FROM RAW MATERIALS TO END PRODUCTS: SUSTAINABILITY IN ITALIAN CERAMIC TILE PRODUCTION

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ABSTRACT

The Italian ceramic tile industry has embraced a broad vision of sustainability, ranging from the use of non-toxic raw materials to efficient, high-performance production systems, from the protection of workplaces to full compliance with regulations and worker rights. The present study seeks to describe the evolution of the Italian Ceramic District (Sassuolo and Fiorano Modenese, Italy) from the environmental point of view during the last few decades. Porcelain tiles are the result of production cycles that have been completely modified in the last two decades. Progressive innovations have transformed age-old history into contemporary value leading Italian porcelain tiles to be an outstanding example of an environmentally sustainable product with exceptional green credentials. Many actions have been carried out to face the

challenges of sustainability and this paper reports the environmental performance of the Italian district, thus promoting international awareness of the outstanding results achieved. The industry-average Environmental Product Declaration (EPD), which provides a transparent and objective statement of a product's environmental performance over its entire lifetime, has been promoted by Confindustria Ceramica and published in 2016. The sectorial EPD, based on primary data for 84 factories accounting for 82.6% of Italian ceramic tile production, guarantees the sustainability of the entire Italian ceramic industry. The Italian tile industry has recently analysed the product's environmental impacts over its entire life cycle by means of a Life Cycle Assessment (LCA). It revealed the superior environmental performance of Italian porcelain floor tiles versus other covering materials. Last but not least, in 2019, Confindustria Ceramica clarified the Italian ceramic sector's position with respect to the 17 new UN Sustainable Development Goals (SDGs) by drafting a Report devoted specifically to the characteristics of the Italian ceramic industry. The results of this report highlight the fact that the continuous research conducted by companies aimed at reducing the impact of their production process makes Italian Ceramics one of today's most sustainable and high-performance materials.

1. INTRODUCTION

The Sassuolo district location is in the Emilia Romagna Region (Italy), where 90% of the national Italian production of ceramic tiles has always been concentrated over the years. The District alone accounts for 81% of the national production (337 million of sqm), with 87 tile producers [i]. This area has been the subject of an extensive research and experimentation activity due to the climatic and meteorological profile of the regional location. The first studies were focused in particular on emissions into the atmosphere [ii][iii][iv][v], due to more critical environmental situation which made it compulsory for ceramic factories facing the issue on bad air quality level in the district at that time (1970). This paper seeks to provide an overview of the evolution of the environmental aspects related to the tile manufacturing process over the last four decades, illustrating not only the aspect of emissions into the atmosphere, but also water and waste recycling and energy consumption. If the first approach of the district to improve the air quality was the "command and control" framework, from the 1990s new policies and management systems have been developed regarding both the requirements of quality and environment. Integrating the environmental issues in the production process, considering design and planning stage as well, had a positive effect on the activities devoted to environmental protection. These system are based on the continuous improvement of the performances [vi], calculated with quantitative and concrete parameters, which have been used for specification of permit conditions and emission limits based on BAT (Best Available Techniques), the most effective techniques in achieving a high level of protection of the environment as a whole. The BAT, developed on a scale that allows implementation under economically and technically viable conditions, have been listed at national level in Italian Decree [vii] and European level, in a BAT reference document or BREF [viii] for ceramic products, including ceramic tiles. In an increasingly sensitive and aware market that tends to select sustainable products, the final user must have access to environmental product performances that comply with specific requirements which, to be credible, can only be severe. In this context, the communication of environmental data plays a fundamental role in the strategy of disseminating information, which must therefore guarantee their technical-scientific and methodological rigor.

2. BIG DATA & "RAPPORTO INTEGRATO"

According to the Industrial Emissions Directive (IED), Italian ceramic tile factories must i) adopt and implement a monitoring program and ii) develop and deliver every year to the competent authority an environmental report containing a picture of the yearly performances of each manufacturing unit. Thanks to the agreement between Confindustria Ceramica and the Emilia Romagna Region all these data are collected and processed by Centro Ceramico and included in a database conceived and developed to be periodically updated in order to show the evolution over time of the investigated aspects. The final result is a report called "Rapporto Integrato" [ix][x][xi], whose goal is to describe the state of the art of the ceramic tile sector concerning the two main strategic aspect of competitiveness for the Italian industry: environment and energy.

The sample consists (this can change during the year under investigation) of around 90 manufacturing units, organized according to the class of product (porcelain stoneware, other products and spray-dried powder) and manufacturing cycle (complete, partial, complete + spray-dried powder for sale).

35 "specific indicators", calculated from the background data measured or directly calculated at company level and declared in the Italian IPPC permit called AIA (Environmental Integrated Authorization), which is specific and verified for each plant involved in this study, have been identified and quantified in order to evaluate the most significant environmental impacts applicable to ceramic tile manufacture, which cover 4 main areas:

- Emission into the atmosphere (pollutants such as: particulate matter PM, Fluorine HF, lead Pb, SOx, NOx, CO, CO2, Aldehydes ALD, Volatile Organic Compounds VOCs)
- Water consumption and wastewater production and discharge (annual consumption of water, Specific Consumption of water, ratio of wastewater recycling R)
- Waste materials/residues from both the production and purification process (specific production of fired and unfired waste, production of exhausted lime)
- Energy consumption and associated emission of greenhouse gas (specific consumption of natural gas, electric energy consumption, total energy consumption)

The indicators are parameters obtained by calculation from product and process quantities measured according a target methodology and are per definition average values on year-based production. The final results of the report provide a snapshot of the actual impact/performance of ceramic sector, updated year after year for every single indicator, which cannot therefore be assimilated directly to limit values to be included in the authorizations. At the same time, it provides each ceramic company with a reference for performing an internal benchmark. The data collected and reported in this paper are updated to 2017, while the calculations for the year 2018 are in progress. As regards the emissions into the atmosphere, by way of example, Figure 1 shows the trend of the impact of the ceramic industry on the territory in this case due to Particulate Matter, the oldest and the most characteristic environmental indicator for ceramic

manufacture. The emission factor FE is calculated from average data as the ratio between Annual Mass Flow of PM (grams) and Annual Production (m^2).

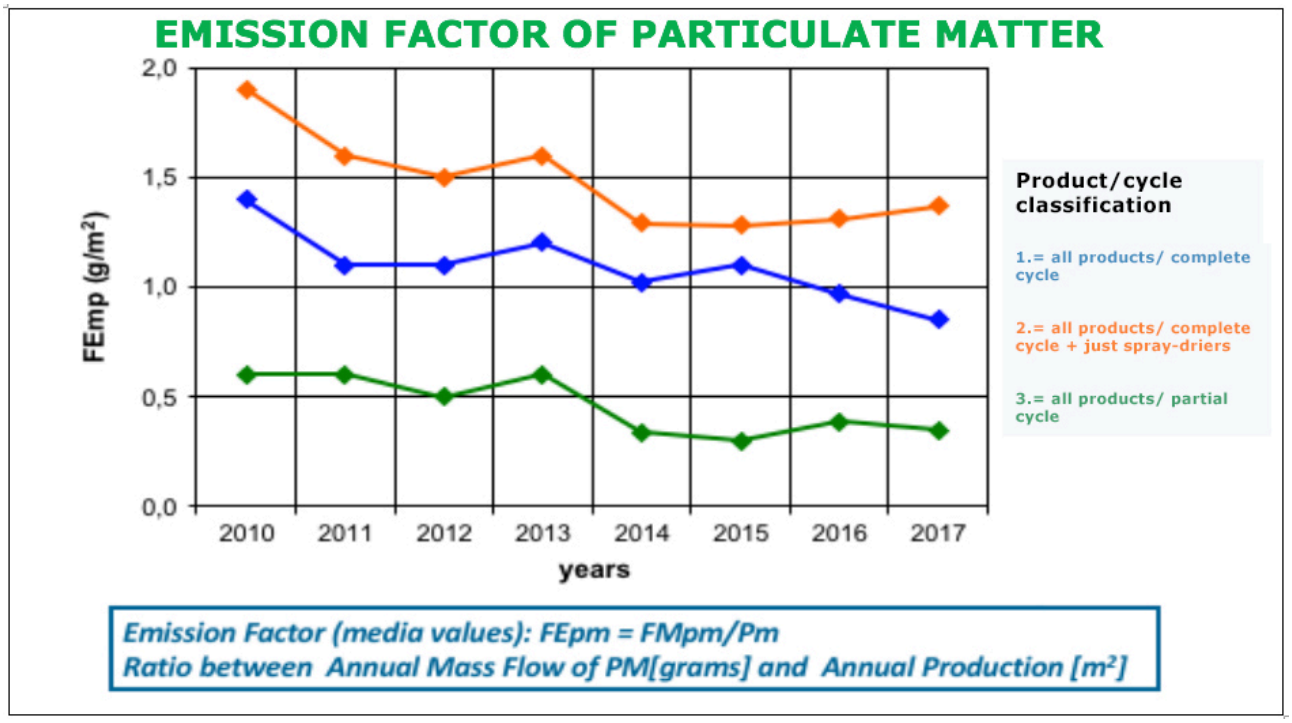

Figure 1: *Emission Factor (FE_{MP}) of Particulate Matter from years 2010 to 2017 considering the classification on products and processes.*

Another option to extrapolate information from the data base is to plot the emission factors of the pollutants under investigation versus year to better understand the evolution of the impact of the ceramic industry during the last few decades. The graph in Figure 2 extends the field of investigation from 1998 to 2017 and shows the effects of environmental policies introduced over time and the technological investments made by companies, such as abatement equipment, which reduced drastically HF emissions.

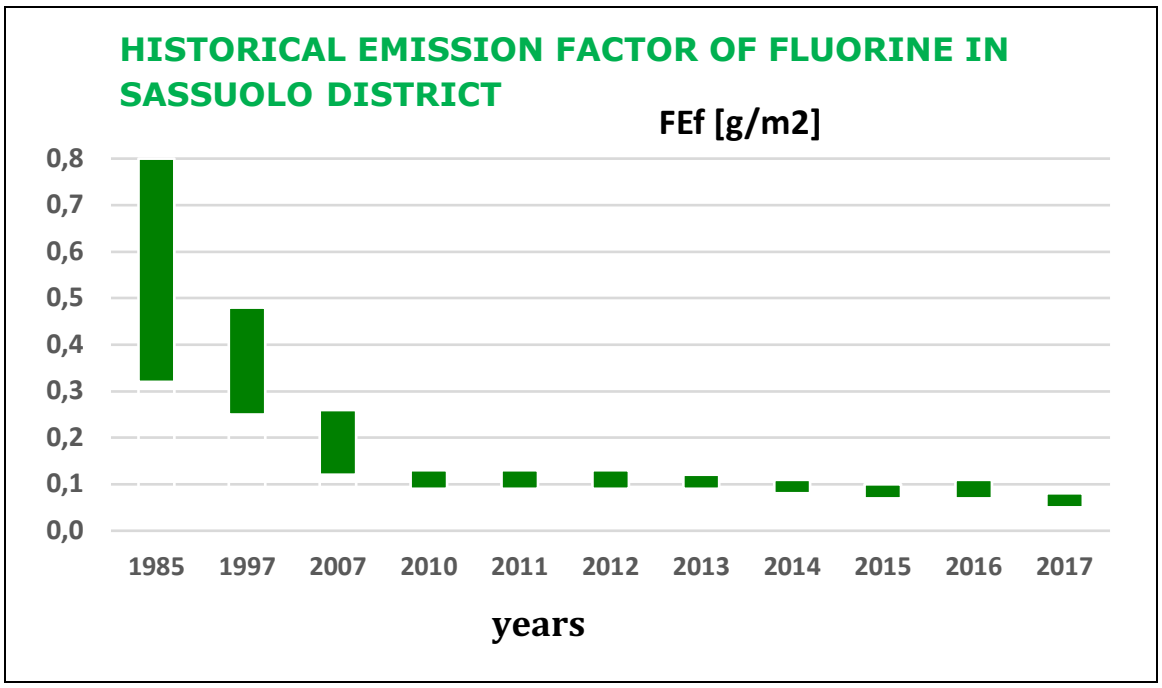

Figure 2: *Emission factor of HF (FEf) - annual average values considering all classifications*

One of the indicators in the area of Emissions to atmosphere deserves a special mention because it appears to show worsening of the environmental performances: Volatile Organic Compounds (VOCs).

Figure 3 shows the increasing trend of VOC emissions during the last 8 years, which depends on the innovative evolution in the district: digital decoration. Digital ink contains many organic solvents [xii] [xiii] and despite the high temperatures reached, in the preheating phase it may not be completely burned, giving rise to local phenomena involving odorous events. The district is managing the relationship with citizens, based on the fact that the VOC concentrations in the emissions are constantly below the limits defined in the local regulation.

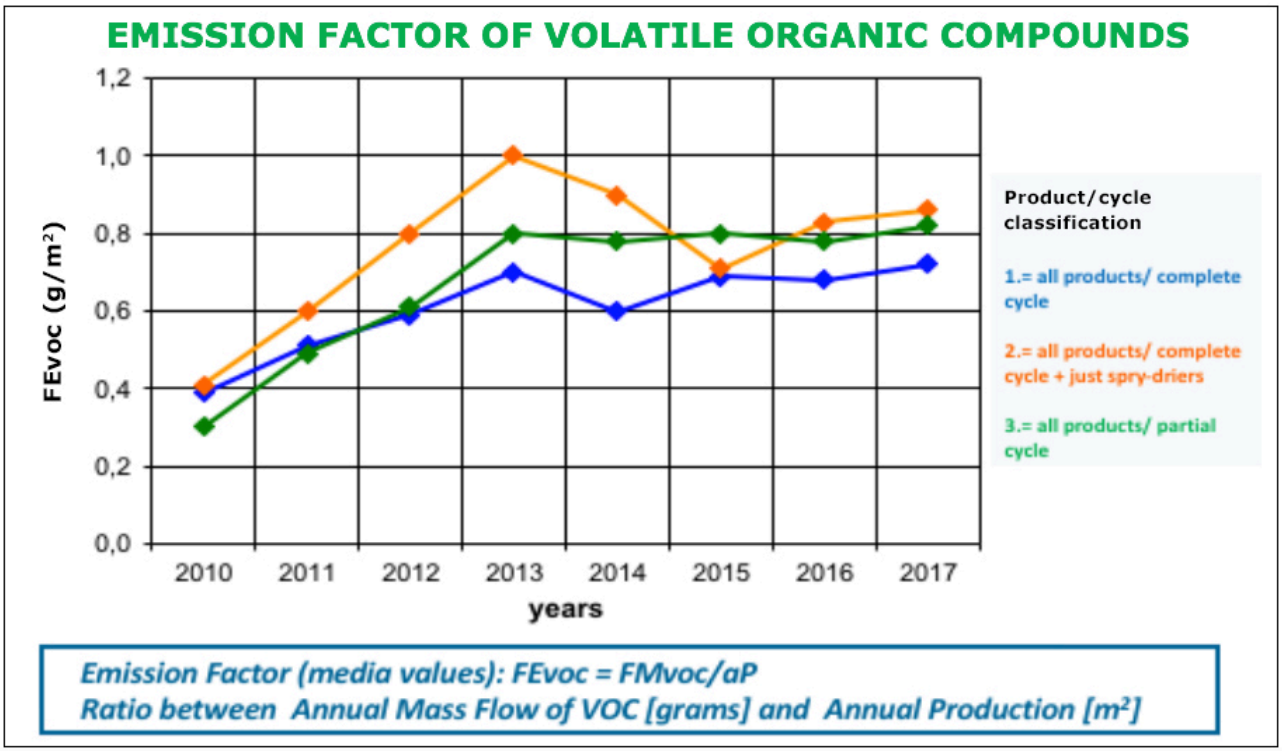

Figure 3: *VOC emission factor - annual average values considering the classification on products and process.*

Furthermore, the increased VOC emission is driving the district towards a technological path to optimize the environmental impact due to digital decoration. The researchers have to find the proper balance between local odour issues, well managed thanks to the collaboration among institutions, researchers and industry, and on the other hand a decrease in certain environmental impacts of the process due to the massive spread of digital decoration in the district: drastic reduction in water requirements, decreased sludge from water purification, reduction of packaging waste, improvement of working conditions for employees. Similar graphics (like the one reported in Figure 3 are available for all the emission factors considered in the report.

For each parameters the data are able also to compare the level of the district with some references: old integrated reports, BAT reported in the sectorial BREF, requirements for the environmental label of excellence (Ecolabel). Figure 4 reports the comparison between the emissions of fluorine and the reference values. The plotted bar represents a scale of values of the emission factor of the pollutants under investigation in which the best performances are at the bottom of the graphic. The current situation of the district with max, medium and minimum values collected in 2017 are highlighted on the left. On the right are reported reference values. As regards the emissions into the atmosphere, the data calculated for particulate matter and fluorine show the position of the Italian district compared to the BAT reference values, exhibiting an improvement compared to the values measured in 1998 [xiv]. All the factories of the Italian ceramic district recorded Particulate Matter (PM) values below the BAT (7.5 g/m^2) and comply with the Ecolabel criterion (5.2 g/m^2). More than 90% of the production sites have a PM emission factor lower than half the Ecolabel value.

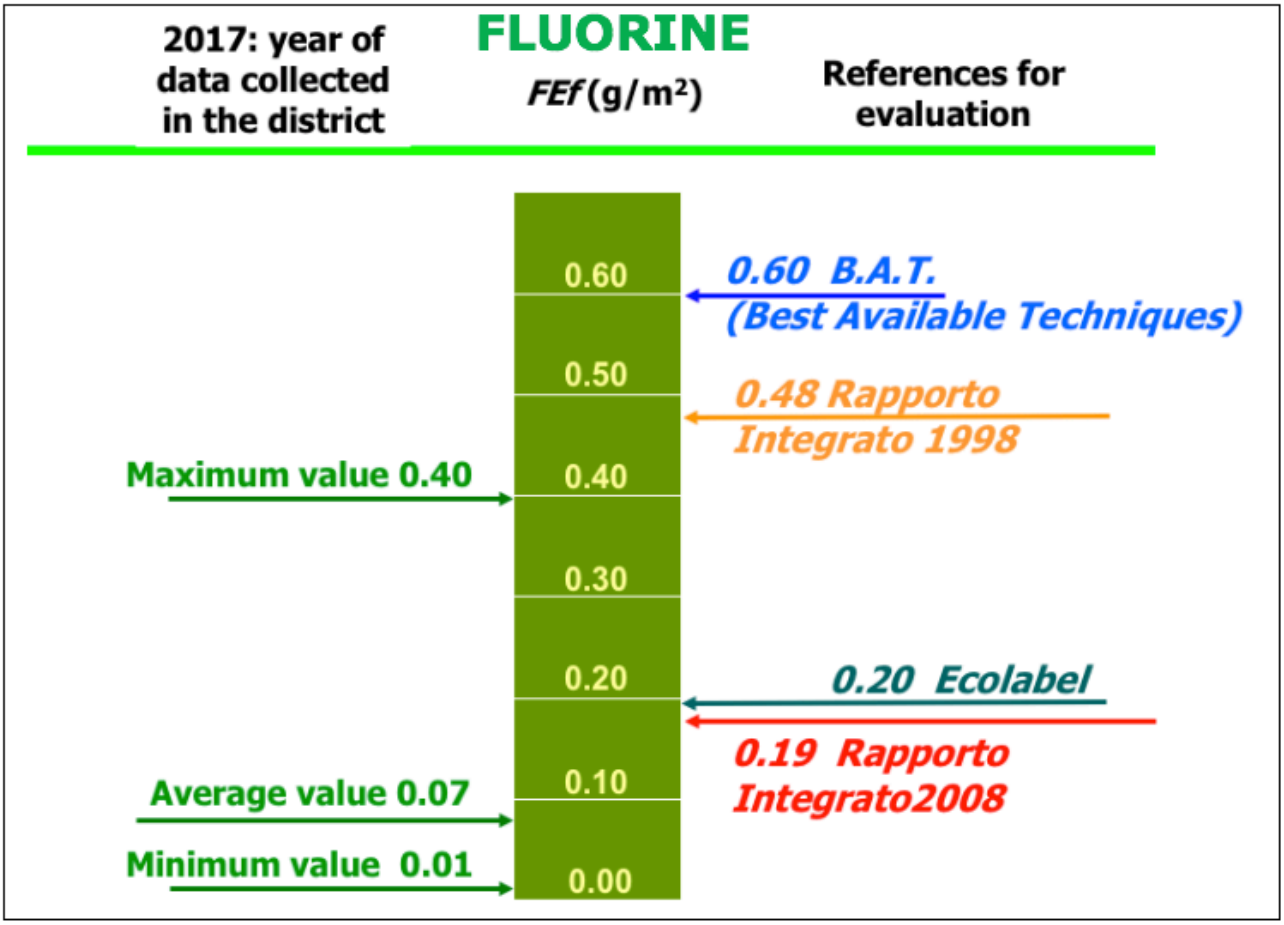

Figure 4: *Fluorine emissions of the district and reference values for comparison*

The Fluorine emission factor was found to be between a minimum of 0.01 and a maximum of 0.40 g/m2 with respect to the BAT reference value of 0.60 g/m2. More than 90% of the plants recorded lower values compared to the Ecolabel criterion of 0.20 g/m2.

On the other hand, the position of the Italian ceramic district with respect to the references for water, materials and energy balance and consumptions [xv] can be represented as well. The indicator that is used to highlight the environmental aspect related to reuse, is the overall recycling factor (internal + external), respectively of wastewater and waste/product residues, expressed as a percentage. In Figure 5 the water balance and materials reuse are reported: the best performances are located in the upper part of the bar and the higher is the percentage value, the better is the indicator.

A 100% wastewater reuse factor indicates that all wastewater from the production cycle is completely reused internally or externally, meaning there is no outside release of water (in surface water bodies or in sewers). A reuse factor greater than 100% is the value for installations that, in addition to reusing all the wastewater produced in their own process, are able to receive additional water from outside, to cover a higher demand of the water requirements of their production cycle. The wastewater re-use factor was between a minimum of 60% and a maximum of 197%. The average re-use factor stands at 108%, with a net improvement compared to 89%

recorded in 1998. Furthermore, for this environmental performance, all the ceramic plants are in compliance with the BAT value of 50%.

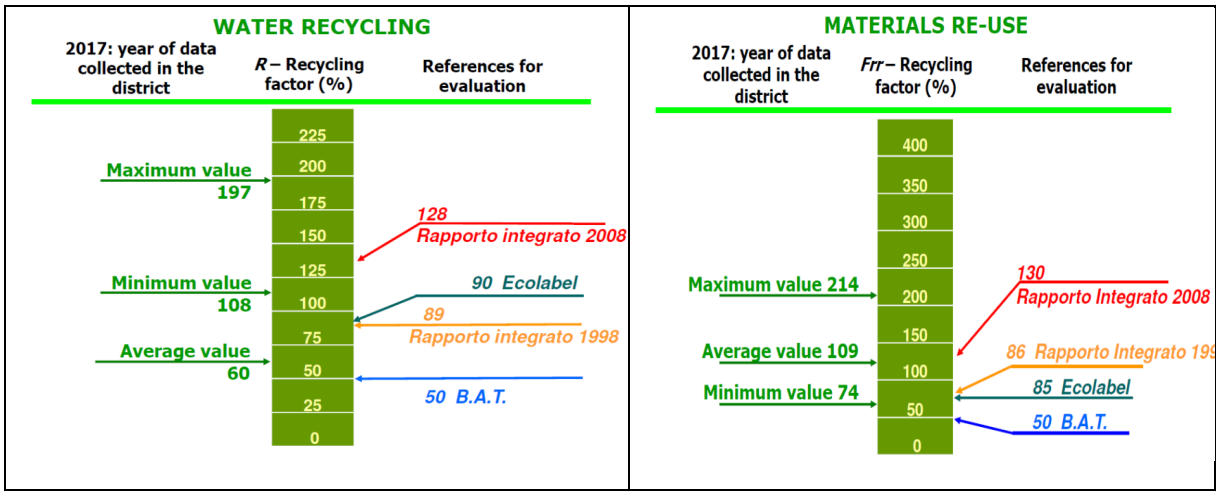

Figure 5: *Water recycling (on the left) and materials re-use (on the right) with relevant reference values.*

A substantially similar situation appears for the waste/residues coming from the production process. The re-use factor was between a minimum of 74% and a maximum of 214%. Against the minimum value of 74%, the consolidated average value of 109% has been recorded. Again, all the ceramic companies respect the BAT limit of 50%, and only 2% are below the 85% value indicated in Ecolabel.

3. ENVIRONMENTAL PERFORMANCE AND COMPETITIVENESS

The emission factors and the consumption values discussed in the previous paragraph evidence the excellent level of environmental performance achieved by the Italian Ceramic Tile Industry. The "cleaner" products using "cleaner" techniques (equipment and materials) applying an integrated management of resources (water, energy, waste & secondary raw materials) have led to a substantial environmental improvement of the life cycle. These "green" results have raised costs for the Italian Ceramic Tile Industry, which has found itself in a possible weaker competitive position due to the increasing environmental efficiency costs and higher energy demand for all the environment "eco-friendly" equipment. The Italian tile producers are facing this situation by using the excellent environmental performance as a competitiveness factor, in response to the increasing demand arising from administration policies, experts, building rating systems, but also from the general public, who are becoming more and more sensitive and aware of the importance of protecting the environment. This attitude increased the interest of consumers (private and public) in "green" products, reinforcing and motivating the ceramic factory to exploit new voluntary tools to attest the sustainability of ceramic tiles with a scientific approach and to communicate the results to the end users. In the last few years the Italian ceramic industry sector has developed

continuous improvement of the green profile of processes and products through various technological, managerial and territorial marketing actions.

Italian ceramic tiles earn numerous credits in sustainable building certification schemes thanks to the fact that the Italian tile producers have striven to achieve the goals of "health, safety and environment". These tools are several and of diverse type: the EU Eco-Management and Audit Scheme (EMAS) [xvi], the certification of the environmental management system according to ISO 14001, the ecological marks scheme represented by substantially environmental labels like European ECOLABEL [xvii], in which ceramic tiles are included in the group of "hard coverings".

The Sassuolo Ceramic District has also promoted the creation of a new ISO international standard defining the characteristics that a ceramic tile must possess in order to be considered sustainable (ISO 17889 – Part I – Ceramic Tiling Systems). The draft standard, which is close to receiving final approval, removes all uncertainty with regard to interpretation of sustainability by adopting a practical "compliant/non-compliant" approach and allows products to be differentiated by means of a measurable score.

For several years, the Circular Economy has been a reference point in the policies of the European Union, which in 2015 promoted a special package of policies for the Circular Economy in member countries, updating the main directives concerning waste management. Also, in Italy, starting from the Environmental Link to the 2015 Stability Law, and with the ad-hoc laws approved in some regions including (first) Emilia-Romagna, the Circular Economy paradigm started to make its way among the public administrations and businesses. Confindustria Ceramica and Regional Institutions have established a collaboration to exploit this new paradigm within the Italian Ceramic District. Based on the fact that the ceramic industry is able to reuse most of its own residues that are created during production, the Emilia-Romagna Region, with executive number n. 16604 of 10/23/2017 linked to the Regional Circular Economy Law, identified four by-products originating from the ceramic sector that can find an effective and certain use within the ceramic production process making a significant contribution to avoiding the consumption of raw materials and preventing waste production. The development of production technology makes the ceramic plants re-use most production waste (raw and fired waste tiles, sludges from washing lines or from polishing lines) reinserting them into the ceramic production cycle instead of other raw materials. This avoids the extraction, transport and use of thousands of tons of materials of natural origin, avoiding the extraction of 600,000 tons of natural raw materials every year.

The most recent action Confindustria Ceramica has put in place regarding sustainability has been the review of the ceramic industry's sustainability projects linked to the 17 Sustainable Development Goals (SDGs) of the UN 2030 Agenda, which will be the new reference on Sustainability and International competitiveness. The Review has identified 55 projects in progress contributing to 9 of 17 total SDGs and may finalize two objectives: the classification of what has been done or is still in progress (green management, health & safety, green product declaration, education) and identification of new development areas with a view to continuous improvement and integrated sustainability.

4. ENVIRONMENTAL PRODUCT DECLARATION –EPD

Among the various green labels, Confindustria has chosen to invest in the EPD declaration (Environmental Product Declaration). EPD is an independently verified and registered document that communicates transparent and comparable information about the life-cycle environmental impact of the chosen product, according to ISO 14025.

PRODUCT STAGE			CONSTRUCTION PROCESS STAGE		USE STAGE							END OF LIFE STAGE				BENEFITS AND LOADS BEYOND THE SYSTEM BOUNDARIES
Raw material supply	Transport	Manufacturing	Transport from the gate to the site	Assembly	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Reuse-Recovery-Recycling-potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D

Figure 6: *Description of the life-cycle steps taken into account in the LCA for the ceramic sector EPD.*

In 2016, Confindustria Ceramica presented the sectorial EPD for Italian Ceramic Tiles, the first in the world with such a large number of companies involved. The document in fact refers to an average ceramic tile product manufactured by Confindustria Ceramica's member companies.

The LCA data were collected in 2014 and the study involves, as primary data, 76 companies and 84 plants, representing around 83% of the Italian ceramic tiles production. As said before the entire life cycle of the product (ceramic "average" products of 1sqm of 19.9 kg/sqm) is considered from cradle-to-grave (raw materials, manufacturing process, transportation, use and re-using/end of life) with a lifetime of 50 years.

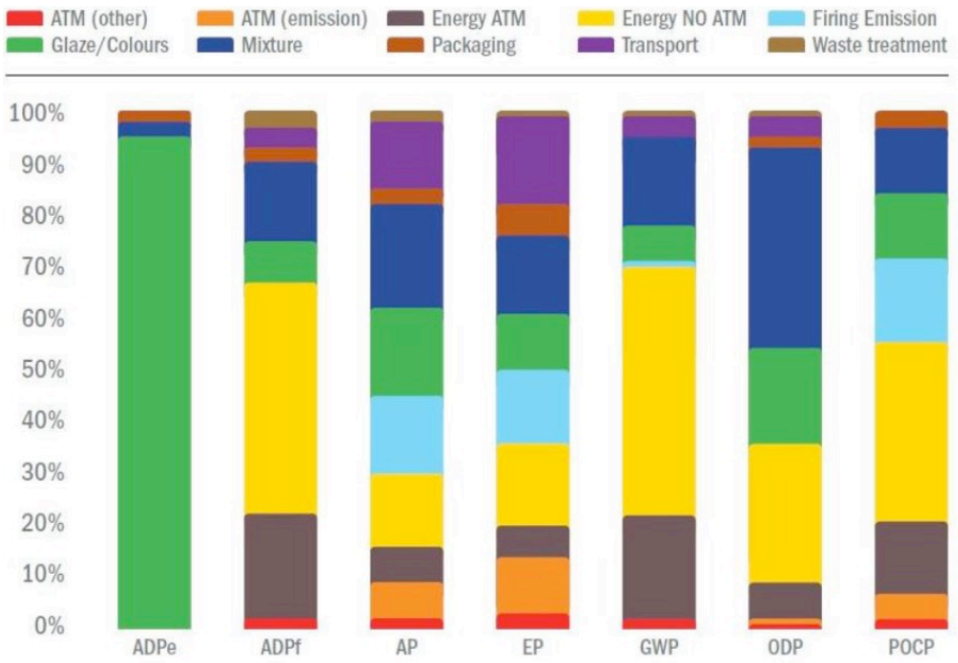

Figure 7: *Impacts due to Italian ceramic tile manufacturing. ADPE = abiotic depletion potential for non-fossil resources; ADPF = abiotic depletion potential for fossil resources; AP = acidification potential of land and water; EP = eutrophication potential; GWP = global warming potential; OPD = depletion potential of the stratospheric ozone layer; POCP = formation potential of tropospheric ozone photochemical oxidants.*

All the stages considered in this study are listed in Figure 6. Most of the background data (energy and water consumption, pollutant emissions) are the same data explained before, measured or directly calculated at company level. Figure 7 shows how most of the impact categories are dominated by energy processes and the consumption of raw materials for ceramic mixtures. The Global Warming Potential stems from the energy process (70%) and from raw materials (18%), while the Ozone Layer depletion is due both to raw materials extraction (37%) and to energy consumption (33%). Eutrophication potential derives from energy consumption (20%), transport (14%) and raw materials extraction (13%).

The EPD declaration has many advantages for the company and for the Italian Ceramic Sector. EPD earns credits in building rating system as LEED (Leadership in Energy and Environmental Designs) or in public tenders under GPP (Green Public Procurement). Moreover, EPD is considered as the most reliable and internationally widespread instrument to transfer with transparency, to the market and to its consumers, aspects related to environmental and social sustainability.

5. CONCLUSIONS

The results and the actions taken in the Italian ceramic district are important for many reasons:

1) the collection of the emission values from the 1970s to the present day is a remarkable asset constituting a big data source to be used for establishing environmental baselines;
2) the results, as the ones reported in this paper, prove the successful effort devoted to environmental protection in the ceramic district. They demonstrate the technological progresses carried out in the sector over the past three decades, quantifying the significant reduction in environmental impact achieved;
3) the results show how successful the model adopted in the Italian ceramic district is, based on effective cooperation among all the stakeholders involved: local Authorities, Research Centres, ceramic tile producers and their association;
4) the environmental challenges have been the driving force for the Italian ceramic tile industry to move towards sustainability which is considered a plus for Italian production and a strong competitiveness factor.

6. ACKNOWLEDGEMENTS

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