Sustainable
ANFACER INITIATIVE

Life cycle assessment

ceramic tiles [national median]

BRAZILIAN ASSOCIATION OF MANUFACTURERS OF CERAMIC TILES, SANITARY WARE AND RELATED PRODUCTS

PUBLISHED BY

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BRAZILIAN ASSOCIATION OF MANUFACTURERS OF CERAMIC TILES, SANITARY WARE AND RELATED PRODUCTS

LIFE CYCLE ASSESSMENT: CERAMIC TILES [NATIONAL MEDIAN]

NAVIGATE:

ANFACER

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PRESENTATION

The main purpose of this document is to present the Life Cycle Assessment study for ceramic tiles. This study is highly relevant for the Anfacer Initiative + Sustainable because it provides a measurement of the impacts of ceramic tile production, enabling measures and investments focused on minimizing negative impacts.

Moreover, this document is aimed at professionals engaged in Sustainable Civil Construction because it delivers robust, relevant technical content for projects that are based on sustainable principles and that are pursuing national and international certification. Based on the data in this study, consumers will be able to make more conscious choices and the ceramic tile industry will find it easier to develop its own environmental declarations, enhancing transparent green communication in the sector.

This is another Anfacer Initiative + Sustainable publication.

Enjoy reading it!

ANFACER

The Brazilian Association of Manufacturers of Ceramic Tiles, Sanitary Ware and Related Products (ANFACER) plays a key role in positioning the Brazilian industry as one of the main global players in the segment.

In function of its political and institutional articulation capacity, its strategic vision and its results orientation, over the years ANFACER has achieved significant advances in the development of the sector, boosting its competitiveness and expanding its markets. Worthy of note are:

STRATEGIC PARTNERSHIP

APEX-BRASIL is a strategic supporter of the Brazilian ceramic tile industry's internationalization initiatives.

GLOBAL EVENT

EXPO REVESTIR is one of the most important events in the global ceramic tile segment, a key instrument in promoting and expanding the market for Brazilian industry.

- The internationalization of the segment, with the incorporation of competencies and competitiveness within a global context;
- The commitment to technical conformity, the enhancement of standardization processes, the stimulation of product and process certification, as well as active participation in international technical committees;
- The strengthening of the Brazilian ceramic tile brand through initiatives that add value, the development of design with a national identity, commercial promotion and participation in industry events;
- Valuing technical knowledge and knowledge of legislation, the national and international markets, among other strategic aspects, as a competitive differential, and promoting its widespread dissemination within the ceramic tile sector with the intensive use of technological resources for managing information and data bases.

It is within this context that ANFACER is now focusing its attention and efforts on the Anfacer Initiative + Sustainable, a program aimed at incorporating sustainability into the management and strategy of companies in the sector.

THE ANFACER INITIATIVE + SUSTAINABLE

To transform the ceramic tile sector, driving the incorporation of socioenvironmental criteria into the management and strategy of companies, ANFACER created the Anfacer Initiative + Sustainable.

The objective of this wide-ranging program is to enable Brazilian companies to add environmental and social value to their businesses, at the same time generating financial results. This will enable the sector to reinforce its global leadership and gain a competitive differential in the Brazilian and international markets.

The transparent disclosure of social, environmental and economic information is a key element in the initiative, a commitment that demands the engagement of leaders, alignment with the principles of sustainability and conformity with basic management and compliance requirements.

The Initiative gains even greater relevance in function of the role that the Brazilian ceramic tile industry plays in the civil construction segment, a sector that generates major impacts in the country.

Another important point is the fact that the Initiative generates value for other stakeholders, functioning as a platform for dialogue and partnerships with architects and interior designers, engineers and construction companies, resellers and consumers in general.

The work, which began in 2016 with the execution of technical measures and the drafting of documents, entered a new phase in 2019, focused on engaging member companies. The participation of the manufacturers contributes towards the positioning of Brazilian ceramic tiles on the national and international markets, as well as enhancing management and driving innovation.

+sustentável
INICIATIVA ANFACER

REFERENCE DOCUMENTS

The following publications have been released by the Anfacer Initiative + Sustainable:

- Avaliação do Ciclo de Vida – Placas Cerâmicas para Revestimento [média nacional] (Life Cycle Assessment – Ceramic Tiles for Coating [national median])
- Greenhouse Gas (GHG) Inventory
- Tabela Ambiental® (Environmental Table®)
- Guia para Sustentabilidade (Guide for Sustainability).

All the publications are available on the website: www.iniciativaanfacer.com.br.

2030 AGENDA

Given its importance, the Brazilian ceramic tile sector is well positioned to contribute to the 2030 Agenda, an ambitious action plan for people, for the planet and for universal prosperity to be achieved over the coming years.

The 2030 Agenda was launched in September 2015, when the 193 member countries of the United Nations Organization (UNO) committed to the Agenda, its 17 Sustainable Development Goals (SDGs) and its 169 targets.

Private sector engagement is fundamental for achieving the SDGs, and the Anfacer Initiative + Sustainable supports and promotes this agenda because it has the human resources and funds to tackle such a challenge. It also promotes the engagement of the sector around this global challenge.

+INFORMATION

Learn about the Anfacer Initiative + Sustainable:
www.iniciativaanfacer.com.br

SECTOR OVERVIEW

Brazil plays a leading role in the global ceramic tile market, occupying the position of third largest producer worldwide.

With an installed production capacity of 1,055 million m2, sales in recent years have averaged 800 million m2, of which 706 million m2 were destined for the domestic market and 94 million m2 for export.

The fact that Brazilian industry employs two manufacturing technologies (dry route and wet route) makes it more competitive than the other producer countries, rooted in a single production method.

In addition to its strategic differential and significant numbers, the Brazilian industry is a global benchmark in energy and water efficiency.

BRAZIL'S PRODUCTION OF CERAMIC TILES
TOTALS 790 MILLION M²

INSTALLED PRODUCTION CAPACITY OF
1,055 MILLION M²

US$ 344.5 MILLION
IN BRAZILIAN CERAMIC TILE EXPORTS

93 COMPANIES IN THE SECTOR
60 OF WHICH ARE ANFACER MEMBERS

22.5 MILLION UNITS PRODUCED

26 MANUFACTURING UNITS IN 8 STATES

25,000 DIRECT JOBS

200,000 INDIRECT JOBS

*2017 DATA

OVERVIEW OF SUSTAINABLE CONSTRUCTION

Civil construction accounts for approximately 15% of Brazil's GDP, including materials, services and the actual construction work. In addition to the economic importance of this activity, there are a series of associated environmental and social impacts, such as the waste generation, the extraction of natural resources, greenhouse gas emissions and soil occupation.

This situation has led to the creation of environmental certifications aimed at providing orientation for and assessing the environmental performance of buildings. The best known and most used building certifications in Brazil are LEED® (Leadership in Energy and Environmental Design) and AQUA-HQE. Both certifications promote the conscious choice of construction materials to reduce the environmental footprint of buildings using Life Cycle Assessment as a tool for quantifying environmental impacts. Therefore, the execution of this sector study provides manufacturers with technical and methodological content permitting them to develop their own "Environmental Product Declaration", presenting their impacts and differentials in detail and enabling the consumer and construction specifier to make a conscious choice.

In addition to favoring sustainable construction, the sector LCA collaborates with the Anfacer Initiative + Sustainable in the identification of areas for improvement and in investing in processes and products that have greater positive impacts and that minimize negative impacts. This is innovation for business sustainability.

This sector study enables manufacturers to issue their Environmental Product Declaration, as well as permitting the builder and project manager to obtain points in the certification process.

Ceramic tiles: direct connection with sustainability

Sustainability is the capacity to prosper and to ensure continuance over time. This definition may also be used to characterize ceramic tiles.

Ceramics manufacture is the oldest industry, with the first pieces having been produced from 10 to 15 thousand years ago. The utensils were used to store water, food and seeds, essential for mankind's survival.

Today, when sustainable development is becoming increasingly important for people, businesses and society, the Brazilian ceramic tile industry is distinguished by its sustainable attributes.

MODULARITY
The broad variety of geometric ceramic tile formats permits a modular approach to the desired environment, reducing cutting, losses and waste generation.

APPLICABILITY
Ceramic tiles can be used in diverse applications, ranging from claddings to accessories, as well as in urban planning and in the interior or exterior finish of buildings. The variety of forms, types, colors and finishes permits creative, personalized installations, resulting in projects that combine beauty with durability.

DURABILITY
In addition to being resistant to extreme climatic conditions, the impact of chemical products, fire, water, humidity, changes in temperature and UV rays, ceramic tiles have a useful life of over 50 years.

CLEANING
The maintenance and cleaning of ceramic surfaces is simple; mostly only water and neutral products are necessary. This ease of maintenance helps reduce consumption costs over the product's lifetime.

ENERGY MATRIX
The Brazilian ceramic tile industry has a modern, energy efficient industrial park that uses natural gas. In the 1990s, the industry almost completely replaced oil and coal with natural gas.

CONTRIBUTION TO ENERGY EFFICIENCY
Ceramic tiles help promote thermal comfort in buildings, in addition to working extremely well in ventilated facade systems, generating reductions of over 30% in energy consumption in such constructions.

WATER CONSUMPTION
Water consumption in the Brazilian ceramic tile industry is one of the lowest in comparison with other producers worldwide. The ease in cleaning also promotes reductions in water consumption throughout the product life cycle.

PRODUCTION EFFICIENCY
Brazilian ceramic tile manufacturing plants enjoy high production efficiency, resulting in lower consumption of natural resources and lower waste generation.

RECYCLABLE

Ceramic tiles are inert materials, manufactured from natural raw materials that are not harmful to nature at the end of their life cycle. Moreover, most ceramic tile manufacturers return the major part of their residues to the manufacturing process as raw materials.

USE OF WASTE

The market offers ceramic tiles that employ pre and post-consumer recycled materials. This represents an environmental benefit in the form of reduced solid waste generation. In a number of cases, the industry incorporates waste from other sectors such as crockery, glass, lamps, among others.

ZERO ALLERGENICS

Different from other coatings or claddings, ceramic tiles are solid and do not promote the proliferation of mites, bacteria, fungi, mold and other allergenics, facilitated by the fact that their surface is easy to clean.

ZERO VOCs

Ceramic tiles are inorganic, emitting zero volatile organic compounds. VOCs, which are emitted by practically ever other type of flooring, are noxious gases that can cause headache, nausea and irritation of the nose, eyes and throat.

ZERO FORMALDEHYDE

Ceramic tiles do not contain the agglomerant common in other claddings. An example is formaldehyde, normally found in products that contain medium density fiber panels, plywood and agglomerates. Formaldehyde leads to an increase in asthma, particularly among children and the elderly.

ZERO PVC

Ceramic tiles do not contain PVC, a resin used in other types of cladding to improve mechanical flexibility and heat stability. PVC contains phthalates and organotins, the use of which has generated concern among healthcare specialists.

NON-SKID

There is a variety of non-skid finishes and textures available for ceramic surfaces , making the product an option that is safe in use.

FIRE RESISTANT

Ceramic tiles are not inflammable, which means that they do not produce smoke in a fire. They also reduce the propagation of flames because they do not burn or release toxic fumes.

RESPONSIBILITY

The Brazilian ceramic tile industry comprises companies committed to operating in compliance with legislation, regulations and standards. The manufacturing plants are directly involved in generating shared value in the regions in which they operate.

LIFE CYCLE ASSESSMENT: CERAMIC TILES

A Sector Study

The purpose of this report is to present the environmental performance profile calculated for the manufacture of ceramic tiles for coating based on the dry route and wet route technologies, in accordance with primary data for the Brazilian market. The analysis was developed based on the Life Cycle Assessment (LCA) technique.

Life Cycle Assessment (LCA) is an environmental management tool aimed at compiling the environmental impacts of a product, process or service during the course of its life cycle.

With the objective of increasing the level of information available for the ceramic tile sector, ANFACER incorporated the development of Sector Life Cycle Assessment into its Sustainability Program. Companies may use this to compare the impact profile of their products with the Brazilian median.

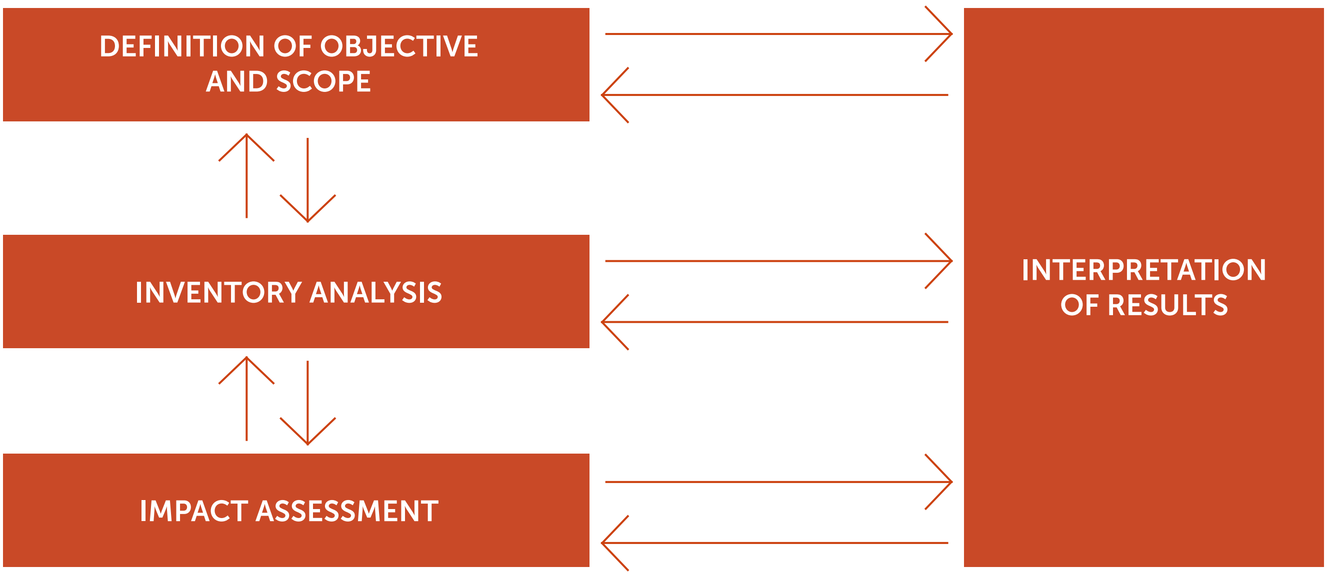
The results of this initiative are characterized as the final delivery of the project undertaken by the Brazilian Association of Manufacturers of Ceramic Tiles, Sanitary Ware and Related Products (ANFACER), thus completing the 1st phase of this association's Sustainability Program.

INTRODUCTION

The LCA may be understood as a quantitative analytical technique aimed at determining the environmental impacts associated with the exercise of the function of a product, process or service (SILVA and KULAY, 2006). For this reason, the tool was chosen to structure the activities undertaken for the present study.

The methodological characteristics of the LCA were normalized by the International Organization for Standardization – ISO (ABNT, 2009a), constituting the ISO 14040 series. According to this standard, LCA studies are organized in four operational phases. These phases appear linked in a logical and iterative manner as shown in Figure 1.

FIGURE 1
LIFE CYCLE ANALYSIS STRUCTURE



The first stage is the Definition of Scope, which comprehends the framework and possible hypotheses necessary for developing the analysis. In structural terms, the ABNT NBR ISO 14040 (2009a) standard details this phase in fourteen elements.

The Analysis of the Life Cycle Inventory phase is characterized as a systematic, gradual and objective procedure whose purpose is to quantify the material and energy flows in the life cycle. The data used in this phase may be obtained from the field (primary data), undertaken on the processing under analysis, or by means of literature (secondary data).

The final product of this process corresponds to a synoptic table in which the amounts of natural and energy resources consumed, as well as emissions to the air, water and soil resulting from the exercise of the function previously established for the product under analysis are quantified, constituting the Functional Unit or, should it be the case, the Reference Flow.

After this, in the Life Cycle Impact Assessment (LCIA) phase, the magnitude and the significance of the product's potential impacts are calculated. The estimates made in this phase of the methodology result in the formulation of the Environmental Impact Profile.

The LCIA entails the qualitative classification of the elementary material and energy flows in relation to the impact categories. This activity is necessary because the same elementary flow may contribute to distinct impacts. After the classification, the results obtained in the inventory are quantitatively correlated in the Characterization phase. The quantification of the results for each impact category is calculated based on reference factors, which magnify the contribution of elementary flows for the environmental effect with which they are associated. Algebraically, the equivalence factors are expressed in the form of a compound reference for the category under analysis.

Classification and Characterization are mandatory procedures in the LCIA.

Lastly, the set of indicators for the impact categories constitutes the product's environmental profile, to be analyzed in the last phase of the LCA, the Interpretation of Results. This phase is aimed at combining, summarizing and discussing the results of the inventory analysis and the impact assessment, iterating the objectives and the scope of the LCA, in addition to the nature and the quality of the data collected for the study. Moreover, the Interpretation of Results is responsible for identifying topics of environmental relevance, assessing the results to establish recommendations, limitations and conclusions.

Considering the methodological structure set forth in ISO 14.040, this work was undertaken in 4 phases:

> Definition of Objective and Scope – *Chapter 1*

> Life Cycle Inventory – *Chapter 2*

> Life Cycle Impact Assessment – *Chapter 3*

> Critical Analysis of Results – *Chapter 4*

Lastly, in Chapter 5, 'Conclusions', the main advances obtained by the research are presented. This chapter also sets forth circumstances which in some way may have influenced the end result of the study, that is, limitations and recommendations, as well as suggestions for future developments..

CHAPTER 1

DEFINITION OF OBJECTIVE AND SCOPE

The specific objective of this chapter is to present the definitions of the objective and scope established for the development of this study and for conducting the mass and energy balances pertinent to the Life Cycle Inventory phase. All the premises defined were validated and are in accordance with the international Product Category Rules, especially those published by the Bauen und Umwelt Institute and by Environdec.

Based on these Category Rules, the definitions of scope used for this LCA are explained and described as follows.

CATEGORY		DEFINITIONS
Scope/Product		Ceramic Tiles for Coatings
Category Rule	Specific set of requirements and guidelines – defined by multidisciplinary teams – for the development of Product Environmental Declarations based on Life Cycle Assessment, in accordance with ISO 14.025:2006, for one or more product categories.	Institut Bauen und Umwelt e.V. (IBU) - PCR for Ceramic Tiles and Panels Source: https://epd-online.com/Pcr/PdfDownload/5332
Reference standards		ISO 14040, 14044, 14025 e EN 15804:2012
Function of product system	This establishes the use of the product under analysis and its function. Usually the function is expressed by an action that is quantifiable.	The application of the LCA technique for the present case comprehended a 'cradle-to-gate' approach. As such, the function defined for the study was "produce ceramic tiles for coatings".

CATEGORY		DEFINITIONS
Boundaries of the Product System	These determine the range of the study in relation to the natural system, to other systems (such as the production of inputs and byproducts), and to the geographical and time boundaries, as well as those related to capital goods (infrastructures that will be incorporated). In this regard, the boundary delimits the set of elementary processes that fulfill the previously defined function and that model the life cycle of a product.	Cradle to the gate of the factory, in function of the uncertainties about secondary data related to subsequent phases and the reach of ANFACER's activities.
Product system	A set of elementary processes that are interconnected by means of material and energy flows, based on which the previously defined function will be undertaken. The LCA methodology encompasses the systems in accordance with the figure below (LCA Systems).	The product system will comprise the elementary processes A1 and A2, while the A3 process is subdivided in accordance with the dry route and wet route technological routes (preparation of mass; milling; drying/atomization; pressing; drying; glazing; firing; classification; rectification; packaging).
Complementary data related to the Product System		
Functional Unit (FU)	According to the ABNT NBR ISO 14044 (ABNT, 2009b) standard, the Functional Unit (FU) is defined as the quantified performance of a product system for use as a reference unit.	Produce $1m^2$ of ceramic tiles for coating.
Reference flow	The quantity of product necessary to fulfill the functional unit established for the study. Therefore, the reference flow is directly related to the product's technical performance in fulfilling its function.	According to the diverse data supplied by the manufacturers participating in the study, the median mass of the tiles is 17.5 kg/m^2.
Period of Coverage	Period of time adopted in collecting primary data	Median production data for 2015
Data exclusion criteria	Quantitative routines used to select the elementary flows to be considered in each elementary process that makes up the product system. According to the ABNT NBR ISO 14040 (2009) standard, the exclusion criteria may be based on the mass and energy representativeness of the entry and exit flows.	Mass or energy flows whose contribution is lower than 1% may be disregarded, limited to a maximum cumulative value of 5%. + Environmental relevance analysis

CATEGORY		DEFINITIONS
Allocation procedures	A set of procedures aimed at distributing the contributions of the entry and exit flows and, consequently, the environmental impacts associated with these, in processes that simultaneously generate more than one product, characterizing a 'multifunctional' situation. Diverse criteria are employed to do this, based on physical components – mass, volume and calorific capacity –, or even on the economic value of the goods and services analyzed (BAUMANN and TILLMAN, 2004; ABNT, 2009b).	This allocation should occur whenever the process generates more than one product or when a single process is shared by different products. The allocation should be based on physical criteria (mass or energy).
Quality requirements	These specify the characteristics of the data necessary for the study to achieve its objectives. The quality requirements include principally parameters such as: the extension of the historical series of data collected; the geographical area in which anthropic processing occurs; the technologies involved; accuracy, completeness and representativeness of the data; the reproducibility of the methods used throughout the LCA; the source of the data and uncertainties related to the information.	Primary data were used for the manufacturing phase of the ceramic tiles for coatings. Secondary data from literature and data banks were used for the phases prior to the manufacture of the tiles, always taking into account the characteristics of the Brazilian industry.

LCA SYSTEMS

PRODUCT MANUFACTURE		CONSTRUCTION		USE								END OF CYCLE				RECYCLING
Raw material	Transportation	Manufacturing	Transportation to the consumer	Assembly	Use	Maintenance	Repair	Replacement	Remodeling	Energy – operation	Water – operation	Deconstruction	Transportation	Waste processing	Final disposal	Recycling
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D

Regarding the product system, all the phases of the main line of the ceramic tile manufacturing process were taken into account in the study, in addition to the processing of elements that feed this process directly, always considering the criterion of data uniformity for effects of modeling.

Regardless of the technological route for manufacturing the tiles, the product system may be divided into 8 stages:

[1] Preparation of the mass;
[2] Pressing;
[3] Drying;
[4] Preparation of the glaze;
[5] Glazing;
[6] Syntering (firing);
[7] Classification and/or rectification and/or polishing;
[8] Packaging and storage.

In function of the different controls adopted by the companies participating in the study to collect data on water and energy consumption, emissions of atmospheric pollutants and waste generation, all the manufacturing stages were grouped in a single elementary process, denominated "production of ceramic tiles for coatings".

Additionally, the following were included as elementary processes of the product system:

[1] Extraction of raw materials;
[2] Extraction of natural gas and petroleum;
[3] Extraction and production of packaging;
[4] Refining of petroleum for production of diesel; and
[5] Extraction of mineral coal – only for the wet route.

For each sub-system the aspects and impacts related to each modality of transport were established, comprehending road, pipeline, maritime and rail transportation.

The schematic forms of the product systems for the manufacture of ceramic tiles for coating for each of the technological routes are presented in figures 2 and 3.

FIGURE 2

PRODUCT SYSTEM FLOWCHART FOR CERAMIC TILE PRODUCTION – DRY ROUTE

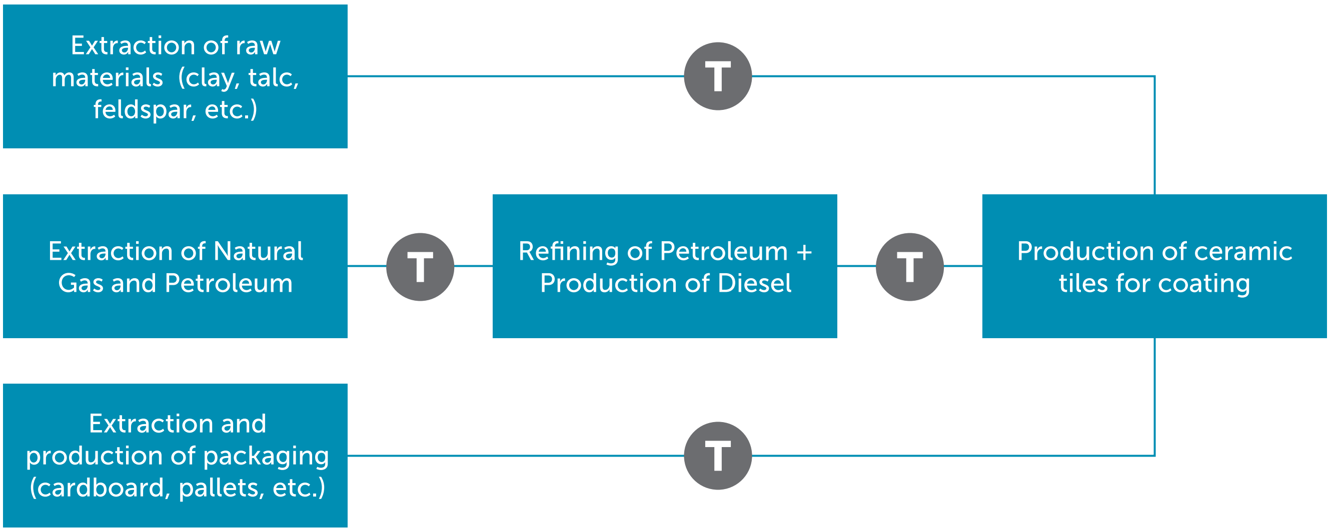
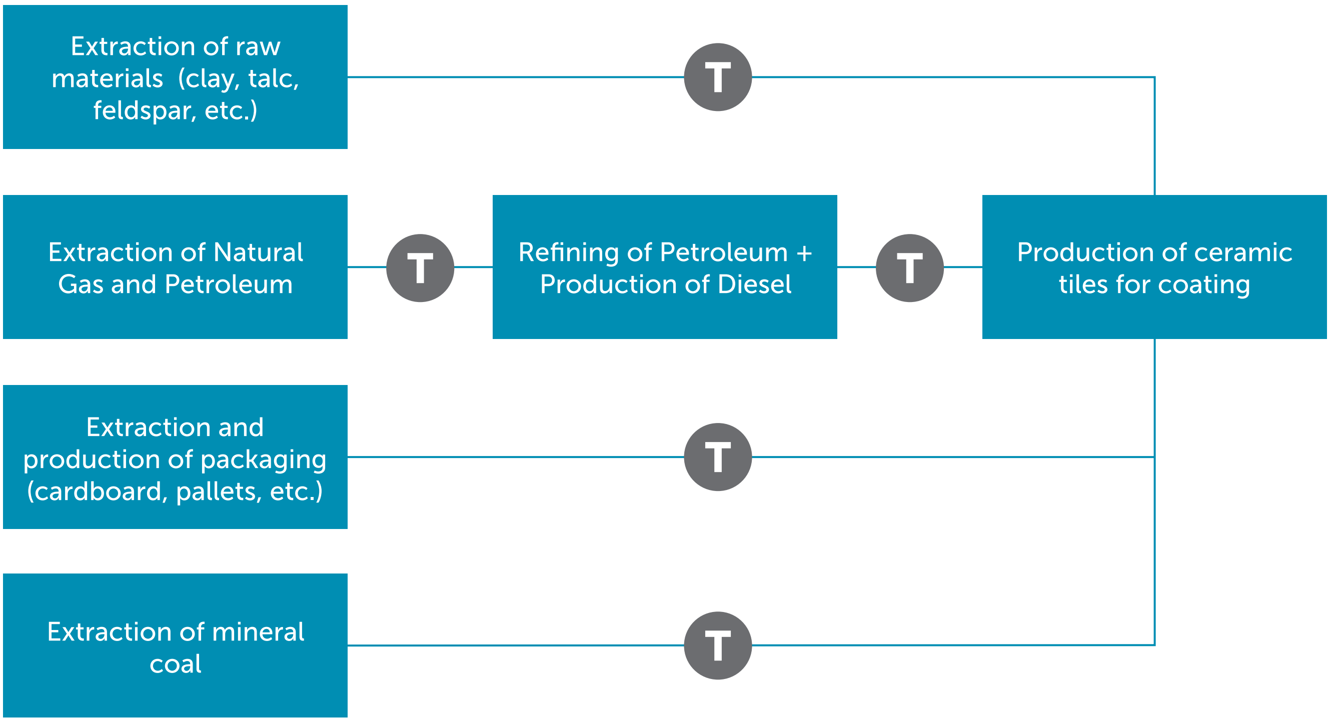


FIGURE 3

PRODUCT SYSTEM FLOWCHART FOR CERAMIC TILE PRODUCTION – WET ROUTE



Elementary processes of the System

The sub-systems for the extraction of raw materials, natural gas and petroleum comprehend all the activities involved in withdrawing the natural resources from the environment under the circumstances and conditions in which they occur in their places of origin. The petroleum and natural gas extracted in Brazil are predominantly offshore in origin, whereas, the imported fuels are mostly obtained from onshore sources (ANP, 2016).

The petroleum refining sub-system comprehends operations involving the transformation of crude petroleum for use as energy and for other applications. In this case, it is used to produce diesel to be consumed in transportation systems and in the operation of the ceramic tile manufacturing units.

The modeling of this stage was based on the median technology used in Brazil, which comprises the following phases (ANP, 2017):

(i) System for heating and desalting crude oil;
(ii) Atmospheric distillation;
(iii) Vacuum distillation;
(iv) Catalytic cracking,
(v) Coking; and
(vi) Hydrotreating. (ANP, 2017)

As mentioned previously, it was defined that the technological coverage should reflect the median production technology in Brazil throughout the production chain. In the case of petroleum produced in Brazil, extraction is predominantly via offshore platform. For petroleum importing countries, local characteristics and peculiarities were respected.

Natural gas, extracted mostly from associated wells in the country (ANP, 2016), is pumped to separating vessels where the water is removed and the hydrocarbons in liquid state are separated. The purification process is complemented in the refining stage, in which liquid particles and hydrocarbon solids are removed. The gas is then channeled to the sweetening or desulfurization unit for removal of the sulfur. In this phase, chemical or physical absorption systems are employed to ensure that the gas is dry and deacidified by the end of the process, in accordance with ANP technical regulation n.º 001/98 (SANTOS et. al., 2002). After this primary treatment, the gas is pumped by pipeline to natural gas processing units for dehydration and fractionation (MELO, 2005). Both on the extraction platforms and in the natural gas processing units, part of the natural gas is used to feed the energy generation systems of the production units (SANTOS et. al., 2002).

Due to the lack of information with a level of precision equivalent to that in the other flows in the product system, the hypothesis that additives and catalysts employed in the petroleum and natural gas extraction subsystem were resources from the environment was admitted in order to simplify the process.

For **diesel** production the fluid catalytic cracking route was adopted to portray the Brazilian median characteristic.

The **extraction and production of packaging** encompasses all the pertinent activities related to obtaining natural resources from the environment for the transformation and manufacture of the packaging used by the ceramic tile industry: wooden pallets and corner pieces, PVC film, packaging tape and cardboard.

The **extraction of mineral coal** in Brazil encompasses the entire process of obtaining this resource for consumption in the ceramic tile manufacturing units. The largest coal reserves in the country are located in the south. These deposits consist of lignite and sub-bituminous coal obtained by open cast mining.

The generation of **electrical energy** was characterized by data bank and adapted for Brazilian conditions in accordance with the energy matrix made available in the Balanço Energético Nacional -EPE, 2016- (National Energy Balance - EPE, 2016) for 2015, as shown in Table 3. Due to its insignificant contribution, solar energy was not considered in the analysis.

TABLE 1:
BRAZILIAN ELECTRICAL ENERGY MATRIX - 2015

SOURCE	CONSUMPTION TWH	PERCENTAGE CONTRIBUTION
Hydroelectric	394.20	64.01%
Natural Gas	79.50	12.91%
Biomass	49.00	7.96%
Petroleum derivatives	29.30	4.76%
Coal and derivatives	27.50	4.47%
Wind	21.60	3.51%
Nuclear	14.70	2.39%
Solar	0.06	0.01%
TOTAL	**615.86**	**100.0%**

The transportation sub-system links the transformation sub-systems and phases described previously. This transportation occurs via the most varied modalities – road, pipeline, maritime and rail –, and corresponds to the circulation of raw materials and intermediary products between the manufacturing units.

The transportation of petroleum imported into Brazil is exclusively maritime. With the exception of the data referring to the “production of ceramic tiles for coating”, all the other sub-systems were modeled based on existing data banks.

Allocation – treatment of multifunctional situations

In virtue of the data banks adopted for this work, multifunctionality was identified in the petroleum processing phase. Therefore the resource of allocation by energy criteria was used for sharing the environmental impact load corresponding to diesel.

To do this, information such as (i) production volume of each petroleum derivative generated in Brazil in 2015, (ii) density, and (iii) Lower Calorific Power of these same intermediaries (ANP, 2016) was used for the calculation of the allocation factors for diesel. The results of this analysis are presented in Table 2 and are applicable to all the analyses verified by this study.

TABLE 2

DETERMINATION OF THE ALLOCATION FACTORS FOR REFINING PETROLEUM - MEDIAN DATA FOR NATIONAL PRODUCTION BASED ON 2015 (ANP, 2016)

PETROLEUM DERIVATIVES	MEDIAN PRODUCTION 2015 [M³]	DENSITY [T/M³]	MASS [KG]	LOWER CALORIFIC POWER [KCAL/KG]]	ENERGY [KCAL]	ALLOCATION [%]
Asphalt	2.02E+06	1.03E+00	2.08E+09	9.79E+03	2.03E+13	2.01%
Coke	4.96E+06	1.04E+00	5.16E+09	8.39E+03	4.33E+13	4.29%
Gasoline A	2.69E+07	7.42E-01	2.00E+10	1.04E+04	2.08E+14	20.59%
Aviation Gasoline	7.25E+04	7.26E-01	5.26E+07	1.06E+04	5.58E+11	0.06%
LPG	9.90E+06	5.52E-01	5.46E+09	1.11E+04	6.06E+13	6.01%
Lubricant	6.40E+05	8.75E-01	5.60E+08	1.01E+04	5.66E+12	0.56%
Naphtha	4.61E+06	7.02E-01	3.24E+09	1.06E+04	3.43E+13	3.40%
Fuel oil	1.43E+07	1.01E+00	1.45E+10	9.59E+03	1.39E+14	13.77%
Diesel Oil	4.95E+07	8.40E-01	4.15E+10	1.01E+04	4.20E+14	41.59%
Other energy products	3.64E+05	8.64E-01	3.14E+08	1.02E+04	3.20E+12	0.32%
Other non-energy products	2.68E+06	8.64E-01	2.32E+09	1.02E+04	2.37E+13	2.34%
Paraffin	1.37E+05	8.20E-01	1.12E+08	1.04E+04	1.17E+12	0.12%
Aviation kerosene	5.66E+06	7.99E-01	4.52E+09	1.04E+04	4.70E+13	4.66%
Lighting kerosene	7.40E+03	7.99E-01	5.91E+06	1.04E+04	6.15E+10	0.01%
Solvent	3.58E+05	7.41E-01	2.65E+08	1.06E+04	2.81E+12	0.28%
Total	**1.22E+08**		**1.00E+11**	**-**	**1.01E+15**	**100%**

Any other allocations applied were the result of the use of data banks to complement the study in question.

CHAPTER 2

LIFE CYCLE INVENTORY

From 2016 to 2017, ANFACER, in partnership with the Centro Cerâmico Brasileiro (Brazilian Ceramic Center), and under the guidance of the Centro de Tecnologia de Edificações (Building Technology Center), collected primary data on the manufacturing process from the main companies in the ceramic tile sector, related to:

> **Quantity;**
> **Type and origin of raw materials;**
> **Quantity of atmospheric emissions;**
> **Consumption, origin and sources of water;**
> **Consumption, origin and sources of energy;**
> **Generation of solid waste and production;**
> **Modalities of transportation of raw materials to and within the manufacturing units.**

PERIOD OF COVERAGE

The period of coverage defined for the project represents the ceramic tiles for coatings industry's median production data for 2015. For this reason, the pursuit of secondary data to complement the information adopted in the Life Cycle Inventory was also concentrated on references for the same year, seeking to ensure the highest possible degree of homogeneity in the information.

The other coverage periods were conditioned to the period of reference of the inventories made available in the data banks. Within the conditions imposed by this work, it may be understood that this alternative presents the most homogeneous and consistent situation possible, with the objective of making use of data from elementary processes in the specialized literature.

DATA QUALITY REQUIREMENTS

As an initial guideline, it was established that the study should reflect the technologies most in use in Brazil, as well as median characteristics in terms of the origin of the raw materials.

The production of ceramic tiles for 2015 was 899.4 million square meters, of which 73.4% were produced via the dry route and the remaining 26.6% via the wet route.

Table 3 below presents the production volume participating in the study, providing primary information about the producers' processes, as well as their monthly production figures for the year of reference. The numbers result in 26% representation for the dry route and 32% for the wet route, with a total sector representation of 27.6%.

TABLE 3
REPRESENTATIVENESS OF THE STUDY (BASE YEAR 2015)

INVENTORY	DRY ROUTE	WET ROUTE
Monthly production (m^2)	14,301,000	6,412,000
Total volume inventoried (millions of m^2)	171.6	76.9
Total production (2015)	659.8	239.6
Representativeness	26%	32%

GEOGRAPHICAL COVERAGE

The geographical coverage comprehends the states of São Paulo and Santa Catarina for ceramic tile production; it also encompasses the countries supplying petroleum and natural gas to Brazil. These Brazilian states account for more than 90% of the country's production.

Any other geographical digressions in the product system models were introduced due to the adoption of data banks, used with the objective of complementing the model within the framework in which it is established.

TECHNOLOGICAL COVERAGE

The technological coverage should reflect the median production technology in Brazil throughout the production chain. Therefore the study covered the two major manufacturing routes in the country.

CHAPTER 3

LIFE CYCLE IMPACT ASSESSMENT

After the phase of collecting primary data ended, the assembly of the product system models of the actual processes was begun, the uniformization of which was undertaken with support from the software SimaPro 8.2.3.0 - PRe Consultants. The entry and exit flows of each elementary process were devised to fulfill the reference flows defined for ceramic tiles. In order to complement the data with information pertinent to the Brazilian energy matrix, transportation, raw material extraction processes, among others, secondary data from secure and accurate national and international sources were researched.

IMPACT ASSESSMENT METHOD

For analysis of the impacts, the methods used were the ReCiPe Midpoint (H) V1.12 / Europe Recipe H method, selected for the Environmental Impact Assessment phase of this LCA. The Midpoint version of ReCiPe permits the quantification of environmental impacts in accordance with eighteen distinct environmental impact categories, in which these effects are modeled based on scientifically established physical standards.

Ten impact categories were selected from within this universe; these were:

- **Climate Change (CC)[1];**
- **Ozone Layer Depletion (OD)[2];**
- **Terrestrial Acidification (TA)[3];**
- **Human Toxicity (HT)[4];**
- **Formation of Photochemical Oxidants (PO)[5];**
- **Formation of Particulate Material (PM);**
- **Occupation of Agricultural Lands (AL);**
- **Water Depletion (WD);**
- **Fossil Resource Depletion (FD);**
- **Eutrophication (EU).**

1. Climate Change: this represents the increase of infrared radiation on the earth's surface, due especially to the growing quantity of CO_2, N_2O, CH_4, aerosols and other gases in the atmosphere, which impede the dispersion of the sun's rays.

2. Depletion of the ozone layer: reduction of the ozone layer in the stratosphere, which permits the passage of ultraviolet radiation to the earth's surface, increasing the incidence of skin problems, eye diseases and interferences in the ecosystem.

3. Acidification: this is caused by the emission of substances soluble in water which primarily result in the reduction of pH in rainfalls. The secondary effects include: alteration in soil acidity content and the degradation of heritage and aquatic life.

4. Human toxicity: the emission of toxic substances in the air, soil or water, such as aromatic compounds, metals and others, that may cause health problems for humans when inhaled or ingested.

5. Ozone Photochemical Formation: mist caused by the photochemical reaction between nitrogen oxides and volatile organic substances, which can decrease photosynthesis activity on flora due to the reduction of solar luminescence.

The process of selecting the method used for impact assessment, and within this, the models that describe the impact categories, was based on information from literature collected in the International Reference Life Cycle Data System Handbook (EC-JRC, 2011) and in the article published by Hauschild et al (2013).

The selection of the impact categories not analyzed in the study was based on criteria such as inaccuracy and inconsistency in the impact quantification models and environmental insignificance.

There follows detailing of the premises that guided the modeling of the elementary processes and provided support for the treatment of data undertaken for the development of the Life Cycle Assessment of ceramic tiles for coating – Brazilian median.

RAW MATERIAL EXTRACTION

The raw materials necessary for the manufacture of ceramic tiles vary significantly in accordance with the technological route. Therefore, during the process of collecting primary data, each manufacturer was requested to supply the information organized in accordance with the manufacturing technology.

The median data obtained for the manufacture of 17.5 kg of ceramic tiles are described in Table 4.

TABLE 4

COMPOSITION OF RAW MATERIALS FOR MANUFACTURE OF MASS

	DRY ROUTE		WET ROUTE	
RAW MATERIALS	MASS AMOUNT [KG]	PERCENTAGE AMOUNT [%]	MASS AMOUNT [KG]	PERCENTAGE AMOUNT [%]
Clays	18.03	99.9%	10.81	58.9%
Feldspar	-	-	3.77	20.5%
Kaolin	-	-	0.97	5.3%
Limestone	-	-	0.58	3.2%
Talc	-	-	0.42	2.3%
Sodium silicate	-	-	0.02	0.1%
Process residue	0.02	0.1%	1.79	9.7%
TOTAL	**18.05**	**100%**	**18.36**	**100%**

A large part of the raw materials used in the ceramic tile industry are natural. After they are mined, the materials are beneficiated, that is, they are broken down or milled, classified in accordance with granulometry and, at times, purified. The clays used in the mass are fundamentally extracted from company-owned deposits, so the entry and exit flows for their processes were accounted for in the manufacture of the ceramic tiles.

For the other raw materials (kaolin, talc and sodium silicate) the contribution to the impact profile is related exclusively to the transportation to the factory, due to the reduced processing involved and the low percentage and environmental significance.

As a result of the unavailability of the industry's own inventory to portray the environmental performance of the extraction of feldspar and limestone, the following international references were adopted:

> Feldspar {RoW} | production | Alloc Def, U (Ecoinvent v3.2);

> Limestone, crushed, washed {RoW} | production | Alloc Def, U (Ecoinvent v3.2).

In both cases, the energy matrix was altered to reproduce the one existent in Brazil in 2015.

For road transportation, the "Transport, lorry >32t, EURO 4/RER U" model, also from the Ecoinvent version 3.2 data bank, was adopted.

After extraction, the raw materials are transported by road to the manufacturing units. This transportation is done by trucks, whose load capacity varies from 16 to 33 metric tons. Based on the information received, the following average distances between the place of extraction and the factories were determined:

> Clay (dry route): 20km
> Remaining ingredients for ceramic mass – wet route – 249 km
> Raw materials for glaze production – 257 km
> Packaging – 152 km

EXTRACTION OF PETROLEUM AND NATURAL GAS

The definitions described in Chapter 1, Definitions of Scope, were used to elaborate the model for this phase related to period, geographical and technological coverage.

For the development of the petroleum extraction sub-system inventory, the origins of the resources consumed in Brazil ¨C via volume processed in the country –, as well as the provenance – onshore or offshore extraction, were identified. Thus, regarding the supply of Brazilian petroleum, it was presumed that the extraction would occur offshore, given that 93% of the country's petroleum comes from offshore sources (ANP, 2016). However, since Brazil is not self-sufficient in the extraction of petroleum for its own use, the countries that supply Brazil with petroleum were also considered in accounting for the environmental loads for the present study. Table 5 presents the national and international load volume processed.

TABLE 5

LOAD VOLUME PROCESSED, DISCRIMINATED BY ORIGIN – 2015 (ANP, 2016)

ORIGIN COUNTRY/REGION	BARRELS/DAY	PERCENTAGE CONTRIBUTION	ACCUMULATED PERCENTAGE CONTRIBUTION	NORMALIZED PERCENTAGE CONTRIBUTION
Brazil	1,648,680	85.66%	85.66%	87.84%
Nigeria	163,446	8.49%	94.15%	8.71%
Saudi Arabia	64,779	3.37%	97.52%	3.45%
Iraq	16,174	0.84%	98.36%	-
United States	12,401	0.64%	99.00%	-
United Kingdom	8,559	0.44%	99.45%	-
Australia	5,905	0.31%	99.75%	-
Algeria	1,991	0.10%	99.86%	-
Equatorial Guinea	1,781	0.09%	99.95%	-
Argentina	782	0.04%	99.99%	-
Kuwait	194	0.01%	100.00%	-
Trinidad and Tobago	**2**	**0.00%**	**100.00%**	
Total	**1,924,693**	**100%**	**-**	**100%**

Thus, for modeling the elementary petroleum extraction process, the following countries were selected based on a cumulative mass contribution criterion: Brazil, Nigeria and Saudi Arabia.

The procedure applied to petroleum was used to identify the origin and provenance of natural gas. The natural gas consumption data by national and imported origin are discriminated in Table 6 below.

TABLE 6

NATURAL GAS PRODUCTION CONSUMED, DISCRIMINATED BY ORIGIN – 2015 (ANP, 2016)

ORIGEM PAÍS/REGIÃO	BARRIS/DIA	PERCENTUAL DE CONTRIBUIÇÃO	PERCENTUAL ACUMULADO DE CONTRIBUIÇÃO	PERCENTUAL DE CONTRIBUIÇÃO NORMALIZADA
Brasil	24.861,00	67,72%	67,72%	68,03%
Bolívia	11.684,00	31,82%	99,54%	31,97%
Argentina	**169,00**	**0,46%**	**100%**	**-**
Total	**1.924.693**	**67,72%**	**-**	**100%**

Thus for natural gas, offshore production in associated mills in Brazil and onshore production in Bolivia were considered for the modeling.

TRANSPORTATION

After extraction, the petroleum (both Brazilian and imported) is pumped to a refining unit by oil pipeline or discharged from ships to petrochemical terminals and then to maritime terminals. No loss of material in transportation via oil pipeline was considered for effects of modeling these movements.

The maritime transportation distances were simulated using georeferencing tools that take into account the regular transportation routes featured in AliceWEB (2017). Based on this analysis, it was verified that the average distance traveled by the petroleum coming from Nigeria and Saudi Arabia to Brazil is respectively 4,733 and 8,498 nautical miles.

According to Vianna (2006), the loss of crude oil in transoceanic transportation is estimated to be 0.83%. Thus, the volume of this resource transported was calculated based on the arithmetic average of the total material leaving the port of origin and the total arriving at the port of destination, generating an emission of 8.30 g of crude oil per kilogram of material transported.

Bolivian natural gas is pumped to the refineries in Brazil via the GASBOL pipeline. According to TBG data (2017), the GASBOL gas pipeline operates under high pressure, pumping gas from Bolivia to the states of Mato Grosso do Sul, São Paulo, Paraná, Santa Catarina and Rio Grande do Sul. Considering that the major ceramic tile production centers are located in São Paulo and Santa Catarina, the average distances the Bolivian natural gas is transported to reach these locations were 1,979 km and 2,103 km respectively.

DATA BANK

Due to the absence of primary data for the petroleum extraction process in Brazil, the offshore extraction of petroleum in Norway was used as a reference. This decision was taken due to the technological similarities in processing between the two countries. The information contained in the inventory was obtained from the Ecoinvent version 3.2 data bank and the origin of the electricity consumed in the process was adjusted to ensure equivalence with Brazilian conditions in 2015.

Regarding the imported petroleum, the datasets that best portrayed the practices in place in the exporting countries used in this study were also identified in the Ecoinvent data base. Therefore, the onshore extraction technology used in Nigeria was of necessity chosen to represent the petroleum obtained from that country, while onshore extraction in the Middle East was adopted for Saudi Arabia.

For the natural gas extracted in Brazil, the study developed for offshore extraction of associated gas in Great Britain, which includes emissions related to processing, energy consumption and transportation of the gas to the coast, was selected. The energy matrix of this inventory was adapted to represent conditions in Brazil in 2015.

Meanwhile, the environmental aspects of the natural gas extracted in Bolivia are oriented by the inventory developed for the onshore extraction of non-associated natural gas in Germany, whose emissions are calculated for the extraction and processing stages.

The identification codes for the inventories used are presented in Table 7.

TABLE 7

DATA BANKS USED TO MODEL PETROLEUM EXTRACTION

INPUT	DATA BANK – ECOINVENT
Petroleum – Brazil	Petroleum {NO}| petroleum and gas production, offshore | Alloc Def, U
Petroleum – Nigeria	Petroleum {NG}| petroleum and gas production, onshore | Alloc Def, U
Petroleum – Saudi Arabia	Petroleum {RME}| production, onshore | Alloc Def, U
Natural Gas – Brazil	Natural gas, at production offshore/GB
Natural Gas –Bolivia	Natural gas, at production onshore/DE U

REFINING OF PETROLEUM – DIESEL PRODUCTION

Currently, modern Brazilian refineries employ physical separation and chemical conversion processes, comprising the following transformation and processing stages:

> System for heating and desalting crude oil;
> Atmospheric and vacuum distillation;
> Fluid catalytic cracking, coking; and
> Hydrotreating.

It is in the hydrotreating stage that both kerosene and diesel, the latter used for the transportation and manufacture of ceramic tiles, are produced.

TRANSPORTATION

The diesel produced at the refineries is pumped via pipeline to the distribution terminals closest to the ceramic tile factories; from the terminals the diesel is then delivered by tanker truck. Transportation via pipeline occurs only when there are no refining units close to the industrial hubs.

Therefore, for example, for the Santa Gertrudes region, the diesel was considered to have as its direct origin the Planalto Paulista Refinery (REPLAN), located in Paulínia (São Paulo).

As a premise in calculating the impacts resulting from the transportation of diesel, only the environmental aspects of road transportation were quantified. The calculation was based on a median travel distance of 124 km.

DATA BANK

The lack of a specific set of inventories describing the environmental performance of the petroleum refining technology led to the pursuit of secondary data that adequately expressed the environmental loads associated with this processing. Based on objective criteria related to the technological and period coverage, the "Crude oil, in refinery/kg/US" inventory was selected from the USLCI data base. The reasons for this option are directly related to the similarity of the refining technology model adopted for the elaboration of this inventory with the median one used by Brazilian refineries during the coverage period of the study.

The aforementioned data bank comprises the following refining stages:

(i) Desalting;
(ii) Distillation;
(iii) Coking;
(iv) Catalytic cracking;
(v) Hydrotreating.

It should be noted that the model's energy matrix was altered in accordance with the characteristics of generation existent in Brazil for 2015.

EXTRACTION OF RAW MATERIALS AND PRODUCTION OF PACKAGING

The consumption of packaging materials in the ceramic tile industry is high, comprehending significant volumes of wood for pallets, cardboard and plastic film. Therefore, during the process of defining the boundary of the product system, it was decided in conjunction with ANFACER that the aspects referring to the extraction and manufacture of these materials should be included in the environmental impact profile of ceramic tiles. The quantity of these resources consumed per m^2 of ceramic tile is detailed in Table 8 below.

TABLE 8

CONSUMPTION OF PACKAGING PER M^2 OF CERAMIC TILE PRODUCED

	DRY ROUTE		WET ROUTE	
RAW MATERIALS FOR PACKAGING	MASS AMOUNT [KG]	PERCENTAGE AMOUNT [%]	MASS AMOUNT [KG]	PERCENTAGE AMOUNT [%]
Wood	0.15	45.2%	0.16	54.6%
Cardboard	0.10	30.1%	0.12	41.0%
Plastic Film	0.08	24.1%	0.01	3.4%
Metal Staples	0.002	0.6%	0.003	1.0%
TOTAL	**0.332**	**100%**	**0.293**	**100%**

During the data collection process, a significant variation in the amount of packaging consumed by the companies participating in the studies was noted. In this respect, among all the primary data used, this area showed a greater tendency towards fragility, that is, insecurity in relation to the information available.

TRANSPORTATION

After extraction and manufacture, the packaging material is sent by road to the ceramic tile manufacturing units. The material is transported by trucks with a capacity varying from 14 to 32 metric tons. Based on the information received, it was determined that the median distance between the suppliers and the ceramic tile manufacturers is 257 km.

To calculate this distance, the quantities of packaging materials and the location of the suppliers of each one of the companies participating in this study were taken into account, using the weighted average of these indicators to arrive at the distance in kilometers.

DATA BANK

Due to the inexistence of primary data for the diverse packaging material manufacturers, as well as the absence of national references in the data banks of LCA studies, global median datasets representing the conditions of extraction and manufacture of the packaging materials were researched. The models adopted for the study are identified in Table 9.

TABLE 9

DATA BANKS USED TO REPRESENT THE EXTRACTION AND MANUFACTURE OF PACKAGING

INPUT	DATA BANK – ECOINVENT
Wood – pallets	Corrugated board box {RoW}| corrugated board box production | Alloc Def, U
Cardboard	Wood, indoor use, at plant/m3/RER
Plastic film	Packaging film, LDPE, at plant/kg/RER

PRODUCTION OF CERAMIC TILES FOR COATING

As described previously, Brazilian ceramic tile production uses two distinct technological routes (dry route and wet route), which results in products that employ different raw materials and have differences in energy and water consumption. To develop the LCI for this stage, the inventories made available by the participating companies were analyzed, adjusting the information to establish national median amounts for each one of the production processes.

CONSUMPTION OF RESOURCES

Table 10 presents a summary of the natural, material and energy resources consumed in the manufacture of 1m^2 of ceramic tile.

TABLE 10

CONSUMPTION OF NATURAL, MATERIAL AND ENERGY RESOURCES IN THE MANUFACTURE OF 1M² OF CERAMIC TILE, BY TECHNOLOGICAL ROUTE

NATURAL, ENERGY AND MATERIAL RESOURCE	UNIT	DRY ROUTE	WET ROUTE
Clays	kg	18.03	10.81
Feldspar	kg	-	3.77
Kaolin	kg	-	0.97
Limestone	kg	-	0.58
Talc	kg	-	0.42
Sodium silicate	kg	-	0.02
Process residue	kg	0.02	1.79
Wood	kg	0.15	0.16
Cardboard	kg	0.10	0.12
Plastic Film	kg	0.08	0.01
Metal Staples	kg	0.002	0.003
Mineral coal	kg	-	0.21
Diesel	liters	0.01	0.01
Electrical Energy	kWh	2.24	2.3
Natural Gas	m^3	1.15	1.77
Water	liters	6.42	25.18

PRODUCTION PROCESS EMISSIONS

The main atmospheric emissions from the ceramic tile production process are related especially to the pressing and combustion processes. In the former, emissions of particulate materials at the rate of approximately 1% of the total raw materials employed in the pressing process were determined. Whereas in combustion, significant quantities of carbon dioxide, nitrogen oxides, sulfur dioxide (due to the natural gas) and fluoridric acid are emitted, in addition to water and nitrogen.

To quantify the gases emitted during the combustion process, stoichiometric balances were calculated, considering that on average natural gas consists of 75% carbon and 25% hydrogen. In accordance with Ruling N.º 41, dated April 15, 1998, by the regulatory agency Agência Nacional do Petróleo, the maximum sulfur content in natural gas should be 80mg/m^3. Consequently, this is the concentration that was used to calculate sulfur dioxide emissions.

The fluoridric acid and nitrogen oxide emissions were supplied in the inventories elaborated by the participating companies.

In addition to the atmospheric emissions, liquid effluents are also generated in the pressing process and in cleaning the manufacturing unit. This wastewater is channeled to a treatment plant to ensure the treated water is compliant with the specifications presented in Table 11 below.

TABLE 11

COMPOSITION OF THE DISCHARGE FROM THE WASTEWATER TREATMENT SYSTEM

DISCHARGE COMPOSITION	CONCENTRATION (MG/L)
Total Solids	4793.33
Boron	1.52
Cadmium	0.007
Lead	0.022
Copper	0.007
Manganese	0.232
Suspended solids	15.17
Sedimentable solids	0.383

CHAPTER 4

CRITICAL ANALYSIS OF RESULTS

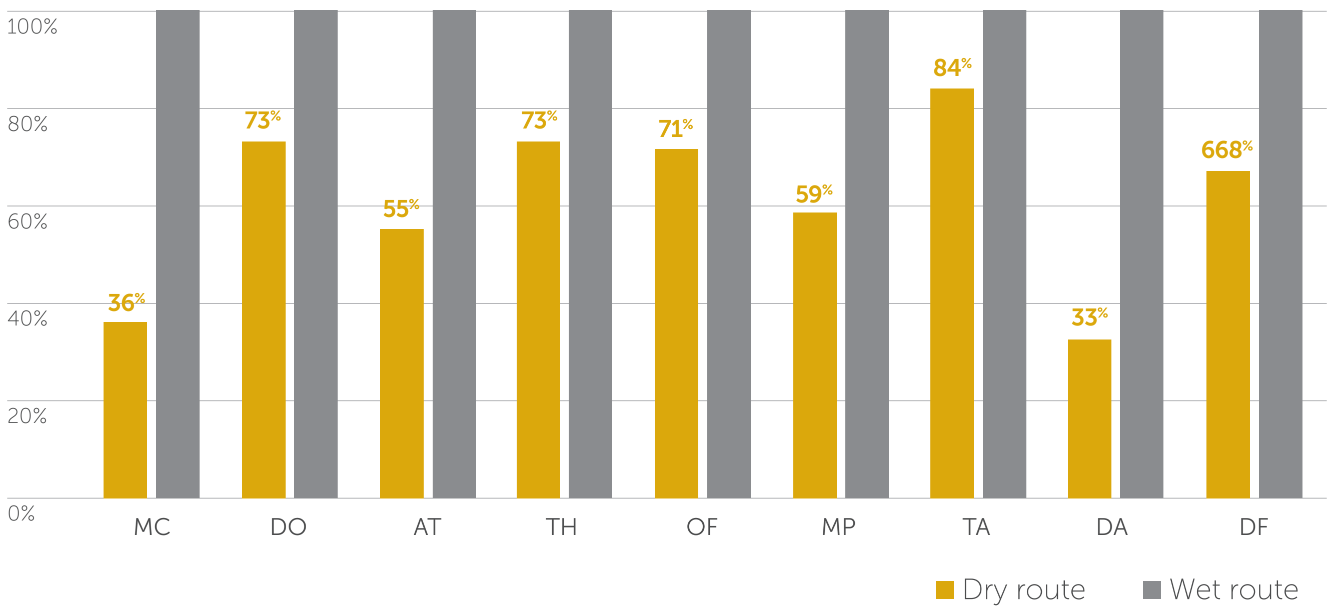
The Life Cycle Inventories elaborated for wet route and dry route ceramic tiles for coatings were made up of elementary flows based on the premises described in the previous chapters. After the characterization of the environmental aspects, the environmental performance profiles presented in Table 12 were obtained for each one of the impact categories covered by this study. The results were calculated for the production of 17.5 kg of ceramic tile, that is, 1m^2.

TABLE 12
ENVIRONMENTAL PERFORMANCE PROFILE FOR THE PRODUCTION OF 1M^2 OF CERAMIC TILE FOR COATING

IMPACT CATEGORY	UNIT	DRY ROUTE	WET ROUTE
Climate Change [CC]	kg CO_2 eq	3.37E+00	9.24E+00
Depletion of Ozone Layer [OD]	kg CFC-11 eq	5.82E-08	7.97E-08
Terrestrial Acidification [TA]	kg SO_2 eq	3.98E-03	7.19E-03
Human Toxicity[HT]	kg 1.4-DB eq	5.59E-02	7.65E-02
Formation of Photochemical Oxidants [PO]	kg NMVOC	3.69E-03	5.19E-03
Formation of Particulate Material [PM]	kg PM10 eq	1.28E-03	2.18E-03
Occupation of Agricultural Lands [AL]	m^2	2.52E+00	2.99E+00
Water Depletion [WD]	m^3	1.31E-01	3.97E-01
Fossil resource depletion [FD]	kg petroleum eq	1.35E+00	1.99E+00
Eutrophication of freshwater	kg P eq	2.24E-05	4.97E-05

Based on the data in Table 12, it was possible to elaborate Chart 4, in which the environmental performance of the two technological routes is compared. As demonstrated in both synoptic analyses, the environmental profiles present significant distinctions, with variations in magnitude of impact of more than 100% for two of the nine impact categories.

CHART
PERCENTAGE COMPARISON OF THE ENVIRONMENTAL PERFORMANCE OF CERAMIC TILES PRODUCED VIA WET ROUTE AND DRY ROUTE



The reason these differences occur is basically centered on the quantity of additional energy resources required in the wet route process, in addition to the actual water consumption and the distinction between the type and origin of raw materials for manufacturing the mass.

It is important to point out that the current routes, dry and wet, differ in environmental profile and in production flow, but there is no direct reference to type or quality. Ceramic tiles are classified globally in accordance with their Absorption Group (ISO 13006). Each absorption group has a specification table for the properties of the ceramic tiles, as shown in the table below.

WATER ABSORPTION	CLASS	MECHANICAL RESISTANCE	DENOMINATION
≤0.1%	-	Extremely high	Technical Porcelain
≤0.5%	BIa	Extremely high	Glazed Porcelain
>0.5 a ≤3.0%	BIb	Very High	Gres
>3.0 a ≤6.0%	BIIa	High	Semi Gres
>6.0 a ≤10.0%	BIIb	Medium	Semi-Porous
>10%	BIII	Low	Porous

In the domestic market, there is a concentration of typologies in each manufacturing route. Domestic production of ceramic tiles by the dry route has a concentration of typology BIIb product, ceramic tiles with 6 to 10% water absorption, denominated semi-porous.

The wet route comprises a concentration of higher added value ceramic tile products, encompassing BIII type tiles and Porcelain tiles which have a specific technical standard, NBR 15755, that employs more rigorous criteria. This therefore provides clarification and attributes weights to the differences in the environmental profile.

Impact Analysis

CLIMATE CHANGE

The climate change impact is directly related to the consumption and combustion of natural gas during the manufacture of the tiles. This activity corresponds to 87% of the emissions for the wet route and 69% of the CO_2eq emissions for the dry route.

Electrical energy consumption is the second highest source of CO_2eq emissions, contributing to 6.5% and 17.4% of the impact respectively for the wet route and the dry route.

Worthy of note in this item is the energy generated in hydroelectric plants in Brazil, which comes second in the list of the most important processes for this impact category. The contribution made by the hydroelectric plants is due to the transformation in soil use, as well as the methane emissions in lakes, which is caused by the anaerobic decomposition of biomass not managed during the construction of the hydroelectric plant dam.

DEPLETION OF OZONE LAYER

The depletion of the ozone layer is one of the impacts that showed the greatest similarity in terms of magnitude between environmental performance profiles. This impact is also the smallest in terms of absolute size.

Emissions of Halon 1301 and Halon 1211 in the atmosphere are responsible for more than 95% of the environmental charge related to depletion of the ozone layer. These originate from international onshore petroleum extraction processes and from cardboard and wooden pallet manufacturing processes. In other words, the activities that contribute to this impact category occur essentially outside Brazilian territory and were computed in the model because of the use of international data banks.

TERRESTRIAL ACIDIFICATION

Sulfur oxide emissions are one of the main causes of terrestrial acidification. The presence of sulfur in fossil fuels is the main source of this impact in ceramic tile production. In this context, the burning of natural gas in the manufacturing units corresponds to 34.0% of the SO_2eq emissions for the wet route methodology, while it accounts for 5.2% of the emissions in the dry route.

Electrical energy generation is the second most significant activity for the wet route and the single most significant for the dry route, resulting in 24.5% and 43.1% of emissions respectively.

HUMAN TOXICITY

The atmospheric emission of fluoridric acid and emissions of boron, cadmium, manganese and lead in the effluent of the ceramic tile manufacturers is one of the main causes of human toxicity. For the wet route, these contributions represent 26.0% of the impact, while they correspond to 27.2% for the dry route.

Electricity generation, due to emissions of metals during fossil-based processes, also makes a significant contribution to this category, representing 22.9% of wet route and 30.6% of dry route emissions.

Lastly, the extraction and manufacture of wooden pallets is the third main process, emitting 18.1% and 22.1% of 1.4-DBeq for the wet route and dry route respectively.

FORMATION OF PHOTOCHEMICAL OXIDANTS

Petroleum processing and burning fossil fuels are the main causes of hydrocarbon, NOx, CO and SO_2 emissions.

Combustion emissions in the road transportation of raw materials and packaging material represent 9.5% of the NMVOC emissions for dry route ceramic tiles and 25% for wet route products. In this case, it should be noted that the proximity of the clay deposits used in dry route processing makes a significant contribution to reducing this environmental impact.

Together, the production of cardboard and wooden pallets corresponds to 28.9% of dry route and 25.9% of wet route emissions. These contributions are due fundamentally to the use of organic raw materials, the cultivation and harvesting of which emits hydrocarbons and NOx to the atmosphere.

Electricity corresponds to 32.2% of dry route and 23.5% of wet route emissions.

FORMATION OF PARTICULATE MATERIAL

The emission of particulate material is well distributed throughout the wet route process, in which the ceramic tile industry's emissions represent 23%; transportation emissions correspond to 13.8%; emissions from the production of electricity, natural gas, diesel and coal total 24.9%; packaging production accounts for 24.5%; and the manufacture of feldspar by itself represents 11.8%. Therefore, for this technological route, the need for previously processed raw materials is a point worth noting.

While for the wet route, the use of energy resources (electricity, diesel and natural gas) totals 39.3% of emissions, and 50.6% are associated with packaging materials, especially those of organic origin (cardboard and wooden pallets), in which particulate emissions are not controlled by closed environments and filtration systems, as occurs in industrial processes

OCCUPATION OF AGRICULTURAL LANDS

The impact related to the occupation of agricultural lands was included in the analysis due to its environmental significance stemming from the quantity of packaging materials used to store ceramic tiles. The use of agricultural land for the production of the wood used in the pallets is the most relevant process for this category, representing 76.2% of the impact for the wet route process and 81.2% for dry route production. Cardboard production comes in second place, accounting for 17.4% of the dry route and 22.6% of the wet route impact.

WATER DEPLETION

Regarding water depletion, there was a significant difference between the technological routes in the most relevant processes. However, this difference is not due exclusively to the volume of water consumed in the milling process, but also to the composition of the ceramic mass.

In this respect, for the wet route, feldspar production ended up accounting for more than 50% of the water depletion. The reason that this occurred is directly related to the data bank used and the secondary data provided by the Ministry of Mines and Energy (MME). According to this ministry, the spraying phase to control particulate material in the extraction of feldspar consumes from 0.75 to 0.37 m^3 of water per metric ton of mineral (MME, 2009), the median value being used to quantify this impact. Due to the unavailability of public data on non-processed feldspar, typical in the ceramic tile sector, the study employed a data base for the standard feldspar manufacturing process, in which water consumption is high.

The cardboard manufacturing process comes in second place for wet route manufacturing, constituting 34.7% of the water depletion impact. However, this same activity reaches the striking figure of 68.0% for this category in the dry route process. Similar to feldspar, cardboard manufacturing involves intense water consumption, reaching the mark of 30m^3 per metric ton of cellulose produced (MARTIN, 2015).

Lastly, electricity is the second major source of water consumption in the dry route and the third for the wet route. In this case, the water used for manufacturing petroleum and by hydroelectric plants is the main driver of consumption.

FOSSIL RESOURCE DEPLETION

Around 82% of the depletion of fossil resources in both manufacturing routes is due to the consumption of natural gas and electricity from non-renewable sources. Especially worthy of note, natural gas consumption represents 76.3% of this impact for the wet route process and 73.3% for the dry route.

The consumption of mineral coal as a contributing source to the energy matrix for the wet route process is another representative environmental aspect for this category, corresponding to 6.5% of the impact.

Whereas the consumption of petroleum as a raw material and an energy source for the manufacture of packaging films accounts for 10.4% of the impact in the dry route process.

EUTROPHICATION OF FRESHWATER

The significance of the eutrophication of freshwater was low in absolute numbers. The main aspect contributing to this impact, corresponding to over 85% for both routes, was the leaching of fertilizers during the cultivation of the timber used to manufacture pallets and cardboard.

CHAPTER 5
CONCLUSIONS

In general terms, it may be considered that the primary and secondary data related to the elementary processes considered relevant for elaborating the product system models are sufficient as a basis for the conclusions of the study, in accordance with the objective and scope defined. As such, the objective defined for this study of quantifying the environmental performance profile associated with the production of ceramic tiles for coating via the dry route and wet route as executed by Brazilian manufacturers, has been fulfilled.

In the course of this project, however, limitations were identified that have inevitably ended up influencing the results obtained to a greater or lesser extent.

The limitation most worthy of note, which is not restricted to this specific study and applies to all studies with the same objective produced in Brazil, is the absence of national data banks to support LCA studies, as noted in the previous chapter. This has a significant effect on a series of impact categories.

Another salient point is the fact that part of the primary data did not present the detailing necessary for the study, leading to the need to develop theoretical calculations for the combustion gases in the drying and water consumption stage. These require better management and study and constitute a weak link in the information gathering process.

The difficulties addressed in this chapter may be seen as potential opportunities for improvement in future studies, always in pursuit of greater accuracy in verifying the environmental performance of ceramic tiles.

BASED ON THE RESULTS OBTAINED, IT MAY BE CONCLUDED THAT:

> The activities related to the combustion of natural gas make a significant and systemic contribution to the majority of the environmental impact categories in the performance profile of ceramic tiles. Particularly worthy of note is their contribution to climate change, terrestrial acidification and the depletion of fossil resources.

> The consumption of electrical energy, diesel, mineral coal and natural gas stand out compared with the other activities in the life cycle of ceramic tiles.

> The influence of packaging on the global environmental impact profile is another salient aspect verified in the study, in terms of the emission of pollutants and the consumption of water, influencing climate change, depletion of the ozone layer, human toxicity, the formation of photochemical oxidants, and the eutrophication and depletion of water.

Lastly, it may be concluded that the results presented herein are, given the limitations and conditioning factors, consistent for effects of representing the environmental performance profile of ceramic tiles for coating produced in Brazil. Moreover, these results may support decision making related to the manufacturing process, with a focus on the environmental and business dimensions and on the sustainable growth of the sector, in line with the objective of the Anfacer Initiative + Sustainable.

This is the first edition of a Life Cycle Assessment for Ceramic Tiles and is part of the Anfacer Initiative + Sustainable, which intends to use this LCA tool systemically. Consequently, there are plans for new editions, with updated primary data, the pursuit of greater accuracy in secondary data and an increase in the percentage of participating manufacturers in order to boost the representativeness of the assessment.

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