



Deliverable D5.4.

# Report on Pre-verified Environmental Product Declaration documentation for pilot plants based on historical data



D5.4. Report on Pre-verified EPD documentation for pilot plants based on historical data.

Dissemination level: PU

## Deliverable report

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## Disclaimer

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DIGIECOQUARRY project is fully concerned about the potential social risks that may arise as consequence of project's activities. For this reason, a dedicated Work Package (WP7 - Mechanisms for social acceptance & interaction with policy makers) is active since the beginning of the project identifying, analysing and monitoring social risks in each of the project sites. Main social risks have been already analysed and classified in deliverables 7.1 and 7.2, including also potential risks of DIGIECOQUARRY technologies' deployment beyond the end of the project. The identification and classification of social risks allows a close follow up of main potential negative impacts in society to avoid them along the whole project activities. Among potential social risks, impact in the workforce is monitored with specific attention to ensure full adaptation of workers to new working technologies and processes and avoid job destruction.

Taking social risks and quarry workers into account is especially crucial in WP5, as its specific goals include monitoring health and safety indicators in the production process, as well as and improving health and safety measures in plants.

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## List of Abbreviations

Abbreviation	Description
ADP	Abiotic Depletion Potential
AP	Acidification potential
C&DW	Construction and demolition waste
CA	Consortium Agreement
CFS	Certificate on the Financial Statements
DoA	Description of Action
EB	Exploitation Board
EC	European Commission
EP	Eutrophication Potential
EPD	Environmental Product Declaration
FW	Use of net fresh water
GA	Grant Agreement
GWP	Global Warming Potential
HWD	Hazardous Waste Disposed
IFS	Individual Financial Statement
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
MoM	Minutes of Meetings
NHWD	Non-Hazardous Waste Disposed
NRSF	Use of non-renewable secondary fuels
ODP	Depletion potential of the stratospheric ozone layer
PCR	Product Category Rules
PENRE	Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials
PENRM	Use of non-renewable primary energy resources used as raw materials
PENRT	Total use of non-renewable primary energy re-sources
PERE	Use of renewable primary energy excluding renewable primary energy resources used as raw materials
PERM	Use of renewable primary energy resources used as raw materials
PERT	Total use of renewable primary energy resources
PFSIGN	Project Financial Statement

POCP	Formation potential of tropospheric ozone
PRC	Project Research Committee
RP	Reporting Period
RSF	Use of renewable secondary fuels
RWD	Radioactive Waste Disposed
SM	Use of secondary material
UEPG	European Aggregates Association
WDP	Water Deprivation Potential
WP	Work Package

# 1 Executive Summary

DIGIECOQUARRY (DEQ) is a four-year EU Horizon 2020 project that aims to enhance quarry operations by leveraging digital technologies to improve health and safety, efficiency, profitability, environmental impact, and social acceptance. The project focuses on quarries that produce aggregate products primarily for the construction sector and includes five pilot sites where new technologies can be developed, tested and validated. The project started in June 2021 and this deliverable aims to communicate the results that have been achieved so far within the Task 5.4.

Task 5.4 aims to further develop an online tool, known as *Plantsmith*, used for generating site-specific Life Cycle Assessment (LCA) reports along with a summary report that can be the basis for an Environmental Product Declaration (EPD) for products produced on site. The LCA results are based on site-specific data connected to a simulation model built within the tool. Further to being the foundation for an EPD, the documentation provides quantitative environmental information at a product level for the base year which can be used to assess the contribution of the activities in the DEQ project to environmental improvements.

Within this deliverable, the methodologies used to collect the site-specific data and create the models are explained and assumptions for the models are given. A new classification framework developed within the project has also been applied to help give more context to the quantitative data and provide a holistic perspective of the environmental concerns for each pilot site. A summary of the quantitative results on the environmental impact at a product level for the five participating pilot sites is also provided. The baseline impact is established for the year 2019, which was chosen to avoid capturing anomalies in production associated with the COVID-19 pandemic.

To allow for the creation of documentation that was relevant to the varying site-specific conditions at each pilot site, new models were developed for the online tool alongside implementations of advancements of the functionality and report templates within the tool, which have now been tested and successfully applied at each site. This has led to the successful creation of documentation for each pilot site. To be published as an EPD, interpretation of the results must be conducted, and the documentation must be approved through a third-party verification process. This lies outside the scope of the project and therefore, the documentation is not verified as defined in the EPD process.

The results of this deliverable provide valuable insight for the further development of *Plantsmith* for the second half of the project. The work in the upcoming stage will aim towards the development of simulation routines implementing environmental findings of the project, to be presented in Deliverable 5.5 in early 2025. The current results also highlight where the largest environmental burdens currently occur at each site, which can help focus the improvement work on the future.

# Introduction

## 1.1 Background

The operation of quarries, as of any surface mining site, carries certain associated effects on the environment, which vary in their nature, scale, and area of influence. Some of the most common environmental impacts of quarrying are the generation of noise, dust and air emissions, ground vibrations, and others. For this reason, one of the main objectives of the DIGIECOQUARRY project is to foster the sustainability of the quarries and improve their environmental performance.

In this context, the goal of task T5.4 *Environmental system evaluation and simulation* is to further develop a simulation platform for the evaluation of environmental impacts for different quarry types and operational strategies. As a first step, this deliverable entails new functionalities added to the simulation platform – *Plantsmith*, that allow the generation of relevant environmental documentation, providing an overview of the environmental situation at each one of the pilot sites in the DEQ project.

It is expected that the information presented in this document contributes to the understanding of the Life Cycle Assessment (LCA) and Environmental Product Declaration (EPD) methodologies, their application in the aggregate sector, and provides the base environmental condition of the pilot sites for future comparison and improvement measurements brought by the DEQ implementation.

## 1.2 Specific Objective for Deliverable

The aim of this deliverable is to provide transparent information on the documentation created through the web-based simulation platform *Plantsmith* for each pilot site based on the EPD framework. The EPD framework aims to provide quantitative environmental information for use in business-to-business communication on a product or service. The documentation has been created using site-specific historical data for the reference year of the project of 2019. The year 2019 has been chosen to avoid capturing abnormal production data associated with the COVID-19 pandemic.

This information will be used for comparative analysis of implementations in the project to assess the environmental improvements on a product level. It will also provide important feedback into the development of the environmental simulation platform in Task 5.4, resulting in the creation of simulation routines for assessing environmental impact to be presented in Deliverable 5.5 of the project. It is important to note that some environmental KPIs in focus for the project are given on a plant level rather than the product level which will not be referred to in this report.

### 1.2.1 Normative references

This document has been produced as part of the Horizon 2020 project DIGIECOQUARRY and should be read in conjunction with the following documents (if possible, considering dissemination level) to provide relevant context to subsequent information:

1. DIGIECOQUARRY Deliverable D1.4: Requirements for H&S improvement, environmental impact minimisation and energy and resources efficiency report. *Confidential*.
2. Background LCA Report for Alenquer quarry operated by Cimpor. *Confidential*.
3. Background LCA Report for Mammendorf quarry operated by CSI. *Confidential*.
4. Background LCA Report for Valdilecha quarry operated by Hanson. *Confidential*.
5. Background LCA Report for Pioltello San Bovio quarry operated by Holcim. *Confidential*.

6. Background LCA Report for Fenouillet processing plant operated by Vicat. *Confidential*.

### 1.3 Limitations

The scope of the compilation of historical data is limited by the availability of information. Some of these limitations will be addressed using data collected over the duration of the project, while others have been deemed to lie outside of the scope of the project, as shown in Table 1.

*Table 1: List of limitations identified with the documentation available based on historical data.*

Limitation	Affected pilot sites	Description	Reasoning	To be addressed in the project?
Exclusion of construction and demolition waste (C&DW).	Vicat	Products produced using C&DW are not included in the historical data.	Limited control of process and access to data from Vicat as the processing is outsourced.	TBC
Country specific environmental regulations not addressed.	All pilot sites	Descriptions of local legislation and procedures conducted based on legislation are not included in the documentation.	Outside the scope of the digital tool in development (Plantsmith).	No
External transport to customer excluded. (A4: after manufacturing)	All pilot sites	Transport of the product to the customer is not included in the historical data.	Lack of historical data available while not mandatory according to standards.	Yes
No third-party verification for publication as an EPD.	All pilot sites	To publish an EPD, all documentation must go through third-party verification. This has not been completed for the sites.	Additional information on the interpretation of the results and action plans is needed to be completed by the sites before a third-party verifier is contracted. The costs for third-party verification are not included in the budget and is not of interest for pilot sites at this time, considering the improvements that	TBC

			are expected to be achieved in the project.	
Direct dust emissions from production are excluded.	All pilot sites	Dust emissions from the production process related to the rock material itself have not been included in the LCA models.	Dust emissions from the production process have been seen to reach background levels within 350m by Sairanen & Rinne (2019) and have, therefore, been deemed a local impact. All sites implement dust reduction measures and, therefore, dust is assumed to be a negligible regional to global impact and excluded from the LCA.	TBC

## 1.4 Social Risk

DIGIECOQUARRY project is fully concerned about the potential social risks that may arise as a consequence of the project's activities. For this reason, a dedicated Work Package (WP7 - Mechanisms for social acceptance & interaction with policy makers) is active since the beginning of the project identifying, analysing and monitoring social risks in each of the project sites. Main social risks have already been analysed and classified in deliverables 7.1 and 7.2 and include potential risks of DIGIECOQUARRY technologies' deployment beyond the end of the project. The identification and classification of social risks allows a close follow up of main potential negative impacts in society to avoid them along the whole project activities. Among potential social risks, impact in the workforce is monitored with specific attention to ensure full adaptation of workers to new working technologies and processes and avoid job destruction. For more information, please refer to the Deliverables 7.1 and 7.2.

Taking social risks and quarry workers into account is especially crucial in WP5, as its specific goals include monitoring safety and environmental indicators in the production process, as well as improving safety and environmental measures in plants. However, this deliverable is specifically focused on the environmental aspects of the project, and therefore, will not address safety-related issues within WP5.

## 2 Methodology

To provide quantitative environmental data for the sites on a product level, a Life Cycle Assessment (LCA) methodology has been used that follows the Environmental Product Declaration (EPD) framework. More information on these methodologies can be found in section 2.2. Site specific historical data is needed to provide high quality results for the EPD; the methodology for collecting this data and applying the LCA methodology is outlined in section 2.1. LCA is a limited methodology that does not fully address all environmental concerns associated with an activity. To provide more context of the quantitative data and give a more comprehensive understanding of environmental impact at the sites, a classification framework developed in the project has been applied and is further outlined in section 2.3.

### 2.1 Collection of historical data

For collecting the relevant historical site data, an iterative process consisting of six main steps outlined in Figure 1 has been followed. The six steps consist of:

1. **Collection of yearly data on consumables and production.** High quality data can be collected from invoices, internal monitoring records, sensors, and sales data, among other sources. Examples of lower quality data include estimations based on site conditions or data collected from other sites with similar conditions.
2. **Evaluation of site activities from a life cycle perspective.** Information is collected on the different activities related to the product, from its extraction until where the product leaves the factory gate. Activities after the product has left the control of the pilot site, e.g., transport to customers has not been considered in the historical data documentation but will be assessed in later stages of the project.

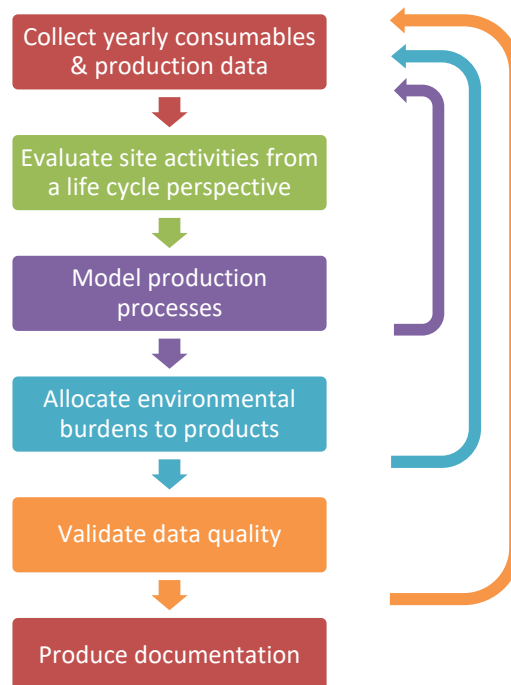


Figure 1: Methodology applied for historical data collection at individual pilot sites.

3. **Modelling of production processes.** The information collected is then used to model the production process in the web-based tool Plantsmith, developed by Roctim (more information can be found at roctimsim.com). For machinery or unit processes that were not included in the tool at the beginning of the project and deemed relevant for the results, new models have been developed to ensure an accurate representation of all the pilot sites included in the project.
4. **Allocation of environmental burdens to products.** Combining the data gathered in steps 1 and 2 with the model produced in step 3, the environmental burdens are allocated to the different products produced at each pilot site.
5. **Validation of data quality.** All the data used for generating the models and allocating the environmental burdens is checked by the source of the data (pilot sites) and assessed to see if any data gaps remain.
6. **Generate documentation.** Background LCA and EPD reports are autogenerated in Plantsmith and shared with the pilot sites to for interpretation of the quantitative results to complete the final stage of the LCA methodology according to ISO 14040.

A new iteration of the process is triggered if the data gap analysis at the end of each step identifies missing information that prevents the process from progressing to the next step.

The historical data has been collected for the reference year of 2019, which was used to avoid capturing any anomalies associated with COVID-19 in the production process.

## 2.2 LCA and EPD methodology

To conduct the background LCA studies at each pilot site and gain quantitative data on the environmental impact, the general LCA methodology outlined in ISO 14040 and 14044 have been followed. ISO 14040 provides the principles and framework of life cycle assessment and ISO 14044 an outline of the requirements and guidelines. Both standards should be referred to for further details.

The generic process for producing an EPD is given in Figure 2 consisting of seven steps. It is important to note that the documentation generated is not verified, and therefore, has not included the last two steps shown in Figure 2 and no published EPD is yet available for the pilot sites in the project.

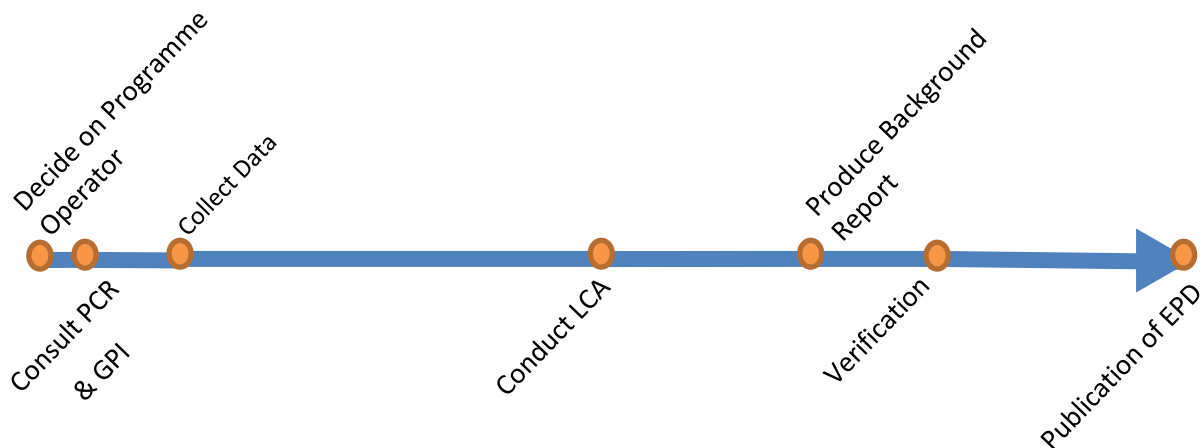


Figure 2: Overview for the generic process for producing an EPD.

The chosen Programme Operator for the project is EPD International. This has been chosen based on the previous development work conducted in the Sweden-based Vinnova project EPD Berg (reference number: 2019-00857) for the environmental simulation platform in Plantsmith. Within the EPD international system, the PCR for construction products, PCR 2019:14 version 1.2.5, has been followed, which has been built on top of the standard EN15804:2012+A2:2019 (also applied in this project).

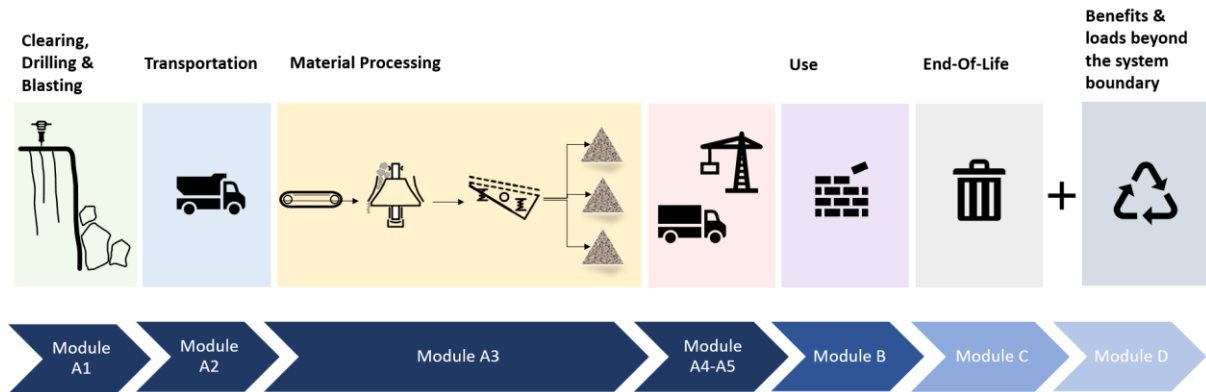


Figure 3: Flow diagram of life cycle activities for aggregates produced in a crushed rock facility and associated EN15804:2012+A2:2019 nomenclature.

The EN15804:2012+A2:2019 standard defines the system as multiple modules, depicted in Figure 3. The modules cover ranging aspects of site preparation, drilling and blasting (A1) through the transportation (A2), processing (A3), external transport (A4), construction (A5), use phase (B), end-of-life (C) and finally to the benefits and loads beyond system boundaries (D).

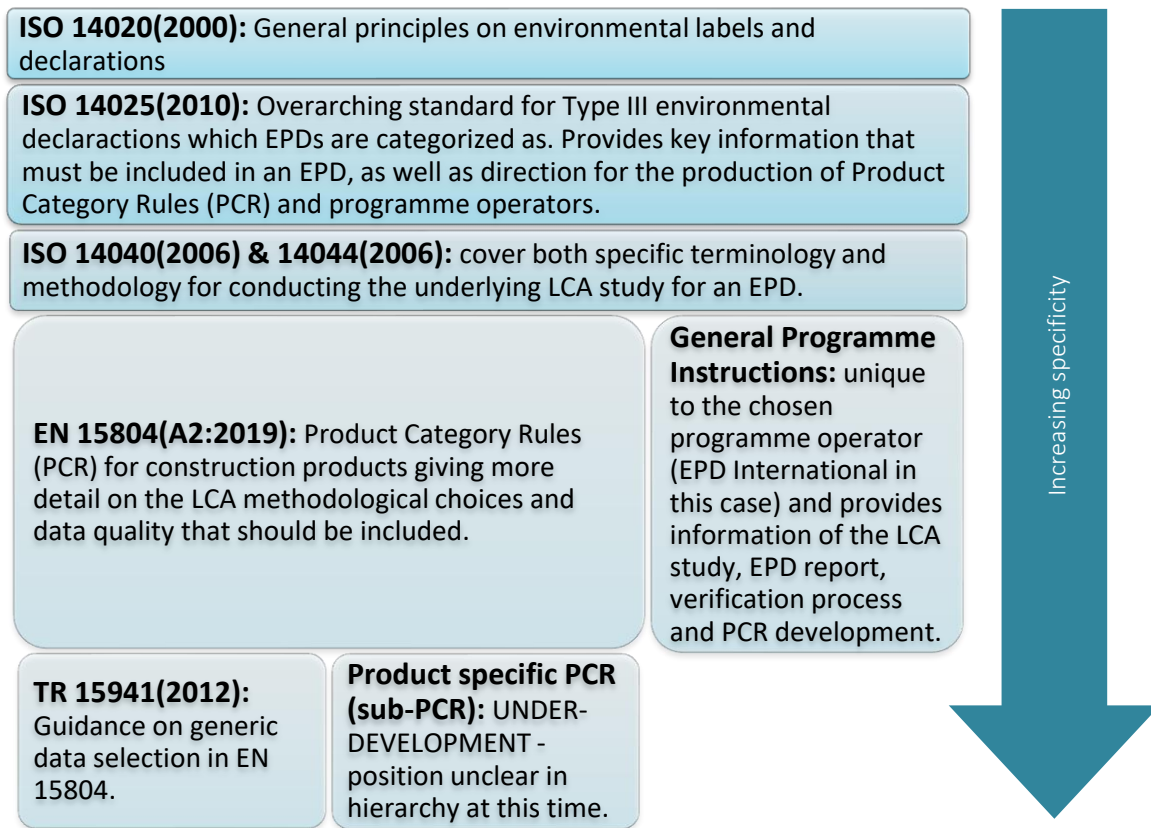


Figure 4: Overview of the hierarchy of standards applicable for the aggregate industry in conducting an EPD.

Further standards give guidance on the EPD framework and documents, including ISO 14020:2000 on general principles for environmental declarations and ISO 14025:2010 which refers to type III environmental declarations, from which EPDs are categorized. Both standards have been referred to in the development of the EPD module in Plantsmith with the chosen programme operator, EPD International, to adhere to the standards. Guidance on generic data selection has also been provided in TR 15941. An overview of applicable standards can be seen in Figure 4. Currently, no sub-PCR is available for aggregate products, however, a sub-PCR for bound aggregate applications is under development by the European Aggregates Association – UEPG, where the release date is still unknown, and therefore, has not been applied. Each standard should be referred to for further details. For more information on standards and regulations that apply to quarries in general concerning environmental aspects, please refer to Deliverable D1.4 in the DEQ project.

## 2.2.1 Assumptions

Due to availability of data and limitations of modelling the plants, some assumptions are made when conducting the LCA studies. Information of the assumptions are listed in general and for each individual site in the following sub-sections.

### 2.2.1.1 General Assumptions

- The data collected for the background data originates from the Sphera Life Cycle Assessment (GaBi) 2021 database, where the region for electricity is the country-specific grid mix from 2018 and EU-28 for all other processes.

- A custom model including the production and consumption of 1 litre of diesel calculates the production and consumption of foreground diesel. Diesel consumption excludes transport between the refinery and the site of use. More information can be found in Appendix B.
- A custom model has been created for the foreground use of explosives that includes manufacturing, transport to site of 300 kilometres, consumption, and use of a custom detonator wire based on the specification of an Orica detonator wire. 10g of detonator wire is estimated to be needed for every kilogram of explosive used. More information can be found in Appendix B.
- Background transport is assumed to happen with EURO 4 trucks.
- All waste treatment processes include 150 kilometres of transport as a standard distance between the extraction and waste handling sites, except for inert waste rock which is assumed to be handled on site unless otherwise stated.
- Waste has been divided into mixed waste for all non-hazardous, and hazardous waste for auxillary materials. The disposal method is assumed to be incineration. Inert waste rock materials are assumed to be disposed of as construction waste unless used in the restoration of the site itself.
- AdBlue is assumed to contain 32.5% urea and is modelled accordingly.
- Flocculants are assumed to be anionic dispersant and ethoxylate non-ionic mixtures and are modelled accordingly.
- Unit conversions are made using standardized values based on the density of the material in question. The conversion values used were as follows:
  - Diesel: 0.820 kg/l
  - Water: 0.997 kg/l
  - Oil: 0.825 kg/l
  - AdBlue: 1.088 kg/l
- No losses are experienced throughout the manufacturing process.
- Production conditions fluctuate throughout the year dependant on demand and site-specific conditions. Therefore, the steady-state conditions given in the Plantsmith model are assumed to be representative of the average scenario for the year.
- The machinery selected within the model are technically representative of machinery found on site.
- Manufacturing of equipment and infrastructure were not included as it is assumed that they cause a nominal contribution to the impact.
- Transportation of staff members to and from site were not included in compliance with PCR 2019:14.
- Any chemicals used for maintenance within the production process not classed as AdBlue (or equivalent) or flocculants have been summated and modelled as a bulk unit. Similarly, metals are bulked and modelled as steel.
- Foreground data inputs into the production process that do not constitute a part of the final product are modelled based on generic datasets.
- Power draw from machines that are not monitored or modelled are estimated based on site knowledge.
- Not all equipment is reflected in the model - any machine deemed to have an equal contribution to energy consumption for all products have been removed for simplicity.

#### 2.2.1.2 Site Specific Assumptions: CIMPOR

- Products that are merged for storage are assumed to have an even split of the total mass when taken out at different stages of the process.
- Granulometry is estimated based on generic blast information.
- Missing datasets for water consumption have been taken from 2020 instead and are assumed to be representative.

#### 2.2.1.3 Site Specific Assumptions: CSI

- Individual product fractions are not available and, therefore, have been modelled as bulk products representing pre-crushing, primary, and secondary products as one group, and tertiary products as another.
- Granulometry is estimated based on generic blast information.
- All waste material is assumed to be used in restoration.
- The plant is modelled as a fixed electricity driven plant and the diesel consumption of the site is assumed to be 90% for transport and 10% for material extraction.

#### 2.2.1.4 Site Specific Assumptions: HANSON

- Production data was only available at a group level and, therefore, simulation data is assumed to be representative of individual product fractions within the product groups.
- Granulometry is estimated based on generic blast information.

#### 2.2.1.5 Site Specific Assumptions: HOLCIM

- 80% of particles under 1mm from granulometry tests are assumed to fall out during the extraction process and fail to enter the system, remaining in the lake.
- Water content remains constant throughout the system at 5%.
- Waste rock material is assumed to be the difference in production and sales.
- Water recycled through the system has been excluded.

#### 2.2.1.6 Site Specific Assumptions: VICAT

- Production data was only available at a group level, and therefore, simulation data is assumed to be representative of individual product fractions within the product groups.
- Electricity is shared between the production plant and the neighbouring cement plant and estimated at 70% of total share.
- Granulometry has been estimated based on simulated production.
- Diesel consumption during extraction is conducted by the supplier of the material where no data is available at this moment. The consumption has, therefore, been estimated based on a Volvo L180H wheel loader carrying 11.66 tonnes in one load taking 7 minutes to excavate and move where:

$$F = \frac{F_e T_s}{vd}$$

Where  $F$  represents diesel consumption in litres/tonne,  $F_e$  represents the fuel efficiency in litres/hour,  $T_s$  represents the extraction time in hours,  $v$  represents the volume of the bucket in  $m^3$ , and  $d$  represents the bulk density of the material in tonnes/ $m^3$ .

- Diesel consumption in transport to and from the site is conducted by contractors where precise data is currently unavailable. Therefore, consumption has been estimated for source material and waste material using SBMI emission factors and the perfect combustion of diesel of 0.037kg/ton-km, based on transport distance of 25km to site for incoming material and 50km from site for waste material.

## 2.3 Classification of Pilot Sites

Given the high variety of quarrying operations, addressing their environmental impacts from a general perspective can be challenging, as well as their comparability. In order to facilitate these tasks, a classification framework was developed. The main goal of this qualitative tool is to provide guidance in identifying the main environmental aspects of a quarry considering certain specific features that influence these effects, such as the excavation method employed at the site, the scale of operation, and other conditions. The proposed framework referred in this chapter was included in a paper accepted for publication and presentation at the World Mining Congress – WMC 2023, which will take place in Brisbane, Australia, in June of the present year (Sánchez et al., 2023).

Table 2 presents a summary of the influence of certain site-specific conditions on the order of magnitude of the different environmental aspects, according to the proposed framework. In general terms, the table relates each environmental aspect considered in the analysis (rows), with conditions that can affect their criticality (columns). The symbology in the table, as stated in Sánchez et al. (2023), represents the following:

- + : the site conditions may increase the order of magnitude of this environmental aspect; therefore, special focus must be put on the corresponding prevention/mitigation measures.
- ++ : it is expected that this environmental aspect is manifested and/or perceived noticeably, therefore, the corresponding prevention/mitigation measures should be among the highest priorities.
- Empty cells indicate no additional influence on the corresponding environmental aspect.

In the following section the priority aspects are listed for each site as the outcome of applying this classification framework, contributing to a more in-depth interpretation of the LCS results.

Table 2. Summary of the influence of certain site-specific.

Environmental impact	Extraction method				Scale of operation <sup>1</sup>		Communities <sup>2</sup>				
	Drill and blast	Mechanical excavation	Dredge	Secondary material	Medium (>200 kt)	Large (>1 Mt)	Nearby	Contiguous (<500 m)	Low humidity	Water scarcity	Rich biodiversity
Visual impact	+	+			+	++	+	++			
Contamination of waterbodies			++	++	+	+	+	+		++	+
Changes to waterbodies			++		+	++	+	+		++	+
Water consumption				+	+	+				++	
Land use, transformation & habitat destruction					+	+		+			++
Emissions of hazardous minerals and metals	+				+	++	+	++			
Land stability							+	++			+
Vibrations	++					+	+	++			
Air emissions	+				+	++	+	++			
Dust emissions	+	+			+	++	+	++	+		
Noise pollution	++	+			+	+		+			
Release of pollutants and toxins				++			+	++			+

<sup>1</sup> A small-scale operation would be the reference point for medium and large-scale quarries, regarding the environmental impacts that can be influenced by the size feature. For this reason, no “small-scale” column is included in this table.

<sup>2</sup> Similarly, non-existing communities in the proximities of the operation would be the reference point for the “nearby” and “contiguous” categories considered in the evaluation.

### 3 System integration in IQS

Based on these methodologies and tools, challenges were identified for sites in the data collection phase to provide quantitative environmental data for the sites. These challenges have contributed to the design of a system integration solution that has been implemented within the DEQ IQS, as illustrated in Figure 5.

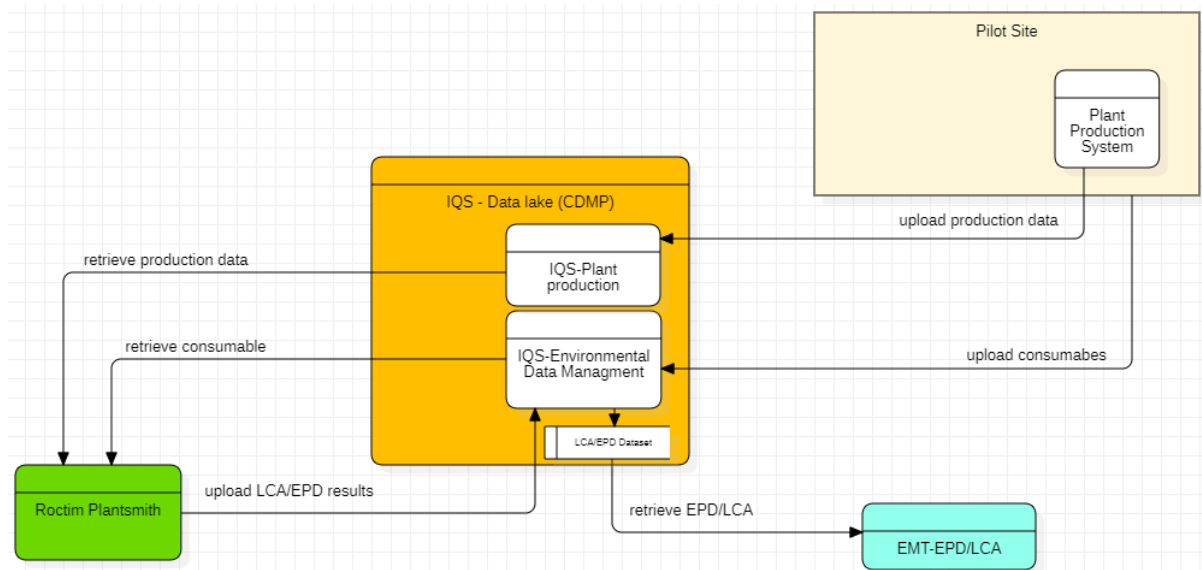


Figure 5: Diagram of the environmental data flow within the IQS

In the developed solution, the sites provide plant production (mass produced in tons) and consumables data (fuel, water, and energy consumption) each month. These data are collected either manually or automatically, when possible, according to the configuration of the information system of the sites. For example, the plant production data (mass produced in tons) can be automatically collected from the SCADA of the site thanks to a dedicated interface with the IQS (data storage interface of environmental data, REST API for the upload of production data...) while the consumables data (fuel, water, energy etc.) can be manually/semi-automatically collected using a dedicated excel template and a REST API for the upload of consumables and allocation matrix data.

Then, these data are stored in the data lake of the site in specific databases dedicated to plant production and to environmental data. These data are made available to relevant data consumers, such as Roctim, for sharing.

Roctim can automatically retrieve these relevant needed data (plant production, consumables and allocation matrix data) thanks to a dedicated interface between the IQS and Plantsmith (data retrieval interface of all environmental data, REST API for the download of production and consumables data)

Once these data are processed within Plantsmith, Roctim can automatically upload the corresponding EPD results and LCA reports, using the dedicated interface with the IQS (REST API for the upload of LCA/EPD results). These data are stored in the data lake of the site in specific databases dedicated to the EPD results then they are made available to relevant data consumers, such as the Environmental Management Tool, for sharing.

Finally, all these environmental data can be automatically retrieved by the Environmental Management Tool (thanks to the REST API to download EPD results) to produce Environmental KPIs and dashboards. The Environmental Management Tool is a data warehouse environment composed of a Talend process, a PostgreSQL

database, a data model and a dashboard (see Figure 6 for reference) designed using Power BI tools accessible through Azure Power Services.

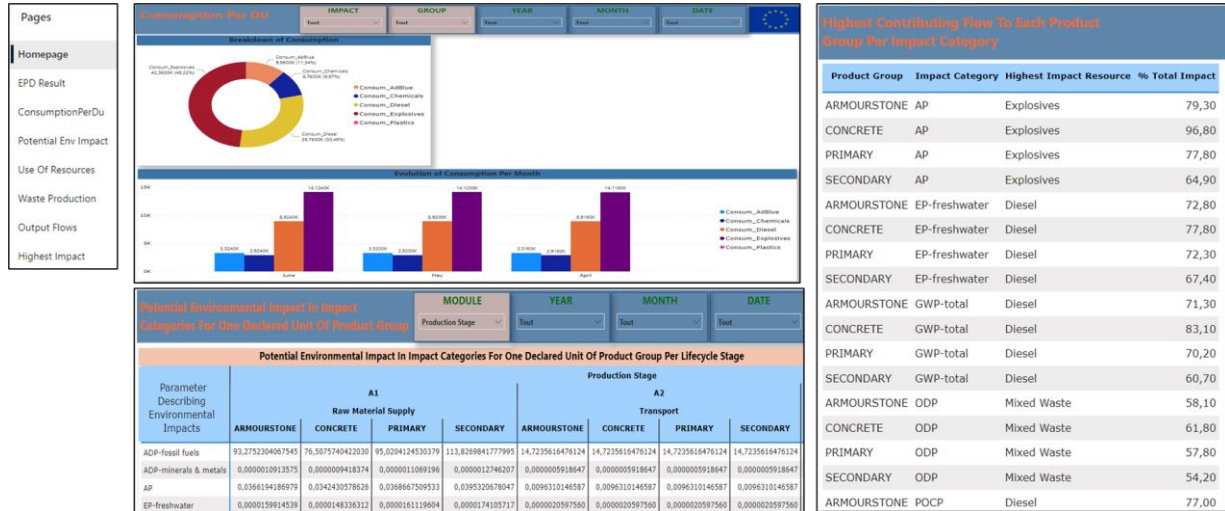


Figure 6: Example of Environmental Dashboards using Power BI

## 4 Summary of Results

### 4.1 Site Classifications

In the following section, the results of the classification framework are given for each pilot site. From this, the high, medium and low priority environmental aspects are identified to help producers understand what should also be considered, additionally to the LCA results.

#### 4.1.1 Alenquer quarry operated by CIMPOR.

*Table 3: Results from applying a classification framework to Alenquer quarry operated by Cimpor.*

<b>Excavation method:</b>	<b>Drill &amp; Blast</b>
<b>Scale of Operation:</b>	<b>Large</b>
<b>Communities:</b>	<b>Contiguous (&lt;500m)</b>
<b>Site specific conditions:</b>	<b>Water scarcity</b>
<b>High priority environmental aspects:</b>	<ul style="list-style-type: none"> <li>Vibrations</li> <li>Noise pollution</li> <li>Emissions of hazardous minerals and metals</li> <li>Dust emissions</li> <li>Land stability</li> <li>Air emissions</li> <li>Release of pollutants and toxins</li> <li>Visual Impact</li> <li>Changes to waterbodies</li> <li>Contamination of waterbodies</li> <li>Water consumption</li> </ul>
<b>Medium priority environmental aspects:</b>	Land use, transformation & habitat destruction
<b>Low priority environmental aspects:</b>	None

#### 4.1.2 Mammendorf quarry operated by CSI.

*Table 4: Results from applying a classification framework to Mammendorf quarry operated by CSI.*

<b>Excavation method:</b>	<b>Drill &amp; Blast</b>
<b>Scale of Operation:</b>	<b>Large</b>
<b>Communities:</b>	<b>Contiguous (&lt;500m)</b>
<b>Site specific conditions:</b>	<b>None</b>
<b>High priority environmental aspects:</b>	Vibrations Noise pollution Emissions of hazardous minerals and metals Dust emissions Land stability Air emissions Release of pollutants and toxins Visual Impact
<b>Medium priority environmental aspects:</b>	Land use, transformation & habitat destruction Changes to waterbodies Contamination of waterbodies Water consumption
<b>Low priority environmental aspects:</b>	None

### 4.1.3 Valdilecha quarry operated by HANSON.

*Table 5: Results from applying a classification framework to Valdilecha quarry operated by Hanson.*

<b>Excavation method:</b>	<b>Drill &amp; Blast</b>
<b>Scale of Operation:</b>	<b>Large</b>
<b>Communities:</b>	<b>Nearby</b>
<b>Site specific conditions:</b>	<b>Low humidity, Water scarcity</b>
<b>High priority environmental aspects:</b>	Vibrations Noise pollution Emissions of hazardous minerals and metals Dust emissions Air emissions Visual Impact Changes to waterbodies Contamination of waterbodies Water consumption
<b>Medium priority environmental aspects:</b>	Land use, transformation & habitat destruction Land stability Release of pollutants and toxins
<b>Low priority environmental aspects:</b>	None

#### 4.1.4 Pioltello San Bovio quarry operated by HOLCIM.

*Table 6: Results from applying a classification framework to Pioltello San Bovio quarry operated by Holcim.*

<b>Excavation method:</b>	<b>Dredge</b>
<b>Scale of Operation:</b>	<b>Medium</b>
<b>Communities:</b>	<b>Nearby</b>
<b>Site specific conditions:</b>	<b>Rich biodiversity</b>
<b>High priority environmental aspects:</b>	Changes to waterbodies Contamination of waterbodies Land use, transformation & habitat destruction
<b>Medium priority environmental aspects:</b>	Visual Impact Water consumption Emissions of hazardous minerals and metals Air emissions Dust emissions Noise pollution Release of pollutants and toxins
<b>Low priority environmental aspects:</b>	Vibrations Land stability

#### 4.1.5 Fenouillet processing plant operated by VICAT.

*Table 7: Results from applying a classification framework to Fenouillet quarry operated by Vicat.*

<b>Excavation method:</b>	<b>Secondary Materials</b>
<b>Scale of Operation:</b>	<b>Small</b>
<b>Communities:</b>	<b>Contiguous (&lt;500m)</b>
<b>Site specific conditions:</b>	<b>Water scarcity</b>
<b>High priority environmental aspects:</b>	Visual Impact Changes to waterbodies Water consumption Contamination of waterbodies Emissions of hazardous minerals and metals Vibrations Air emissions Dust emissions Release of pollutants and toxins Land stability
<b>Medium priority environmental aspects:</b>	Land use, transformation & habitat destruction Noise pollution
<b>Low priority environmental aspects:</b>	None

## 4.2 Quantitative LCA results for presentation in an EPD.

The results of the LCA give quantitative estimates for environmental impact in 38 different impact categories, based on the results of the Life Cycle Inventory (LCI) and Life Cycle Impact Assessment (LCIA). The LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks. The characterization model in line with EN 15804:2019 has been used. The results for the 32 compulsory impact categories for the programme operator, EPD International, are given for each pilot site for modules A1-A3 in section 4.2.1, module C in section 4.2.2, and module D in section 4.2.3. The results are displayed for the average of all products produced in 2019 for the declared unit of one tonne of aggregate product.

### 4.2.1 Results for Production (A1-A3)

Table 8: Results for all pilot sites for 32 compulsory impact categories according to EPD International for modules A1-A3.

Total for A1-A3 (Production including Extraction (A1), Transport (A2) and Manufacturing (A3))						
Indicator	Unit	CIMPOR	CSI	HANSON	HOLCIM	VICAT
<i>Potential environmental impact for mandatory indicators according to EN 15804</i>						
GWP-fossil	kg CO <sub>2</sub> eq.	1.46	3.91	2.01	2.64	1.067e+1
GWP-biogenic	kg CO <sub>2</sub> eq.	8.026e-3	2.862e-2	1.528e-3	4.742e-2	1.102e-1
GWP-luluc	kg CO <sub>2</sub> eq.	7.681e-3	1.843e-2	1.296e-2	5.625e-3	6.223e-2
GWP-total	kg CO <sub>2</sub> eq.	1.47	3.96	2.03	2.7	1.085e+1
ODP	kg CFC 11 eq.	1.592e-11	4.383e-11	1.35e-11	4.888e-9	6.012e-9
AP	mol H <sup>+</sup> eq.	8.349e-3	1.741e-2	1.188e-2	7.516e-3	5.479e-2
EP-freshwater	kg PO <sub>4</sub> <sup>3-</sup> eq.	1.093e-5	5.546e-5	1.552e-5	8.119e-5	2.699e-4
EP-freshwater	kg P eq.	3.642e-6	1.849e-5	5.173e-6	2.706e-5	8.997e-5
EP-marine	kg N eq.	3.727e-3	7.761e-3	5.335e-3	2.997e-3	2.452e-2
EP-terrestrial	mol N eq.	4.327e-2	8.853e-2	6.174e-2	3.288e-2	2.685e-1
POCP	kg NMVOC eq.	8.292e-3	1.572e-2	1.075e-2	7.306e-3	5.219e-2
ADP-minerals & metals*	kg Sb eq.	4.327e-7	6.87e-7	3.43e-7	6.256e-6	8.5e-6
ADP-fossil*	MJ	2.035e+1	5.183e+1	2.874e+1	3.825e+1	1.542e+2
WDP	m <sup>3</sup>	6.356e-1	2.151e+1	3.325e-1	8.63	1.788e+2

*Potential environmental impact – additional mandatory and voluntary indicators*

GWP-GHG	kg CO <sub>2</sub> eq.	1.43	3.85	1.97	2.62	1.053e+1
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*Use of resources*

PERE	MJ	4.64	1.558e+1	3.82	2.328e+1	1.188e+1
PERM	MJ	0	0	0	0	0
PERT	MJ	4.64	1.558e+1	3.82	2.328e+1	1.188e+1
PENRE	MJ	2.037e+1	5.187e+1	2.878e+1	3.827e+1	1.544e+2
PENRM	MJ	2.05e-8	4.218e-12	4.185e-13	1.865e-5	2.31e-5
PENRT	MJ	2.037e+1	5.187e+1	2.878e+1	3.827e+1	1.544e+2
SM	kg	0	0	0	0	0
RSF	MJ	0	0	0	0	0
NRSF	MJ	0	0	0	0	0
FW	m <sup>3</sup>	1.447e-2	5.069e-1	6.287e-3	2.037e-1	4.18

*Waste production*

Hazardous waste disposed	kg	7.777e-8	3.257e-8	3.024e-9	1.31e-7	2.165e-6
Non-hazardous waste disposed	kg	5.516e+1	5.001e+2	6.173e+1	6.97e+1	2.215e+2
Radioactive waste disposed	kg	1.68e-4	1.449e-3	6.673e-4	1.261e-3	6.563e-3

*Output flows*

Components for re-use	kg	0	0	0	0	0
Material for recycling	kg	0	0	0	0	0
Materials for energy recovery	kg	0	0	0	0	0
Exported energy, electricity	MJ	0	0	0	0	0

Exported energy, thermal	MJ	0	0	0	0	0
Acronyms	<p>GWP = Global Warming Potential; ODP = Depletion potential of the stratospheric ozone layer; AP = Acidification potential; EP = Eutrophication Potential; POCP = Formation potential of tropospheric ozone; ADP = Abiotic Depletion Potential; WDP = Water Deprivation Potential, PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials; PERM = Use of renewable primary energy resources used as raw materials; PERT = Total use of renewable primary energy resources; PENRE = Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials; PENRM = Use of non-renewable primary energy resources used as raw materials; PENRT = Total use of non-renewable primary energy resources; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Use of non-renewable secondary fuels; FW = Use of net fresh water</p>					
1	<p>The indicator includes all greenhouse gases included in GWP-total but excludes biogenic carbon dioxide uptake and emissions and biogenic carbon stored in the product. This indicator is thus almost equal to the GWP indicator originally defined in EN 15804:2012+A1:2013.</p>					
.	<p>Disclaimer: The results of this environmental impact indicator shall be used with care as the uncertainties of these results are high or as there is limited experience with the indicator.</p>					

## 4.2.2 Results for End-of-Life (C1-C4)

Table 9: Results for all pilot sites for 32 compulsory impact categories according to EPD International for modules C1-C4.

Total for C1-C4 (End-of-life)						
Indicator	Unit	CIMPOR	CSI	HANSON	HOLCIM	VICAT
<i>Potential environmental impact for mandatory indicators according to EN 15804</i>						
GWP-fossil	kg CO <sub>2</sub> eq.	1.34	1.34	1.34	1.34	1.34
GWP-biogenic	kg CO <sub>2</sub> eq.	-1.62e-3	-1.62e-3	-1.62e-3	-1.62e-3	-1.62e-3
GWP-luluc	kg CO <sub>2</sub> eq.	1.11e-2	1.11e-2	1.11e-2	1.11e-2	1.11e-2
GWP-total	kg CO <sub>2</sub> eq.	1.35	1.35	1.35	1.35	1.35
ODP	kg CFC 11 eq.	2.68e-16	2.68e-16	2.68e-16	2.68e-16	2.68e-16
AP	mol H <sup>+</sup> eq.	8.05e-3	8.05e-3	8.05e-3	8.05e-3	8.05e-3
EP-freshwater	kg PO <sub>4</sub> <sup>3-</sup> eq.	1.209e-5	1.209e-5	1.209e-5	1.209e-5	1.209e-5
EP-freshwater	kg P eq.	4.03e-6	4.03e-6	4.03e-6	4.03e-6	4.03e-6
EP-marine	kg N eq.	3.93e-3	3.93e-3	3.93e-3	3.93e-3	3.93e-3
EP-terrestrial	mol N eq.	4.35e-2	4.35e-2	4.35e-2	4.35e-2	4.35e-2

<i>POCP</i>	kg NMVOC eq.	7.59e-3	7.59e-3	7.59e-3	7.59e-3	7.59e-3
<i>ADP-minerals &amp; metals*</i>	kg Sb eq.	1.2e-7	1.2e-7	1.2e-7	1.2e-7	1.2e-7
<i>ADP-fossil*</i>	MJ	1.81e+1	1.81e+1	1.81e+1	1.81e+1	1.81e+1
<i>WDP</i>	m3	1.26e-2	1.26e-2	1.26e-2	1.26e-2	1.26e-2
<b>Potential environmental impact – additional mandatory and voluntary indicators</b>						
<i>GWP-GHG</i>	kg CO2 eq.	1.32	1.32	1.32	1.32	1.32
<b>Use of resources</b>						
<i>PERE</i>	MJ	1.04	1.04	1.04	1.04	1.04
<i>PERM</i>	MJ	0	0	0	0	0
<i>PERT</i>	MJ	1.04	1.04	1.04	1.04	1.04
<i>PENRE</i>	MJ	1.81e+1	1.81e+1	1.81e+1	1.81e+1	1.81e+1
<i>PENRM</i>	MJ.	0	0	0	0	0
<i>PENRT</i>	MJ	1.81e+1	1.81e+1	1.81e+1	1.81e+1	1.81e+1
<i>SM</i>	kg	0	0	0	0	0
<i>RSF</i>	MJ	0	0	0	0	0
<i>NRSF</i>	MJ	0	0	0	0	0
<i>FW</i>	m <sup>3</sup>	1.19e-3	1.19e-3	1.19e-3	1.19e-3	1.19e-3
<b>Waste production</b>						
<i>Hazardous waste disposed</i>	kg	9.55e-10	9.55e-10	9.55e-10	9.55e-10	9.55e-10
<i>Non-hazardous waste disposed</i>	kg	2.84e-3	2.84e-3	2.84e-3	2.84e-3	2.84e-3
<i>Radioactive waste disposed</i>	kg	3.29e-5	3.29e-5	3.29e-5	3.29e-5	3.29e-5
<b>Output flows</b>						
<i>Components for re-use</i>	kg	0	0	0	0	0

Material for recycling	kg	0	0	0	0	0
Materials for energy recovery	kg	0	0	0	0	0
Exported energy, electricity	MJ	0	0	0	0	0
Exported energy, thermal	MJ	0	0	0	0	0
Acronyms	<p>GWP = Global Warming Potential; ODP = Depletion potential of the stratospheric ozone layer; AP = Acidification potential; EP = Eutrophication Potential; POCP = Formation potential of tropospheric ozone; ADP = Abiotic Depletion Potential; WDP = Water Deprivation Potential, PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials; PERM = Use of renewable primary energy resources used as raw materials; PERT = Total use of renewable primary energy resources; PENRE = Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials; PENRM = Use of non-renewable primary energy resources used as raw materials; PENRT = Total use of non-renewable primary energy re-sources; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Use of non-renewable secondary fuels; FW = Use of net fresh water</p>					
1	<p>The indicator includes all greenhouse gases included in GWP-total but excludes biogenic carbon dioxide uptake and emissions and biogenic carbon stored in the product. This indicator is thus almost equal to the GWP indicator originally defined in EN 15804:2012+A1:2013.</p>					
*	<p>Disclaimer: The results of this environmental impact indicator shall be used with care as the uncertainties of these results are high or as there is limited experience with the indicator.</p>					

### 4.2.3 Results beyond the System Boundary (D)

Table 10: Results for all pilot sites for 32 compulsory impact categories according to EPD International for modules D.

#### Total for D (Benefits or loads beyond the system boundary)

Indicator	Unit	CIMPOR	CSI	HANSON	HOLCIM	VICAT
<i>Potential environmental impact for mandatory indicators according to EN 15804</i>						
GWP-fossil	kg CO <sub>2</sub> eq.	1.79e-1	-1.55	-4.085e-1	-5.497e-1	-8.33
GWP-biogenic	kg CO <sub>2</sub> eq.	-7.966e-3	-1.732e-2	-2.698e-3	-3.491e-2	-9.985e-2
GWP-luluc	kg CO <sub>2</sub> eq.	3.138e-3	-6.339e-3	-1.651e-3	5.151e-3	-4.6e-2
GWP-total	kg CO <sub>2</sub> eq.	1.746e-1	-1.57	-4.124e-1	-5.789e-1	-8.47
ODP	kg CFC 11 eq.	-1.293e-11	-2.242e-11	-1.044e-11	-4.387e-9	-5.408e-9
AP	mol H <sup>+</sup> eq.	2.117e-4	-7.353e-3	-2.94e-3	1.347e-3	-4.188e-2

<i>EP-freshwater</i>	kg PO <sub>4</sub> <sup>3-</sup> eq.	2.618e-6	-2.893e-5	-2.339e-6	-5.303e-5	-2.31e-4
<i>EP-freshwater</i>	kg P eq.	8.727e-7	-9.644e-6	-7.796e-7	-1.768e-5	-7.7e-5
<i>EP-marine</i>	kg N eq.	3.291e-4	-3.1e-3	-1.145e-3	1.094e-3	-1.847e-2
<i>EP-terrestrial</i>	mol N eq.	1.776e-3	-3.692e-2	-1.514e-2	1.23e-2	-2.02e-1
<i>POCP</i>	kg NMVOC eq.	-2.195e-4	-6.465e-3	-2.502e-3	9.299e-4	-4.e-2
<i>ADP-minerals &amp; metals*</i>	kg Sb eq.	-2.301e-7	-3.52e-7	-1.685e-7	-5.34e-6	-7.503e-6
<i>ADP-fossil*</i>	MJ	1.46	-2.099e+1	-5.97	-9.29	-1.146e+2
<i>WDP</i>	m <sup>3</sup>	-2.663e-1	-1.933e+1	-4.09e-2	-7.5	-1.609e+2
<b>Potential environmental impact – additional mandatory and voluntary indicators</b>						
<i>GWP-GHG</i>	kg CO <sub>2</sub> eq.	1.761e-1	-1.53	-3.967e-1	-5.515e-1	-8.22
<b>Use of resources</b>						
<i>PERE</i>	MJ	5.9e-2	-5.39	-2.973e-1	-1.244e+1	-7.86
<i>PERM</i>	MJ	0	0	0	0	0
<i>PERT</i>	MJ	5.9e-2	-5.39	-2.973e-1	-1.244e+1	-7.86
<i>PENRE</i>	MJ	1.44	-2.103e+1	-6	-9.31	-1.147e+2
<i>PENRM</i>	MJ.	-1.845e-8	-3.796e-12	-3.767e-13	-1.678e-5	-2.079e-5
<i>PENRT</i>	MJ	1.44	-2.103e+1	-6	-9.31	-1.147e+2
<i>SM</i>	kg	0	0	0	0	0
<i>RSF</i>	MJ	0	0	0	0	0
<i>NRSF</i>	MJ	0	0	0	0	0
<i>FW</i>	m <sup>3</sup>	-6.137e-3	-4.522e-1	-1.204e-3	-1.756e-1	-3.75
<b>Waste production</b>						
<i>Hazardous waste disposed</i>	kg	-6.878e-8	-2.741e-8	-1.383e-9	-1.15e-7	-1.947e-6
<i>Non-hazardous</i>	kg	-4.964e+1	-4.5e+2	-5.555e+1	-6.27e+1	-1.994e+2

waste disposed						
Radioactive waste disposed	kg	-5.583e-5	-5.355e-4	-4.146e-5	-7.09e-4	-3.091e-3
<b>Output flows</b>						
Components for re-use	kg	0	0	0	0	0
Material for recycling	kg	0	0	0	0	0
Materials for energy recovery	kg	0	0	0	0	0
Exported energy, electricity	MJ	0	0	0	0	0
Exported energy, thermal	MJ	0	0	0	0	0
Acronyms	GWP = Global Warming Potential; ODP = Depletion potential of the stratospheric ozone layer; AP = Acidification potential; EP = Eutrophication Potential; POCP = Formation potential of tropospheric ozone; ADP = Abiotic Depletion Potential; WDP = Water Deprivation Potential, PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials; PERM = Use of renewable primary energy resources used as raw materials; PERT = Total use of renewable primary energy resources; PENRE = Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials; PENRM = Use of non-renewable primary energy resources used as raw materials; PENRT = Total use of non-renewable primary energy resources; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Use of non-renewable secondary fuels; FW = Use of net fresh water					
<sup>1</sup>	The indicator includes all greenhouse gases included in GWP-total but excludes biogenic carbon dioxide uptake and emissions and biogenic carbon stored in the product. This indicator is thus almost equal to the GWP indicator originally defined in EN 15804:2012+A1:2013.					
*	Disclaimer: The results of this environmental impact indicator shall be used with care as the uncertainties of these results are high or as there is limited experience with the indicator.					

### 4.3 Comparison of results

For a more comprehensive overview of the results, the results for module A1-A3 are examined further. Six impact categories have been chosen that connect with some of the main KPIs of the project. These include: GWP – total, AP, EP – marine, POCP, WDP, and Non-hazardous waste disposal (NHWD). All results have been benchmarked against the Spanish Sector EPD for natural aggregates. This has been chosen due to its representation of over 300 quarries. Figure 7 shows the results for each pilot site for modules A1-A3 for the chosen impact categories.

The environmental impact of the six impact categories previously mentioned have also been examined for different sizes and categories of quarries along with their proximity to communities, as defined in the classification framework. The results can be seen in Figure 7, Figure 8 and Figure 9, respectively.

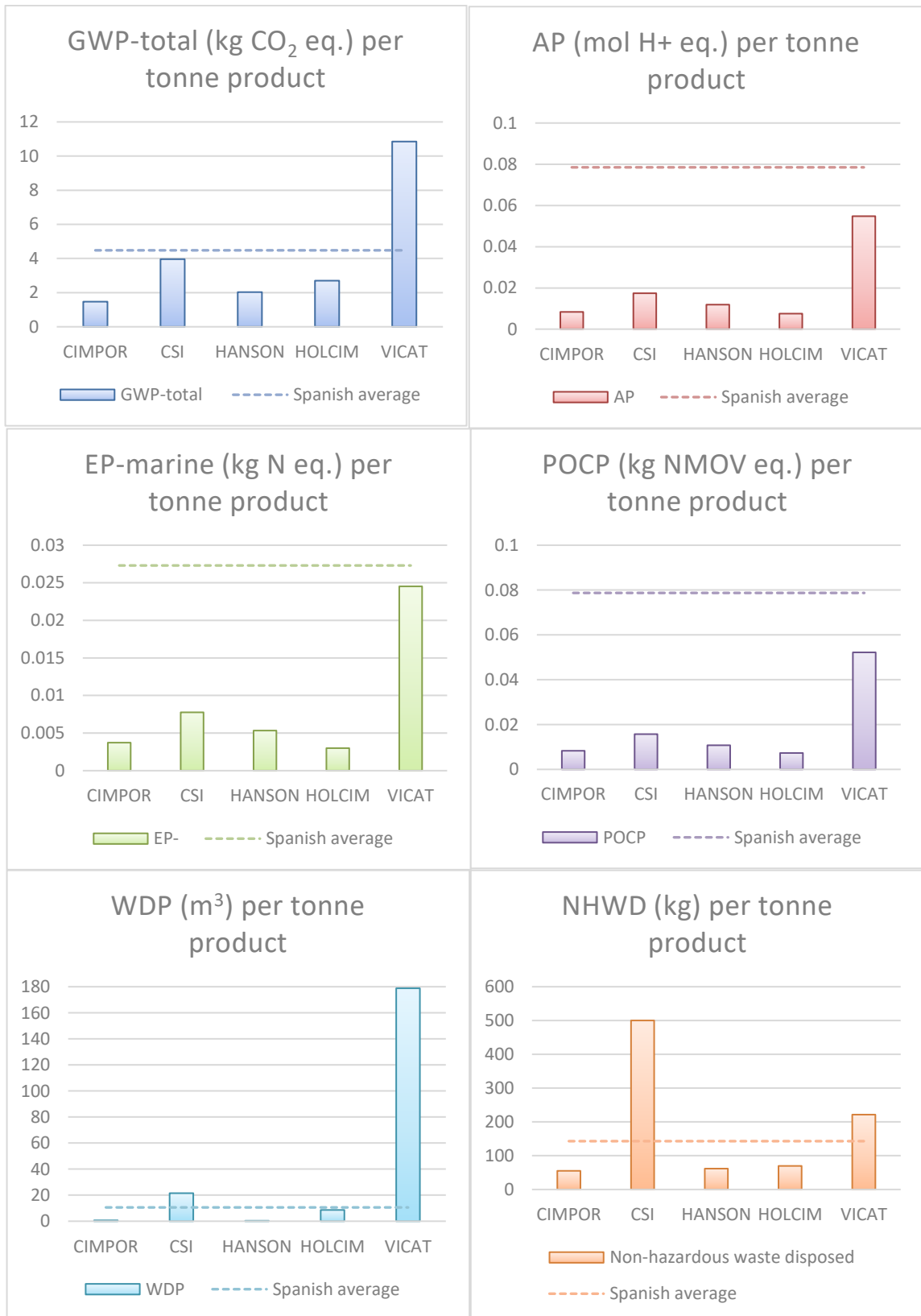


Figure 7: Results for all five pilot sites for module A1-A3 in six chosen impact categories.

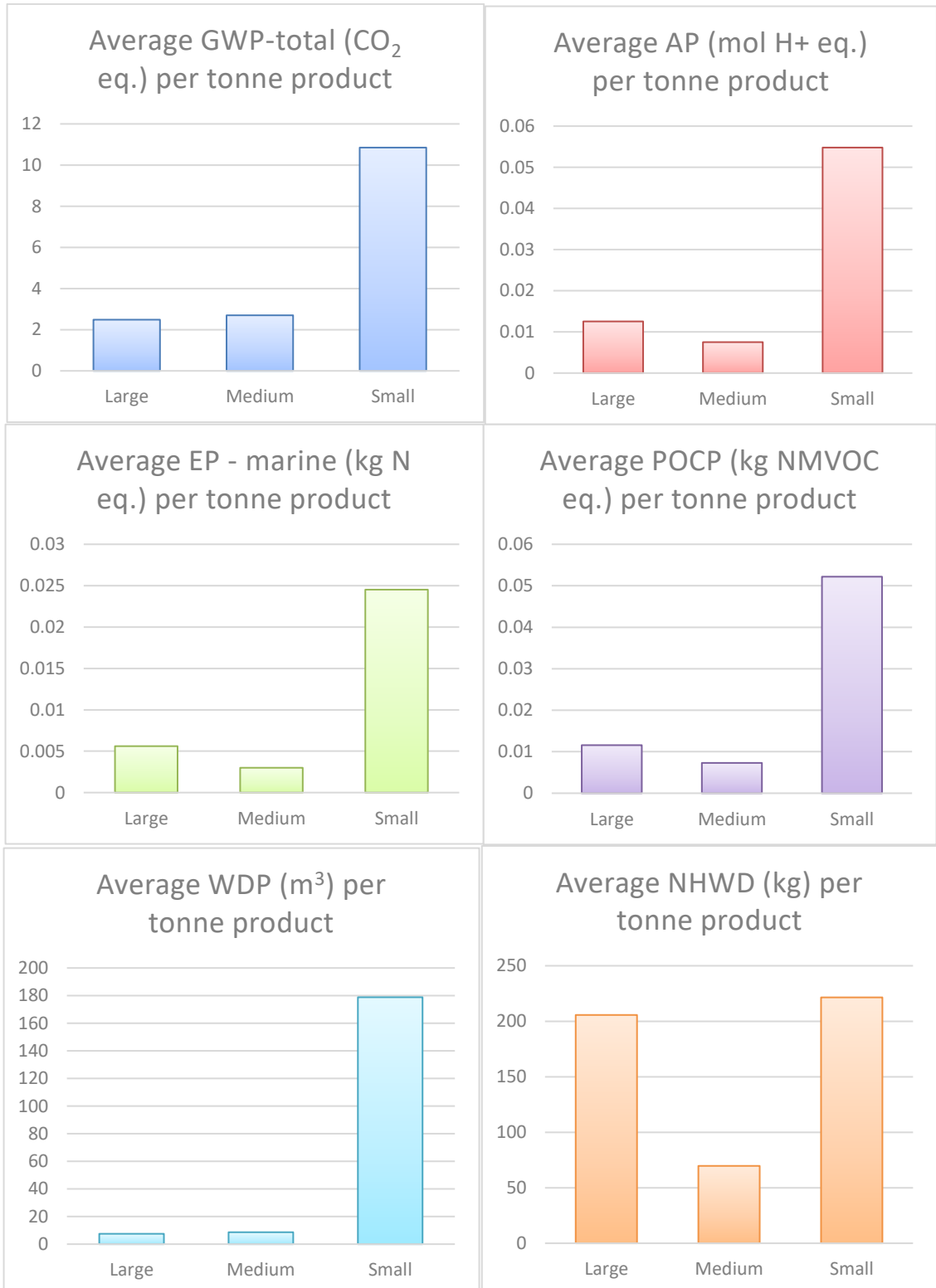


Figure 8: Comparison of results per tonne product in six impact categories based on quarry size.

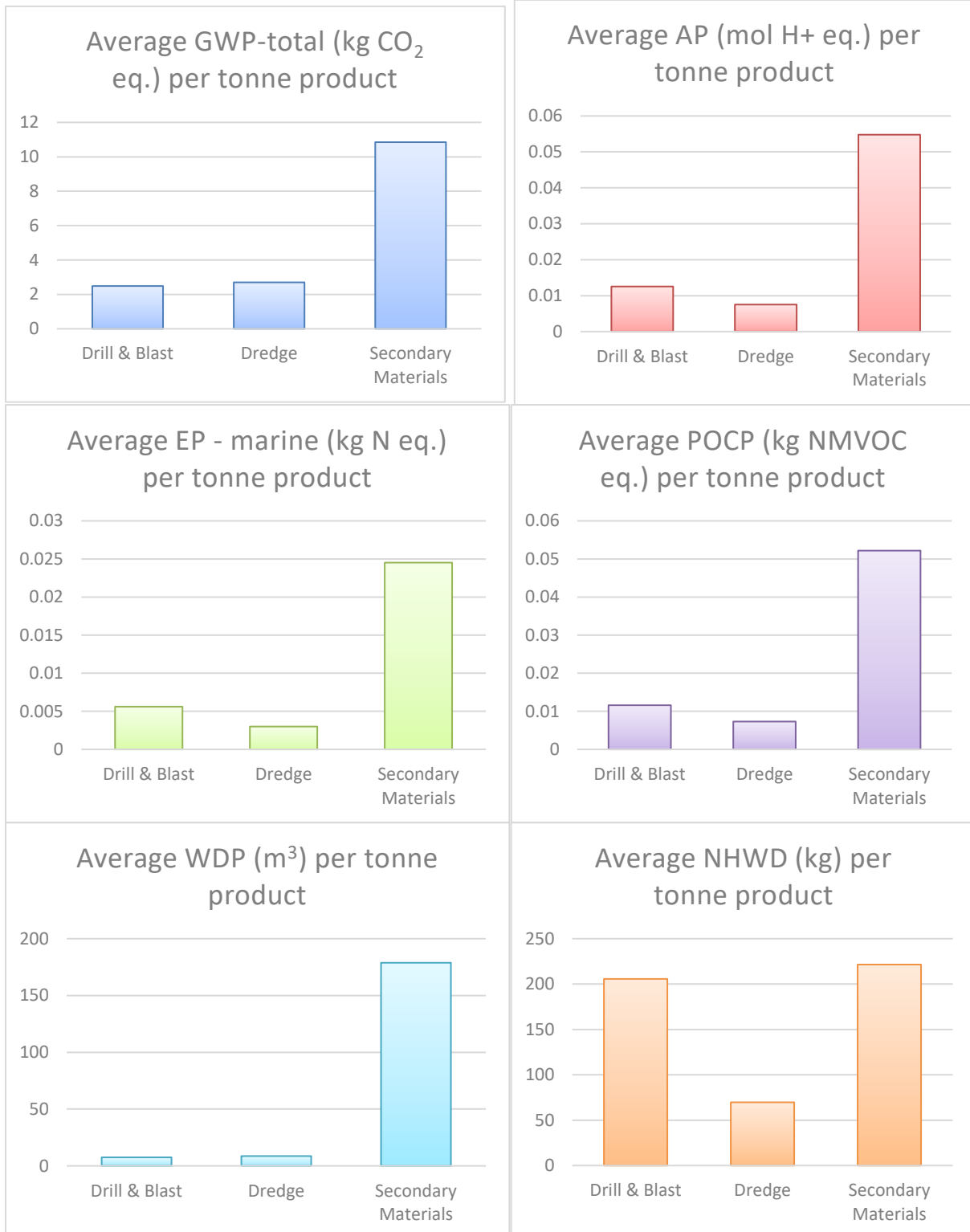


Figure 9: Comparison of results per tonne product in six impact categories based on quarry type.

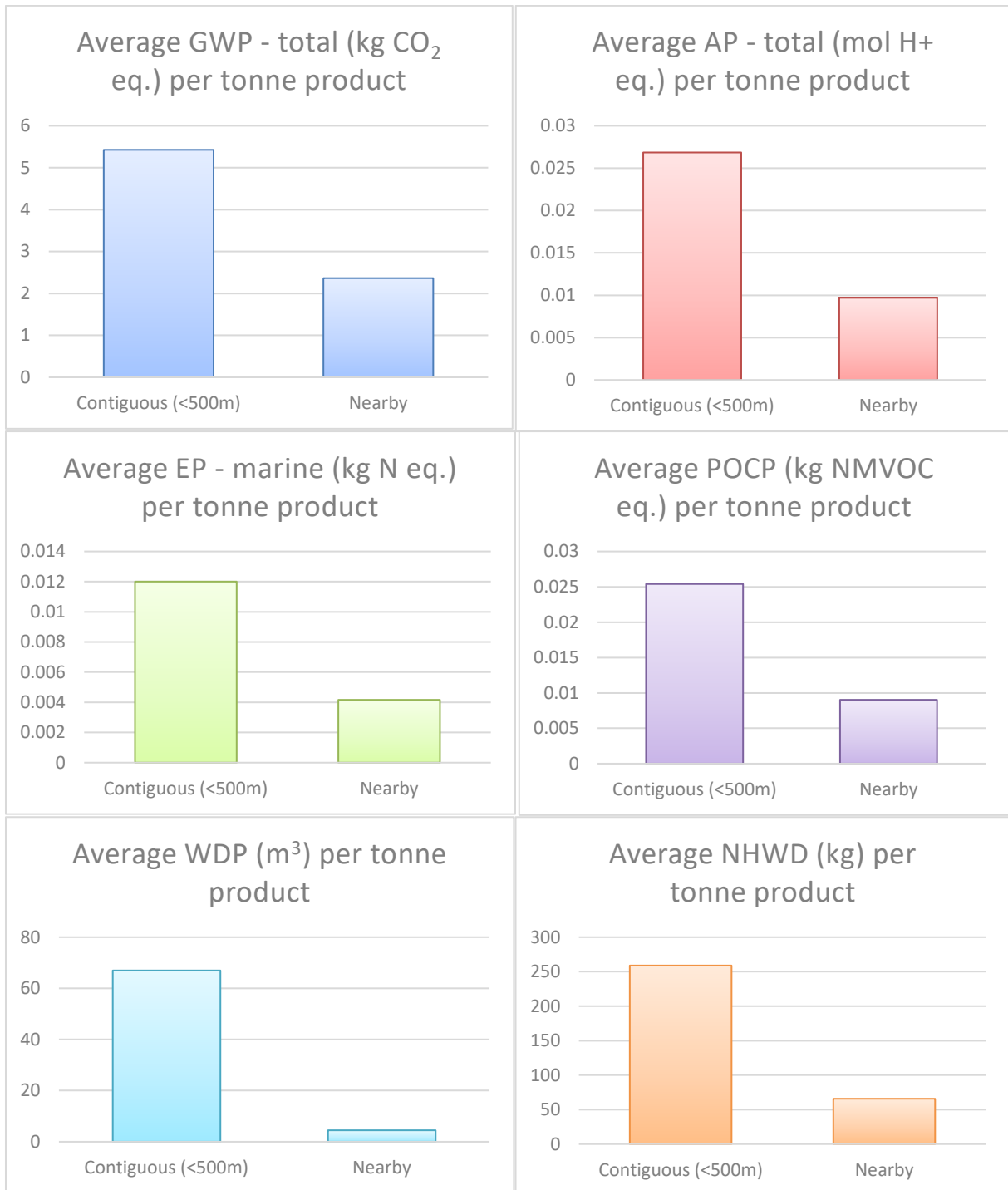


Figure 10: Comparison of results per tonne product in six impact categories based on proximity to communities.

## 4.4 Discussion of results

The methodologies developed within the DIGIECOQUARRY project for conducting site-specific LCA studies for EPD generation, connected to process simulations, have been applied successfully in all five pilot sites, resulting in the creation of product-specific EPD documentation for further interpretation. The EPD documentation, however, have not gone through third-party verification and, therefore, do not represent valid EPDs at this stage. Applying the methodologies has helped identifying challenges for the pilot sites that have been used in generating new solutions to be integrated into the IQG that can aid producers in this step. The development of a classification framework has also aided in identifying particular challenges relevant for the pilot sites within the project when it comes to environmental concerns. However, these challenges are not always relevant to the individual sites, for example in Valdilecha, the water table is over 100m deep, and so despite the high level of water scarcity in the area, water contamination is not a concern and highlights the need for further analysis by the individual sites once the assessment has been conducted.

The results from creating the EPD documentation provide a benchmark for each quarry to assess improvement actions as the project progresses. They can also help validating the environmental improvements that are expected to be achieved for the sites at a product level. For a majority of impacts, the pilot sites are below the Spanish average, suggesting that these sites are already applying best practices when it comes to environmental aspects. However, some of the differences can be country related, especially considering that country-specific electricity mixes were used for the sites. Further investigation is suggested for each site to properly comparison with other quarries within their country, for a more valid assessment of performance. WDP and NHWD are areas where the sites did not perform as well, however, this is in line with the goals of DIGIECOQUARRY where these are two of the areas noted for improvement.

Within the six categories examined, significant variation can be seen between the sites. Examining the results for different sizes and types of quarries also shows a relevant variation in environmental performance at a product level and can indicate that a similar effect for economies of scale can be seen for environmental savings in quarries, i.e., larger productions lead to efficiency gains and cost savings. The type and size of quarry could also be an influencing factor when comparing the environmental performance of aggregate products, considering the significant variations seen. However, as the same division of pilot sites is seen for size and type, it is not possible to determine the individual contribution of these factors. The small number of pilot sites involved in the project also means that no conclusions can be made at a broader level at this stage. Nevertheless, the results can help indicate what challenges are apparent for the different quarries within the project, providing guidance for future actions in the upcoming phases of the project. It also suggests that comparison between quarries of different type can be difficult due to the uniqueness of each quarry.

The quality of the data also differs between sites; however, all sites have been able to provide site-specific information for both the system inputs and outputs, and the production process, giving an overall high quality to the data. As the same generic datasets have been used for the background systems, the results between pilot sites can be more comparable than those for general EPDs, although this may reduce the representativeness of the results in reality. An example is waste disposal which has been modelled as incineration in the background dataset. This is not representative of all sites and highlights areas of improvement for the tool in increasing the variety of background datasets available in the tool. However, this should be balanced against added complexity to the tool and should only be addressed where significant differences are highlighted in sensitivity analyses of the environmental results.

Certain assumptions due to limitations on the data and models themselves have been made which can affect the accuracy of the results. These are listed in section 2.2.1 and should be considered before any interpretations of the results above are made.

Vicat is the only site where external transport occurs as part of A2 and also has some of the largest environmental impacts. This supports previous assessments that transport is an important aspect of the environmental performance of aggregate production and should be considered carefully by consumers and city planning for

production locations close to urban hubs. The inclusion of A4 in future parts of the project will help provide more information for actors involved in decision-making and is likely to be a valuable contribution to the project.

There is still room for improvement in the methodology and tool itself to increase the accuracy of the results, and any changes implemented in later stages of the project should be assessed separately for their effect on the quantitative results, to determine whether changes to environmental performance are the result of methodological changes or actions at the individual quarries.

## 5 Conclusions

Production models were completed for all five pilot sites in the tool Plantsmith. Site-specific data collected by the pilot sites could be connected to the production models and provide estimates for 38 environmental impact categories. Documentation has then been provided to each pilot site for the identified product groups, based on their similar environmental impacts. This information can be the basis for creating an EPD, if further interpretation and verification steps are completed. An example of the EPD document created by the tool can be seen in Annex I.

The applied methodologies have identified challenges for the producers in data collection which has contributed to the creation of a solution now implemented in the IQS. The process has also helped to identify areas for the improvement of the tool and methodologies themselves. The knowledge gained will help guide development within the coming phases of the project to maximise the benefit of solutions for the producers.

The quantitative environmental data obtained through the production of the EPD documentation can be used to objectively assess the impact of solutions implemented during the project on the environmental performance at a product level. However, a clear distinction must be made between variations in the results that occur due to methodological changes and those as consequences of actions and solutions implemented at the quarries in later stages of the project.

## 6 References

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- Svensk Standard [SIS]. Aggregates for railway ballast (EN 13450). 2003

## Appendix I: Example of EPD documentation produced for HANSON.

### Company information

Owner of the EPD:

Hanson Hispania (HANSON)

Contact:

Cesár Fernandez

cesar.fernandez@hanson.biz

Description of the organisation:

Hanson Hispania (HANSON) is a subsidiary of HeidelbergMaterials, which is the leading aggregates producer in the world with around 55,000 employees at more than 3,000 production sites in more than 50 countries on five continents. Concerning membership and clustering, HANSON is member of UEPG (European Aggregates Association), ANEFA (Spanish Aggregates Producers Association), Oficemen (Spanish cement association), Cembureau (European Cement Association), Anefhop (Spanish ready-mix association), GCCA (Global Cement and Concrete Association) and, additionally, partner of Bird Life. The core activities of HeidelbergCement include the production and distribution of cement and aggregates. Its downstream activities include mainly the production of ready-mix concrete, asphalt and other building products.

Product-related or management system-related certifications

**Product information**

Product name:

Aggregates



Product categories:

As several aggregate products are produced at this facility, the products in this LCA report have been grouped based on their similar environmental impacts considering the number of crushing phases they have passed through at the production facility. All groups declared in this EPD have shown no more than 10% difference in any of the impact categories declared in the EPD. The decided grouping of the products can be seen below:

Product Group:	Included Products:
Armourstone Primary Secondary Concrete	Armourstone, 0/40, 40/90, 0/35, 25/55, 14/25, 5/25, 0/12, 0/5, 0/2,5, Concrete mix,

Production site:

HANSON - Valdilecha, ES

Production:

Valdilecha Quarry in Madrid is a crushed rock facility extracting from a limestone deposit located approximately 32 km from its main customers in Madrid.

Geographical scope:

ES

Product identification:

Concrete, asphalt civil engineering work, road construction, armourstone, mortar and lime additive.

Product description:

Aggregate products in various fractions from a limestone origin.

Product Standards:

CEN Standard	Product group, Armourstone	Product group, Primary	Product group, Secondary	Product group, Concrete
EN 12620:2002+A1 Aggregates for concrete	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
EN 13043:2002 Aggregate for bituminous mixtures and surface treatments for roads, airfields and other trafficked areas	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
EN 13242+A1:2007 Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
EN 13055:2016 Lightweight aggregates	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
EN 13139:2002 Aggregates for mortar	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
EN 13450:2002 Aggregates for railway ballast	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Product Properties:

UN CPC code:

1532

## LCA information

### Functional unit / declared unit:

1000 kg product, at the production site.

### Reference service life:

Not relevant for product based on PCR.

### Time representativeness:

The data used to model product manufacturing corresponds to 2019. The data from EPDs and generic databases are all from 2018 or later. No data used is older than 10 years.

### Database(s) and LCA software used:

The background LCA for this EPD was conducted using the online aggregate industry specific software *Plantsmith*. The connected database to the software is built from the GaBi 2021 database.

### Description of system boundaries:

Cradle to gate for aggregate products used in further products that are not recognizable at end-of-life, for example, concrete, asphalt or mortar. For unbound aggregate products a cradle to gate with modules C1–C4 and module D is applied.

A1 represents the acquisition of raw material. This is conducted through the removal of overburden, drilling, and blasting virgin rock for aggregates. Some material can be sourced from contracted rock which is an uncontaminated waste product from other activities e.g., road blasting. The amount of each input material for the aggregate products can be seen on page 9.

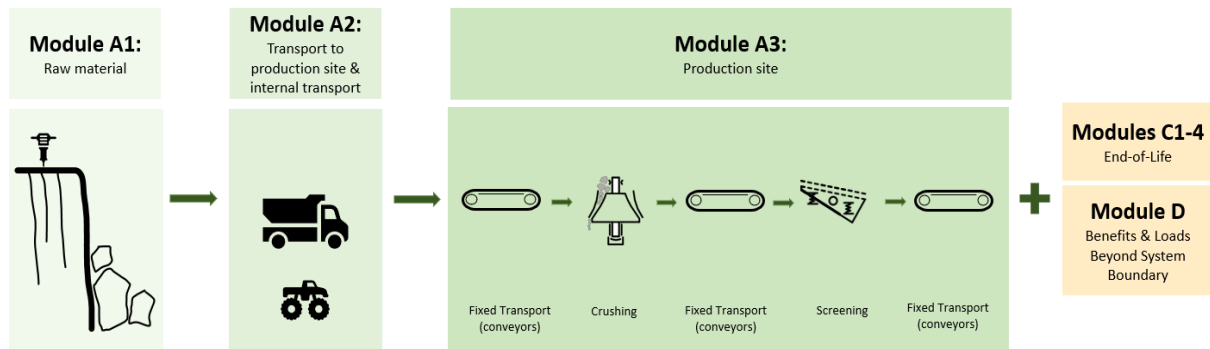
A2 represents the transportation to site of external material (contracted rock), or internal transportation conducted with yellow machinery.

A3 represents the manufacturing process. For aggregate products this includes crushing and screening with fixed transportation between processes using conveyor belts. Some products can also be washed which are indicated on page 4 under *product categories*.

C1-C4 represents the end-of-life for aggregate products. For all bound uses of aggregates, for example concrete, C-module is not declared under the exemption stated in section 5.2 of EN 15804:2012+A2:2019. For information on end-of-life for these products, please refer to a relevant EPD for concrete, asphalt or mortar. Considering the multiple purposes for unbound aggregates, a likely scenario has been proposed where the unbound aggregate remains in its original use yet is transported to a new location. The new location is estimated to be 20 km from its original position. Considering this scenario, no impacts occur for module C1, C3 or C4 and are, therefore, not reported.

D module represents benefits or loads beyond the system boundary. Given the end-of-life scenario used for module C, the unbound aggregate is assumed to displace the use of virgin aggregate products. 10 % losses are assumed over the lifespan and recovery of the secondary aggregates and, the secondary product is therefore credited with avoiding 900 kg of virgin material after waste processing has been applied.

System diagram:



Excluded lifecycle stages:

The life cycle modules included are those marked with an “X”. Information not declared in the LCA study is marked “ND”.

	Product stage			Construction process stage		Use stage							End of life stage				Resource recovery stage
	Raw material supply	Transport	Manufacturing	Transport	Construction installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Reuse-Recovery-Recycling-potential
Module	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
Modules declared	x	x	X	ND	ND	ND	ND	ND	ND	ND	ND	ND	x	x	x	x	x
Geography	Swe	Swe	Swe										Swe	Swe	Swe	Swe	Swe
Specific data used	>90%																
Variation – products	<10%																
Variation – sites	NR																

#### Allocation:

The production process has been split into sub-processes in *Plantsmith* depending on the individual products and environmental burdens have been allocated based on the mass of product produced in each sub-process.

#### Scenarios:

The analysis is carried out using factory-specific data for use of energy and utilities and waste generation, as well as product-specific data for use of raw materials. Therefore, the results represent the product system and no other scenarios were applied.

#### Data used:

Site-specific production data has been retrieved for HANSON - Valdilecha from the production site in ES. The upstream and downstream processes have been modelled based on data from EPDs and generic databases from Sphera Solutions GmbH and EcoInvent.

#### Cut-off:

The study applies a cut-off criterion of maximum 1% of the material and energy inputs of the system. This means that the sum of excluded material inputs does not exceed 1% of the total material inputs.

#### Transportation:

The external transport of the raw materials to the production site is carried out by diesel-powered trucks, for the most part EURO6 if the material is not blasted on site. Internal transport is conducted with various yellow machines where site specific data is used for fuel consumption and maintenance. Fixed transport solutions within the manufacturing process have been included in module A3 due to their integration with the manufacturing process.

#### Energy utilities:

Electricity demand in the facilities is modelled using the residual grid mix from Sweden based on generic data from Sphera Solutions GmbH (2021). The distribution for the electricity residual grid mix is based on data from 2017. The climate impact of the residual mix used is 0.051 kg CO<sub>2</sub> eq. per kWh.

#### Direct emissions from production site:

Within the scope of the study, the only direct emissions from the production site comes from fuel consumption in various diesel-powered machines. The emissions from diesel combustion in these machines is modelled on generic emission factors for combustion of diesel in construction machines.

More information:

Calculations were conducted with the aid of *Plantsmith*, a specific modelling tool developed for the aggregate industry. For more information on the models behind the calculations, please refer to their website: <https://www.roctim-plantsmith.com/>

For a list of all standards that this LCA study and EPD document conform with, please refer to the reference list.

For more information concerning aggregate production in general, please refer to the following organisations:

- European Aggregates Association [UEPG]: <https://uepg.eu/>
- Sveriges Bergmaterialindustri [SBMI]: <https://www.sverigesbergmaterialindustri.se/>

**Content information**

Product components	Weight, kg
Virgin Rock	1000.0
Contracted Rock	0.0
TOTAL	1000.0

No substances that appear in the REACH candidate list of SVHC (Candidate List of Substances of Very High Concern) are present or used in the product concerning this EPD.

**Environmental Information per Product Group**

**Potential environmental impact for mandatory indicators according to EN 15804**

The estimated impact results are only relative statements, which do not indicate the endpoints of the impact categories, exceeding threshold values, safety margins and/or risks.

Results per functional or declared unit							
Indicator	Unit	A1	A2	A3	Tot.A1-A3	C1-C4	D
GWP-fossil	kg CO <sub>2</sub> eq.	3.804e-1	1.38	2.578e-1	2.01	1.34	-4.085e-1
GWP-biogenic	kg CO <sub>2</sub> eq.	-9.865e-4	-1.773e-3	4.287e-3	1.528e-3	-1.62e-3	-2.698e-3
GWP-luluc	kg CO <sub>2</sub> eq.	1.541e-3	1.138e-2	3.934e-5	1.296e-2	1.11e-2	-1.651e-3
GWP-total	kg CO <sub>2</sub> eq.	3.809e-1	1.38	2.621e-1	2.03	1.35	-4.124e-1
ODP	kg CFC 11 eq.	1.16e-11	1.776e-16	1.899e-12	1.35e-11	2.68e-16	-1.044e-11
AP	mol H <sup>+</sup> eq.	3.215e-3	8.005e-3	6.652e-4	1.188e-2	8.05e-3	-2.94e-3
EP-freshwater	kg PO <sub>4</sub> <sup>3-</sup> eq.	2.063e-6	1.238e-5	1.077e-6	1.552e-5	1.209e-5	-2.339e-6

EP-freshwater	kg P eq.	6.876e-7	4.126e-6	3.59e-7	5.173e-6	4.03e-6	-7.796e-7
EP-marine	kg N eq.	1.263e-3	3.92e-3	1.515e-4	5.335e-3	3.93e-3	-1.145e-3
EP-terrestrial	mol N eq.	1.672e-2	4.339e-2	1.635e-3	6.174e-2	4.35e-2	-1.514e-2
POCP	kg NMVOC eq.	2.743e-3	7.548e-3	4.555e-4	1.075e-2	7.59e-3	-2.502e-3
ADP-minerals & metals*	kg Sb eq.	1.976e-7	1.058e-7	3.958e-8	3.43e-7	1.2e-7	-1.685e-7
ADP-fossil*	MJ	4.91	1.85e+1	5.33	2.874e+1	1.81e+1	-5.97
WDP	m <sup>3</sup>	2.367e-2	1.207e-2	2.968e-1	3.325e-1	1.26e-2	-4.09e-2
Acronyms	GWP = Global Warming Potential; ODP = Depletion potential of the stratospheric ozone layer; AP = Acidification potential; EP = Eutrophication Potential; POCP = Formation potential of tropospheric ozone; ADP = Abiotic Depletion Potential; WDP = Water Deprivation Potential						

\* Disclaimer: The results of this environmental impact indicator shall be used with care as the uncertainties of these results are high or as there is limited experience with the indicator.

#### Potential environmental impact – additional mandatory and voluntary indicators

Results per functional or declared unit							
Indicator	Unit	A1	A2	A3	Tot.A1-A3	C1-C4	D
GWP-GHG <sup>3</sup>	kg CO <sub>2</sub> eq.	3.706e-1	1.35	2.545e-1	1.97	1.32	-3.967e-1
<i>Additional voluntary indicators e.g., the voluntary indicators from EN 15804 or the global indicators according to ISO 21930:2017</i>							

<sup>3</sup> The indicator includes all greenhouse gases included in GWP-total but excludes biogenic carbon dioxide uptake and emissions and biogenic carbon stored in the product. This indicator is thus almost equal to the GWP indicator originally defined in EN 15804:2012+A1:2013.

## Use of resources

Results per functional or declared unit							
Indicator	Unit	A1	A2	A3	Tot.A1-A3	C1-C4	D
PERE	MJ	3.142e-1	1.03	2.47	3.82	1.04	-2.973e-1
PERM	MJ	0	0	0	0	0	0
PERT	MJ	3.142e-1	1.03	2.47	3.82	1.04	-2.973e-1
PENRE	MJ	4.92	1.853e+1	5.33	2.878e+1	1.81e+1	-6
PENRM	MJ.	9.743e-14	9.146e-14	2.296e-13	4.185e-13	0	-3.767e-13
PENRT	MJ	4.92	1.853e+1	5.33	2.878e+1	1.81e+1	-6
SM	kg	0	0	0	0	0	0
RSF	MJ	0	0	0	0	0	0
NRSF	MJ	0	0	0	0	0	0
FW	m <sup>3</sup>	7.971e-4	1.182e-3	4.308e-3	6.287e-3	1.19e-3	-1.204e-3
Acronyms	PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials; PERM = Use of renewable primary energy resources used as raw materials; PERT = Total use of renewable primary energy resources; PENRE = Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials; PENRM = Use of non-renewable primary energy resources used as raw materials; PENRT = Total use of non-renewable primary energy re-sources; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Use of non-renewable secondary fuels; FW = Use of net fresh water						

## Waste production and output flows

### Waste production

Results per functional or declared unit							
Indicator	Unit	A1	A2	A3	Tot.A1-A3	C1-C4	D
Hazardous waste disposed	kg	1.018e-9	9.336e-10	1.073e-9	3.024e-9	9.55e-10	-1.383e-9
Non-hazardous waste disposed	kg	1.227e-3	2.752e-3	6.172e+1	6.173e+1	2.84e-3	-5.555e+1
Radioactive waste disposed	kg	4.986e-5	2.241e-5	5.95e-4	6.673e-4	3.29e-5	-4.146e-5

### Output

Results per functional or declared unit							
Indicator	Unit	A1	A2	A3	Tot.A1-A3	C1-C4	D
Components for re-use	kg	0	0	0	0	0	0
Material for recycling	kg	0	0	0	0	0	0
Materials for energy recovery	kg	0	0	0	0	0	0
Exported energy, electricity	MJ	0	0	0	0	0	0
Exported energy, thermal	MJ	0	0	0	0	0	0

### **Additional information**

*Please provide any additional information about ongoing environmental work on site here.*

The facility maintains a permit issued in accordance with the Environmental Code (Miljöbalken) and is monitored by the local authority. The routine monitoring to maintain our permit includes: vibration levels, and discharges of pollutants into any outflowing water. Corrective action is taken if any breaches do occur during our routine monitoring.

### **Differences versus previous versions**

*No previous versions of this EPD are currently available*

## References

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