WHAT ROLE DO CERAMIC TILES PLAY IN GREEN PROCUREMENT AND SUSTAINABLE BUILDING?

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ABSTRACT

Many countries are promoting green procurement as an instrument for voluntarily transferring the environmental criteria established by the public sector (public green procurement) or private companies to the product and services supply chain. This presentation analyzes the current situation for green procurement globally and evaluates how this instrument might affect ceramic tiles.

The current scenario with its promotion of environmental issues, in which there is a great proliferation of ecolabelling, ecological symbols and logos, certificates, etc. poses new opportunities for ceramic tiles but, in turn, the range and complexity of the different options on offer has led to a lot of confusion, both amongst consumers and within the ceramic tile value chain. This is why, in this paper, a brief overview is provided of the main environmental labels and certificates that can be used as requirements for ceramic tiles, when their marketing involves green procurement processes.

Many of these environmental communication systems (ecolabels, building certification, etc.) are based on the analysis of the entire life cycle of products and they assess the transparency of environmental information, particularly in the case of sustainable construction. This is why, in order to respond to the demand that exists, the results of a recent study on ceramic tile life cycle assessment are presented.

Finally, a SWOT analysis of the situation for ceramic tiles with respect to green procurement has been conducted, in order to present some of the most topical questions on the subject for discussion.

1. WHAT IS GREEN PROCUREMENT?

Based on various reference sources, green procurement can be defined as the process of hire, tender or acquisition (hereafter procurement) in which the contractor or purchaser decides to establish requirements for products, services, works or contracts (hereafter products) in order to reduce their environmental impact during their life cycle, compared with the impact the products would have if they were acquired having the same basic utility without establishing these requirements. When green procurement is promoted by public entities, it is known as public green procurement (hereafter PGP).

1.1. Green procurement in developed countries

In many developed countries legislation to ensure the inclusion of environmental criteria in public procurement is gaining precedence, especially in the United States and the European Union. In Europe the European Commission has introduced a series of measures to increase the level of PGP in all its Member States and has defined target sectors, which include sectors related to building and construction, both in the acquisition of the materials of which buildings are made and in the construction, use and demolition phases [1-2]. In the United States the Environmental Protection Agency (USEPA) has published guides for the implementation of public procurement processes in the public sector, both at the federal and other levels [3].

In order to better understand the situation in the developed countries, the scientific literature that evaluates our cumulative experience of green procurement [1-9] has been reviewed. One can see from these sources that it is being implemented in more and more countries, although there is no question that those countries that appear to have the most documented experience of its practical application are, as we have already indicated, the United States and the European Union. The information found in these literature sources on the current situation, opportunities and problems encountered in green procurement, when it is related to construction and building products, is summarized below:

- Green procurement is increasing in the more developed countries, although much more in the public than in the private sector. In the public sector various studies indicate that 40 to 50% of public tenders and contracts in the European Union already include environmental criteria, partly because numerous European, national, regional and local legislations make it compulsory to incorporate them. If we take into account the fact that in the OECD (Organization for Economic Cooperation and Development, which acts as an umbrella entity for the most industrialized countries) public procurement amounts on average to 15% of gross domestic product, we can see the importance that the possession of some kind of environmental differentiation for the products companies offer may have in just a few years' time, because there are numerous legislative initiatives designed to extend this process to all public procurement in virtually all the developed countries. In the private sector our collective experience indicates that green procurement becomes established primarily for two reasons, either because it affords immediate tangible benefits (for example it saves energy) or it serves as a prevention measure to avoid incurring legal problems in the supply chain. However, there are also private companies, especially large ones, which adopt corporate criteria that are similar to those in the public sector, chiefly for reasons related to the image they wish to project.

- As far as methodology is concerned, historically it has been based on demanding certain requirements from suppliers, the most common of these, in green procurement, being the introduction of environmental management systems and ecolabelling. The advantage of these criteria is that they are simple and easy to verify, and they do not increase the costs or paperwork involved in procurement processes. Most of the criticism levelled against them stresses the fact that, with these criteria, requirements do not necessarily focus on controlling the greatest impacts of the products or services which are acquired and that procurement processes place a lot of emphasis on the contractual process but then fail to establish a follow-up system.

- To partially solve these problems, in recent years in PGP there has been a tendency to demand more extensive environmental information, so environmental product declarations based on life cycle assessment are usually used. The advantage of this system is that it offers more detailed environmental information. The main barriers it faces are the fact that these data may be more difficult for the purchaser or contractor to process, if they lack the right level of expertise and it may also prolong and complicate the procurement process. In addition, there is the risk that, if very stringent criteria are established or too much environmental information is required, the number of suppliers that can seize business opportunities may be reduced and this may limit competition. Although this is a problem for the contractor, it is seen as a great advantage for these suppliers because, with this information at their disposal, they have an edge on their competitors.

To sum up, there is a strong legislative and social tendency to promote green procurement, supported by theoretical studies that insist on making consumption trends the point at which to start by providing more environmental information to the consumer. PGP is well consolidated for some products and is rapidly gaining ground in the case of others, such as building materials. Cumulative experience is important and, although there is an intense debate about which are the best tools and methodologies for developing green procurement processes, these have matured considerably in recent years and currently there is a lot of activity in this field in the developed countries.

1.2. Green procurement in emergent countries

In these countries governments are becoming increasingly aware that they cannot continue with a 'pollute today and clean up tomorrow policy', because it is leading to environmentally serious and irreversible scenarios, and that they will need to make great efforts to correct these current excesses.

Since 2000, in the so-called emergent countries there is a growing interest in extending the adoption of the environmental practices employed by developed countries in order to ensure sustainable development. These practices include green procurement, especially PGP. This is why it is considered to be of interest to study the situation in the emerging countries [10-12]:

- There is considerable agreement, at least in political circles, that the establishment of environmental criteria in public procurement is a mechanism with huge potential for the introduction of environmental improvements. The reality is that, although the governments of these countries have started to pass legislation in order to introduce PGP, in practice there are hardly any criteria for its application and it is also difficult to verify because the environmental certification systems have notable deficiencies and little credibility. Another disadvantage in these countries is the perception that the application of PGP may act as a barrier for their own products, so these criteria tend to be applied more stringently to imported products than to ones that are manufactured internally.
- Nevertheless, there are parameters that indicate a slight increase in PGP, for instance the existence of top local companies which are starting to offer more ecological products and services, numerous studies performed by local entities that indicate the enormous potential of PGP in reducing environmental problems, the increasing interest of companies in these countries in obtaining environmental certificates, etc. These factors suggest that PGP processes will mature in a few years' time, at least in regions or areas of greater economic and social development.

2. WHAT ENVIRONMENTAL COMMUNICATION TOOLS ARE NORMALLY REQUIRED IN GREEN PROCUREMENT?

As has been indicated above, in green procurement environmental requirements are demanded from suppliers and a simple way for them to show their compliance is to have some form of recognized certificate. The chief environmental communication tools that currently exist are summarized below.

2.1. Eco-management systems

Eco-management systems (EMS) are applied to organizations and not to products, but up to now this has been one of the most widely demanded green procurement requirements [8]. They are either a compulsory requirement or they take the form of a series of points which are awarded during the process of adjudicating a purchase to companies that have an EMS. The two most widely established eco-management systems are:

- **The EMS based on the series of ISO 14000 standards** is the most widely known system internationally and probably the one that has been most widely adopted. The set of standards by which it is regulated was approved by the International Standardization Organization (ISO) in September 1996 so this system has existed for 15 years and many ceramic tile manufacturers all over the world have introduced it and have this ISO certification.

- **The European Community Eco-Management and Audit System (EMAS)** is a voluntary EU regulatory system for the implementation and recognition of an EMS. The EMAS programme has been available to companies in industrial sectors since 1995 and later became available to all economic sectors, including public and private services. In practice, this system has had less success amongst European ceramic tile manufacturers than the ISO 14000 system, perhaps because it is less well-known internationally and its criteria are more stringent. However, the EMAS system is widely recognized at the European level and is being used as a reference criterion by many European governments in PGP processes.

Recently, in July 2011, the ISO committee approved the ISO 14006 Ecodesign standard [13]. This standard can be complemented by the ISO 14001 series, regulating the systematic integration of environmental aspects into product design and development. This system is certifiable and, although it is still premature to estimate the level to which it may be implemented in the future, it could be an interesting option which is worth considering in green procurement processes.

2.2. Product ecolabels

The ISO committee has classified ecolabels into three types: type I or certified ecolabels; type II or environmental product self-declarations; and type III or environmental product declarations [14]. The main features of the three types of ecolabel are summarized in Table 1:

- **Certified ecolabels (Type I).** These are voluntary labels. They are awarded on the basis of multiple criteria, which are verified by an independent third party. They can be established by public or private institutions at the regional, national or international level and they enable us to distinguish which products within a product category have the least environmental impact. For ceramic tiles it is possible to obtain a European ecolabel [15-17], as criteria have been set within the hard floor covering category, in which a significant number of

European manufacturers have been included. The criteria are very stringent and to obtain the ecolabel all the required thresholds must be met, in other words it is based on a criterion of excellence. Although there are other type 1 ecolabels for ceramic tiles (for example in Hong Kong, Japan, New Zealand, etc.), in general they are not as specific as the type used in Europe, with the exception of Australia, which has established an ecolabel for ceramic tiles with similar criteria to those of their European counterparts [18]. In green procurement these ecolabels have the advantage that they are easy to identify and do not require the use of experts during the procurement process.

- **Environmental Product Self-declarations (Type II).** Type II environmental ecolabels are self-declared claims made by manufacturers, importers, distributors, retailers, etc., with the aim of communicating an environmental improvement of some specific aspect of their products. These labels do not need to be verified by an independent third party, although if they have been this increases their credibility. This system enables companies to declare a certain product characteristic or quality themselves, for example its recycled content, or the limited use of specific resources or emissions.

- **Environmental Product Declarations (EPD or Type III).** Type III environmental declarations present quantified environmental information about the life cycle of products based on independent validated Life Cycle Assessment (LCA) studies. The studies must be performed in accordance with specific guidelines agreed for each product category, known as Product Category Rules (PCRs). EPDs are intended more for communication between companies than for the end consumer, although their use is not exclusive and no threshold has to be met to obtain them because they are based on the principle of transparency and not on the principle of excellence. In theory, they offer the advantage of enabling comparisons to be made between products that fulfil the same function, but in practice it is difficult to compare indicators that measure different impact categories. However, given that they provide a lot of information systematically, they are widely used in green procurement processes. EPDs are of particular interest to ceramic tile manufacturers, as they can provide standardized information to professionals in the building industry, such as architects, designers, etc. and they are the only labels that enable us to evaluate not only the environmental impact of individual ceramic tiles but also of a ceramic tiling system as a whole, when tiles form part of more complex construction systems, such as buildings. On the other hand, they pose the problem of complexity in their interpretation, so they are not very useful when targeted directly at the end consumer.

	Certified Ecolabels (Type I)	Environmental Self-declarations (Type II)	Environmental Product Declarations (Type III)
Objective	To indicate better environmental performance in a product category	To communicate specific environmental aspects	To present standardized life cycle information
Is LCA required?	No	No	Yes
Is verification required by third parties?	Yes	Not required but increases credibility	Not required but increases credibility
Standard	ISO 14024	ISO 14021	ISO 14025/ISO 21930
Communication for the end consumer	Good	Good	No
Usefulness in Green Procurement	Good	Average	Good

Table 1. Product ecolabels certified by the ISO committee

2.3. Sustainable building certificates

Sustainable building, based on various sources, can be defined in practical terms as building conducted in accordance with criteria that achieve a reduction in environmental impact, taking into account the selection of the land used for building and materials, and the construction processes, in addition to the phases of use and demolition of a building, including social and economic criteria in these phases as well.

One of the most successful communication tools in sustainable construction is building certification, as it is a way of offering highly credible information with criteria that are more or less stringent but independent. One of the problems associated with sustainable building certificates is that there are many of local scope. Some of the characteristics of these sustainable building certificates are summarized in Table 2.

Methodology	Full Title
BREEAM	Building Research Establishment Environmental Assessment Method
Method for assessment and certification of building sustainability in the design, execution and maintenance phases. BREEAM assesses impact in 10 categories: management, health and well-being, energy, transport, water, materials, waste, ecological use of land, pollution and innovation.	
LEED	Leadership in Energy and Environmental Design (LEED)
Environmental certification system aimed at improving the environmental performance of buildings with respect to the following aspects: land use, energy consumption, water consumption, CO_2 emissions, indoor environmental quality, management of materials and resources and design innovation.	
VERDE	VERDE tool, Spanish Green Building Board
GBC España-VERDE Certification is an assessment tool for the environmental certification of buildings. The methodology is based on using a LCA tool at each stage of the building process and entails adaptation of the SBTool to the Spanish context.	
SB TOOL	Sustainable Building Tool
Software which implements the method for assessing the sustainability of Sustainable Building Challenge (originally Green Building Challenge) projects.	
HQE	Haute Qualité Environnementale
A voluntary labelling system for buildings based on a series of points a building must comply with in order to demonstrate that it is a building with high environmental quality. The method is based on the explicit formalization of 14 objectives, whose maximization is aimed at achieving optimum environmental performance of a building. These objectives are bundled in eco-construction, eco-management, comfort and health categories.	
GREEN GLOBES	
Green Globes is an online environmental certification tool for buildings. It originated from the BREEAM method adapted to Canada and was later exported to the USA. It is linked to the ATHENA LCA tool specifically designed for buildings and applicable to Canada and the USA. It can currently include assembly and building material LCA. How to include LCA even further in the certification process is under review.	
BDM	Le pôle Bâtiments durables méditerranéens
A methodology for diagnosing and assessing the sustainability, especially environmental sustainability, of a construction or rehabilitation project, bearing in mind its life cycle. Projects are assessed and later validated during their project, building and use phases.	
CASBEE	Comprehensive Assessment System for Building Environmental Efficiency
An analytical tool, the aim of which is to evaluate a building from two points of view: the quality of the building and the environmental loads it exerts on its surroundings.	

Table 2. Sustainable building certificates (source: UNESCO Chair in Life Cycle and Climate Change)

Further details of two of the most well-known certificates internationally are provided below:

- **BREEAM Certificate.** The BREEAM certificate emerged in 1990 as one of the main sustainability certificates in the United Kingdom and nowadays it continues to be the most widely used and recognized British certification method, although it has gradually been adopted all over the world. The methodology it proposes evaluates ten impact categories: management, health and well-being, energy, transport, water, materials, waste, ecological use of land, pollution and innovation. The points obtained in each category are environmentally weighted to take into account the relative importance of each area of impact. The results for each category are added together to yield a single global score for the building, which is used to rank it on a five-grade scale, indicating the level of BREEAM compliance.

- **LEED Certification.** LEED stands for "Leadership in Environmental Energy and Design". This certification is awarded by the US Green Building Council or USGBC. Introduced in the USA in 2000, the LEED certification has made rapid advances and has now become an international standard with an excellent reputation worldwide. It is probably the most widely adopted system and has been used for the certification of buildings in over 30 countries. Its grading system focuses on respect for the principles of saving energy and ecological building and it is used to classify 'Sustainable Buildings'. To do this a building undergoes an environmental impact assessment throughout its entire useful life. The USGBC has established a list of specifications and a series of points is assigned to each of them as an aid to architects during the planning phase. The evaluation system depends on the intended use and complexity of a building, but in general the certification grade reflects the number of points which are scored: a LEED (bronze), silver, gold or platinum (maximum) certificate.

What is the role of ceramic tiles in sustainable construction certificates?

In these building certification systems ceramic tiles have the following generic potentialities, which can confer advantages to a building as a whole:

- Most of these systems assess the amount of recycled material buildings contain and, given that during tile manufacturing processes water and waste products are recycled, they can increase the value of a building.
- Ceramic tiles do not emit volatile organic compounds so they contribute to the good quality of the air inside a building.
- They reduce the heat island effect in buildings if the solar reflectance index is high, which is usually the case with light-coloured glazed tiles.

There are also certain types of tiles that provide innovations or new functions to a building or the place where they are installed and they may be valued highly by the architect and even by these certification systems, serving as examples of ecodesign. Amongst these, some that have recently been developed may be highlighted [19]:

- Tiles with reduced thickness, which lowers the consumption of raw materials and energy, as well as the impacts associated with their distribution and final disposal.

- Tiles with surfaces that offer new functions: anti-slip properties; photocatalytic effects to eliminate environmental pollutants and purify the air; surfaces that are easy to clean, reducing the consumption of water and detergent in their use phase; bactericidal capacity to limit biological risks; surfaces that avoid superficial electrostatic loads, etc.

- Tiles that include functional elements: photovoltaic plates which can produce renewable energy or smart systems that reduce the need to install auxiliary elements.

- Tiles with bodies that have special functions: regulatory effects on environmental humidity or highly porous bodies with substantial thermal insulation and acoustic properties.

- Innovations in the integration of tiles into buildings: for example dry installation or the use of tiles in ventilated façades.

The ceramic tile sector should explore all these possibilities and options for environmental improvement and stress their value to architects and end consumers so that applications that few competitor products can provide can be offered.

3. ARE THERE ANY LIFE CYCLE ASSESSMENT STUDIES ON CERAMIC TILES?

The first documented LCA studies on ceramic tiles appeared in about 2000 [16-17] and their aim was to establish the criteria for the European ecological label for ceramic tiles. In addition, there are other LCA studies which were primarily performed for comparative purposes or to evaluate specific improvements or types of products [20-23]. However, the former we might regard as somewhat obsolete because they do not include all the environmental improvements that have been introduced in recent years [24-34], while the most recent studies are very specific and cannot be considered to represent the entire ceramic tile sector.

For these reasons and because there is a growing demand for environmental information about ceramic tiles, made insistently by the people who market them [35], an updated LCA test was needed for the sector. In this context, the GiGa (Environmental Management Research Group) (ESCI or Higher School of International Commerce at the Pompeu Fabra University) and the ITC (Institute of Ceramic Technology at Jaume I University), with the collaboration and support of ASCER (Spanish Ceramic Tile Manufacturers' Association), performed a life cycle assessment involving the ceramic tile sector following ISO LCA standards [36-37] with the aim of obtaining scientifically valid and objective benchmark values for the different environmental loads of ceramic tiles. The scope of the study is summarized in Table 3.

Concept	Description
Functional unit	1 m^2 to cover walls or floors for 50 years
Type of tiles	Porosity: earthenware tile, stoneware tile and porcelain tile Colour of the fired tile body: red and white Forming: pressing and extrusion Raw materials preparation: dry and wet method
Representativeness of the sector sample	56 Spanish companies About 50% of Spanish production
Cycle analyzed	From cradle-to-grave. Phases: manufacturing (including extraction and processing of raw materials), distribution (including transport, installation and management of packaging waste), use and end of life
Exclusions	Machinery and industrial equipment Non-ceramic waste recycling process Impact of raw materials with a content <1% (by weight)

Table 3. Scope of the LCA conducted by Giga-ITC

The data analyzed in each phase are explained in detail in the literature [38-39] and there is a brief summary of the inventory so, if readers require more information, they can refer to the sources cited:

Phase A. Manufacturing:

- Input and Output of Materials. The consumption of raw materials, fuel and water, as well as the generation of emissions and waste products and their treatment, has been analyzed. The waste resulting from maintenance operations or other activities external to the manufacturing process are not included in the inventory as they are outside the limits of the system.
- Consumption and Energy Production Data. In general, data on the consumption and production (including cogeneration) of electrical and thermal energy have been included in the inventory.

For material and energy inputs all the impacts generated upstream (extraction, production and transport) were analyzed and for outputs all the impacts generated downstream were considered.

Phase B. Distribution:

- Transport or Distribution of the Product. Here fuel consumption as a result of transport and the emissions associated with it have been taken into account.

- Management of Packaging Waste. The management of packaging waste has been regarded as different, depending on the geographical area (Spain, Europe and the rest of the world), in each case taking the average data for different types of management (incineration, recycling or the dumping of waste at rubbish tips).
- Installation of the Product. The use of mortar adhesive during the installation of all types of ceramic tiles has been analyzed.

Phase C. Use.

- Consumption of Materials. Water and detergent consumption over a period of 50 years has been calculated, depending on their use (domestic, commercial or health care) [40].
- Impact. During its use phase the product is regarded as being inert, consuming no energy and producing no significant impact on the environment (it emits no volatile compounds and does not make compounds soluble in water, etc.).

Phase D. End of Life

- Energy Consumption. Bearing in mind the fact that, on average, ceramic tiles account for less than 1% of the total weight of buildings, we can regard the energy consumption associated with dismantling them as insignificant.
- Waste Management. Once a building has been demolished, it is assumed that 83% of the tiles are dumped at landfills and the remaining 17% are assigned to other uses (based on management data averages for Spain).

As for the environmental impact assessment phase of the LCA, the environmental impact categories and the methodology were selected from the options recommended by the operating manual for the application of LCA ISO standards [41].

Impact Category	Description
Depletion of abiotic resources (DAR)	The depletion potential for each extraction of minerals and fossil fuels is determined in kg Sb equivalent.
Acidification potential (AP)	It takes into account emissions of acidifying substances such as HF, HCl, SO_2, etc. (in kg). The acidification potential is determined in kg SO_2 equivalent.
Eutrophication potential (EP)	It takes into account the emission of nutrients into the air (for example NO_x which lead to the formation of nitrates), water (for example phosphorus) or the soil (in kg). The eutrophication potential is determined in kg phosphate equivalent (PO_4^{3-}).
Global warming potential (GWP)	It takes into account atmospheric emissions of greenhouse gases and includes direct and indirect emissions (transport of raw materials and products, emissions resulting from the production of the electrical energy that is consumed, etc.). The global warming potential is measured for a period of 100 years in kg CO_2 equivalent.
Ozone depletion potential (ODP)	It takes into account the emission of substances into the air which can deplete the ozone layer (in kg). The depletion potential for each emission into the air is determined in kg R11 equivalent (trichlorofluoromethane).
Photochemical ozone formation potential (POFP)	It takes into account emissions of photochemical ozone formation precursors (Volatile Organic Compounds, CO, NO_x, etc.) (in kg). The photochemical ozone formation potential of each emission is established in kg ethylene equivalent.

Table 4. Impact indicators used for the analysis.

As well as these categories, in the impact analysis a series of flow indicators have been included as an aid to decision-making and the interpretation of results. These indicators are:

- **Primary energy consumption:** the total gross amount of calorific energy, derived from renewable and non-renewable sources, which is consumed by the system, taking into account both the direct consumption required to manufacture the product and indirect consumption derived from activities performed to obtain direct energy. Unit of measurement: Mega Joules (MJ).
- **Water consumption:** the total amount of fresh water consumed by the system. It is calculated by adding up the total amount of water consumed throughout the life cycle of the product. Unit of measurement: kilograms (kg).

The information obtained from the study is summarized in Table 5. The value intervals obtained for the impact categories that were selected are shown in this table and the phase that contributes most is indicated for each of the impact categories that were evaluated (average values are recorded). The most relevant findings were as follows:

- The global warming potential is a very significant impact category, which is also reflected in the primary energy consumption flow indicator. It is mostly the CO_2 emissions produced in fuel combustion during the generation of electricity, the combustion and extraction of natural gas during the manufacturing process (spray-drying, drying and firing stages) and fuel consumption during the transport of materials and products that contribute to this category. In this category the phase that contributes most corresponds to the production of CO_2 equivalent during combustion processes in the manufacturing phase (69%). Consequently, improvement requires promoting measures designed to reduce energy consumption during this phase. There are other external factors which the company cannot control, such as the energy production mix in the country where the manufacturing centre is located. In addition, during the distribution phase, if the distances raw materials and products are transported are minimized or transport by sea rather than by road is used to cover the same distance, impacts can be reduced.
- In the other impact categories which make a significant contribution, the manufacturing phase is important in the abiotic resource depletion potential category (owing to the consumption of raw materials and non-renewable fuels) and in the acidification potential category (emission of acid compounds during manufacture).
- The phase in which tiles are used can also be seen to have a great impact on water consumption, as a result of the cleaning of tiles over a useful life of 50 years. The use of detergents means that this phase makes the greatest contribution to the impact categories corresponding to eutrophication and photochemical ozone formation potentials. Although this activity is subject to user habits, the location of tiles and the scenario in which they find themselves, average values have been taken on the basis of various assumptions. However, we should emphasize that energy is not required to clean tiles, whereas materials they compete with do require the use of a great deal of energy during this phase. Moreover, given the high durability of tiles, it is unnecessary to replace them during the time span used for the analysis, unlike possible outcomes for other alternative materials.

Indicator	Units	Interval	Phase of Greatest Contribution
Depletion of abiotic resources	kg Sb eq.	0.063-0.075	MANUFACTURE (76%)
Acidification potential	kg SO_2 eq.	0.059-0.074	MANUFACTURE (54%)
Eutrophication potential	kg PO_4^{-3} eq.	0.008-0.009	USE (43%)
Global warming potential	kg CO_2 eq.	12-14	MANUFACTURE (69%)
Ozone depletion potential	kg R11 eq.	$(1.78\text{-}1.90)10^{-6}$	MANUFACTURE (84%)
Photochemical ozone formation potential (POFP)	kg C_2H_4 eq.	0.011-0.012	USE (65%)
Primary energy consumption	MJ	205-235	MANUFACTURE (56%)
Water consumption	kg of water	321-344	USE (62%)

Table 5. Environmental profile of the ceramic tiles included in the analysis

One of the interesting possibilities that LCA tools offer is their ability to simulate scenarios in order to see the repercussions they might have on the more significant impact categories. Some of the results obtained during this sensitivity analysis, in which two of the most important variables, tile weight and energy consumption during the production phase, are considered, are summarized below:

- **Tile weight:** variation in tile weight affects the amount of raw material used for their manufacture, influencing the primary energy which is required, atmospheric emissions, the amount of material that needs to be transported, etc. To investigate the effect of this variable, an analysis was performed which indicates that to obtain a significant variation (higher than 10%) in the abiotic resource depletion and global warming potential categories a weight reduction of about 50% is required.

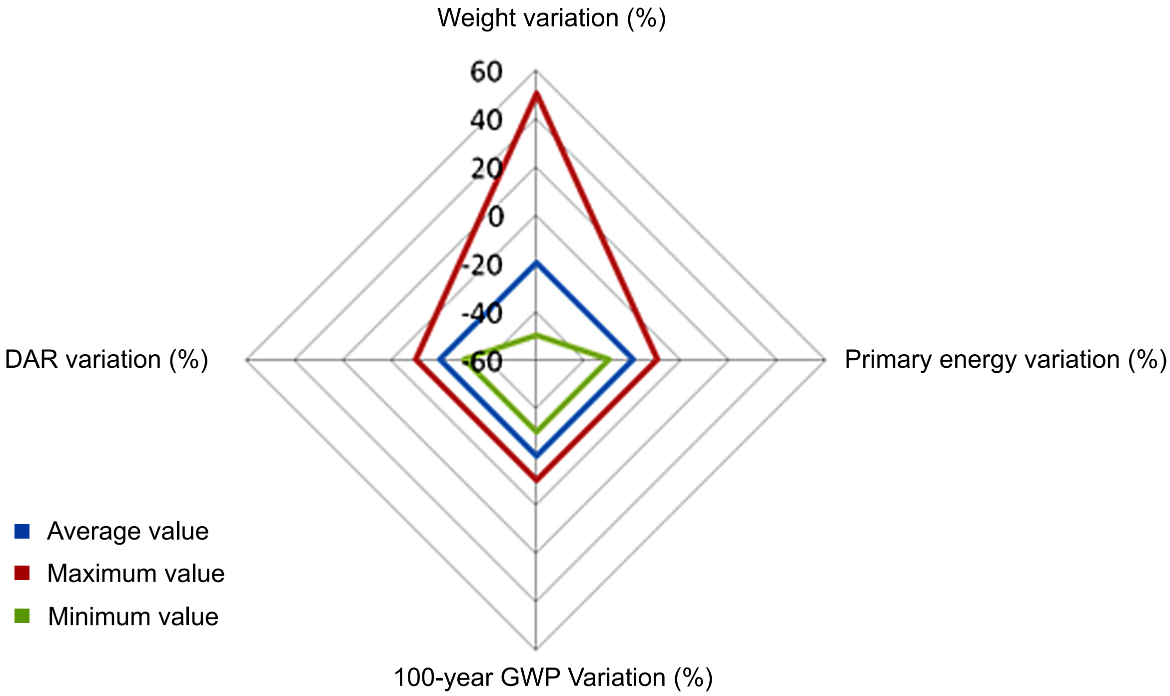

Figure 1. Variations in impact categories as a result of tile weight variations of 50% (Maximum: average + 50%, minimum: average – 50%)

- **Energy consumption**: To determine the significance of thermal energy variation in the final LCA result for tiles, the life cycle stages in which energy consumption can be reduced were identified. Taking into account the Action Plan proposed by the European Commission for 2020, which establishes the need for a reduction in energy consumption of 20% by increasing energy efficiency, establishing a renewable energy quota of up to 20% and a quota of 10% for biofuels and other renewable fuels in transport, a reduction in CO_2 equivalent emissions in the entire tile life cycle of about 10% can be achieved. A plant currently using the Best Available Techniques in direct thermal energy consumption barely exceeds an energy efficiency of 40–45%. So to reduce these emissions and substantially increase energy efficiency radical changes need to be introduced, such as the replacement of the spray-drying process with dry route or alternative processes [42], the introduction of new drying and firing systems [43-44], or the incorporation of renewable energy sources, etc.

4. THE SITUATION OF CERAMIC TILES IN GREEN PROCUREMENT: SWOT ANALYSIS

Finally, a brief SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis was made of the situation of ceramic tiles in green procurement, the aim of which was to serve as a basis for the discussion during the panel debate after the presentation.

Weaknesses

- To reduce the environmental impact of the ceramic tile manufacturing process it is necessary to introduce radical changes and take risks, in particular to reduce the associated CO_2 emissions [45].
- A tile is not a final construction system, but forms part of other more complex systems so that its environmental performance in the phase corresponding to its use depends on the system as a whole.
- The existence of many environmental communication tools creates confusion amongst manufacturers and consumers and even professionals so it is necessary to adopt various strategies in order to be able to compete in green procurement processes, depending on the geographical area concerned, and on whether a purchase will be public or private.
- The lack of transparency and proactiveness in the environmental information of some manufacturers and suppliers may be an obstacle, given that, if they do not carry out their own studies, their competitors will, selecting the most unfavourable data for ceramic tiles [21].

Threats

- The use in green procurement of local environmental labels and certificates in such a way that they act as commercial barriers without the effect of a real reduction in environmental impact having any importance.
- The increasing attention that specific CO_2 emissions receive as a result of initiatives such as the carbon footprint, which, if it is used as the primary environmental parameter, may adversely affect ceramic tiles compared with other alternative products and hide their qualities in other impact categories.
- The tendency that exists in many environmental labels and certificates to only consider life cycle as far as the factory gate, excluding the use phase, which is the one in which ceramic tiles present unquestionable advantages in comparison with products with the same function.

Strengths

- The European ceramic tile manufacturing industry uses the Best Available Techniques vis-à-vis energy and environmental issues.
- A great deal of work has been done in relation to environmental issues in recent years so there is a lot of environmental information about manufacturing processes.
- Ceramic tiles have very positive intrinsic properties in their use phase: they are durable, easy to clean, consume hardly any energy, contribute to air quality in indoor environments (no COV emissions), are classified as non-combustible material, etc.
- There are specific tools (such as the European ecolabel) for ceramic tiles that can afford competitive advantages over other competing products.
- The ceramic tile sector is characterized by intense R&D&I activity, which has enabled important innovations. These are of great interest from the point of view of green procurement, as noted above.

Opportunities

- There is scope for improvement in reducing the most significant impact category, the global warming potential, by increasing energy efficiency during the current manufacturing process.
- If new manufacturing processes with lower energy and raw materials consumption are developed, this would place ceramic materials in a more advantageous position.
- The inclusion of ceramic tiles in more complex systems also poses opportunities for innovation in this field.
- Green procurement processes have evolved considerably in developed countries and they are being extended to construction materials so ceramic tiles must position themselves accordingly. To do this, convincing environmental communication is necessary both at the individual company level and in the sector as a whole, in order to make the most of the strengths of ceramic tiles.

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