maintenance (RSTA, 2023)

1.4.8. Rejuvenation

Rejuvenators restore the chemical components of asphalt lost in the aging process and are designed to penetrate, flux and co-mingle with the existing asphalt binder. An asphalt rejuvenator penetrates the asphalt well below the surface to chemically revitalise and protect the asphalt binder maltenes (RSTA, 2023)

1.4.9. Retexturing

Retexturing is described in the Design Manual for Roads and Bridges (DMRB) as the mechanical reworking of an existing surface to improve its frictional characteristics of the aggregates and hence its skid resistance.

Apart from improving road safety, the re-use of existing road surfacing materials will considerably reduce the attendant energy consumption in quarrying, processing, laying new road surfacing materials and waste removal. By extending the life of existing surfaces and by making best use of what's available, the conservation of substantial quantities of irreplaceable high-quality aggregate is ensured (RSTAa, no date).

1.4.10. In-situ Recycling

In-situ recycling is to restore a failed road pavement by recycling and reusing the existing construction materials to construct a new pavement with strength and life expectancy, that is equal to that of a traditionally designed and reconstructed pavement without any materials leaving site. The need to dispose of huge volumes of waste materials, import processed virgin aggregates and hot bituminous bound material is greatly reduced. (Highways Magazine, 2015).

2. Current processes

The LCA (Life cycle assessment) approach was originally developed in the 1960s and 1970s as an approach to quantify environmental sustainability against specific criteria for a product's full life cycle or from "cradle-to-grave."

The LCA process can be used to look at a number of different criteria including greenhouse gas emissions, energy use, etc. The LCA approach, therefore, lends itself to quantifiable environmental sustainability comparison between widely different techniques to achieve the same ends.

2.1. ISO 14040 Environmental management. Life cycle assessment. Principles and framework

ISO 14040:2006 describes the principles and framework for LCA including: definition of the goal and scope of the LCA, the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, the relationship between the LCA phases, and conditions for use of value choices and optional elements (ISO, 2023).

2.2. ISO 14025: Environmental labels and declarations

BS ISO 14025 helps users present quantified environmental information on the life cycle of a product to enable comparisons between products fulfilling the same function, paying due attention to the level of awareness of the target audience (ISOa, 2023).

2.3. Environmental Product Declarations

Environmental product Declarations (EPD) are defined by ISO 14025 as "providing quantified environmental data using predetermined parameters and, where relevant, additional environmental information" (BSI, 2010).

The EPD is a summary of the LCA and Product Category Rules (PCR) activities that enable simple comparisons of environmental impacts. Once a company has produced an EPD this should be made publicly available.

The European Standard for the generation of EPD for construction products, EN 15804, was published in 2012.

EPD are generated based on data obtained through Life Cycle Assessment (LCA). A LCA is performed using a peer reviewed Product Category Rules document (PCR) in line with EN 15804, ISO 14025, and other related international standards.

2.4. Product Category Rules

Product Category Rules (PCR) are defined in ISO 14025 as a "set of specific rules, requirements, and guidelines for developing Type III environmental product declarations for one or more product categories" (BSI, 2010).

In simpler terms, the PCR define how the EPD will be created for a specific product, such as an asphalt binder. This includes how system boundaries are chosen, what impact categories will be included and what methodology will be used. By developing a PCR, an industry can align itself on the methodology to be used to ensure consistent application of best practices and guiding principles for LCA development to demonstrate the industry's commitment to sustainability.

2.5. PCR PN514

PCR PN514 is a PCR document for the assessment of the environmental performance of construction products.

The PCR requires A1-A3 to be included as minimum, however stages A4, A5, B, C and D are optional for inclusion. Therefore, some EPDs could include more stages than others. (BRE, 2014).

2.6. EN15804 Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products.

The EN 15804 is the Environmental Product Declaration (EPD) standard for the sustainability of construction works and services. The standard makes the LCA information in the construction industry transparent and comparable. The first version was published in 2012, known as EN 15804+A1 “Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products”. A second version of the standard called EN 15804 +A2 was published in 2019, with the main goal to align the standard based EPDs with the Product Environmental Footprint (PEF) formats.

The new revision of EN15804 (EN15804+A2) meant that all construction products now must declare modules A1-A3, as well as C1-C4, and module within an EPD. These life stages were previously optional. The revised norm specifically states that only under very specific conditions it would still be possible to do a cradle-to-gate (A1-A3 only) EPD (BSI, 2021).

2.7. PREN 17392-1:2020 (Draft) Sustainability of construction works - Environmental product declarations - Core rules for road materials - Part 1: Bituminous mixtures.

The PREN 17392-1: 2020 is currently a draft document and is on hold as there is currently not a consensus on the content.

It has been designed to provide a structure to ensure that all EPDs of construction products, construction services and construction processes are derived, verified, and presented in a harmonized way. The document provides additional rules for EPDs specifically for bituminous mixtures. It complements the core product category rules for all construction products and services as established in EN 15804. The approach taken for this PCR may be considered applicable and adaptable for other bitumen-based products (BSI, 2020).

In addition to the common parts of EN 15804, the document for bituminous materials:

- Defines the system boundaries.
- Defines the modelling and assessment of material-specific characteristics.
- Defines allocation procedures for multi-output processes along the production chain.
- Includes the rules for calculating the LCI and the LCIA underlying the EPD.
- Provides guidance for the determination of the reference service life (RSL).
- Gives guidance on the establishment of default scenarios. (BSI, 2020).

Principles used include the following:

- PCR covering bituminous materials.
- from cradle to beyond the building life cycle based on EN 15804.
- EPD will be based on declared units (e.g., tonnes of material) and not functional units (e.g., km of road);
- All use of inert material in the quarry: reclamation, sound and dust protection must be included in stages A1 to A3 of the EPD.
- Data quality will be described (e.g., Average yearly value, average 10 years value, or maximum value ever encountered). (BSI, 2020).

Only the declaration of the modules, A1-A3, C1-C4 and D required for compliance with this document.

The document does provide details of system boundaries for A1-A3 (see figure 3).

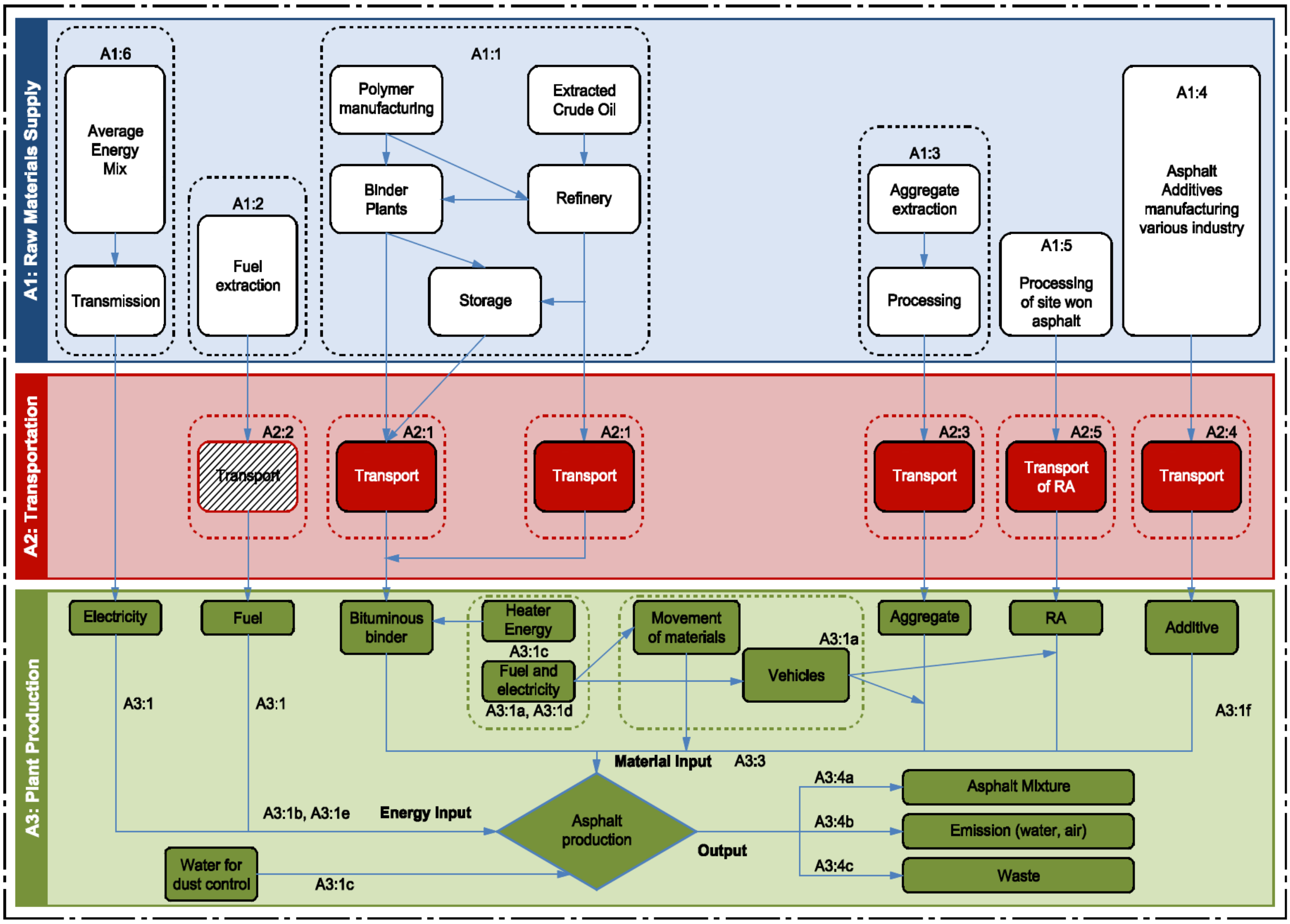

Figure 3: Diagram of the system boundaries, processes and data types (BSI, 2020)

It also provides descriptions for A1-A5 In addition to the text in EN 15804.

- A1: Raw Material Supply

Data for all these processes will be based on secondary data, supplier data sources and/or existing national LCI data. Transportation distances that are part of upstream processes, involving transport of a raw material through the supply chain before it arrives to the plant, are considered part of the secondary data. The following impacts are included:

a) Impacts of all co-products of crude oil refining including extraction, transport, refining, and storage. The co-products of interest to this PCR guidance include gasoline, diesel, residual fuel oil, polymers, bitumen additives and bituminous binder. The Eurobitume LCI Methodology is used to allocate the relative impacts of the crude oil refining process across the different co-products.
b) Impacts associated with the extraction and production of burner fuels.
c) Impacts associated with the mining, extraction, and production of aggregate.
d) Impacts associated with the use of asphalt additives (including water for foaming).
e) Impacts associated with the processing of site won asphalt to become RA.
f) Transportation of site-won asphalt to the processing plant, is considered to be zero because it is part of the previous system supplying recycled aggregate into the current system. The system boundary is considered to be crossed at the site once the reclaimed asphalt enters the processing plant and impacts after this point (e.g., crushing and sieving) are considered in this system.
g) Impacts associated with the production of electricity and transmission to asphalt plant. (BSI,.2020)

- A2: Transport to Asphalt Mixing Plant

Transportation distances of raw materials to the plant are considered to be primary data.
a) Transportation of bituminous binders to the asphalt mixing plant.
b) Transportation of aggregate to the asphalt mixing plant.
c) Transportation of asphalt additives to the asphalt plant.
d) Transportation of the burner fuels to the asphalt mixing plant.

e) Transportation of Reclaimed asphalt (RA) from processing unit to asphalt plant.

- A3: Manufacturing

All data collected for this part of the system will be directly based on plant operations and will be considered primary data.

a) Energy (fuel and electricity) used at the plant for the mix production process including:
1) Vehicles used in moving aggregate and other related mobile equipment used on site for the production of asphalt mixtures.
2) Burner used for drying and heating of aggregates and RA.
3) Heating of bituminous binder in storage tanks.
4) Movement of materials (belts and conveyors) through the plant and mixing process.
5) Asphalt mixture storage in silos.
6) Asphalt Additive addition completed at the plant.

b) Total amount of water used on the plant for dust control, etc.

c) Total amount of bituminous binder, aggregates, reclaimed asphalt and additives used.

d) Output/emissions from plant:
1) Total plant emissions from stack according to ISO 14025.
2) Waste associated with plant and equipment maintenance activities (e.g., loader tyres, lubricants, dust filter).

- A4: Transportation from the production gate to the construction site

Transportation distance of the asphalt mixture from the production gate to the construction site are considered to be primary data.

- A5: Installation of the product

All data collected for this part of the system will be directly based on plant operations and will be considered primary data.

a) Transportation of the paving and compaction equipment to the construction site.

b) Energy (fuel) used by the equipment at the construction site including:
1) Sweepers, including the use of water.
2) Equipment to apply tack or bond coat.
3) Material Transfer Vehicle.
4) Heaters to heat the substrate.
5) Asphalt paver / finisher.
6) Compaction equipment.
7) Other equipment used to be able to apply and compact the bituminous product and except equipment for traffic management, traffic control, road markings, cutting the grass, etc., which is not to be included.

c) Total amount of water used to cool the drums of the compaction equipment can be neglected as they meet the cut-off criteria.

d) Output/Emissions from plant
1) Waste associated with equipment cleaning and maintenance activities (e.g., paver and Compaction). (BSI,2020).

2.8. Guidance for the Application of GHG Scope 1 & 2 in Local Highways Authorities February 2022

The Future Highways Research Group (FHRG) developed a step-by-step guidance to assist Local Highways Authorities (LHAs) and their contractors in implementing the GHG (greenhouse gas) protocols for measuring and reporting carbon emissions. The guidance follows what the GHG protocol refers to as the *operational control approach* and is intended to identify the emissions from LHAs over which they have control or influence.

The primary objective of the document is to provide standardised, highways-specific guidance for applying the GHG standards for scope 1 and 2 within LHAs. The guidance will assist LHAs in determining what their carbon footprint includes and how to monitor and measure the applicable data. This will enable LHAs and their contractors to calculate their carbon emissions and carbon footprint on a comparable basis. Data collected for this report has followed the guidance.

2.9. National Highways

In 2021 National Highways set out their Net zero plan for highways with a commitment to have net zero emissions from construction and maintenance activity by 2040. In 2022, National Highways launched their Net Zero plan for concrete, steel and asphalt. The roadmaps describe how emissions can be reduced through:

- Decarbonising the raw materials
- Decarbonising the manufacture of the materials
- Decarbonising transport and construction emissions

The process aligns with the A1 to A5 modules defined by EN15804: Sustainability of Construction Works. (National Highways, 2023).

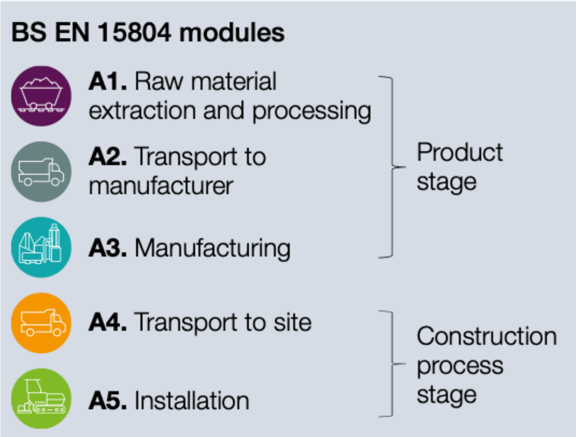

Figure 4: BS EN 15804 modules (National Highways, 2023).

National Highways states that “every tonne of asphalt that we lay emits an average of 70 kg CO^2” and carbon assessment have now been completed for the different types of asphalts in accordance with A1-A5.

National Highways Asphalt Net Zero Plan sets out the following actions:

- **Embedding whole life carbon reduction into pavement asset management.**
  The Asset Class Strategy for Pavements defines the approach for maintaining pavement assets. The new strategy has been developed and it defines a new approach to extending asset life. A combination of preventative maintenance and using more durable, longer-life materials is an important enabler in realising a reduction in asphalt use. It also reduces the disruption to customers associated with resurfacing works.

- **More durable asphalt materials will deliver longer service life.**
  Increased material durability can extend the lifespan of asphalt surfaces and reduce re-surfacing frequency and material use. Material selection and mix design is critical to maximising asphalt service life. Long-life asphalt surfaces can deliver whole life financial cost and carbon reductions even if their initial construction cost is higher.

- **Best practice pavement construction will reduce maintenance and operational carbon.**
  Adopting best construction practices will extend the service life of asphalt pavements and reduce operational carbon associated with their use. We will be advocating construction processes that reduce joints (e.g. echelon paving), maintain asphalt delivery consistency and quality (e.g. material transfer vehicles) and enhance surface regularity to improve ride quality.

- **Building less new road infrastructure will directly reduce demand for asphalt.**
  'Building less' is a component of our Net Zero Plan and this will reduce our demand for asphalt, further driving down our carbon emissions associated with these materials. This must be balanced against the need to deliver a modern and efficient road network that meets the needs of the nation. Building less also reduces disruption for our customers given fewer maintenance interventions will be required to maintain roads in the future. (National Highways, 2023).

2.10. What do clients want?

Publicly Available Specification (PAS) 2080 is a global standard for managing infrastructure carbon and has been authored to meet World Trade Organisation requirements. The framework looks at the whole value chain, aiming to reduce carbon and reduce cost through more intelligent design, construction and use (Carbon Trust, 2023).

PAS 2080 looks at the whole life cycle of the carbon used on projects and promotes reduced carbon, reduced cost infrastructure delivery and a culture of challenge in the infrastructure value chain where innovation can be fostered. Clients applying this standard will require information from their value chain of their carbon emissions.

National Highways have launched their Net zero highways: our zero carbon roadmap for concrete, steel and asphalt plan in which they have an action that requires Tier 1 and 2 suppliers to be PAS2080 certified by the end of 2025. National Highways (National Highways, 2023). National Highways obtained certification to PAS 2080 in 2022.

3. Scope of project

3.1. Boundaries

The life cycle analysis in this study is limited by so-called system boundaries. Because this study is conducted from cradle-to-laid, the following modules were, in accordance with the methodology in section 3.2, included in this study: the extraction of raw materials and energy (A1), transport to the production location (A2), production phase (A3), transport to construction site (A4) and construction (A5). The use phase (Module B), the demolition and waste phase (Module C) and the reuse and recycling phase (Module D) have not been considered, see figure 2.

3.2. Methodology

It is vital that carbon figures for treatments are comparable and accurate. Following a review of current processes and tools for completing carbon footprints and following the proposed National Highways approach. Using Figure 2 as the basis, the treatment carbon footprints include Cradle to Practical Completion, which are stages A1-A5. The breakdown of these sections will follow the draft PREN 17392-1:2020 (Draft) Sustainability of construction works - Environmental product declarations - Core rules for road materials - Part 1: Bituminous mixtures. This was the only document, at the time of writing, that had a formal description for highway related processes looking at sections A4 and A5.

Section A4, also included the return journey of all the construction plant and equipment. Please note that section A5 does not include the removal of existing road surface.

Data was converted to $kgCO^2e$ using either:

- UK Government GHG conversion factors from the Department for Business, Energy & Industrial Strategy and the Department for Environment Food & Rural Affairs.
- ICE Database. The ICE database can be used as 'proxy data' in the absence of country specific data. This is also a common approach in life cycle assessment (LCA) where the driver is as much to make a comparison as to arrive at an absolute number.
- Company specific EPD's. EPD's were obtained for a number of products to give accuracy to the carbon calculations.

Density factors were either obtained from the specific materials companies or from the Bath Inventory - Version 2.0 (2011). (National Highways a, 2023). The Bath Inventory figures can be found in Appendix B.

3.3. Data Gathering

All contributors of this report were requested to send carbon relevant product information for this assessment. Several suppliers have delivered relevant data in the form of EPDs, certification and energy documentation, which were verified and amended, if required, to meet the methodology above.

3.4. Assumptions

- On delivery of material, vehicles were classed as 'fully laden'.
- Return vehicles were either classed as 'average laden' if the whole delivery was not required or 'empty' if full delivery was accepted.

4. RESULTS

4.1. Overall

A total of 13 companies participated in this project. Please note that some participants contributed carbon figures for more than 1 type of treatment. For treatments that had more than 1 participant an average has been taken of their figures. A list of participants can be found in Appendix A.

Table 1 below shows an average carbon dioxide equivalent (kgCO^2e) per m^2 figure for all the treatments that have participated. For the following figures, an assumption of 200 miles round trip was used for A4.

Treatment	Units	A1 – A3	A4	A5	Overall total
Rejuvenation	kgCO^2e/m^2	0.023	0.016	0.015	0.054
Preservation	kgCO^2e/m^2	0.361	0.013	0.066	0.440
Surface Dressing – Single layer Carriageway	kgCO^2e/m^2	0.497	0.195	0.023	0.715
Surface Dressing – Double Layer (Racked In) Carriageway	kgCO^2e/m^2	0.729	0.188	0.021	0.938
Surface dressing – Decorative	kgCO^2e/m^2	0.729	0.134	0.018	0.881
Surface dressing – Footway	kgCO^2e/m^2	0.319	0.057	0.007	0.383
Microsurfacing	kgCO^2e/m^2	0.761	0.034	0.012	0.773
Geosynthetics	kgCO^2e/m^2	0.890	0.021	0.104	1.015
Crack and Joint repairs	kgCO^2e/m^2	7.035	n/a	n/a	n/a
Spray Injection Patching	kgCO^2e/m^2	1.123	0.845	1.455	3.436
Retexturing - Waterblasting	kgCO^2e/m^2	0.00059	0.185	0.127	0.312
Retexturing - shotblasting	kgCO^2e/m^2	0.039	0.169	0.149	0.357
In-situ recycling *	kgCO^2e/m^2	6.4198	0.6168	0.880	7.916
Thermal patching	kgCO^2e/m^2	0.368	1.189	1.108	2.665
Ironworks – reinstatement systems	kgCO^2e/m^2	1.061	n/a	n/a	n/a

Table 1: CO^2e figures for treatments

*Please note that this figure has been calculated on emissions from a 200mm depth in-situ recycling example and excludes the 40mm surface wearing course. Figures may vary for different depths.

The following sections look at a few examples, which compare the treatments in table 1 to traditional materials. The traditional materials have been calculated using the same process, from data, method statements and processes obtained from asphalt manufacturing companies, National Highways, MPA (Minerals Products Association) and local highways authorities.

4.2. Treatments vs traditional

Table 2 below looks at an example project of an average days work filling 20mm depth patches and travelling 100 miles to site, and 100 miles return.

Please note that the figures do not include break out or removal of existing road surface.

Treatment	Units	A1 - A3	A4	A5	A1-A5 Total
Spray Injection Patching	$kgCO^{2}e/m^{2}$	1.123	0.845	1.455	3.436
20mm SMA (Warm mix, straight run bitumen, 0% recycled content)	$kgCO^{2}e/m^{2}$	2.200	2.555	1.911	6.666
20MM SMA (Warm mix, PMB, 0% recycled content)	$kgCO^{2}e/m^{2}$	2.393	2.555	1.911	6.859
20mm SMA (Hot mix, straight run bitumen, 10% recycled content)	$kgCO^{2}e/m^{2}$	2.155	2.555	1.911	6.621

Table 2: Project example - 20mm depth patch

Table 3 below looks at an example project of an average days work filling 40mm depth patches and travelling 100 miles to site, and 100 miles return.

Please note that the figures do not include break out or removal of existing road surface.

Treatment	Units	A1 - A3	A4	A5	A1-A5 Total
Thermal patching	kgCO^2e/m^2	0.368	1.189	1.108	2.665
30mm SMA (Warm mix, straight run bitumen, 0% recycled content)	kgCO^2e/m^2	4.400	2.555	3.884	10.839
30MM SMA (Warm mix, PMB, 0% recycled content)	kgCO^2e/m^2	4.787	2.555	3.884	11.226
30mm SMA (Hot mix, straight run bitumen, 10% recycled content)	kgCO^2e/m^2	4.310	2.555	3.884	10.749

Table 3: Project example - 40mm depth patch

Table 4 below looks at an example project of 40mm depth, 30,000m^2 and travelling 100 miles to site, and 100 miles return.

Please note that the figures do not include break out or removal of existing road surface.

Treatment/resurface	**Units**	**A1 – A3**	**A4**	**A5**	**Total (A1-A5)**
Rejuvenation	$kgCO^2e/m^2$	0.023	0.016	0.015	0.054
Preservation	$kgCO^2e/m^2$	0.361	0.013	0.066	0.440
Surface Dressing	$kgCO^2e/m^2$	0.497	0.195	0.023	0.715
Microsurfacing	$kgCO^2e/m^2$	0.760	0.034	0.012	0.773
Geosynthetics	$kgCO^2e/m^2$	0.890	0.021	0.104	1.015
30mm SMA (Warm mix, Straight run bitumen, 10% recycled content)	$kgCO^2e/m^2$	3.680	0.495	0.392	4.567
30mm SMA (Warm mix, PMB, 10% recycled content.	$kgCO^2e/m^2$	3.996	0.495	0.392	4.567
40mm HRA	$kgCO^2e/m^2$	5.11	0.594	0.588	6.292

Table 4: Project example - 40mm depth

Table 5 below looks at an example resurfacing project of 100mm depth, 30,000m^2 and travelling 100 miles to site, and 100 miles return.

Please note that the figures do not include break out or removal of existing road surface.

Treatment		**Units**	**A1 - A3**	**A4**	**A5**	**Line Total**	**Overall Total**
Rejuvenation		$kgCO^2e/m^2$	0.023	0.016	0.015	0.054	0.054
Surface dressing		$kgCO^2e/m^2$	0.497	0.195	0.023	0.715	0.715
Microsurfacing		$kgCO^2e/m^2$	0.761	0.034	0.012	0.773	0.773
100mm resurface	$kgCO^2e/m^2$	$kgCO^2e/m^2$	5.11	0.594	0.588	6.292	14.35
	60mm Binder (Hot Mix, 20% recycled content)	$kgCO^2e/m^2$	6.287	0.990	0.783	8.060	
100mm resurface	40mm HRA	$kgCO^2e/m^2$	5.110	0.594	0.588	6.292	13.94
	60mm Binder (Warm mix, 20% recycled content)	$kgCO^2e/m^2$	5.879	0.990	0.783	7.652	
100mm resurface	30mm SMA (Warm mix, straight run bitumen 10% recycled content)	$kgCO^2e/m^2$	3.680	0.495	0.392	4.567	12.22
	60mm Binder (Warm mix, 20% recycled content)	$kgCO^2e/m^2$	5.878	0.990	0.783	7.652	
100mm resurface	30mm SMA (Warm mix, PMB 10% recycled content)	$kgCO^2e/m^2$	3.996	0.495	0.392	4.567	12.878
	60mm Binder (Warm mix, 0% recycled content)	$kgCO^2e/m^2$	6.225	0.990	0.783	7.652	

Table 5: Example project – 100mm depth

4.3. In-situ recycling

Table 6 below shows an example of in-situ recycling against a conventional re-surface at a depth of 200mm, 38,157 m^2 and travelling 100 miles to site, and 100 miles return.

Please note that the figures for 200mm resurface do not include break out or removal of existing road surface.

<table>
<tr><th colspan="2">Treatment</th><th>Units</th><th>A1 - A3</th><th>A4</th><th>A5</th><th>Line Total</th><th>Overall total</th></tr>
<tr><td rowspan="2">200mm in-situ recycling</td><td>40mm SMA</td><td>$kgCO^2e/m^2$</td><td>3.680</td><td>0.495</td><td>0.392</td><td>4.567</td><td rowspan="2">12.483</td></tr>
<tr><td>170mm in-situ recycling</td><td>$kgCO^2e/m^2$</td><td>6.4198</td><td>0.6168</td><td>0.880</td><td>7.916</td></tr>
<tr><td rowspan="3">200mm resurface</td><td>40mm SMA</td><td>$kgCO^2e/m^2$</td><td>3.680</td><td>0.495</td><td>0.392</td><td>4.567</td><td rowspan="3">24.308</td></tr>
<tr><td>60mm Binder</td><td>$kgCO^2e/m^2$</td><td>5.878</td><td>0.990</td><td>0.782</td><td>7.650</td></tr>
<tr><td>100mm Base</td><td>$kgCO^2e/m^2$</td><td colspan="3">12.091</td><td>12.091</td></tr>
</table>

Table 6: In-situ recycling vs traditional resurfacing

4.4. Longevity

Service life is the 'average' or 'typical' life of a treatment and as such can be used for asset management purposes. On any given road the treatment may have a greater or lesser life depending upon circumstances. The 'life' of a treatment is the time at which significant maintenance becomes necessary. (ADEPT/RSTA, 2017).

Surface Treatment	Average Service Life
Surface dressing	
Low to medium traffic	15 years
Medium to high traffic	10 years
Micro surfacing	
Carriageway	10 years
Footway	15 years
Slurry surfacing	
Carriageway	6 years
Footway	10 years
High friction surfacing	
Hot applied	8 years
Cold applied	12 years

Table 7: Average service life (ADEPT/RSTA, 2017).

Table 8 below looks at the GHG emissions shown in $kgCO^2e$ over a 25-year period. Showing the number of applications or resurface, with the first application or resurface taking place in year 1.

Treatment	A1-A5 $kgCO^2e/m^2$	Service Life Years	Number of applications or resurface	$kgCO^2e/m^2$ over 25 years
Rejuvenation	0.054	5	5	0.270
Microsurfacing	0.773	10	2	1.546
Surface Dressing	0.715	10	2	1.430
40mm Surface Course – HRA	6.292	10	2	12.584
30mm SMA (Warm) (10% Recycled content) (Straight run bitumen)	4.567	10	2	9.134

Table 8: Carbon footprints over a period of 25 years

5. Glossary of Terms

- ADEPT - Association of Directors of Environment, Economy, Planning and Transport
- BSI – The British Standards Institution
- CO2 – Carbon Dioxide
- EPD – Environmental Product Declaration
- GHG – Greenhouse Gas
- HFS – High Friction Surfacing
- HRA - Hot Rolled Asphalt
- ISO – International Organisation for Standardisation
- $kgCO^2e$ – Kilogram Carbon dioxide equivalent
- LCA – Life Cycle Assessment
- LCIA - life cycle impact assessment
- LHA – Local Highway Authority
- MPA – Minerals Products Association
- NH – National Highways
- PAS - Publicly Available Specification
- PCR - Product Category Rules
- PSV Polished Stone Value
- RSTA - The Road Surface Treatments Association
- SIP – Spray Injection Patching
- SMA - Stone Mastic Asphalt

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7. Appendices

7.1. Appendix A: Participants

Please note that some participants contributed carbon figures for more than 1 type of treatment.

- Archway Products Ltd
- ASI Solutions ltd
- Eurovia Surface Treatments (EST)
- Henry Williams & Son Ltd
- Huesker
- IKO
- Kiely Bros Ltd
- Roadtechs
- Saint Gobain
- Stabilised Pavements Ltd
- Thermal Road Repairs
- Velocity
- WJ Products Ltd

7.2. Appendix B: Density Factors

Material	Density	Units	Source
Cement: general	1.50	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Cement: general - 25% fly ash	1.86	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Cement: general - 50% fly ash	1.86	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Cement: general - 25% blast furnace slag	1.86	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Cement: general - 50% blast furnace slag	1.86	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Fibre Cement	1.86	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Portland Cement (dry kiln)	1.50	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Portland Ash Cement	1.50	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Soil-Cement	1.86	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Copper: general	8.90	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Recycled Copper	8.90	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Steel: general	8.00	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Aluminium: general	2.70	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Lead: general	11.34	t/m^3	Bath Inventory - Version 2.0 (2011)
Standard Paint	1.20	kg/litre	Bath Inventory - Version 2.0 (2011)
Mortar (cement:sand mix)	1.90	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Plastic (PVC)	1.40	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Quarried aggregate	2.00	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Recycled aggregate	2.00	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Asphalt	2.30	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Bitumen	1.00	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Standard Brick	2.30	tonnes / 1000 bricks	Bath Inventory - Version 2.0 (2011)
Clay	1.90	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Sand	1.85	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Soil	1.70	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Stone: general	2.00	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Stone gravel/chippings	2.00	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Slate	2.70	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Timber: general	0.50	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Particle Board	0.75	kg/m^2	Bath Inventory - Version 2.0 (2011)
Plywood	0.54	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Sawn Hardwood	0.60	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Sawn Softwood	0.50	tonnes/m^3	Bath Inventory - Version 2.0 (2011)
Concrete	2.40	tonnes/m^3	Bath Inventory - Version 2.0 (2011)

Reference: National Highways a,2023