TYNEDALE
ROADSTONE
PART OF MGL GROUP

Smart Carbon

Asphalt Life Cycle Assessment

Performed By

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1. Project Description and Methodology

1.1 Background

Established in 1971, MGL Group is one of the North East's largest privately owned civil engineering and demolition businesses, with over 50 years of construction industry expertise. MGL Group through its companies have the capabilities and experience to deliver a wide range of services to reshape the built environment. The MGL Group of companies are shown in Figure 1. Tynedale Roadstone specialises in production of bituminous macadam and asphalt products. Whereas Rainton Construction performs the road surfacing and cold milling services.

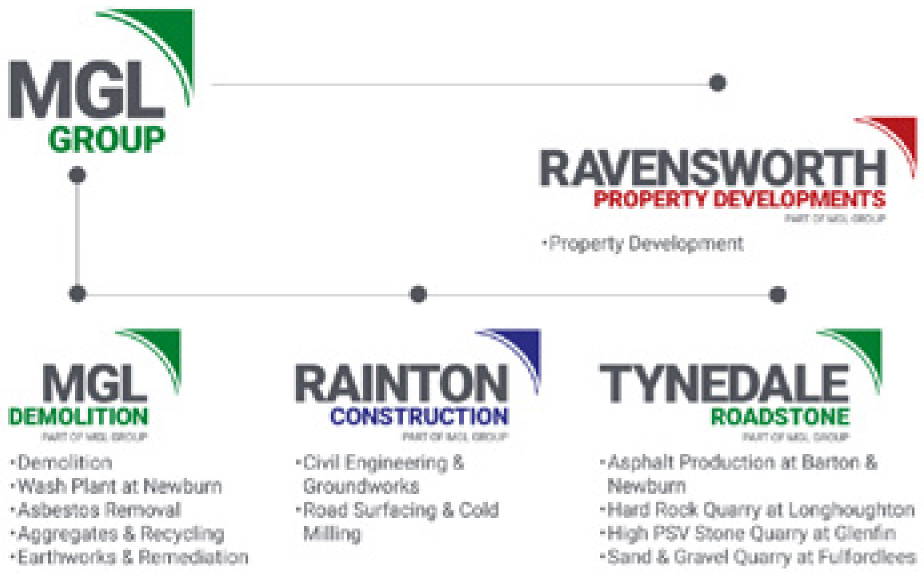

Figure 1

Sustainability is a key focus in all areas of the business. Over the years several sustainable solutions have been undertaken such as innovative use of waste materials in road construction, use of LowTherm additives to reduce energy consumption in asphalt production, use of UK recycled steel, and use of Reclaimed Asphalt Pavement (RAP) and fillers.

This project was initiated so that MGL Group could learn which factors are more (or less) important to the carbon footprint of their Asphalt products when their entire product lifecycle is considered. This is vital knowledge to have in order to be able to deliver on MGL's sustainability objectives. It was also hoped that this Life Cycle Assessment (LCA) exercise would be a good vehicle for MGL to explore the opportunities for environmental impact reduction in its products.

The manufacturing process and activity data referred to this study could be considered as confidential information and should not be shared with external parties without the permission of MGL Group.

The Tynedale Roadstone produces various types and grades of Asphalts from its state-of the-art production plant in Newcastle Upon Tyne and North Yorkshire in conformance to ISO 9001:2015 and ISO 13108 standards.

For this study 15 types of Asphalts mixes were considered which covers most of the production.

The Phoenic Starbatch 2500s Asphalt plants at Barton and Newburn uses cold feed unit with variable DC belt feeders, oil fired burners and hot bins to discharge the mixed batches directly onto vehicles. The Asphalt mixes are then transported to construction site and laid within the prescribed time. Additional heating of Asphalt is not required once it leaves the production facility. The figure 2 shows the plant flow diagram.

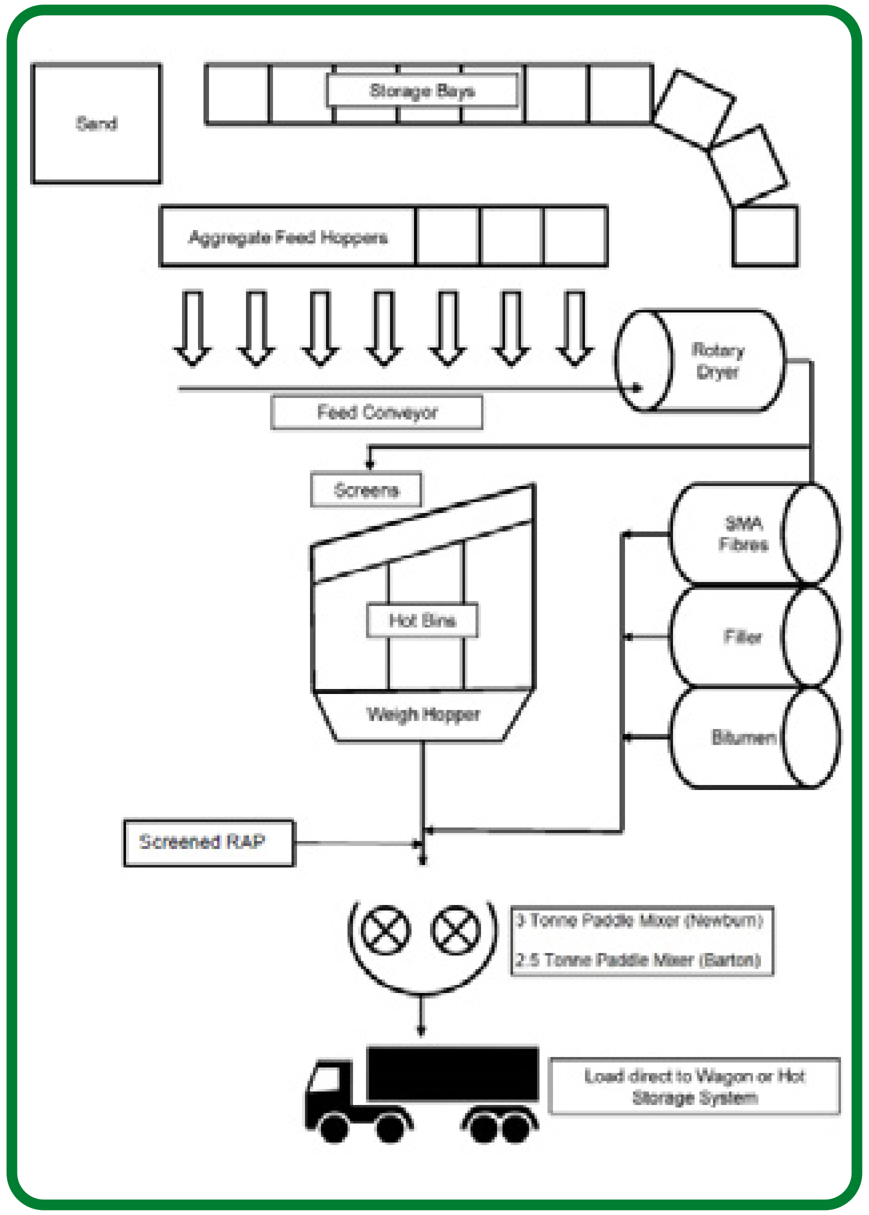

Figure 2

1.2 Goal and Scope

This report is in accordance with BS EN 15804: 2012+A2:2019 Sustainability of construction works — Environmental product declarations — Core rules for the product category of construction products and includes the core impact categories.

It is important that life cycle and carbon footprint studies also observe compliance with the requirements of ISO 14040:2006 – Environmental management – Life cycle assessment – Principles and framework, when any external communications are made, such as within the supply chain. In relation to this, the carbon footprint study was undertaken based on the principles and requirements of ISO 14040:2006.

The goal and scope of the study was agreed between MGL Group and SmartCarbon Ltd. The goal for the study is to prepare an internal report with a complete LCA information so that MGL prepares itself for the potential requirement of Environmental Product Declaration (EPD) of its products as well as identify hot spots in order to improve its products in terms of sustainability. The scope is to study all fifteen asphalt mixtures produced and at Barton and Newburn facility and used by Rainton Construction for road construction. MGL recognises the client expectations in regard to the environmental impact of its products and construction activities. This study is a step towards creating an EPD and making it available to interested parties in the future.

The Life cycle Process Flow for the product was drawn up and agreed on the basis of these discussions. The functional unit studied is one tonne of Asphalt.

The inventory data was collected and managed by SmartCarbon Ltd in collaboration with MGL Group staff. All calculations involved in building up the Life Cycle Inventory (quantity/Functional unit, conversions of units, other calculations, reference processes and materials and assumptions taken) have all been checked, recorded, and stored by SmartCarbon. The sources of all data are provided in detail in the next section.

Lastly the review of the Inventory data and the report was assigned to Dr Mary Argyraki. Some additional and consequent interrogation of the data was carried out during the writing up of this report. Any assumptions, gaps and limitations are highlighted in this report so that results are transparent and thus can be interpreted in view of these limitations and can be revisited, if need be, in the future.

The Function and quality characteristics of the studied product (Appendix 1) are as follows:

- The Asphalt mixes are applied in layers depending upon the intended use and client specifications.
- The Asphalt surfaces provide a smooth, durable surface that can withstand the intended traffic, varying weather conditions, and is relatively easy to maintain and repair.
- Essentially the product is acting as a strong, flexible binder that holds together the aggregate particles to create a stable road surface.
- Suitable applications include roads, highways, cycle lanes, airport runways, taxiways, and driveways.
- Asphalt Conforms to BS EN 13108-1, BS EN 13108-4 and BS EN 13108-5, PD 6691:2022
- Asphalt's Expected life span is 15 to 25 years.

Unit of Analysis – Since the Asphalt produced by MGL Group is used for different applications and by different parties, the declared unit is as one tonne of Asphalt produced for use by MGL Group. Establishing the reference flow, on the basis of a quantified performance, would need research and/or users' survey and many products are simply studied using one unit of product as declared unit, as in this study. This needs to be noted when comparisons with rival products or a standard need to be made.

The boundaries of the system are shown in the figure 3 below. Criteria for insignificance was set at 1% based on mass as per the BS EN 15804. In addition, it is ensured that any input or process with significant environmental impact is included. The excluded materials were fuel additives which are well below the 1% by mass threshold, and not deemed of environmental significance. Cumulatively the mass included in the system boundary exceeds 95%.

There was no need to allocate overhead building energy to the various products as overhead energy was available for the Asphalt production only. The electricity for Asphalt production at Newburn facility is assumed to be 65% of the total overhead electricity. This was estimated by MGL Group based on plant energy rating and running hours.

There were no co-products from the manufacturing process. Hence, it was not necessary to apply any allocation of primary data between coproducts in calculations for this study.

The application of tack coat is required only in certain cases of resurfacing of existing roads, where the mid or surface layers is being replaced. Whereas for construction of new roads or resurfacing where base layer is replaced, the tack coat is not used. Due to this low usage in specific scenarios the tack coat is kept out of the study boundary. The impact of tack coat is relatively low compared to the overall impact, nonetheless it is calculated separately and provided in Appendix 2.

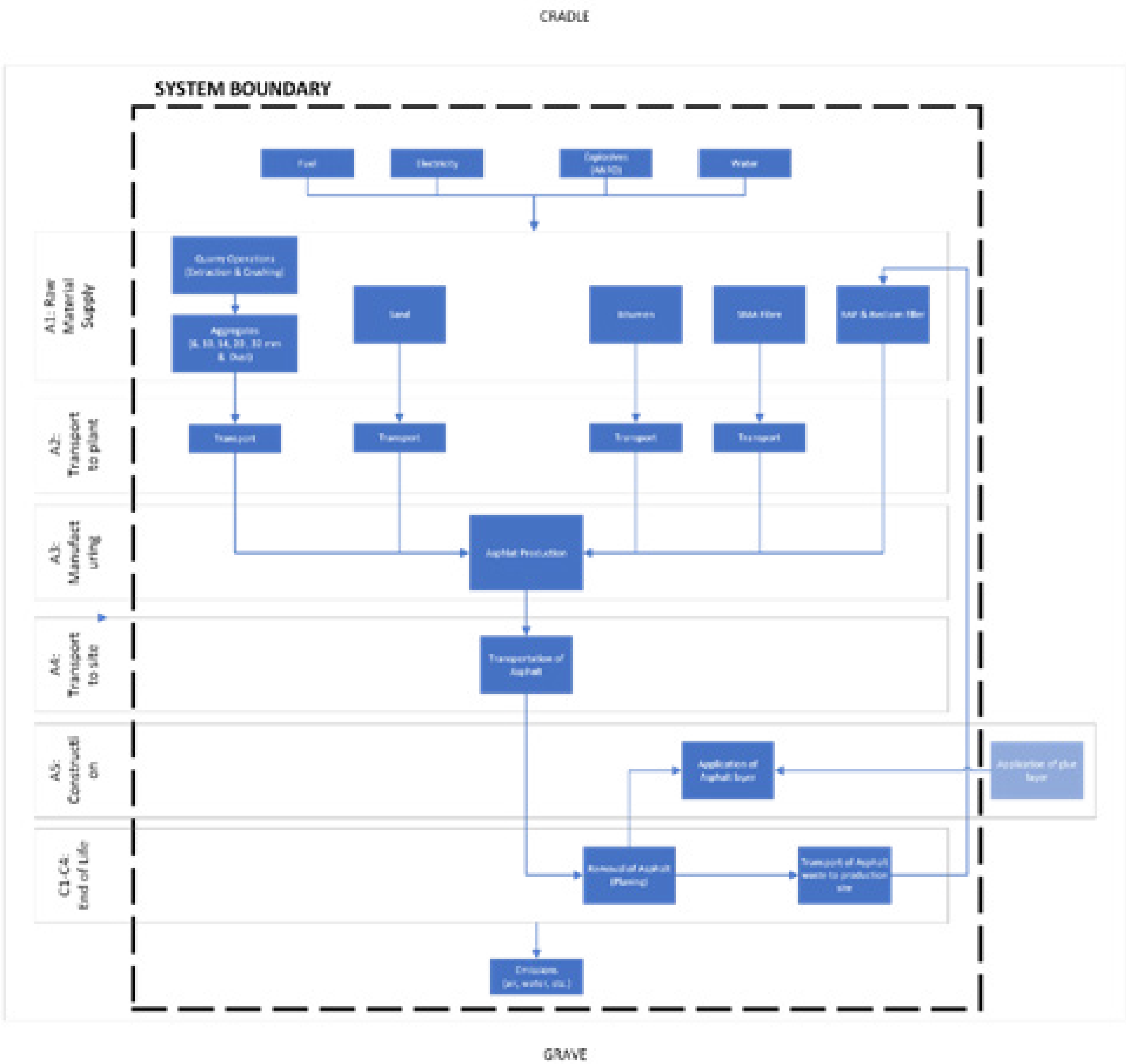

Figure 3: Process Map

*** These activities occur is some scenarios only**

1.3 Inventory Data and Analysis

1.3.1 Unit processes

The system of study and its boundaries are shown. The following Unit processes were included as below. More details are included in the next section.

- Raw material extraction and processing (A1)
- Raw material transport (A2)
- Manufacturing (A3)
- Asphalt transport (A4)
- Construction (A5)
- Deconstruction (C1)
- Waste Transport (C2)
- Credit for Recycling (D)

The repair of asphalt surface is similar to construction and due to the variability, it is not considered separately under Use stage (B).

1.3.2 Material and Energy

The activity data for the analysis and impact assessment were provided by MGL group for the 12-month period between 1st April 2023 and 31st March 2024.

Quantities of materials used per functional unit were based on the Asphalt mix ratios provided by MGL Group.

All materials that have been included the final study are:

- Aggregates of various sizes (6, 10, 14, 20, & 32mm) and dust
- Explosives (Ammonium Nitrate Fuel Oil)
- Water
- Sand
- Bitumen
- Cellulose Fibre

Waste from manufacturing was negligible as all waste is reused as fillers within the same facility. Similarly, the solid waste generated during construction is assumed to be negligible, as 100% of reclaimed asphalt is collected and delivered back to the production plant.
The end-of-life stage, therefore, consists only the energy consumed during planning and the transportation of reclaimed asphalt back to the facility.

PRODUCTION ENERGY

Energy used in terms of fuel and electricity are:

- Diesel
- Burning Oil (Kerosene)
- Natural Gas
- Liquified Petroleum Gas (LPG)
- UK Grid Electricity

1.4 Data Assessment and Carbon footprint calculations

1.4.1 Data Assessment

The sources of data used and an assessment of the quality of that data is provided below:

Input/Activity	Data source	Data Quality
Materials	Suppliers in UK Specifications and quantity by MGL Group Life Cycle impact assessment was calculated by SmartCarbon using ecoinvent database V3.11, Allocation, cut-off, EN15804. EuroBitume Life Cycle Assessment 4.0 for bitumen (2025) results based on EN15804 A2 Cut off and infrastructure is excluded.	High High
Process Energy	Fuel and electricity consumption by MGL Group Life Cycle impact assessment was calculated by SmartCarbon using ecoinvent database V3.11, Allocation, cut-off, EN15804 .	Very High High
Transport	The freighting of input materials finished prod-uct, and waste was calculated from data pro-vided by MGL and estimated distances. The transportation data provided was not re-stricted to asphalt related activities. However, for time being there was no attempt to allocate between asphalt and other activities. Life Cycle impact assessment was calculated by SmartCarbon using ecoinvent database V3.11, Allocation, cut-off, EN15804.	Medium Medium (Ecoinvent factors applied closest to the specific mode of transport used)

Information on the origin and the reference materials or processes using the ecoinvent v3.11 data base are all included in Appendices 2-5.

The primary data provided by MGL Group is specific to the technology used in its manufacturing process. It is site specific and considered to be good quality. In some cases, due to lack of granular data the overall input and output data is used rather than intermediate process specific data.

The geographical scope of the raw materials and manufacturing are the United Kingdom. The geographic coverage is considered very good.

2. Life Cycle Impact Assessment Results

Summary calculations of life cycle impacts are provided in the tables 1 to 15:

The core impact categories specified in BS EN 15804:2012+A2:2019 were considered and listed as below:

1. Ozone depletion
2. Acidification
3. Eutrophication: freshwater
4. Eutrophication: marine
5. Eutrophication: terrestrial
6. Photochemical oxidant formation: human health
7. Material resources: metals/minerals
8. Energy resources: non-renewable
9. Water use
10. Climate change: total
11. Climate change: fossil
12. Climate change: biogenic
13. Climate change: land use and land use change

Product:
AC 6 dense surf gritstone

Impact Category	Unit	A1 - A3	A4 - A5	C1 - C4	D*
ozone depletion	kg CFC-11-Eq	7.57E-07	8.55E-08	1.77E-07	
acidification	mol H+-Eq	2.31E-01	8.43E-03	1.74E-02	
eutrophication: freshwater	kg P-Eq	3.35E-03	2.73E-04	5.62E-04	
eutrophication: marine	kg N-Eq	4.96E-02	2.03E-03	4.19E-03	
eutrophication: terrestrial	mol N-Eq	5.45E-01	2.19E-02	4.52E-02	
photochemical oxidant formation: human health	kg NMVOC-Eq	2.29E-01	1.34E-02	2.76E-02	
material resources: metals/minerals	kg Sb-Eq	4.71E-05	1.38E-05	2.84E-05	
energy resources: non-renewable	MJ, net calorific value	3.53E+03	5.58E+01	1.15E+02	
water use	m3 world Eq de-prived	2.58E+00	2.96E-01	6.11E-01	
climate change: total (EF v3.1 - IPCC 2021)	kg CO2-Eq	6.49E+01	3.93E+00	8.11E+00	
climate change: fossil (EF v3.1 - IPCC 2021)	kg CO2-Eq	6.47E+01	3.92E+00	8.10E+00	
climate change: biogenic (EF v3.1 - IPCC 2021)	kg CO2-Eq	2.49E-01	2.56E-03	5.25E-03	
climate change: land use and land use change (EF v3.1 - IPCC 2021)	kg CO2-Eq	2.54E-02	1.33E-03	2.73E-03	

Table 1: AC 6 dense surf gritstone

*** This product does not use any reclaimed asphalt as raw material. The reclaimed asphalt for this product is recycled at the end of life at the same facility into another asphalt mix. Due to the complexity of the open loop recycling the Module D is not calculated.**

Product:
AC 10 close surf Gritstone

Impact Category	Unit	A1 - A3	A4 - A5	C1 - C4	D
ozone depletion	kg CFC-11-Eq	7.19E-07	8.55E-08	1.77E-07	-1.35E-08
acidification	mol H+-Eq	1.93E-01	8.43E-03	1.74E-02	-1.46E-03
eutrophication: freshwater	kg P-Eq	3.21E-03	2.73E-04	5.62E-04	-4.42E-05
eutrophication: marine	kg N-Eq	3.96E-02	2.03E-03	4.19E-03	-3.25E-04
eutrophication: terrestrial	mol N-Eq	4.35E-01	2.19E-02	4.52E-02	-4.07E-03
photochemical oxidant formation: human health	kg NMVOC-Eq	1.82E-01	1.34E-02	2.76E-02	-2.04E-03
material resources: metals/minerals	kg Sb-Eq	4.04E-05	1.38E-05	2.84E-05	-2.41E-06
energy resources: non-renewable	MJ, net calorific value	2.59E+03	5.58E+01	1.15E+02	-8.69E+00
water use	m3 world Eq de-prived	2.26E+00	2.96E-01	6.11E-01	-6.98E-02
climate change: total (EF v3.1 - IPCC 2021)	kg CO2-Eq	5.27E+01	3.93E+00	8.11E+00	-6.11E-01
climate change: fossil (EF v3.1 - IPCC 2021)	kg CO2-Eq	5.25E+01	3.92E+00	8.10E+00	-6.10E-01
climate change: biogenic (EF v3.1 - IPCC 2021)	kg CO2-Eq	2.06E-01	2.56E-03	5.25E-03	-3.79E-04
climate change: land use and land use change (EF v3.1 - IPCC 2021)	kg CO2-Eq	1.95E-02	1.33E-03	2.73E-03	-2.00E-04

Table 2: AC 10 close surf Gritstone

Product:

AC 20 dense binder Hardstone / Limestone

Impact Category	Unit	A1 - A3	A4 - A5	C1 - C4	D
ozone depletion	kg CFC-11-Eq	7.07E-07	8.55E-08	1.77E-07	-1.80E-08
acidification	mol H+-Eq	1.69E-01	8.43E-03	1.74E-02	-1.95E-03
eutrophication: freshwater	kg P-Eq	3.17E-03	2.73E-04	5.62E-04	-5.90E-05
eutrophication: marine	kg N-Eq	3.35E-02	2.03E-03	4.19E-03	-4.34E-04
eutrophication: terrestrial	mol N-Eq	3.68E-01	2.19E-02	4.52E-02	-5.44E-03
photochemical oxidant formation: human health	kg NMVOC-Eq	1.53E-01	1.34E-02	2.76E-02	-2.72E-03
material resources: metals/minerals	kg Sb-Eq	3.74E-05	1.38E-05	2.84E-05	-3.22E-06
energy resources: non-renewable	MJ, net calorific value	1.99E+03	5.58E+01	1.15E+02	-1.16E+01
water use	m3 world Eq de-prived	2.11E+00	2.96E-01	6.11E-01	-9.33E-02
climate change: total (EF v3.1 - IPCC 2021)	kg CO2-Eq	4.53E+01	3.93E+00	8.11E+00	-8.16E-01
climate change: fossil (EF v3.1 - IPCC 2021)	kg CO2-Eq	4.51E+01	3.92E+00	8.10E+00	-8.15E-01
climate change: biogenic (EF v3.1 - IPCC 2021)	kg CO2-Eq	1.79E-01	2.56E-03	5.25E-03	-5.06E-04
climate change: land use and land use change (EF v3.1 - IPCC 2021)	kg CO2-Eq	1.58E-02	1.33E-03	2.73E-03	-2.68E-04

Table 3: AC 20 dense binder Hardstone / Limestone

Product:

AC 20 Heavy Duty Binder Hardstone / Limestone

Impact Category	Unit	A1 - A3	A4 - A5	C1 - C4	D
ozone depletion	kg CFC-11-Eq	7.03E-07	8.55E-08	1.77E-07	-1.89E-08
acidification	mol H+-Eq	1.72E-01	8.43E-03	1.74E-02	-2.04E-03
eutrophication: freshwater	kg P-Eq	3.16E-03	2.73E-04	5.62E-04	-6.18E-05
eutrophication: marine	kg N-Eq	3.42E-02	2.03E-03	4.19E-03	-4.54E-04
eutrophication: terrestrial	mol N-Eq	3.76E-01	2.19E-02	4.52E-02	-5.69E-03
photochemical oxidant formation: human health	kg NMVOC-Eq	1.57E-01	1.34E-02	2.76E-02	-2.85E-03
material resources: metals/minerals	kg Sb-Eq	3.72E-05	1.38E-05	2.84E-05	-3.37E-06
energy resources: non-renewable	MJ, net calorific value	2.08E+03	5.58E+01	1.15E+02	-1.21E+01
water use	m3 world Eq de-prived	2.10E+00	2.96E-01	6.11E-01	-9.76E-02
climate change: total (EF v3.1 - IPCC 2021)	kg CO2-Eq	4.62E+01	3.93E+00	8.11E+00	-8.53E-01
climate change: fossil (EF v3.1 - IPCC 2021)	kg CO2-Eq	4.60E+01	3.92E+00	8.10E+00	-8.53E-01
climate change: biogenic (EF v3.1 - IPCC 2021)	kg CO2-Eq	1.83E-01	2.56E-03	5.25E-03	-5.29E-04
climate change: land use and land use change (EF v3.1 - IPCC 2021)	kg CO2-Eq	1.63E-02	1.33E-03	2.73E-03	-2.80E-04

Table 4: AC 20 Heavy Duty Binder Hardstone / Limestone

Product:
35/14 HRA Surface Course

Impact Category	Unit	A1 - A3	A4 - A5	C1 - C4	D
ozone depletion	kg CFC-11-Eq	6.55E-07	8.55E-08	1.77E-07	-6.64E-09
acidification	mol H+-Eq	2.28E-01	8.43E-03	1.74E-02	-7.19E-04
eutrophication: freshwater	kg P-Eq	3.63E-03	2.73E-04	5.62E-04	-2.18E-05
eutrophication: marine	kg N-Eq	4.95E-02	2.03E-03	4.19E-03	-1.60E-04
eutrophication: terrestrial	mol N-Eq	5.43E-01	2.19E-02	4.52E-02	-2.00E-03
photochemical oxidant formation: human health	kg NMVOC-Eq	2.17E-01	1.34E-02	2.76E-02	-1.00E-03
material resources: metals/minerals	kg Sb-Eq	4.10E-05	1.38E-05	2.84E-05	-1.19E-06
energy resources: non-renewable	MJ, net calorific value	3.34E+03	5.58E+01	1.15E+02	-4.28E+00
water use	m3 world Eq de-prived	3.40E+01	2.96E-01	6.11E-01	-3.44E-02
climate change: total (EF v3.1 - IPCC 2021)	kg CO2-Eq	6.02E+01	3.93E+00	8.11E+00	-3.00E-01
climate change: fossil (EF v3.1 - IPCC 2021)	kg CO2-Eq	5.99E+01	3.92E+00	8.10E+00	-3.00E-01
climate change: biogenic (EF v3.1 - IPCC 2021)	kg CO2-Eq	2.47E-01	2.56E-03	5.25E-03	-1.86E-04
climate change: land use and land use change (EF v3.1 - IPCC 2021)	kg CO2-Eq	2.52E-02	1.33E-03	2.73E-03	-9.85E-05

Table 5: 35/14 HRA Surface Course

Product:
30/14 HRA Surface Course

Impact Category	Unit	A1 - A3	A4 - A5	C1 - C4	D
ozone depletion	kg CFC-11-Eq	6.50E-07	8.55E-08	1.77E-07	-7.76E-09
acidification	mol H+-Eq	2.33E-01	8.43E-03	1.74E-02	-8.41E-04
eutrophication: freshwater	kg P-Eq	3.68E-03	2.73E-04	5.62E-04	-2.54E-05
eutrophication: marine	kg N-Eq	5.11E-02	2.03E-03	4.19E-03	-1.87E-04
eutrophication: terrestrial	mol N-Eq	5.60E-01	2.19E-02	4.52E-02	-2.34E-03
photochemical oxidant formation: human health	kg NMVOC-Eq	2.24E-01	1.34E-02	2.76E-02	-1.17E-03
material resources: metals/minerals	kg Sb-Eq	4.11E-05	1.38E-05	2.84E-05	-1.39E-06
energy resources: non-renewable	MJ, net calorific value	3.48E+03	5.58E+01	1.15E+02	-5.00E+00
water use	m3 world Eq de-prived	3.69E+01	2.96E-01	6.11E-01	-4.02E-02
climate change: total (EF v3.1 - IPCC 2021)	kg CO2-Eq	6.17E+01	3.93E+00	8.11E+00	-3.51E-01
climate change: fossil (EF v3.1 - IPCC 2021)	kg CO2-Eq	6.14E+01	3.92E+00	8.10E+00	-3.51E-01
climate change: biogenic (EF v3.1 - IPCC 2021)	kg CO2-Eq	2.54E-01	2.56E-03	5.25E-03	-2.18E-04
climate change: land use and land use change (EF v3.1 - IPCC 2021)	kg CO2-Eq	2.62E-02	1.33E-03	2.73E-03	-1.15E-04

Table 6: 30/14 HRA Surface Course

Product:
SMA 10 Surface Gritstone

Impact Category	Unit	A1 - A3	A4 - A5	C1 - C4	D
ozone depletion	kg CFC-11-Eq	7.11E-07	8.55E-08	1.77E-07	-1.76E-08
acidification	mol H+-Eq	2.12E-01	8.43E-03	1.74E-02	-1.91E-03
eutrophication: freshwater	kg P-Eq	3.43E-03	2.73E-04	5.62E-04	-5.77E-05
eutrophication: marine	kg N-Eq	4.40E-02	2.03E-03	4.19E-03	-4.23E-04
eutrophication: terrestrial	mol N-Eq	4.83E-01	2.19E-02	4.52E-02	-5.31E-03
photochemical oxidant formation: human health	kg NMVOC-Eq	2.00E-01	1.34E-02	2.76E-02	-2.66E-03
material resources: metals/minerals	kg Sb-Eq	2.21E-04	1.38E-05	2.84E-05	-3.15E-06
energy resources: non-renewable	MJ, net calorific value	3.00E+03	5.58E+01	1.15E+02	-1.13E+01
water use	m3 world Eq de-prived	2.45E+00	2.96E-01	6.11E-01	-9.11E-02
climate change: total (EF v3.1 - IPCC 2021)	kg CO2-Eq	5.75E+01	3.93E+00	8.11E+00	-7.97E-01
climate change: fossil (EF v3.1 - IPCC 2021)	kg CO2-Eq	5.72E+01	3.92E+00	8.10E+00	-7.96E-01
climate change: biogenic (EF v3.1 - IPCC 2021)	kg CO2-Eq	2.41E-01	2.56E-03	5.25E-03	-4.94E-04
climate change: land use and land use change (EF v3.1 - IPCC 2021)	kg CO2-Eq	2.25E-02	1.33E-03	2.73E-03	-2.61E-04

Table 7: SMA 10 Surface Gritstone

Product:
SMA 6 surface Gritstone

Impact Category	Unit	A1 - A3	A4 - A5	C1 - C4	D
ozone depletion	kg CFC-11-Eq	7.26E-07	8.55E-08	1.77E-07	-9.40E-09
acidification	mol H+-Eq	2.29E-01	8.43E-03	1.74E-02	-1.02E-03
eutrophication: freshwater	kg P-Eq	3.49E-03	2.73E-04	5.62E-04	-3.08E-05
eutrophication: marine	kg N-Eq	4.84E-02	2.03E-03	4.19E-03	-2.26E-04
eutrophication: terrestrial	mol N-Eq	5.31E-01	2.19E-02	4.52E-02	-2.84E-03
photochemical oxidant formation: human health	kg NMVOC-Eq	2.21E-01	1.34E-02	2.76E-02	-1.42E-03
material resources: metals/minerals	kg Sb-Eq	2.24E-04	1.38E-05	2.84E-05	-1.68E-06
energy resources: non-renewable	MJ, net calorific value	3.42E+03	5.58E+01	1.15E+02	-6.06E+00
water use	m3 world Eq de-prived	2.59E+00	2.96E-01	6.11E-01	-4.86E-02
climate change: total (EF v3.1 - IPCC 2021)	kg CO2-Eq	6.29E+01	3.93E+00	8.11E+00	-4.26E-01
climate change: fossil (EF v3.1 - IPCC 2021)	kg CO2-Eq	6.27E+01	3.92E+00	8.10E+00	-4.25E-01
climate change: biogenic (EF v3.1 - IPCC 2021)	kg CO2-Eq	2.60E-01	2.56E-03	5.25E-03	-2.64E-04
climate change: land use and land use change (EF v3.1 - IPCC 2021)	kg CO2-Eq	2.52E-02	1.33E-03	2.73E-03	-1.40E-04

Table 8: SMA 6 surface Gritstone

Product:

50/10 HRA Surface Course

Impact Category	Unit	A1 - A3	A4 - A5	C1 - C4	D
ozone depletion	kg CFC-11-Eq	6.65E-07	8.55E-08	1.77E-07	-4.91E-09
acidification	mol H+-Eq	2.16E-01	8.43E-03	1.74E-02	-5.31E-04
eutrophication: freshwater	kg P-Eq	3.55E-03	2.73E-04	5.62E-04	-1.61E-05
eutrophication: marine	kg N-Eq	4.63E-02	2.03E-03	4.19E-03	-1.18E-04
eutrophication: terrestrial	mol N-Eq	5.08E-01	2.19E-02	4.52E-02	-1.48E-03
photochemical oxidant formation: human health	kg NMVOC-Eq	2.04E-01	1.34E-02	2.76E-02	-7.41E-04
material resources: metals/minerals	kg Sb-Eq	4.07E-05	1.38E-05	2.84E-05	-8.77E-07
energy resources: non-renewable	MJ, net calorific value	3.07E+03	5.58E+01	1.15E+02	-3.16E+00
water use	m3 world Eq de-prived	2.80E+01	2.96E-01	6.11E-01	-2.54E-02
climate change: total (EF v3.1 - IPCC 2021)	kg CO2-Eq	5.72E+01	3.93E+00	8.11E+00	-2.22E-01
climate change: fossil (EF v3.1 - IPCC 2021)	kg CO2-Eq	5.70E+01	3.92E+00	8.10E+00	-2.22E-01
climate change: biogenic (EF v3.1 - IPCC 2021)	kg CO2-Eq	2.33E-01	2.56E-03	5.25E-03	-1.38E-04
climate change: land use and land use change (EF v3.1 - IPCC 2021)	kg CO2-Eq	2.34E-02	1.33E-03	2.73E-03	-7.28E-05

Table 9: 50/10 HRA Surface Course

Product:

55/10 HRA Surface Course

Impact Category	Unit	A1 - A3	A4 - A5	C1 - C4	D
ozone depletion	kg CFC-11-Eq	6.67E-07	8.55E-08	1.77E-07	-4.91E-09
acidification	mol H+-Eq	2.08E-01	8.43E-03	1.74E-02	-5.31E-04
eutrophication: freshwater	kg P-Eq	3.51E-03	2.73E-04	5.62E-04	-1.61E-05
eutrophication: marine	kg N-Eq	4.43E-02	2.03E-03	4.19E-03	-1.18E-04
eutrophication: terrestrial	mol N-Eq	4.86E-01	2.19E-02	4.52E-02	-1.48E-03
photochemical oxidant formation: human health	kg NMVOC-Eq	1.96E-01	1.34E-02	2.76E-02	-7.41E-04
material resources: metals/minerals	kg Sb-Eq	4.03E-05	1.38E-05	2.84E-05	-8.77E-07
energy resources: non-renewable	MJ, net calorific value	2.89E+03	5.58E+01	1.15E+02	-3.16E+00
water use	m3 world Eq de-prived	2.59E+01	2.96E-01	6.11E-01	-2.54E-02
climate change: total (EF v3.1 - IPCC 2021)	kg CO2-Eq	5.51E+01	3.93E+00	8.11E+00	-2.22E-01
climate change: fossil (EF v3.1 - IPCC 2021)	kg CO2-Eq	5.49E+01	3.92E+00	8.10E+00	-2.22E-01
climate change: biogenic (EF v3.1 - IPCC 2021)	kg CO2-Eq	2.25E-01	2.56E-03	5.25E-03	-1.38E-04
climate change: land use and land use change (EF v3.1 - IPCC 2021)	kg CO2-Eq	2.22E-02	1.33E-03	2.73E-03	-7.28E-05

Table 10: 55/10 HRA Surface Course

Product:
14/20 PCC'S +68PSV HS

Impact Category	Unit	A1 - A3	A4 - A5	C1 - C4	D*
ozone depletion	kg CFC-11-Eq	7.01E-07	8.55E-08	1.77E-07	
acidification	mol H+-Eq	1.34E-01	8.43E-03	1.74E-02	
eutrophication: freshwater	kg P-Eq	3.14E-03	2.73E-04	5.62E-04	
eutrophication: marine	kg N-Eq	2.41E-02	2.03E-03	4.19E-03	
eutrophication: terrestrial	mol N-Eq	2.67E-01	2.19E-02	4.52E-02	
photochemical oxidant formation: human health	kg NMVOC-Eq	1.10E-01	1.34E-02	2.76E-02	
material resources: metals/minerals	kg Sb-Eq	3.68E-05	1.38E-05	2.84E-05	
energy resources: non-renewable	MJ, net calorific value	1.07E+03	5.58E+01	1.15E+02	
water use	m3 world Eq de-prived	1.95E+00	2.96E-01	6.11E-01	
climate change: total (EF v3.1 - IPCC 2021)	kg CO2-Eq	3.45E+01	3.93E+00	8.11E+00	
climate change: fossil (EF v3.1 - IPCC 2021)	kg CO2-Eq	3.43E+01	3.92E+00	8.10E+00	
climate change: biogenic (EF v3.1 - IPCC 2021)	kg CO2-Eq	1.37E-01	2.56E-03	5.25E-03	
climate change: land use and land use change (EF v3.1 - IPCC 2021)	kg CO2-Eq	1.03E-02	1.33E-03	2.73E-03	

Table 11: 14/20 PCC'S +68PSV HS

*** This product does not use any reclaimed asphalt as raw material. The reclaimed asphalt for this product is recycled at the end of life at the same facility into another asphalt mix. Due to the open loop recycling the Module D is not calculated.**

Product:
AC 32 Dense Base Hardstone / Limestone

Impact Category	Unit	A1 - A3	A4 - A5	C1 - C4	D
ozone depletion	kg CFC-11-Eq	7.02E-07	8.55E-08	1.77E-07	-1.80E-08
acidification	mol H+-Eq	1.65E-01	8.43E-03	1.74E-02	-1.95E-03
eutrophication: freshwater	kg P-Eq	3.15E-03	2.73E-04	5.62E-04	-5.90E-05
eutrophication: marine	kg N-Eq	3.24E-02	2.03E-03	4.19E-03	-4.34E-04
eutrophication: terrestrial	mol N-Eq	3.57E-01	2.19E-02	4.52E-02	-5.44E-03
photochemical oxidant formation: human health	kg NMVOC-Eq	1.48E-01	1.34E-02	2.76E-02	-2.72E-03
material resources: metals/minerals	kg Sb-Eq	3.68E-05	1.38E-05	2.84E-05	-3.22E-06
energy resources: non-renewable	MJ, net calorific value	1.89E+03	5.58E+01	1.15E+02	-1.16E+01
water use	m3 world Eq de-prived	2.07E+00	2.96E-01	6.11E-01	-9.33E-02
climate change: total (EF v3.1 - IPCC 2021)	kg CO2-Eq	4.40E+01	3.93E+00	8.11E+00	-8.16E-01
climate change: fossil (EF v3.1 - IPCC 2021)	kg CO2-Eq	4.39E+01	3.92E+00	8.10E+00	-8.15E-01
climate change: biogenic (EF v3.1 - IPCC 2021)	kg CO2-Eq	1.74E-01	2.56E-03	5.25E-03	-5.06E-04
climate change: land use and land use change (EF v3.1 - IPCC 2021)	kg CO2-Eq	1.52E-02	1.33E-03	2.73E-03	-2.68E-04

Table 12: AC 32 Dense Base Hardstone / Limestone

Product:
AC 32 Dense Binder Hardstone / Limestone

Impact Category	Unit	A1 - A3	A4 - A5	C1 - C4	D
ozone depletion	kg CFC-11-Eq	7.03E-07	8.55E-08	1.77E-07	-1.80E-08
acidification	mol H+-Eq	1.69E-01	8.43E-03	1.74E-02	-1.95E-03
eutrophication: freshwater	kg P-Eq	3.15E-03	2.73E-04	5.62E-04	-5.90E-05
eutrophication: marine	kg N-Eq	3.33E-02	2.03E-03	4.19E-03	-4.34E-04
eutrophication: terrestrial	mol N-Eq	3.66E-01	2.19E-02	4.52E-02	-5.44E-03
photochemical oxidant formation: human health	kg NMVOC-Eq	1.52E-01	1.34E-02	2.76E-02	-2.72E-03
material resources: metals/minerals	kg Sb-Eq	3.71E-05	1.38E-05	2.84E-05	-3.22E-06
energy resources: non-renewable	MJ, net calorific value	1.98E+03	5.58E+01	1.15E+02	-1.16E+01
water use	m3 world Eq de-prived	2.09E+00	2.96E-01	6.11E-01	-9.33E-02
climate change: total (EF v3.1 - IPCC 2021)	kg CO2-Eq	4.51E+01	3.93E+00	8.11E+00	-8.16E-01
climate change: fossil (EF v3.1 - IPCC 2021)	kg CO2-Eq	4.49E+01	3.92E+00	8.10E+00	-8.15E-01
climate change: biogenic (EF v3.1 - IPCC 2021)	kg CO2-Eq	1.78E-01	2.56E-03	5.25E-03	-5.06E-04
climate change: land use and land use change (EF v3.1 - IPCC 2021)	kg CO2-Eq	1.58E-02	1.33E-03	2.73E-03	-2.68E-04

Table 13: AC 32 Dense Binder Hardstone / Limestone

Product:
AC 32 Heavy Duty Binder Hardstone / Limestone

Impact Category	Unit	A1 - A3	A4 - A5	C1 - C4	D
ozone depletion	kg CFC-11-Eq	7.01E-07	8.55E-08	1.77E-07	-1.93E-08
acidification	mol H+-Eq	1.70E-01	8.43E-03	1.74E-02	-2.09E-03
eutrophication: freshwater	kg P-Eq	3.15E-03	2.73E-04	5.62E-04	-6.31E-05
eutrophication: marine	kg N-Eq	3.37E-02	2.03E-03	4.19E-03	-4.63E-04
eutrophication: terrestrial	mol N-Eq	3.71E-01	2.19E-02	4.52E-02	-5.81E-03
photochemical oxidant formation: human health	kg NMVOC-Eq	1.54E-01	1.34E-02	2.76E-02	-2.91E-03
material resources: metals/minerals	kg Sb-Eq	3.68E-05	1.38E-05	2.84E-05	-3.44E-06
energy resources: non-renewable	MJ, net calorific value	2.03E+03	5.58E+01	1.15E+02	-1.24E+01
water use	m3 world Eq de-prived	2.09E+00	2.96E-01	6.11E-01	-9.97E-02
climate change: total (EF v3.1 - IPCC 2021)	kg CO2-Eq	4.56E+01	3.93E+00	8.11E+00	-8.72E-01
climate change: fossil (EF v3.1 - IPCC 2021)	kg CO2-Eq	4.54E+01	3.92E+00	8.10E+00	-8.71E-01
climate change: biogenic (EF v3.1 - IPCC 2021)	kg CO2-Eq	1.81E-01	2.56E-03	5.25E-03	-5.41E-04
climate change: land use and land use change (EF v3.1 - IPCC 2021)	kg CO2-Eq	1.60E-02	1.33E-03	2.73E-03	-2.86E-04

Table 14: AC 32 Heavy Duty Binder Hardstone / Limestone

Product:
AC 32 Heavy Duty Base Hardstone / Limestone

Impact Category	Unit	A1 - A3	A4 - A5	C1 - C4	D
ozone depletion	kg CFC-11-Eq	7.00E-07	8.55E-08	1.77E-07	-1.93E-08
acidification	mol H+-Eq	1.65E-01	8.43E-03	1.74E-02	-2.09E-03
eutrophication: freshwater	kg P-Eq	3.15E-03	2.73E-04	5.62E-04	-6.31E-05
eutrophication: marine	kg N-Eq	3.24E-02	2.03E-03	4.19E-03	-4.63E-04
eutrophication: terrestrial	mol N-Eq	3.56E-01	2.19E-02	4.52E-02	-5.81E-03
photochemical oxidant formation: human health	kg NMVOC-Eq	1.48E-01	1.34E-02	2.76E-02	-2.91E-03
material resources: metals/minerals	kg Sb-Eq	3.65E-05	1.38E-05	2.84E-05	-3.44E-06
energy resources: non-renewable	MJ, net calorific value	1.89E+03	5.58E+01	1.15E+02	-1.24E+01
water use	m3 world Eq de-prived	2.06E+00	2.96E-01	6.11E-01	-9.97E-02
climate change: total (EF v3.1 - IPCC 2021)	kg CO2-Eq	4.39E+01	3.93E+00	8.11E+00	-8.72E-01
climate change: fossil (EF v3.1 - IPCC 2021)	kg CO2-Eq	4.38E+01	3.92E+00	8.10E+00	-8.71E-01
climate change: biogenic (EF v3.1 - IPCC 2021)	kg CO2-Eq	1.74E-01	2.56E-03	5.25E-03	-5.41E-04
climate change: land use and land use change (EF v3.1 - IPCC 2021)	kg CO2-Eq	1.52E-02	1.33E-03	2.73E-03	-2.86E-04

Table 15: AC 32 Heavy Duty Base Hardstone / Limestone

While the exact contribution varies between the Asphalt mixes, on average, the relative contributions of the different life stages to the Total Climate change emissions (CO2e) are represented in the pie chart on the figure 4.

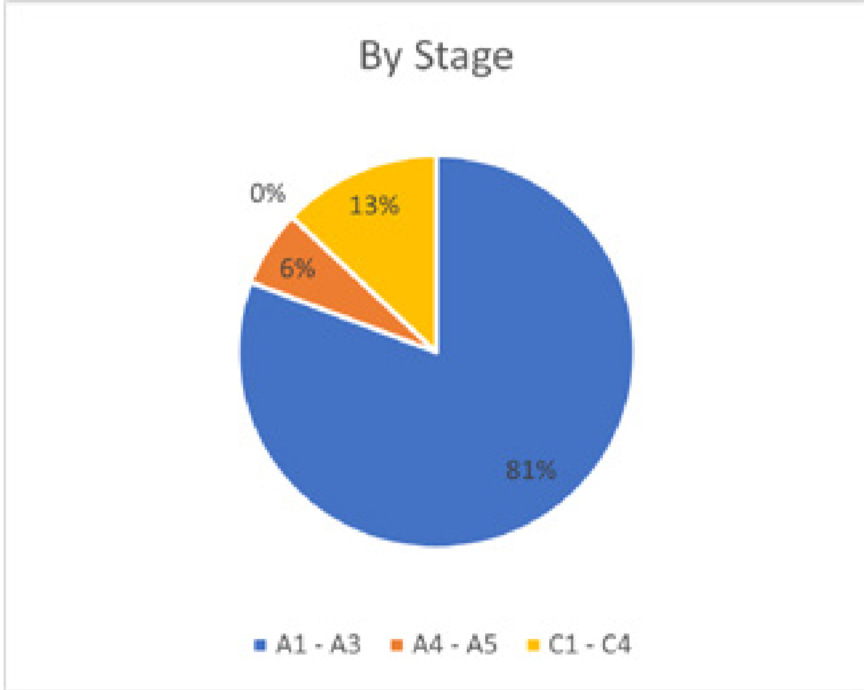

Figure 4: Life cycle stage impact

As it can be seen, 81% of Product Life cycle CO2e emissions come from production, followed up by 13% from end of life and 6% from construction stage. The average impact from raw materials for one tonne of Asphalt is provided in figure 5 below.

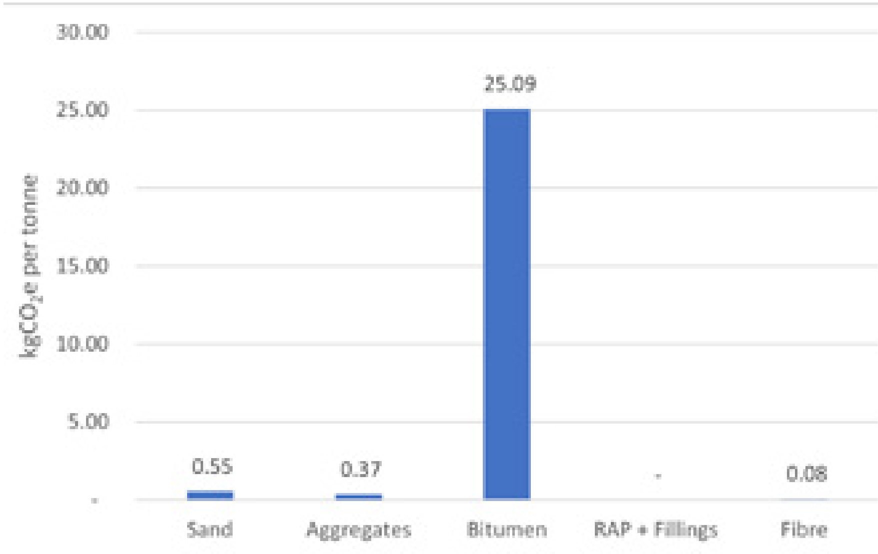

Figure 5: Raw material impact

As it can be seen, the most significant impact (as carbon equivalent) of the materials used was from bitumen. Since, the ecoinvent dataset for bitumen was dated, a more recent and geographically aligned data from EuroBitume was used instead so that more accurate impact is calculated for this significant material.

3. Discussion

In general, life cycle assessments are used:

- To compare two alternative products or processes, or to compare to a reference one -for example for labelling purpose
- To identify opportunities for improvements, whether at various points in the life cycle or in specific components. This is particularly applicable to organisations who commit to improve continually and to be sustainable.
- To inform and thus assist in decision making and provide directions for product/process development. This is particularly applicable for Government or Corporate strategies.

In terms of this study fifteen types of Asphalt mixes were investigated. When compared with other publicly available product footprints the following were observed:

The UK Conversion factor for GHG reporting (DESNZ, 2025) provides 39.21 kgCO2e per tonne of Asphalt. In comparison and on average, MGL's 15 Asphalt mixes were 32% higher ranging from 34.49 (-32%) to 61.66 (57%).

The recently published ICE database v.4.1 provides more up to date figures and by binder (bitumen) content. This allows for better comparison and on average MGL's Asphalt is found to be 15% lower ranging from 32% to 10% lower. Detailed comparison is provided below in table 16..

ICE Database 4.1		MGL Results			Difference
Materials	Embodied Carbon	Materials	Bitumen Content	A1 - A3	
Asphalt, 3% (bitumen) binder content (by mass)	50.68	14/20 PCC'S +68PSV HS	1.5%	34.48720333	-32%
Asphalt, 3.5% binder content	53.42	AC 20 dense binder Hardstone / Limestone	3.5%	45.26145552	-15%
		AC 32 Dense Base Hardstone / Limestone	3.3%	44.02826636	-18%
		AC 32 Dense Binder Hardstone / Limestone	3.5%	45.10178767	-16%
		AC 32 Heavy Duty Binder Hardstone / Limestone	3.6%	45.55182758	-15%
		AC 32 Heavy Duty Base Hardstone / Limestone	3.3%	43.94154562	-18%
		AC 20 Heavy Duty Binder Hardstone / Limestone	3.7%	46.18136228	-14%
Asphalt, 5% binder content	61.62	AC 10 close surf Gritstone	4.8%	52.70085443	-14%
Asphalt, 5.5% binder content	64.36	55/10 HRA Surface Course	5.5%	55.11466134	-14%
		SMA 10 Surface Gritstone	5.7%	57.48078164	-11%
Asphalt, 6% binder content	67.09	50/10 HRA Surface Course	5.9%	57.20595292	-15%
Asphalt, 6.5% binder content	69.83	35/14 HRA Surface Course	6.5%	60.18648074	-14%
		SMA 6 surface Gritstone	6.6%	62.92119927	-10%
Asphalt, 7% binder content	72.56	AC 6 dense surf gritstone	6.8%	64.92178598	-11%
		30/14 HRA Surface Course	6.8%	61.66306551	-15%

Table 16 Comparison of MGL's product and ICE Database for various mixtures

The lower carbon impact for MGL's Asphalt could be attributed to the efficiencies in the production process and transportation.

The main findings of this study are summarised and briefly discussed below:

- The Production stage (A1-A3) seems to contribute the most in the product's impact. The quantity of bitumen used in the mixes was the largest contributor. Where feasible reducing the bitumen content will help reduce the overall impact. However, the bitumen content is standardised and reducing it may require new product standards to be published.

- The reclaimed Asphalt is re-used in most of the MGL's Asphalt mixes, which helps to reduce the impact from using virgin aggregates. Where feasible, increasing the RAP and reclaim fillers would be beneficial.

- Since the quarry operations for aggregates are carried out by MGL, site specific data was available. When compared to average aggregate impact from ecoinvent database (European average), MGL's aggregate found to have lower impact. This can be attributed to less energy used in shallower quarrying activities, typical in United Kingdom, and local quarry operation efficiencies.

- In terms of energy consumed during manufacturing, replacing Burning Oil, Gas Oil and LPG with Natural Gas or electricity will reduce the product's carbon footprint. Such reduction is encouraged, as it is within the control of the MGL. It is worth noting that MGL has already moved to using Natural Gas in one of its production facilities.

- In terms of transportation emissions, MGL's fuel consumption was found to be lower than European average. This could be partly attributed to use of fuel additives such as SulNox and use of a Fleet management system to monitor vehicle speed and acceleration and modify drivers' behaviours. However, it is worth noting that, a. the ecoinvent dataset for fuel efficiency has not been updated since 2013, b. the fuel efficiency data provided by MGL is just for total distance and fuel consumption. We do not have an accurate loading for the return trips. These two factors may also contribute to the apparent lower fuel consumption by MGL vehicles.

- Any improvements in transportation distances for raw materials as well as or modes of transport, will improve the product's overall impact. Further, accurate vehicle trip loading information as well as update in ecoinvent dataset may result in substantial differences of the transportation impacts.

In general, LCA is an iterative process, which means that in the light of new information or alternative developments, the study can be adjusted and/or revisited. It is worth bearing in mind, that LCA produces potential impacts -not actual- and these are not space or time related. In this respect LCA results are inherently uncertain. This is also typical for many environmental and risk assessments.

A major source of uncertainty in LCA though comes from the choices of the closest representative materials or processes to the ones used in the product, which are made using LCA databases as well as the choices on emission models. Whilst care was taken for these choices, it is possible that the results may be different if other choices are made. Should MGL Group wish to investigate further the exact content of the materials used and their manufacturing processing, the results could be easily recalculated. Similarly, any other Asphalt mixes produced at the plant using same methodology may also be calculated by varying the content percentage. Finally, the approximation to a representative material within the ecoinvent database may be more uncertain in some of the materials or flows.

Despite the limitations, the usefulness of life cycle assessment (as in this case of the product carbon footprint) is that it can highlight hot spots for improvements as well as iteratively be revisited in the light of new knowledge or new legal or other pressures for change. In view of its uncertainty though, any future use of this study for comparative assertions, will require care and a consistent and transparent approach for all scenarios, as well as external verification if these become publicly available.

4. Conclusions

The life cycle impacts of the asphalt mixes produced by MGL Group was comparable to other benchmark figures and in most cases was lower. This was attributed to local quarry practices, manufacturing, and transportation efficiencies.

The production stage was the largest contributor with bitumen being the raw material with highest impact. Any variation bitumen content will have significant impact on the overall footprint. Moving to natural gas as primary fuel for asphalt production will help lower the production impact. Similarly, reducing the transportation distance by sourcing the raw materials locally will have positive impact.

For future studies, it is advisable to improve the accuracy of the vehicle trip loading information. In addition, the impact of products is likely to show differences only if local conditions of production facilities are different. For example, if the distances for raw materials and construction sites are different.

Appendix 1 Product specification – Asphalt types

Recipe	Sand	Dust	Stone 6 mm	Stone 10 mm	Stone 14 mm	Stone 20 mm	Stone 32 mm	Bitumen All Pens	Reclaim Filler	RAP	Fibre Pellets
AC 6 dense surf gritstone		62.20%	31.00%					6.80%	0.00%		
AC 10 close surf Gritstone		37.40%	22.50%	23.30%				4.80%	2.00%	10.00%	
AC 20 dense binder Hardstone / Limestone		32.00%	5.50%	10.20%	11.70%	20.10%		3.50%	2.00%	15.00%	
AC 20 Heavy Duty Binder Hardstone / Limestone		29.00%	3.00%	10.00%	14.00%	22.30%		3.70%	3.00%	15.00%	
35/14 HRA Surface Course	53.00%			11.00%	22.50%	1.50%		6.50%	5.50%		
30/14 HRA Surface Course	57.90%			11.30%	17.50%			6.80%	6.50%		
SMA 10 Surface Gritstone		22.00%	11.00%	44.50%				5.70%	6.50%	10.00%	0.30%
SMA 6 surface Gritstone		25.70%	59.40%					6.60%	8.00%		0.30%
50/10 HRA Surface Course	43.10%		8.00%	39.00%				5.90%	4.00%		
55/10 HRA Surface Course	39.50%		6.00%	45.00%				5.50%	4.00%		
14/20 PCC'S +68PSV HS						98.50%		1.50%			
AC 32 Dense Base Hardstone / Limestone		27.00%	5.50%	5.00%	7.70%	15.00%	19.50%	3.30%	2.00%	15.00%	
AC 32 Dense Binder Hardstone / Limestone		27.00%	5.50%	5.00%	7.70%	15.00%	19.30%	3.50%	2.00%	15.00%	
AC 32 Heavy Duty Binder Hardstone / Lime-stone		27.00%	5.90%	5.00%	7.70%	15.00%	17.30%	3.60%	3.50%	15.00%	
AC 32 Heavy Duty Base Hardstone / Limestone		27.00%	5.90%	5.00%	7.70%	15.00%	17.60%	3.30%	3.50%	15.00%	

Appendix 2 Tack Coat Impacts – Colbond-50

Product:
Tack Coat – Colbond-50

Impact Category	Unit	A1 - A3	A4
ozone depletion	kg CFC-11-Eq	1.79E-08	8.17E-11
acidification	mol H+-Eq	9.78E-04	8.76E-06
eutrophication: freshwater	kg P-Eq	3.96E-05	2.63E-07
eutrophication: marine	kg N-Eq	1.66E-04	2.30E-06
eutrophication: terrestrial	mol N-Eq	1.73E-03	2.49E-05
photochemical oxidant formation: human health	kg NMVOC-Eq	1.89E-02	1.47E-05
material resources: metals/minerals	kg Sb-Eq	9.98E-07	1.07E-08
energy resources: non-renewable	MJ, net calorific value	1.08E+01	5.47E-02
water use	m3 world Eq deprived	5.64E-02	3.18E-04
climate change: total (EF v3.1 - IPCC 2021)	kg CO2-Eq	2.47E-01	3.61E-03
climate change: fossil (EF v3.1 - IPCC 2021)	kg CO2-Eq	2.47E-01	3.60E-03
climate change: biogenic (EF v3.1 - IPCC 2021)	kg CO2-Eq	4.85E-04	2.12E-06
climate change: land use and land use change (EF v3.1 - IPCC 2021)	kg CO2-Eq	1.07E-04	1.34E-06

MGL
GROUP
RESHAPING THE BUILT ENVIRONMENT