EPD® – Environmental Product Declaration

BI-COMPONENT MORTAR for Follo Line

Project "Railway Tunnel"

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Mortars applied to a Surface (Construction product) Appendix A to PCR 2012:01 "Construction Products and Construction Services" Version (v2.0)

UN CPC code 37510

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1. INTRODUCTION

Mandatory statements of environmental product declaration (EPD)® describes from a lifecycle perspective, the total environmental impact of a "Bi-component mortar", included in the twin railway tunnels that connect the cities of Oslo and Ski, establishing a central axis for interurban development to the south of the Norwegian capital. The goal of this study is to provide information regarding the environmental impact of the Bi-component mortar fabricated and used by the alliance between ACCIONA Construction and Ghella within the Joint Venture AGJV, for the Follo Line Project (Norway). The program operator of this EPD® is The International EPD® System.

The EPD® covers "Bi-component mortar" only. It includes the following modules; *A1-A3 Production stage* (extraction and processing of raw materials, transportation up of raw material to the factory gate, and manufacturing of the Bi-component mortar). *A4-A5 Construction stage* (A4 Transport to construction site and A5 Construction process), and *C1-C4 End of life stage.* The *B1-B7 Use stage,* and *C1* and *C3* stages have been taken into account for the analysis although their value has not been relevant. Module D, *Benefits and loads beyond the life cycle*, has not been taken into account during the analysis. Within the International EPD® system based on ISO standard 14025, this EPD® was drawn up in accordance with Product Category Rules (PCR) *Mortars applied to a Surface (Construction product) Appendix A to PCR 2012:01 "Construction Products and Construction Services" Version (v2.0)* [1]. (See www.environdec.com for further information about the EPD® system) and with CEN standard 15804 (Sustainability of construction works) [2]. The time coverage for data collection is one year.

The intended use of the EPD® is to communicate environmentally relevant information and LCA results to support the assessment of the sustainable use of resources and of the impact of construction works on the environment.

This EPD® was developed by AGJV. It has been verified by Marcel Gómez Ferrer, individual verifier, and the certification is valid internationally and for five years.

As this EPD® is based on data relating to Follo Line railway tunnels during 2017, the results might not be representative for the Bi-component mortar of other railway tunnels. EPD® of construction products may not be comparable if they do not comply with EN 15804. Environmental product declarations within the same product category from different programs may not be comparable. In order to decide if the results can be representative for other railway tunnel, the most important aspects that should be checked to be comparable with other Bi-component mortars are:

- Composition
- Origin of materials
- Bi-component mortars functionality
- The geographical representativeness of data

2. DESCRIPTION OF THE COMPANY

The Spanish company Acciona and Italian Ghella have joined forces and established AGJV, an innovative company with extensive international tunnel experience.

Acciona Ghella Joint Venture is commissioned by the Norwegian government's agency for railway services (Bane NOR) to construct the main part of the tunnel at the Follo Line (EPC TBM). The company is located at the construction site at Åsland in Oslo, and started up in 2015. The project will be finalized in 2021, and includes Scandinavia's longest railway tunnel.

3. DESCRIPTION OF THE BI-COMPONENT MORTAR

This EPD® refers to Bi-component mortar fabricated and used by AGJV at the Follo Line Project. This project is the biggest rail project in Norway, and consists of two twin rail tunnels, each 19.5 km long with an inside diameter of 8.8 meters, that will connect the cities of Oslo and Ski, establishing a central axis for interurban development to the South of the Norwegian capital. Designed for trains traveling at 250 km/h, connecting the inhabitants of the two cities, the tunnels are being excavated simultaneously by four huge, double shield tunnel boring machines (TBMs).

The studied Bi-component mortar is fabricated in one factory located near the tunnel of Follo Line. Bi-component mortar is a bonding material that integrates construction materials into a single element. Mortar must be strong, durable and capable of keeping the wall intact and must help to create a water resistant barrier. In the case of tunnel constructions, the Bi-component mortar is used to fill the space between tunnel concrete elements and drilled rock, regardless of mixing ratio. The life expectancy of the tunnel as well as the studied Bi-component mortar is at least 100 years.

This Bi-component mortar meets the requirements of the Jernbaneverket template for Environmental Accounts in Norway. This EPD® covers all the batches of Bi-component mortar produced by the studied plant with care for sustainable development principles.

Figure 1. Bi-component mortar plant.

4. FUNCTIONAL UNIT

The studied Bi-component mortar is being used in the Follo Line railway tunnel (Norway). A Functional Unit is a concept used to compare the life cycle results of different products on a like-for-like basis.

The declared functional unit for the EPD® is defined as 1 m^2 (1000 l and 1269 kg at density 1, 26 t/m^3), with a thickness of 20 cm.

5. SYSTEM BOUNDARIES AND DATA QUALITY

Life cycle stages and information modules are defined in the standard EN 15804, Figure 2. It must be highlighted that raw materials, transport and manufacturing processes are included in the LCA calculations, and core modules according to PCR. This "Cradle-to grave" LCA analysis includes the following modules: *A1-A3 Production stage* (extraction and processing of raw materials, transportation up of raw material to the factory gate, and manufacturing of the Bi-component mortar). *A4-A5 Construction stage* (A4 Transport to construction site and A5 Construction process). *C2* and *C4 End of life stage* (Transport to final waste treatment and Disposal).The *B1-B7 Use stage,* and *C1* and *C3* stages have been taken into account for the analysis although their value has not been relevant.

Module D *Benefits and loads beyond the life cycle* has not been taken into account during the analysis. In order to assess the environmental potential according to EN 15804 and follow Mortars applied to a Surface (Construction product) Appendix A to PCR 2012:01 "Construction Products and Construction Services" Version (v2.0) the impact method CML 2001 (updated in January 2016) has been used. This model is an LCA methodology developed by the Center of Environmental Science (CML) of Leiden University in the Netherlands.

Production Stage A1-A3			Construction Stage A4-A5		Use Stage B1-B7							End-of-Life Stage C1-C4				Benefits and loads beyond the system boundary
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
Raw material supply	Transport	Manufacturing	Transport	Construction	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Demolition	Transport	Waste processing	Disposal	Re-use recovery and recycling potential
X	X	X	X	X	MND	MND	MND	MND	MND	MND	MND	MND	X	MND	X	MND

Description of the system boundary (x – Included in LCA, MNA – Module Not Declared)

Figure 2. Stages of the LCA according to EN15804 [2].

It must be noted that at least 99% of materials and energy requirements for the life cycle have been considered. The substances contained in the product that are listed in the "Candidate List of Substances of Very High Concern (SVHC) for authorization" do not exceed 0,1% weight of the product.

The electricity used comes from Norway national grid, and composed of 96.2% hydropower, 1.4% wind power, 1.8% natural gas, 0.3% waste, 0.2 hard coal and 0.1% others. [database of GaBi software]. The contribution to global warming of the Norwegian gas is 0.038 kg CO2 equiv./kWh.

The time coverage for data collection is one year. The geographical system boundary is Norway. All processes are valid for the production sites in Norway. An overview of system boundaries and included processes is given in the Figure 3 below.

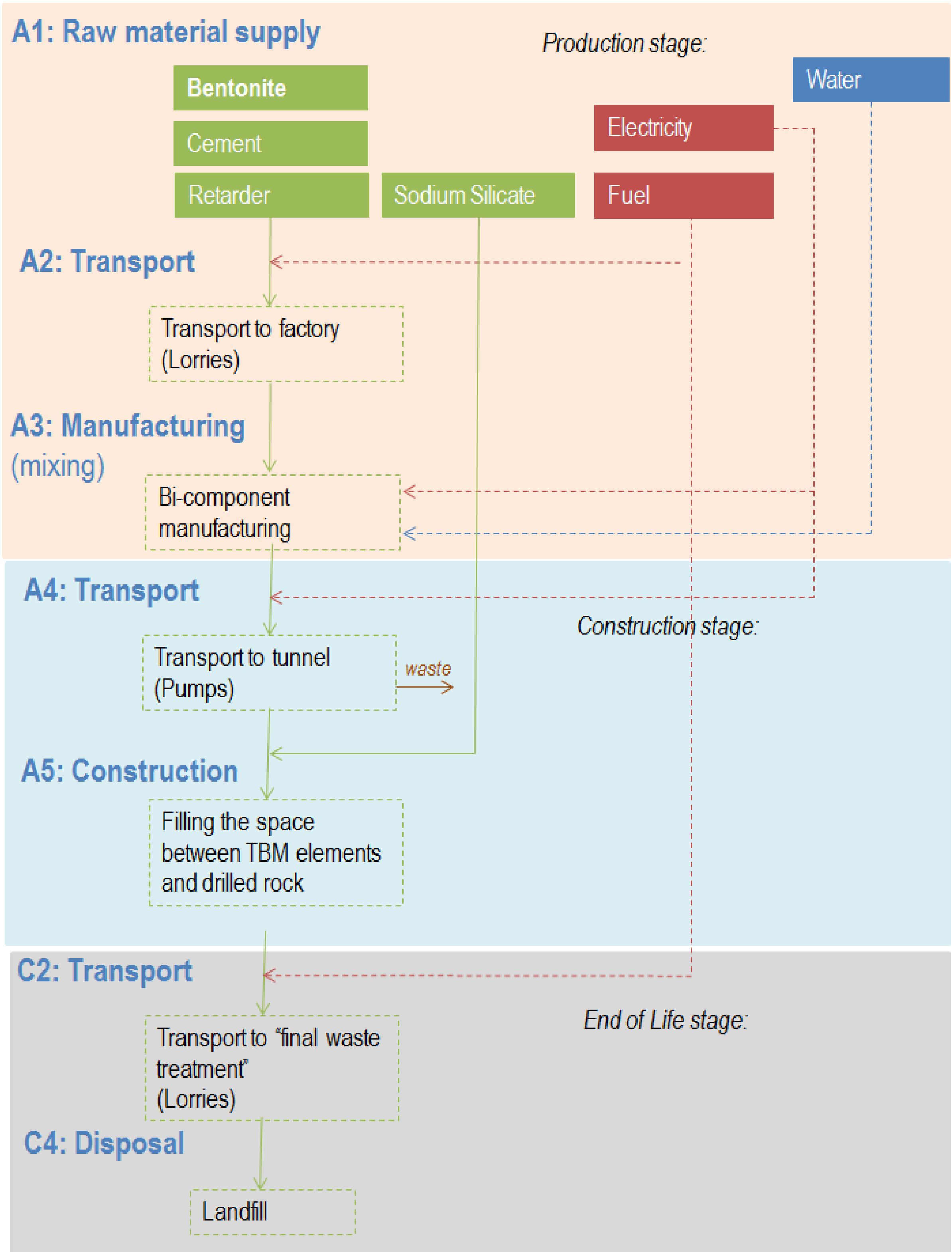

Figure 3. System boundaries of the production of the 1 m² of Bi-component mortar.

6. CONTENT DECLARATION

Specific data regarding Bi-component mortar production and quantities of raw materials and energy requirements was collected from the work site as well as the rest of stage studied. The data used in this report are average values, gathered during one year factory analysis.

The process of the Bi-component mortar production consists of the steps that are listed below:

1. Dose water.
2. Dose bentonite.
3. Mix for pre-define time to grout test and optimization.
4. Dose cement.
5. Add retarder.
6. Mix for pre-define time subject to grout test and optimization.

In the LCA assessment of the production stage (A1-A3) and construction stage (A4-A5) of the Bi-component, all available data were considered. The material and energy flows are presented by all raw materials, and electric power consumption. The same applies to the transport A2 – from the factory of raw materials to the factory of Bi-component that is located in situ of the Follo line Project and transport A4- run by pipes mounted in the tunnel from the factory of Bi-component to the place of its implantation. All these data are owned and provided by AGJV. Data related to the modules C2 and C4 were assumed. Finally, the waste generated in the production of Bi-component mortar are measured daily and refer to material losses during the transport by pipes in the construction stage. Some materials were not found in the available database. Suppliers of some raw materials are not always the same. Therefore, for the LCA study was assumed that the distance of the trucks from different providers to the place of construction is an average value. Also, due to the lack of information related to the end of life scenarios of Norwegian construction waste, the scenario of 100% landfill has been assumed.

All necessary background data relevant for modelling of the production process were taken from database within *GaBi ts 2017* (GaBi Software-System and Database) [9]. The geographical representativeness of data reflects the region where the production is located, Norway in this case. Life cycle inventory (LCI) includes the main raw materials used in each stage is given in the table below:

Component A	Weight [%]
Water	61-64
Bentonite	1-4
Cement	25-28
Retarder	0.2-0.5
Component B	**Weight [%]**
Sodium Silicate	5-8
TOTAL	**100**

Table 1: Required raw materials for production of 1 m² of Bi-component mortar

The Component B is added in the construction stage, as the hardening agent. The transport scenario is to deliver the raw materials to the production site by truck.

Regarding the construction stage, the transport is carried out by tubes and pumps, which push material to the construction site. During this process some material losses during a transport are noted and taken into account. The average value of waste taken from the period considered is 24 kg/m^2.

In the use stage, there is not expected any emission to air, water or ground, through evaporation, leakage or radiation during the use stage of the Bi-component. The Bi-component mortar during the use stage is closed between the rock and concrete elements, therefore during its lifespan of 100 years, no maintenance, repair, replacement and refurbishment are foreseen. Mortars are static construction materials, and require no water or energy in the use stage.

Regarding the end of life stage, mortars for surface use are not considered as a part of the structure of the tunnel. Therefore during the tunnel destruction, the extra energy required to break these application can be neglected. The distance to the final waste treatment is estimated as 50 km by a lorry, according to the reference [Statistics Norway; 2013]. The waste from the end of life is considered as non-hazardous. This waste can be disposed in the Landfill or recycled as crushed material.

7. ENVIRONMENTAL PERFORMANCE

The environmental performance section of the declaration is based on a life cycle assessment (LCA) carried out by AGJV in 2017. In order to assess the environmental potential according to EN 15804 [2] and Mortars applied to a Surface (Construction product) Appendix A to PCR 2012:01 "Construction Products and Construction Services" Version (v2.0) [1], the most, related to the Bi-component mortar, the indicators presented in the table below were evaluated via GaBi ts software. Results of LCA analysis are presented in the following table 2:

Table 2: LCA results: Environmental Impacts for $1m^3$ of Bi-component mortar

Parameter	Unit	Upstream Process	Core processes		Downstream Processes							Module D	TOTAL
		A1	A2	A3	A4	A5	B1-B7	C1	C2	C3	C4		
Environmental impact *(according to CML2001-Apr.2013)*													
Global warming potential	Kg CO_2-eq	6,99E+01	3,97E-01	2,83E-01	5,65E-03	0,00E+00	0,00E+00	0,00E+00	1,64E+00	0,00E+00	3,72E+00	0,00E+00	7,59E+01
Depletion potential of the stratospheric ozone layer	Kg CFC 11-eq	2,41E-07	1,33E-13	1,23E-12	4,45E-13	0,00E+00	0,00E+00	0,00E+00	5,47E-13	0,00E+00	3,49E-12	0,00E+00	2,41E-07
Acidification potential of soil and water	Kg SO_2-eq	1,67E-01	8,88E-04	3,02E-04	2,66E-03	0,00E+00	0,00E+00	0,00E+00	3,51E-03	0,00E+00	2,19E-02	0,00E+00	1,96E-01
Eutrophication potential	Kg $(PO_4)^{3-}$-eq	3,03E-02	2,11E-04	4,65E-05	4,00E-04	0,00E+00	0,00E+00	0,00E+00	8,32E-04	0,00E+00	2,99E-03	0,00E+00	3,48E-02
Formation potential of tropospheric ozone	Kg C_2H_4-eq	1,88E-02	-2,80E-04	2,66E-05	6,93E-05	0,00E+00	0,00E+00	0,00E+00	-1,07E-03	0,00E+00	1,73E-03	0,00E+00	1,93E-02

Abiotic depletion potential for non-fossil resources	Kg Sb equivalents	9,65E-05	3,21E-08	1,07E-06	1,70E-07	0,00E+00	0,00E+00	0,00E+00	1,32E-07	0,00E+00	1,30E-06	0,00E+00	9,92E-05
Abiotic depletion potential for fossil resources	MJ, net calorific value	2,05E+03	5,47E+00	2,13E+00	7,40E+00	0,00E+00	0,00E+00	0,00E+00	2,25E+01	0,00E+00	4,80E+01	0,00E+00	2,13E+03
Resource use													
Use of renewable primary energy excluding renewable primary energy resources used as raw materials	MJ, net calorific value	6,67E+01	2,75E-01	3,47E+01	1,38E+00	0,00E+00	0,00E+00	0,00E+00	1,13E+00	0,00E+00	5,80E+00	0,00E+00	1,10E+02
Use of renewable primary energy resources used as raw materials	MJ, net calorific value	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

Total use of renewable primary energy resources	MJ, net calorific value	6,67E+01	2,75E-01	3,47E+01	1,38E+00	0,00E+00	0,00E+00	0,00E+00	1,13E+00	0,00E+00	5,80E+00	0,00E+00	1,10E+02
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials	MJ, net calorific value	2,07E+03	5,49E+00	3,83E+00	7,62E+00	0,00E+00	0,00E+00	0,00E+00	2,26E+01	0,00E+00	4,97E+01	0,00E+00	2,16E+03
Use of non-renewable primary energy resources used as raw materials	MJ, net calorific value	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Total use of non-renewable primary energy resources	MJ, net calorific value	2,07E+03	5,49E+00	3,83E+00	7,62E+00	0,00E+00	0,00E+00	0,00E+00	2,26E+01	0,00E+00	4,97E+01	0,00E+00	2,16E+03
Use of secondary material	kg	1,48E+01	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,48E+01
Use of renewable	MJ, net calorific value	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

secondary fuels													
Use of non-renewable secondary fuels	MJ, net calorific value	8,90E+01	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	8,90E+01
Net use of fresh water	M^3	0,256	1,00E-03	5,30E-02	2,21E-03	0,00E+00	0,00E+00	0,00E+00	2,10E-03	0,00E+00	9,43E-03	0,00E+00	3,23E-01
Waste to disposal													
Hazardous waste disposed	kg	2,98E+01	2,88E-07	1,47E-08	2,06E-07	0,00E+00	0,00E+00	0,00E+00	1,19E-06	0,00E+00	7,85E-07	0,00E+00	2,98E+01
Non-hazardous waste disposed	kg	6,38E+00	4,19E-04	1,51E-02	2,40E+01	0,00E+00	0,00E+00	0,00E+00	1,73E-03	0,00E+00	2,30E+02	0,00E+00	2,61E+02
Radioactive waste disposed	kg	2,98E+01	7,49E-06	7,06E-04	8,66E-05	0,00E+00	0,00E+00	0,00E+00	3,08E-05	0,00E+00	6,71E-04	0,00E+00	2,98E+01

As it can be seen in the Figure 4 and Table 2, the impact of the LC of Bi-component mortar for covering 1 m2 surface is mainly dominated by the production stage (A1-A3). This contributes with nearly 86-100% to the total environmental impacts of the Bi-component mortar. The negative values of POCP for A2 and C2 are related to the truck and is caused by the division of the NOX emissions into the two single emissions NO2 and NO during the upgrade from GaBi 4 to GaBi 5/6. The NO has a negative effect on the POCP since it reduces the close ground ozone formation [14].

Regarding the waste treatment (C4) represents about 0-11% of the impact.

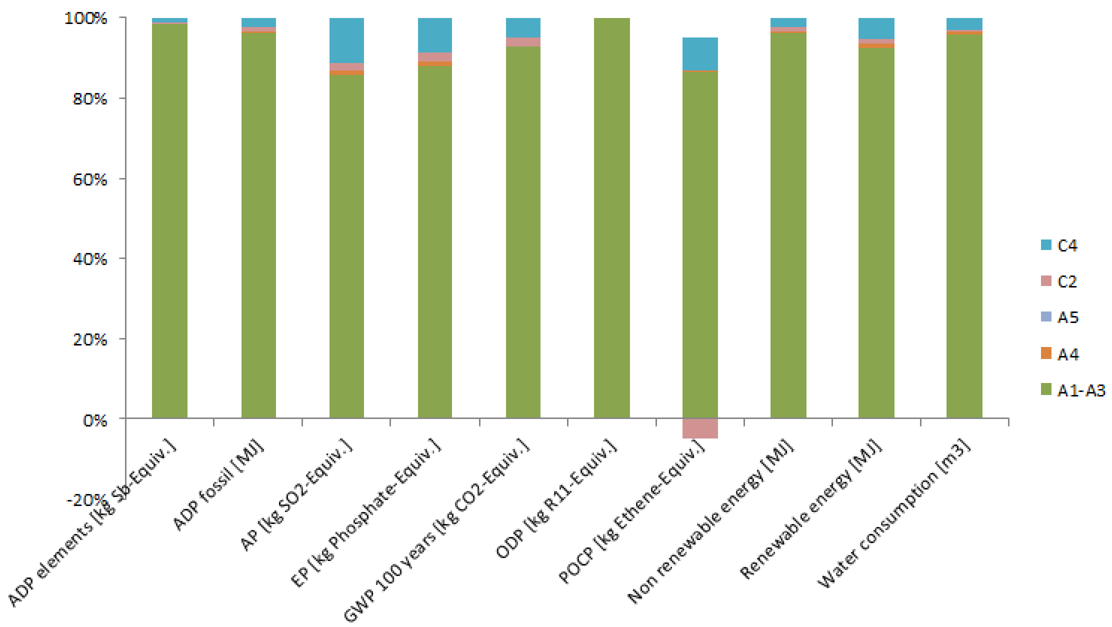

Figure 4. Dominance analysis according to different modules (A1-A3, A4, A5, B1-B7, C1-C4).

8. VERIFICATION AND CONTACT

Table 3: Demonstration of verification

CEN standard EN 15804 served as the core PCR *Mortars applied to a Surface (Construction product) Appendix A to PCR 2012:01 "Construction Products and Construction Services" Version (v2.0)* *serves as the specific PCR for this EPD®* *Product Category Rules (PCR) review was conducted by the Technical Committee of the International EPD®* System. Chair: Massimo Marino. Contact via info@environdec.com
Independent verification of the declaration, according to ISO 14025:2006 ☐ *internal* ☒ *external*
Independent Verifier: *Marcel Gómez Ferrer* *Marcel Gómez Ferrer Consultoría Ambiental* www.marcelgomez.com info@marcelgomez.com Barcelona SPAIN *Approved by:* *The International EPD® System.* Operated by EPD® International AB, www.environdec.com, Sweden.

Table 6: Contact

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9. REFERENCES

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- [7] ISO 14044:2006 Environmental management-Life Cycle Assessment-Requirements and guidelines.
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- [13] GaBi website: http://www.gabi-software.com

10. CHANGES FROM THE PREVIOUS VERSION OF THE EPD

This EPD has been modified from revision 2020-11-06 in the following points:

1. The company description has been changed from ACCIONA to ACCIONA GHELLA JOINT VENTURE
2. The logo of the company has been modified
3. Typo error from the index has been modified