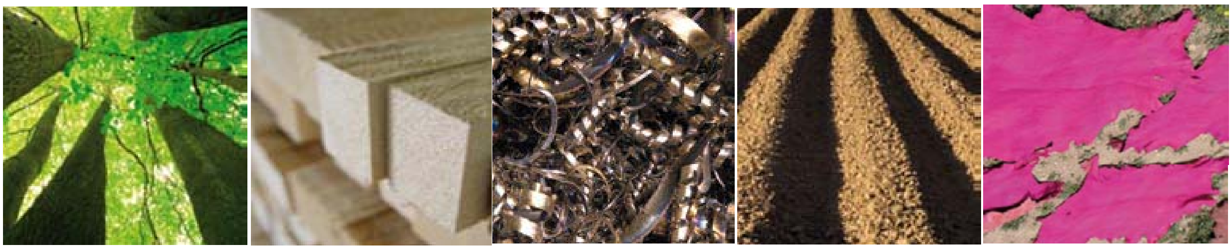

CIP Eco-innovation
Pilot and market replication projects
Call 2013

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Deliverable 4.3 - LCA and Eco-Dossier (EN)

Project acronym WINCER
Contract ECO/13/630426

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European Commission | Executive Agency for Small and Medium-sized Enterprises

Co-funded by the Eco-innovation Initiative of the European Union

Summary

1. LCA analysis and results

LCA study was carried out to assess the environmental impacts concerning the production of WINCER tiles, by Thinkstep AG.
LCA calculation rules and background requirements follow the EN 15804 and results refer to a specific product ("STONEWORK GL SR, type WINCER, code K1EH") from Marazzi's plant.
Within this study an LCA according to ISO 14040 and ISO 14044 has been performed for WINCER tile to evaluate the environmental performance, manufactured by Marazzi group at the production plants located in Sassuolo and Fiorano (Modena, Italy). The LCA is based on data declared by Marazzi group.
The LCA model was created using the GaBi 8 Software system for life cycle engineering, developed by thinkstep AG. The GaBi 2017 LCI database provides the life cycle inventory data for several of the raw and process materials obtained from the background system.

1.1 Product system

The specific ceramic tile is that named "STONEWORK GL SR, type WINCER, code K1EH". The body contains the following raw materials:

- Scraps of glass recycling process 52%
- Raw scraps of other tile productions 28%
- Clay 17%
- Glazes (kaolinite, thinners, binders, etc.) < 2%
- Others (fluidifying agents, thinners, inks) < 1%

Glazes consist of raw materials like clay, quartz, bentonite, natural pigments and frits.
The production process starts with mixing glass scraps, clay and ceramic wastes from other productions that are milled in a continuous milling machine with ground water to form a slurry. This step includes a fluidifying agent (trisodium phosphate) and alumina to improve the milling performance.
The glass used in Wincer is scrap from the second stage of the glass recycling process; such scraps cannot be recycled and so usually end up in landfill. However, this waste material becomes very useful in ceramic production: glass scraps can replace feldspars and, thanks to their very small dimension, it is possible to reduce the milling time, so less energy consumption is required in this particular operation.
The slurry produced is then sent to spray driers, producing a dry powder, using thermal energy and an atomizer at high air pressure to disperse the slurry and form uniform granules ready to be pressed and shaped.
The milling and the atomization processes take place in the Sassuolo plant, all the other steps (including the glaze production) take place in the Fiorano plant.
Glazes are prepared with many different raw materials like kaolinite, alumina (Al_2O_3) and several inorganic oxide (K_2O, Na_2O, Fe_2O_3, etc.), sodium silicate, binders. This pressed grain carpet is then dried (temperature of 470 K – 570 K) and glazed. The firing phase takes place at the temperature of 1290 K (instead of 1470 K as for a usual porcelain tile production) in order to give the typical ceramic tile features of abrasion, water resistance and longevity. At the end of the process, before the storage and packaging phases, tiles are colored with ink, cut and ground to the desired size.

Due to technical reason, this product production is performed in a dedicated production line not shared with other kinds of product.

1.2 Product Function, Declared Unit and System Boundary#

The declared unit for this study is 1 kg of Wincer ceramic tiles plus associated packaging, produced in Marazzi's plants, located in Sassuolo and Fiorano, and used as tiles for walls and floors providing a decorative and hard-wearing surface.
Results are also shown for 1 m^2 of tile. 1 m^2 of tile surface plus associated packaging; this has an average weight of 22,7 kg, and the average thickness is 9,5 mm.
This LCA study refers to a “cradle-to-gate study” with only manufacturing phases included.
Production of machines, facilities and infrastructure required during manufacture are excluded from the assessment as these impacts will be trivial compared to the process impacts.
The system boundary of the EPD follows the modular design defined by EN 15804. The modules included in this study are those of the production phase:

- **A1.** Raw materials supply (extraction, processing, recycled material)
- **A2.** Transport to manufacturer
- **A3.** Manufacturing

The other modules concerning the installation, use stage, End-of-Life and next production system were not considered.

1.3 Allocation

Multi-output allocation generally follows the requirements of ISO 14044, section 4.3.4.2. Allocation of background data (energy and materials) taken from GaBi 2017 databases is documented online at http://www.gabi-software.com/international/support/latestupdate/.
End-of-Life allocation generally follows the requirements of ISO 14044, section 4.3.4.3.
In general the allocation principles use in standard GaBi dataset are explained within GaBi-Documentation for GaBi 8.
The overall production of Marazzi group comprises further products and manufacturing plants beside the product and sites considered in this study.
In some cases, specific data for Wincer production was not available at a disaggregated level, so various allocation rules have been applied based on the site and on particular manufacturing departments.
An internal loop is used inside the software model, in order to represent the production of unfired wastes (the so-called “scarto crudo”) and the immediate reuse of it.
Wastewater outside the production process is treated directly by Marazzi group and it is completely recovered. In Wincer production the water used is clean ground water so it is not possible to loop such water back, but different percentages (see Chapter 3.2) of this water in different departments are sent to a water treatment to be internally recovered in other kinds of production operations (not part of Wincer production). This water sent to recycling in order to be re-used is considered in this LCA as a “material for recycling”.
Overall, for module A1-A3, no credit is applied to recovered materials or energy from waste treatment.
For incineration processes emissions are calculated according to the specific composition of the incinerated material. For the waste incineration plant an R1-value of 0,6 is assumed.
Electrical energy is produced on site (by a turbine) and some of this is sent to the grid. When modeling electricity impacts only the direct impacts of electrical energy from the Italian grid mix net of the self-produced amount are considered.
In case of recycling, the allocation principles use in GaBi dataset are explained within GaBi-Documentation for GABI8.

For plastics, wood and paper coming from raw materials packaging that are recycled at their end of life, a cut-off approach is applied and then impacts related to recycling and potentials benefits after recycling are not considered.

1.4 Cut-off criteria

EN 15804 requires that where there are data gaps or insufficient input data for a unit process the cut-off criteria shall be 1% of renewable and non-renewable primary energy usage and 1% of the total mass of this unit process. The total neglected flows from the product stage must be no more than 5% of product inputs by mass or 5% of primary energy contribution.

For this study, all known inputs and outputs have been accounted for and modeled. The only exception is for polyelectrolytes used in the water treatment which are used in quantities that amount to less than 0,001% of the mass input to the unit process. Therefore this study conforms to the cut-off criteria requirements of /EN 15804/.

For the processes within the system boundary, all available energy and material flow data have been included in the model. The approach used is a conservative one, overestimating burdens to prove irrelevance. Where required to fill data gaps, proxy data have been used and selected based on the practitioner's experience of similar products/production routes.

1.5 Selection of LCIA methodology and impact catergories

The environmental impact assessment categories are based on the CML methodology (CML 2001 – April 2013) and are described in Table 1 as required by EN15804.

- Table 1 - Environmental impact assessment - category description/indicators

Impact category	Description	Abbreviation	Unit
Abiotic Depletion Potential (elementary)	Scarcity of resources (ores, silicates)	ADPe	kg Sb eq.
Abiotic Depletion Potential (fossil)	Scarcity of resources (fossil energy carriers)	ADPf	MJ
Global Warming Potential	Greenhouse gases causing climate change	GWP 100	kg CO_2 eq.
Acidification Potential	Emissions causing acidifying effects (acid rain, forest decline)	AP	kg SO_2 eq.
Eutrophication Potential	Emissions causing over-fertilization of soil or water	EP	kg $(PO_4)^{3-}$ eq.
Photochemical Ozone Creation Potential	Ozone formation in the lower atmosphere causing summer smog	POCP	kg C_2H_4 eq.
Ozone Depletion Potential	Ozone depletion in the higher atmosphere	ODP	kg CFC11 eq.
Primary Energy Demand (non-renewable)	Measure for consumed fossil energy carriers	PED (non-renewable)	MJ
Primary Energy Demand (renewable)	Measure for consumed renewable energy carriers	PED (renewable)	MJ

1.6 Assessment indicators according to EN 15804

The following environmental parameters apply data based on the LCI (Tables 2-4). They describe the use of renewable and non-renewable material resources, renewable and non-renewable primary energy and water.

- Table 2 - Life cycle inventory indicators on use of resources

Indicator	Unit
Use of renewable primary energy excluding the renewable primary energy resources used as raw materials (PERE)	MJ, calorific value ([Hi] lower calorific value)
Use of renewable primary energy used as raw materials (PERM)	MJ, calorific value ([Hi] lower calorific value)
Total use of renewable primary energy (primary energy and renewable primary energy resources used as raw materials) (PERT)	MJ, calorific value ([Hi] lower calorific value)
Use of non-renewable primary energy excluding the non-renewable primary energy resources used as raw materials (PENRE)	MJ, calorific value ([Hi] lower calorific value)
Use of non-renewable primary energy resources used as raw materials (PENRM)	MJ, calorific value ([Hi] lower calorific value)
Total use of non-renewable primary energy (primary energy and non-renewable primary energy resources used as raw materials) (PENRT)	MJ, calorific value ([Hi] lower calorific value)
Use of secondary materials (SM)	kg
Use of renewable secondary fuels (RSF)	MJ, calorific value ([Hi] lower calorific value)
Use of non-renewable secondary fuels (NRSF)	MJ, calorific value ([Hi] lower calorific value)
Use of fresh water resources (FW)	m^3

- Table 3 - Life cycle inventory indicators on waste categories

Indicator	Unit
Hazardous waste disposed (HWD)	kg
Non-hazardous waste disposed (NHWD)	kg
Radioactive waste disposed (RWD)	kg

- Table 4 - Life cycle inventory indicators on output flows

Indicator	Unit
Components for re-use (CRU)	kg
Materials for recycling (MFR)	kg
Materials for energy recovery (MER)	kg
Exported electrical energy (EEE)	MJ
Exported thermal energy (EET)	MJ

1.7 Data collection

All data were collected using customized data collection templates and are available in the detailed report prepared by Thinkstep AG.

1.8 Life Cycle Impact Assessment (LCIA) results

The results of the impact categories are following reported in Fig. 1 and Fig. 2.

From Fig. 1 it is clear that the main contribution to total production impacts from the cradle to gate processes is due to the A1 module for any impact indicator. This module takes into account both the energy and the raw materials production (as clay, chemical compounds, pigments, etc.).
Transports module, A2, has noticeable contributions to two indicators EP and AP and is due to both the production of the fuel and the emissions related to its combustion.
Global production module, A3, contributes to EP, POCP and ODP because of paper/cardboard production for packaging.
ADPe is mainly influenced by inks and ADPf by energy production processes, both belonging to A1 module.

Fig. 2 shows in detail the contribution of the main processes, as energy, emissions or raw materials production.

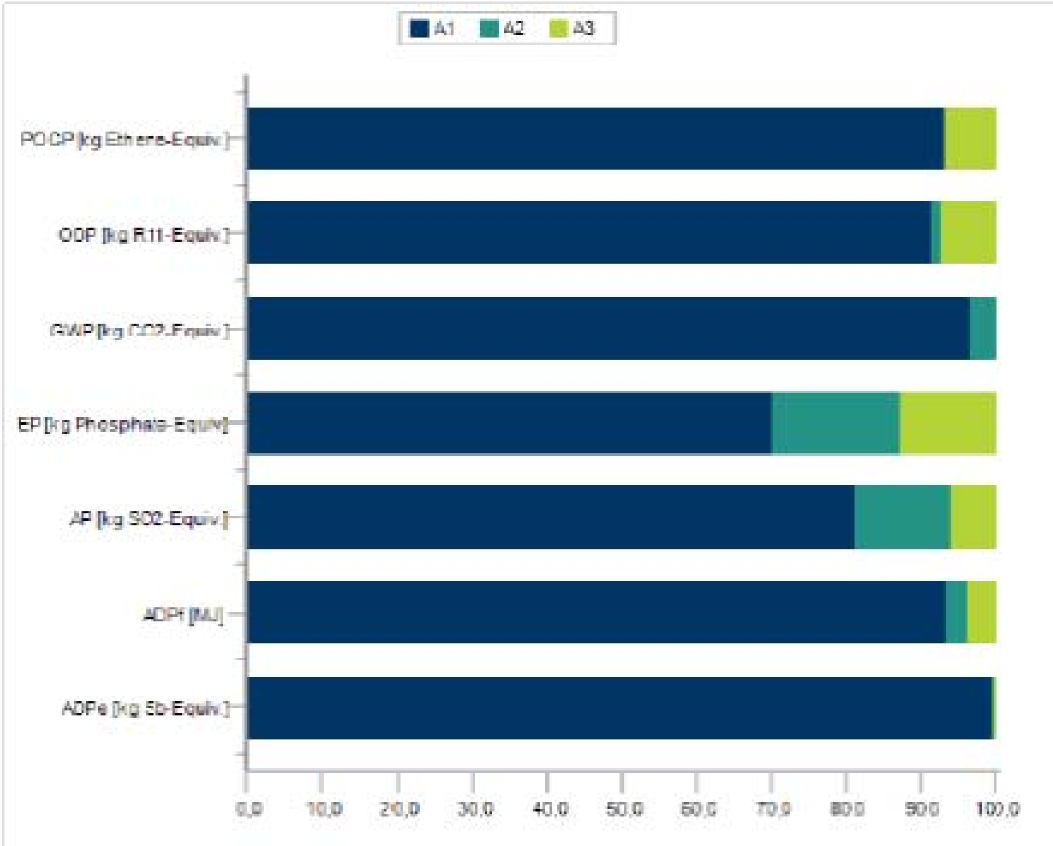

Figure 1: relative contribution of each life cycle stage to different environmental indicators.

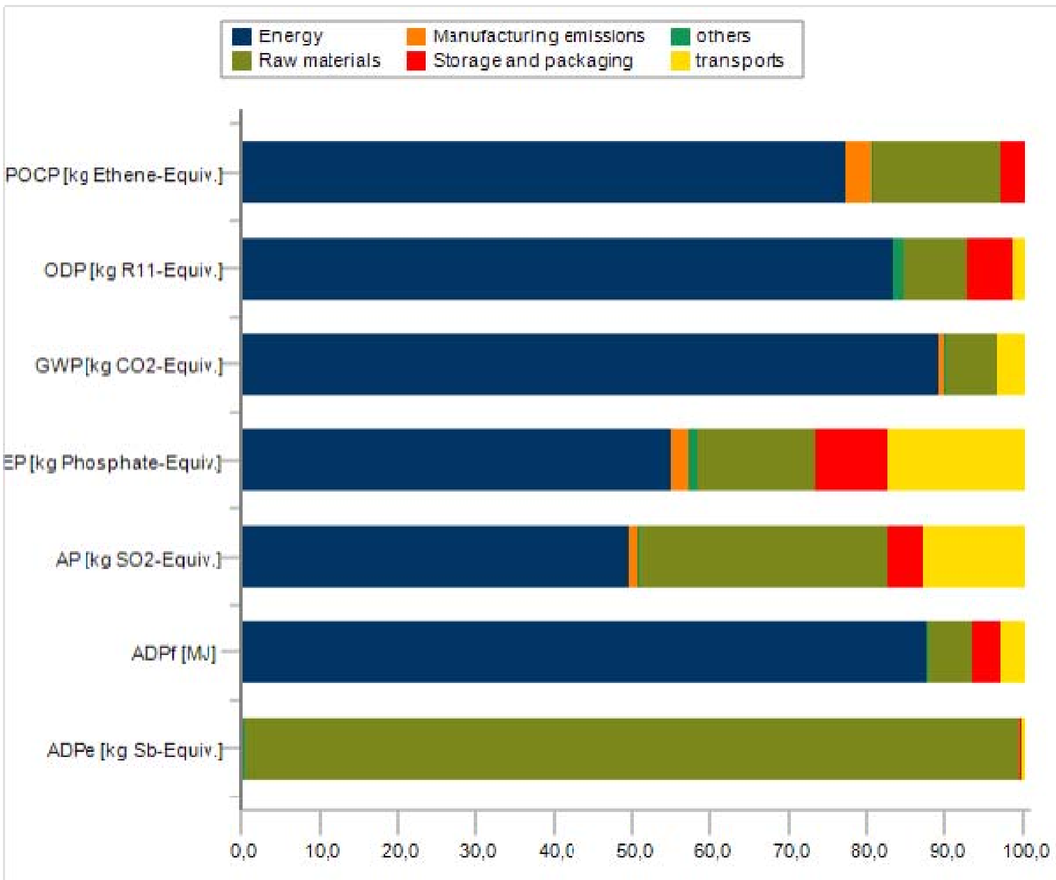

Figure 2: relative contribution of main process phases to different environmental indicators.

The core focus of this project is the use of a high percentage of secondary material, both internally and externally recovered. The most interesting secondary material used in Wincer tiles is the glass powder obtained as scraps from the glass recycling process, as noted previously, this ‘sub-product’ is usually sent to landfill, because it is not suitable for recycling into new glass products. It was used to replace other traditional components (i.e. feldspar).
In a typical ceramic recipe this component can account for up to 40% of the total material input, and that in the Wincer recipe the glass powder content is around 50%. It is therefore evident that the impact relating to raw material production in the atomization phase will be significantly lower than for a typical porcelain tile, and the main contributor to impacts is the energy consumption. Moreover, the small grain dimension of the glass powder allows a shorter milling time compared to a traditional production.

The other important contributor to the impact indicators is linked to raw materials. The two phases that most influence the impacts are the glaze and the ink production, in particular with reference to AP and ADPe indicators.
Glazes and inks used in this production contain several metal oxides and the production of some of them (as cobalt or antimony) have a high impact related to AP and ADPe indicators. Ink’s impact is quite considerable for some impact categories such as AP and ADPe, while glaze production contributes to ADPe indicator because of the lead presence. Figure 3 shows the relative contribution of the different inks used in Wincer production.
Cyan ink is the principal contributor for all impacts apart from ADPe, this is due mainly to the cobalt oxide content. Gold ink is responsible of almost all the impact for ADPe impact due to the antimony oxide presence.
It should be noted that even if glazes and ink components contain oxides of lead, cobalt and antimony, all raw materials used in the WINCER project are considered not hazardous for human safety and environment in compliance with REACH and CLP regulations.

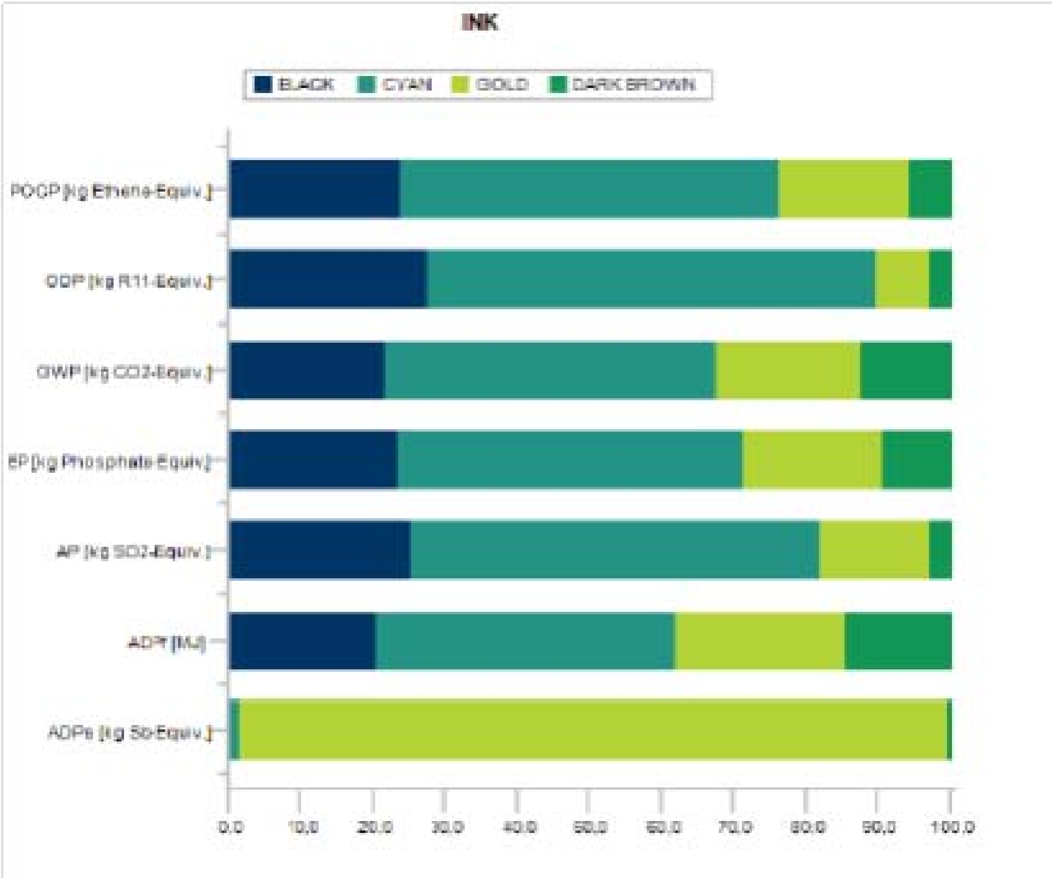

Figure 3: relative contribution of different inks

1.9 Sensitivity analysis

Changing the value of some primary data, like secondary materials used (such as unfired wastes and glass scraps) and clay amount, the answer of the system in terms of impacts has been evaluated. These parameters have been evaluated so to identify the changes occurring in case of a change in the recipe.
Another parameter object of this analysis is the firing consumption, both as natural gas and electricity consumption, as it depends on the type of mixture at issue. In this case a variability of ± 5% is considered in order to evaluate possible improvements. The Table **5** shows the variations considered and how the results of this study are influenced by them.

- Table 5 - Sensitivity analysis results

	Unfired waste		Glass scraps		Clay		Firing EE consumption		Firing natural gas consumption	
	-5%	+5%	-5%	+5%	-5%	+5%	-5%	+5%	-5%	+5%
GWP [kg CO_2-eq.]	-3,54E-03 %	3,54E-03 %	-0,12 %	0,12 %	-0,05 %	0,05 %	-0,13 %	0,13 %	**-1,53 %**	**1,53 %**
ODP [kg CFC11-eq.]	-4,98E-05 %	4,98E-05 %	-4,99E-03 %	4,99E-03 %	-0,06 %	0,06 %	-0,21 %	0,21 %	-0,11 %	0,11%
AP [kg SO_2-eq.]	-8,30E-03 %	8,30E-03 %	-0,19 %	0,19 %	-0,50 %	0,50 %	-0,09 %	0,09 %	-0,65 %	0,65 %
EP [kg $(PO_4)^{3-}$- eq.]	-0,03 %	0,03 %	-0,43 %	0,43 %	-0,54 %	0,54 %	-0,10 %	0,10 %	-0,76 %	0,76 %
POCP [kg Ethen eq.]	-0,01 %	0,01 %	0,56 %	-0,56 %	-0,29 %	0,29 %	-0,13 %	0,13 %	**-1,57 %**	**1,57 %**

A further analysis has been performed to evaluate how impacts are affected by replacing feldspar with glass scraps during production of atomized powder raw materials. A typical recipe for porcelain tile (melting material around 38%) has been evaluated and the impact of atomized powder raw materials production relative to the overall A1-A3 contribution has been highlighted in comparison to the Wincer contribution (glass powder up to 50%). In Table 6 the relative contribution of the atomized powder production (only raw materials production) is shown as a percentage of the overall A1-A3 contribution (A1-A3 is 100%). As shown in the table, the relative contribution of the atomized powder production compared to the overall tile production impacts in case of a Wincer tile is much lower than an average porcelain tile produced by Marazzi.

- Table 6 - Sensitivity analysis results - relative contribution of atomized powder production on A1-A3, considering only the raw materials

	Tipical porcelain tile	Wincer tile
GWP [kg CO_2-eq.]	24%-25%	1,09%
ODP [kg CFC11-eq.]	69%-75%	0,43%
AP [kg SO_2-eq.]	54%-56%	2,80%
EP [kg $(PO_4)^{3-}$- eq.]	26%-27%	3,35%
POCP [kg Ethen eq.]	37%-39%	2,08%

1.11 Conclusion

The use of the glass recycling process scraps is particularly significant: this material is a secondary material with no associated impacts as it is ready-to-use. During the recycling process the glass is broken and sorted by size, before being re-melted and formed in another glass container; during these phases a very fine powder is formed. This powder comes from glass granules that are too small to find an application in industrial processes and usually end up in landfill without a technological application. Several tests demonstrated that these glass scraps work perfectly as a flux that can replace feldspar in the ceramic production. This can significantly reduce impacts associated with raw material production in the atomization process.

Overall most of the impact categories and LCI parameters are dominated by energy processes followed by raw materials consumption for ceramic mixture.

Within A1-A3 module, main outcomes are the following:

- For global warming potential (100 year timescale) the highest contribution is due to energy production (around 94%), while around 7% of the total GWP is due to the mixture raw material production (1% due to raw materials for atomized powder while 4% due to raw materials for glaze production, 2% for ink production). Indeed, packaging raw material has a negative value (-5%), thanks to the carbon dioxide sequestered in the fibre content of paper and wood.
- The principle contribution to the ozone depletion potential (ODP) is from energy production processes (ca. 82%) followed by ink production (ca. 5%) and packaging because of the paper and cardboard production (ca. 6%).
- Energy production processes influence photochemical ozone creation potential (POCP) impacts with a contribution equal to 82% followed by raw materials production (19%) while transports processes contribute with a negative value (-6%).
- Eutrophication potential (EP) is primarily due to energy production processes (55%) followed by transports (17%) and storage and packaging (9%).
- Acidification potential (AP) is mainly caused by energy production processes (47%) followed by raw materials production for ink (20%), for glaze (12%) and transports (12%).
- Abiotic depletion potential (fossil) (ADPf) is mainly due to energy production processes (87%).
- Abiotic depletion potential (elements) (ADPe) main contributor is mainly linked to raw materials production for ink (78%) due to a specific ink (so called “GOLD”) containing antimony and for glaze (21%), in particular due to a particular glaze (so called “457”) containing lead.

2. Ecological criteria for Ecolabel

To obtain the EU Ecolabel for ceramic tiles, specific procedures have to be followed.

Even if Ecolabel has not been requested for WINCER tile yet, here following an assessment of compliance and validity criteria of compliance are reported in order to provide useful information for a future request of the "Flower" logo.

In Table 7 the ecological criteria for Ecolabel for ceramic tiles are shown together with an evaluation for WINCER tile.

- Table 7 - Ecolabel ecological criteria for ceramic tiles and Ecolabel evaluation for WINCER tile (positive: ☺; negative: ☹)

Criterion	*Parameter*	*Exclusion threshold*	*Evaluation for WINCER tile*	*Documents needed*
1. Raw material extraction	1.2 - Extraction management	The applicant shall provide a technical report including the following documents: • the authorization for the extraction activity; • the environmental recovery plan and/or Environmental Impact Assessment report; • the map indicating the location of the quarry; • the declaration of conformity to the Directive 92/43/CEE (habitats) and Directive 79/409/CEE (birds) and their subsequent amendments. In areas outside the European Community, a similar technical report is required to demonstrate compliance with the UN conservation on Biological Diversity (1992).	☺	*Suitable report supplied by the applicant*

Tab.7 (continue)

Criterion	***Parameter***	***Exclusion threshold***	***Evaluation for WINCER tile***	***Documents needed***
2. Raw material selection	2.1 - Absence of risk phrase (additives to raw material in the ceramic mix)	**Addition of products with the following risk phrases are not allowed: R45, R46, R49, R50, R51, R52, R53, R54, R55, R56, R57, R58, R59, R60, R61, R62, R63, R68.** **Alternatively it is possible to consider the classification of the EC regulation n. 1272/2008 of the UE Parliament an of the Council (4). Addition of products with the following risk phrases are not allowed: H350, H340, H350i, H400, H410, H411, H412, H413, EUH059, H360F, H360D, H361f, H361d, H360FD, H361fd, H360Fd, H360Df, H341.**	☺	*Ceramic mix formulation - Conformity declaration supplied by the applicant*
	2.2 - Limitation of the presence of some substances in the additives (for glazed tiles only)	**Concentration (% in weight of the glaze) not exceed the following values:** **- Lead: 0.5 %** **- Cadmium: 0.1 %** **- Antimony: 0.25 %**	☹ *Lead >0.5%*	*Glaze mix formulation - Conformity declaration supplied by the applicant*
	2.3 - Limitation to the presence of asbestos and polyester resin in the raw materials	**- Raw materials cannot contain asbestos;** **- Raw materials cannot contain polyester resin more than 10% in weight on total raw material.**	☺	*Mix formulations - Conformity declaration supplied by the applicant*

Tab.7 (continue)

Criterion	***Parameter***	***Exclusion threshold***	***Evaluation for WINCER tile***	***Documents needed***
4. Production process	4.1.b - Energy consumption: Energy Requirement for Firing (ERF)	**ERF ≤ 3,5 MJ/kg, of tiles (stoked)**	☺	*Calculations and suitable report supplied by the applicant*
	4.2.a - Water consumption and use (Fresh water consumption)	**Fresh water specific consumption: - Csw ≤ 1 litre/kg of tiles (stoked)**	☺	*Calculations and suitable report supplied by the applicant Water balance and/or environmental management system*
	4.2.b - Water consumption and use (Water recycling)	**Water recycling ratio not below 90%**	☺	
	4.3.b - Emission to air	**Emission factor of particulate matter (dust) from spray drying, pressing and glazing (cold emissions) not exceeding 5 g/m^2**	☺	*Report from a third and certified laboratory - Suitable reports supplied by the applicant*
		Emission factor of particulate matter (dust), Fluorine, Nitrogen oxides, Sulphur dioxides from firing kilns not exceeding the following values: - Dust: 200 mg/m^2 - Fluorine: 200 mg/m^2 - NO_x: 2500 mg/m^2 - SO_2: 1500 mg/m^2 (S content in raw material S ≤ 0.25%) - SO_2: 5.00 mg/m^2 (S content in raw material > 0.25%)		
	4.4. - Emission to water	**Pullutants concentration in discharged water not exceeding the following values: - Suspended solid: 40 mg/l - Cadmium: 0,015 mg/l - Crome$^{(VI)}$: 0,15 mg/l - Iron: 1,5 mg/l - Lead: 0,15 mg/l**	☺	*Report from a third and certified laboratory - Suitable reports supplied by the applicant*

Tab.7 (continue)

Criterion	***Parameter***	***Exclusion threshold***	***Evaluation for WINCER tile***	***Documents needed***
5. Waste management	5. - Treatment system	**Demonstration of the availability of a treatment and management system, in particular respect to the following procedures of:** • **separation and use of recyclable materials;** • **recovery of materials for other uses;** • **handling and disposing of hazardous waste.**	☺	*Calculations and suitable report supplied by the applicant Materials balance and/or environmental management system*
	5.2. - Recovery of waste	**Minimum ratio value (in wt%) of the waste reused (internally or externally) respect the total waste produced: $\geq$ 85%**	☺	
6. Use phase	6.1. - Release of dangerous substances	**Release of dangerous substances not exceeding the following values:** **- Lead: 80 mg/m^2** **- Cadmium: 7 mg/m^2**	☺	*Report from a third and certified laboratory*
7. Packaging	7. - Technical specification on the use of recycled materials to produce package	**Paper packaging has to contain recycled material not below 70%**	☺	*Packaging sample and suitable reports supplied by the applicant*
8. Fitness for use	8. - Technical specification obtained through standardized methods and/or internal ones	**Declaration of conformity specific for the intended use: wall, floor or wall/floor (in case of suitability for both)**	**Wall / floor for indoor use; Floor for outdoor use In areas not subjected to thermal shock**	*Report from a third and certified laboratory*

Tab.7 (continue)

Criterion	*Parameter*	*Exclusion threshold*	*Evaluation for WINCER tile*	*Documents needed*
9. Consumer information	9. - Information that has to be reported on the packaging and/or in the attached documents	• **Ecolabel mark;** • **usage and maintenance product advertisements;** • **information about the recycle and disposal circuit;** • **information on European Ecolabel (www.ecolabel.eu)**		*Packaging sample and text supplied by the applicant*
10. Information reported on Ecolabel mark	10. - The second box of the mark has to contain the following text	• **lower energy consumption of the production process** • **lower air and water emissions** • **improvement of the customer information and of the waste management**		*Packaging sample and text supplied by the applicant*

All the Ecolabel criteria are fulfilled, apart the "2.2- Limitation of the presence of some substances in the additives (for glazed tiles only)". In particular, the glaze applied to WINCER tile contains lead 0.5%. In any case, it is interesting to note that the criterion "6.1. - Release of dangerous substances" is respected and, following the test ISO 10545-15 (see the Deliverable 4.1 "Product characterization and UNI Keymark), the lead release is 10 mg/m^2, thus below the limit of 80 mg/m^2.

Therefore, in order to proceed with the Ecolabel certification, another glaze (a lead-free glaze, not containing dangerous substances in general) has been already studied and it will be used for the future industrial productions of WINCER tiles.

3. Evaluation on Respirable fraction of Crystalline Silica (RCS) in workplace

An evaluation of Respirable Crystalline Silica, was performed on the WINCER spray dried powder, respect to a traditional porcelain stoneware spray dried powder.

The experimental method to determine the Free Crystalline Silica on samples is the "Size Weight Respirable Fraction", SWERF method and in particular the "Size Weight Respirable Fraction of Crystalline Silica", SWERFCS method. This is not a standardized method yet, and it was set-up by the Industrial Mineral Association (IMA) and largely used. The final results is expressed in percentage of SWERFCS (RCS potential).

This method is based on the experimental determination of RCS by powder sedimentation in a liquid (bi-distilled water) on the base of probability function, following the EN 481.

Both the spray dried powder (traditional and WINCER) were thermally treated at 500°C for 2 hours to eliminate organic fraction due to the presence of additives (dispersants) used to prepare the ceramic slurries. These additives, if present, may alter the powder sedimentation.

Following the above mentioned method, results reported in Table 8 show a significantly lower amount of RCS in WINCER powder respect to a traditional one. Even if the measurement uncertainty is relatively high (10-15%), we can estimate that the RCS in WINCER spray dried powder is reduced of about 63% respect to a traditional porcelain stoneware.

Results are justified by the lower amount of quartz in WINCER tile formulation respect to a traditional porcelain stoneware one. Quantitative X-rays analyses of both the spray dried powders are shown in Table 9.

- Table 8 - Evaluation of crystalline silica respirable fraction (% SWERFCS) of WINCER and a traditional spray dried powders.

	% SWERFCS
WINCER spray dried powder	1.9%
Traditional spray dried powder	5.2%

- Table 9 - Quantitative mineralogical composition of spray dried powders (determined by Rietveld-RIR method) and amount of quartz (determined by calibration curve), in weight %.

Method	**Phases**	**WINCER spray dried powder**	**Traditional spray dried powder**
Rietveld-RIR	**Quartz**	12.0±0.2 wt%	28.3±0.2 wt%
	Microcline	2.4±0.3 wt%	4.5±0.3 wt%
	Plagioclase	15.2±0.3 wt%	38.1±0.3 wt%
	Illite	5.5±0.7 wt%	10.6±0.7 wt%
	Muscovite/illite	2.6±0.6 wt%	6.2±0.6 wt%
	Kaolinite	7.7±0.5 wt%	12.3±0.4 wt%
	Amorphus phase	54.6±3.0 wt%	*Not present*
Calibration curve	**Quartz**	10±5 wt%	25±5 wt%