CEDR Transnational Road Research Programme
Call 2013: Programme name

funded by Austria, Germany,
the Netherlands, Norway, Slovenia and UK

EDGAR
Evaluation and Decision Process for Greener Asphalt Roads

Recommended Product Category Rules (PCRs) for bituminous materials and technologies

Deliverable 2.1
November, 2014

Project Coordinator:
BRRC – Belgian Road Research Centre

Project Partners:
EPFL – Ecole Polytechnique Fédérale de Lausanne
TRL – Transport Research Laboratory
NTNU – Technical University Trondheim

CEDR Call 2013: Energy Efficiency
EDGAR
Evaluation and Decision Process for Greener Asphalt Roads

Recommended Product Category Rules for bituminous materials and technologies

Due date of deliverable: 15/09/2014
Actual submission date: 17/11/2014
Re-submission date: 16/02/2014

Start date of project: 16/04/2014 End date of project: 15/04/2016

Author(s) of this deliverable:
Wayman, Matthew & Peeling James, TRL Limited, UK
Maeck, Johan & De Visscher, Joëlle, BRRC, Belgium

PEB Project Manager:
Ripke, Oliver

Version: 1.1, 02/2015

Table of contents

Executive summary

The principal aim of the EDGAR project is to bridge the gap between innovation in the bituminous materials sector and adoption of the new technologies by national road administrations (NRAs). It aims to do this by providing NRAs with an assessment methodology which places sustainability information on the new technologies at their fingertips, enabling them to make informed decisions, and facilitate quick adoption of the technologies that provide the biggest advances towards sustainability for the highways sector and society as a whole.

This document details the exploratory research that has been undertaken to define the scope for the EDGAR methodology. The regulatory approach in Europe which underpins the assessment of construction products has been determined, along with the basis for following a life-cycle-based methodology to assess products.

In recent years, efforts have been made to standardise environmental information that is declared alongside products, through the use of Product Category Rules (PCRs) to produce Environmental Product Declarations (EPDs). By exploring the scope of current use, the relevance of these processes to the aims of EDGAR was considered. A wide-ranging review of environmental impact categories with potential relevance to bituminous products or highways in general was also conducted, to begin to inform the decision as to which impact categories will eventually form part of the 'basket' of indicators for NRAs to use to make informed judgements about novel products in the future.

Ultimately, as a result of the review, a way forward for the EDGAR methodology could be decided. It was decided that the methodology should be life-cycle based and extend beyond 'cradle-to-gate', in order to include some appraisal of durability of the products being assessed, and their influence on use-phase impacts of the road. EDGAR will seek to devise a manageable set of indicators (less than ten in number) that are meaningful and relevant to NRAs, and ultimately measurable. The process devised should be repeatable for novel products and not be too data- or time- intensive. It was decided that, based on the decisions regarding scope, the EDGAR methodology should complement the EN 15804 approach that has been used so far to produce standard EPDs for asphalt in several countries. Going forward in the project, environmental indicator selection should be based on an assessment of significance for asphalt. Significance could be assessed by 'normalisation' in the first instance. There may also be one or two additional environmental indicators that are particularly relevant to bituminous products or highways that are normally beyond the scope of a traditional LCA or EPD that should be included. Socio-economic indicators such as life-cycle cost, user delay, responsible sourcing and health & safety should be considered for inclusion in the final basket of indicators, to arrive at a more holistic sustainability assessment methodology, rather than one that is solely focussed on environmental issues.

1 Introduction

1.1 Background

The issue of assessing the environmental performance of construction products is gradually rising in prominence to sit alongside economic performance as one of the key selection criteria for construction projects in Europe. In the past, the merits of alternative proposals for civil engineering projects might typically have been assessed on the basis of ‘up front cost’: the initial capital outlay. This has now shifted to a more ‘whole life’ approach, particularly for highway asset management, whereby the costs of maintenance interventions across the design life of an asset are considered from the outset in addition to the initial capital outlay. This type of analysis provides a much more informed picture of the economic input that will be required in order for the asset to remain in a serviceable condition through its design lifetime. This type of ‘whole life’ approach to costing is formalised in the ISO EN 15686 series of standards.

From the perspective of sustainability, similar techniques to assess the environmental impacts of products or services have been in existence since the late 1960s and early 1970s. Coca-Cola first used a life-cycle based technique to quantify the energy, material and environmental consequences of packaging from the extraction of raw materials through to disposal (Hunt & Franklin, 1996). The technique was later formalised and more widely adopted as a result of initiatives of the Society of Environmental Toxicology and Chemistry (SETAC). A SETAC working group coined the term ‘life cycle assessment’ (LCA) in the early 1990s and a combined SETAC-United Nations Environment Programme (UNEP) working group later led to the development of the initial 14040 series of standards for LCA in the late 1990s. A perusal of the list of contents for the *International Journal of Life Cycle Assessment*, since first publication in 1996, shows published LCA work shifting focus through methodological challenges in the late 1990s and early 2000s, before its first real widespread application to waste management challenges and packaging. Later in the 2000s, the application to products across more sectors becomes far more extensive.

Until recently, LCA has never really been deployed to great extent as a technique in the general field of civil engineering. The focus so far has mainly been on the performance of the asset once in service: its energy and water efficiency performance. In the last few years, the energy efficiency agenda seems to have expanded once again to incorporate ‘embodied carbon’, which might be described as the emissions of carbon associated with the materials utilised in construction ‘cradle-to-site’, and all that this entails in terms of accounting for recycled content and wastage during production, amongst other aspects. As a result, the life-cycle approach emerged in the civil engineering sector albeit in a streamlined format; an approach that is often termed ‘carbon footprinting’. In some respects carbon footprinting was the vehicle through which life-cycle thinking became more widely adopted across many product sectors in a direct response to the climate change agenda, and a series of specifications and protocols including PAS 2050 and the Greenhouse Gas Protocol, and culminating in the release of ISO 14067, were developed directly to provide transparency and normalise the process. Subsequently, the introduction of the harmonised standards for *Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products (*EN 15804:2012) advocated a modular approach to assessing several impacts across the product life cycle. The introduction of this standard continued the journey to full LCA, and in some respects, may eventually lead to a semblance of full sustainability assessment for the construction sector.

In some respects, in terms of LCA, the road pavement sector has evolved somewhat independently to other areas of civil engineering. Initially the 'use phase' of highways was put to one side, since improving the energy efficiency of road transport vehicles was reckoned to be the responsibility of the vehicle manufacturing sector. This left the material, construction and end-of-life aspects within scope and generic studies began to emerge including full pavement LCAs (Stripple), pavement component LCAs (Eurobitume, 2011) and comparisons of flexible versus rigid construction (Milachowski *et al*., 2011). More recently more attention has been given to the fact that the use phase is not entirely independent of the remainder of the life cycle, since interactions exist between the vehicle and the pavement (in terms of rolling resistance, roughness and rigidity), and the road user and the construction cycle (in terms of occupancy and resultant road user delay). Research has been conducted in these areas in an attempt to quantify the scale of these effects (Huang, 2009; MIRAVEC). These studies and many more will feature in the initial review of WP1 of this project.

Despite the progress made in advancing and employing life cycle-based methodologies to assess energy efficiency and environmental impacts in civil engineering, and the highways sector in particular, assessment and reporting in this area is rarely demanded by road administrations across Europe as standard practice. Despite this, other external drivers impress upon the sector, including material criticality, energy efficiency and greenhouse gas regulation, and social responsibility. As a result, highways sector companies recognise the need to innovate, become more energy efficient and generally more sustainable. Towards this end, innovation in the sector has occurred and continues to occur.

1.2 Aim of the report

The principal aim of the EDGAR project is to bridge the gap between innovation in the bituminous materials sector and adoption of the new technologies by national road administrations (NRAs). It aims to do this by providing NRAs with an assessment methodology which makes sustainability information on the new technologies readily accessible to the decision-making process, and facilitates quick adoption of the technologies that offer the greatest sustainability benefits for the highways sector and society as a whole.

The aim of this report is to explore some of the boundaries for sustainability assessment of bituminous materials, through a review of the relevant standards and the advances that the highways sector has already made in the area. It also examines the relevance of Environmental Product Declarations (EPDs) in devising such a process. Regarding impact assessment, the available sets of sustainability impact indicators are considered for their relevance to the bituminous materials sector, and the next steps in the process of selecting a relevant set of indicators for novel bituminous products is proposed. Completing each of these tasks has helped to establish the scope for the assessment methodology that will be developed later in the EDGAR project, which will aim to utilise the most appropriate existing tools and methodologies in a framework for road administrations to use to assess novel bituminous technologies.

2 Standards for sustainability in construction works

The European Commission encourages life cycle thinking through Integrated Product Policy (IPP). A communication has been adopted on IPP[1]. IPP acknowledges the fact that all products cause environmental degradation in some way, whether it be through manufacturing, use or disposal. IPP seeks to minimise these impacts by looking at all phases of the product life cycle and taking action where it is most effective. LCA is firmly established as the primary tool through which IPP should be implemented.

The Construction Products Regulation (574/2014) is the basis of technical performance standards and CE marking for construction products in Europe. As a passed regulation, it follows the most direct pathway of EU law and has binding requirements for each member state without the need for adoption by each individual national government. The Construction Products Regulation sets seven Basic Requirements for Construction Works (BRCW), three of which impress environmental requirements on construction products:

(3) Health, hygiene and the environment - The construction works must be designed and built in such a way that they will, throughout their life cycle, not be a threat to the hygiene or health and safety of workers, occupants or neighbours, nor have an exceedingly high impact, over their entire life cycle, on the environment quality or on the climate during their construction, use and demolition, in particular as a result of any of the following:

(a) the giving-off of toxic gas

(b) the emissions of dangerous substances, volatile organic compounds VOC), greenhouse gases or dangerous particles into indoor or outdoor air

(c) the emission of dangerous radiation

(d) the release of dangerous substances into ground water, marine waters, surface waters or soil

(e) the release of dangerous substances into drinking water or substances which have an otherwise negative impact on drinking water

(f) faulty discharge of waste water, emission of flue gases or faulty disposal of solid or liquid waste

(g) dampness in parts of the construction works or on surfaces within the construction works.

(6) The construction works and their heating, cooling, lighting and ventilation installations must be designed and built in such a way that the amount of energy they require in use shall be low, when account is taken of the occupants and of the climatic conditions of the location. Construction works must also be energy-efficient, using as little energy as possible during their construction and dismantling.

(7) Sustainable use of natural resources - The construction works must be designed, built and demolished in such a way that the use of natural resources is sustained and in particular ensure the following:

(a) Reuse or recyclability of the construction works, their materials and parts after demolition;

(b) Durability of the construction works;

(c) Use of environmentally compatible and secondary materials in the construction works.

[1] Communication on Integrated Product Policy: http://ec.europa.eu/environment/ipp/ippcommunication.htm

As a result of the BRCWs, the environmental performance of construction products across many aspects is enshrined in EU law. Further to the law specific to construction products, there is also a Commission Recommendation on the *use of common methods to measure and communicate the life cycle performance of products and organisations* (2013/179/EU)[2]

Life cycle assessment is a standardised technique, formalised by ISO 14040:2006 and 14044:2006. In addition, a life cycle approach lies at the heart of the following standards:

- EN ISO 14025 – Environmental labels and declarations. Type III environmental declarations. Principles and procedures.
- ISO 14046:2014 Environmental management. Water footprint. Principles, requirements and guidelines.
- ISO 14067:2013 Greenhouse gases. Carbon footprint of products. Requirements and guidelines for quantification and communication.

The following standard is specific to construction products:

- EN 15804:2012+A1:2013 - Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products. This standard has not been adopted in the United States; instead they use the precursor ISO 21930:2007.

ISO 14025, 14040 and 14044 are the normative references of EN 15804. Here are its stated objectives:

- To provide LCA-based information and additional information on the environmental aspects of products.
- To assist purchasers and users to make informed decisions between products; these declarations are not comparative assertions
- To encourage improvement of environmental performance
- To provide information for assessing the environmental impacts of products over their life-cycle.

The standard EN 15643-2 provides a useful overview of how EN 15804 (at the product level) contributes to the overall sustainability assessment of buildings. This is shown in Figure 2-1. Since EDGAR proposes to assess at the bituminous product level, EN 15804 seems to be the most applicable standard.

[2] Commission Recommendation on communication of life cycle performance: http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32013H0179

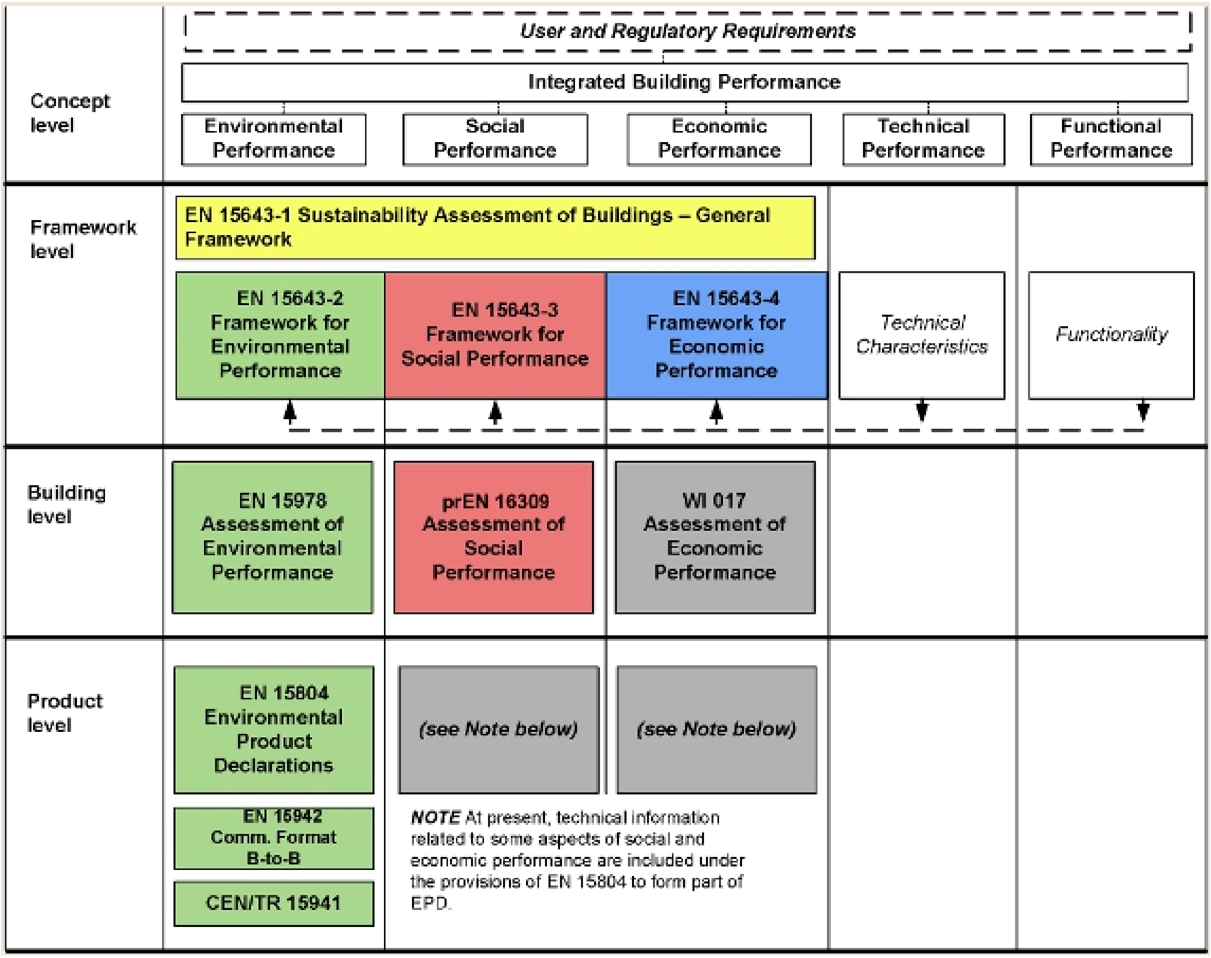

Figure 2-1: Sustainability of construction works - Assessment of buildings part 2: Framework for the assessment of environmental performance (EN 15643-2)

The diagram clearly states that "technical information related to some aspects of social and economic performance are included under the provisions of EN 15804 to form part of the EPD." It is necessary to delve deeper into the standard to determine what particular aspects these are. EN15804 lists the following indicators for a compliant EPD; these appear to be mandatory indicator categories.

Environmental impact indicators:

1) Global Warming Potential (GWP)
2) Ozone Depletion Potential (ODP)
3) Acidification potential (AP)
4) Eutrophication potential (EP)
5) Formation potential of tropospheric ozone (POCP)
6) Abiotic depletion potential for non-fossil resources (ADP-elements)
7) Abiotic depletion potential for fossil resources (ADP-fossil fuels).

Resource use indicators:

8) Use of renewable primary energy excluding renewable primary energy resources used as raw materials
9) Use of renewable primary energy resources used as raw materials
10) Total use of renewable primary energy resources (primary energy and primary energy resources used as raw materials)

11) Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials
12) Use of non-renewable primary energy resources used as raw materials
13) Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materials)
14) Use of secondary material
15) Use of renewable secondary fuels
16) Use of non-renewable secondary fuels
17) Use of net fresh water.

Waste category indicators:

18) Hazardous waste disposed
19) Non-hazardous waste disposed
20) Radioactive waste disposed.

Output flow indicators:

21) Components for re-use
22) Materials for recycling
23) Materials for energy recovery
24) Exported energy.

To report against the environmental impact categories, the characterisation factors[3] would need to be sourced from the European Life Cycle Database (ELCD) or the Leiden Institute of Environmental Sciences Method (CML). Considering the set of 24 indicators, it is hard to see how any have a primary motive other than that of environmental protection, and therefore qualify the note in Figure 2-1 that suggests that “some aspects of social and economic performance are included under the provisions of EN 15804 to form part of the EPD’. Some indicators such as (5) *Formation potential of tropospheric ozone* (otherwise known as ‘summer smog’) does have a health perspective and some of the output flow indicators (21-24) have an economic element, but the primary perspective of all the indicators in EN 15804 could be classified as ‘environmental’. In the context of EDGAR this has an important consequence, since one of the objectives of the project is to look beyond solely environmental indicators and to consider economic and social impacts, and therefore to evaluate bituminous technologies against all three facets of sustainability: the environmental, the economic and the social. To do this it will be necessary to select some additional indicators beyond those included in EN 15804 that have a particular relevance to the asphalt life cycle, in order to cover the economic and social facets.

The scope of assessments according to EN 15804 should cover the product stages presented in Table 2-1. A first consideration of how these modules might be applied to bituminous products is also provided in the table (and will be considered to a greater extent WP1).

[3] Characterisation factors are used to convert life cycle inventory data into environmental impact potentials.

Table 2-1: Product stages from EN 15804 and potential relevance to bituminous products

Product Stage	Description	Potential relevance to bituminous products
A1	Raw material extraction and processing, processing of secondary material	Extraction of constituent materials, refining/grading; crushing/grading of RA
A2	Transport to manufacturer	As described.
A3	Manufacturing	Heating & mixing
A4	Transport to the building site	As described.
A5	Installation into the building	Paving & rolling
B1	Use	[Trafficking by road vehicles]; dust generated; leaching; acoustic performance, skid resistance, visibility
B2	Maintenance	Winter maintenance regimes
B3	Repair	Crack sealing, surface dressing, patching etc.; associated consequences on traffic
B4	Replacement	Inlay and overlay; speed of installation and associated consequences on traffic flow
B5	Refurbishment	N/A
B6	Operational energy use	[Lighting requirement]; affected by surface albedo; rolling resistance and the consequential effect on fuel consumption by traffic
B7	Operational water use	N/A
C1	De-construction, demolition	Planing
C2	Transport to waste processing	Transport to first stockpile
C3	Waste processing	N/A
C4	Disposal	N/A – very rarely landfilled
D	Reuse, recovery or recycling potentials	To be determined.

It is important to take into account durability in product assessment, since a product might perform exceptionally on cradle-to-gate, but disintegrate within a very short time once placed on the road. Assessing only on a cradle-to-gate or cradle-to-site basis would not pick this up. A Reference Service Life (RSL) or Estimated Service Life (ESL) – see 15804 Annex A or EN 15978, 15686 (part 8) – is required if modules beyond A5 are determined to be within scope. An RSL would need to be stated and justified so that all incidences of B1-B6 can be quantified within the assessment. Evaluating modules beyond A5 in the life cycle would allow the durability of the product to be assessed, should it be possible to derive the ESL with some degree of accuracy. A starting point for the ESL would be the anticipated design life for the product in a given road application, defined in terms of million standard axles (msa) of traffic, or a similar measure. A design life defined in this way would come with a provision for maintenance defined by deterioration models. However, estimating ESL at the outset of a product's lifetime is a difficult task, particularly when the product may be novel and, as yet, not fully tested as a component of a highway pavement in use. The approach should therefore be to consider the likelihood that the novel product will be able to meet the same performance requirements as a known reference material, and formulate a level of risk accordingly that could be considered in a decision model (WP3).

The durability of a product is also a function of the environment in which it is placed and is dependent on a wide range of other factors, which amongst others include weather conditions when laying, quality of workmanship, quality of the subgrade or lower bound layer on which the material is placed, topography of the road section, prevailing weather conditions and traffic characteristics. Such factors are more likely to be known or predicted with some accuracy once the specific road site is known and therefore it should be assessed as part of the highway section's EPD, rather than the material's EPD.

3 Pre-existing Product Category Rules (PCRs) for asphalt and related products

Chapter 2 explored the generic set of PCRs for construction products that are available in EN 15804. This is the rule set that was followed to produce generic EPDs such as those available for German asphalt (Federal Ministry for Environment, Nature Conservation, Construction and Nuclear Safety, 2013). In addition to EN 15804, there are some other sets of PCRs and related research projects already exist that are relevant to asphalt:

- Norwegian Product Category Rules (NPCR) 18 Asphalt and crushed stone 10.11.2010
- EPD UN CPC 375: Concrete
- CLF PCRs for concrete
- EPD Product Group: UN CPC 53211: Highways (Except Elevated Highways), Streets and Roads v1.02
- ECOLABEL: an FP7 project.

The first three sets of PCRs are for specific construction products; one for asphalt and two for concrete. The concrete PCRs can be differentiated on the basis of their geographical applicability: The EPD has been devised to have global applicability and the CLF PCRs are aimed at the North American market. The product group EPD is aimed at 'highways' and is classified according to the United Nation's Central Product Classification (CPC)[4]. Project ECOLABEL has been identified as a project that could complement the EDGAR project and a summary is provided of ECOLABEL's first public deliverable. Aside from ECOLABEL, no other current research seemed to focus on PCRs for construction products. A comparison of the features of the four identified PCR documents is presented in Table 3-1.

3.1 Norwegian Product Category Rules (NPCR) 18 Asphalt and crushed stone 10.11.2010

This set of Product Category Rules (PCR) were created with the intention of aiding companies in preparing an Environmental Product Declaration (EPD) for asphalt and/or crushed stone. The PCR was based on a supplement to ISO 14025 and EN 15804, which it refers to on numerous occasions.

The PCR covers cradle to gate for crushed stone and cradle to gate (mandatory) and construction stage (optional) for asphalt. The PCR summarises some of the guidelines and important aspects relating to asphalt and crushed stone that must be covered in an EPD.

This set of PCRs is provided in full in Annex A.

3.2 EPD UN CPC 375: Concrete

This PCR provides a set of rules, requirements and guidelines for developing an EPD for unreinforced concrete products for use in buildings and other construction works. The scope extends to ready mixed concrete, concrete blocks and kerbstone, and mortar. The PCR covers cradle to gate and as an option, can also cover the transport to site and construction stages.

[4] The CPC code for bituminous mixtures is 37940 (in Version 2 of the UN Registry), and could be used to define the scope of EDGAR hereafter.

Each stage of the life-cycle was clearly described with the key processes that would have an impact on the environmental performance. The PCR also provided very detailed descriptions about the allocation of input flows and output emissions, the system boundaries, the units, the quality of data in the PCR and its availability for verification.

3.3 Carbon Leadership Forum (CLF) PCR for Concrete

This PCR was developed for use in North America, but can be applied globally if the relevant standards are adhered to. The main aim was to model the environmental impacts of the concrete material component of products that use concrete including cast in place concrete, precast concrete, concrete masonry units and concrete pavements.

This PCR covers cradle-to-gate, but there is an option where the construction process can be included as well (gate to construction site). The PCR goes through each stage of the life-cycle, detailing the processes that must be addressed in terms of environmental impact. The PCR focused on issues surrounding data such as the data quality, data variability and data availability for verification. It was also very clear in detailing the allocation assumptions and how the EPD report should be laid out.

3.4 EPD Product Group: UN CPC 53211: Highways (Except Elevated Highways), Streets and Roads v1.02

The PCR covers the assessment of environmental performance for highways (excluding elevated highways), streets and roads (as defined by UN CPC 53211) and was developed in accordance with ISO 14025:2006 and several other international standards. It not only includes cradle through construction, but also covers operation and maintenance stages (stages B1-7).

The importance of data and data quality requirements is discussed in detail. It also provides examples of the sources of generic data from databases that would be relevant in Europe. This EPD was the only document to make reference to biodiversity and noise and vibration as potential environmental impacts.

3.5 ECOLABEL Project

Zukowska *et al*. (2014) produced *Deliverable D1.1: Assessment of current labelling approaches applied to roads design, construction maintenance and rehabilitation, as well as the products used to build them (asphalt mixtures and cement based mixtures)* under the ECOLABEL project (Theme: FP7 SST.2013 5-3).

The main aim of the ECOLABEL project was to analyse the most relevant existing approaches of labelling in respect to road infrastructures and products. Key performance indicators (KPIs) were also focused on in this deliverable. ECOLABEL presented and reviewed many different outputs from around the world. This included the following:

- 14 sustainability rating systems
- 15 software and online tools
- 15 EU projects
- 8 national projects

All the relevant information relating to existing sustainability assessment methodologies, labelling, software and online tools was presented in a map, which was split into five sustainability “pillars”: environmental, economic, social, technical and climate resilience. Using all the data collected, potential indicators for the ECOLABEL methodology were identified and then classified to a relevant category of sustainability. This review will be valuable when the assessment methodology for EDGAR is devised.

Table 3-1: Summary of existing PCRs with potential relevance to bituminous products

Basic information about the PCR	Norwegian PCR 18 asphalt and crushed stone	EPD UN CPC 375 for concrete	CLF PCR for concrete	EPD Product Group UN CPC 53211 for highways, streets and roads
Main Contributors	PCR Work Group and Ostfold Research	WBCSD Cement Sustainability Initiative	Carbon Leadership Forum	WSP, Swedish Transport Administration and Norwegian National Rail Administration
Date Published	November 2010	February 2013	November 2012	February 2014
Date valid until	November 2015	February 2018	November 2017	October 2016
Geographical Scope	Global	Global	Focus on North America, but global	Global
Life-cycle Scope	Cradle to gate (A1-A3), but A4-A5 is optional	Cradle to gate (A1-A3), but A4-A5 is optional	Cradle to gate (A1-A3), but A4 is optional	Cradle through construction (A-B)
Focus of PCR	Asphalt and crushed stone	Concrete	Concrete	Highways, streets and roads

Are these topics discussed in the PCR?	Norwegian PCR 18 asphalt and crushed stone	EPD UN CPC 375 for concrete	CLF PCR for concrete	EPD Product Group UN CPC 53211 for highways, streets and roads
Terms and definitions	✓	✓	✓	✓
Declared units	✓	✓	✓	✓
Output as SI units	✓	✓	✓	✓
System boundaries	✓	✓	✓	✓
Allocation rules	✓	✓	✓	✓
Cut-off criteria	✓		✓	✓
Data for the PCR	✓	✓	✓	✓
Data quality	✓	✓	✓	✓
Data variability			✓	
Data availability for verification		✓	✓	
Examples of data sources and databases used			✓	✓
Detailed description of potential issues at each life-cycle stage		✓	✓	
Desired structure of report	✓	✓	✓	✓

Are these standards discussed in the PCRs?	Norwegian PCR 18 asphalt and crushed stone	EPD UN CPC 375 for concrete	CLF PCR for concrete	EPD Product Group UN CPC 53211 for highways, streets and roads
ASTM C94			✓	
ASTM C90			✓	
CSA A 23.1 / A 23.2			✓	
EN 206-1		✓		
EN 15804	✓	✓		✓
EN 15942		✓		
EN 15978		✓		
ISO 9001				✓
ISO 14001				✓
ISO 14020		✓		
ISO 14025	✓	✓	✓	✓
ISO 14040			✓	✓
ISO 14044		✓	✓	✓
ISO 14046			✓	
ISO 21930		✓	✓	✓

Table 3-1 (cont.): Summary of existing PCRs with potential relevance to bituminous products

Are these impact categories discussed in the PCRs?	Norwegian PCR 18 asphalt and crushed stone	EPD UN CPC 375 for concrete	CLF PCR for concrete	EPD Product Group UN CPC 53211 for highways, streets and roads
Depletion of abiotic resources (fossil)		✓		
Depletion of abiotic resources (element)		✓		
Global warming potential	✓	✓	✓	✓
Depletion of stratospheric ozone layer	✓	✓	✓	
Photochemical ozone creation (smog)	✓	✓	✓	✓
Acidification of land and water	✓	✓	✓	✓
Eutrophication	✓	✓	✓	✓
Chemicals	✓		✓	✓
Use of renewable primary energy excluding renewable primary energy resources used as raw material	✓	✓	✓	✓
Use of renewable primary energy resources used as raw material	✓	✓	✓	✓
Total use of renewable primary energy resources	✓	✓	✓	✓
Use of non renewable primary energy excluding non renewable primary energy resources used as raw materials	✓	✓	✓	✓
Use of non renewable primary energy resources used as raw materials	✓	✓	✓	✓
Total use of non renewable primary energy resources	✓	✓	✓	✓
Use of secondary material	✓	✓	✓	✓
Use of renewable secondary fuels	✓	✓	✓	✓
Use of non-renewable secondary fuels	✓	✓	✓	✓
Net use of fresh water	✓	✓	✓	✓
Waste Disposal: Hazardous	✓	✓	✓	✓
Waste Disposal: Non-hazardous	✓	✓	✓	✓
Waste Disposal: Radioactive	✓	✓		
Waste: Recyclable products	✓		✓	
Components for re-use		✓	✓	
Materials for recycling	✓	✓	✓	
Materials for energy recovery	✓	✓	✓	
Exported energy		✓	✓	
Particulate matter emissions			✓	
Biodiversity				✓
Noise and vibrations				✓

Considering the four PCR documents summarised in Table 3-1 as a whole allows a few common themes to be realised:

- Construction product PCRs seem to be limited to EN 15804 steps A1-A5, only full asset-based assessments are extended beyond module A5.
- Not *all* indicator categories in EN 15804 are advocated for assessment by *all* PCR documents, however, each PCR includes an assessment of the majority of indicators, and each set of PCRs omits some indicators.
- The Norwegian set of PCRs appears to be a very useful starting point for EDGAR's assessment methodology, and could easily be enhanced to provide a more comprehensive sustainability assessment methodology.

Some communications from the CEN/TC 350 Working Group (2013) are inconclusive as to whether EPDs for individual construction products should be limited to A1-A3 (or A5), or be extended to include the lifetime within the infrastructure asset (i.e. the building or constructed highway) and report against the extended life-cycle A1-C4 (or D).

Should the Norwegian PCRs be chosen as a starting point, the first objective would be to extend the scope beyond A5, to include lifetime and end-of-life stages. This would allow durability and lifetime impacts, such as influence on traffic, to be analysed within the scope of the assessment. A further enhancement would be to revisit the approach taken to recycling, and how the benefits of recycling are realised. Currently, a fairly straightforward approach is used to displace virgin material with recycled, assign it zero impact, and assume that the properties of the recycled are equivalent to those of virgin materials. Each of these assumptions would have to be re-visited and the impact category set extended.

4 Evaluation criteria relevant to the asphalt life cycle

A consideration of the requirements of EN 15804 in relation to the asphalt life cycle (summarised in Table 2-1), and the review process undertaken to produce Deliverable 1.1, have together yielded an in-depth appreciation of the asphalt life cycle, the types of technological improvements that might be undertaken within it to deliver sustainability benefits, and where these feature along the life cycle. What remains is to devise a method of how to assess the sustainability of the technologies and what to assess. This chapter considers potential evaluation criteria (indicator categories) that might be included within an assessment methodology, that fall inside and outside the scope of EN 15804, their potential significance in relation to bituminous technologies, and answer the wider project brief to provide a 'sustainability' assessment methodology rather than simply an 'environmental' assessment methodology.

4.1 Within the scope of EN 15804

The 24 indicators within the scope of EN 15804 are outlined in Chapter 2. As previously mentioned, the actual indicator sets included within specific PCRs seems to vary, though the majority of indicators are generally included (see Table 3-1). The indicators that are not self-explanatory are expanded upon in Section 5.1.

4.2 Outside the scope of EN 15804

A wide variety of indicators fall outside the scope of EN 15804, however, some are potentially very relevant to bituminous products, covering environmental aspects that are particularly relevant to the industry, and others that can be used to formulate a sustainability-extended assessment methodology, rather than one that simply focusses on environmental objectives.

A number of additional environmental indicators are considered for inclusion, these are:

- Ecotoxicity
- Resilience to climate change
- Urban heat island effect
- Biodiversity
- Noise

The descriptions of each of the indicators above are expanded in Section 5.2. In relation to socio-economic indicators, a broad perspective was taken since it seemed evident that these type of indicators had not really been considered before in relation to construction materials or bituminous products.

A variety of sources of socio-economic indicators were considered, these were:

- EN 16309 Sustainability of construction works – assessment of social performance of buildings – calculation methodology;
- BS 8902:2009 Responsible sourcing sector certification schemes for construction products – specification;
- ISO 2600:2010 Guidance on social responsibility;
- ISO 15686-5 Building & constructed assets – service life planning – part 5: life cycle costing;

- UNEP-SETAC Towards a life cycle sustainability assessment – making informed choices on products; and
- The Global Reporting Initiative (2011) Sustainability reporting guidelines.

The full sets of socio-economic indicators obtained from these documents are presented in Annex B.

4.2.1 EN 16309 Sustainability of construction works – assessment of social performance of buildings – calculation methodology

EN 16309 recommends a set of indicators that could be used to assess the social performance of buildings. Whilst these were developed directly for buildings, rather than construction products or infrastructure assets, the recommended set of indicators was reviewed for potential relevance to bituminous products. Until product level social assessment is developed, as indicated by the CEN framework (Figure 2-1), this set of indicators appears closest to the reasoning that might eventually resolve to the set of product-level indicators. All indicators are focussed on the use phase of the building.

On first sight, few of the building level indicators seem at all relevant to products, perhaps with the exception of some neighbourhood characteristics such as acoustic/noise performance, emissions and thermal characteristics (related to the urban heat island). Furthermore, some novel bituminous products may target greater resilience to climate change, which is another criterion of EN 16309.

4.2.2 BS 8902:2009 Responsible sourcing sector certification schemes for construction products - specification

This standard provides a framework for the development of sector certification schemes for responsible sourcing of construction products (British Standards Institute, 2009). Issues of stakeholder identification and engagement were discussed along with relevant sustainability issue identification and reporting. A series of environmental, social and economic indicators were presented. Whilst the requirement to report against many of the environmental indicators is already a requirement of other standards such as EN 15804, some of the socio-economic indicators are not, and focus on impacts of the business where raw materials are sourced and products are made: how are the staff and local community treated? Is business practice ethical and does the business have long-term financial viability?

4.2.3 ISO 26000:2010 Guidance on social responsibility

ISO 26000 recognises the importance of socially responsible behaviour and its contribution to sustainable development. Social responsibility can be defined as the willingness of an organisation to incorporate social and environmental considerations in its decision making and be accountable for impacts of its decisions and activities on society and the environment (British Standards Institute, 2010).

The standard discusses topics such as gender equality, complicity, human rights, stakeholder engagement and organisational governance. Guidance was provided on the following social responsibility core subjects, which were sub-categorised.

- Human Rights
- Labour practices
- Fair operating practices
- Consumer issues

- Community involvement and development

4.2.4 ISO 15686-5:2008 Building & constructed assets – service life planning – part 5: life cycle costing

BS ISO 15686 provides guidelines for performing life-cycle cost (LCC) analyses of buildings and constructed assets. LCC analysis should cover a defined list of costs over the physical, technical, economic or functional life of a constructed asset, over a defined period of analysis (British Standards Institute, 2008). The standard presented a series of indicators that can be used to measure the whole-life cost:

- Payback period – The time taken to cover investment costs. The payback period can be calculated from the number of years elapsed between the initial investment, its subsequent operating costs and the time at which cumulative savings offset the investment;
- Savings-to-investment ratio – Expresses the ratio of savings to costs;
- (Adjusted) internal rate of return – The compound rate of interest that, when used to discount the costs and benefits over the period of analysis, makes costs equal to benefits when cash flows are reinvested at a specified interest rate; and
- Annual cost or annual equivalent value – The uniform annual amount equivalent to the project net costs, taking into account the time value of money throughout the period of analysis.

4.2.5 UNEP-SETAC Towards a life cycle sustainability assessment – making informed choices on products

The UNEP document addresses the concept of life cycle sustainability assessment (LCSA) by encompassing all three pillars of sustainability: i) environmental, ii) economic and iii) social. The environmental life-cycle assessment (LCA), life-cycle costing (LCC) and social life-cycle assessment (LCSA) were all discussed separately with a variety of case studies. Together, the three methods can be utilised in a life-cycle sustainability assessment. Case studies were also provided for the LCSA.

4.2.6 Global Reporting Initiative report

Indicators for the economic, environmental and social performance of an organisation or product are presented with sub-categories for each indicator type. Nine economic indicators, 30 environmental indicators and 45 social indicators were discussed in the report.

4.2.7 Discussion of socio-economic indicators

Indicators were considered for their suitability for inclusion in the assessment methodology of bituminous materials.

Of the constituent parts of asphalt, aggregate is likely to be sourced locally, but bitumen will be sourced from further afield As a result, responsible sourcing can become an important issue that should be addressed. Responsible sourcing refers to a commitment made by companies to take into account social and economic responsibilities when managing relationships with suppliers (ICC, 2008).

A number of issues that are relevant to the sourcing of bitumen include the following:

- Corruption – this can be an issue in developing countries that are rich in fossil fuels or minerals. Corruption can arise among key decision makers and lower level officials tasked with policy implementation (Kolstad et al., 2008).
- Displacement of indigenous populations – population displacement caused by the extraction of oil is a common phenomenon in countries such as Nigeria, Sudan and Ecuador (Terminski, 2011).

In the 'society performance' indicators of the Global Reporting Initiative's Sustainability Reporting Guidelines (see Annex B), both corruption and impact on local communities were included as separate aspects, with three indicators that could be used to measure the impacts of these two categories. Such indicators could be deemed relevant to a product level assessment but would be equally relevant in assessments at the corporate level.

Three further indicators were considered particularly relevant to the asphalt life cycle, these were:

- Life-cycle cost
- User delay cost
- Health and safety for road workers and road users

Life cycle cost, which is used to determine all the costs associated with the entire design cycle of a life asset, is recommended for use as an indicator. Life cycle cost as an indicator is fully documented within BS ISO 15686-5:2008. A series of indicators, such as the payback period, could be used within the assessment methodology to represent the whole-life cycle cost. User delay cost refers to the additional costs that users are subjected to because of work involved in the construction of asphalt, related to time delay and cost to the economy,.vehicle operating costs related to fuel consumption and accident costs related specifically to the road works. Health and safety, of both road workers and road users, would cover aspects such as toxicity, noise and vibration, skid resistance and visibility.

More detailed descriptions of the socio-economic indicators recommended for further consideration in relation to the EDGAR assessment methodology are provided in Section 5.3.

4.3 The significance of impacts

The requirement of EN 15804 to report against 24 indicator categories is challenging, particularly for novel products. It is perhaps an exercise that can only be carried out with the assistance of commercial LCA software, and indeed has been, to produce extensive databases of EPDs for construction products in Germany and the Netherlands. In Germany, the Ökobau database[5] contains EPDs for a wide range of construction products compiled by the Federal Ministry for Environment, Nature Conservation, Construction and Nuclear Safety (2013). The methodologies used to produce material EPDs in Ökobaudat follow EN 15804.
In the Netherlands, the so-called MRPI certificates granted by the Stichting MRPI[6] (Milieu Relevante Product Informatie) contain EPD-like information according to the Dutch Standard NEN 8006, also for a wide range of construction products.

The practicality of reproducing the full EPD process for novel products will be explored in greater detail in Deliverable 2.2. Furthermore, it is also important to consider the appetite of the industry to report against all 24 indicators for each novel product that comes along, given

[5] www.oekobaudat.de
[6] www.mrpi.nl

the intensity of data collection that the process will entail. For novel products, having a reduced indicator set that covers the key, significant impacts of bituminous products is probably a more realistic solution, and one that is more likely to be adopted by industry.

An exercise could therefore be conducted to identify the significant impacts from the set of 24. Two example EPDs for asphalt products, one from Spain and one from Norway, are presented in Annex C and D respectively. Three further EPDs from Ökobaudat[5], covering steps A1-A3 for Stone Mastic Asphalt and Asphalt Concrete (binder course and base), are also available (annex E). Stichting MRPI have granted two MRPI certificates to asphalt related products, one emulsion based asphalt concrete and one asphalt concrete produced at 100 °C (SBK, 2012). For this product, all life cycles steps are taken into consideration and all environmental impact criteria defined in EN15804 (see section 2) are quantified (Annex F).

In the Netherlands, an environmental footprint software tool DUBOCALC is also developed, used by road authorities to assess/compare bids from different contractors. In the tool only general products (e.g. general warm mix asphalt, general SMA, etc) are mentioned, with no EPDs in the strict sense.

An EPD has also been prepared for asphalt by the Federation of French Building Industry (2014). This EPD follows the French PCR standard NF P01-010, and considers the entire life cycle of a square metre of asphalt pavement over a 100 year lifetime.

Using Europe-wide datasets (some of which are listed in Table 4-1), the figures in these EPDs could be ‘normalised’.

Table 4-1: Some example datasets that could be used to normalise the impacts reported in EPDs

Method	Normalisation sets
CML-IA	World 1990, 1995, 2000; EU28, EU25, 2000; EU25, 2000; West Europe, 1995; Netherlands, 1997
ILCD Midpoint	EU-27, 2010
IMPACT 2002+	Europe , 2000
ReCiPe	Europe 2000; World, 2000
BEES+	USA, 1997
TRACI	US-Canada, 2008; US, 2008; Canada, 2008
USEtox	Europe, 2004; North America, 2002/2008

The process of normalisation would involve dividing the impacts present in the EPDs by the total impact across Europe within a given year. This process would identify which impacts are most significant and therefore should be considered for inclusion in the overall EDGAR assessment method.

It could be considered that some indicators act as a proxy for others. For example, the impact categories of abiotic depletion potential of fossil and non-fossil resources probably adequately reflect many of the resource use and output flow indicators and vice versa, so there is probably only a requirement to measure one or the other. In spite of this, it has been demonstrated that carbon footprints should generally not be used as a reliable proxy for general environmental sustainability. A study by Laurent *et al*. (2012) investigated the correlation between carbon footprint and 13 other impact scores for in excess of 4,000 products and services, three of which are presented in Figure 4-1. The study concluded that, for infrastructure-related projects and others that are dominated by fossil fuel consumption, carbon footprint did correlate well with other indicators such as acidification and eutrophication. Conversely, toxicity, land use and general non-energy related resource consumption impacts were far less well correlated to carbon footprint.

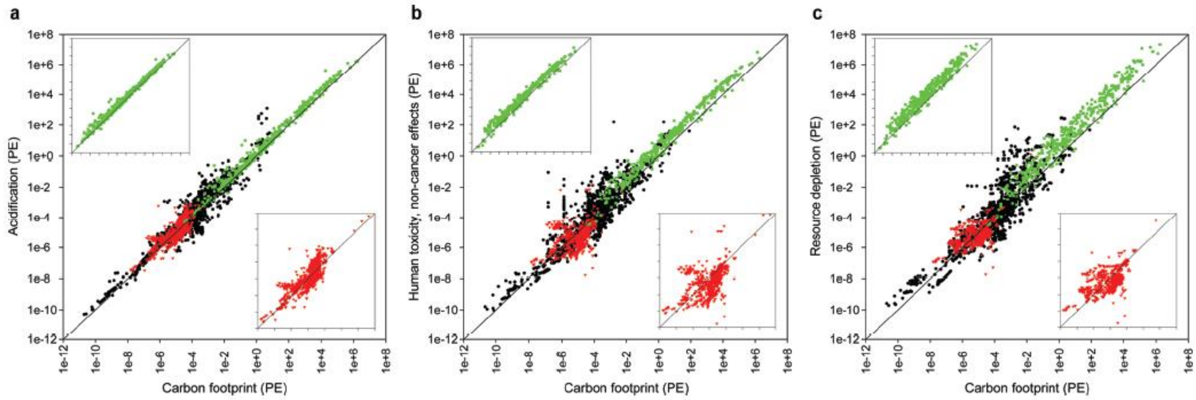

Figure 4-1: Investigating the correlation between carbon footprint and (a) acidification, (b) human toxicity, non-cancer impacts and (c) resource depletion (extracted from Laurent et al. (2012)). Infrastructure-related products (green squares) and energy-related products (red triangles) are highlighted within the overall dataset

5 Evaluation criteria in detail

5.1 Indicators included within EN 15804

5.1.1 Global warming potential (GWP)

Global warming can be defined as the gradual increase of the earth's average atmospheric temperature due to increased levels of greenhouse gases. This includes carbon dioxide (CO_2), chlorofluorocarbons (CFCs) and a wide range of other pollutants (IPCC, 2013). The impact of global warming has been witnessed since the 1950s; the atmosphere and the ocean have both warmed, levels of snow and ice have decreased and the sea level has risen (IPCC, 2013). These impacts have all correlated with a rapid rise in greenhouse gases.

The global warming potential (GWP) is a useful metric for comparing the potential climate impact of greenhouse gases. GWPs compare the integrated radiative forcing over a specified period relative to that of CO_2 taking into account the absorption properties of the gases and their lifetimes (Cowell and Clift, 1999).

The production, manufacturing and transportation of asphalt produce carbon dioxide emissions, which can contribute to global warming.

5.1.2 Ozone depletion potential (ODP)

The ozone layer describes the region in the upper atmosphere that absorbs ultraviolet (UV) radiation, releasing it as heat (Australian Government Department of the Environment, no date). This protects the living organisms on Earth from the harmful effects of UV light. There is significant evidence that the ozone is being destroyed by a group of manufactured chemicals called ozone depleting substances (ODS), which contain chlorine and/or bromine. Examples of ODS include CFCs, halons and carbon tetrachloride. They are broken apart in the upper atmosphere by intense UV light allowing chlorine and bromine to destroy ozone at a rapid rate (Australian Government Department of the Environment, *ibid*.).

Similarly to GWPs for global warming, Ozone Depletion Potentials (ODPs) are used to assess the relative ozone depletion for different ODS. They describe ozone destruction by different chlorinated or brominated compounds in relation to that of CFC-11, once they are in an equilibrium state in the upper atmosphere.

A study by Moretti *et al*. (2013) looked at the production of three different asphalt mixes to be applied to a road pavement and found that the impact from ODP was negligible.

5.1.3 Acidification potential (AP)

Pollutants such as sulphur dioxide (SO_2) and nitrogen oxides (NOx) can be emitted into the atmosphere through the combustion of fossil fuels. This can cause acidification of the soil and water by entering the environment via wet deposition in rainfall, cloud water, mist and dew or dry deposited acidifying gases (APIS, 2014). Acid rain occurs when SO_2 and NOx react in the atmosphere with water, oxygen and other chemicals in the atmosphere to form various acidic compounds. The presence of these compounds in ecosystems can impact negatively on soil and water, and affect nutrient cycling.

Acidification is assessed in relation to the release of H+ ions. Impact assessment factors have been developed that relate H+ production to the mass of relevant emissions and in relation to the acidification potential of sulphur dioxide (Cowell and Clift, 1999).

Emissions released from the production of asphalt could contribute to the production of localised acidification depending on prevailing weather conditions.

5.1.4 Eutrophication (marine and terrestrial) (EP)

Eutrophication is characterised by excessive plant and algal growth due to the increased availability of one or more limiting growth factors needed for photosynthesis. It is a natural process that has been accelerated by human activities through point-source discharges and non-point loadings of limiting nutrients, such as nitrogen or phosphorus (Chislock *et al*., 2013). Eutrophication causes the creation of dense algal blooms, which significantly reduces water quality. When the blooms die, they create an anoxic layer in water bodies. This can have severe consequences for organisms, fisheries, drinking water sources and recreational water bodies (Chislock *et al*., 2013).

Nitrogen tends to be the limiting nutrient in terrestrial ecosystems, and either phosphorus or nitrogen can be limiting in aquatic ecosystems. Therefore it is preferable to calculate two sets of results for eutrophication; one for N-limited and one for P-limited environments (Cowell and Clift, 1999). Algal chlorophyll and dissolved oxygen can also be used as measures for eutrophication.

The impact of constructing asphalt pavements is limited in terms of eutrophication. The manufacturing of asphalt pavements is the stage most likely to contribute to eutrophication (Schench, 2000).

5.1.5 Formation potential of tropospheric ozone (smog)

This refers to the formation of photochemical ozone creation (otherwise known as 'photochemical smog' or 'summer smog') due to interdependent reactions between photochemical oxidants, nitrogen oxides (NOx) and UV light in the atmosphere. The most abundant photochemical oxidant is ozone (O_3). Ozone production is enhanced in polluted air containing NOx. The presence of volatile organic compounds (VOCs) accelerates the reactions forming O_3 and hence, enhancing ozone production (Cape, 1997). Photochemical ozone creation is particularly prevalent in cities and can have a toxic effect of plants and human health when present in excessive concentrations.

Photochemical ozone creation potentials (POCPs) describe the change in ozone concentration due to a small increased release of a substance in relation to that caused by a small increased release of ethylene. Andersson-Skold *et al*. (1992) discussed the calculation of 75 different organic compounds and carbon monoxide as POCPs.

In relation to asphalt pavements, the transportation of materials to site is the process that contributes the most towards photochemical ozone creation (Schenck, 2000).

5.1.6 Depletion of abiotic resources (non-fossil elements)

Abiotic resources in the context of non-fossil elements include a vast range of minerals such as phosphoric minerals and different types of ores (silver, gold, copper). Depletion of these non-renewable resources is regarded as a sustainable development issue and has a huge impact on everyday lives.

Guinée (1995) discussed a method used for assessing abiotic resource depletion using Equation 1:

$$\text{Abiotic Depletion of minerals } = \sum_i ADP_i * m_i$$

Equation 5-1: Defining abiotic depletion potential of minerals

Where:

$$ADP_i = \frac{\frac{DR_i}{(R_i)^2}}{\frac{DR_{ref}}{\left(R_{ref}\right)^2}}$$

And:

ADP $_i$ = Abiotic Depletion Potential of resource (generally dimensionless)

m_i = quantity of resource, i, extracted (kg)

R $_i$ = Ultimate reserve of resource, i (kg)

DR $_i$ = Extraction rate of resource, i (kg per year)

R_{ref} = Ultimate reserve of the reference resource, antimony (kg)

DR_{ref} = Extraction rate of the reference resource, antimony (kg per year)

Resource depletion of minerals is a significant issue in terms of constructing asphalt pavements, primarily due to primary mineral extraction and consumption.

5.1.7 Depletion of abiotic resources (fossil fuels)

Depletion of abiotic resources in the context of fossil fuels includes resources such as coal, crude oil and natural gas. This can have consequences for issues such as electricity production and fuel supply (Brentrup *et al*., 2002). For assessing the depletion of abiotic fossil fuel resources, an adapted method from Equation 1 was also suggested by Guinée (1995).

$$\text{Abiotic Depletion of fossil fuels} = \sum_i ADP_i * m_i$$

Equation 5-2: Defining abiotic depletion potential of fossil fuels

Where:

$$ADP_{fossil\ energy} = \frac{\frac{DR_{fossil\ energy}}{\left(R_{fossil\ energy}\right)^2}}{\frac{DR_{ref}}{\left(R_{ref}\right)^2}}$$

And:

ADP = Abiotic Depletion Potential of fossil energy (kg antimony eq. / MJ fossil energy)

m_i = quantity of resource, i, extracted (kg)

$R_{fossil\ energy}$ = Ultimate reserve of resource, i (kg)

$DR_{fossil\ energy}$ = Extraction rate of resource, i (kg per year)

R_{ref} = Ultimate reserve of the reference resource, antimony (kg)

DR_{ref} = Extraction rate of the reference resource, antimony (kg per year)

Resource depletion of fossil fuels (as bitumen) in the production of asphalt pavements is most evident in the raw materials stage (Schench, 2000). Fossil fuels are also consumed throughout production, transportation and installation.

5.1.8 Resource use, waste and output-flow indicators

The remaining seventeen indicators recommended by EN 15804 (presented in Chapter 2) are straight summations from the inventory that covers the necessary life cycle modules for the selected functional unit. They do not require the use of characterisation factors in order to arrive at an environmental impact potential, as do the indicators described in 5.1.1 to 5.1.7.

5.2 Potential additional environmental indicators

5.2.1 Ecotoxicity

Ecotoxicity refers to the potential impact on an ecosystem from the release of toxic substances. The impacts of toxic substances can affect freshwater, marine and terrestrial ecosystems. Human activities have resulted in the pollution of heavy metals in many areas around the world.

Emissions released into the air are a major anthropogenic source of metals to the soil. Ecotoxicity in soils is largely linked to local soil chemistry and can impact on soil quality and plant life. Ecotoxicity in water can affect any dwelling organisms and rapidly alter the food chain. Ecotoxicity to humans can be related to the use of pesticides on crops.

Concentrations of heavy metals in soil and water are managed through the establishment of environmental quality criteria. A popular method of assessing ecotoxicity in aquatic environments is using HC50, which is the hazardous concentrations affecting 50 % of the species at their EC level. Simply speaking, this is the level where 50 % of the individuals of the species are affected by a particular toxic substance (Haye *et al*., 2007).

The measurement of ecotoxicity in soils varies between different metals. For example, the soil pH is a robust predictor for assessing levels of Cu, meanwhile the electrical conductivity of pore water is the best parameter for assessing Ni concentrations (LC-IMPACT, 2012).

The production of asphalt can result in increases in the ecotoxicity to water, soil and humans. The transportation of materials to the site is the most likely stage where elevated levels of ecotoxicity could be witnessed in the environment.

5.2.2 Resilience to climate change

Resilience to climate change describes the ability of societies to adapt and be better prepared for a changing climate. The impacts of climate change such as sea level rise, increased risk of drought, increased risk of flooding, higher temperatures and increased frequency and intensity of storms present a huge challenge in building resilience. Examples of resilience can include better forecasting and early warning systems, improving data collection and, developing adaptation plans and policies.

Climate change resilience could be relevant to asphalt technologies because the warmer, wetter conditions could affect the functionality and performance of asphalt, resulting in a need for more maintenance of pavements.

Resilience to climate change is not easily measurable or quantifiable. In the UK, a report by Defra (2010) discussed using relevant data against indicators to measure the progress in climate change resilience.

5.2.3 Urban heat island effect

The urban heat island (UHI) effect is the process whereby urban regions experience warmer temperatures than their rural surroundings (US EPA, 2005a). There are a number of factors that contribute to the urban heat island effect:

- Reduced vegetation in urban areas – less shade and moisture in urban areas;
- Properties of urban materials – generally surface materials have a lower albedo than in rural areas and therefore, reflect less and absorb more of the sun's energy. They also have higher heat capacities;
- Urban geometry – tall buildings slow down cooling at night; and
- Anthropogenic heat – from a variety of sources and estimated by totalling all the energy used for heating and cooling, running appliances, transportation and industrial processes.

The UHI can produce some negative effects which include the following:

- Increased energy consumption, due to the requirement to cool to achieve thermal comfort for inhabitants;
- Elevated emissions of air pollutants and greenhouse gases;
- Negative impact on human health due to exacerbation of the impact of heatwaves; and
- Reduced water quality.

New pavement technologies have been implemented in urban areas to try and reduce the impact of the UHI effect. Examples have included pavements that increase solar reflectance and/or are made of permeable materials. These store less heat and have lower surface temperatures compared to conventional pavements (US EPA, 2005b). UHI can be assessed by measuring air temperatures in cities. Surface temperatures from Landsat satellite images of urban areas can also be recorded (US EPA, 2005a).

5.2.4 Biodiversity

Biodiversity can be defined as the variety, quantity and distribution of the components of life whether they are species, ecosystems or genes (European Academies Science Advisory Council, 2005). A series of indicators can help to measure or at least, represent the key components of biodiversity. A few examples are provided below:

- Extent of ecosystems / biomes
- Trends in abundance / distribution of selected species
- Changes in status of threatened / protected species

The EU is committed to preserving biodiversity through the EU Biodiversity Strategy to 2020. Over the last 25 years, the EU has built up a vast network of 26,000 protected areas in all member states (European Commission, 2014b).

In relation to the production of asphalt, the largest threat to biodiversity is from noise. This can have a significant impact on animals in the local area, especially birds. Dust produced from asphalt production can also have a negative impact on flora and fauna. Furthermore, the storage of artificial aggregates can threaten the biodiversity due to seepages into the soil and groundwater reserves (EAPA, 2007). Biodiversity impacts are clearly closely related to ecotoxicity.

5.2.5 Noise and vibration

Environmental noise is defined as unwanted or harmful outdoor sound created by humans (Council Regulation, 2002). Noise can cause serious direct and indirect health effects such as damage to hearing or the triggering of mental disorders. The largest impact of environmental noise is the impact on sleeping habits (European Commission, 2014a). Attempts to identify and measure noise are explained in the Environmental Noise Directive (2002/49/EC). The most common noise indicators are as follows (Council Regulation, 2002):

- Lden (day-evening-night noise indicator for overall noise annoyance); and
- Lnight (night-time noise indicator for sleep disturbance).

WHO (2009) reports that anything over 40dB for the Lnight can result in adverse health effects. EAPA (2007) highlighted the main sources of noise from the production of asphalt:

- Main sources from the plant: dryer drum, burner, ventilation behind filter installation and screeds including by-pass; and
- Traffic noise: In the yard by loaders during transport from the aggregate stock to feeder hopper and, from lorries supplying raw materials and collecting asphalt mixes.

Surface course asphalts and their composition have the biggest influence on noise and vibration during the use phase. This is considered as a socio-economic impact related to ‘health and safety for road users’ (acoustic surface characteristics).

5.3 Potential additional socio-economic indicators

5.3.1 Life-cycle cost

Life-cycle cost can be defined as “the cost of an asset or its parts throughout its life cycle, while fulfilling performance requirements” (BS ISO 15685-8:2008). Life-cycle costing has addressed the importance of calculating operation and maintenance costs as well as the initial costs.

Life-cycle costing can be applied to asphalt and/or road pavement schemes to take account of all costs from design and construction to end-of-life. The use of a life-cycle model or tool is beneficial in drawing together all components of the life-cycle of an asset and helping to address issues of risk and uncertainty by factoring in sensitivity analyses (BS ISO 15685-8:2008).

5.3.2 Responsible sourcing

Responsible sourcing is concerned with managing a product from the point at which component materials are mined or harvested, through manufacture and processing. It is based on a thorough appreciation of environmental, social and economic issues throughout the product’s supply chain and correct management of these issues.

The supply chain for construction products might be local (e.g. for common aggregates) or stretch far overseas (in the case of bitumen). Despite this, in both cases, the influence the product has on the communities where it is sourced and manufactured raises similar issues: how is the workforce treated and is adequate attention paid to employment law and worker's rights? How about the local community - are negative impacts from supply chain activities adequately mitigated and are complaints properly dealt with? Is business practice ethical and free from bribery and corruption? What about the financial stability of the business and can it be relied on as a source of income for the community in the long term? At the product level it might be possible to consider some of these issues to make a more holistic assessment of sustainability, though some will be hard to measure without direct cooperation from the companies themselves.

5.3.3 Material criticality

Material criticality relates to issues of resource insecurity that are connected to a range of different factors, which include the following (Speirs *et al*., 2013):

- Supply factors – Geological availability and economic availability;
- Geopolitical factors – Policy and regulation, geopolitical risk and supply concentration;
- Demand factors – Future demand projections and ability to substitute; and
- Other factors – cost reduction via technology and innovation, and environmental issues.

This is relevant to asphalt and road pavements because bitumen, and possibly high-PSV aggregates, can be defined as a critical material. The Highways Agency (2013) highlighted both materials as having potential for supply disruption. Different materials can be ranked and compared against each other by assessing the material against each factor i.e. supply factor. Nowakowska (2012) ranked a number of materials and used the results to define a list of critical materials.

5.3.4 User delay cost

User delay costs refer to the additional costs incurred by the users as a result of work taking place concerned with an asset. This includes traffic delay costs, vehicle operating costs and accident costs and can be related to any stage of the project where users may be subject to delays (for example, at the construction stage, during maintenance or end-of-life).

As they are indirect and difficult to measure, user costs have often been emitted from life-cycle costing studies. User delay costs will vary significantly between different projects at different sites. An example by Elinkaareltaan Tarkoituksenmukainen Sllta (ETSI), a European project on bridges, recognised the importance of user delay costs. In their final model, they included calculations for the driver delay cost, the vehicle operating cost and the costs for healthcare due to accidents (Sundquist and Karoumi, 2013).

5.3.5 Health and safety for road workers

Working on live carriageways is one of the most hazardous areas of network operations for organisations such as the UK Highways Agency. In 2005, there were five fatalities on the Highways Agency's strategic road network (Highways Agency, 2010). Therefore the health and safety for road workers is of paramount importance. The Highways Agency released a report in 2010 focused on a road worker safety strategy that was applicable to all road users, which covered traffic management activities, maintenance and renewal schemes and vehicle recovery (Highways Agency, 2010).

For maintenance and renewal schemes, exposure to asphalt fumes whilst working on site can be a potential threat to the health and safety of road workers. Studies of the toxic effect of asphalt fume exposures have reported eye, nasal and throat irritation among workers (Butler *et al*., 2000). These symptoms are defined as being mild and transient in nature. Other symptoms potentially linked to asphalt fumes included skin irritation and rashes, nausea, decreased appetite and headaches (Butler *et al*., 2000).

The impact of asphalt fumes can be studied by monitoring the health of road workers. McClean *et al*. (2004) looked at the inhalation and dermal exposure to polycyclic aromatic compounds (PACs) among asphalt paving workers. During work shifts, personal air samples were collected for each worker's breathing zone.

The use of lower-temperature asphalts has led to a significant improvement in working conditions. This is because there is a strong correlation between the production temperature of asphalt and fume production (D'Angelo *et al*., 2008).

5.3.6 Health and safety for road users

The maintenance and rehabilitation of roads is crucial in providing an adequate road condition for road users. Certain characteristics of the road condition such as rutting, texture and roughness can be linked to road safety and the number of accidents.

McLean and Foley (1998) discussed the importance of texture in determining the skid resistance of roads. They highlighted that the macrotexture of the road surface was the best indicator for skidding accident risk. Ihs *et al*. (2011) also discussed the importance of rutting depth and its effect on the likelihood of road accidents.

A number of characteristics of road condition can be assessed by using real-time measurements in the field from a range of various products:

- Stiffness used as a proxy for strength of the road – Deflectograph, Traffic Speed Deflectometer;
- Measuring skid resistance of the road – SCRIM;
- Surface condition of the road – TRAffic speed Condition Surveys (Gallagher, 2009); and
- Acoustic surface characteristics.

Estimates indicate that more than 30 % of EU citizens are exposed to road traffic noise levels above that viewed acceptable by the World Health Organisation (WHO) and 10 % of the population report severe sleep disturbance because of transport noise (Viner *et al*., 2006). The most significant source of road traffic noise is generated by the interaction of the vehicle's tyres with the road surfaces. Surface texture, porosity and aggregate size have an impact on the overall traffic noise although the relationships are complex. Different types of surface will produce different levels of traffic noise; newly laid roads are the quietest, meanwhile sprayed bituminous seals and concrete surfaces are generally the noisiest (*ibid*.).

The acoustic performance of road services is measured by using the ISO Statistical Pass-By (SPB) method, which assesses the influence of road surfaces on traffic noise levels. This test includes the measurement of the maximum pass-by levels and speeds of a sample of light and heavy vehicles; sufficient measurements are taken to ensure the reliability of measurements (Viner *et al*., 2006). New roads now must comply with the Highways Authority Products Approval Scheme (HAPAS) in order to achieve certification for use in road construction and maintenance programs (*ibid*.).

Toxicity related impacts (of both workers and consumers) are partly covered by EU regulation, EC No. 1907/2006, which is concerned with the registration, evaluation, authorisation and restriction of chemicals (REACH). REACH regulations came into force in 2006 and aim to provide a high level of protection to human health and the environment from the use of chemicals (EC Regulation, 2006). A major part of REACH is the requirement for manufacturers and importers of substances to register them with a central European Chemicals Agency (ECHA).

As part of REACH regulations, safety data sheets provide an integral mechanism for circulating appropriate safety measures on substances and mixtures. Safety data sheets are necessary under the following circumstances (HSE, 2012):

- If a substance / mixture is classified as dangerous under the Dangerous Substances Directive;
- If a substance / mixture is persistent, bioaccumulative or toxic;
- If a substance / mixture is in the list of European Chemical Agency's "candidate list" of substances of very high concern; and
- If a substance / mixture poses a threat to human health or environmental hazards.

Although asphalt is not classified as hazardous, suppliers will often produce a safety data sheet to distribute amongst their customers. Safety data sheets provide REACH information requirements, information for safe handling of the asphalt and potential risks to health (Eurobitume, 2012). The main hazards related to asphalt are the temperature of the material. Furthermore, risks can be exacerbated by the production of dust containing quartz, which is present in the aggregate. The content of quartz varies depending on the type of aggregate (Lafarge Tarmac, 2013).

6 Discussion

The process of evaluating the environmental performance of construction is well founded in EU law through the Construction Products Regulation (574/2014). Assessing impacts on a life-cycle basis is a well-established and valuable technique, recommended by the EU, through Commission Recommendation 2013/179/EU, and standardised through the ISO 14040 series of standards. EN 15804, devised by the CEN/TC 350 committee, promotes a life-cycle based assessment approach for construction products through derivation of a set of Product Category Rules (PCRs) that can be used to assess products and create Environmental Product Declarations (EPDs). The PCRs in EN 15804 are more prescriptive than the method for LCA in ISO 14044, but also necessarily generic so that the framework can apply to any construction product or service. Chronologically either side of publication of EN 15804, PCRs have been developed for specific construction products, including asphalt, aggregates and concrete. These individual PCRs are very prescriptive to product type, and have a life cycle period of assessment limited to either 'cradle-to-gate' or 'cradle-to-installation' (A1 to A3 or A5, using terms of the EN 15804 methodology). Limiting the scope in this way avoids the need to assess the 'reference service life' of a product, which is a complex exercise that needs to reflect its durability and potentially the response to site specific conditions as part of an asset. Evidence of the use of PCRs to assess asphalt with this truncated life cycle was identified more than once when EPDs for conventional asphalt were created in Germany and Norway. Extending the life cycle beyond installation so far seems to mean moving beyond the scope of individual construction products to entire assets e.g. 'highways'. The existence of one set of PCRs could be determined for UN product classification 53211 'highways' and evidence of their use was identified at least once for road projects in Spain.

Given the information relating to the use of PCRs that could be uncovered, and the extent of their use to create EPDs, only a few things could really be asserted at this stage. In relation to the extent of use, it might be asserted that creation of EPDs is a time- and data-intensive process, and this is one reason that only a few examples have been produced. The EPDs produced are fairly nondescript in nature, simply listing the functional unit, the quantified impacts and units of measurement, and nothing by way of interpretation. Additionally, and for the same reasons, PCRs might only be used to produce 'generic' national EPDs for individual construction materials, so that they can be utilised to meet criteria in 'green rating' systems for buildings such as LEED (Leadership in Energy and Environmental Design)[7] in the United States, BNB (Bewertungssystem Nachhaltiges Bauen) in Germany[8], or BREEAM (the Building Research Establishment Environmental Assessment Method)[9] in the United Kingdom, rather than one for each variation on the same material. Using EPDs in this way may encourage sustainable building design, but is not likely to drive innovation in the bituminous materials or highways sectors, and this should be the niche that EDGAR's methodology aims to fill, focussing on appropriate parts of the life-cycle and on the impacts of interest to NRAs.

Environmental and wider sustainability indicators, that are potentially relevant to bituminous construction materials and highways in general, have been extensively reviewed in this report. A 24 environmental indicator assessment process is specified for use in EN 15804, though sets of fewer indicators have been used to produce some EPDs that are already in existence. When considering what might be useful for novel product assessment, the results

[7] http://www.usgbc.org/leed
[8] https://www.bnb-nachhaltigesbauen.de/
[9] http://www.breeam.org/index.jsp

of which will be considered in a decision analysis process by NRAs, a smaller ‘basket’ of relevant, meaningful indicators should be devised. Use of the ‘full set’ of 24 indicators is more appropriate for generic ‘asphalt’ and should therefore be reserved for EPD assessments to be used in green building rating systems, since it would require a very involved assessment process that would be non-repeatable for each novel product that comes onto the market, in the timescales available to assess such products. Past research has shown that ‘proxy’ representation of impacts (e.g. using carbon footprint as an indicator of other quantifiable impacts) is probably flawed and should be avoided in compiling the final basket.

Some of the indicators in the set of 24 will have little relevance to asphalt, in terms of magnitude of impact. A process of normalisation will therefore be conducted to determine the most significant indicators to remain in the final basket. This will involve taking generic asphalt EPDs or life cycle inventories, and normalising the dataset using the total environmental impacts for a geographical region (e.g. EU-28). This will reveal the relative magnitude of impacts in the EPD or inventory and therefore determine the impact categories of most significance to form part of the final suite. Normalisation should be the first step in devising the methodology in D2.2. Aside from impact categories identified by normalisation, other environmental indicators outside the current set of 24 may be of considerable interest to NRAs, as well as other socio-economic indicators that might be included to arrive at a more holistic ‘sustainability’ assessment methodology. From the review of indicators, those of most relevance appear to be noise, life cycle cost (incorporating user delay) and health & safety impact. However, more information should be gathered to inform the final choice of indicators, not least regarding the potential measurability of each impact and the reliability of assessment methodologies. Consideration should also be given to whether the final methodology should be freely available or utilise commercially available software.

7 Conclusions & recommendations

Research so far has explored approaches to the environmental assessment of construction products, the scope of assessment, relevant standards and potential sustainability indicators to form part of an assessment methodology to assess novel bituminous products.

The original brief for this deliverable (as specified in the Description of Work) was to create the basis for ‘sustainability-extended environmental product declaration’, using EN 15804 as a starting point, and recommend a set of product category rules for bituminous products.

The PCR/EPD process is in some ways relevant to a methodology for assessing novel bituminous products. The Norwegian PCR for asphalt will provide a starting point that can be built upon during the course of EDGAR; it will inform the boundaries for assessment, such as what processes are relevant at each stage of the asphalt life cycle. In many respects, however, the EPD process is not commensurate with the goals of EDGAR. EPDs are the culmination of a data-intensive process that would most likely involve the use of commercially available software. For these reasons they have so far mainly been produced for ‘generic’ products. The EPD process for individual construction products is also generally limited in scope to cradle-to-gate or site and results in an unwieldy number of indicators should the standardised EN 15804 process be followed. Construction product EPDs in this format are useful intermediates in ‘green building’ rating systems but are probably not of much direct use to ‘end users’ such as NRAs. The recommended PCR set for bituminous products is therefore those available in EN 15804, with consideration given to the supplementary requirements of the Norwegian PCR set. The EPD/PCR process is not, however, recommended for *novel* bituminous products. The process used to assess novel products should be more streamlined, tailored to highways, more holistic with regards to sustainability and directly relevant to NRAs as the end user. This does not mean that clear boundaries for assessment should not be set to maintain transparency in the assessment process. These guiding principles will be taken forward into the next phase of research that will determine the methodology for assessment.

The review of EPDs, related standards, research and impact categories assisted in formulating the way forward for EDGAR:

- The methodology should be life-cycle based;
- The methodology should extend beyond ‘cradle-to-gate’, in order to include some appraisal of durability of the products being assessed, and their influence on use-phase impacts of the road;
- EDGAR should devise a manageable set of indicators (perhaps 6-10) that are meaningful and relevant to NRAs, and ultimately measurable;
- The EDGAR process should be repeatable for novel products and not be too data- or time- intensive;
- Environmental indicator selection should be based on an assessment of significance for asphalt. Significance could be assessed by ‘normalisation’ in the first instance. There may also be one or two additional environmental indicators that are particularly relevant to bituminous products or highways that are normally beyond the scope of a traditional LCA or EPD that should be included;
- Socio-economic indictors such as life-cycle cost, user delay, responsible sourcing and health & safety should be considered for inclusion in the final basket of indicators, to arrive at a more holistic sustainability assessment methodology, rather than one that is solely focussed on environmental issues; and

- Given the conclusions above, the EDGAR methodology should complement rather than adhere completely to the EN 15804 approach. The EDGAR methodology will filter sustainable novel asphalt products from the less sustainable, and therefore provide a useful intermediate step that could later lead to full assessment of the product through creation of an EPD.

The final set of indicators for which measurements methodology will be devised/selected in Deliverable 2.2, will depend on:

- The outcome of the normalisation of the generic asphalt EPDs;
- The findings of Deliverable 1.1 (due in month ten of the project) that will extensively review existing bituminous technologies and past research, to define the scope for EDGAR and relevant indicators; and
- Input from the Advisory Group and PEB.

Notwithstanding these further inputs, at this stage the basket of indicators is likely to be similar to the set presented in Table 7-1.

Table 7-1: Likely composition of the indicator set for the EDGAR methodology

Environmental	Social	Economic
Based on normalisation, 2-4 indicators from: • Resource depletion (abiotic) • Resource depletion (fossil fuels)) • Global Warming Potential (GWP) • Ozone Depletion Potential (ODP) • Acidification potential (AP) • Eutrophication potential (EP) • Formation potential of tropospheric ozone (POCP) • Abiotic depletion potential for non-fossil resources (ADP-elements) • Abiotic depletion potential for fossil resources (ADP-fossil fuels) • Direct resource use, waste disposal or other output flow indicators	• Health & safety for road users (possibly incorporating 'noise') • Health & safety for road workers (incorporating Toxicity) • Sourcing	• Life cycle cost • User delay

8 Acknowledgement

The research presented in this report/paper/deliverable was carried out as part of the CEDR Transnational Road Research Programme Call 2013. The funding for the research was provided by the national road administrations of Austria, Germany, Netherlands, Norway, Slovenia and UK.

9 References

Acciona Infraestructuras (2013) “Environmental product declaration N-340 road”, S-P-00516

Air Pollution Information System (APIS) (2014) “Acid deposition”, http://www.apis.ac.uk/overview/pollutants/overview_Acid_deposition.htm (Visited 21 July 2014)

Andersson-Skold Y, Grennfelt P and Pleijel K (1992) “Photochemical ozone creation potentials: A study of different concepts”, Journal of Air and Waste Management Association 42(9), p1152-1158

Australian Government Department of the Environment (n.d.) “The ozone layer”, http://www.environment.gov.au/protection/ozone/ozone-science/ozone-layer (Visited 24 July 2014)

Brentrup F, Kusters J, Lammel J and Kuhlmann H (2002) “Impact assessment of abiotic resource depletion”, International Journal of LCA 7(5), p301-307

British Standards Institution (2008) “BS ISO 15686-5:2008 Buildings and constructed assets – Service life planning – Part 5: Life cycle costing”, BSI

British Standards Institution (2009), “BS 8902:2009 Responsible sourcing sector certification schemes for construction products - Specification”, BSI

British Standards Institution (2010) “BS ISO 26000:2010 Guidance on social responsibility”, BSI

Butler M A, Burr G, Dankovic D, Lunsford R A, Miller A, Nguyen M, Olsen L, Sharpnack D, Snawder J, Stayner L, Sweeney M H, Teass A, Wess J and Zumwalde R (2000) “Hazard Review: Health effects of occupational exposure to asphalt”, US Department of Health and Human Services

Cape J N (1997) “Photochemical oxidants – What else is in the atmosphere besides ozone?” Phyton (Austria) Special Issue: Free Radicals 37(3), p45-58

Carbon Leadership Forum (2013) “Product category rules (PCR) for ISO 14025 Type III environmental product declarations (EPDs)”, United States: University of Washington

CEN/TC 350 (2013) “CEN TC350 seminar: implementation of EN 15804 – background information”, http://portailgroupe.afnor.fr/public_espacenormalisation/CENTC350/CEN-_TC350_seminar_EN15804_presentations.pdf (Visited 04 November 2014)

Chislock M F, Doster E, Zitomer R A and Wilson A E (2013) “Eutrophication: Causes, consequences and controls in aquatic ecosystems”, Nature Education Knowledge 4(4): 10

Cowell S J and Clift R (1999) “Introductory manual for life cycle assessment: Version 2.1”, Centre for Environmental Strategy, University of Surrey

Council Regulation (EC) 2002/49 of 25 June 2002 relating to the assessment and management of environmental noise [2002] OJ L189/12

D'Angelo J, Harm E, Bartoszek J, Baumgardner G, Corrigan M, Cowsert J, Harman T, Jamshidi M, Jones W, Newcomb D, Prowell B, Sines R and Yeaton B (2008) "Warm-mix asphalt: European practice", In cooperation with American Association of State Highway and Transportation Officials, FHWA-PL-08-007

Department for Environment, Food and Rural Affairs (Defra) (2010) "Measuring adaptation to climate change – a proposed approach", February 2010

Department for Environment, Food and Rural Affairs (Defra) (2011) "Causes of air pollution", http://uk-air.defra.gov.uk/air-pollution/causes, (Visited 23 July 2014)

Department for Environment, Food and Rural Affairs (Defra) (2014) "Guide to UK air pollution information resources", June 2014

Directoraat General Rijkswaterstaat (2002) "Abiotic resource depletion in LCA: Improving characterisation factors for abiotic resource depletion as recommended in the new Dutch LCA handbook"

EAPA (European Asphalt Pavement Association) (2007) "Environmental guidelines on best available techniques for the production of asphalt paving mixes"

Eurobitume (2011) "Life cycle inventory: bitumen", Brussels: Belgium

Eurobitume (2012) "Health and bitumen", Bitumen Day – 13th of March 2012, Brussels

European Academies Science Advisory Council (2005) "A user's guide to biodiversity indicators", The Royal Society

European Commission (EC) Regulation (2006) "EC 1907/2006 Registration, evaluation, authorisation and restriction of chemicals (REACH), The European Parliament and the Council of the European Union

European Commission (2014a) "Noise: The EU policy on environmental noise", http://ec.europa.eu/environment/noise/ (Visited 03 October, 2014)

European Commission (2014b) "Nature and biodiversity", http://ec.europa.eu/environment/nature/index_en.htm (Visited 03 October, 2014)
World Health Organisation (WHO) "Night noise guidelines for Europe"

Federal Ministry for Environment, Nature Conservation, Construction and Nuclear Safety (2013) "Okobau" http://www.nachhaltigesbauen.de/baustoff-und-gebaeudedaten/oekobaudat.html (Visited 14 November, 2014)

Federation of French Road Building Industry (2014) "Collective environmental and health data sheet statement (FDES) in accordance with French standard NF P 01-010 – hot mix asphalt pavement"

Gallagher A (2009) "Measuring the condition of roads (pavements)", IHT North Eastern Branch Conference, PCIS

Global Reporting Initiative (2011) "Sustainability Reporting Guidelines", Version 3.1

Guinée J B (1995) “Development of a methodology for the environmental life-cycle assessment of products; with a case study on margerines”, Thesis, Leiden University

Haye S, Slaveykova V I and Payet J (2007) “Terrestrial ecotoxicity and effect factors of metals in life cycle assessment (LCA)”, Chemosphere 68, p1489-1496

Haider M & Kriegisch M (2013) “Final Report: MIRAVEC - Modelling Infrastructure Influence on RoAd Vehicle Energy Consumption”

Health and Safety Executive (HSE) (2012) “REACH and Safety data sheets”

Highways Agency (2010) “Road Worker Safety Strategy: Aiming for zero”, PR012/10
Highways Agency (2013) “Infrastructure and material criticality: project findings report: Investigating Material Criticality”, in partnership with the University of Leeds, TRL and Halcrow.

Huang Y, Bird R, Bell M.(2009) “A comparative study of the emissions by road maintenance works and the disrupted traffic using life cycle assessment and micro-simulation”, Transport Res Part D 14, p197–204

Hunt, R.J. and Franklin W E (1996) LCA – how it came about – personal reflections of the origin and development of LCA in the USA, International Journal of Life Cycle Assessment 1(1) 4-7.

Ihs A, Gustafsson M, Eriksson O, Wiklund M and Sjogren L (2011) “Road user effect models – the influence of rut depth on traffic safety”, VTI rapport 731A

International Chamber of Commerce (ICC) (2008) “ICC guide to responsible sourcing: Integrating social and environmental considerations into the supply chain”

Intergovernmental Panel on Climate Change IPCC (2013) “Climate Change 2013: The Physical Science Basis”, Working Group I contribution to the fifth assessment report of the Intergovernmental Panel on Climate Change

Kolstad I, Wiig A and Williams A (2008) “Tackling corruption in oil rich countries: The role of transparency”, CMI, Chr. Michelsen Institute, U4 brief, Feb 2008 No.3

Lafarge Tarmac (2013) “Safety data sheet: Asphalt”, Issue No.6, http://www.lafargetarmac.com/media/107701/safety-data-sheet-asphalt.pdf (Visited 30 September 2014)

Laurent A, Olsen S I and Hauschild M Z (2012) “Limitations of carbon footprint as indicator of environmental sustainability”, Environmental Science and Technology 46, p4100-4180

LC-IMPACT (2012) “Recommended assessment framework, method and characterisation factors for ecotoxicity and human toxicity: Phase 1 (report and model + factors”, Deliverable 2.1, http://www.lc-impact.eu/userfiles/D2.1Toxicity_February_2012.pdf

McClean M D, Rinehart R D, Ngo L, Eisen E A, Kelsey K T and Herrick R F (2004) “Inhalation and dermal exposure among asphalt paving workers”, The Annals of Occupational Hygiene 48(8), p663-671

McLean J and Foley G (1998) "Road surface characteristics and condition: effects on road users", Research Report ARR 314

Milachowski C, Stengel T & Gehlen C (2011) "Life cycle assessment for road construction and use". Brussels: EUPAVE – European Concrete Paving Association.

Moretti L, Di Mascio P and D'Andrea A (2013) "Environmental impact assessment of road asphalt pavements", Modern Applied Science 7(11), P1-11

National Aeronautics and Space Administration (NASA) "Key Indicators: Carbon dioxide concentration", http://climate.nasa.gov/key_indicators/ (Visited 21 July 2014)

Norwegian EPD Foundation (2010) "Product category rules (PCR) for preparing an environmental product declaration for product group asphalt and crushed stone", NCPR 18

Norwegian EPD Foundation (2011) "Environmental declaration AGB 11 asfalt (bransjegjennomsnitt)", 216N

Nowakowska M (2012) "Defining critical raw materials in the EU: Information gaps and available solutions", US-EU workshop on mineral raw materials flow and data, Brussels, 12 September 2012

SBK (2012) "Nationale Milieudatabase Stichting Bouwkwaliteit", https://www.milieudatabase.nl/ (Visited 09 January 2015)

Schenck N (2000) "EPA report, Using LCA for procurement decisions: A case study performed for the US Environmental Protection Agency", http://www.asphaltsystemsinc.com/epa-report

Speirs J, Houari Y and Gross R (2013) "Materials Availability: Comparison of material criticality studies – methodologies and results Working Paper III", UKERC / WP / TPA / 2013 / 002, Imperial College Centre for Energy Policy and Technology (ICEPT)

Stripple H (2001) "Life cycle inventory of asphalt pavements. Sweden", IVL Swedish Environmental Research Institute Ltd. European Asphalt Pavement Association (EAPA) and Eurobitume

Sundquist H and Karoumi R (2013) "Life Cycle Cost Methodology and LCC Tools", ETSI Bridge Life Cycle Optimisation

Terminski B (2011) "Oil-induced displacement and resettlement: Social problem and human rights issue", Research Paper, School for International Studies, Simon Fraser University, Vancouver

UNEP SETAC (2001) "Towards a Life Cycle Sustainability Assessment: Making informed choices on products report", Life Cycle Initiative

United Nations (2008) Central Product Classification (CPC) Version 2. New York: United Nations.

United States Environmental Protection Agency (US EPA) (2005a) "Reducing urban heat islands: Compendium of strategies – Urban heat island basics"

United States Environmental Protection Agency (US EPA) (2005b) “Reducing urban heat islands: compendium of strategies – cool pavements”

Viner H, Abbott P, Dunford A, Dhillon N, Parsley L and Read C (2006) “Surface texture measurement on local roads”, PPR148

WBCSD Cement Sustainability Initiative (2013) “UN CPC 375 Concrete”, PCR 2013:02

WSP & Swedish Transport Administration (Trafikverket) (2014) “Highways (except elevated highways), streets and roads. Product category rules according to ISO 14025: 2006”

Zukowska E A, Jullien A, Cerezo A, Keijzer E, Lorino T, Bouteldja M (2014) “ECOLABEL Deliverable 1.1: Assessment of current labelling approaches applied to roads design, construction maintenance and rehabilitation, as well as the products used to build them (asphalt mixtures and cement based materials)”

Annex A: Norwegian PCRs

PRODUCT-CATEGORY RULES (PCR)

For preparing an environmental declaration (EPD) for Product Group

Asphalt and crushed stone

NPCR 18

November 2010

NPCR 18 Asphalt and crushed stone 10.11.2010 2

1. General information

These product category rules (PCR) are intended for companies preparing an Environmental Product Declaration (EPD) for asphalt and/or crushed stone (see chapter 6.1 for definition of product group).

The PCR is based on and represent a supplement to ISO 14025 [1] and the coming European standard prEN 15804 - *Sustainability of construction works – Environmental Product Declarations – core rules for the product category of construction products [2] (Draft 2010-10-12).*

The PCR covers cradle to gate for crushed stone and cradle to gate (mandatory) and construction stage (optional) for asphalt.

Program operator:
Næringslivets Stiftelse for Miljødeklarasjoner
NHO, Postboks 5250 Majorstuen, 0303 Oslo

The PCR have been prepared by the members of the PCR Work Group (WG) and Ostfold Research. Members of the PCR WG:
Foreningen Asfalt og Veiservice (FAV) (The Norwegian association of asphalt and road service), Roar Telle Byggemiljø , Ingunn Marton

Consultants:
Østfoldforskning (Ostfold Research) , Kari-Anne Lyng and Anne Rønning

2 Executive summary

Table 1 sums up the most important aspects defined distinctively for this particular product category. More details are given in the following sections.

Table 1: PCR for asphalt – executive summary

Section	Topic	PCR – asphalt	Reference in ISO 14044	Reference in ISO 14025	Reference in prEN 15804
4	Terms and definitions	Asphalt, crushed stone, recycled asphalt, reuse in production	3	3	3
6.1	Product category	Asphalt and crushed stone		6.7.1 6.7.2	6.1
6.3.2	Declared unit	1 tonne of manufactured crushed stone /asphalt	4.2.3.2 4.3.3.3		6.3.2
6.3.3	Reference service life	Not relevant, but should be stated by manufacturer in the EPD for different applications.			6.3.3
6.3.4	System Boundaries	Cradle to gate	4.2.3.3 4.3.3.4		6.3.4
	Scenarios				
6.3.7	Developing product level scenarios	Laying/installation of 4 cm asphalt			6.3.8
6.4.1	Allocation rules	Allocation according to mass [kg]	4.3.4		6.4.3
7	Additional information	The content of harmful substances/ chemicals should be declared in EPD.		7.2.3 7.2.4	7.48.2

3 Scope

The intended application of these Product Category Rules (PCR) is to give guidelines for development of Environmental Product Declarations (EPD) for cradle to gate for crushed stone and asphalt, and in additional optional construction stage for asphalt, and to further specify the underlying requirements of the limited Life Cycle Assessment (LCA). The core rules valid for all construction products are given in standard prEN 15804, and are expected known by those preparing the EPD.

4 Terms and definitions

General definitions are given in the standard prEN 15804, chapter 3.

4.1
Asphalt

Product mainly consisting of crushed stone and bitumen used as road surface with other applications such as surfaces on airport runways, outdoor car parks and schoolyards.

4.2
CML

The CML 2001 [3] is an impact assessment method collection, which restricts quantitative modelling to relatively early stages in the cause-effect chain to limit uncertainties and group LCI results in so-called midpoint categories, according to themes. These themes are common mechanisms (e.g. climate change) or commonly accepted grouping (e.g. ecotoxicity).
(May be replaced by ELCD handbook requirements.)

4.3

Crushed stone
Stone material with specified quality produced in stamp mills/crushing plants. Commonly used as filling material in many construction applications.

4.4
Recycled asphalt
Asphalt that has been in use and has reached its end of life and hence been removed from road or other application, transported back to factory and used as input to production of new asphalt.

4.5
Reuse in production
E.g. asphalt waste from asphalt production used as input to asphalt production (closed loop recycling).

5 Comparability of EPD of construction products

General rules for comparability are given in the standard prEN 15804, chapter 5.3.
Contents of project report and EPD shall be as specified in prEN 15804, chapters 7 and 9.
All EPDs shall display separate results from cradle to gate-analysis to allow aggregation to provide complete information for construction works.

6 Product Category Rules for LCA

6.1 Product Category

The product groups are:
- crushed stone from cradle to gate
- asphalt from cradle to gate (mandatory), and construction phase (optional)

6.2 Life Cycle stages to be included

See chapter 6.3.4. Figure 1 and 2.

6.3 Calculation rules for the LCA

6.3.1 Functional unit

Not relevant.

6.3.2 Declared unit

The declared unit is used when an EPD is based on one or more information modules rather than on LCA.
The declared unit (cradle to gate) is:
1 tonne of crushed stone
1 tonne of manufactured asphalt
1 tonne layed asphalt with thickness 4 cm

6.3.3 Reference service life

Not relevant.

6.3.4 System boundaries

The life cycle stages for crushed stone (cradle to gate) are shown in Figure 1.

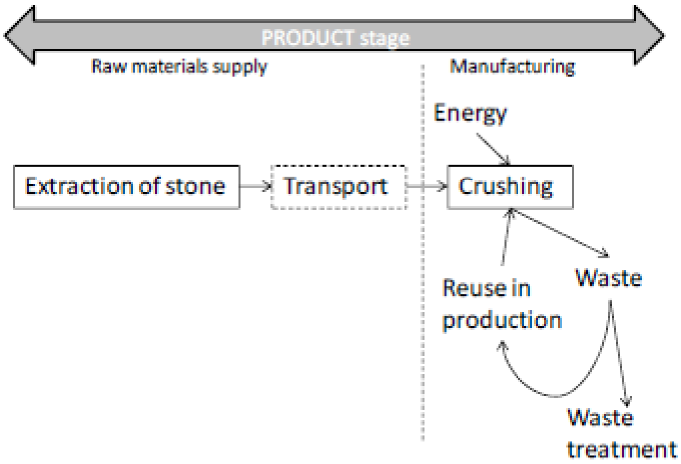

Figure 1: System boundaries and life cycle stages of crushed stone

Crushed stone may be an independent product or a material input to asphalt production or other products.

The life cycle stages for installed asphalt are shown in Figure 2.

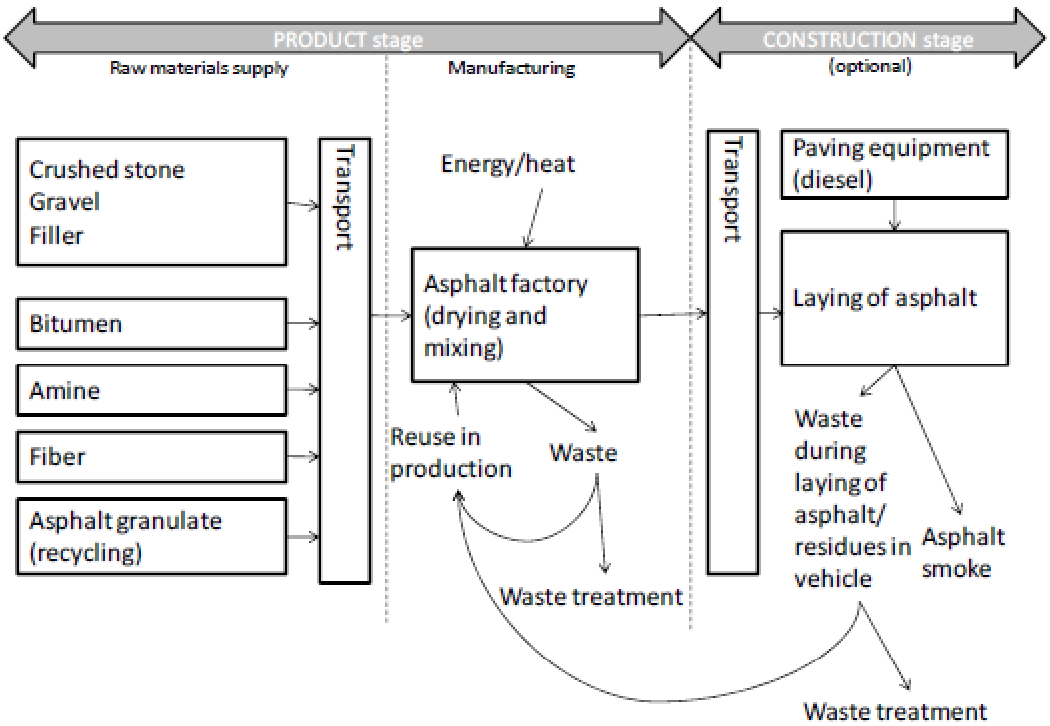

Figure 2. See also Fig. 1 in prEN 15804.

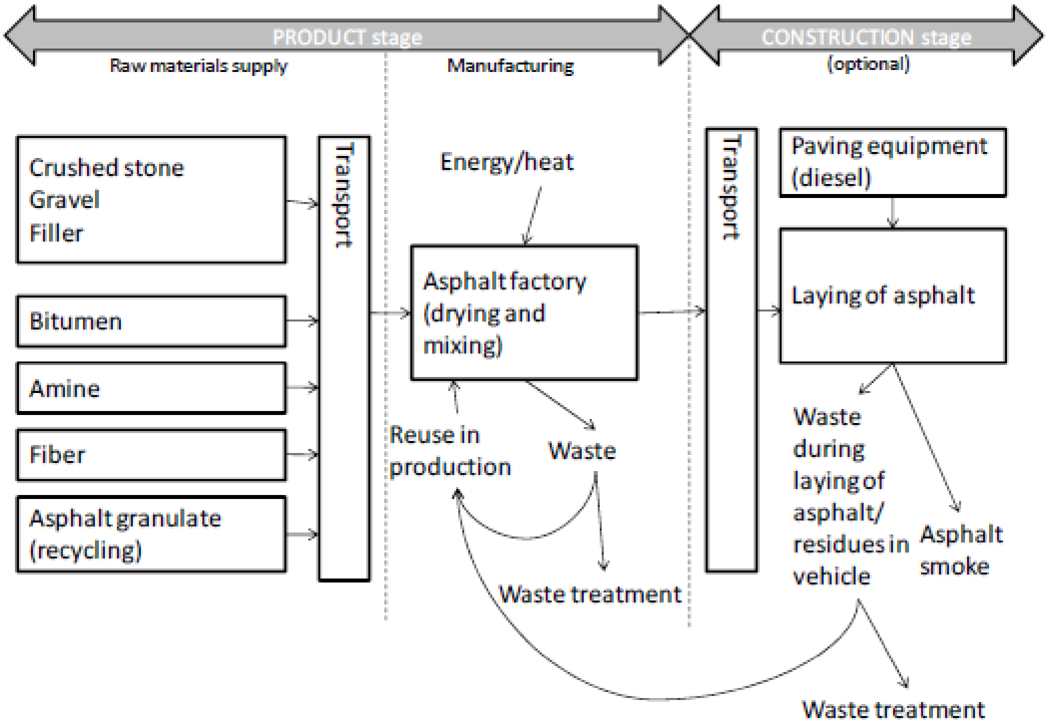

Figure 3: System boundaries and life cycle stages of asphalt

Bitumen produced according to the stardards NS-EN 12591 *Bitumen and bituminous binders - Specifications for paving grade bitumens [8]* and NS-EN 14032 *Bitumen and bituminous binders. Framework specification for polymer modified bitumens [9].*

Use of bitumen emulsion as adhesive (bond coat) in construction phase according to standard NS-EN 13808 Bitumen and bituminous binders - Framework for specifying cationic bituminous emulsions [10].

6.3.5 Criteria for the exclusion of inputs and outputs (cut-off)

General cut-off criteria are given in standard prEN 15804, section 6.3.5.
Excluded from the calculations:

- Production of machinery for production of crushed stone and asphalt due to assumption of low impact relative to other impacts

A list of hazardous and toxic materials and substances shall be included in the inventory and the cut-off rules do not apply to such substances.

6.3.6 Data quality requirements

General requirements and guidelines concerning use of generic and specific data and the quality of those are described in the standard prEN 15804, sections 6.3.6 and 6.3.7.
In addition the following rules should be applied:

- For manufacturing of product (crushed stone or asphalt), specific annual data shall be applied
- Actual data age (when data was collected) shall be stated.
- If site-specific data with certificate of origin cannot be obtained, the mix of electricity used should be the grid mix in the country where main energy consuming processes take place. (e.g. NordEl mix for production sites located in Norway). The mix of electricity (calculation procedure) shall be documented by citing sources for environmental impact from production and for electricity mix.

- For directly consumed heat and electricity, production and infrastructure of consumed heat and electricity should be included in accordance with PCR for Electricity, Steam, and Hot and Cold Water Generation and Distribution , PCR CPC 17 [11]. As a result, infrastructure must be included for energy production.
- Hazardous waste shall be specified according to EU Directives 91/689/EEC and 75/442/EEC (specific and/or average background) or updates/directive in force in the relevant country.

Specific data shall always be applied when possible. If an EPD exists for a purchased subproduct, the EPD should be used as data source/input to the LCA.

All transport must be included and allocated based on the weight [tonne km] of transported product. Specific transport distances are to be used when available. If no such information is available, the following transport scenario and distances shall be used:
Transport of asphalt from production site to laying location: estimated to 35 km. If other distance is applied, this must be clearly stated and justified in the EPD. This transportation distance is defined as a part of construction stage, which is optional. It is however recommended to include this transport distance in a cradle to gate EPD.

6.3.7 Scenarios on product level
The optional construction stage for cradle to gate EPD is defined by the scenario described below.

Construction process stage (optional) – only relevant for EPD of asphalt
The construction process stage is based on laying of 1 tonne of asphalt with a layer thickness of 4 centimetres. All machinery fuel and materials consumed during laying of the asphalt must be included, such as use of paving equipment. Both production of fuel and emissions from combustion of the fuel shall be included.

If other thickness than 4 cm is used in the calculation, this must be explained in the EPD.
Waste handling of residue if not reused in production (residues in car and related to laying) shall be included. Emissions such as asphalt smoke must be included in the LCA.
Secondary materials leaving the system boundary shall be declared in module D, “supplementary information beyond the building life cycle”

6.3.8 Units
SI units shall be used

6.4 Inventory analysis

6.4.1 Allocation of input flows and output emissions
General allocation rules including closed-loop and open-loop allocation procedures are given in the standard prEN 15804.

Allocation should be performed in the following order
1 Physical properties (e.g. mass)
2 Economic value

Allocation related to transport shall be based on the weight [tonne km] of transported product.
The environmental impacts from recycling are allocated to the next life cycle. The recycling processes shall be treated as closed loop recycling, as long as no changes occur in the inherent properties of the recycled material. In such cases, the need for allocation is avoided since the use of secondary material displaces the use of virgin (primary) materials. Recycled materials that are used in the fabrication of the product shall have no environmental impact on the new product.

6.5 Impact assessment

Parameters shall be declared and reported according to standard prEN 15804, sections 6.5, 7.2.2 and 7.3. Characterisation method is specified for each environmental impact category. Environmental impact should be declared as stated in prEN 15804, chapter 6.5:

- Global warming potential, GWP, in kg CO_2 - equivalents, 100 years (latest version of IPCC)
- Depletion potential of the stratospheric ozone layer, ODP (ozone depletion potential), in kg CFC 11-equivalents, 20 years (CML 2001 or updates)
- Acidification potential of land and water sources, AP, in kg SO_2 – equivalents (CML 2001 or updates)
- Eutrophication potential, EP in kg PO_4 –equivalents (CML 2001 or updates)
- Formation potential of tropospheric ozone photochemical oxidants, POCP (photochemical oxidants creation potential), in kg C_2H_4-equivalents). (CML 2001 or updates)

CML may be replaced by ELCD handbook requirements.

Parameter	Parameter unit expressed per functional/declared unit
input of renewable primary energy not including feedstock (renewable energy resources)	MJ, net calorific value
Input of renewable feedstock	MJ
Total input of renewable primary energy	MJ
input of non renewable primary energy not including feedstock (non renewable energy resources),	MJ, net calorific value
Input of non renewable feedstock	MJ
Total input of non renewable primary energy	MJ
Input of secondary material	kg
Input of renewable secondary fuels	MJ
Input of non renewable secondary fuels	MJ
Input of net fresh water	m^3

Waste to disposal should be declared as:

- Hazardous waste (kg) according to EU directive 91/689/EEC and 75/442/EE and updates. (Current regulations that apply in Norway: Regulation for recycling and treatment of waste, FOR-2004-06-01-930, with amendment FOR-2010-06-25-979,
- Ministry of Environment (Norwegian: Avfallsforskriften)).
- Non hazardous waste (kg)
- Radioactive waste

7 Additional environmental information

An EPD for asphalt and crushed stone shall include the following information related to environmental issues, in addition to the environmental information derived from LCA.

7.1 Chemicals

Specification of materials and substances that can adversely affect human health and environment shall be reported.

A detailed list of the product’s substances (chemicals used in manufacture), including CAS number and health class (Risk phrases or CLP regulations (Regulation (EC) No 1272/2008) when these are in force), shall be included in the product content declaration. The content of substances shall be declared in weight %. In cases where information about contents could affect patent or company secrets, a qualitative list of chemicals and their expected functions is sufficient, including the Risk phrases.

7.2 Recyclability

Under end of life description the manufacturer should describe the recommended waste handling and state the recyclability of product (weight percentage of materials in product that are recyclable).

8 Content of the EPD

The content of EPDs (cradle to gate) for crushed stone and asphalt is described below:
1. Information about product: product name, reference to this PCR, description of applications and density.
2. Information about manufacturer
3. The following information must be presented in a red box on the front page:
    - LCA results for GWP (Global warming potential)
    - LCA results for energy use (fossil and non fossil)
    - The amount of recycled material used (weight percentage according to definition of recycled asphalt in chapter 4 Terms and definitions) (only for asphalt)
    - Production temperature (only for asphalt)

4. Product specification (material content of product in % and data sources for each material).
5. LCA results for cradle to gate (and optional construction stage for asphalt): material use, energy use, environmental impact categories and waste, for raw materials extraction, transport, production, construction stage (optional and only for asphalt) and in total.
6. Information about use phase: what are the factors that influence the service life?
7. Information about end of life: Description of recommended waste handling of product. The recyclability of product should be stated in % of product weight.
8. Methodological decisions, description of some life cycle stages are not included
9. Period of validity and statement that environmental declarations from different programmes may not be comparable
10. References

9 Period of validity of the document

This document is valid until 10.11.2015.

10 References

1. ISO 14025: 2006 Environmental labels and declarations –Type III environmental declarations – Principles and procedures

2. prEN 15804: 2010 Sustainability of construction works – Environmental Product Declarations – core rules for the product category of construction products.

3. CML 2010: Universiteit Leiden, Website of Instititute of Environmental Sciences (CML), Faculty of Science. CML-IA Characterisation Factors found at: http://cml.leiden.edu/software/data-cmlia.html

4. ISO 21930: 2007 Sustainability in building construction - Environmental declaration of building products

5. ISO 14044: 2006 Environmental management - life cycle assessment - requirements and Guidelines NPCR 18 Asphalt and crushed stone 10.11.2010 14

6. ISO 14001: 2004 Environmental management – Specification of the requirements of an environmental management system (EMS)

7. EMAS – The Eco-Management and Audit System – Specification of the requirements of an environmental management system (EMS)

8. NS-EN 12591: 2009 Bitumen and bituminous binders - Specifications for paving grade bitumens.

9. NS-EN 14023: 2010 Bitumen and bituminous binders. Framework specification for polymer modified bitumens.

10. NS-EN 13808: 2005 Bitumen and bituminous binders. Framework for specifying cationic bituminous emulsions.

11. PCR 2007: Product category rules for preparing an environmental declaration for Electricity, Steam, Hot and cold water, generation and distribution, PCR CPC 17, Version 1.1.

Annex B: Socio-economic indicator sets

EN 16309: 2014

Building life cycle stage - use stage	
Building-related characteristics	**User- and control system-related characteristics for interaction with the building**
Accessibility	**Health and comfort**
1) Accessibility for people with additional needs	18) Thermal comfort
2) Access to building services	19) Indoor air quality
Adaptability	20) Visual comfort
3) ease of potential for adapting to other use	**Impacts on neighbourhood**
Health and comfort	21) Emissions
4) Thermal characteristics	**Safety and security**
5) Characteristics of indoor air quality	22) Security against intruders and vandalism
6) Acoustic characteristics	
7) Characteristics of visual comfort	
8) Spatial characteristics	
Impacts on neighbourhood	
9) Noise	
10) Emissions	
11) Glare/overshadowing	
12) Shocks/vibrations	
Maintenance and Maintainability	
13) Maintenance operations	
Safety and security	
14) Resistance to climate change	
15) Accidental actions (earthquake, explosions, fire and traffic impacts	
16) Personal safety and security against intruders and vandalism	
17) Security against interruptions of utility supply	

BS 8902: 2009

Social	Economic
Workers' condition	Contribution to the built environment
Safe & healthy working conditions	Ethical business practice
Child / slave labour	Contribution to diversity and stability of local economy
Fair wages	Long-term financial viability
Working hours and holidays	
Freedom to join trade unions	
Equality with respect to gender, ethnicity and religion	
Complaints and prosecution	
Skills and training	
Community relations	

UNEP SETAC (2011)

Social	Economic
Human rights	Investment costs
Working conditions	VAT
Child labour	Motor vehicle tax
Fair salary	Fuel costs
Working hours	Maintenance costs
Health and safety	Costs for end-of-life disposal
Indigenous rights	Water disposal costs
Total employees	Labour costs
Wages	Revenues
	Raw material costs
	Energy costs
	Equipment costs
	Discount analysis

ISO 15686-5: 2008

Economic
Payback period
Net savings
Savings-to-investment ratio
(Adjusted) internal rate of return
Annual cost or annual equivalent value

BS ISO 26000: 2010

Social
Human Rights: Sub categories include due diligence, risk situations, avoidance of complicity, resolving grievances, discrimination, civil / political rights and child labour.
Labour practices: Sub categories include employment, conditions of work and social protection, social dialogue, health & safety at work and human development and training.
Fair operating practices: Sub categories include anti-corruption, fair competition, promoting social responsibility in the value chain and respect for property rights.
Consumer issues: Sub categories include fair marketing, protecting consumers' health and safety, sustainable consumption, consumer service and support, consumer data protection and privacy, access to essential services and education and awareness.
Community involvement and development: Sub categories include community involvement, education and culture, employment creation and skills development, technology development and access, wealth and income creation, health and social investment.

Global Reporting Initiative (2011)

Social	Economic
Labour practice and decent work indicators	**Economic performance:**
Aspect: Employment	Economic value generated and distributed
Total workforce by employment type, contract and region	Financial implications, risks and opportunities presented by climate change
Total number and rate of new employer hires	Coverage of organisation's defined benefit plan obligation
Benefits provided to full-time employees	Significant financial assistance received from Government
Return to work and retention rates after parental leave	**Market presence:**
Aspect: Labour / management relations	Range of ratios of standard entry level wage by gender compared to local minimum wage
Percentage of employees covered by collective bargaining agreements	Policy, practices and proportion of spending on locally-based suppliers
Minimum notice period regarding operational changes, including whether it is specified in collective agreements	Procedures for local hiring and proportion of senior management hired from local communities
Aspect: Occupational health and safety	**Indirect economic impacts:**
Percentage of total workforce represented in formal joint management-worker health and safety committees	Development and impact of infrastructure investments and services provided primarily for public benefit
Rates of injury, occupational disease, lost days and total number of work-related fatalities	Understanding and describing significant indirect economic impacts including extent of impacts
Education, training, counselling and risk-control programs in place to assist workforce members	
Health and safety topics covered in formal agreements with trade unions	
Aspect: Training and education	
Average hours of training per year per employee per gender	
Programs for skills management and lifelong learning that support the continued employability of employees	
Percentage of employees receiving regular performance and career development reviews	
Aspect: Diversity and equal opportunity	
Composition of governance bodies and breakdown of employees per employee category according to gender	
Aspect: Equal remuneration for women and men	
Ratio of basic salary and remuneration of women to men by employee category	
Human Rights performance indicators	
Aspect: Investment and procurement processes	
Percentage and total numbers of investment agreements and contracts that have clauses incorporating human rights concerns	
Percentage of significant supplier contractors that have undergone human rights screening	
Total hours of employee training and policies and procedures concerning aspects of human rights	
Aspect: Non-discrimination	
Total number of incidents of discrimination and corrective actions taken	
Aspect: Freedom of association and collective bargaining	
Operation and significant suppliers identified in which the right to exercise freedom of association and collective bargaining may be violated	
Aspect: Child labour	
Operations and significant suppliers identified as having significant risks for incidents of child labour	

Global Reporting Initiative (2011) (cont.)

Aspect: Forced and compulsroy labour
Operations and significant suppliers identified as having significant risks for incidents of forced compulsory labour
Aspect: Security practices
Percentage of security personnel trained in the organisation's policies or procedures concerning aspects of human rights.
Aspect: Indigenous rights
Total number of incidents of violations including rights of indigenous people and actions taken
Aspect: Assessment
Percentage and total number of operations that have been subject to human rights reviews and / or impact assessments
Aspect: Remediation
Number of grievances related to human rights filed, addressed and resolved through formal grievance mechanisms
Society performance indicators
Aspect: Local communities
Percentage of operations with implemented local community engagement, impact assessments and development programs
Operations with significant potential or actual negative impacts on local communities
Prevention and mitigation measures implemented in operations with significant potential or actual negative impacts on local communities
Aspect: Corruption
Percentage and total number of business units analysed for risks related to corruption
Percentage of employees trained in organisation's anti-corruption policies and procedures
Actions taken in response to incidents of corruption
Aspect: Public policy
Public policy positions and participation in public policy development and lobbying
Total value of financial and in-kind contributions to political parties and politicians
Aspect: Anti-competitive behaviour
Total number of legal actions for anti-competitive behaviour
Aspect: Compliance
Monetary value of significant fines and total number of non-monetary sanctions for non-compliance with laws and regulations
Product Responsibility performance indicators
Aspect: Customer health and safety
Life cycle stages in which health and safety impacts of products and services are assessed for improvement
Total number of incidents of non-compliance with regulations and voluntary codes concerning health and safety impacts of products and services during their life-cycle
Aspect: Product and service labelling
Type of product and service information required by procedures and percentage of significant products and services subject to such info. requirements
Total number of incidents of non-compliance with regulations and voluntary codes concerning marketing communications including advertising, promotion and sponsorship by type of outcomes
Aspect: Customer privacy
Total number of substantiated complaints regarding breaches of customer privacy and losses of customer data
Aspect: Compliance
Monetary value of significant fines for non-compliance with laws and regulations concerning the provision and use of products and services

Annex C: Example Spanish EPD – N-340 road

Results for a 1 km stretch of N-340 road (over a 20 year period).

Environmental Performance	Unit/km	Construction	Operation	Maintenance	TOTAL
Resource and energy use					
Non-renewable materials	kg	2,55E+06	3,38E+04	2,73E+05	2,85E+06
Renewable materials	kg	1,90E+07	1,32E+07	6,75E+06	3,90E+07
Non-renewable energy	MJ	2,06E+06	5,18E+05	8,55E+05	3,43E+06
Renewable energy	MJ	3,21E+04	1,68E+05	9,40E+03	2,10E+05
Secondary resources without calorific value	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Secondary resources with calorific value	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Recovery energy flow	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Water (direct use)	kg	1,18E+06	0,00E+00	0,00E+00	1,18E+06
water (life cycle)	kg	1,89E+07	1,30E+07	6,70E+06	3,86E+07
Impact categories (CML 2001_Nov 2010)					
Global warming	kgCO_2 eq.	5,47E+04	3,08E+04	1,84E+04	1,04E+05
Global warming, biogenic carbon contribution	kgCO_2 eq.	1,95E+03	1,30E+03	5,69E+02	3,82E+03
Acidification	kgSO_2 eq.	1,93E+02	1,32E+02	6,01E+01	3,85E+02
Photochemical oxidant formation	Kg ethene eq.	5,31E+01	9,99E+00	3,13E+01	9,43E+01
Eutrophication	Kg PO_4^{2-} eq.	3,18E+01	7,61E+00	7,36E+00	4,67E+01
Others					
Dangerous waste	kg	3,17E+00	0,00E+00	5,15E-01	3,68E+00
Not dangerous waste	kg	1,70E+05	3,34E+04	7,66E+04	2,80E+05

Annex D: Example Norwegian EPD – 216N (translated)

The declared unit (DE) is one metric tonne of asphalt.

Material resources (kg/DE)		**Production of raw materials**	**Production of asphalt**	**Laying asphalt**	**Total**
Recycled, renewable resources		98	-	-	98
Virgin, renewable resources	Water	731	131	50	912
Recycled, non-renewable resources		-	-	-	-
Virgin, non-renewable resources	Sand, stone and other minerals	834	1	6	841
	Calcium/ limestone	20	0	0	20
	Oil feedstock	51	-	-	51
Energy resources (MJ/DE)		**Production of raw materials**	**Production of asphalt**	**Laying asphalt**	**Total**
Fossil energy	Coal	40	12	5	57
	Oil	419	303	111	833
	Natural gas	112	19	8	138
Nuclear		43	29	5	77
Renewable energy	Biomass	<0.5	<0.5	<0.5	<0.5
	Hydropower	11	22	1	34
	Wind power	1	1	<0.5	2
Miscellaneous	Waste and steam	<0.5	<0.5	<0.5	<0.5
Unspecified		<0.5	<0.5	<0.5	<0.5
Environmental impacts (kg/DE)		**Cradle-to-gate**		**Laying**	
Waste	kg waste		3	1	
Eutrophication	kg P_4O_3 eq		0.08	0.012	
Photochemical oxidation	kg C_2H_2 eq		0.08	0.010	
Ozone	kg CFC-11 eq		2.59E-05	1.18E-06	
Acidification	kg SO_2 eq		0.438	0.048	
Greenhouse	kg CO_2 eq		48	8	

effect					
Waste and largest emissions by weight (25)					

Annex E: Example German EPD – Datenbank - ÖKOBAUDAT

Process Data set: Splittmastixasphalt SMA (nl)

Collapse all sections | Go back | Close

Process information

Key Data Set Information	
Location	DE
Reference year	1999
Name	Splittmastixasphalt SMA
Use advice for data set	Dieser Datensatz beinhaltet die Ergebnisse für die Module A1 – A3 gemäß EN 15804. Der vorliegende Datensatz ist mit einem Sicherheitszuschlag von 20% auf die Ergebnisse versehen. Das Umweltprofil beinhaltet die Aufwendungen für die Lebenszyklus-Stadien "Cradle to Gate". Es basiert hauptsächlich auf Literaturrecherchen.
Technical purpose of product or process	Splittmastixasphalt; Dicken und Dichten variieren je nach Aufbau (s. Schneider Bautabellen für Ingenieure)
Classification number	1.5.01
Classification	Class name : Hierarchy level OEKOBAU.DAT: 1.5.01 Mineralische Baustoffe / Asphalt / Splittmastixasphalt
General comment on data set	Dieser Datensatz beinhaltet die Ergebnisse für die Module A1 – A3 gemäß EN 15804.
Copyright	Yes
Owner of data set	PE INTERNATIONAL
Quantitative reference	
Reference flow(s)	Splittmastixasphalt, eingebaut - 1000.0 kg (Masse)
Time representativeness	
Data set valid until	2013
Time representativeness description	Jährlicher Durchschnitt
Technological representativeness	
Technology description including background system	Die Ökobilanzergebnisse umfassen die Lebenszyklusstadien der Herstellung der Vorprodukte bis hin zur Rohstoffgewinnung und Verarbeitungsprozesse von als Input dienenden Sekundärstoffen (z.B. Recyclingprozesse), deren Transporte zum Werk sowie die Produktion selbst, einschließlich der Bereitstellung von allen Hilfs- und Betriebsstoffen, Energie, sowie die vollständige Abfallbehandlung oder die Deponierung der Restabfälle während des Stadiums der Produktion. Die Module A1, A2 und A3 sind hier als ein aggregiertes Modul A1-A3 ausgewiesen. Falls für diesen Datensatz weitere Module berechnet wurden, sind diese separat zu finden und können für eine Betrachtung des gesamten Lebenszyklus zusammengeführt werden. Die Lebenszyklusanalyse von Splittmastixasphalt umfasst die Lebenswegabschnitte cradle to gate, d.h. insbesondere die Prozesse der Gewinnung der Zuschläge und der Herstellung von Bitumen. Berücksichtigt wurden die Transporte der Rezepturbestandteile zur Asphaltmischanlage sowie der Herstellungsaufwand. Die Systemgrenze bildet der eingebaute Splittmastixasphalt. Transporte vom Werk zur Baustelle sind nicht berücksichtigt und müssen bei Systembetrachtungen eingerechnet werden.

Modelling and validation

Administrative information

Environmental indicators

Indicators of life cycle

Indicator	Direction	Unit	Production A1-A3	Function type
Erneuerbare Primärenergie als Energieträger (PERE)	Input	MJ	33.79	General reminder flow
Erneuerbare Primärenergie zur stofflichen Nutzung (PERM)	Input	MJ	0	General reminder flow
Total erneuerbare Primärenergie (PERT)	Input	MJ	33.79	General reminder flow
Nicht-erneuerbare Primärenergie als Energieträger (PENRE)	Input	MJ	4118	General reminder flow
Nicht-erneuerbare Primärenergie zur stofflichen Nutzung (PENRM)	Input	MJ	0	General reminder flow
Total nicht erneuerbare Primärenergie (PENRT)	Input	MJ	4118	General reminder flow
Einsatz von Sekundärstoffen (SM)	Input	kg	0	General reminder flow
Erneuerbare Sekundärbrennstoffe (RSF)	Input	MJ	0.0373	General reminder flow
Nicht erneuerbare Sekundärbrennstoffe (NRSF)	Input	MJ	0.3633	General reminder flow
Einsatz von Süßwasserressourcen (FW)	Input	m3	32.73	General reminder flow
Gefährlicher Abfall zur Deponie (HWD)	Output	kg	0	General reminder flow
Entsorgter nicht gefährlicher Abfall (NHWD)	Output	kg	391.2	General reminder flow
Entsorgter radioaktiver Abfall (RWD)	Output	kg	0.02016	General reminder flow
Komponenten für die Wiederverwendung (CRU)	Output	kg	0	General reminder flow
Stoffe zum Recycling (MFR)	Output	kg	0	General reminder flow
Stoffe für die Energierückgewinnung (MER)	Output	kg	0	General reminder flow
Exportierte elektrische Energie (EEE)	Output	MJ	0	General reminder flow
Exportierte thermische Energie (EET)	Output	MJ	0	General reminder flow

Indicators of the impact assessment

Indicator	Unit	Production A1-A3
Globales Erwärmungspotenzial (GWP)	kg CO2-Äqv.	77.11
Versauerungspotenzial von Boden und Wasser (AP)	kg SO2-Äqv.	0.2293
Potenzial für den abiotischen Abbau fossiler Brennstoffe (ADPF)	MJ	4069
Eutrophierungspotenzial (EP)	kg Phosphat-Äqv.	0.02356
Abbau Potential der stratosphärischen Ozonschicht (ODP)	kg CFC 11-Äquiv.	5.919E-8
Potenzial für den abiotischen Abbau nicht fossiler Ressourcen (ADPE)	kg Sb-Äqv.	0.00001166
Bildungspotential für troposphärisches Ozon (POCP)	kg Ethen-Äqv.	0.1669

Annex F: Example Dutch EPD - MRPI dataset (in Dutch, accessed www.bamwegen.nl/)

milieu relevante product informatie MRPI

BEDRIJFSINFORMATIE

bam infra
BAM Wegen bv

BAM Wegen bv
Winthontlaan 28
3526 KV Utrecht
Postbus 2419
3500 GK Utrecht
Tel. (030) 287 68 76
E-mail: info@bamwegen.nl

VOOR

leab
Laag Energie Asfalt Beton

MRPI-CODE	30.1.00011.003
DATUM AFGIFTE	17 november 2009
FUNCTIONELE EENHEID	1 ton LEAB geschikt voor toepassing als tussen- en/of onderlaag in asfalt conform de geldende RAW-bepalingen voor Steenslag Asfalt Beton voor toepassing in Nederland. De gegevens op dit MRPI®-certificaat zijn opgesteld conform NEN8006:2004 en het MRPI®-toetsingsprotocol voor NEN8006:2004, versie 1.0
ONDERDEEL VAN FUNCTIONELE EENHEID	1 ton LEAB uit een gasgestookte asfaltcentrale

PRODUCTIEOMSCHRIJVING

Grondstof	ton/ton
Steenslag	0,303
Natuurlijk zand	0,159
Productiestof	0,009
Vulstof zwak	0,008
Asfaltbitumen (70/100)	0,017
Asfaltgranulaat	0.504

MILIEUPROFIEL

Thema	Abiotische uitputting	Broeikas effect	Aantasting ozonlaag	Humane toxiciteit	Ecotoxiciteit water (zoet water)	Ecotoxiciteit terrestrisch	Fotochemische oxidantvorming	Verzuring	Vermesting
Eenheid (equivalenten)	kg Sb	kg CO_2	kg cfk11	kg 1,4DB	kg 1,4DB	kg 1,4DB	kg ethyl	kg SO_2	kg PO_4^{-3}
Productiefase	6.4E-01	3.7E+01	9.3E-06	8.5E+00	9.4E-01	4.4E-02	7.3E-03	2.0E-01	2.5E-02
Levering	3.0E-02	5.3E+00	6.6E-07	1.5E+00	2.8E-01	5.9E-03	1.2E-03	3.5E-02	7.3E-03
Afdankfase	1.4E-02	5.3E+00	3.0E-07	7.3E-01	6.5E-01	1.9E-03	3.0E-04	3.0E-03	1.2E-02

NVTB Nederlands Verbond Toelevering Bouw

NVTB en VROM stimuleren het gebruik van deze milieurelevante productinformatie voor berekening van het milieuprofiel van een gebouw/bouwwerk overeenkomstig de "Bepalingsmethode materiaalgebonden milieuprestatie van gebouwen en GWW-werken".

milieu relevante product informatie MRPI

MILIEUMATEN

Thema	Grondstoffen	Energie	Emissies	Afval niet gevaarlijk	Afval gevaarlijk
Eenheid	jaar⁻¹	MJ	jaar⁻¹	kg	kg
Productiefase	3.8E-11	5.4E+02	8.0E-10	4.7E-01	5.7E-02
Levering	8.2E-13	3.0E+01	9.3E-11	1.7E-03	1.0E-02
Afdankfase	1.8E-12	6.4E+01	1.6E-10	4.1E-03	2.5E-02

MILIEUPROFIEL EN PROFIELMATEN

Representatief voor: LEAB geleverd in Nederland

OPMERKINGEN:

- Het type brandstof in de asfaltcentrale is een belangrijke parameter voor de milieuprestatie. Er is gerekend met 100% aardgas.
- De inzet van een hoog percentage asfaltgranulaat is relevant voor een verbeterde milieuprestatie.

LEVENSFASEN

- Winning grondstoffen
- Productie materialen
- Transport naar de bouwplaats
- Sloop
- Afvalverwerking aan het eind van de toepassing

OVERIGE LEVENSFASEN EN BENODIGDE MATERIALEN EN PROCESSEN

De volgende levenscyclusfasen zijn niet inbegrepen:
- Aanleg
- Gebruik en onderhoud

Laboratoriumproeven en praktijkervaringen geven aanleiding om te verwachten dat de prestatie tijdens de toepassing tenminste gelijkwaardig is aan de toepassing van traditioneel Steenslag Asfalt Beton.

KWALITATIEVE INFORMATIE

In 1998 is gestart met experimenten om asfaltproductie bij lage temperatuur mogelijk te maken. In 2003 werd resultaat geboekt en zo ontstond het inmiddels gepatenteerde Halfwarm-procedé. Het produceren van asfalt bij 100°C in plaats van 165°C was daarmee mogelijk. Tijdens de ontwikkeling van het Halfwarm-procedé was het niet mogelijk in het laboratorium specie en proefstukken te vervaardigen die van voldoende kwaliteit waren. BAM Wegen is verder gegaan met praktijkproeven via een pad van trial and error. Resultaat was dat in 2003 LEAB (Laag Energie Asfalt Beton) door BAM Wegen in de markt is geïntroduceerd, een volwaardig halfwarm alternatief voor conventioneel warm asfaltbeton voor alle categorieën wegen.

OVERIGE BEDRIJFSINFORMATIE

BAM Wegen maakt deel uit van Koninklijke BAM Groep en onderkent haar verantwoordelijkheid met het oog op toekomstige generaties.

Milieu: Wij streven ernaar onze milieuprestaties te verbeteren. Wij treffen alle redelijkerwijs mogelijke maatregelen om onze activiteiten zodanig uit te voeren dat milieu-effecten zo minimaal mogelijk zijn. Wij onderkennen onze verantwoordelijkheid ten aanzien van de natuur en streven ernaar elk negatief effect zo klein mogelijk te houden.

Energie en hulpbronnen: Wij zullen de efficiency verhogen. Wij onderkennen het energiegebruik van de gebouwde omgeving en de uitdagingen van klimaatverandering. Wij zetten ons in om de energie-efficiency van onze activiteiten, producten en diensten te verbeteren. Wij zullen onze activiteiten en prestaties regelmatig evalueren om na te gaan hoe wij energie, transport en watergebruik kunnen verminderen. Ook zullen wij hergebruik bevorderen en afval zoveel mogelijk beperken. Waar mogelijk zullen wij alternatieve materialen en methoden toepassen om in samenwerking met onze opdrachtgevers en toeleveranciers grondstoffen optimaal te gebruiken.

NVTB NEDERLANDS VERBOND TOELEVERING BOUW

NVTB en VROM stimuleren het gebruik van deze milieurelevante productinformatie voor berekening van het milieuprofiel van een gebouw/bouwwerk overeenkomstig de "Bepalingsmethode materiaalgebonden milieuprestatie van gebouwen en GWW-werken".