MHS SEVE v3

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Methodology, Assumptions and Data Sources

November 2016

SEVE

Eco-comparateur

Summary

Introduction

This document presents the methodology, the selected assumptions in setting up the SEVE tool, as well as the sources of data used in the common database of all SEVE users.

NB: Environmental data specific to industry professionals will not be discussed in this document, since they are the property of their respective owners. We remind that obligatorily, these data must be substantiated by an authorised external body, the supporting document being enclosed with the data on its creation.

It is important to recall that:

- SEVE is an eco-comparator used for comparing of two or more solutions in response to calls for tenders.
- SEVE is not used to calculate the environmental impacts of a worksite in absolute terms, although it can provide a good approximation.
- In fact, SEVE is not suitable for determining greenhouse gas footprints either (Bilan Carbone®, OMEGA TP®, etc.).

1.1. System boundary

The SEVE tool enables:

- Evaluating the environmental impacts of a road building worksite based on 7 indicators (described in the User Manual, the SEVE presentation brochure and the IDDRIM Technical Report on the Eco-Comparator[1])
- Comparing several roads and utilities solutions of an urban development project, of a road building or earthwork project, of a new works or maintenance project, etc.
- Comparing solutions that offer the same level of service (technically equivalent solutions)

1.1.1. What the "system" takes into account:

The "system" covers:

- Production of the materials used for producing mixtures (bituminous or hydraulic), including their extraction from the natural environment and their various treatments including the freight operations upstream of the project or the production plants of these mixtures.
- Production of mixtures using these materials in production plants (bituminous mixes/cold mixes/materials treated with hydraulic binders/concretes)
- All transport operations (transport before the production the plant, incoming and outgoing freight at the worksite, or internal transport at the site)
- Implementation operations at the worksite (earthworks, setups, application of layers, dismantling operations, planing, etc.)
- The treatment of products disposed of or recycled on completion of the works (including the environmental cost of landfilling, but not including the environmental cost or the benefits of recycling in

[1] The Technical Report 160 on the SEVE eco-comparator will be reviewed by IDDRIM following the transition from Version 2 to Version 3.

accordance with the inventory method recommended in NF P 01-010 and standard NF EN 15 804, which has replaced it).

- The infrastructures of asphalt plants and construction machinery (excluding heavy vehicles).

1.1.2. What the "system" does not take into account:

The "system" does not take into account:

- The movement of personnel (business unit or manufacturing plant), whose weight is considered negligible.
- Transport-related unavailability.
- The infrastructures of non-bituminous mixing plants and heavy vehicles (14 T trucks, etc.).

For each MJ of energy consumed on a worksite or in a plant, the "provision" of this energy will be taken into account (e.g., for diesel fuel: petroleum extraction, its transport to Europe, refining, distribution, etc.).

More generally, each resource used by the worksite will have to be followed up over its entire life cycle.

1.1.3. Segmentation of the indicators "Process Energy (MJ)" and "Greenhouse Gas Emissions (t of CO2 eq.)" CO2)"

These indicators have been segmented according to different stages:

- Extraction of raw materials
- Transport upstream of the production plant,
- Production of mixes,
- Incoming freight at the worksite,
- Implementation at the worksite,
- Outgoing freight from the worksite

The "production of mixes", and the "upstream transport" are presented separately and only for the following product groups:

⇒ Mastic asphalt [AS],

⇒ Concretes [EB]

⇒ Bituminous asphalt [EB],

⇒ Cold-mix asphalt [EF]

⇒ Materials treated with hydraulic binders [MT]

For these 5 product families, the environmental impacts are therefore presented according to the 6 steps delineated above.

These products are among the most significant in the public works area. This segmentation makes it possible to identify the plants with the highest emissions and those for which companies have a certain flexibility in reducing emissions and improving environmental performance.

For the particular family of Standard Concrete [BS], which was present since the creation of SEVE in 2010, due to lack of specific data on certain sub-steps, the breakdown involved 5 steps and accordingly, the assessment of impacts was carried out in 3 main steps: Extraction of raw materials, incoming freight at the worksite and application. The environmental cost of “production of mixtures” and “upstream transport” was merged into the environmental cost of “raw material extraction”.

1.2. Functional unit

Above all, SEVE is a tool for comparing several solutions. This involves comparing similar worksites in terms of level of service and functionality.

Thus, it would be inappropriate to compare two worksites, which, on completion, will have different reference service lives.

Thus, two solutions compared in SEVE must meet the following conditions:

- **Full compliance with the customer's specifications;**
- **Same quality of service, especially from the point of view of dimensional design (optionally, the solutions may involve scenarios with one or more maintenance proposals);**

1.3. Data produced by the French Road Industry Unions Association (USIRF)

Some data are not available in external databases on the market. A working group consisting of USIRF members determined the ratios, consumption data and other essential data for the creation of the database, such as the database of construction machinery prepared by the USIRF Equipment Commission

These data were validated by an external body before being integrated into the software.

The concept of provided product: the concept of provided product applies only to asphalt mix additives. A provided product is a delivered product. In the case of a provided product, it is assumed that an average transport was integrated into the environmental cost of the product.

1.4. External data

- FD P01-015: Energy and transport data sheet
- ADEME: Emission Factors Guide – Version 5.0 and 6.1
- LCA of bituminous mixes produced by the USIRF (manufacture and application) (2015)
- Eurobitume LCI report published in March 2011 (Eurobitume Life Cycle Inventory, March 2011, *process and infrastructure*).
- LCA performed by the Technical Association of Hydraulic Binders Industry (ATILH) for cement, published in 2009
- LCA Report produced by the National Union of Aggregate Producers (UNPG) on aggregate in 2011
- LCA Report produced by the Union of Lime Producers (UPC), February 2010
- Environmental and Health Product Declaration (FDES) on pavers produced by the Study and Research Centre for the Manufactured Concrete Industry (CERIB)

- Environmental and Health Product Declarations for asphalt produced by the Mastic Asphalt Association, October 2019
- Base Eco Invent 3.0

2. Products and Formulations section

2.1. The "Aggregate" family

Introduction

The emission factors are based on the results of FDES sheets produced by UNPG.

The UNPG has produced three FDES Environmental and Health Product Declarations: "hard rock aggregate", "soft rock aggregate" and "recycled aggregate".

The environmental costs of the materials used within the "aggregate" family in SEVE are primarily based on these results.

This is the most recent study (2007/2008) carried out for this type of materials at national level.

It should be noted that the selected functional unit for these FDES declarations is the tonne of produced aggregate "at site gates". This means that adding the transport of these materials from their production site (quarry, recycling centre, etc.) to their place of use (worksite, plant, etc.) is essential

2.1. Natural aggregate

This resource represents natural aggregates (obtained from natural deposits external to the worksite).

The environmental cost of "natural aggregate" is calculated by weighting the FDES data of "hard rock aggregate" and "soft rock aggregate" according to the respective output of each type of rock at national level (as an initial approach 50%/50%).

"Natural aggregate" is obtained from quarries of natural materials outfitted with a facility for processing materials.

Last known results of aggregate LCA:

For 1 tonne	Climate change (in t of CO2 eq.)	Process energy (MJ)
FDES of "Hard rock aggregate" (*)	0.00257	60.9
FDES of "Soft rock aggregate" (*)	0.00230	64.9
GR100: Natural aggregate	**0.00244**	**62.9**

(*): Last known provisional results as of July 2010

Specifically, the "natural aggregate" SEVE resource covers: limestones, eruptive materials, alluvial sands and gravels, sand, ballast, etc., intended to be used directly as backfill, or to be added to asphalt mixes, to gravel treated with hydraulic binders or to reconstituted natural gravels.

For the other SEVE indicators, the following values are used:

For 1 tonne	Consumption of aggregate (in t)	Use of asphalt aggregate (in t)
GR100: "Natural aggregate"	1	0

GR100 does not cover: recycled aggregates, slag, shale, filler, clinker and asphalt aggregates.

2.2. Gravel, sand, added filler

These resources have been added in order to make the database easier to read, particularly for the IA (Industry Administrator) in charge of filling out the forms in SEVE.

The environmental costs for these 3 resources are considered to be equivalent to the “natural aggregate” resource.

As regards the added filler, to date, no FDES has been produced for this material. It should be noted that added filler is generally used in small quantities (<2%), and that the environmental costs of transport are often much higher than the environmental costs involved in the manufacturing process. For these reasons, as an initial approach, the added filler will be considered to be assimilated to a natural aggregate.

2.3. Recycled aggregate

This resource covers materials obtained from a recycling facility for excavated material. Worksite excavated material used upstream of the recycling facility generally consists of “demolition concrete”, “pavement sections”, “kerb stones”, etc.

These recycled materials may be intended for use:

- Directly at the worksite (as backfill or in the body of a pavement structure)
- In MTHB formulations (Materials Treated with Hydraulic Binders) (passage through a mixing plant).

The following are not taken into account within this resource:

Asphalt aggregates intended to be reintroduced into the production of hot mixes.

For 1 tonne	Climate change (in t of CO2 eq.)	Process energy (MJ)
“Recycled aggregate” FDES (*)	0.00296	47.4
GR200: “Recycled aggregate”	**0.00296**	**47.4**

(*): Last known results as of August 2011

For the other SEVE indicators, the following values are used:

For 1 tonne	Consumption of aggregate (in t)	Use of asphalt aggregate (in t)
GR200: “Recycled aggregate”	**0**	**0**

Indeed, using recycled aggregate precludes the consumption of natural aggregate.

Moreover, this resource does not affect the asphalt aggregate and therefore does not impact the indicator “Use of asphalt aggregate”.

2.4. Slag aggregate

Slag is a by-product of steel. To estimate the impacts related to slag production, an economic allocation has been made between slag and steel using the method proposed in the Laboratory of Bridges & Highways Bulletin (BLPC) no. 276, 2009.

- The impacts of the production of one tonne of virgin unalloyed steel are calculated based on the LCI in the Ecoinvent 2.2 database: Steel, converter, unalloyed, at plant/RER.
- We assume a production of 1 t of slag for 3 t of steel.
- We assume an economic allocation coefficient of 2.6% for the slag.

We then calculate the environmental cost of one tonne of slag, which is equal to 3 x 2.6% x the environmental cost of one tonne of virgin steel.

For 1 tonne	Climate change (in t of CO2 eq.)	Process energy (MJ)	Natural aggregate consumption (in t)	Use of asphalt aggregate (in t)
Slag	0.125	2530	0	0

2.5. Shale aggregate

Shales are materials found in coal dumps (in particular at Nord Pas de Calais and Loire).

To enable their use in road construction, these products must pass through a treatment plant (crushing, screening, etc.).

These materials are considered to have an environmental cost equivalent to that of recycled aggregate.

2.6. Asphalt aggregate

This resource concerns only:

- Materials produced by recycling asphalt mixes that underwent treatment (crushing / screening) and are intended to be recycled directly into the manufacture of asphalt mixes at the plant

This resource does not concern:

- Asphalt aggregate (milling materials) intended to be used straightaway at the site as backfill without prior treatment

We can therefore assume that the environmental cost (CO2 and energy) of asphalt aggregate is identical to that of recycled aggregate.

The distinctive characteristic of asphalt aggregate is expressed in the indicator “Use of asphalt aggregates”.

2.7. Reclaimed demolition waste

A resource called “demolition waste produced and reused on the same worksite” is created with zero environmental cost. This refers to inert materials reused on worksites.

3. Asphalt binders

3.1. Pure bitumens

Bitumen data were taken from the Eurobitume LCI report published in March 2011 (Eurobitume (Life Cycle Inventory, March 2011, *process with infrastructure*).

The values take into account the extraction of crude oil and its transport, refining and storage in the refinery. They correspond to pure bitumen. Since more detailed data of bitumen grades were not available, as an initial approach, we will assume that the environmental cost of the bitumen is not dependent on grade.

For 1 tonne	Climate change (in t of CO2 eq.)	Process energy (MJ)
Pure bitumen 10/20	0.247	3686
Pure bitumen 15/25	0.247	3686
Pure bitumen 20/30	0.247	3686
Pure bitumen 35/50	0.247	3686
Pure bitumen 50/70	0.247	3686
Pure bitumen 70/100	0.247	3686
Pure bitumen 160/200	0.247	3686

3.2. Bitumen fluxed with a petroleum-based fluxing agent

Data related to bitumen fluxed with a petroleum-based fluxing agent are considered equivalent with pure bitumen.

3.3. Polymeric bitumens

Bitumen data were taken from the EUROBITUME LCI report published in March 2011 (EUROBITUME (Life Cycle Inventory, March 2011, *process with infrastructure*).

The values take into account the extraction of crude oil and its transport, refining and storage in the refinery. The data taken into account are those that include the infrastructures. .

This binder is combined with a polymerised additive (source: Eco-Profile of SBS, International Institute of Synthetic Rubber Producers, I. Boustead & D. L. Cooper, July 1998) in different proportions and at an environmental cost equivalent to the manufacture of modified bitumen (cost based on the LCI of the polymer-modified bitumen 2011: electrical consumption of 72 MJ of electricity/t.)

For 1 tonne	Climate change (in t of CO2 eq.)	Process energy (MJ)
Polymerised additive	3.6503	43200
Pure bitumen	0.2467	3686
Production of modified binder	0.00187	222

Given:

For 1 tonne	Climate change (in t of CO2 eq.)	Process energy (MJ)
Polymeric bitumen 3%	0.3507	5093
Polymeric bitumen 3.5%	0.3677	5291
Polymeric bitumen 4%	0.3847	5489
Polymeric bitumen 4.5%	0.4018	5686
Polymeric bitumen 5%	0.4188	5884
Polymeric bitumen 5.5%	0.4358	6081
Polymeric bitumen 6%	0.4528	6279
Polymeric bitumen 6.5%	0.4678	6476
Polymeric bitumen 7%	0.4868	6674

3.4. Bitumen emulsions and foamed bitumen

Bitumen emulsions and foamed bitumen

The emulsion consists of a mixture of:

- X% bitumen at 160°C,
- Y% water at 55°C,
- 0.15% “amine” type stabiliser
- 0.2% hydrochloric acid

Emulsification is performed in a special dedicated plant comprising an emulsification unit and including all the processes involved in maintaining the products at a specific temperature, flow movement, control, etc.

According to the data of the EUROBITUME ICV of March 2011, the impacts of the production stage are calculated by assuming a consumption of energy of 72 MJ/t of emulsion (source: Eurobitume) and a consumption electricity of 140 MJ/t of water for heating the water from 10 to 40°C (thermodynamic calculation based on 90% efficiency).

In addition, for calculation purposes, we assume a process energy consumption of 3.08 MJ/MJ of electricity and process emissions of 3.08 MJ/MJ of electricity and emissions of 0.000026 t CO2 eq./MJ of electricity (source: FD P 01-015 Table 5).

It is important to take these assumptions into account when calculating the environmental cost of any company-specific emulsion manufacturing.

In the absence of data provided by the manufacturer, the “amine” stabiliser is assimilated to diethanolamine (Ecoinvent 2.2 base, diethanolamine, at plant / RER). This stabiliser is present in small quantity; the following values have been used:

For 1 tonne	Climate change (in t of CO2 eq.)	Process energy (MJ/t)
Amine	3.6522	67468

The data for hydrochloric acid were taken from the Ecoinvent 2.2 database (hydrochloric acid, 30% in H2O, at plant / RER):

For 1 tonne	Climate change (in t of CO2 eq.)	Process energy (MJ/t)
Hydrochloric acid	0.8511	20575

As an initial approach, the manufacture of foamed bitumen may be assimilated to that of emulsion.

Based on this, the following table may be inferred:

						Environmental Impacts	
	Emulsion 60%	Emulsion 65%	Emulsion 69%	Foamed bitumen	Unit	CO2 (in t eq)	Process energy (MJ)
Emulsion ingredients							
Amines	0.15%	0.15%	0.15%	0.00%	t	*3.6523*	*67468*
Hydrochloric acid	0.20%	0.20%	0.20%	0.00%	t	*0.8511*	*20576*
Pure bitumen	60.00%	65.00%	69.00%	90.00%	t	*0.247*	*3686*
Water	39.65%	34.65%	30.65%	10.00%	t	*0.0003*	*7.43*
Manufacture of emulsion (emulsification and binder heaters) **MJ**	392.73	371.17	353.92	264.88	MJ/T		
Manufacture of emulsion (emulsification and binder heaters) **CO2 (T)**	0.0033153	0.0031333	0.0029877	0.0022360	T CO_2/T		
Process energy (MJ/t of emulsion)	**2750**	**2912**	**3042**	**3583**			
CO2 (in t eq./ t of emulsion)	**0.159**	**0.171**	**0.181**	**0.224**			

4. Hydraulic binders

4.1. Cement

Cement data were taken from a Life Cycle Inventory (LCI) compiled by the Technical Association of Hydraulic Binders Industry (ATILH) for mainland France.

The cement types targeted by the LCI of ATILH are “grey” cements meeting the requirements of the NF EN 197-1 standard and the compositions of which correspond to average formulations of cements produced in mainland France.

- Portland cement CEM I
- Portland slag cement CEM II AS
- Portland fly ash cement CEM II AV
- Portland limestone cement CEM II AL
- Portland limestone cement CEM II AL
- Portland composite cement CEM II BM
- Blast furnace cement CEM III A
- Blast furnace cement CEM III B
- Composite cement CEM V/A-(S, V)

Per tonne		Climate change (in t of CO2 eq.)	Process energy (MJ)
Portland cement	CEM I	0.866	5946
Portland composite cement	CEM II AS	0.753	5319
	CEM II AV	0.755	5074
	CEM II AL	0.759	5108
	CEM II B L	0.648	4392
	CEM II B M	0.629	4398
Blast furnace cement	CEM III A	0.461	3717
	CEM III B	0.247	2560
Composite cement	CEM V	0.502	3777

(ATILH data)

For the sake of simplification, in SEVE, three types of cements have been included:

- Cement I
- Cement II
- Cement III

For the “process energy” and “climate change” indicators:

- We will use the value produced by the ATILH for CEM I.
- For CEM II, we calculate the average of cement types: CEM II AS, CEM II AV, CEM II AL, CEM II BL, CEM II B M.
- For CEM III, we calculate the average of cement types CEM III A and CEM III B.

For the “Aggregate consumption” indicator:

We assume that cement types CEM II and CEM III consist of reclaimed materials: slag, fly ash, etc., which do not impact the “aggregate consumption” indicator; this is not the case of the clinker, which primarily consists of materials obtained from the natural environment.

It is assumed that CEM II consists on the average of 60% clinker while CEM III consists on the average of 40% clinker. Clinker is the only material that impacts the aggregate consumption indicator.

For the “Natural aggregate consumption” indicator, we have selected the following values:

For 1 tonne	Climate change (in t of CO2 eq.)	Process energy (MJ)	Consumption of aggregate (t)
CEM I	0.866	5946	1
CEM II	0.7088	4858.2	0.6
CEM III	0.354	3138.5	0.4

4.2. Lime

The data were taken from the LCI of UPC (2008-2009 data): LCI of “road construction” type quicklime and slaked lime. For the aggregate consumption data we did not use the data in the LCI of the UPC; however, we assumed a consumption of one tonne of aggregate for one tonne of quicklime, according to the calculation adopted for natural aggregate and clinker.

For 1 tonne	Climate change (in t of CO2 eq.)	Process energy (MJ)	Consumption of aggregate (t)
“Road construction” type quicklime	1.096	4500	1
Slaked lime	0.857	3850	1

4.3. Asphalt binders

There is a large number of suppliers and types of asphalt binders. The carbon footprint of asphalt binders is largely attributable to the amount of clinker and lime in the formulation.

The ideal solution is to obtain the percentages of A) clinker (equivalent to Cement I) and B) lime in the formulation from the supplier and then reconstruct the formula in a simplified format:

- Clinker: A%
- Lime: B%
- Slags: 100% - A% - B%
- + 1 overall coefficient for processing in the mixing plant

If the precise values of A and B cannot be obtained, SEVE 3 proposes three types of binders with impacts calculated in advance by USIRF administrators, according to the following rules:

- A road binder with low clinker content, which will be modelled by taking: A=10% and B=0%
- A road binder with medium clinker content (between 10% and 30%), which will be modelled by taking: A=30% and B=0%
- A road binder with high clinker content (between 31% and 70%), which will be modelled by taking: A=70% and B=0%

Rules applied in SEVE:

HRBs with low clinker content	If the clinker content is <10%	We use: clinker = 10%
HRBs with medium clinker content	If 10% <clinker <30%	We use: clinker = 30%
HRBs with high clinker content	If 31% <clinker <70%	We use: clinker = 70%

Consequently:

For 1 tonne	Climate change (in t of CO2 eq.)	Process energy (MJ)	Consumption of aggregate (t)
HRBs with low clinker content	0.2004	2908	0.1
HRBs with medium clinker content	0.3486	3591	0.3
HRBs with high clinker content	0.6450	4958	0.7

4.4. Fly ash

Per tonne	Climate change (in t of CO2 eq.)	Process energy (MJ)	Consumption of aggregate (t)	Consumption of asphalt aggregate (t)
Fly ash	0.385	2660	0	0

Calculated based on BLPC data (BLPC no. 276 of December 2009): production of one tonne of ash for 40000kWh of electricity at an economic allocation coefficient of 0.7% for the ash.

5. Concrete

SEVE includes a cold mixing plant model, which allows creating “custom-made” formulas of materials treated with hydraulic binders. Accordingly, this functional feature of SEVE should be used in priority, especially when large quantities of materials are involved.

However, in order to facilitate the use of SEVE, the database provides users with 2 types of concrete that can be used in an initial study, or in the case of small amounts of MTHB.

5.1. Concrete C25/30, Concrete C35/45

For these 2 materials, the impact related to water is considered negligible (<2%).

Finally, an overall coefficient accounting for mixing in a mixing plant is added.

Concrete C25/30 (per tonne)

	Climate change (tCO2eq)	Process energy (MJ)	Consumption of aggregate (t)	Formula
Natural aggregate	0.00244	62.9	1	**84.10%**
CEM III	0.354	3138.5	0.4	**15.90%**
				(% x distance)
Transport of aggregates (30km)	0.0000813	1.010064	0	**25.23**
Transport of CEM III (100km)	0.0000813	1.010064	0	**15.90**
				(Mixing)
Mixing in a mixing plant	0.00128	36.3	0	**1**
Density: 2.2				
Per tonne	**0.0630**	**630**	**0.905**	
Per m3	**0.1386**	**1386**	**1.990**	

Concrete C35/45 (per tonne)

	Climate change (tCO2eq)	Process energy (MJ)	Consumption of aggregate (t)	Formula
Natural aggregate	0.00244	62.9	1	**83.00%**
CEM I	0.866	5946	1	**17.00%**
				(% x distance)
Transport of aggregates (30km)	0.0000813	1.010064	0	**24.90**
Transport of CEM I (100km)	0.0000813	1.010064	0	**17.00**
				(Mixing)
Mixing in a mixing plant	0.00128	36.3	0	**1**
Density: 2.25				
Per tonne	**0.1539**	**1141**	**1.000**	
Per m3	**0.3463**	**2568**	**2.2500**	

5.2. Concrete C25/30

It has been modelled according to a formula for non-bituminous materials containing:

- 84.10% natural aggregate transported to the concrete mixing plant for 30km in a 24 T truck
- 15.90% CEM III cement transported to the concrete mixing plant for 100 km in a 24 T tanker
- Its density is 2.2 t/m3

5.3. Concrete C35/45

It has been modelled according to a formula for non-bituminous materials containing:

- 83% natural aggregate transported to the concrete mixing plant for 30km in a 24 T truck
- 17% CEM I cement transported to the concrete mixing plant for 100 km in a 24 T tanker
- Its density is 2.25 t/m3

6. Asphalts

The FDES sheets produced by the Mastic Asphalt Association have been used:

- Asphalt-based surfacings for roadway-type road building applications
- Asphalt-based surfacings for sidewalk-type road building applications
- Asphalt and bituminous sheet used for parking decks and engineering structures called Mixed-Use Centres

The values are based on the FDES, using data indicated in the production column, then multiplying these data by the typical service life estimated in the FDES.

The functional unit is expressed in m². The mass per m² is indicated in the chapter "Functional Unit" of each FDES document.

- 84 kg/m2 for the roadway
- 48 kg/m2 for the sidewalk
- 63.8 kg/m2 for the sealing of the engineering structure
- 3.8 kg/m2 for the bituminous sheet

Important:

The presented data apply only to the production of materials; **transport and application data should be factored in separately in the SEVE tool.**

Based on this, the following table may be inferred:

For 1 m²	Unit	Climate change (tCO2eq)	Process energy (MJ)	Consumption of aggregate (t)	Use of aggregate (t)
Road asphalt	m2	0.00805	175	0.07	0.0084
Sidewalk asphalt	m2	0.00466	103	0.04	0.0048
Sealing asphalt for structural work (gravel asphalt + bituminous sheet)	m2	0.00841	220	0.055	0
Bituminous sheet 3 mm (for information)	m2	0.00486	74.6	0	0

7. Additives for asphalt mixes

7.1. High-density polyethylene (HDPE)

This additive is used as a polymerised additive for direct feed in production plants.

The values provided in the Ecoinvent 2.2 database should used: "Polyethylene, HDPE, granulate, at plant, RER".

For 1 tonne	Unit	Climate change (tCO2eq)	Process energy (MJ)
HD polyethylene additive	tonne	1.9299	25499

7.2. Red pigment (iron oxide)

The values provided in the Ecoinvent 2.2 database should be used (Iron ore, 65% Fe, at beneficiation, GL)

	Unit	Climate change (tCO2eq)	Process energy (MJ)
Red pigment	tonne	0.017	387

8. Pavers

Two categories of pavers are presented in SEVE:

- Concrete pavers
- Pavers made of natural material (such as granite or sandstone)

The laying bed and the seams are not included in these resources. Therefore, the user must add these materials in the SEVE database (sand, mortar, emulsion, etc.). In addition

8.1. Concrete pavers

To determine the factors involved in the use of concrete pavers, we will rely on the FDES document "Concrete road paving stones" produced by the Study and Research Centre for the Manufactured Concrete Industry (CERIB - January 2007).

In this FDES document, the functional unit is 1 m^2 of concrete pavers in 10 cm by 20 cm with a thickness of 6 cm. The values for climate change and process energy are derived from the FDES, using the data indicated in the production column and multiplying these data by the typical service life estimated in the FDES. Regarding the aggregate consumption, the consumption taken into account was equivalent to the assessed paver mass in the functional unit.

	Unit	Climate change (tCO2eq)	Process energy (MJ)	Aggregate consumption (t)
Concrete pavers	m^2	0.0171	145	0.140

8.2. Pavers made of natural materials

For pavers made of natural materials, we have used the LCI of "natural stone pavers" produced by the Technical Centre for Natural Construction Materials (CTMNC) of August 2008. The data are provided for 1 m^2 of pavers with the dimensions of 10 X 10 X 7 cm.

The values for climate change and process energy are derived from the FDES, using the data indicated in the production column and multiplying these data by the typical service life estimated in the FDES. Regarding the aggregate consumption, the consumption taken into account was equivalent to the assessed paver mass in the functional unit.

These data are then extrapolated for pavers of 10 X 10X 10 cm and 10 X 10 X14 cm.

For different paver dimensions, as an initial approach, we may assume that the factors to be applied are proportional to the height of the pavers (e.g. for 14 cm thick pavers, we can use the values of 7 cm thick pavers, to which a factor of 14/7 is applied).

	Unit	Climate change (tCO2eq)	Process energy (MJ)	Aggregate consumption (t)
Pavers made of natural materials (10x10x7 cm)	m^2	0.0097	432	0.1415
Pavers made of natural materials (10x10x10 cm)	m^2	0.0138	617	0.2021
Pavers made of natural materials (10x10x14 cm)	m^2	0.0194	864	0.2830

9. The “Other” family

9.1. Water

Water data are taken from the Ecoinvent 2.2 database (tap water, at user / RER)

	Unit	Climate change (tCO2eq)	Process energy (MJ)
Water	m3	0.0003	7.43

9.2. Mortar

The data for calculating the environmental costs of mortar were obtained based on the following assumptions:

- Composition
  - 78.05% natural aggregate, at a transport of 30 km by 24 T semi-trailer
  - 21.95% CEM I, at a transport of 100 km by 24T semi-trailer
- Density = 2.05

For 1 unit	Unit	Climate change (tCO2eq)	Process energy (MJ)	Consumption of aggregate (t)
Mortar	t	**0.1970**	**1436**	**1**
Mortar	m 3	**0.4038**	**2945**	**2.05**

9.3. Steel for concrete reinforcement

For 1 tonne	Climate change (in t CO2 eq.)	Process energy (MJ)	Consumption of aggregate (t)	Consumption of asphalt aggregate (t)
Steel for concrete reinforcement	1.45	29,920	0	0

Data extracted from Ecoinvent 2.2: Reinforcing steel, at plant/RER (63% converter unalloyed, 37% electric un and low alloyed + hot rolling).

9.4. Geotextile

	Climate change (in t of CO2 eq.)	Process energy (MJ)	Consumption of aggregate (t)	Consumption of asphalt aggregate (t)

Geotextile 100g/m2 (per m2)	0.0003	3.06	0	0
Geotextile 150g/m2 (per m2)	0.00045	4.59	0	0

Representative data of geotextiles used for public works was obtained from Plasticeurope; it takes into account the cost of energy and CO2 of the polypropylene and an additional cost of 50% for processing

10. Energy and fuels

Energy data were derived from the FD P01-015 data sheet: "Environmental quality of construction products - Energy and transport data sheet"

Additional data (densities, conversions, etc.) were taken from the Emission Factors Guide of ADEME (Version 5.0, January 2007)

10.1. Diesel / Domestic Fuel Oil

Diesel and domestic fuel oil (FDO) have the same emission factors. Diesel is used for registered vehicles (trucks, binder spreaders, sweepers, etc.), while DFO is used for construction machinery.

From the viewpoint of environmental cost, these products are considered identical. The difference between these two sources of energy lies in their applicable tax status (VAT).

The emission factors of diesel/DFO must be known:

- by litre (to determine the emission of vehicles)
- by MJ to enable their inclusion in the thermal model.

The data were taken from the FD P01-015 data sheet with the following values:

- density = 0.85 kg/L;
- PCI = 42 MJ/kg.

Overview for energy sources	Unit	Climate change (in t of CO2 eq.)	Process energy (MJ)
Energy for machinery			
Domestic fuel oil	L	0.00308	38.26
Energy for plants			
Domestic fuel oil	MJ	$8{,}63 \times 10^{-5}$	1.07

10.2. Heavy fuel

Heavy fuel is used in asphalt mixing plants as burner fuel.

The data were taken from the FD P01-015 data sheet:

	Overview for energy sources	Unit	Climate change (in t of CO_2 eq.)	Process energy (MJ)
Energy for plants				
	Heavy fuel	MJ	9,14 x10^{-5}	1.18

10.3. Natural gas

Natural gas is used in asphalt mixing plants as burner fuel.

The data were taken from the FD P01-015 data sheet:

	Overview for energy sources	Unit	Climate change (in t of CO_2 eq.)	Process energy (MJ)
Energy for plants				
	Natural gas	MJ	6,24 x10^{-5}	1.03

10.4. Electricity

N/A: This resource is not available in SEVE, since the worksites targeted by SEVE do not have direct access to electrical power (such as the case of electrically-operated machinery). The consumption of electricity for the manufacture and formulation of input materials (aggregates, bitumen, etc.) has already been taken into account in the data used in SEVE.

11. Transport

11.1. Road transport

For road transports, only the environmental costs attributable to the diesel fuel consumption of vehicles are assessed.

Unlike construction machinery, therefore, the amortisation of the steel weight of the truck or its maintenance are not taken into account. This is a simplifying assumption, justified by the fact that the maintenance operations and the amortisation of trucks are significantly lower compared to their consumption than construction machines, which are subject to more intense wear.

11.2. Transport by 24 t semi-trailer

In accordance with the FD P01-015 data sheet, the average consumption of a full truck is: 38L/100km

To determine consumption on empty runs, we apply a factor of 2/3.

The payload is 24 t.

According to the standard, the environmental cost of road transport is proportional to the fuel consumption.

- 1 litre of diesel fuel = 38.26MJ
- 1 litre of diesel fuel = (2872x1 + 3.91x25 + 0.37x298) = 3080g CO2eq

We use the formula on page 27 of the standard.

Calculation of consumption in litres per t.km (tonne-kilometre) transported with empty return:

$$\mathbf{Consommation}_{semi\,24t\,retour\,\grave{a}\,vide} = \frac{\left(\frac{38l}{100km} \times 1km_{\,aller} + \frac{38l}{100km} \times \frac{2}{3} \times 1km_{retour}\right)}{24t\,utiles} = 0,0264\,\frac{litre}{tK}$$

Calculation of consumption in litres per t.km transported with full load:

$$\mathbf{Consommation}_{semi\,24t\,retour\,\grave{a}\,plein} = \frac{\left(\frac{38l}{100km} \times 1km_{\,aller}\right)}{24t\,utiles} = 0,0158\,\frac{litre}{tK}$$

In this case, the consumption attributable to an effectively transported tonne must take into account only the outgoing journey.

11.3. Transport by 14 t truck and transport by 9 t truck

The average consumption of a 14 t truck is not provided in the FD P01-015 data sheet.

Based on the feedback of road works companies, it was determined that:

- The average consumption of a truck with a 14 t payload is 34 l/100 km with full load.
- The average consumption of a truck with a 9t payload is 30l/100 km with full load.

To determine consumption on empty runs, we apply a factor of 2/3.

Similarly to the calculation for a 24 t semi-trailer, the following ratios were determined:

Calculation of consumption in litres per t.km transported by 14 t truck with empty return:

$$\text{Consommation} = \frac{\left(\frac{34l}{100km} \times 1km\ (aller) + \frac{34l}{100km} \times \frac{2}{3} \times 1km(retour)\right)}{14t\ utiles} = 0{,}040\ \frac{litre}{tk}$$

Calculation of consumption in litres per t.km transported by 14 t truck with full load:

$$\text{Consommation} = \frac{\left(\frac{34l}{100km} \times 1km\ (aller)\right)}{14t\ utiles} = 0{,}024\ \frac{litre}{tk}$$

Calculation of consumption in litres per t.km transported by 9t truck with empty return:

$$\text{Consommation} = \frac{\left(\frac{30l}{100km} \times 1km\ (aller) + \frac{30l}{100km} \times \frac{2}{3} \times 1km(retour)\right)}{9t\ utiles} = 0{,}055\ \frac{litre}{tk}$$

Calculation of consumption in litres per t.km transported by 9t truck with full load:

$$\text{Consommation} = \frac{\left(\frac{30l}{100km} \times 1km\ (aller)\right)}{9t\ utiles} = 0{,}033\ \frac{litre}{tk}$$

11.4. Transport by 24 t tanker.

This mode of transport primarily relates to transports of bitumen.

The average consumptions are identical to a 24 t semi-trailer. In most cases, the returns are empty.

Therefore, the environmental cost of a 24 t tanker is identical to a 24 t semi-trailer with empty return.

11.5. Transport of emulsion in a spreader

This transport mode applies to the transport of emulsions in binder spreaders, which are specifically intended for this activity.

The average consumption of a spreader depends on its capacity (typically 4, 6, 8 or 10 m3). As an initial approach, we consider the spreader cost per t.km as being equivalent to that of a 14 T truck with empty returns.

The environmental cost of a 14 t truck with empty return is therefore identical to the costs of transport of emulsion in a spreader.

11.6. Transport by mixer truck of 6 to 8 m^3

This mode of transport primarily relates to the transport of concrete.

Given the uncertainty involved in using either of the mixer truck models (6 or 8m3), at the time of the study, it was decided to keep a single resource in SEVE for modelling transport by mixer truck.

The average consumption of these mixer trucks is close to that of a 14 t truck with a payload of (34 l/100 km) at full load. In most cases, the returns are empty.

11.7. Transport by tipper truck or dumper

This mode of transport relates to transports (within the worksite area) carried out by specialised earthmoving work machinery.

The engine power ratings of a tipper/dumper truck and the 24 T truck are equivalent. In addition, transports are always with empty returns, since no materials are delivered to the cutting face.

Next, we apply the environmental cost of the diesel fuel to all the above factors and we obtain:

For 1 t.km	Climate change (in t of CO2 eq.)	Process energy (MJ)
t.km of a 24 t truck with empty return	8.13×10^{-5}	1.010
t.km of a 24 t truck with full load	4.87×10^{-5}	0.605
t.km of a 14t truck with empty return	1.23×10^{-4}	1.530
t.km of a 14t truck with full load	7.39×10^{-5}	0.918
t.km of a 9t truck with empty return	1.69×10^{-4}	2.100
t.km of a 9t truck with full load	1.02×10^{-4}	1.260
t.km of a 24 t tanker truck	8.13×10^{-5}	1.010
t.km mixer truck of 6 to 8 m3	1.23×10^{-4}	1.530
t.km of a tipper or dumper truck	8.13×10^{-5}	1.010
t.km of emulsion in a spreader	1.23×10^{-4}	1.530

11.8. Rail transport

We are using the data obtained from the Emission Factors Guide of ADEME.

On page 61, we retrieve the data applying to mainland France. The trains used to transport aggregates are mostly “full trains”.

In addition, the ratio of “fuel-based” and “electric” freight used by ADEME to reconstruct the average for France is 86%(electric)/14%(thermal).

The energy consumption data are calculated based on the CO2 eq. emission factors for DFO and electrical power obtained from the FD P01-015 data sheet.

For 1 t.km	Climate change (in t of CO2 eq.)	Process energy (MJ)
Electric rail transport	9,38 x 10-6	1.11
Fuel rail transport	5,01 x 10-5	0.622
French mixed rail transport	1,51 x 10-5	1.04

11.9. River transport

The Emission Factors Guide of ADEME V. 6.1, we find the following data for France:

		Grams of diesel fuel per t.km
Self-propelled	<400t	14.0
	400 – 650 t	13.8
	650 – 1000 t	12.3
	1000 – 1500 t	11.5
	>1500 t	9.5
Pushers	295 – 590 kW	8.6
	590 – 880 kW	7.8
	>880 kW	6.8

As an initial approach, the categories used for the transport of aggregate are self-propelled vessels exceeding 650 t. The small difference between the values for self-propelled vessels >650 t enables us to calculate an average between 12.3, 11.5 and 9.5 grams.

The consumption of diesel fuel is 11.1 g/tkm. To estimate the environmental cost of river transport, we will assume a diesel fuel density of 0.85 kg/l and we will use the diesel fuel data from in the FD P01-015 data sheet (table 8, page 28).

For 1 t.km	Climate change (in t of CO2 eq.)	Total primary energy (MJ)
River transport	4,13 x 10-5	0.500

11.10. Maritime freight

On page 67 of the Emission Factors Guide of ADEME V 6.1, we have retrieved the average data for bulk carriers.

We consider that the most representative category for the maritime freight of aggregate is the 1980 Handymax (40,000 t).

The consumption of diesel fuel is 1.2 g/tkm. To estimate the environmental cost of river transport, we will assume a diesel fuel density of 0.85 kg/l and we will use the diesel fuel data from in the FD P01-015 data sheet (table 8, page 28).

For 1 t.km	Climate change (in t of CO2 eq.)	Process energy (MJ)
River transport	4,35 x 10-6	0.0540

12. Construction equipment

The environmental cost of a construction machine is determined based on the following parameters:

- Power rating of the machine (P)
- Average number of hours of daily use (hours/d)
- Consumption per base kW at an engine load of 100%
- Load rate (%)
- Idling rate (%)
- Service life of the machine (in hours)
- Mass of the machine (in t)
- Maintenance
- Transfers
- Emission factors of the fuel/diesel fuel and steel

⇒ ***Consumption of the machines in litres is calculated per hour***:

$$Conso1 = Puissance \times Taux\ de\ charge \times Conso\ par\ KW\ de\ base\ à\ 100\%\ de\ charge\ d'un\ moteur$$

Where:

Power: this is the average or typical power of the respective category

Power load ratio: % of engine power absorbed in running mode

Consumption in litres per base kW at an engine load of 100% = 0.27 l/kW (USIRF data)

We factor in the number of hours of use per day and the idling rate:

$$Conso_{carburant} = Conso1 \times Nb\frac{heures}{jour} \times (1 - (0{,}75 \times Taux\ de\ ralenti))$$

Where:

No. of hours/day: the hours of operation recorded on the timer of the equipment.

Idling rate: the percentage of time in which the engine turns idly, consuming about 25% of its power in running mode

⇒ ***Factoring in the transfers of equipment:***

Only non-registered machinery needs to be transferred using heavy-vehicle carrier trucks. Diesel fuel machines are not affected by these transfers. The incoming trip of the carrier to the worksite is included in the operating hours.

An inclusive "transfer" calculation is made on the following basis: 1 transfer every 3 days per vehicle, which represents 15 litres/transfer, i.e. 5 litres/day for the vehicle (USIRF data).

$$Conso_{transferts} = 5\ litres\ gazole\ par\ jour$$

⇒ ***Amortisation:***

Amortisation is evaluated in terms of t of steel/days of use.

$$Amortissement = \frac{Masse\ de\ l'engin}{Durée\ de\ vie} \times Nb\frac{heures}{jour}$$

Service life (hours): This refers to the first typical life cycle of the equipment at road building companies before the sale of the equipment.

At the end of the first life cycle, the machines are generally refurbished and resold on the second-hand market.

In SEVE, the adopted approach consists in distributing the environmental costs of the manufacture of machines over this first life cycle (and not over the total life span of the machine), ignoring the refurbishment and end-of-life stages of machines.

⇒ ***Maintenance:***

The cost of maintenance is evaluated as follows:

$$Entretien = Coef_{entretien} \times Amortissement$$

Maintenance coefficient: the coefficient that must be applied to the initial mass of material to estimate the maintenance cost (on the average 1 for conventional equipment and 2 for equipment that uses a large number of wear parts)

Important note:

The data were completed for construction equipment and are not applicable to industrial production equipment (in particular quarries); the idling rates, service life and maintenance coefficient may be significantly different in these applications.

The following values are used for fuel and steel resources:

For 1 unit	Climate change (in t of CO2 eq.)	Process energy (MJ)
Diesel/household fuel (litre)	0.00308	38.26
Steel (t)*	1.719	35,510

** Steel data obtained from the Ecoinvent 2.2 database: Steel, low-alloyed, at plant/RER (63% converter low alloyed, 37% electric un and low alloyed + hot rolling)*

In total,

$$\left(\frac{CO2}{Energie}\right)_{Engin} = \left(Conso_{carburant} + Conso_{transferts}\right) \times \left(\frac{CO2}{Energie}\right)_{\frac{Gazole}{FO\,D}} + (Amortissement + Entretien) \times \left(\frac{CO2}{Energie}\right)_{Acier}$$

Important note:

Infrastructures were taken into account only for construction machinery, where they were considered to be non-negligible.

As regards the transports on site (14 t, 19 t and 24 t truck), the impact of infrastructures was not included in the calculation of the environmental cost in accordance with the NF P01-010 standard. Likewise, the impact of infrastructures on the road transports was not included in calculations, for the same reasons.

13. Asphalt plant model

The energy consumption of the plant (not including upstream transports) was derived from:

- Consumption at the burner/dryer (about 80% of the total)
- “Incidental” consumptions

SEVE users should add these components and their transports before determining the formula.

13.1. Consumption at the burner/dryer

Burner consumption depends on multiple parameters. SEVE uses 4 parameters, considered to be “significant” and “predictable”.

$$\begin{pmatrix} \textit{Température de l'enrobé} \\ \textit{Teneur en eau moyenne des matériaux} \\ \textit{\% d'agrégats d'enrobés} \\ \textit{Teneur en eau résiduelle des enrobés}(*) \end{pmatrix} \Rightarrow \textit{Consommation}$$

(*) Only for asphalt mixes <100°C

The temperature of an asphalt mix is the asphalt mix temperature indicated in its Technical Data Sheet. It may vary between 80°C and 180°C.

The average water content of materials reflects the water content of the mixture of constituents (sand, gravel, asphalt aggregates, etc.). It is therefore variable in each formulation. This factor is essential in calculating the energy consumption: a variation of 1% of water content of the input mixture results in a variation of 15% in the burner consumption.

The percentage of asphalt aggregate is calculated based on the formulation components for which the "use of asphalt aggregate" impact is equal to 1. This is the case of resource GR250 "Asphalt aggregate".

The residual water content of asphalt mixes is a parameter taken into account when the temperature of asphalt mixes is lower than 100°C.

SEVE users must imperatively take into account all the additives (transport and production) in the asphalt mix formulations that may lower the production temperature.

The temperature formula was determined by major asphalt producers of the industry. It has been correlated to actual monitoring processes at asphalt plants for different types of production representative of current practices.

13.2. Incidental consumptions

Operation of the loader(s) that feed the plant

The loader's average consumption is based on the following assumption:

Consumption of 200 litres of DFO per day, at an average rate of 600 t/d, i.e. 0.33 litres of DFO per manufactured tonne.

According to the database:

- 1 litre of DFO = 38.26 MJ
- 1 litre of DFO = 3.08 kg CO_2eq.

The environmental cost related to the loader operation is:

- 0,33 x 38,26 = **12,62 MJ**,
- and **1.01 kg CO_2** eq. per tonne of produced bituminous mix.

Boiler for maintaining binders at controlled temperatures

An internal survey has indicated that the energy consumption of this process is 40 MJ of thermal energy per ton produced. There are different types of energy that feed a binder storage facility: electric, heavy fuel oil and natural gas. We will start by assuming an allocation of 1/3 electrical energy, 1/3 heavy fuel oil and 1/3 natural gas.

According to the database, we will thus obtain:

- [40 x 3.08 + 40 x 1.03 + 40 x 1.18] / 3 = **70.5 MJ** per produced tonne
- [40 x 0.026 + 40 x 0.0624 + 40 x 0.0914] / 3 = **2.40 kg CO_2** eq. per produced tonne

Operation of the electrical sections at the plant and the office of the Plant Manager/console operator

An internal survey has indicated that the energy consumption of this process is 7.2 MJ of electric energy per ton produced. According to the database, we will thus obtain:

- 7.2 x 3.08 = **22.18 MJ** per produced tonne
- 7.2 x 0.026 = **0.187 kg CO_2** eq. per produced tonne

Amortisation of facilities (concrete + steel)

The facilities have been assimilated to: 150 t steel (Steel low-alloyed, Ecoinvent 2.2) and 100 m^3 concrete (Concrete C25/30), i.e.:

- An energy cost of 150 x 35,500 + 100 x 1,386 = 5,463,600 MJ for the facility
- An energy cost of 150 x 1,720 + 100 x 138.6 = 271,860 Kg CO_2 for the facility.

On the average, over the life span of the plant systems, estimated at 15 years, a plant produces 1,500,000 t. Therefore, the energy and carbon costs per tonne are:

- **3.64 MJ** per tonne produced.
- **0.18 kg CO_2** eq. per produced tonne.

Other types of consumption (personnel transport)

In accordance with the definition of the "system boundaries", consumption pertaining to transport of personnel is not taken into account.

Overall, the "incidental" consumptions represent:

For 1 tonne	Climate change (in t of CO2 eq.)	Process energy (MJ)
Incidental consumptions	**0.00377**	**108.94**

In general, the cumulated energy consumption of these elements represents approximately 20 to 25% of the total energy consumption. This energy may be produced using many types of fuel (household fuel, gas or electricity).

14. Model of a non-bituminous mixing plant

In the SEVE system, the “non-bituminous mixing plant” model corresponds to a cold-mixing plant, such as: production plant for gravel treated with hydraulic binder, concrete mixing plant, humidified reconstituted gravel (HRG) production plant etc.

Un forfait de fabrication a été établi sur la base d’informations transmises par les adhérents de l’Usirf.

It factors in:

- Consumption attributable to the mixer operation: 2 kWh of electricity per tonne
- Operation of the plant feed loader: 0.3 kg of heavy fuel oil per tonne

It does not take into account the cost of amortisation of the facilities (steel and concrete of engineering structures). In fact, unlike the asphalt mixing plants, the share of maintenance and amortisation of these facilities over the entire life cycle appears to be negligible. SEVE users should also account for transports occurring upstream of the materials (aggregate and binders) in the formulation. For the manufacturing component only, we have selected:

For 1 tonne	Climate change (in t of CO2 eq.)	Process energy (MJ)
Mixing of one tonne	**0.00128**	**36.3**

15. Excavated material and planings produced by the worksite

Apart from the transport, which was already accounted for in SEVE, the environmental cost of the planings produced by the worksite and the inert waste material intended for recycling is nil. In fact, these materials are intended for recycling and are provided to a future worksite (inventory method).

As regards inert excavated material intended for final disposal, the environmental costs are:

For 1 tonne	Climate change (in t of CO2 eq.)	Process energy (MJ)
Inert excavated material intended for final disposal	0.0122	306

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