Life Cycle Assessment of Ceramic coverings - ASCER

Annex 1 of ITC Report C234994. Pre-verification draft version

Castellón, 23rd of November 2023

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1. General Aspects

In June 2023, a signed quote was received from the Spanish Association of Ceramic tile Manufacturers (hereinafter ASCER) for the preparation of a sectoral Life Cycle Assessment (hereinafter LCA) and the elaboration and drafting of its respective draft FDES (Environmental and Health Declaration Sheets in english) for ceramic covering. The collection of the data necessary for the preparation of this study began in May 2023 and ended in November 2023. These tasks are carried out through the project entitled "Elaboration of collective FDES for the Spanish ceramic sector" financed by ASCER and the *Conselleria de Hacienda, Economía y Administración Pública* of the Generalitat Valenciana within the framework of the collaboration agreement signed between both institutions.

This study has been carried out by the Institute of Ceramic Technology (hereinafter ITC) through the application of a computer tool, DAPCER, developed by the ITC, the UNESCO Chair of Life Cycle and Climate Change of the Escola Superior de Comerç Internacional de la Universitat Pompeu Fabra (ESCI-UPF) and its spin-off Cyclus Vitae Solutions, S.A., at the request of ASCER, in a project financed by IMPIVA and FEDER funds.

2. Definition of Objectives and Scope of the study

2.1. Objective of the study

The purpose of this LCA study is to obtain a collective FDES of ceramic coverings, of sectoral scope for ceramic coatings, encompassing various water absorption groups and forming methods (in accordance with standard ISO 13006:2012 [21]) within the INIES program. FDES, to be used in B2B communication processes (also designated type III declarations in accordance with ISO nomenclature [19]), are based on an analysis of the environmental impacts generated throughout the life cycle of the products being studied.

In addition, the study shall allow ASCER and its associates to identify the strengths and weaknesses of their products from an environmental standpoint and enable improvement actions to be established to reduce the environmental impacts associated with the products they make and market.

The present LCA study follows the recommendations and conforms to the requirements of international standards ISO 14040:2006 [13] and ISO 14044:2006 [14], as well as ISO 14025:2006 [16], EN 15804:2012+A2:2019 [18], and EN 17160:2019 [15]. Standard EN 17160:2019 was developed in accordance with version EN 15804:2012+A1:2013 so that, in those points in which EN 17160:2019 differs from the most recent version of EN 15804, what is indicated in the latter will be applied. In this study, the General Rules of the INIES programme have also been followed.

2.1.1. Intended audience

The intended audience of this study are ASCER, as the requesting entity, and those companies or entities that ASCER deems appropriate. This FDES is expected to be used in B2B and B2C communication processes, primarily, as well as by accredited bodies for the verification of FDES (INIES program). It is worth noting that some of the inventory data has been previously verified by an independent third party.

2.2. Scope of the study

2.2.1. Description of products

The scope of the study includes ceramic coverings manufactured by companies associated with ASCER in the geographical and technological environment of Spain between the years 2021 and 2022. Many of these production facilities are located in the province of Castellón. Specifically**, a representativeness of 55% of ceramic covering production in square meters within the sector** (both partial and full cycle companies) has been achieved.

Table 1 presents the number of companies that have participated in this study.

Table 1 Companies Subject to Study Based on Installation Type

Manufacturers of spray-dried granule companies	Full Cycle Companies	Partial Cycle Companies
6	10	28

The primary function of this product is to cover surfaces, encompassing both floors and walls, for both interior and exterior applications based on the specific technical requirements of each coating. In this study, it will be assumed that ceramic coverings with water absorption below 10% are utilized for flooring and facades, while those with water absorption exceeding 10% are employed for wall coverings. In both scenarios, the intended usage is residential, as outlined in the PCR for ceramic coverings [15].

The key components of ceramic coverings are outlined in Table 2.

Table 2 Key Components of Ceramic Coverings.

Substance		Composition
Ceramic body	Clays, feldspars, sands, fired and unfired ceramic scrap	97%
Glaze	Feldspars, carbonates, quartz, zirconio, etc.	3%

The substances contained in the product listed in the 'List of Substances of Very High Concern (SVHC) for Authorization' do not exceed 0.1% by weight of the product.

2.2.2. Functional unit

The functional unit has been defined as *"covering 1 m^2 of a surface (floors, walls, and facades) in a residential scenario with ceramic coverings (21 kg/m^2 average weight) for 50 years."*

2.2.3. System boundaries

A1. Raw materials supply:

- Extraction, preparation, and processing of raw materials.
- Extraction and production of ancillary materials or pre-products, including ceramic glazes.
- Production and transport of energy.

A2. Transportation:

- Average transport of raw materials and ancillary materials from the extraction or production site to the ceramic covering manufacturing plant.

A3. Manufacturing:

- Product manufacture.
- Waste collection and recycling processes to manufacturing of secondary raw materials.
- Production of packaging.

The results of modules A1, A2, and A3 are added up and jointly declared in a single value A1-A3.

A4 and A5. Construction:

- Transport (from the factory gate to the construction site) (A4).
- Installation and construction process stage (A5).

B. Use:

- Use (B1).

- Maintenance (B2).

- Repair (B3).

- Replacement (B4).

- Refurbishment (B5).

- Operational energy use (B6).

- Operational water use (B7).

C. End-of-life:

- Deconstruction (C1).

- Transportation of waste (C2).

- Waste processing (C3).

- Waste disposal (C4).

D. Environmental benefits and loads beyond the system boundaries.

- Reuse, recovery and/or recycling potentials, expressed as net impacts and benefits.

Please see the information modules assessed in Table 3.

Table 3 Information modules.

PRODUCT STAGE			CONSTRUCTION PROCESS STAGE		USE STAGE							END-OF-LIFE STAGE				BENEFITS AND LOADS BEYOND THE SYSTEM BOUNDARIES
Raw materials supply	Transportation	Manufacturing	Transport	Construction – installation process stage	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction	Transportation	Waste processing	Waste disposal	Reuse, recovery and recycling potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

2.2.4. Exclusion criteria of inputs and outputs

In this *cradle to grave* LCA study, the cut-off criteria applied was 1% of renewable and non-renewable primary energy usage and 1% of the total mass input of unit processes whose data were insufficient. In all, more than 95% of all the system's material and energy inputs and outputs were included, unavailable or unquantified data being excluded. The excluded data were as follows:

- Diffuse particle emissions into the atmosphere generated during transportation and storage of raw materials of a dusty nature.

- **Non-legislated**, channelled atmospheric emissions generated in the combustion stages (spray drying, drying of parts and firing).
- Long-term emissions have not been considered (>100 years).
- The processes of recycling and reuse of wastes generated throughout the life cycle of ceramic coverings that are to become part of another system, following PCR criteria [15].
- Production of industrial equipment and machinery, owing to the difficulty involved in inventorying all the goods involved, and also because the LCA community considers the environmental impact per unit product to be low in relation to the other processes that are actually included. In addition, the databases used do not include these processes, so that inclusion would require an additional effort beyond the scope of the study.
- Administrative department and employees' own transport
- The losses of mortar and its packaging in stage A5.

2.2.5. Assumptions made

The data for the inventory of the product's manufacturing stage have been mostly provided by participating companies associated with ASCER. For the remaining stages, typical scenarios outlined in the RCP are applied. [15]. The principle of modularity in the allocation of environmental loads has been followed, i.e. they apply where they occur, and the "polluter pays" principle has been followed. The main assumptions were as follows:

- **Thermal energy from Natural Gas.** The impacts associated with natural gas production, distribution, and consumption were obtained from the *Managed LCA (GaBi) content[33]*, using national-level average data as a reference, as read from *LCA for Experts (GaBi)[32]*. A lower heating value (LHV) of 10.554 kWh/Nm^3.
- **Electricity:** When considering the environmental impacts associated with the production of electricity consumed in the system, the electricity mix of the year 2022 and data from MITERD will be taken into account [27] in order to facilitate the breakdown by type of technology.

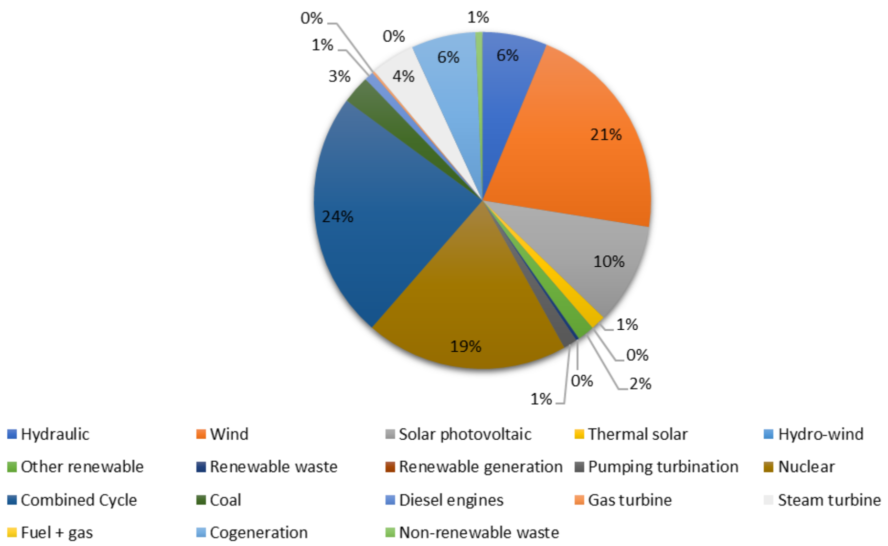

Figure 1 Electricity mix for the year 2022 by technology.

- **Air Emissions:** The atmospheric emissions of Volacovering Organic Compounds (VOCs) during the firing stage of ceramic coverings are regulated in the latest updates of the Integrated Environmental Authorizations. In cases where the studied companies do not yet have this limit value, a concentration of 20 mg/Nm^3 per emission source under real conditions has been assigned.

Regarding atmospheric particle emissions during the firing stage, in many cases, since their concentration value is below 10 mg/Nm^3, they are exempt from regulatory measurements. Therefore, a concentration of 5 mg/Nm^3 has been considered for these sources.

- **Raw materials transport distances.** 21km has been considered, from decoration material manufacturers and spray dried granule manufacturers to ceramic covering factories, based on estimates derived from road distances[29].
- **Transports:** To calculate the impacts associated with raw materials transportation, the total amount of raw materials was added up and the type of transport was allocated in accordance with its origin. For all road transportation of raw materials in Spanish and European territory, the use of a trailer with a maximum load of 27 t conforming to the Euro 6 standard was contemplated.

  In the case of packaging (cardboard, wood, and plastic) transportation, the use of a truck with a maximum load of 17.3 t conforming to the Euro 6 standard was assumed.

  In any event, for transportation distances equal to or smaller than 300 km, trucks made the return trip empty, whereas for distances exceeding 300 km they returned full of other merchandise. The return trip was therefore not included in the analysed system inventory. An average transportation speed of 65 km/h was supposed.

  In relation to maritime transportation of raw materials for the covering decoration an average freighter with a 100000–200000 t capacity was included.

  Wastes generated in the different life cycle modules were transported by truck for management, depending on the type of wastes, according to NF EN15804+A2/CN[23]:

  - Hazardous wastes: distance of 300km.
  - Non-hazardous wastes: distance of 50km.
  - Inert wastes: distance of 30km.
- **Diesel.** For road and inland transport, a diesel fuel with the following characteristics has been selected from the GaBi database: 7.86 % by weight of biocomponents; 5.90 % by weight of biogenic carbon; 6.91 % by weight share of bio C in total C; for use in transport process share_CO2_bio: 0.0691
- **Waste management**: Several waste management scenarios have been defined, based on data published in Eurostat [28] and in NF EN15804+A2/CN[23]. More details can be found along the inventory analysis description.
- **Pallets.** A large proportion of pallets used were EUR-pallets (of standard size) and they allowed reuse, up to 5 uses being assumed; this being the average number of times that this pallet could be used by the value chain within the system boundaries. It was thus sought to highlight the responsibility of a pallet's first user with regard to the created waste, even if there was still a third party, foreign to this study, that was going to reuse the pallet.
- **Decoration materials.** Due to the lack of updated information, the environmental information used in the previous 2018 sectoral study has been considered [2].

In the course of the Inventory analysis, other assumptions and constraints applied in conducting the study are explained.

2.2.6. Expression of results

The purpose of this study is to obtain Environmental Product Declarations under the INIES program, following the corresponding PCR [15]. Regarding the expression of the results for the impact categories of the products under study, a production-weighted average will be presented for each of the participating companies in the study, without making distinctions regarding the different covering groups included in the considered sample.

3. Inventory analysis

The qualitative and quantitative data included in the inventory were mostly provided directly by ASCER associates, in some cases obtained from unit processes and in others, from several aggregated processes, depending on their availability or accessibility. In other cases, it was necessary to resort to literature references or scenarios in the PCRs; in these last two cases, the source used is always cited. In the course of the inventory analysis chapter, the main constraints produced, both in process selection in the model designed in the LCA software and in the inventory data, are described. In addition, Sections 5.2. and 5.3. present a detailed analysis of the main constraints and data quality description.

The scope of the study, and hence of the inventory, is defined as *cradle to grave*, therefore including the product stage (raw materials extraction and preparation, ceramic covering manufacture and transportation between these stages), covering transportation, installation, use, and end-of-life.

Section 3.6. contains a detailed description of the rules followed for the calculation and allocation of inputs and outputs.

The processes included in this inventory are shown in Figure 2 and are described below.

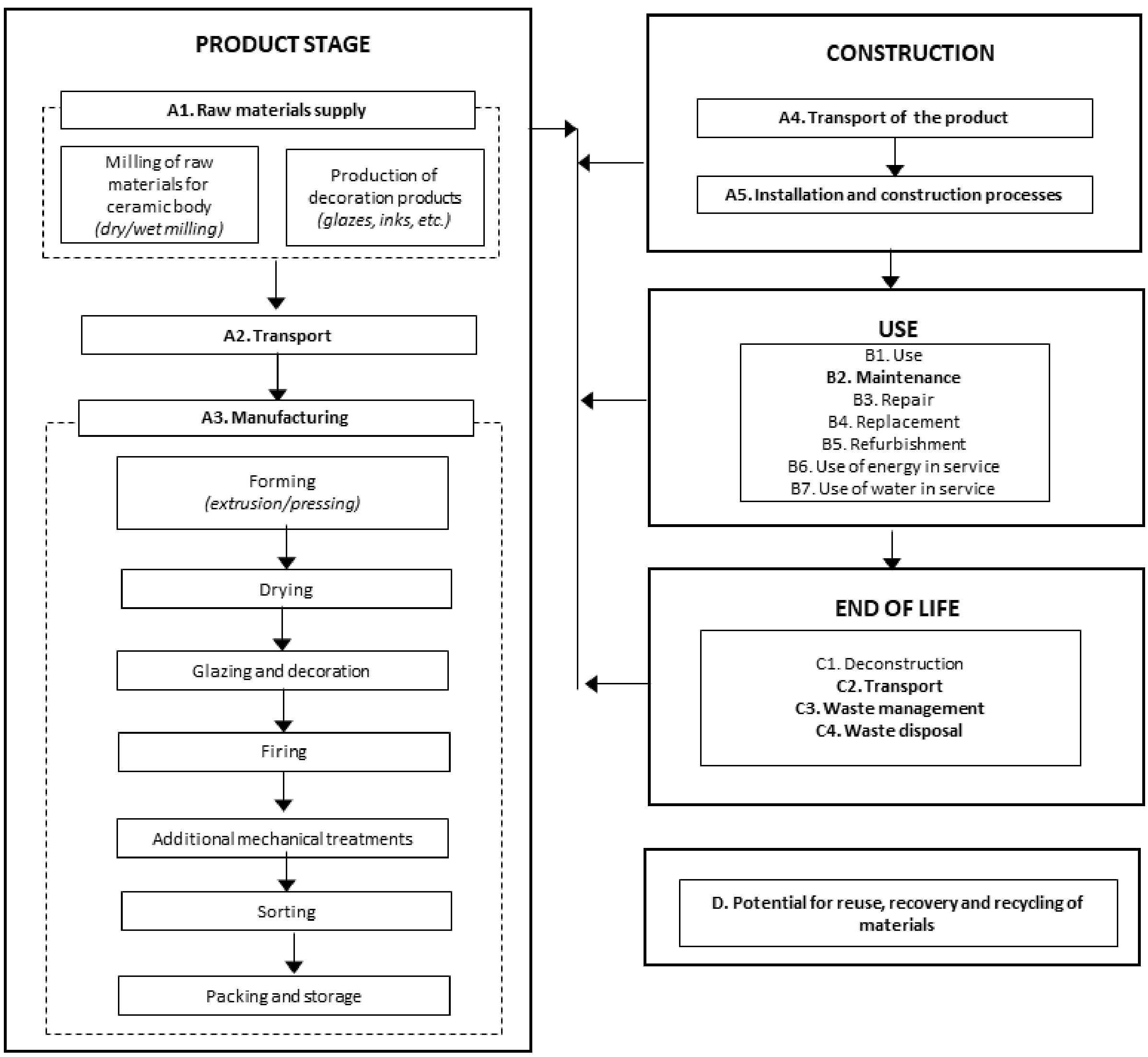

Figure 2 Scope of the Life Cycle Assessment study.

The tables in Annex 1 detail the inventory data of the entire life cycle considered of the product.

Stages A1, A2, and A3 are shown in aggregate form: A1–A3.

3.1. Product stage (A1–A3)

The product stage was divided into the following modules:

- Raw materials supply (A1) (see Section 3.1.1.)
    - Raw materials for the ceramic body (see Section 3.1.1.1.)
        - Formulation
        - Storage and metring
        - Milling
    - Raw materials for ceramic covering decoration (see Section 3.1.1.2.)
        - Transport of raw materials to the glaze, engobe and ink manufacturing plant (see section 3.1.1.1.2.1.)
        - Production of frits, glazes, engobes, and inks (see Section 3.1.1.2.2.)
- *Raw materials transportation (A2)* (see Section 3.1.2.)
- *Ceramic covering manufacture (A3)* (see Section 3.1.3)
    - Forming (see Section 3.1.3.1.)
    - Drying (see Section 3.1.3.2.)
    - Decoration (see Section 3.1.3.3.)
        - Unpacking of the decoration materials (see Section 3.1.3.3.1.)
        - Grinding and application of the decoration (see Section 3.1.3.3.2.)
    - Firing (see Section 3.1.3.4.)
    - Mechanical treatments (see Section 3.1.3.5.)
    - Sorting (see Section 3.1.3.6.)
    - Packaging (see Section 3.1.3.7.)
    - Aggregate data of ceramic covering manufacture (see Section 3.1.3.8.)

The aggregate data of the manufacturing stage for which no unit process data were available are included in Section 3.1.3.8.

To quantify the environmental impacts related to the extraction and transportation of raw materials, commercial databases, specifically developed by *Managed LCA (GaBi) content* [33] and Ecoinvent 3.9.1. [34]. Specific data sources for each material are detailed in Annex 2.

3.1.1. Raw materials supply (A1)

This section deals with the raw materials, both for the ceramic body and for ceramic covering decoration, i.e. glazes, engobes, and inks. In view of the specificity of ceramic covering decoration materials, this section sets out a detailed description of the obtainment process.

3.1.1.1. Raw materials for ceramic body

The raw materials required for the manufacture of the ceramic body of the coverings are classified as: plastic and non-plastic or lean raw materials. In general, the relative proportion of these two types of materials may be deemed such that the resulting mixture is sufficiently plastic to enable appropriate covering moulding while also contributing sufficient green strength to allowing covering processing.

- The plastic raw materials par excellence are clays and kaolin.
- The most common non-plastic or lean raw materials are silica sand, alkaline feldspars, or calcium carbonate.
- Other raw materials to be considered is unfired ceramic scrap, which is incorporated into the process in the raw materials milling stage.

The inventory table included in Annex 1 shows the raw materials chosen for the formulation of the ceramic covering backing under study, indicating the quantities of each one of them. An average composition has been obtained from the data provided by the spray dryer spray dryer suppliers.

3.1.1.1.1. Raw materials transportation to the spray-dried granule manufacturing plant

Considering their type and origin, the raw materials essential for the ceramic body are transported via land or sea from their extraction points to the spray drying manufacturing plant. For maritime transport, a specific type of cargo ship has been selected, with transport distances varying based on the origin. For road transport within national and European territories, we consider the use of a Euro 6-compliant trailer truck with a maximum load of 27 tons, as outlined in section 2.2.5. of this report. The inventory tables in Appendix 1 provide a comprehensive breakdown of the distances and transportation methods for each product type.

All raw materials constituting the ceramic body are transported in bulk, meaning they do not require packaging materials. The models employed for the transportation processes are included in the *Managed LCA content database (GaBi) [33]* and ecoinvent [34]. The distance data reflects the average transportation distance from the raw material origin to the factory, regardless of the material type. In this context, the impact generated by transportation is primarily linked to the weight of the cargo rather than the specific type of merchandise. To calculate the ratios presented in the inventory tables (Appendix 1), all raw materials composing ceramic pieces were aggregated, and the percentage transported via each type of transportation means was then calculated.

Regarding the raw materials for the ceramic body, the origins have been reported by the spray-dried granule manufacturers. Land transport distances were determined using online road maps, and maritime transport distances were obtained from navigation maps [29].

3.1.1.1.2. Spray-dried granule manufacture

The preparation of raw materials is generally carried out in specialized companies, spray-dried granules manufacturing companies and in full-cycle companies.

To perform the calculations, data averaged by the quantity manufactured by spray-dried granule plants was obtained for each of the relevant inputs and outputs in the process: consumption and origin of raw materials, atmospheric emissions, wastes, and consumption of water and thermal and electrical energy. Regarding consumption and origin of raw materials, available data from spray-dried powder companies and full-cycle companies.

Formulation

In this process, the raw materials amounts and sources were defined, adjusting these to production process characteristics and required end performance.

Storage and metring

The raw materials were supplied from their sources after being subjected to treatments for removing metallic iron, sieved (separating coarse particles > 15cm), and homogenised. The major raw materials with higher particle size distributions were transported in solids tankers and unloaded and stored in closed industrial premises; the minor raw materials and those with a finer particle size distribution were unloaded and stored in silos.

Milling

This stage in the production process entails achieving a thorough and homogeneous mixture of various components with a specified particle size, preparing it for the appropriate moulding of the ceramic body. The milling operation is termed dry milling when conducted without water and wet milling when performed in its presence.

Dry milling

Dry grinding is carried out with hammer mills or, more commonly, with pendular mills, which can produce smaller particles. Pendular mills are equipped with a heating system to facilitate the grinding of wet clays, and a pneumatic classifier that can extract the smaller particles, with the larger particles remaining inside the chamber for a longer period of time until the desired size is reached. The milled material can be used by extrusion or pressing.

Wet milling

Wet milling was carried out in a ball mill, which ran continuously or batchwise. The mill was fed with solids mixed with water and a deflocculant was added to help keep the solids in suspension. The milled product in suspended form is known as a *slurry*. The resulting slurry was kept in storage tanks equipped with stirrers to homogenise the product.

Spray drying

The slurry obtained was dried in a continuous, automatic process (spray drying), which yielded hollow spherical agglomerates, known as spray-dried powder granules, with a controlled moisture content (about 6% by weight) and a suitable shape and size for the granules to flow appropriately in the forming process.

Before pressing, the spray-dried granules were passed through a vibratory screen to remove possible impurities and large agglomerates of aggregates of granules stuck together.

With a view to minimising particle air emissions, cleaning systems have been installed, the retained particles being reused as raw material. CO_2, NO_x and SO_2 emissions in the spray drying stage were related to the natural gas combustion process itself and were, therefore, allocated to the process *Thermal Energy from Natural Gas*.

Cogeneration systems

The spray dryer includes a simultaneous heat and power cogeneration system by means of gas turbines, using natural gas as fuel, the combustion of which provides hot gases directly to the drying stage. Part of the cogenerated electricity is self-consumed and part is fed into the grid for sale and distribution[11][12].

To account for the consumption of natural gas in the spray drying stage, the cogenerated thermal energy and the self-consumed cogenerated electrical energy were taken into account, as well as the gas consumed in the post-combustion burners. For the calculation of the cogenerated gas, consumed in the manufacture of coverings in the form of thermal or electrical energy, the Certificate of efficiency of the cogeneration process of the atomisation and full cycle companies has been taken as a reference**¡Error! No se encuentra el origen de la referencia.**. Specifically, the cogeneration efficiency values associated with useful heat CHP Hη and electricity CHP Eη from the certificates have been taken and the system losses have been distributed proportionally. The share of cogenerated electricity sold is subtracted from the consumption of natural gas entering the cogeneration system.

The necessary material and energy inputs and outputs for obtaining the spray-dried granules used in the manufacture of 1 m^2 product are quantified in the inventory tables of Annex 1.

3.1.1.2. Raw materials for ceramic covering decoration

The data relating to decoration materials (frits, engobes, glazes and inks) were those used in the previous sectoral study in 2018 [2], as more up-to-date data were available.

Ceramic glazes are mainly composed of inorganic raw materials, the most common ones used in the formulation are ceramic frits, feldspars, quartz, zirconium, carbonates, kaolins, others. The composition of the glazes varies according to the type of ceramic covering on which they are to be applied, as well as the required effects and properties. Ceramic glazes for ceramic coverings contain a variable percentage of frits, crystalline raw materials, and ceramic pigments.

Ceramic frits are insoluble glasses, prepared in advance by complete melting of their original raw materials and sudden cooling with water or air, forming glazed flakes called 'frits'. Based on data from sectoral studies, it has been estimated that 50% of the raw materials used in glazes are subjected to the "fritting" process.

In addition to the frits and the previously mentioned raw materials, additives (such as suspending agents, deflocculants, and binders) are used in the formulation of glazes, engobes, and inks. These additives, employed in small proportions, help maintain the rheological properties of the suspension within optimal levels. This is done to facilitate the application process and ensure that the decorated surfaces, once fired, exhibit the desired appearance in terms of texture and colour uniformity.

3.1.1.2.1. Transport of raw materials to the glaze, engobe and ink manufacturing plant

Based on the distance between the extraction point and the decoration material processing plant, raw materials are transported via land or sea. Maritime transport involves a selected type of cargo ship, with varying transport distances depending on the origin. For road transport within national and European territories, a Euro 6-compliant trailer truck with a maximum load of 27 tons is considered, as specified in section 2.2.5 of this report. The detailed breakdown of distances and transport methods is presented in the inventory table (Appendix 1).

All raw materials constituting the glaze are transported in bulk, eliminating the need for packaging materials. Distance data reflect average transportation distances from the raw material origin to the factory, regardless of material type. The transportation impact, in this case, is linked to the weight of the load rather than the type of merchandise. To calculate the percentages in the inventory table (Appendix 1), all raw materials for ceramic pieces have been aggregated, and the percentage for each type of transport has been computed.

Origins of raw materials are sourced from data provided by glaze, engobe, and ink suppliers. Land transport distances have been determined using available online road maps. [29] and for maritime routes, the distance information has been obtained from online navigation maps [30].

To calculate the ratios that appear in the inventory tables (Annex 1), all the raw materials making up the ceramic coverings were added together weighted by production of each type of composition, and the percentage that travelled in each type of means of transport was calculated.

The decoration materials are transported in a truck with a payload of 17.3 tons that complies with Euro 6 standards directly from the frit and glaze factories to the plants of the companies participating in the study. The distances used in the LCA study have been calculated based on a weighted average by the supplied quantity from the glaze suppliers of the companies associated with ASCER.

3.1.1.2.2. Production of frits, glazes, engobes, and inks

The frit manufacturing process begins with the dosing of the raw materials, previously selected and controlled in the established proportion. By means of pneumatic transport, it is transferred to a mixer and then to the furnace where the actual fritting takes place, which can be carried out in continuous or intermittent furnaces. In any case, on leaving the furnace, the molten material is cooled either with water (the main process) or with air. In the case of NOx and SO_2 emissions generated during the fusion of frits, the portion corresponding to the combustion of natural gas has been excluded. The emission factors for the fuel are taken as 1.67 mg/MJ for SO_2 and 69.31 mg/MJ for NOx. [7].

Frits can be applied dry, as granules, or as part of the composition of glazes. For the latter purpose, frits, together with other raw materials and ceramic pigments, are wet milled into a suspension.

Half of the glazes utilized by coating manufacturing companies are introduced to the market in dry form, encompassing granules, dry glazes, and micronized glazes. Subsequently, these dry formulations undergo a wet milling process within the same ceramic manufacturing plant. Meanwhile, the remaining portion of glazes is already milled before reaching consumers.

Pre-milled glazes are made available in either kilns or jugs, dependent on the chosen application technique, as elaborated in the subsequent details.

In instances where glazes are marketed in dry form, they are securely packed in polypropylene sacks, commonly referred to as big bags. These sacks typically weigh around 1.5 kg, containing 1000 kg of glaze.

On the other hand, already-milled glazes are packaged in 800-liter tank. The transportation of these containers from the manufacturing site to the glaze manufacturing plant is facilitated using a truck with a payload capacity of 27 tons. This vehicle complies with Euro 6 standards and utilizes fuel produced within Spain. The transportation distances for polypropylene containers (big bags and tanks) are 450 km and 35 km, respectively. Additionally, the transportation distance for wooden pallets is 45 km.

The inputs and outputs for the manufacture of the decoration materials required to decorate 1 m^2 product are detailed in the inventory tables (Annex 1).

Due to challenges in gathering the necessary manufacturing information for decoration materials, data from previous sector studies have been employed. [2].

3.1.2. Raw materials transportation (A2)

A distance of 21 km has been considered, between the spray dryer factories and the covering factories and between the decoration material factories and the covering factories, based on estimates made on the basis of road distances [29].

In the case of the transport of spray dried granules, the means of transport used is a 28-tonne tanker truck and for the transport of decorative materials a 28 tonne payload truck; both comply with the Euro 6 standard.

3.1.3. Manufacturing (A3)

3.1.3.1. Forming

The spray-dried powder is received at the ceramic covering manufacturing plants and stored in silos. Utilizing a weighing-controlled conveyor belt feeding system, the powder is directed to the shaping stage.

The system employed to shape ceramic coverings involves unidirectional dry pressing, conducted with hydraulic or oleodynamic presses. For large-format coverings with reduced thickness special compaction processes are used.

To a lesser extent, the extrusion method is utilized in some manufacturing plants. In this process, the raw materials are dry ground, mixed with water to achieve a moisture content of 15-20%, resulting in a paste commonly known as kneaded. This kneaded dough is then processed through an extrusion machine that imparts shape to the mass.

3.1.3.2. Drying

The formed ceramic coverings were set in dryers to reduce their moisture content, thus notably increasing covering mechanical strength and enabling subsequent covering processing. The drying cycle depended both on the operation variables (temperature, air flow rate, etc.) and on the characteristics of the pressed coverings (size, moisture content, compactness, etc.).

The material and energy inputs and outputs for the covering forming and drying processes are detailed together in the inventory tables (Annex 1). The specific electricity consumption data are included in the section of the table *Aggregate data of the ceramic covering manufacturing plant* (Annex 1). Thermal energy consumption breakdown was also unknown, so that natural gas consumption in this stage is calculated in the section on *Firing*.

CO_2, NO_x and SO_2 emissions in the drying stage were related to the natural gas combustion process itself and were, therefore, allocated to the process *Thermal Energy from Natural Gas*.

3.1.3.3. Decoration

After emerging from the drying chamber, select pieces undergo a meticulous coating process in the glazing line. This involves the careful application of one or multiple layers of engobe, glaze, and inks. The objective is to endow the surface of the fired product with a diverse range of technical and aesthetic attributes. These include impermeability, ease of cleaning, a glossy finish, vibrant colour, distinctive surface texture, as well as robust chemical and mechanical resistance.

The engobe, glazes, and inks are purchased from specialized suppliers.

3.1.3.3.1. Unpacking of the decoration materials

The packaging waste generated in the preparation and application stage of the glazes is either reused through a deposit, return, and return system, as mentioned earlier, or it is managed as waste. For waste management, the management hypothesis presented in Table 4 has been defined, based on data published in Eurostat on packaging waste managed in Spain during the year 2020 [28]. For any waste management scenario, it has been assumed that the distance between the factory and the waste destination is 50 km.

Table 4 Scenarios for the Management of Packaging Waste from Glazes [28].

Waste	Incineration (%)	Recycling (%)	Landfill (%)
Plastics [ELW 150102] and [ELW 150110*]	2,3	71,9	25,8
Wooden pallet [ELW 150203]	0	96,3	3,7

3.1.3.3.2. Milling of the glazes and application of the decoration materials

50% of the glazes used by the coating manufacturing companies are received dry and are wet milled in ball mills in the coating manufacturing companies until a ceramic suspension is obtained.

The glazing operation was performed by successively applying the glaze suspensions, using different techniques. The resulting surface was then decorated using different types of applications (inkjet inks and traditional applications with silk screen).

The quantities of decorative raw materials to this process are presented in the inventory tables in Annex 1. The electricity consumption of the grinding and glaze application process, as well as applied and associated particulate emissions have been included in the section of the inventory table "Aggregate data of the ceramic manufacturing plant".

3.1.3.4. Firing

This is the most important stage in the production process, where the previously formed coverings undergo a fundamental change in their properties, giving rise to a hard material, which is resistant to water and chemicals and, in general, exhibits excellent performance features.

The ceramic coverings were fired by single firing in single-deck roller kilns that allowed firing in cycles of 35 to 65 minutes, reaching temperatures of about 1000–1200°C, depending on the nature of the composition.

In the section on *Firing* of the inventory tables (Annex 1), the input and output flows corresponding to the ASCER companies firing process are set out, always in relation to the manufacture of 1 m^2 ceramic covering.

With respect to this process, it may be noted that the specific electricity consumption data were unknown and, as in previous processes, this consumption is included as *Aggregate data of the ceramic covering manufacturing plant* (Annex 1).

Due to the high temperatures of this process, the air emissions measured by the specialised companies include emissions due to the combustion of natural gas and the decomposition of raw materials. In order to avoid double counting, the emissions due to combustion of natural gas have been extracted from the emissions measurements taken by specialised companies, as these are already accounted in the thermal energy process from natural gas, taking as fuel emission factor of SO_2, 1.67 mg/MJ, and for NOx, 69.31 mg/MJ [7].

In the case of CO_2 emissions due to the decomposition of carbonates present in the support composition, these are accounted for in the inventory table in Annex 1 as "Decarbonation".

3.1.3.5. Mechanical treatments

The pursuit of novel effects in ceramic coatings has given rise to a variety of additional treatments for pieces post-firing: pre-cutting, cutting, surface polishing, grinding and more. These treatments can be conducted either in-house by the ceramic manufacturing companies or outsourced to specialized service providers.

Such finishing processes are applied either in wet or dry conditions to pieces that have undergone thorough inspection and classification based on their flatness and edge straightness.

Concerning the water used in wet machining processes, companies employing these techniques often implement a closed circuit to facilitate water reuse. These processes, however, result in a significant water evaporation, leading to increased suspended solids and conductivity in the recycled water. To address this, the water undergoes a settling treatment for solids removal. The obtained sludge is either bagged in big bags or subjected to filter pressing. These waste materials are managed by authorized handlers, typically disposed of in landfills, and occasionally reintroduced as raw materials into the manufacturing process, although this is less common due to the chemical characteristics of the sludge. To compensate for water loss through evaporation and circuit purging to reduce conductivity, water needs to be replenished into the process.

Among the companies participating in this study, approximately 35% engage in the production of pieces subjected to these treatments. Table 5 illustrates the prevalence of the most common mechanical treatments, both in dry and wet conditions, expressed as a percentage of the total machined production.

Table 5 Most Common Mechanical Treatments in Ceramic covering Manufacturing Companies

Wet processing treatment (grinding, polishing, cutting etc)	Dry processing treatment (grinding, cutting)
70%	30%

A significant percentage of the surveyed companies do not have specific consumption data (both for water and electricity) for this stage. Therefore, the electrical consumption and waste generated in this process stage are included in the Aggregate Data for Covering Manufacturing, and water consumption is accounted for in the glazing water section, assuming the treatment is done via wet processing.

3.1.3.6. Sorting

Although the sorting operation plays no role in product characteristics, it is a very important process in the production cycle. In this stage, the material was selected and subdivided as a function of the quality criteria established by companies associated to General Management companies and/or as a function of market orientations themselves.

In these quality control processes, any defective pieces unsuitable for sale are systematically identified and removed. The pieces meeting the minimum quality standards for sale undergo manual and/or automated classification into first, second, and/or third class based on their technical and aesthetic attributes.

3.1.3.7. Finished product packaging

The sorted coverings were packed in primary cardboard packaging that generally only covered the edges. The number of coverings included in each cardboard box varied according to covering size and weight. The different cardboard boxes were stacked on a wooden pallet, which were reusable up to 5 times by a deposit and return system. The pallets were covered by shrink or heat-shrink LDPE film or bags that adapted to pallet size. Once the pallet had been formed, it was stored in an area devoted to that purpose.

For transportation of these packaging materials (straps, pallets, film and cardboard) from their manufacturing site to the covering factory, a model was chosen of a truck with a useful load of 17.3 t, which conformed to the Euro 6 standard. The estimated distance was provided by ASCER companies.

The average amount of packaging materials and distance travelled are set out in the inventory table (Annex 1). The electric power consumption in this stage and the amount of packaging waste generated were calculated together with other *aggregate data of the ceramic covering manufacturing plant* (Annex1).

3.1.3.8. Aggregate data of ceramic covering manufacture

Due to the difficulty of differentiating certain consumption in each of the unitary processes, this section includes aggregate data associated with the manufacture of ceramic coverings. Specifically, these are the waste generated, the electrical energy purchased and generated on site by means of photovoltaic panels, and the cold atmospheric emissions of particles.

In relation to atmospheric emissions, the calculation has been made on the basis of the values measured by the control entities, ECMCA (Collaborating Entities for Environmental Quality). As we do not have all the specific data on the emission of pollutants in each source of aspirations of each of the companies, they have been grouped together and considered jointly in the section Aggregate data.

Due to the challenge of distinguishing specific consumptions in each of the unit processes, this section includes both purchased and on-site generated electrical energy, the latter often facilitated by photovoltaic panels. In the case of companies with partial cycle operations, this coincides with the electric energy consumed for ceramic coating manufacturing, along with the generated waste. All these factors are referenced to the production of 1 m2 of ceramic coating.

Regarding the waste generated during the manufacturing stage concerning the process, they are managed as follows:

- Pre-firing mixture preparation waste (LER 101201): managed by spray-dried granule manufacturers and full-cycle companies. These wastes are shredded and reintroduced into the milling process as raw materials after appropriate adjustment of the ceramic composition formulation. The quantities reintroduced referring to the Functional Unit are presented in the inventory table (Annex 1; module A1 Raw Material Supply; referenced as "Recycling").

- Waste from parts after firing (LER 101208): these are managed through authorised waste management companies. In most cases, this waste is reintroduced into the covering manufacturing process as external recycling. In other cases, it is destined for another process.

- Sludges and aqueous suspensions containing ceramic materials (LER 080202 and LER 080203) generated in the cleaning operations of the mills in the glaze preparation section and those obtained in the cleaning of the glazing lines and cleaning operations in the general plant. These are managed by companies through the companies that manufacture atomised granules (atomisers) or through full cycle companies, being introduced into the milling process as raw material. The quantities referred to the Functional Unit are presented in the inventory table (Annex 1; module A1 Raw Material Supply; referenced as "Reintroduced raw").

- The solid material retained in the air emission treatment systems (LER 101203) of the hot and cold sources are managed through companies that manufacture atomised granules, both full cycle companies and atomising companies, to be fed into the milling process as raw material.

- The packaging material wastes generated at the covering manufacturing plants are mainly: plastic waste (LER 150102), cardboard (LER 150101) and wood (LER 150103). These are managed by authorised waste managers for recovery. The environmental loads associated with the transport of these wastes have been inventoried using a model for a truck with a capacity of 17 tonnes.

Table 6 Specific waste per m² of covering produced.

Waste grouped	Specific waste LER code	LER code	Average (production weighted) quantity (kg/m²)
Hazardous waste for recycling	Used oil	13 02 05 *	2.0E-02
	Aerosols	15 01 11 *	
	Contaminated packaging	15 01 10*	
	Contaminated used filters/traps and absorbents	15 02 02*	
	Contaminated soil	17 01 06*	
	Pre-firing enamels	10 11 09*	
	Oil filters	16 01 07	
	Pre-firing glazes	101109*	
Non-hazardous waste for recycling	Scrap	17 04 05	3.4
	Electronic and electrical equipment	16 02 14	
	Fired scrap	10 12 08	
	Unfired scrap	10 12 01	
	Aqueous suspensions containing ceramic materials	08 02 03	
	Aqueous sludges containing ceramic materials	08 02 02	
	Particulates and dust	10 12 13	
Paper and cardboard wastes destined for recycling	Cardboard/paper packaging	15 01 01	1.1E-02
Wood wastes going for recycling	Wooden packaging	15 01 03	1.5E-02
Plastic wastes going for recycling	Plastic packaging	15 01 02	1.8E-02
	Plastics	07 02 13	
Waste fired ceramics for recycling in another process	Fired scrap	10 12 08	3.3E-01

(*) Residuos peligrosos

3.2. Construction (A4-A5)

3.2.1. Transport (A4)

For the INIES programme, a representative transport scenario with an equivalent distance between Castellón and north-France has been taken road transport (27t Euro 6 truck), 1390km. This scenario applies to all the products under study.

Additional technical information for the transport from the factory gate to the construction site ceramic coverings is shown in Table 7.

Table 7 Additional information on the transport of coverings to the construction site (expressed per functional unit)

Parameter	Average ceramic covering profile
Fuel type and consumption	0.4519l/m² diesel
Distance	1390 km truck
Capacity utilisation (including no-load return)	85% truck
Bulk density of transported products	

3.2.2. Installation and construction processes (A5)

3.2.2.1. Packaging waste reception and management

Once the product has been brought to the point of installation, it is unpacked and installed.

A scenario that represents packaging waste management were created, considering the statistical mean values for non-hazardous waste management (cardboard, plastics, and wooden pallets) for Europe. Note that increased distance from the geographic area raised waste treatment data uncertainty. Table 8 summarises the destination of the waste the scenario considered.

A distance of 50km to the waste management facilities is considered according to CN/NF15804+A2.

Table 8 Scenarios for ceramic covering packaging waste management[28]..

Type of waste management	Europe
Paper and cardboard	
Incineration (%)	0
Recycling (%)	99.8
Controlled landfill (%)	0.2
TOTAL	100
Plastic	
Incineration (%)	0.5
Recycling (%)	92.8
Controlled landfill (%)	6.8
TOTAL	100
Wood	
Incineration (%)	0.6
Recycling (%)	98.7
Controlled landfill (%)	0.5
TOTAL	100

In this study, an open cycle model was used and, therefore, both the recycling processes and their respective environmental impacts or benefits that were going to become part of another system were not allocated to the product analysed. However, those burdens and benefits were in fact included in a separate module, module D (see Section 3.5.).

3.2.2.2. Product installation process

In accordance with PCR recommendations [15], Option 1 of the proposed scenarios in this standard was selected: use of mortar and water for ceramic covering installation. Adhesive mortars are cementitious adhesives consisting of a mixture of hydraulic binders, organic mineral fillers, and additives, which only need to be mixed with water or a liquid addition just before use. They are made up of a mixture of grey or white cement, mineral fillers of a silica and/or limestone nature, and organic additives: water retainers, water-redispersible polymers, rheological modifiers, fibres, etc.[31]

The amounts of the materials involved in covering installation, in relation to the functional unit, are set out in the inventory tables of Annex 1 in the present report.

At this stage, companies have stated that an average of 5.3% of covering waste is generated during the installation process. This quantity may vary slightly between factories and covering formats, as the quantity by weight depends on the formats of the ceramic coverings and the geometry of the surface to be covered.

At this stage, the production, transport (A1-A3 and A4) and treatment of this waste has been considered, as indicated in the PCRs [15]. Mortar losses are excluded.

In regard to waste generated was transported by truck for management, depending on the type of wastes, according to NF EN15804+A2/CN [23]:

- Hazardous wastes: distance of 300km.
- Non hazardous wastes: distance of 50km.
- Inert wastes: distance of 30km.

Table 9 shows the technical information by product type studied for the installation stage (A5).

Table 9 Technical information of stage A5 by type of product studied.

<table>
<tr><th colspan="2">Parameter</th><th>Result (expressed per functional unit)</th></tr>
<tr><td colspan="2">Supplementary materials for installation</td><td>3.3 kg</td></tr>
<tr><td colspan="2">Water use</td><td>0.8 l</td></tr>
<tr><td colspan="2">Use of other resources</td><td>Not applicable</td></tr>
<tr><td colspan="2">Quantitative description of the type of energy (regional mix) and consumption during the installation process</td><td>Not applicable</td></tr>
<tr><td rowspan="4">Waste of materials at the construction site before processing of waste generated at the product installation (specified by type)</td><td>Product losses (g)</td><td>1121</td></tr>
<tr><td>Packaging wastes: cardboard (g)</td><td>127</td></tr>
<tr><td>Packaging wastes: plastic (g)</td><td>33</td></tr>
<tr><td>Packaging wastes: wood (g)</td><td>264</td></tr>
<tr><td rowspan="11">Output of materials (specified by type) as a result of waste treatment waste at the construction site, e.g. from waste collected for recycling, energy recovery, disposal (specified by route)</td><td>Product losses for recycling (g)</td><td>0</td></tr>
<tr><td>Product losses for final deposition (g)</td><td>1121</td></tr>
<tr><td>Carboard for incinerating (g)</td><td>0</td></tr>
<tr><td>Carboard for recycling (g)</td><td>127</td></tr>
<tr><td>Cardboard for final deposition (g)</td><td>0</td></tr>
<tr><td>Plastic for incinerating (g)</td><td>0</td></tr>
<tr><td>Plastic for recycling (g)</td><td>31</td></tr>
<tr><td>Plastic for final deposition (g)</td><td>2</td></tr>
<tr><td>Wood for incinerating (g)</td><td>2</td></tr>
<tr><td>Wood for recycling (g)</td><td>261</td></tr>
<tr><td>Wood for final deposition (g)</td><td>2</td></tr>
<tr><td colspan="2">Direct emissions to ambient air, soil and water</td><td>Not relevant</td></tr>
</table>

3.3. Product use

The use stage was divided into the following modules:

Use (B1)

Maintenance (B2)

Repair (B3)

Replacement (B4)

Refurbishment (B5)

Operational energy use (B6)

Operational water use (B7)

Once it had been installed, the product needed neither water nor energy input for use and no maintenance after installation, except the normal cleaning operations and do not emissions into the environment. For this reason, of all the aforementioned modules, only the environmental loads allocatable to product maintenance were considered (module B2).

According to ASCER, the reference service life of the product was the same as that of the building in which it was installed because, provided it was installed properly, the product need not readily be replaced and has a long service life. According to the PCRs, this time span is defined as 50 years[15].

Additional technical information on the service life and performance of the two types of coverings under study is presented below.

Table 10 Additional information on the service life of sectoral ceramic covering coverings.

Parámetro	Recubrimientos cerámicos
Reference Service Life	Minimum 50 years
Declared product properties (on gate), coatings, etc.	Minimum values of the relevant characteristics according to the ISO 13006 standard. For more information request technical data sheets according to model.
Design parameters of the application (manufacturer's instructions), including references to good practices.	For more information request technical data sheets according to model.
Estimated quality of work, when installed according to the manufacturer's specifications	For more information request technical data sheets according to model.
Estimation of the quality of work, when installed from outside environment (for outdoor applications), e.g. weathering, pollutants, UV radiation and wind exposure, building orientation, shading, temperature, etc.	Minimum values of the relevant characteristics according to the ISO 13006 standard. For more information request technical data sheets according to model.
Indoor environment (for indoor applications), e.g. temperature, humidity, chemical exposure	Minimum values of the relevant characteristics according to the ISO 13006 standard. For more information request technical data sheets according to model.
Conditions of use, e.g.: frequency of use, mechanical exposure, etc.	For more information request technical data sheets according to model.
Maintenance, e.g.: required frequency, type and quality and replacement of replaceable components	For more information request technical data sheets according to model.

3.3.1. Maintenance (B2)

In this module, it is considered that the maintenance operations are reduced to cleaning. It could be done with a damp cloth and, if the surface exhibited dirt or grease, cleaning agents such as detergents or bleaches could be added. To calculate the amount of detergent, understood as a surfactant, the cleaners available on the market were estimated to contain 5% of this type of compounds in their formulation.

Maintenance was defined in accordance with the PCRs [15], considering residential use, this scenario has been defined based on specific conditions and cleaning frequencies over a 50-year time span for each type of ceramic coating and the most common placement (floor or wall).

These conditions entail cleaning with water and detergent every three months for 50 years for coverings installed on walls, and once a week for porcelain coverings installed on floors (once a week with water and every two weeks with water and detergent). The quantities involved are detailed in the inventory tables in Annex 1 of this report.

To obtain an average amount of water and detergent used to clean floor and wall ceramic coverings, production data provided by ASCER have been considered:

- Porcelain covering: 66.5% (floor covering)
- Stoneware: 7.5% (floor covering)
- Covering: 25.1% (wall covering)
- Special coverings: 0.3% (wall covering)

The amounts involved being set out in the inventory tables of Annex 1 in the present report and inTable 11.

Table 11 Technical information at the B2 stage for the sectoral profile ceramic coverings studied.

Parameter	Result (expressed per functional unit)
Maintenance process	According to PCR for ceramic coverings (EN17160) residential scenario for floor and walls cleaning
Maintenance cycle	Washing 7,69E-01 times a week with water and detergent
Auxiliary materials for maintenance (e.g. cleaning agents) (specifying each material)	Detergent: 8.38E-05 kg/m^2 per wash
Material wastage during maintenance (specifying the type)	Not applicable
Net consumption of tap water	0.1 l/m^2 per wash
Energy input during maintenance (e.g. vacuum cleaning), type of energy carrier (e.g. electricity) and amount, if applicable and relevant	Not applicable

3.4. End-of-life

3.4.1. Deconstruction and demolition (C1)

Once its service life has ended, the product is removed, whether under building refurbishment or during demolition. In building demolition, in any case, the impacts allocatable to product disassembly were negligible, as specified in the ceramic covering PCRs [23].

3.4.2. Transportation (C2)

Product waste was transported in a large tonnage truck (24 t) conforming to the Euro 6 standard for management, by disposal at landfills of inert waste. An average distance of 50 km was assumed from the building site to the treatment to the final destination. The truck return trip was also included (100% empty return trips).

3.4.3. Gestión de residuos para reutilización, recuperación y reciclaje (C3)

For the INIES programme as described in the PCR [15], 0% of the coverings were recycled and/or reused.

3.4.4. Disposal (C4)

According to the INIES programme default scenario, the entire product was sent to controlled landfill after its service life had ended life [23].

Table 12 shows the technical information on the end-of-life stage for the four products studied.

Table 12 Technical information on end-of-life stages for INIES programme.

Parameter	Result (expressed per functional unit)
Collection process, specified by type	24.3 kg/m^2
Recovery system, type-specific	0 kg
Disposal, specified by type	24.3 kg to controlled landfill

Parameter	Result (expressed per functional unit)
Scenario development assumptions (e.g. transport)	The product waste is transported in a Euro 6 truck (27 t) to be managed by landfill. An average distance of 30km from the building site to treatment plant to the. Also included is the return journey of the lorries (100% empty return).

3.5. Module D. Potential environmental benefits and loads from reuse, recovery, and recycling activities

Module D reports the existence of environmental credits, i.e. avoided environmental impacts due to the reuse, recovery or recycling of the net system output streams of modules A4-C4, as well as the net environmental loads resulting from recycling operations. Each recycled waste stream is credited with the avoided production of the raw material it would be displacing in the technosphere if recycled, considering specific efficiencies for each material (Table 13). In Module D they are calculated for substitution purposes only for the resulting net output stream.

Loads were assumed to be avoided by:

a. Valorising (recycling and incinerating) packaging waste generated in the construction stage (section 3.2.2.1.)

The recycling efficiencies are detailed in Table 13

Table 13 Assumptions made for module D

Type of waste	Qs/Qp	Replaced product
Cardboard	95%	Corrugated cardboard
Plastic	80%	LDPE film
Wood	95%	Pine wood fibres

The formula applied for calculating the impact corresponding to Module D is

$$D = (R_2 - R_1) \times \left(E_{recycled} - E^{*}V\right) \times \frac{Q_P}{Q_S}$$

Where:

R_2: is the amount of material leaving the system that will be recovered in a downstream system. This quantity corresponds to the waste generated in modules A4, A5, B and C that is destined for recycling. Expressed in kg.

R_1: is the amount of input material into the product system that has been recovered from a previous system. Expressed in kg.

$E_{recycled}$: It is the amount of material leaving the system that will be recovered in a subsequent system. This quantity corresponds to the waste generated in modules A4, A5, B, and C that are destined for recycling. Expressed in kilograms.

E*V It is the environmental burden associated with the material, from cradle to the point of functional equivalent, where it would replace the secondary material used in the subsequent system.

Q_R/Q_S: It is the quality ratio between the recovered (recycled) output material and the substituted material. These ratios are presented Table 13.

3.6. Input and output calculations and allocation rules

In accordance with the standards and PCRs [23][18][15], whenever possible, the causality principle was applied when it came to allocating the inputs and outputs in processes with multiple inputs and/or outputs. Therefore, it was sought to establish the existing physical relationship between system inputs and outputs and their different products. When this was not possible, the mass and volume criterion was applied. Generally, in the allocation of inputs and outputs to the functional unit, production-weighted averages, both in mass and in m^2, were calculated, as set out below.

- The consumption of raw materials, water, thermal energy and electrical energy, as well as the generation of waste and atmospheric emissions of particles in the stage of preparation of raw materials for the support and acid emissions in the combustion processes have been provided by the spray dryer manufacturing companies and correspond to general data for the year 2022. In order to allocate these inputs and outputs to the Functional Unit, the production of spray dryer granules of each plant has been considered.

- The indicators of electrical and thermal energy consumption in the manufacturing stage of ceramic pieces, quantities of glaze, and packaging materials come from general data from the year 2022 (except for 2 companies whose data are from 2021). In order to allocate these inputs and outputs to the Functional Unit, a production criterion for each plant has been considered.

- To obtain the average value of atmospheric emissions per process stage, the statistical measure "median" has been applied.

In the inventory table (Annex 1), you will find a detailed description of the considerations taken for each parameter.

With relation to other calculation consideration, the following may be noted:

- The recycling processes, whose resulting secondary material, was part of another system and were modelled as open cycles, i.e. the recycling processes were allocated to the product made from the secondary raw materials (and not to the products being studied). Thus, in the case of recycling factory waste, such as packaging or end-of-life waste, only the collection and transportation process from the manufacturing plant to the treatment site was included. The benefits and environmental loads stemming from recycling the wastes generated in A4-C4 modules are declared in D module.

3.7. Data validation

Annex 2: Sources of the data used details the sources of the information used.

3.8. Biogenic carbon content

As required by standard EN 1580:2012+A2:2020 [18], the carbon content of both the product and its packaging was separately declared.

In the case of the product at issue, ceramic coverings, the covering components were inorganic, so that the biogenic carbon calculation did not apply. In regard to the packaging used for covering distribution, its mass was less than 5% of the total product mass, so that the declaration of packaging biogenic carbon content was omitted. The mass percentage of the packaging used was declared for each type of studied covering in Table 14.

Table 14 Packaging amount in the product

Packaging material	Quantity (kg/m²)	% (by weight)
Cardboard	1.3E-01	0,6%
Plastic	3.3E-02	0,2%
Wood	2.6E-01	1,3%

4. Life Cycle Impact Assessment (LCIA)

The results obtained are relative expressions and do not predict impacts in endpoint categories, exceedance of levels, safety margins, or risks.

The results shown include both the direct material and energy outputs and inputs of the factory and those from previous and subsequent processes that are carried out throughout the considered product life cycle. Thus, they include, for example, emissions from raw materials extraction and processing or those from the different transportations required.

The considered stages in this study are shown in Table 3.

The inventory data were modelled using LCA for experts software0 with the support of the databases [33].

4.1. Environmental impact categories

The selected impact categories and flow indicators, the applied impact assessment methods and the characterisation factors used were those recommended by standard EN 15804:2012+A2:2019 [18] included in the Environmental Footprint method. The applied characterisation factors were those of the Eq-jrc available at the following Web link: https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml. The environmental impact parameters to be declared were divided into basic (to be declared in the EPD) and additional (to be included in the LCA report and that can be declared in the EPD).

Table 15 Basic environmental impact categories

Basic environmental impact category parameters	Abbreviation	Unit(*)
Global warming potential[a]	GWP-total[a]	kg CO_2 equivalent
Global warming potential of fossil fuel	GWP-fossil	kg CO_2 equivalent
Biogenic global warming potential	GWP-biogenic	kg CO_2 equivalent
Global warming potential of land use and change of land use[b]	GWP-luluc[b]	kg CO_2 equivalent
Stratospheric ozone layer depletion potential	ODP	kg CFC 11 equivalent
Acidification potential, accumulated exceedance	AP	mol H+ equivalent
Eutrophication potential of fresh water	EP-freshwater	kg PO_4 equivalent
Eutrophication potential of marine water	EP-marine	kg N equivalent
Eutrophication potential, accumulated exceedance	EP-terrestrial	mol N equivalent
Tropospheric ozone formation potential	POCP	kg NMVOC equivalent
Depletion potential of abiotic resources for minerals and metals[c d]	ADP - minerals&metals	kg Sb equivalent
Depletion potential of abiotic resources for fossil resources[c]	ADP-fossil	MJ, net calorific value
Water deprivation potential	WDP	m^3 world equivalent deprived

[a] Total GWP is the sum of: GWP-fossil, GWP-biogenic, and GWP-luluc

[b] GWP-luluc may be omitted as separate information if its contribution is <5% of total GWP in the declared modules, excluding module D.

[c] The abiotic depletion potential is calculated and declared by means of two different parameters:
- ADP-minerals&metals includes all resources of non-renewable abiotic materials (i.e. excluding fossil resources)
- ADP-fossil includes all fossil resources and also uranium

[d] Last reserve model of the ADP-minerals&metals model.

*Expressed per functional unit

Table 16 Additional environmental impact categories

Additional environmental impact category parameters	Abbreviation	Unit(*)
Emissions of particulate matter	PM	Disease incidence
Ionising radiation, human health	IRP	kBq U235 equivalent
Ecotoxicity fresh water	ETP-fw	CTUe
Human toxicity, carcinogenic effects	HTP-c	CTUh
Human toxicity, non-carcinogenic effects	HTP-nc	CTUh

Additional environmental impact category parameters	Abbreviation	Unit(*)
Impacts related to land use and quality	SQP	dimensionless

*Expressed per functional unit

The results obtained are relative expressions and do not predict impacts in endpoint categories, exceedance of levels, safety margins, or risks.

4.2. Parameters relative to resource use, waste production, and output materials

The following tables set out the parameters relative to resource use, waste production, and output materials assessed.

Table 17 Parameters relative to resource use.

Parameter	Abbreviation	Unit(*)
Use of renewable primary energy excluding renewable primary energy resources used as raw material	PERE	MJ, net calorific value
Use of renewable primary energy used as raw material	PERM	MJ, net calorific value
Total use of renewable primary energy (primary energy and renewable primary energy resources used as raw material)	PERT	MJ, net calorific value
Use of non-renewable primary energy, excluding non-renewable primary energy resources used as raw material	PENRE	MJ, net calorific value
Use of non-renewable primary energy used as raw material	PENRM	MJ, net calorific value
Total use of non-renewable primary energy (primary energy and primary energy resources used as raw materials)	PENRT	MJ, net calorific value
Use of secondary materials	SM	kg
Renewable secondary fuel use	RSF	MJ, net calorific value
Non-renewable secondary fuel use	NRSF	MJ, net calorific value
Net use of running water resources	FW	m^3

*Expressed per functional unit

Table 18 Parameters relating to waste production and output materials.

Parameter	Abbreviation	Unit(1)
Hazardous waste removed	HWD	kg
Non-hazardous waste removed	NHWD	kg
Radioactive waste removed	RWD	kg
Output of components intended for reuse	CRU	kg
Output of materials intended for recycling	MFR	kg
Materials for energy valorisation (energy recovery)	MER	kg
Exported energy	EE	MJ (per energy vector)

*Expressed per functional unit

The results obtained are relative expressions and do not predict impacts in endpoint categories, exceedance of levels, safety margins, or risks.

4.4. Results of ceramic coverings

Table 19, Table 20 and Table 21 present the results of the impact categories for the FDES associated with sectoral ceramic covering profile.

Table 19 Results of environmental impacts (1) for 1 m² of sectoral ceramic covering covering.

	GWP-GHG	GWP-total	GWP-fossil	GWP-biogenic	GWP-luluc	ODP	AP
	[kg CO_2 eq.]	[kg CO_2 eq.]	[kg CO_2 eq.]	[kg CO_2 eq.]	[kg CO_2 eq.]	[kg CFC11 eq.]	[mol H+ eq.]
A1-A3	11.9	12.1	12.0	3.0E-02	6.9E-03	2.0E-08	2.9E-02
A4	0.6	0.6	5.7E-01	-6.3E-03	4.3E-03	6.7E-14	3.7E-03
A5	1.6	1.6	1.6	-5.9E-04	1.3E-03	1.0E-09	3.7E-03
B1	0	0	0	0	0	0	0
B2	2.3E-01	2.5E-01	2.4E-01	2.0E-03	1.8E-05	1.1E-07	2.6E-03
B3	0	0	0	0	0	0	0
B4	0	0	0	0	0	0	0
B5	0	0	0	0	0	0	0
B6	0	0	0	0	0	0	0
B7	0	0	0	0	0	0	0
C1	0	0	0	0	0	0	0
C2	6.3E-02	6.4E-02	6.5E-02	-8.7E-04	5.8E-04	8.2E-15	6.2E-05
C3	0	0	0	0	0	0	0
C4	1.1E-01	1.1E-01	1.1E-01	1.1E-03	4.7E-04	6.3E-14	8.1E-04
Module D	-2.0E-01	-2.1E-01	-2.1E-01	-8.9E-05	-5.4E-04	-4.3E-09	-6.8E-04
Total	14.4	14.7	14.6	2.5E-02	1.3E-02	1.3E-07	3.9E-02

NOTE 1: Global warming potential. UNE EN15804:2012+A1:2014 (**GWP-GHG**); Total global warming potential (**GWP-total**); Global warming potential of fossil fuels (**GWP-fossil**); Biogenic global warming potential (**GWP-biogenic**); Global warming potential of land use and change of land use (**GWP-luluc**); Stratospheric ozone layer depletion potential (**ODP**); Acidification potential (**AP**); Eutrophication potential of fresh water (**EP-freshwater**).

Table 20 Results of environmental impacts (2) for 1 m² of sectoral ceramic covering covering.

	EP-freshwater	EP-marine	EP-terrestrial	POCP	ADP-m&m (1)	ADP-fossil (1)	WPD (1)
	[kg eq.]	[kg N eq.]	[mol N eq.]	[kg NMVOC eq.]	[kg Sb eq.]	[MJ]	[m³]
A1-A3	9.0E-05	9.3E-03	1.0E-01	2.7E-02	5.8E-05	182.0	2.2
A4	1.7E-06	9.2E-04	1.0E-02	2.7E-03	3.2E-08	7.5	5.7E-03
A5	6.7E-06	1.2E-03	1.3E-02	3.4E-03	3.1E-06	15.2	0.2
B1	0	0	0	0	0	0	0
B2	6.0E-06	2.8E-04	1.1E-02	1.9E-03	1.7E-08	1.5	13.7
B3	0	0	0	0	0	0	0
B4	0	0	0	0	0	0	0
B5	0	0	0	0	0	0	0
B6	0	0	0	0	0	0	0
B7	0	0	0	0	0	0	0
C1	0	0	0	0	0	0	0
C2	2.3E-07	1.8E-05	2.2E-04	5.8E-05	4.2E-09	0.9	7.6E-04
C3	0	0	0	0	0	0	0
C4	2.3E-06	2.2E-04	2.4E-03	6.5E-04	1.1E-08	1.5	8.3E-03
Module D	-1.7E-06	-2.1E-04	-2.2E-03	-5.6E-04	-8.0E-08	-3.5	-4.8E-03
Total	1.1E-04	1.2E-02	1.4E-01	3.6E-02	6.1E-05	208.5	16.1

NOTE: Eutrophication potential of fresh water (**EP-freshwater**); Eutrophication potential of marine water (**EP-marine**); Eutrophication potential. accumulated exceedance (**EP-terrestrial**); Tropospheric ozone formation potential (**POCP**); Depletion potential of abiotic resources for minerals and metals (**ADP-m&m**); Depletion potential of abiotic resources for fossil resources (**ADP-fossil**); Water deprivation potential (**WDP**).

	EP-freshwater	EP-marine	EP-terrestrial	POCP	ADP-m&m (1)	ADP-fossil (1)	WPD (1)
	[kg eq.]	[kg N eq.]	[mol N eq.]	[kg NMVOC eq.]	[kg Sb eq.]	[MJ]	[m³]
Warning 1: The results of these environmental impact indicators should be used with caution. as the uncertainties of the results are high and experience with this parameter is unlimited.							

Table 21 Results of additional environmental impacts for 1 m² of sectoral ceramic covering covering.

	PM (1)	IRP (2)	ETP-fw (1)	HTP-c (1)	HTP-nc (1)	SQP (1)
	[incidence of diseases]	[kBq U235 eq.]	[CTUe]	[CTUh]	[CTUh]	[dimensionless]
A1-A3	1.4E-05	3.2E-01	29.5	3.2E-09	6.7E-08	82.6
A4	6.1E-08	2.0E-03	5.3	1.1E-10	4.6E-09	2.6
A5	7.9E-07	4.8E-02	4.2	3.1E-10	1.4E-08	12.4
B1	0	0	0	0	0	0
B2	1.7E-08	1.9E-03	7.4E-01	8.7E-11	1.0E-08	279.0
B3	0	0	0	0	0	0
B4	0	0	0	0	0	0
B5	0	0	0	0	0	0
B6	0	0	0	0	0	0
B7	0	0	0	0	0	0
C1	0	0	0	0	0	0
C2	4.8E-10	2.4E-04	6.2E-01	1.3E-11	5.6E-10	3.6E-01
C3	0	0	0	0	0	0
C4	9.8E-09	1.9E-03	8.8E-01	1.1E-10	1.2E-08	3.4E-01
Module D	-3.8E-09	-9.3E-03	-1.0E+00	3.5E-12	-1.0E-09	-1.5
Total	1.5E-05	3.8E-01	41.3	3.8E-09	1.1E-07	377.3

NOTE: Emissions of particulate matter (**PM**); Ionising radiation. human health (**IRP**); Ecotoxicity fresh water (**ETP-fw**); Human toxicity. carcinogenic effects (**HTP-c**); Human toxicity. non-carcinogenic effects (**HTP-nc**); Impacts related to land use and quality (**SQP**).

Warning 1: The results of these environmental impact indicators should be used with caution. as the uncertainties of the results are high and experience with this parameter is unlimited.

Warning 2: This impact category deals mainly with potential impacts of low doses of ionising radiation on human health from the nuclear fuel cycle. It does not consider effects due to possible nuclear accidents or occupational exposure due to disposal of radioactive waste in underground facilities. Ionising radiation potential from soil. from radon or from some building materials is not measured with this parameter.

In addition, Table 22 and Table 23 present the parameters describing the resource use and waste categories generated over the life cycle considered, as well as environmental information describing other output streams for porcelain stoneware for the FDES of the INIES programme.

Table 22 Results of the resource use parameters for 1 m² of sectoral ceramic covering covering.

	PERE	PERM	PERT	PENRE	PENRM	PENRT	SM	RSF	NRSF	FW
	[MJ, net calorific value]	[MJ, net calorific value]	[MJ, net calorific value]	[MJ, net calorific value]	[MJ, net calorific value]	[MJ, net calorific value]	[kg]	[MJ, net calorific value]	[MJ, net calorific value]	[m³]
A1-A3	41.4	0	41.4	183.0	0	183.0	0	0	0	3.9E-02
A4	4.6E-01	0	4.6E-01	7.5	0	7.5	0	0	0	5.1E-04
A5	3.7	0	3.7	15.2	0	15.2	0	0	0	4.0E-03
B1	0	0	0	0	0	0	0	0	0	0
B2	5.7	0	5.7	1.5	0	1.5	0	0	0	1.8E-01
B3	0	0	0	0	0	0	0	0	0	0

	PERE	PERM	PERT	PENRE	PENRM	PENRT	SM	RSF	NRSF	FW
	[MJ, net calorific value]	[MJ, net calorific value]	[MJ, net calorific value]	[MJ, net calorific value]	[MJ, net calorific value]	[MJ, net calorific value]	[kg]	[MJ, net calorific value]	[MJ, net calorific value]	[m³]
B4	0	0	0	0	0	0	0	0	0	0
B5	0	0	0	0	0	0	0	0	0	0
B6	0	0	0	0	0	0	0	0	0	0
B7	0	0	0	0	0	0	0	0	0	0
C1	0	0	0	0	0	0	0	0	0	0
C2	6.3E-02	0	6.3E-02	0.9	0	0.9	0	0	0	6.8E-05
C3	0	0	0	0	0	0	0	0	0	0
C4	1.7E-01	0	1.7E-01	1.5	0	1.5	0	0	0	2.8E-04
Module D	-3.0	0	-3.0	-3.5	0	-3.5	0	0	0	-1.9E-03
Total	**51.5**	**0**	**51.5**	**209.6**	**0**	**209.6**	**0**	**0**	**0**	**2.2E-01**

NOTE: Use of renewable primary energy excluding renewable primary energy resources used as raw material **(PERE);** Use of renewable primary energy used as raw material (**PERM);** Total use of renewable primary energy (primary energy and renewable primary energy resources used as raw material) (**PERT**); Use of non-renewable primary energy, excluding non-renewable primary energy resources used as raw material (**PENRE**); Use of non-renewable primary energy used as raw material (**PENRM);** Total use of non-renewable primary energy (primary energy and primary energy resources used as raw materials) (**PENRT**); Use of secondary materials (**SM**); Renewable secondary fuel use (**RSF**); Non-renewable secondary fuel use (**NRSF**); Net use of running water resources (**FW).**

Table 23 Results of parameters related to waste generation and other parameters describing other outflows for 1 m² of sectoral ceramic covering covering.

	HWD	NHWD	RWD	CRU	MFR	MER	EE
	[kg]	[kg]	[kg]	[kg]	[kg]	[kg]	[MJ, per energy vector]
A1-A3	3,0E-02	4,7	3,8E-03	0	3,7E-01	0	0
A4	2,3E-11	1,1E-03	1,3E-05	0	0	0	0
A5	1,6E-03	1,4E+00	4,0E-04	0	1,5	0	0
B1	0	0	0	0	0	0	0
B2	6,4E-12	5,0E-02	1,8E-05	0	0	0	0
B3	0	0	0	0	0	0	0
B4	0	0	0	0	0	0	0
B5	0	0	0	0	0	0	0
B6	0	0	0	0	0	0	0
B7	0	0	0	0	0	0	0
C1	0	0	0	0	0	0	0
C2	2,7E-12	1,3E-04	1,6E-06	0	0	0	0
C3	0	0	0	0	0	0	0
C4	2,3E-08	6,8	2,0E-05	0	0	0	0
Module D	-3,4E-08	-8,8E-04	-2,2E-05	0	0	0	0
Total	**3,2E-02**	**13,0**	**4,3E-03**	0	**1,8**	0	0

NOTE: Hazardous waste removed (**HWD**); Non-hazardous waste removed (**NHWD**); Radioactive waste removed (**RWD**); Output of components intended for reuse (**CRU**); Output of materials intended for recycling (**MFR**); Materials for energy valorisation (energy recovery) (**MER**); Exported energy (**EE**).

5. Interpretation of results

5.1. Discussion of results

In the following sections, the contribution of each stage of the life cycle of the assessed impact categories is presented for ceramic coverings.

The results obtained in the environmental impact assessment of the average ceramic covering profile are shown in Figure 3 for the basic impact categories, respectively, according to EN 15804+A2 [18]

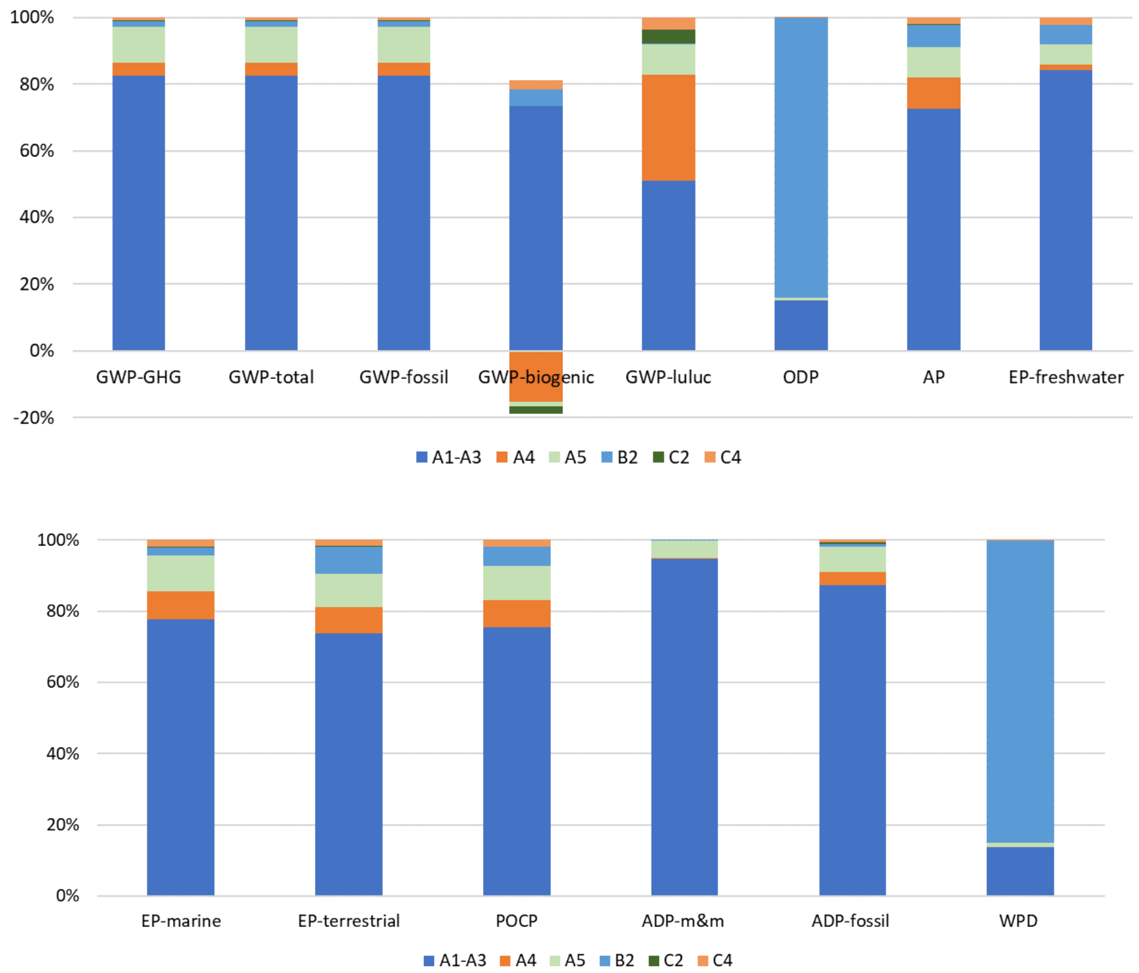

Figure 3 Environmental profile of ceramic coverings.

The extraction and transport of the raw materials of the support contribute 39% in EP-freshwater and 27% in GWP-luluc, with contributions; in the rest of the impacts, the contribution of these processes is equal to or less than 14%.

Glazes, for which data is taken from the sectoral LCA report conducted in 2018, account for 1.16kg/m^2 of CO_2 equivalent, i.e. almost 8.5% of the total GWP.

The preparation of the raw materials to obtain the spray-dried granules accounts for around 20% of the ADP-fossil and GWP impacts due to the consumption of natural gas in spray drying; the rest of the impacts generated by this stage account for less than 8.5% of the total life cycle.

The manufacture of ceramic coverings is the stage with the greatest impact, mainly due to the consumption of natural gas in the drying and firing operations. Specifically, this stage accounts for 46% of the GWP, the origin of which mainly comes from the consumption of natural gas and the decarbonation of ceramic compositions. Natural gas consumption in these stages accounts for almost 50% of the consumption of fossil resources (ADP-fossils). This stage contributes between 10-23% to the impact categories AP, EP (all) and POCP. The rest account for impacts of less than 6.5%.

As for the distribution stage, the use of fuels in road transport has an impact of 34% of the GWP-luluc and 21% of the biogenic GWP, due to the biodiesel loading of the fuel selected from the data (see section 2.2.5.). In all other environmental impact categories it contributes less than 10%.

The installation stage, on the other hand, contributes more than 2% in almost all the impact categories analysed, as a consequence of the mortar used for ceramic covering installation.

Maintenance considers the cleaning of ceramic covering for 50 years with water and detergent. These two flows are responsible for >85% in ODP and WPD due to the use of detergent (use of defoamers in the synthesis) and water consumption, respectively.

End-of-life is an insignificant stage, the greatest impact of which is GPW-luluc (7.4% of the total) due to the landfilling of 30% of the ceramic coverings in landfills; the rest does not account for more than 2% in any of the impact categories.

5.2. Parameters contribution

According to Annex O from NF EN 1504+A2/CN2022, a contribution relative assessment was carried out in order to determine the most influent parameters and classify them.

In this regard, the relative contribution of each process and parameter from the inventory table have been assessed for the GWP-total and WDP categories impact, ordering them from higher to lower impact. Processes were classified in three different groups, according to Annex O from NF EN 1504+A2/CN2022:

- Group 1: processes with a relative accumulated impact to 50%.

- Group 2: processes at group 1 and others processes with high impact, to account a relative accumulated impact of 80%.

- Group 3: other processes different to those of group 1 and group 2.

The results obtained for the sectoral ceramic covering profile are shown in Table 24 and Table 25.

Table 24. Parameters contribution ceramic covering profile (accumulative %) for GWP-total impact.

Group	Process	GWP-total
		% accumulative
Group 1	Thermal energy from natural gas for drying and firing	48
	Thermal energy from natural gas for spray drying	68
Group 2	Transport from manufacturing plant to installation site	81
Group 3	Other processes	100

Table 25. Parameters contribution for ceramic covering profile (accumulative %) for WDP

Group	Process	WDP
		% accumulative
Group 1,2	Water used for product installation	85
Group 3	Other processes	100

5.3. Sensitivity assessment

The relevance of the significant parameters and their influence on the results are analysed below. The GaBi Analyst function of the GaBi 10.7.0.183. software program [32] was used to simulate changes in the value of each parameter and to calculate the corresponding results.

To start with, those parameters were identified whose variability at 99% could cause the result to change for the global warming potential-total (GWP-total) impact category, according to EN 1580+A2 standard.

Table 26 summarises those parameters whose variation ±99% on the average initial value would modify the value of the selected impact indicator by more than 2% (in absolute value) for sectoral ceramic covering.

Table 26 Parameter variation by more than 2% (in absolute value) for sectoral ceramic covering

Parameter	Parameter variation GWP (%)
Quantity of raw materials for the substrate (raw weight)	35%
Natural gas consumption in firing and drying of ceramic covering	32%
Natural gas consumption in spray drying	16%
Quantity of glaze	8%
Obtaining raw materials for the substrate	7%
Mortar used for ceramic covering installation	6%
CO2 atmospheric emissions from the decomposition of raw materials	6%
Obtaining raw materials for the glaze	5%
Consumption of electrical energy in covering production	4%
Electricity generated from natural gas	4%
Distribution of ceramic coverings	3%

The most sensitive parameter for the global warming potential (GWP) category is the quantity of spray-dried granules used for the ceramic body, as this is the basis for the calculation of other inputs and outputs, followed by the thermal energy consumption in the drying and firing stages in the ceramic covering and spray-dried granule drying, as the combustion heat from natural gas is used to obtain the energy required in these processes.

Other sensitive inventory parameters are the extraction processes of the raw materials present in the ceramic substrates, as well as the transport required for the distribution of the finished coverings and the consumption of electrical energy in the covering manufacturing plant.

5.4. Constraints

The main constraints of the study were as follows:

- Obtaining updated manufacturing data for decoration materials proved challenging. This was addressed by utilizing bibliographic and sectorial data [2]
- Assigning water consumption, electrical and thermal energy, and atmospheric particle emissions from aspirations at different stages of the ceramic covering manufacturing process in a specific manner, carried out at some of the facilities of the participating companies in the project. This was addressed by grouping these consumptions by plant.

Except for the data used to assess the product stage, primary data developed through the hypotheses outlined in the RCP [15] have been employed in all other cases. It's crucial to note that the results calculated here are specific to the established hypotheses and may vary under different criteria and assumptions.

Despite the outlined limitations, it is deemed that the results obtained in this study are representative as they are based in current information provided by the participating companies.

5.5. Análisis de calidad de datos

5.5.1. Uncertainty

The precision and accuracy of the data chosen from the databases used [33] and [34] have been evaluated by their authors and it has been obtained that the degree of uncertainty is acceptable with the objective to be presented in the report.

On the other hand, the deviation of the data provided by the companies has been calculated and processed to obtain production-weighted averages.

Nevertheless, the data provided in this study is considered to have a low degree of uncertainty, since it refers to information from the companies and has been explained in detail by those responsible for the companies participating in the study.

5.5.2. Integrity

All the major processes in the system analysed were included, and 95% of all the material and energy inputs and outputs of the analysed system were considered.

The life cycle of these ceramic covering was modelled with the DAPCER tool, developed with LCA for experts (GaBi) 10.6.2.9. and 235 flows were parameterised of each type of ceramic covering. Of these flows:

- 57% of the data has been directly provided by the manufacturers of atomized granule and ceramic coverings. This information is related to the production of spray-dried powder and the manufacturing of formed coverings. Specifically, it includes the type and quantity of raw materials required for ceramic body manufacturing and their origins, thermal and electrical energy, water consumption, packaging quantities and origin, atmospheric emissions, and waste generation.
- 16% of the data has been obtained from previous bibliographic sources and sector-specific information, exclusively referring to the manufacturing of decoration materials.
- 20% of the data has been sourced from bibliographic references and solely pertains to the management of packaging waste.
- 6% of the data has been defined through hypotheses, as outlined in Section 2.2.5 of this study and the PCR [15].

5.5.3. Representativeness

The primary data used for this study represents 55% of Spanish ceramic covering production in 2022.

Data quality was assessed as required by EN 15804+A2 [18], applying UNEP criteria [25] to evaluate their technological, geographic, and time-related representativeness. Annex 2 sets out the score of each dataset with relation to these three criteria, considering a 5-point rating scale: very good (1 point), good (2 points), average (3 points), poor (4 points), and very poor (5 points).

All the generic data included is available in the current ILCD format. Generally, the level of temporal representativeness of the secondary data is good."

5.5.3.1. Time-related coverage

The manufacturer-specific data represent a full year and correspond to the years 2022 and 2021 and are therefore less than 5 years old.

As for the generic data taken from the databases, they are not older than 10 years with respect to the reference year of study, 2022.

All generic data included are available in the current ILCD format. In general, the level of temporal representativeness of the secondary data is good.

Whenever possible, data referring to the country in which the process in question takes place have been used or, when this was not possible, regional or global data have been applied (see Annex 2).

The level of geographical representativeness of the primary data used is very good and, in general, good for secondary data.

5.5.3.2. Geographic coverage

Wherever possible, data were used relating to the country in which the process at issue was developed or, when this was not possible, regional or global data were applied (see Annex 2). For more information, see Annex 2.

The level of geographic representativeness of the primary data used was very good and, in general, that of the secondary data was good.

5.5.3.3. Technological coverage

The data used reflected the technological reality of the system analysed.

The level of technological representativeness of the primary data used was very good and, in general, that of the secondary data was good.

5.5.4. Consistency

To assure the consistency of the data used, the professional database with the construction materials extension *LCA for Experts (Sphera)* 0 were always used. When it came to combining these data with the directly measured data in the factory, ILCD good practices criteria were followed.

5.5.5. Reproducibility

The methods and data used are described so that independent professionals, provided they have the same databases, can reproduce the same results. For the sake of confidentiality, models of commercial databases could not be reproduced in the report (though they may be consulted if they are acquired); in contrast the data calculated or added by the authors are described in detail (see Annex 2).

5.6. Selection of values, reasons, or expert statements

In the present study, different experts were consulted, their conclusions being applied in accordance with the study aim. Assumptions were made both for the energy consumptions and for the production processes of different raw materials.

Treatment of sectoral data

- The information collected from the manufacturers has been treated statistically on an individual basis and, subsequently, a collective treatment has been carried out, studying the dispersion of the data, eliminating non-logical values in order to, finally, make averages weighted by the production of each of the participating companies.

Production processes:

- The carbonate production process was taken as being from limestone, as its major component is carbonate.

Water consumption:

- For the water consumed in the ceramic covering manufacturing process (A3) and maintenance (B2), a process has been chosen that allows regionalisation to the target country.

Infrastructures:

- Following the recommendations of the LCA community, infrastructure use was not included in the inventory, as its environmental impact per unit product was low in relation to the other processes that are included.

6. Available verification data

The GaBi (Sphera) 10.6.2.9. software program was used in the Life Cycle Assessment study. The models created using this program can be consulted by accredited verifiers of INIES program.

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8. Annexes

Annex 1. Inventory data of the life cycle of ceramic coverings

Table A1. 1 below shows the inventory data provided by the companies under study.

Table A1. 1 Table of ceramic covering life cycle inventory data of the companies under study (production-weighted average).

Parameters	Units	Weighted average
I. MANUFACTURE OF THE PRODUCT		
SUPPLY OF RAW MATERIALS (A1)		
Raw materials for ceramic body		
Weight of raw ceramic body	kg/m^2	**22.03**
Clay	expressed as decimal	**0.5234**
Sand	expressed as decimal	**0.0675**
Kaolin	expressed as decimal	**0.0363**
Feldspar	expressed as decimal	**0.2575**
Carbonates	expressed as decimal	**0.0325**
Deflocculant	expressed as decimal	**0.0067**
Pigments	expressed as decimal	**0.0029**
Recycled/reintroduced	expressed as decimal	**0.0732**
Raw materials for decoration		
Borates	expressed as decimal	**0.0353**
Carbonates	expressed as decimal	**0.0964**
Quartz	expressed as decimal	**0.2351**
Feldspars	expressed as decimal	**0.2364**
Kaolin	expressed as decimal	**0.0721**
Silicates	expressed as decimal	**0.0302**
Zinc oxide	expressed as decimal	**0.047**
Zirconium	expressed as decimal	**0.1392**
Alumina	expressed as decimal	**0.0142**
Clay	expressed as decimal	**0.0335**
Other	expressed as decimal	**0.0606**
TRANSPORT (A2)		
Transport of raw materials for the support		
Regional (150km truck 27t)	expressed as decimal	**0.5691**
National (500km truck 27t)	expressed as decimal	**0.1000**
North Spain (900km truck 27t)	expressed as decimal	**0.0035**
France (1500km truck 27t)	expressed as decimal	**0.0017**
Italy (1000km vessel+200km truck 27t)	expressed as decimal	**0.0830**
Romania & Turkey (3000km vessel+200km truck 27t)	expressed as decimal	**0.2023**
Ukraine (3500km vessel+200km truck 27t)	expressed as decimal	**0.0069**
United Kingdom (4200km ship+200km truck 27t)	expressed as decimal	**0.0336**
Transport of raw materials for decoration		
Distance of 500km by 27t truck	expressed as decimal	**0.371**
Distance of 2000km by 27t truck	expressed as decimal	**0.234**
Distance of 3500 km by freighter	expressed as decimal	**0.231**
Distance of 10000 km by freighter	expressed as decimal	**0.164**
COVERING MANUFACTURING (A3)		

Parameters	Units	Weighted average
Milling of raw materials		
Dry milling		
Dry milling	expressed as decimal	**0.004**
Wet milling		
Wet milling	expressed as decimal	**0.996**
Purchased electricity	MJ/m²	**3.24**
Electricity generated on site by solar energy	MJ/m²	**6.67E-02**
Natural gas consumed (cogenerated thermal energy, self-consumed cogenerated electricity and gas from post-combustion burners)	MJ/m²	**32.84**
Consumption of ground water	l/m²	**3.32**
Consumption of tap water	l/m²	**4.85E+00**
Quantity of water recycled from external sources in milling	l/m²	**2.38**
Particulate matter emission in the spray dryer and general aspirations	mg/m²	**1092.89**
NOx emission in the spray drying (1)	mg/m²	**0**
SO2 emission in the spray dryer (1)	mg/m²	**0**
Moisture of the ceramic body before the dryer entry	expressed as decimal	**0.064**
Oils and fats in atomisation	kg/m²	**5.26E-03**
Alumina balls	kg/m²	**5.26E-03**
Diesel used for internal transport	kg/m²	**2.83E-04**
Hazardous waste in spray drying	kg/m²	**2.43E-01**
Manufacture of the formed covering		
Distance between spray dryer supplier and covering manufacturing plant	km	**21.00**
Forming and drying		
Thermal energy in drying (2)	MJ/m²	**0**
Particulate emissions	mg/m²	**251.92**
Nox emissions (1)	mg/m²	**0**
SO2 emissions (1)	mg/m²	**0**
Moisture of the parts at the exit of the dryer	expressed as decimal	**0.005**
Glazing		
Quantity of glazes	kg/m²	**0.57**
Glaze purchased milled	expressed as decimal	**0.34**
Glaze to be milled in covering factory	expressed as decimal	**0.66**
Quantity of inks	kg/m²	**0.01**
Ground water	l/m²	**3.40E+00**
Tap water	l/m²	**2.29E+00**
Recycled water from other companies	l/m²	**0.00**
Firing		
Thermal energy in drying + firing (natural gas) (2)	MJ/m²	**6.37E+01**
Particulate emissions	mg/m²	**6.89E+02**
NOx emissions	mg/m²	**0.00E+00**
SO2 emissions (1)	mg/m²	**1.85E+03**
HF emissions (1)	mg/m²	**3.64E+02**
Cov emissions	mg/m²	**1.48E+03**
Decarbonation	expressed as decimal	**4.67E-02**
Additional mechanical treatments		

Parameters	Units	Weighted average
Distance travelled for mechanical treatments	km	**1.14E+00**
Packaging of the finished product		
Cardboard	kg/m^2	**1.27E-01**
Film	kg/m^2	**2.26E-02**
Strapping	kg/m^2	**9.09E-03**
Non-reusable pallets	kg/m^2	**1.97E-01**
Europallets	kg/m^2	**6.78E-02**
Number of reuses of Europallets	times a pallet is reused	**5.00E+00**
Porexpan	kg/m^2	**1.77E-04**
Polypropylene	kg/m^2	**1.27E-03**
Distance from the cardboard factory. truck transport 27 t	km	**5.89E+01**
Distance from film factory. truck transport 27 t	km	**7.69E+01**
Distance from strapping factory. truck transport 27 t	km	**3.09E+01**
Distance from the covering pallet factory	km	**3.40E+01**
Distance from polystyrene covering factory	km	**4.65E+01**
Distance from the polypropylene factory. truck transport 27 t	km	**1.35E+01**
Aggregate data of the covering manufacturing plant		
Purchased electricity	MJ/m^2	**8.02E+00**
Electricity generated on-site by solar energy	MJ/m^2	**7.65E-02**
Particulate emissions from general aspiration (glazing. mechanical treatments. etc.)	mg/m^2	**3.92E+02**
Hazardous waste	kg/m^2	**1.98E-02**
Non-hazardous waste	kg/m^2	**3.42E+00**
Waste from fired ceramic coverings deposited in landfill sites	kg/m^2	**0.00E+00**
waste from raw ceramic coverings deposited at landfills	kg/m^2	**0.00E+00**
waste fired ceramic coverings that are recycled in another process	kg/m^2	**3.28E-01**
paper and cardboard wastes destined for recycling	kg/m^2	**1.12E-02**
waste wood going to recycling	kg/m^2	**1.52E-02**
plastic wastes going to recycling	kg/m^2	**1.77E-02**
diesel consumed in internal transport	kg/m^2	**3.20E-02**
alumina rollers	kg/m^2	**1.90E-03**
Press oils	kg/m^2	**3.04E-03**
Iron	kg/m^2	**6.82E-04**
Alumina distance	km	**6.67E+01**
Distance press oils	km	**3.89E+01**
Distance iron	km	**4.00E+00**
Waste water not reintroduced into the process	l/m^2	**1.62E-01**
Manufacture of engobes and glazes		
Ceramic frits	Expressed as decimal	**5.00E-01**
Water	l/kg of frit	**1.85E+00**
Electricity	MJ/kg of frit	**1.08E+00**
Thermal energy (natural gas) for frit melting	MJ/kg of frit	**1.05E+01**
BigBag packaging for 1 tonne of glaze	kg	**1.51E+00**
No. of reuses of BigBags (glazes)	number of times a bigbag is reused	**2.50E+01**

Parameters	Units	Weighted average
Pallet for 1 tonne of glaze	no. of pallets per tn glaze	1.00E+00
Mass of 1 coke of 800 l	kg/cocio	9.08E+00
No. of reuses of cokes (glazes)	number of times a cocio is reused	3.84E+00
Distance from the BigBags factory	km	2.19E+02
Distance from the coke factory	km	6.32E+01
Distance from the glaze pallet factory	km	1.40E+02
HCl emissions	mg/kg of frit	5.70E+01
HF emissions	mg/kg of frit	2.90E+01
NOx emissions	mg/kg of frit	8.62E+03
Particulate matter emissions	mg/kg of frit	2.30E+02
SO2 emissions	mg/kg of frit	1.30E+02
Heavy metal emissions (class1 + class2)	mg/kg of frit	2.90E+01
Oils and greases in glaze factory	kg/kg of frit	7.00E-02
Hazardous waste generated at the glaze factory	kg/kg of frit	1.00E-02
Non-hazardous waste generated at the glaze factory	kg/kg of frit	9.20E-01
Share of plastic packaging wastes that are landfilled	Expressed as decimal	2.58E-01
share of plastic packaging waste incinerated	Expressed as decimal	2.26E-02
share of plastic waste that is recycled	Expressed as decimal	7.19E-01
Share of wood waste that is incinerated	Expressed as decimal	2.28E-05
Share of wood waste to be recycled	Expressed as decimal	9.63E-01
Share of wood waste going to landfill	Expressed as decimal	3.69E-02
Distance between the point of generation and the point of management	km	1.00E+02
Distance between the colouring site and the covering factory	km	2.10E+01
II. CONSTRUCTION		
TRANSPORT (A4) and INSTALLATION AND CONSTRUCTION PROCESSES (A5)		
Transport		
Distribution in Spain	Expressed as decimal	0
Distribution in France	Expressed as decimal	1
Distribution to the rest of the world	Expressed as decimal	0
Distance considered in the distribution in Spain	km	3.00E+02
Distance considered in the distribution to Europe	km	1.39E+03
Distance considered in the distribution to the rest of the world (FREIGHTER)	km	6.52E+03
Packaging waste management		
Incinerated cardboard waste in Spain	Expressed as decimal	0.0000
Incinerated cardboard waste in Europe	Expressed as decimal	0.0000
Incinerated cardboard waste in the rest of the world	Expressed as decimal	0.0000
Recycled cardboard waste in Spain	Expressed as decimal	0.9906
Recycled cardboard waste in Europe	Expressed as decimal	0.9984
Recycled cardboard waste in the rest of the world	Expressed as decimal	0.9906
Waste cardboard deposited in landfills in Spain	Expressed as decimal	0.0094
cardboard waste sent to landfill in Europe	Expressed as decimal	0.0016
Waste cardboard deposited in landfill in the rest of the world	Expressed as decimal	0.0094
Wood waste incinerated in Spain	Expressed as decimal	0.0000
Wood waste incinerated in Europe	Expressed as decimal	0.0059

Parameters	Units	Weighted average
Incinerated wood waste in the rest of the world	Expressed as decimal	**0.0000**
Wood waste recycled in Spain	Expressed as decimal	**0.9630**
Wood waste recycled in Europe	Expressed as decimal	**0.9872**
Recycled wood waste in the rest of the world	Expressed as decimal	**0.9630**
Wood waste disposed of in landfills in Spain	Expressed as decimal	**0.0369**
Waste wood deposited in landfill in Europe	Expressed as decimal	**0.0069**
Waste wood deposited in landfill in the rest of the world	Expressed as decimal	**0.0369**
Incinerated plastic waste in Spain	Expressed as decimal	**0.0226**
Waste plastic incinerated in Europe	Expressed as decimal	**0.0046**
Plastic waste incinerated in the rest of the world	Expressed as decimal	**0.0226**
Recycled plastic waste in Spain	Expressed as decimal	**0.7192**
Recycled plastic waste in Europe	Expressed as decimal	**0.9279**
Recycled plastic waste in the rest of the world	Expressed as decimal	**0.7192**
Waste plastic deposited in landfills in Spain	Expressed as decimal	**0.2582**
Waste plastic deposited in landfill in Europe	Expressed as decimal	**0.0675**
Plastic waste to landfill in the rest of the world	Expressed as decimal	**0.2582**
Installation and construction process		
Percentage of covering waste in the installation process	Expressed as decimal	**5.34E-02**
Cementitious adhesive	kg/m^2	**3.30E+00**
Distance from adhesive factory	km	**1.00E+02**
Water for covering installation	l/m^2	**8.00E-01**
III. USAGE		
Service life	years of service life without replacement	**5.00E+01**
MAINTENANCE (B2)		
Weekly washing frequency	cleanings per week	**7.69E-01**
Water required for 1 wash	l/m^2	**1.00E-01**
Detergent required for 1 wash	kg/m^2	**8.38E-05**
Distance from detergent factory	km	**1.00E+02**
Electricity for 1 wash	MJ/m^2	**0.00E+00**
Thermal energy (natural gas) for 1 wash	MJ/m^2	**0.00E+00**
IV. END OF LIFE		
End-of-life management		
Recycling of coverings after their useful life	Expressed as decimal	**0**

(1) NOx and SO2 emissions in this stage are associated with the natural gas combustion process itself, and will therefore be attributed to natural gas, so the part corresponding to natural gas combustion has been eliminated from the emissions data provided for the inventory, in accordance with the emission factors published in [7]. The NOx emission factor is 69.31 mg/MJ of natural gas and the SO2 emission factor is 1.67 mg/MJ of natural gas.

(2) Thermal energy from covering drying accounted for in firing.

Annex 2. Source of data used

Table A2.1 sets out the source of the data used in the present Life Cycle Assessment study, as well as the data level of quality, where 1 is very good and 5 is very poor. The point score was made in accordance with the UN global guidance principles on the development of LCA databases [25] and NF EN 15804+A2/CN2022-10 [23].

Table A2.1 Source of the data used in the Life Cycle Assessment.

PROCESS				DATA LEVEL OF QUALITY		
				REPRESENTATIVENESS		
GENERAL PROCESSES	DATABASE	PROCESS NAME IN THE DATABASE		Geographic	Technical	Time-related
Raw materials extraction and transportation	Direct from companies	n.a.		1	1	1
Production of decoration materials	Sectoral data	n.a.		1	1	1
Milling	Direct from companies	n.a.		1	1	1
Spray drying	Direct from companies	n.a.		1	1	1
Forming	Direct from companies	n.a.		1	1	1
Drying	Direct from companies	n.a.		1	1	1
Decoration	Direct from companies	n.a.		1	1	1
Firing	Direct from companies	n.a.		1	1	1
Sorting and packaging	Direct from companies	n.a.		1	1	1
Plant energy consumption	Direct from companies	n.a.		1	1	1
Waste management model	Data from literature	n.a.		1	1	1
RAW MATERIALS						
Materias primas del soporte	**Compiled by author from company data**					
Kaolin production	Sphera - GaBi	EU-27: Kaolin fine, granular or powder, moisture content 0 to 30%, expressed in dry mass	2015-2025	2	2	1
Clay production	Ecoinvent 3.9.1	RoW_ Clay pit production	2023	2	1	1
Sand production	Sphera - GaBi	DE:Silica sand (flour)	2020-2023	3	1	1
Deflocculant production	Sphera - GaBi	GLO: Dispersion agent (mixture of phosphate with polyacrylate)	2016-2019	2	2	2
Feldspar production	Sphera - GaBi	IT: Feldspar (estimation)	2019-2022	3	3	1
Extraction and beneficiation of calcium carbonate	Sphera - GaBi	DE: Limestone flour (0.1mm) ts	2020-2023	3	1	1
Glaze raw materials	**Compiled by author from company data**					
Extraction and beneficiation of silicates	Sphera - GaBi	DE: Silica sand (flour),	2020-2023	3	1	1
Clay production	Ecoinvent 3.9.1	RoW_ Clay pit production	2023	2	1	1
Extraction and beneficiation of calcium carbonate	Sphera - GaBi	DE: Limestone flour (0.1mm) ts	2020-2023	3	1	1
Feldspar production	Sphera - GaBi	IT: Feldspar (estimation)	2019-2022	3	3	1
Kaolin production	Sphera - GaBi	EU-27: Kaolin fine, granular or powder, moisture content 0 to 30%, expressed in dry mass	2015-2025	2	2	1
Alumina production	Sphera - GaBi	EU-28: Aluminum oxide mix (alumina, Al2O3)	2016-2019	2	2	2
Borate production	Sphera - GaBi	EU-28: Borax pentahydrate	2019-2022	2	1	1

PROCESS				DATA LEVEL OF QUALITY		
				REPRESENTATIVENESS		
GENERAL PROCESSES	DATABASE	PROCESS NAME IN THE DATABASE		Geographic	Technical	Time-related
Extraction and beneficiation of zirconium	Sphera - GaBi	GLO: Zirconium dioxide (highly pure)	2019-2022	2	1	1
Quartz oxide production	Sphera - GaBi	ES: Siliceous sand (fine flour) (SiO2)	2020-2023	1	1	1
Zinc oxide production	Sphera - GaBi	DE: Zinc oxide (American process)	2019-2022	3	1	1
PACKAGING						
Wood production (pallets)	Sphera - GaBi	RER: EUR-flat pallet production (sin absorción)	2016-2019	2	2	2
Production of big bags	Sphera - GaBi	DE: Polypropylene fibers (PP) PE	2016-2019	3	2	2
Production of cocios	Sphera – GaBi	RER : Polypropylene injection moulding part (PP)	2020-2023	2	2	1
Production of corrugated cardboard for covering packaging	Sphera - GaBi	EU-28: Corrugated board e 2018. Average production	2018-2021	2	1	1
Film for covering packaging	Sphera - GaBi	DE: Polyethylene film (PE-LD; without additives)	2016-2019	3	1	2
Straps for covering packaging	Sphera - GaBi	RER: Polystyrene part (PS)	2005-2012	2	n.d	3
EPS (expanded polystyrene) for covering packaging	Sphera - GaBi	RER: EPS- expanded polystyrene (white, 25kg/m3, cradle-to-gate, A1-A5)	2012	2	1	3
FUELS, ELECTRICITY AND CONSUMABLES						
Fuel oil production	Sphera - GaBi	RER: Heavy fuel oil at refinery (1.0wt.% S)	2017-2023	2	1	1
Diesel fuel production	Sphera - GaBi	RER: Diesel mix at filling station ts (10 ppm sulphur, 7.23 wt.% bio components)	2017-2023	2	1	1
Thermal energy production from natural gas	Sphera - GaBi	ES: Thermal energy from natural gas ts	2017-2023	2	1	1
Production of press lubricating oil, greases, lubricants, etc.	Sphera - GaBi	RER: Lubricants at refinery	2017-2023	2	1	1
Alumina and balls rollers	Sphera - GaBi	EU-28: Aluminum oxide mix (alumina, Al2O3)	2016-2019	2	1	1
Electricity production	Custom creation based on the mix provided by REE using Sphera - GaBi processes	ES: electricity from biogas ts	2017-2023	1	1	1
		ES: electricity from biomass ts	2017-2023	1	1	1
		ES: electricity from hard coal ts	2017-2023	1	1	1
		IT: electricity from geothermal ts	2017-2023	3	1	1
		ES: electricity from heavy fuel oil (HFO) ts	2017-2023	1	1	1
		ES: electricity from hydropower ts	2017-2023	1	1	1
		ES: electricity from natural gas ts	2017-2023	1	1	1
		ES: electricity from nuclear ts	2017-2023	1	1	1
		ES: electricity from photovoltaic ts	2017-2023	1	1	1
		ES: electricity from solar thermal	2017-2023	1	1	1
		ES: electricity from waste ts	2017-2023	1	1	1
		ES: electricity from wind ts	2017-2023	1	1	1
WATER						
Ground water supply	Sphera - GaBi	ES: Tap water ts (from groundwater)	2020-2023	1	1	1
Tap water supply	Sphera - GaBi	DE: Potable water from groundwater PE	2016-2019	3	1	2
Recirculated water from other companies	-	Sin impacto asociado	-	n.a.	n.a.	n.a.
TRANSPORTATION						

PROCESS				DATA LEVEL OF QUALITY REPRESENTATIVENESS		
GENERAL PROCESSES	**DATABASE**	**PROCESS NAME IN THE DATABASE**		**Geographic**	**Technical**	**Time-related**
Road transport by truck	Sphera - GaBi	GLO: Truck trailer de 27t payload EURO 6	2020-2023	2	1	1
		EU-28:Articulated lorry transport incl. fuel, Euro 0-6 mix,27 t	2020-2023	2	1	1
		GLO: Truck trailer de 22t payload EURO 6	2019-2022	2	1	1
		GLO: Truck trailer de 17,3t payload EURO 6	2020-2023	2	1	1
Maritime transport	Sphera - GaBi	GLO: Bulk commodity carrier (average)/ocean GLO	2020-2023	2	1	1
WASTE MANAGEMENT AND AVOIDED LOADS						
Management of construction and demolition waste at landfill	Sphera - GaBi	EU-28: Inert matter (Unspecific construction waste) on landfill	2016-2019	2	1	2
Pallet disposal at landfill	Sphera - GaBi	EU-28:Vertedero pallet (Commercial waste for municipal disposal; ES, GR, PT	2020-2023	1	1	1
Incineration of Wood and cardboard	Sphera - GaBi	EU-28: Commercial waste in municipal waste incineration plant	2020-2023	2	3	1
Incineration of plastics	Sphera - GaBi	EU-28: Plastic packaging in municipal waste incineration plant	2020-2023	2	2	1
Plastics and cardboard disposal at landfill	Sphera - GaBi	EU-28: Commercial waste (ES, GR, PT) on landfill	2020-2023	1	2	1
Wooden pallet recycling	Sphera - GaBi	ES: Crédito_Pine timber (65% humedad sin absorción)	2018-2021	1	2	1
Plastics recycling	Sphera - GaBi	RER: Polyethylene film (PE-L)	2016-2019	3	1	2

n.a.: not aplicable

The following table shows the level of quality and the score used for each of the representativeness analysed:

Table A2.2 Pedigree definition used for the analysis of the representativeness of the data used.

Data level of quality	Score	Geographical representativeness	Technical representativeness	Temporal representativeness
Very Good	1	Data from the study area	Process and product data studied. Same state of applied technology as defined in the objective and scope (i.e. identical technology).	Less than 3 years difference between the reference year according to the documentation and the time period for which the data are representative
Good	2	Average data from the largest area where the surveyed area is included	Data on the processes and products studied (with similar technology). Evidence of deviations in the state of the technology, e.g. different by-products.	Less than 6 years difference between the reference year according to the documentation and the time period for which the data are representative
Medium	3	Data from the area with similar manufacturing conditions	Data processes and products studied, but with different technology. This level also applies when the technology is not specified.	Less than 10 years difference between the reference year according to the documentation and the time period for which the data are representative
Poor	4	Data from area with slightly similar manufacturing conditions	Data on related processes or products	Less than 15 years difference between the reference year according to the documentation and the time period for which the data are representative
Very poor	5	Data from an unknown or significantly different area	Data on related processes but on a different scale or from a different technology	Unknown data age or more than 15 years difference between the reference year according to the documentation and the time period for which the data are representative