LIFE Project Number

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FINAL Report – Version for publication

Covering the project activities from 01/07/2013 to 31/03/2017

Reporting Date

21/07/2017

LIFE+ PROJECT NAME or Acronym

LIFE SANISTER

Project Data

Project location	ITALY	
Project start date:	01/07/2013	
Project end date:	31/07/2013	**Extension date:** n.a.
Total Project duration (in months)	45 months	
Total budget	€ 2,298,282	
Total eligible budget	€ 2,151,132	
EU contribution:	€1,075,565	
(%) of total costs	46,80%	
(%) of eligible costs	50%	

Beneficiary Data

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1. Executive Summary

Project Objectives
The project aimed to revise the production process in the Vitreous Sanitary Ware (VSW) ceramic sector by introducing relevant amounts of glass cullet waste from urban waste disposal in the ceramic blends formulations. The project focused process innovations designed to a) provide a sustainable management, in terms of recovery of large amounts of glass cullet waste (soda lime glass: SLG), b) improve environmental performances of the ceramic sector by reducing CO2 emissions, c) enhance sustainability by energy saving and natural resources preservation.
In VSW production no extensive use has hitherto been made of SLG, although its introduction would yield remarkable benefits. The replacement of feldspar-like materials (up to some 40-50%), or of fluxagents (about 40-50 %), with SLG would provide: (i) savings in natural resources consumption (often imported because of increasing scarceness in European countries, implying also fuel consumption and emissions for transport); (ii) reductions of process energy consumption and CO2 emissions.
Introduction of SLG allows (a) to lower VSW production's firing temperatures from 1230-1250°C to 1120-1150°C, and (b) to shrink soaking times by 20%. The related CO2 emissions reduction will be quantified through the Life Cycle Assessment. All this can be realized by an acceleration of main ceramic reaction kinetics exploiting the SLG high reactivity.

Expected outputs and results
Taking profit from promising solutions emerged in Partners' previous studies/lab-scale experimentations, SANITSER was meant to tackle technological hurdles hampering the introduction of SLG in VSW production, through following targets:

1. Deep re-definition of the best performing firing time-temperature cycles as a function of the SLG content;
2. Optimization of the firing cycles and slips composition to guarantee preservation of technological quality of the final ceramic bodies with respect to present standards for marketability;
3. Revision of the glaze compositions in the context of firing time-temperature cycles fixed anew;
4. Adjustment of the process dynamics/parameters as a function of the rheological properties of new slips formulated with SLG.

The targets on the VSW production were:

a. to proof technical feasibility of substitution of about 50% of feldspar saving natural resources' deposits and preserving landscape;
b. to extend the achievements of point a) to slips bearing pitcher and granite proving a possible substitution of 100% ;
c. to obtain a reduction of at least 16-18% in energy consumption and in related CO2 emissions by lowering by 80-110°C the ceramic bodies' firing temperature and shrinking soaking times;
d. to reduce production costs rising industrial competitiveness and promoting a shift from a traditional man-labor-oriented to a technology-driven manufacturing, bearing SLG and pitcher, and eventually to the fully novel one substituting 100% of hard-component (feldspar+quartz) with granite and SLG.

During project realization, 120 ton of primary raw materials (feldspar, quartz) were expected to be saved and the same amount of SLG waste recycled; 9500 Sm3 of gas was expected to be saved with related CO2 reduction of 1,3 t, excluding the performances obtained by avoided transport of primary resources. Impact was expected to be very high, as partners represent the whole supply chain for the ceramic industry.

Key deliverables

The following key deliverables were foreseen and produced:

- [B1] One pilot plant for waste SLG preparation
- [B2] Slip-rheology adjustment strategy
- [B3] Revised glaze composition following new firing time-temperature cycles
- [B4] One glazing pilot plant
- [B5] One pilot VSW production plant
- [B6] Two reports on the physical properties of large final ceramic bodies produced with SLG (interim and final)
- [B7] Report on optimized slip design and process parameters after pre-industrial trials
- [B8] Report on the sanitary ware industrial production tests
- [B9] 1 design for an industrial VSW plant optimised for the new SANITSER body
- [C1] 4 reports on the time-temperature composition relationships, based on increasing production levels on lab, pilot, pre-industrial and industrial scale
- [C2]1 Life Cycle Assessment report, 1 Draft of an Environmental Product Declaration according to ISO 14025
- [C3] 1 Report on the socio-economic impacts of the project and S-LCA evaluation matrix
- [D1-D2] Project brochure; proceedings and pictures of local seminars, open days, midterm and final conference, notice boards, project website, Layman's report
- [E7] 1 After-LIFE communication plan

Activities carried out and results obtained

B1: Construction works of the pilot plant for waste SLG preparation started in December 2013, delayed with respect to the original planning due to modifications in the original pilot plant project that provided for quality improvements and lower investments. Construction has been planned and implemented by MI in 3 phases to use test results for determination of needed upgrades. By February 2016 the plant was validated to supply the high amounts of materials needed for the pre-industrial and industrial tests. However, finest particles released during the materials' production resulted to be higher than foreseen, which led to an improvement of the aspiration system in February 2017, enhancing production efficiency and product quality and impacting on the final economic assessment of the plant.

B2: A huge set of lab-trials has been performed by SETEC to define the Slip-rheology adjustment strategy. A first data-package on the trials was presented in the meeting of the 25th of October 2013, timely achieving this milestone. As foreseen, the main activities have been concluded by end of January 2014, permitting implementation at pilot scale, though some optimization was performed until the end of April 2014 to further increase the percentage of recovered components. SANITSER 13 formula, selected for the casting tests in Action B6, is made of recovered materials for 43.62%.

B3: GEMICA completed glaze formulations to be used for testing in pilot plants by May 2014 (PSI-97 formula), while the standard formula PSI-103 was identified in November 2014 after many experiments. Necessary adjustments to give greater brightness occurred until March 2015, achieving 12% of secondary raw material employment. In December 2015 MI found a new source of boric glass scrap, till then excluded from the formulations due to reduced availability on the market. Introduction permitted to increase the secondary raw material use first until 16% and later even till 20%, enamels that were tested during the industrial trials. The best formulas were also revised to produce colored enamels and the last formula was optimised with an anti-bacterial functionality by SE.TE.C. Overall GEMICA formulated and

prepared about 5030 different formulas of the glaze and, on each of them, SETEC performed at least 4 tests, running a more detailed analysis on final formulations.
The main targets to formulate a white glaze with the right linear thermal expansion and the right physical characteristics when fired over the slip, having the same final aspect (smooth surface, no spots, holes or cracks, etc) of the glazes currently on the market, have been achieved.
B4: The final design of the pilot plant for glaze preparation was completed by GEMICA in due time. First part of the production line has been installed by the end of December 2013 (foreseen end of January 2014), equipping an existing line with the mobile magnetic separator. This temporary configuration favored the execution of pilot test, being more suitable to deal with the small amounts to be produced in the first phase. The installation of the plant in its final configuration, necessary to deal with the foreseen increase in quantity requirements, has thus been delayed to November 2014 without adversely affecting project execution. Due to environmental reasons, and particularly as to lower dust emissions during the loading phase of industrial trials, between October 2015-March 2016 the plant was completed with a dust aspiration system mounted on top of the mill. Finally a floor scale electronic balance was added to better face the industrial trials.
B5: The pilot plant to produce VSW pieces in 1:1 scale was designed by SE.TE.C. technical office within November 2013. Due to some delays of the suppliers the plant was ready by end of April 2014, with a four month delay. Fine-tuning and start-up were concluded by 15/05/2014. The final plant complies with all the foreseen slip requirements.
B6: In order to assess at pilot scale the physical properties of large final ceramic bodies made of the materials developed in action B2 and B3, 100 sanitary ware pieces (wash basins, bidets and WC pans) have been produced in SE.TE.C. pilot plant. The best pieces after casting, have also been finished, glazed and fired at 1165-1170°C, decreasing of about 80-100°C the firing temperature of traditional cycles. 85% Of the production showed no defects or cracks. Best pieces produced have been photographed, stored and used for fairs and demonstration of the new technology. The Action was completed by the end of September 2015, with a delay of 3 months due to several technical difficulties encountered but solved.
B7: Two companies that had confirmed their availability to take part in pre-industrial tests during 2014 withdraw when it came to operational agreements. Fortunately Ceramica Scarabeo expressed its interest during the midterm conference and 2 other companies with a higher operational flexibility were found, Kerasan and Ceramica Amerina, offering an interesting variety of production scenarios. From March 2016 trials kicked off: SE.TE.C. produced the slip, the companies performed the casting, drying and finishing, after which SE.TE.C. performed the glazing and firing at the correct lower temperature. 200 Qualitatively sound pieces were produced, of which 20% toilets and bidets, 80% sinks and totaling 8 types of articles. The trials permitted to assess and solve some slip rheological problems during casting.
B8: For the industrial tests Ceramica Amerina was substituted by Ceramica Alice, a mid-sized company that could better organise the bigger trials within its production capacity. The bigger amounts permitted the companies to not only do the casting, but as well the enameling and firing in their equipments at the required lower temperature. 1.824 Pieces were produced, of which 1.761 resulted of good quality, being mostly wash-basins and some WCs/bidets representing 8 different shapes. All required parameters on quality achievements, energy consumption as well as environmental and socio economic impacts could be obtained and process parameters or slip/glaze compositions adjusted under different productive scenarios.
B9: A design has been delivered of an industrial plant that allows to optimise the benefits of the SANITSER process while being suitable also to produce conventional sanitary ware. Specifically for SANITSER formulae it features an intermittent firing kiln, that should work

at a lower temperature than needed for conventional production. Technical design data and considerations, production planning, determination of quantities and description of the technological cycle have all been provided, together with drawings and 2D and 3D pictures showing the plant's architecture. It will allow for energy saving and CO_2 emission reduction of about 18%.

C1: Determination of the time-temperature-composition parameters performed by focused mullite growth kinetics, definition of a new time-temperature interval for HT-ceramic process and assessment of the macroscopic properties of final ceramic outputs to understand the principles underlying the changes of the fired body's physical properties induced by new composition-temperature time parameters. Four reports were produced: 1st on time-temperature-composition of lab test (Jan 2014, updated in March 2014 and 2015), with which the milestone "First stage of refinement of time-temperature-composition parameters, transferable to pilot scale of use" was achieved. A 2nd report was based on results of pilot tests (Dec 2015), a 3rd on pre-industrial trials (August 2016). The final report reconsidered all outputs from previous studies, integrating them with the results from industrial testing, and confirmed the transferability of SANITSER innovation to an industrial scale also in terms of phase composition appeared upon thermal treatment, microstructures and degree of homogeneity achieved for such ceramic bodies and for their enamelled surfaces.

C2: LCE visited partners' sites/plants to understand the conventional and innovative production process; defined the goal and scope of the LCA; assessed relevant Product Category Rules; analyzed European Product Declaration (EPD) guidelines for construction products and main EPD published in this field; analyzed ISO 14067:2013 requirements; collected data related on raw materials used in SANITSER 13 slip. Validated data were normalized to the selected declared unit. Four models were implemented: traditional system, pilot system (B6), pre-industrial system (B7), industrial system (B8). Models generation required the choice of appropriated datasets where primary data were not available: for sake of robustness and coherence with the Webtool Database, Ecoinvent 2.2 was mainly taken as source of secondary data. Environmental impact categories (and related indicators) were given by the existing PCR rules. The classification and characterization method was elaborated within the SigmaPro tool based on EN 15804 characterization factors, applied to the four SANITSER LCA models, and benchmarked with calculated environmental impacts of the Ecoinvent operation *Sanitaryware, at plant/RER U.* The results were laid down in the Life Cycle Assessment report and interpreted, and a draft EPD was delivered.

A web-based tool to support LCA activities was also designed and implemented with the aim to gather LCA quantitative information from each involved partner; evaluate environmental performances related to raw materials, slips and glazes; and evaluate and compare environmental performances related to different sanitary wares.

C3: Before implementing the S-LCA study, LCE developed a customised methodological approach, specific for the target, by literature study, discussion of main hypothesis with partners and meeting Civita Castellana stakeholders to collect information on socio-economic issues. It analysed the production phases included in the system boundary, geographical location and stakeholders involved in each of them. A set of socio-economic indicators was defined, data collection amongst stakeholders was organized and an evaluation matrix was defined. Unfortunately many stakeholders outside the partnership could not reply so LCE had to highly rely on experts' judgment results of some surveys conducted by ASLs and other literature. Results showed only marginal impacts on social issues, except for an important impact on health and safety due to the strongly reduced % of inhalable crystalline silica in the SANITSER raw material. <omissis>

Also, LCE benchmarked the life cycle costing performance of the SANITSER technology for producing sanitary ware versus the traditional process, using the international standard ISO

15686:2008 and following the usual steps of goal and scope definition, LCC methodology definition, LCC Inventory, and final results. Data referred to the three production stages costs (slip, glaze and sanitary ware) were collected by means of a questionnaire submitted to project partners, guidance and joint definition and validation. Once calculated, results were analysed per declared unit (1 ton sw) and as total costs over plant service life. The analysis confirmed that the adoption of SANITSER technology allows significant savings in operating costs, mainly due to the lower costs for raw materials and energy requirements. Maintenance and substitution costs are supposed to decrease as well, since SANITSER innovative slip and glaze are foreseen by experts to reduce the level of stress on machineries.

D1: A corporate image was realized by an LCE graphic designer in September 2013, and applied to dissemination materials, website and project documents formats. A 4 pages brochure was designed yet in early November 2013. A Stakeholders Mailing List has been drawn up since project start and updated in occasion of project events, which have also been publicized through LinkedIn groups, news on websites and press releases. Stakeholders have been kept informed on project progress and achievements through 3 yearly newsletters in spring 2014, 2015 and 2016.

A half-day seminar was organised in December 2013 close to Civita Castellana to raise awareness of the sanitary ware industry and local stakeholders. The relative press release resulted in 2 articles on the local press. In September 2014 a second seminar was organized within the framework of the fair Tecnoargilla in Rimini, where SETEC was also present with a stand.

Awareness was risen in the local community of the Civita Castellana ceramic district by a seminar in December 2015 targeting the manufacturers of the ceramic district. A presentation the day before at a technical high school at Civita Castellana saw 100 enthusiastic participants. Thereupon, with this and another high school, 5 Open Days were organised where the highest classes received information on the sanitary ware industry and its environmental impacts and on the LIFE funded SANITSER project and its results. 106 Students were involved. Also industrial trials participant Ceramica Scarabeo organised a presentation in its premises targeting its commercial network explaining the importance of environmental innovation.

In February 2014 SETEC exposed and disseminated informative materials about the SANITSER project at the important international expo Indian Ceramics and in October 2015 this was repeated at the CERAMITEC fair in Munich. MI exposed project materials at the 2nd European Mineralogical Conference held in Rimini in September 2016.

Two articles on the project - jointly drafted by SETEC, MI and University of Milano – have been published on the specialized journal Ceramic World Review in 2014 and a last one has recently be accepted for publication on Cerâmica Journal.

A closure event was held on the 10th of March 2017 for 71 hosts, that received a short presentation of project results and were then hosted at the pilot plant where posters guided the visitors through the various stages of the production process, while project partners provided further explanations. After lunch a interactive session on future perspectives concluded the event.

D2: The Notice Board and the logo of the project were realized by LCE and placed at partners' premised by 30/09/2013 as foreseen. LCE realized also a drop flag in order to have a format easy to transport. Placement of the notice boards at the premises of VSW manufacturers where the test cycles were performed was done at the start of their activities.

The website was on line on 13/09/2013 at the address http://www.sanitser.eu, with contents in Italian and in English, and regularly updated with project news. All partners placed a link to the SANITSER website on their institutional sites. A restricted area of the website was designed and created by LCE in order to support documents sharing among partners, in a dedicated repository, and newsletter creation. The number of visitors of the website from its creation to the end of project was 2.914, below the goal of 200 monthly. The Layman's Report was printed before the closure event to be distributed amongst the audience. An English and an Italian version are available.

E6: MI participated to the Kick off Meeting of LIFE12 projects and performed regularly screenings to identify projects that could offer concrete opportunities for fruitful networking, first focusing LIFE and later adding the Eco-innovation programme. Due to the specificity of the technical problems addressed by SANITSER, some difficulties were encountered as other projects focused different ceramic sectors or other aspects of the production process and were not interested. MI participated to two events of projects related to waste glass recycling and sustainable glass production (FRELP LIFE12 ENV/IT/000904 and ECO/13/630426/WINCER) and one networking meeting with the GREEN SINKS project (LIFE12 ENV/IT/000736) was hosted by SETEC in March 2015. Furthermore SE.TE.C. and LCE presented their new project ECONOMICK (LIFE15 CCM IT 000104) to MI and GEMICA, and plans to trial SANITSER formulation in the new intermittent kiln that is being developed in that project. In September 2016 partners of ECOTILES (LIFE14 ENV/IT/000801) were met, which led to their visit to SANITSER final conference and SE.TE.C.'s visit to their conference in May 2017. The Platform meeting organized by National Contact Point Life in collaboration with Confindustria Ceramica and Laterizi and Centro Ceramica Bologna was, though after project end, a very good occasion to meet stakeholders and exchange experiences and results.

Longterm benefits and replication and transferibility potential

The project showed the industrial feasibility of a reduction of 18% in methane consumption; 18% reduction of related CO_2 emissions; 41% reduction in the use of primary raw materials, including Feldspar and Quartz, substituted by 80% of pre-consumer and 20% of post-consumer glass waste. Translated to the estimated production of 50 million pieces of Vitreous Sanitary Ware in Europe and Turkey annually, the technology would allow to significantly improve the **environmental footprint** of Vitreous Sanitary Ware production, offering a potential reduction in methane consumption of 77 million m^3; in CO_2 emissions of 206.8 million $kgCO_2eq$; in the use of primary raw materials of 557.169 ton; and valorisation of about 442.127 ton of pre-consumer and 115.042 ton of post-consumer glassy waste.

The findings are expected to strongly boost **competitiveness** of the European VSW sector: firstly due to cost savings on raw materials (ca.15%), energy cost (ca. 9,8%), transport of material supply over shorter distances, and lower investment and maintenance costs for the kiln that can fire at a ca. 7% lower temperature. Secondly, SANITSER technology permits the production of higher quality VSW thanks to the more performing materials. Thirdly, because products can comply with LEED specification and easily get an Environmental Product Declaration (EPD) using the project's LCA outputs, so improving the companies' image.

From a **health** point of view, the innovation significantly reduces workers' exposure to free crystalline silica (estimated at about 84%), contributing to the avoidance of silicosis.

These excellent outcomes allow the partners to proceed with the industrialisation and commercialisation of the innovations. Moreover, they already found several other sectors and applications where the SANITSER findings can be usefully applied, which may lead to a bigger impact in the near future.

2. Introduction

Description of background, problem and objectives

SANITSER targets solutions to the following environmental problems related to the ceramic production process:

a) high consumption of raw materials coming from domestic and foreign mines and quarries.
Indeed, feldspar consumption for VSW in Italy was, in 2011, of about 40.000 tons, in Europe (without Russia and Turkey) of 150.000 ton/y in Europe and in the world of 2.000.000 ton/y. The total/partial substitution with recycled SLG will enable a significant reduction in the quantity of raw materials extracted. It will also permit to increase the use of pitcher. Furthermore, utilization of domestic and waste material will not only remarkably reduce the demand for raw materials, but also the pollution due to the land and sea transportation.

b) significant amount of waste soda lime glass from separate collection of solid urban waste presently not recycled and landfilled.
There is a great availability of waste glass from urban separate garbage disposal, but the state-of-the-art does not allow everywhere its full and efficient exploitation in terms of recycling. This surplus of cullet, which is expected to increase, is presently landfilled. Moreover waste glass availability could be further increased improving the urban waste sorting and the industrial treatment of cullet. The use of SLG in substitution of feldspar for VSW allows the use of the total fraction < 0,1 mm from Sasil plant.

c) *high consumption of energy for ceramic production core processes, such as vitreous sanitary wares firing, resulting in a significant impact in terms of CO2 emissions in the atmosphere.*
Ceramic manufacturing industry is remarkably energy consuming. In “fine” ceramic sectors such as sanitary wares, from 10 to 18% of production costs is due to energy consumption. Currently the kilns’ firing temperature for the target products ranges from 1230-1250°C, which will be reduced by SANITSER by about 80- 110°C. Firing time is also expected to decrease by 20%.

d) reduction of use of water and domestic cleaning agents (both the natural and synthetic ones) because of the high anti-bacteria action provided by the new glazes.

Expected longer term results

It is evident how SANITSER contributes to achievement of European environmental objectives. Indeed, it responds to the 6th and 7th Environmental Action Plan (EAP) main principles related to natural resources and waste management. Coherence with the Thematic Strategy on the prevention and recycling of waste (COM(2005)666 final) is as well evident: if waste cannot be prevented, as many of the materials as possible should be recovered.

Moving towards a circular economy is today at the heart of the resource efficiency agenda established under the Europe 2020 Strategy for smart, sustainable and inclusive growth, in particular the flagships Resource Efficient Europe, Industrial Policy for the Globalisation Era and Innovation Union. Sanitser shares and implement the vision of the Roadmap to a Resource-efficient Europe (2011) and of the Circular Economy package (adopted in 2014 and currently being improved).

Concerning the IPPC Directive, the present project accomplishes with the following principles to be considered for determining BAT: a) less use of hazardous substances (explosives for feldspar production); b) the furthering of recovery and recycling of waste; c) technological advances and changes in scientific knowledge and understanding; d) the nature, effects and volume of the emissions concerned; e) the consumption and nature of raw materials (including water) used in the process and their energy efficiency; f) the need to prevent or reduce to a minimum the overall impact of the emissions.

Moreover the BAT individuated for ceramic sectors clearly confirms the relevance of process-related primary actions, first of all the optimal choice of raw materials. The Bref for ceramic industry indicates as best available techniques the ones capable of combining better environmental performances and economic advantages. In this sense, energy saving measures based on reduction of ceramic firing temperature and time imply a reduction in CO2 emissions as well as economic savings.

The project is carried out in the North and Central Italy, comprising the two principle districts of the VSW industry in Europe, North-East and Civita Castellana districts in Italy. The results that will be obtained for the VSW production can also be transferred to other Countries and technologies, including tableware and tiles production.

3. Technical part

The project aims to revise the production process in the Vitreous Sanitary Ware (VSW) ceramic sector by introducing relevant amounts of glass cullet waste from urban waste disposal in the ceramic blends formulations. The project focuses process innovations designed to a) provide a sustainable management, in terms of recovery of large amounts of glass cullet waste (soda lime glass: SLG), b) improve environmental performances of the ceramic sector by reducing CO2 emissions, c) enhance sustainability by energy saving and natural resources preservation.

In VSW production no extensive use has hitherto been made of SLG, although its introduction would yield remarkable benefits. The replacement of feldspar-like materials (up to some 40-50%), or of flux-agents (about 40-50 %), with SLG would provide: (i) savings in natural resources consumption (often imported because of increasing scarceness in European countries, implying also fuel consumption and emissions for transport); (ii) reductions of process energy consumption and CO2 emissions.

Introduction of SLG allows (a) to lower VSW production's firing temperatures from 1230-1250°C to 1120-1150°C, and (b) to shrink soaking times by 20%. The related CO2 emissions reduction will be quantified through the Life Cycle Assessment. All this can be realized by an acceleration of main ceramic reaction kinetics exploiting the SLG high reactivity.

SANITSER pursues to remove the obstacles that hamper so far feldspars substitution with SLG: 1. revision of firing time-temperature cycles as a function of the new compositions with SLG; 2. proper management of the rheological behavior of slips bearing SLG, in order to avoid an excess of thixotropy which might result in a difficulty of casting; 3. deformations control of large ceramic output owed to pyro-plasticity effects; 4. revision of the glaze formulation, so as to have it matching the modified time-temperature cycles of firing and the new bulk compositions, and avoiding an increase of production costs. To this end, a slip-rheology adjustment strategy has to be created, as well as a revision of glaze composition in the light of firing time-temperature cycles.

Trials are carried out on increasing scale, from laboratory until pilot tests on industrial plants by stakeholders of the VSW sector. They require the realisation of 3 pilot plants adapted for 1) different raw materials blending; 2) glaze preparation (GEMICA); 3) VSW production. Physical properties of large final ceramic bodies made at pilot scale are assessed and slip design and process parameters optimized in pre-industrial tests cycles. On the basis of production tests on industrial plants an industrial VSW plant will be designed for production of VSW-pieces tailored to these new parameters of time-temperature. The activities are accompanied by monitoring of time-temperature-composition parameters and environmental impact parameters, while at the end social and economic impact will be evaluated. Dissemination Activities will provide for transfer of knowledge to the target sectors as to foster future exploitation of results.

3.1. Technical progress, per task

3.1.1 B1 Realisation of a pilot plant for waste SLG preparation

Expected timing: 01/07/2013 - 31/03/2014
Actual timing: 01/07/2013 - 31/03/2016 (and further modifications in February 2017)

- *Activities performed and problems incurred*

Minerali Industriali's pilot plant is intended to prepare different raw materials (SLG and/or feldspar and/or quartz and/or pitcher) to realize Sanitaryware Body Mix (SBM) and Sanitaryware Glaze Mix (SGM).

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Construction and optimization works of the existing line number 3, started in December 2013 and were implemented in 3 phases:

Phase 1 (concluded end August 2015)

This phase was focused on enhancing magnetical separation, installing a new drier connected to the existing de-dusting system and installation of the feeding hopper;
In this phase was also completed transport system line of final product: propeller and connection to silos were installed, and also all the ducts, hoppers to sieves and air classifier have been coated with alumina bricks (Sarosint ceramic) in order to improve wear-resistance.

Phase 2 (concluded end March 2016)

In this second phase a new screen to realize a pre-screening phase was installed, aimed to lighten the load on the next screen in order to optimize particle size distribution. When treating dry materials with a very fine particle size it is very important to tighten the particle size distribution on the various levels of screening. A modification was also made to the dryer to improve the energy efficiency of the machine, installing a pre-combustion chamber. This operation ended in March 2016.

Phase 3 (February 2017)

In February 2017 a further optimization and adjustment of the aspiration system was implemented.

- *Progress indicators and results achieved*

The SANITSER project allows to valorize the fine size portion of glassy sand, that could not be used by glass industry. This by-product of the recovery of glass, that has a PSD almost under 100 micron, can be milled to reach the best PSD for sanitaryware production, and "cleaned" by magnetical separation. This fine sized glass was till now destined to low value brick industry, but thanks to SANITSER we can use it now as a valuable component of the new body formulation, with an important technological contribution.
Iron reach minerals contained in granite and considered as magnetic pollutant are reduced to a very low level, under 0,2% of Fe_2O_3 with this plant layout.

3.1.2 B2 Slip-rheology adjustment strategy

Foreseen timing: 01/07/2013 – 31/03/2014
Actual timing: 01/07/2013 – 30/04/2014

- *Activities performed and problems incurred*

SE.TE.C.'s development of a slip-rheology adjustment strategy suitable to control thixotropy and optimise castability of Vitreous China body with a firing temperature of 1150-1180°C, started with introducing raw materials that could replace hard materials (quartz and feldspars), actually used in the sanitaryware formulations. The study began with three formulations (SANITSER 1, SANITSER 2, SANITSER 3) featuring simultaneous use of a raw material obtained from recycled glass GS-VF <omissis> of a ventilated ceramic pitcher (vitreous-china), that comes entirely from the recovery of the sanitaryware ceramics production <omissis>, a feldspar material from the recovery of the Verbania granite quarries dumps F60P-VF<omissis>and a decreasing amount of quartz <omissis> These formulations were prepared according to the traditional method of preparation of sanitaryware bodies and inserting percentages of deflocculants (sodium silicate , sodium carbonate and barium) such as to reach the classic conditions for the casting (specific weight from 1800 to 1820; viscosity 310-280; thixotropy 25-35). Bodies formulated with suitable specimens were cast in plaster moulds with the aim to obtain the measure of the shrinkage percentage , that after a drying step, were fired at different temperatures in a gradient kiln from 1110-1190° C. According to the target of this project the temperatures chosen for the cooking of the bodies should be lower about 50-80 ° C than the ordinary temperature for traditional sanitaryware. This firing test allowed us to obtain a curve of vitrification for the three different mixtures bringing the total shrinkage percentage in function of temperature. After firing, the specimens were subjected to the test of water absorption percentage (in compliance with the EN 997 norm) and also reported the values of absorption as a function of temperature.
From the data obtained it is observed that not all mixtures are within the ranges prescribed by the EN 997 for the percentage of water absorption, therefore the trials to obtain the right formulation for VC has continued with two new formulations (SANITSER 4 and 5) providing an increase of glass percentage, and with the decrease of quartz percentage, and an increase of of granite . On these bodies, deflocculated with the same additives used in ceramic sanitaryware, the same tests were performed as on the formulations mentioned above. The sintering curves obtained showed that mixture 5 is within absorption values required by the norm EN 997 for sanitary ceramics at a temperature of 1160-1170° C. This result is very satisfactory as the decrease in firing temperature is, compared to traditional ceramics (which are fired at 1240°C), of 80° C.
Given the good results obtained, at the suggestion of Minerali Industriali, SE.TE.C. at this point of the research has set itself the ambitious goal to completely replace the raw materials such as quartz and feldspar with the employed recovered materials. In the formulations SANITSER 6 and SANITSER 6B a new raw material is used, called Aplite, a feldspar, , for the replacement of quartz. In the 6B body has also been added a percentage of magnesium carbonate to increase the fusibility of the body in the range of chosen firing temperatures. Repeating the test for measuring the shrinkage percentage and the total percentage of water absorption thevitrification curve is obtained. The value of water absorption obtained at 1170°C is lower than the limit of the norm EN 997, and is half respect to body 5. The plateau of vitrification for the body 6B is of 20-30° C, compared to the mixtures previously formulated which showed instead a range of 10-20° C. For the two last mixtures, SANITSER 6 and 6B, dilatometric tests were performed, with a dilatometer present in our laboratory, required to verify the thermal expansion of the ceramic material after firing for a comparison with the dilatometric coefficients of traditional vitreous china body. For both bodies the dilatometric coefficients obtained were higher than those of traditional ceramics, therefore the study for the optimal formulation of the mixture continued with the inclusion of two new raw materials, in particular a flux as Talc, even if with a low percentage. The formulation SANITSER 7 showed immediately rheological advantages superior to previous formulations,

because the percentage of deflocculants used to make the body castable is less than half regarding the amount of sodium silicate. This is a considerable advantage, because the use of high amounts of sodium silicate creates difficulties and firing defects in sanitaryware, such as formation of cords and dark spots.. In the curve of vitrification, shrinkage percentage values and total absorption percentage show very similar parameters compared to the body 6B, while dilatometric coefficients performed on this mixture SANITSER 7 shows lower values and in line with the standard values for a vitreous china. Of this mixture was then carried out a differential thermal analysis to verify the body phase transformations with increasing temperature up to 1100 ° C. The DTA-TG showed that the important exothermic and endothermic transformations found in Sanitser 7 are the same of the vitreous china standards, while in the temperature range between 650-1000° C the behaviour of the curve for SANITSER 7 were different from the curve obtained for the VC standard , presumably due to the presence of glass and talc.
At this point the body SANITSER 7 has been studied more in depth in order to compare all the rheological, chemical and physical properties with those of a mixture of ceramic sanitary ware. The study forecasted after the deflocculation of the body 7, with the usual deflocculates, the casting of a proof test for measuring thickness, which allows you to check the filling of moulds with the mixture and the consequent formation of thickness in the inner zones of the piece to be cast. For this test a gypsum mould cup with drain cast is used, where the mixture is cast and drained after an hour and after an hour and a half. The thickness was measured with a thickness gauge after drying. At the same time particular samples are cast for determination of resistance to bending after dying. Determination of resistance to bending is crucial because the body, after casting, is dried and moved manually, therefore, must have a resistance that does not crumble in the hands of the operator during these operations. Moreover appropriate samples are cast and fired at 1170° C to determine the deformation in the firing of the body, to verify the warpage of the piece and to determine the resistance to bending after firing.
Last tests aimed to verify the conformity to the norm UNI 4543 of SANITSER 7, that requires for ceramic a value greater than 3950 N, what is needed to make sure the static load test required in the CE mark for sanitaryware, and according to norm EN 997. This latter provides the application of a load of 4.00 kN on sanitaryware for one hour. The body Sanitser 7 showed values in line with those of a mixture of traditional vitreous china. At this point on the body 7 was performed particle size distribution measurement by means of a laser granulometer which allows to determine the average size of the particles that make up the body and their distribution between 0.3-100 microns. The particle size of the mixture is critical for the good castability and drying of the body after casting. A body with too fine granulometry cast into plaster moulds loses water slowly, and then forms a thickness in millimetres less than normal and the casted piece is also soft. The subsequent drying step is therefore slower, with the possible problems of deformation of the casted piece at the demould stage, as the cast piece is not manageable; while body granulometrically too large shows a rapid formation thickness with a fast drying of the piece in the mould, which leads to breakage of the piece itself before the step of demoulding . The body Sanitser 7 shows that 90 % of the particles have an average diameter less than 25 microns, in line with the standard VC parameters, but the fraction passing to 5 microns is lower compared to a traditional body, allowing a better drying and formation thickness than traditional body . For a further comparison an heating microscope test was performed on SANITSER 7 and traditional VC, to verify the firing curve of the bodies and their fusibility. The behaviour of the SANITSER 7 curve shows a slope such that the plateau area is shifted to 1150-1180 ° C, compared to the body VC where the plateau is in the range 1210-1240 ° C.
The SANITSER 7 body slip is at this point of the studies in line with the parameters and the

objectives we had set ourselves, and the material was used to cast two WC pans in SE.TE.C. pilot plant (action B6).
Starting from the excellent results obtained on Sanitser 7, which has determined the optimal percentage of SLG glass to be used, the research was focused to enhance the formulation in terms of components, by further increasing the content of recycled products. Adjustments were also made on the formulation to try to decrease the price of the body, with targeted adjustments to replace talc with other less expensive raw materials.

For all following formulations the vitrification curve was performed. After the casting of test specimens of shrinkage (20 cm long) and firing these specimens to temperature set in a range from 1140-1180°C, the shrinkage was measured andthe test of water absorption performed.
The values of water absorption percentage are in accordance with the UNI 4543 and UNI EN 997 at 1170°C for the bodies 9-10 and 11, the latter mixture, however, shows a shrinkage percentage after firing higher than the normal range for VC body, which is typically from 11 to 12%. Adjustments in the formulation of VC, made for the replacement of talc has not yielded the expected results in the rheological characteristics and values of water absorption and shrinkage after firing.
Therefore, after a meeting with Minerali Industriali, it was decided to keep the talc between the raw materials used for this body, as it allows us to lower the firing temperature around 1165° C and it give to the body an absorption rate and a shrinkage in the range already illustrated for formulation Sanitser 7.
After some attempt, SANITSER 13 formula reaches the primary objective of the project "saved primary resources 40-50%", as the total percentage of raw materials recovery and recycling is at 43.62%.
This body SANITSER 13 has been used for the casting test in SE.TE.C. pilot plant (see B6). Wash basins, bidet and WC pans were obtained and, after glazing with PSI-103 (optimal formulation of glaze by GEMICA, as described in phase B3), fired in the pilot kiln installed at SE.TE.C. premised, to verify the complete production cycle.
No particular problems incurred, apart from the known complexity of the trial process.

- *Progress indicators and results achieved*

A first data-package on the trials was presented in the meeting of the 25th of October (milestone at 31/10/2013).

As foreseen, the main activities have been concluded by end of January 2014, permitting implementation at pilot scale, though some optimization was performed till to the end of April 2014 to further increase the percentage of recovered components.

The tests performed firstly on small objects and subsequently on a sanitary article (as childhood WC pan), showed a good castability of the body, a good and homogeneous formation thickness and hardness of the casted piece without any problems. The optimal formulation for the vitreous china body that fires in the range 1150-1180°C temperatures has been identified and characterized, and its results are all sufficiently in line with the set targets:

Characteristics	**Expected values**	**Obtained values**	**Y/N**
Shrinkage (green)	about 4%	2.76 %	Y
Shrinkage (fired)	about 10%	10.95 %	Y
M.O.R (fired)	about 540 Kg/cm2	554.9 Kg/cm2	Y
E-modulus (fired)	about 31 GPa	32 GPa	Y
Average Linear thermal expansion	6.7×10^{-6} C^{-1}	6.9×10^{-6} C^{-1}	Y
Water absorption	0.5%	0.2 %	Y

Viscosity at t=0	about 900-1100 P	1050 P	Y
Viscosity at t=60 min	about 5500-6000 P	5900 P	Y

The final formulation, Sanitser 13, allowed to verify the data obtained initially with Sanitser 7 and shown in the table. The rheology of the same body was verified in the production phase (Action B6)., at SE.TE.C. pilot plant. Indeed, producing a greater amount than in the laboratory stage for casting the ceramic products permits to observe the real rheologic behaviour of the body in function of aging time.

- *Deliverables*

- Report “Slip-rheology adjustment strategy” - delivered 31/01/2014 (Annex 3 IR)

3.1.3 B3 Glaze composition revision in the light of new firing time-temperature cycles

Foreseen timing; 01/07/2013 -30/06/2016
Actual timing: 01/07/2013 – 30/11/2016

- *Activities performed and problems incurred*

The aim of this Action B3 is to develop glazes with ideal linear thermal expansion and physical characteristics when fired over the slip, developed in Action B2, to have the same characteristics of the glaze presently used for sanitaryware, notwithstanding the lower firing temperature and the recovered cullet used.
G.E.M.I.C.A. prepared glaze tests with different kind of special glass wastes, like boron glass, barium glass, neon glass and alkali glass, prepared by Minerali Industriali through special treatments to avoid any kind of pollution.

Glazes were prepared by GEMICA's technician by wet grinding, sieving and de-ironing, and mixing, as described in the deliverable Annex 2 MR, in samples of about 100 g/each.

Control of chemical-physical properties.
Most of the analysis were done in SE.TE.C. laboratory, to save resources on the purchase by Gemica of a laser granulometer, yet available at SE.TE.C.'s lab. SE.TE.C. also provides a qualified figure - Eng. Marco Calcagni - to carry out the analysis and write the final report.

During the action, GEMICA has prepared about 5030 different formulas of the glaze and, on each of them, SE.TE.C. performed at least 6 tests on each formulationSE.TE.C. performed at least 4 tests. For the final formulations more detailed analysis have been carried out, including: granulometric curve, scolino test, fusion curve, dilatometric coefficients, brightness and surface roughness measurements and all the tests relating to the regulation UNI EN 14688 and UNI 4543. In total about 300250 tests were done, to achieve the result described below.

The first step of the action consisted in the verification of glass fusibility for the raw materials furnished by Minerali industriali. The test was run using a scolino (draining canal), an inclined plane 6,5 cm high and 6 cm wide made of cavities and graduated channels. The glaze, in the form of a tablet was inserted in the cavity. The tablet wa obtained by compressing 2 gr. of previously dried powder with a piston. After this process and firing, the glaze melts and drips into the graduated channels depending on its fusibility. According to our production standards, the fusibility of the glaze should be from 2,5 to 3,5 graduated lines. Analyzing the raw materials individually, it was found that the material most suitable for the low temperature of 1172° is the VB-FF glass even though it goes beyond the third line.

The second step consisted in using the VB-FF glass in standard formulation for glaze in sanitary ware; to this end, it was added to other raw materials (matting and glass, quartz VR4, F7SE feldspar, calcium, dolomite, zinc oxide, zirconium) as reported in the formulations tested (see B3 deliverable Annex 2 MR).
The result, obtained adding the boric glass VB-FF, showed a good fusibility and a better surface gloss, while for opacification it is necessary to increase the zirconium silicate to the formula.

To obtain the melting curve for the glaze a heating microscope was used, which was made available by SE.TE.C.. The curves obtained give us some data, in particular that the two enamels have the same melting temperature, but the curve of the enamel with a greater percentage of glass VB-FF (PS1-6) has a lower softening temperature.
Tests of enamels were then repeated by replacing boric acid glass with alkali glass (VBI-FF), while maintaining the rest of the formulation unchanged. As a “crackle effect” was detected (PSI-85), the alkali concentration was modified obtaining a smooth surface, but opaque (PSI-86, PSI-87, PSI-88). Furthermore, test results did not improve the melting temperature. At this point it was therefore considered more appropriate to increase the percentage concentration of feldspar NA Extra 75 and decrease the percentage of quartz QLZ-FF, not changing the amount of alkaline glass. Other two formulations of enamel were produced, PS1-89 and PS1-90, wherein repeating the firing tests. We observed that surface of the glaze for both new formulation was not perfectly glossy and with low brightness. The heating microscope showed a curve with the melting temperature of about ten degrees lower compared to previous formulations, at 1178°C, for both glazes. The firing test, at 1165°C by gradient kiln, on glazes PS1-89 and PS1-90 showed a good fusibility. After this first goal, following tests increased the concentration of feldspar (PSI-91), and the percentage of glass VB-FF (PSI-92).

The results obtained with new samples were visually good and with excellent fusibility. However, contrary to our expectations, the surface of both the glazes did not appeared bright and nor had the characteristics of gloss to make them conform to the standards of industrial production. As expected results at this temperature range had not been achieved, we decided to act on other raw materials. Dolomite was thus removed and replaced with calcium carbonate, which should have allowed for a better contribution to fusion (PSI-93). However, results were not yet satisfactory and another attempt was done increasing the percentage of zinc (PSI-94), which greatly contributes with its chemical-physical characteristic to the formation of a glaze with high gloss at low temperature. The resulting melting point was too high if compared to the standard used in industrial production, but the surface was smooth and shiny.

The test on formulation PSI-95 and PSI-96, gave a higher fusibility than the previous sample. They have the same formulation, but with a smaller percentage of zinc. The curves obtained with the test of the lower heating microscope confirmed the excessive melt of these formulations. Tests showed a smooth surface and good gloss.

The glaze PSI-96 was used for glazing the first piece casted in SE.TE.C. pilot plant, with SANITSER 7 vitreous china. As we noted the poor coverage of the glaze on the support of vitreous china, with the enamel appearing as a clear or crystalline glaze, next step was to reformulate the enamel to make it more opaque, adding <omissis> more zirconium.

The glaze PSI-97 was used for glazing the second piece, obtained casting the SANITSER 7 vitreous china. The surface of the sanitary ware fired piece looked shiny bright and perfectly covered. The PSI-97 formulation thus became the standard base for our glaze, based on which we proceeded to implement necessary adjustments to meet all quality parameters. Indeed, glaze colour and brightness were still very different to the standard white glaze used in sanitary ware. New formulations, from PSI-98 till PSI-106 were tested on the basis of colorimetric parameters measured on the surface of the glazes (see deliverable). Among all the formulations tested, the PSI-103 glaze was chosen, having a higher degree of whiteness than the original. On the final glaze obtained (PSI-103) a series of measurements needed to be carried out to assess if target values for normal glaze conditions are achieved. After the test, we used the PSI-103 glaze to glaze the third piece, obtaining a fired piece with a good quality.

All these compositions of glaze have been analyzed and tested, alone and fired in SE.TE.C laboratory with the slip provided by SE.TE.C., to find the best composition, evaluating color, fusibility, possible effects of cracking and gloss of the surface. These tests were carried out together with the staff of SE.TE.C (Ing. Calcagni Marco).

3 fired pieces, using respectively PSI-95, PSI-97 and PSI-103 glaze

In December 2015 Minerali Industriali found a new source of boric glass as scrap coming directly from the producers. Though first tests had shown that boric glass could probably increase the amount of recovered materials used in the enamels, it had been disregarded due to poor availability in supply. Now broad availability could be assured, GEMICA and SE.TE.C. addressed activities to:

- Insert boric glass in the formulations
- Introduce the greatest possible amount of recovered material in the enamel.

To adjust the percentages of the materials the following new formulations were tested:

- PSI-104 to 106: discarded for superficial defects
- PSI-107, <omissis>
- PSI-108, <omissis>
- PSI-109, <omissis>

The use of boric glass allowed to:

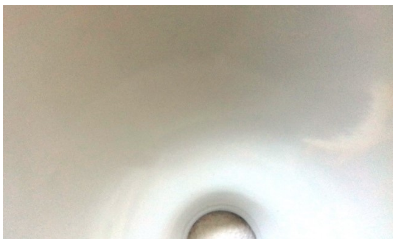
- Increase the percentage of recovered raw materials <omissis>
- Further decrease the melting temperature by about 5 °C
- Make the surface of the glaze smoother and more brilliant

PSI-109 formulation exceeded 15% of recycled raw materials <omissis>

During the pre-industrial and industrial tests of actions B7 and B8, we continued to fine-tune the formula of the glaze to achieve the best results, compatible with the Sanitser 13 body and aesthetical requirements:

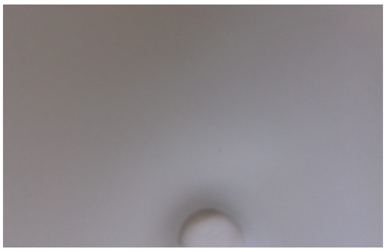
- Based on the PSI-109 formula, glaze formulation revision continued with colored enamels (with the addition of special oxides to obtain blue, orange, pink, blue light), pearly enamel (PSI-110), and matt enamel (PSI-111). They were formulated by GEMICA and analyzed and featured in SE.TE.C. laboratory, using also tools specially purchased by GEMICA (Glossmeter and Colorimeter) for the definition of brightness and color.
- Striving to reach a content of recycled materials of about 20%, GEMICA formulated PSI-112 and PSI-113. The latter has indeed a percentage of recovered raw materials of 19.20%, combined with a very high degree of white, resulting from the greater use of zinc oxide (ZnO). Furthermore, the higher fusibility of the glaze (i.e. a lower softening and melting temperature) helps to alleviate the problem of pinhole and allows us to fire the sanitary ware pieces at a temperature of 1165 °C. PSI-113 enamel was therefore chosen for the industrial production (B8) (see Annex 3 FR).

The characterization of this last enamel has been carried out by SE.TE.C. staff, repeating the same analysis already performed to characterize the glaze PSI-103 according to the applicable European and Italian standards (see annex 3 FR). The PSI-113 enamel has been compared in color and gloss determination with the previous ones, using the instruments which GEMICA purchased to this end, detecting a higher degree of white and a brightness, superior of about one-and-half point to PSI-109. If compared to a standard enamel, the degree of white is greater of about 3.5 points. Furthermore, the development of glossy and matt glazes, starting with the PSI-109 formula, has allowed us to expand the future commercial potential. Below some pictures for comparison.



PSI-109

PSI-113



PSI-111 Matt glaze

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PSI-111/MATT WHITE

PSI-112/GLOSSY GLAZE

Lastly, SE.TE.C. added a special additive to the glaze to obtain an antibacterial glaze, which offers an extra improvement to the environmental footprint of sanitary ware as it allows to reduce the use of water and detergents for cleaning. In the picture below all the colours and antibacterial glazes obtained.

A final book with pictures and lab reports of the selected glazes in several colours has been draft by SE.TE.C. (see deliverable Annex 3 FR).

- *Progress and results achieved*

First tests on glazes had to be completed in January 2014 but, given the close connection with action B2, to do trials on all formulations of mixture selected by SE.TE.C. and overcome the technical challenges described, the operations were delayed. Moreover, the scarcity of the boric glass led to the search for a valid substitute, alkaline glass VBI-FF, on which were then repeated all tests initially programmed for other types of glass.
The formulations to be used for testing in pilot plants were ready by May 2014 (PSI-97 formula), while the standard formula PSI-103 was produced in November 2014, with necessary adjustments to give greater brightness until March 2015. The standard formula has been refined when boric glass became available and according to the needs in the course of the trials, as foreseen in the proposal, and during pre-industrial and industrial testing.
Controls on PSI-113 (white) have been carried out to verify if compliance with the pre-set standards has been respected according to all the main technological parameters that define glaze quality. These are:

Granulometry control:

Characteristic	Standard industrial glaze	Our glaze PSI-103	Our glaze PSI-113
Bayer cone	1÷2% in weight with sieves of 16,900 mesh/cm2	1.5% in weight with sieves of 16,900 mesh/cm2	1.2% in weight with sieves of 16,900 mesh/cm2
Granulometer pacified with zirconium silicate	75÷80% of glaze particles, should be less than 10 micron	78% of glaze particles have a diameter less than 10 micron	80% of glaze particles have a diameter less than 10 micron

Colorimetry control:

Colorimetry parameters	Standard white glaze	PSI-103	PSI-113
L*	91.37	91.97	94.22
a*	0.84	0.16	+0.40
b*	-0.67	-1.25	+1.55
Brightness (gloss degree at 60°)	> 140	144	144.6
Surface roughness	Ra < 0.12 micron Rt < 0.8 micron	Ra < 0.08 micron Rt < 0.66 micron	Ra < 0.07 micron Rt < 0.56 micron

Physical properties:
The main target physical properties for PSI-113 glaze were obtained. As explained before and detailed in the following table, the melting curve differs from the standard one. Thus some of the obtained values (marked with / in the table) differ from the expected standard parameters,

though this do not makes the glaze not suitable, as what does matter is the melting temperature, which was achieved.

Characteristics	**Expected values**	**Obtained values**	**Y/N**
Shrinkage temperature	About 850-900°C	1080-1087°C	/
Softening temp.	About 950-1000°C	1090-1094°C	/
Sphere temp	about 1020-1050°C	1118-1120°C	/
Half-sphere temp	about 1050-1120°C	1123-1125°C	/
Melting temp	About 1150-1180°C	1141-1151°C	Y
Average linear thermal expansion	about 6.0-6.5 x 10^{-6} C^{-1}	6.9 x 10^{-6} C^{-1}	Y
Luminosity (measurements by Spectroeye)	>90	>94	Y
Brightness (gloss degree at 60°)	>140	=144.6	Y
Colour:	L*93.10, a*-0.93, b*3.82	L*94.22, a*0.40, b*-1.55	Y
Surface roughness	Ra<0.12 micron, Rt<0.8micron	Ra < 0.06 micron Rt < 0.56 micron	Y
Specific weight temperature 20÷25°C	1,650÷1,790 Kg/l	1,720÷1,740 Kg/l	Y
viscosity	270°÷310°(Gallenkamp)	300°(Gallenkamp)	Y
thixotropy (1min)	10°÷18°(Gallenkamp)	15 ÷16°(Gallenkamp)	Y
Preservation of surface brightness and luminosity in case of: (1) alkalis contact (NaOH 5%) at160°C for 30m; (2) acids contact (NaCl 50% and H2SO4 1:3) at room temperature and for 72h; (3) dyes contact at room temperature and for72h	PASS	PASS	Y
Resistance: to abrasion by Al2O3-sand for 210s	PASS	PASS	Y
Thermal shocks (5cycles repeated of heating at110°C in a calcium-chloride water-solution and quenching in icy-water; to water and vapor	PASS	PASS	Y

The main targets to formulate a white glaze with the right linear thermal expansion and with the right physical characteristics when fired over the slip were obtained, to have the same final aspect (smooth surface, no contamination like black or green spots, no hole or crack, etc) of the glaze presently used for sanitary ware.

- *Deliverables*

- Interim Report on revised glaze composition following new firing time-temperature cycles, delivered at 31/01/2014 (Annex 4 IR).

- Report on revised glaze composition following new firing time-temperature cycles, final version, produced in November 2014 (Annex 2 MR)
- Final book with pictures and lab reports of the selected glazes in several colours which proved to have the optimal formulation, delivered at 30/11/2016 (Annex 3 FR)

3.1.4 B4 Design and construction of pilot plant for glaze preparation

Foreseen timing: 01/07/2013 – 31/03/2014
Actual timing: 01/07/2013 – 21/11/2014 (further improvements performed until August 2016)

- *Activities performed and problems incurred*

As described in the proposal, Gemica's pilot plant, a line dedicated to glaze preparation, required the following equipment: 1000 lt rotary mill for glaze; screen for glaze screening; magnetic separator for glaze; electrical control panel.
Fine-tuning the design during first project months, it resulted necessary to add as well a mixer to mix all the components with the binders, obtaining the glaze. The final design was completed in August 2013, as foreseen.
It appeared more suitable to follow a different planning than originally foreseen, keeping the magnetic separator initially mobile to more easily manage the small quantities of glaze produced for enameling tests of samples made in SE.TE.C. during the pilot operations. Therefore, the plant has been realized in two different phases. This planning allowed to produce the glaze in the progressively increasing quantities required for the different project actions.

Phase 1 (concluded in March 2014):

- ✓ Purchase of the magnetic separator for glaze and installation, performed in December 2013. The magnetic separator is not installed on a dedicated line, but it is “mobile” and connected when in use for pilot production to a small line already in use in GEMICA plant, to facilitate managing the small amounts of glaze.
- ✓ The expected electrical works have been performed.

This solution was suitable only for the pilot production tests; for greater quantities a second phase has been performed, in which the planned dedicated pilot line was installed, to guarantee quality and greater quantities of glaze (about 500 kg per lot/day) without interfering with normal production on the existing line.

Phase 2 (concluded within November 2014),

- ✓ Realization of the dedicated line for glaze, installation of the rotary wet mill for glaze preparation (100 lt) with related screen and magnetic separator (see phase 1), in the final configuration, as expected by the original pilot plant design.
- ✓ Purchase and installation of the enamels mixer.

Due to environmental reasons (dust emissions during the loading in the mill) the plant was then completed with a dust aspiration system to be mounted on the top of the mill, to ensure in the industrial trial phase an increased glaze production with a suitably reduced environmental impact (lower dust emission and protection of workers health). Works started in October 2015.

The aspiration system was modified in March 2016 as the suction arm initially installed did not have sufficient power to ensure the required healthiness. Because of the greater volumes of glaze to be prepared for the final stages of the project, Gemica has decided to replace the aspiration arm with a localized suction ventilation system consisting of a ventilation system with capture devices, transport pipes, engine-fan group, air purification system, ejection chimneys, receiving hoods near scales. The new plant had to be built in such a way as to minimize the risk for operators and to avoid contamination with raw materials used in the enamel preparation process.

The pilot plant was then completed with a floor scale electronic balance. Initially, Gemica thought to be able to perform the weighing operations with the equipment already in its possession. However, during the pre-industrial trials the project activity started to enter into conflict with the conventional production processes. Hence the need to purchase a new balance. The new weighing scale was purchased in August 2016 in anticipation of phase B8, where a greater amount of enamel had to be produced for ceramic companies that participated in the trials.

- *Progress and results achieved*

The final pilot plant design was completed in due time. First part of the production line has been installed in time, by end of December 2013 (foreseen end of January 2014); the final configuration was completed by November 2014, differently as was originally foreseen. This delay in the completion of the plant has favored the execution of pilot tests, because before the installation of the line in its final configuration, all the glazes to be tested were produced on an existing line, more suitable for dealing with the small amounts to produced in the first phase. Further adjustments to the dust aspiration system, necessary to face the industrial trials, were then performed and ready by March 2016, and for the same reason a floor scale electronic balance was added.

Achieved results include:
- pilot plant design
- 1 dedicated pilot glaze preparation line (1 mill with screen and magnetic separation) able to produce about 500 kg of glaze per lot/day.

Throughout the project in GEMICA were produced about 8000 kg of glaze (considering all the different formulations tested and the total of the pieces produced).

- *Deliverables and reports*

- Deliverable 'Design pilot glazing plant', delivered at 31/08/2013 (Annex 5 IR)
- Deliverable 'Pictures constructed glazing pilot plant', due at 31/01/2014, delivered after full installation, 21/11/2014 (Annex 3 MR).
- 'Further pictures of the dust aspiration system in the realized pilot plant for glaze preparation', delivered 10/08/2016 (Annex 4 FR).

3.1.5 B5 Design and Construction of a pilot VSW production plant

Foreseen timing: 01/07/2013 – 31/03/2014
Actual timing: 01/07/2013 – 15/05/2014

- *Activities performed and problems incurred*

The Pilot plant was designed by SE.TE.C. technical office within November 2013 and it is formed by the following list of machine:

- N.1 Turboblunger 0.5 Cu.M 1st phase: in this dissolver are introduced clays, water and deflocculants. Its stirring system is made up of a stator and a rotor. This kind of machine is the solution to dissolve ball clays.
- N.1 Turboblunger 1 Cu.M 2nd phase: in this dissolver are introduced kaolin, quartz and feldspar and the dissolved clays from 1st phase. The description of this dissolver is like the former but obviously is bigger.

- N.2 Vibrating sieves with de-ironing for 1st and 2nd phase. These sieves have the important role to eliminate impurities present in the raw materials; moreover they subtract any kind of magnetic impurities (like iron) that could be present.
- N.2 tanks with slow stirrer for 1st and 2nd phase. These tanks are used for slip homogenization and storage. They have a simple mechanical paddle stirrer that has a rotation speed approximately of 16 rpm.
- N.3 Pneumatic pumps: these membranes pumps are used to transfer slip in the different part of the plant.
- N.1 Casting bench: this machine allow the mechanized casting of sanitaryware. The production processes are the same as for the manual casting, but in this case the plaster moulds are installed on automated benches.
- N.1 Intermittent dryer: this machine has the role to low water content of cast pieces from 15 to 1 % . Dryer has a thermal generator to introduce heat necessary to remove the excess of water and axial fans to avoid hot air stratification in the ceiling.
- N.1 Glazing booth: it is made entirely of stainless steel ,it allows manual glazing and was designed to minimize diffusion of dust toward the operator thanks to an ingenious abatement system.
- N.1 Kiln: this little kiln permits to fire glazed pieces, reaching temperatures over 1300 °C .
- N.1 slip line to distribute slip in the plant.
- N.1 Pneumatic line to distribute compressed air in the plant.
- N.1 electric line to give electric energy to the machines .
- N.1 water line to distribute water in the plant.

Selection of providers and placement of orders took place in December 2013 and the installation was performed between February-April. Unfortunately, suppliers of SE.TE.C. had a little delay in the ending of their work. Anyway this little problem has been solved within April 2014 when the plant was finalised, without any repercussions on the project's progress.
This plant has been prepared the SANITSER 13 Vitreous china body, for the casting of WC pans, bidets and wash basins. It produced about 2500 kg of body for casting, that in B6 phase has give articles of different sizes and shapes.

- *Progress and results achieved*

- Design ready within 31/11/2013
- Plant ready by end of April 2014 (foreseen was December 2013)
- Started up and fine-tuned by 15/05/2014 (foreseen was 31/01/2014)
Achieved results are in line with what was foreseen in the proposal:
One pilot VSW production plant to prepare VSW pieces in 1:1 scale, with the following slip requirements:

Characteristics	**Expected values**	**Obtained values**	**Y/N**
Green slip resistance	25-30 kg/cm2	25 kg/cm2	Y
Fired slip resistance	> 380 kg/cm2	555 kg/cm2	Y
Green slip shrinkage	< 4%	3 %	Y
Shrinkage < 13%	< 13%	11 %	Y
Water absorption after firing	< 0.5%	0.2 %	Y

With such a slip, the plant should be able to produce two VSW-bodies a time in traditional gypsum casts. The pieces will be first dried, glazed and eventually fired.

- *Deliverables*

- Design pilot VSW production plant - delivered at 30/11/2013 (Annex 6 IR)

- Pictures of the realized pilot VSW production plant - delivered at 15/04/2014 (Annex 7 IR)

3.1.6 B6 Assessment of the physical properties of large final ceramic bodies

Foreseen timing: 01/01/2014 – 30/06/2015
Actual timing: 15/04/2014 - 30/09/2015

- *Activities performed and problems incurred*

Due to the slight delay in the completion of SE.TE.C.'s pilot plant, this action started in April 2014. Objective is the assessment at pilot scale of the physical properties of large final ceramic bodies made by the materials developed in Action B2 and B3 and matching the technical requirements for marketability. After the development of Vitreous China body Sanitser 7, first two WC pan were casted, glazed and fired in the pilot plant of SE.TE.C. (see photos in deliverable B.3 - Glaze composition revision in the light of new firing time-temperature cycles). However, as yet explained under Action B2, adjustments were made on the formulation to try to decrease the price of the body and increase the percentage of recovered materials used, leading to the SANITSER 13 formula, reaching the primary objective of the project "saved primary resources 40-50%", as the total percentage of raw materials recovery and recycling is at 43.62%.
The SANITSER 13 body and glaze PSI-103 (Gemica production) were used in Pilot tests carried out on the pilot plants realized within action B5 by SE.TE.C., using the materials produced by the pilot plants developed in Action B2 and B3.
The action saw a very close and harmonic collaboration between SE.TE.C., which was to carry out the tuning of the body, and GEMICA, who had to prepare the glazes for pilot production. Difficulties where encountered from May 2015 onwards, due to serious health problems of one of GEMICA’s technical responsible for production and development (Operation Manager, Mr. Carabelli). For this reason, SE.TE.C. has taken steps to support the work with its own staff in order to move the project forward on time.
Eng. Marco Calcagni replaced in the final step of this phase B6 GEMICA's technical staff, aiding in the production and recording of data and problems in the finished pieces (in particular defects due to the glaze).

Body preparation
The pieces production is done manually in SE.TE.C. pilot plant and organized as follows. About 75 pieces have been produced so far, following this steps:
a) first phase dissolving: clays, together with water and deflocculants, are placed into the dissolver. The working time with these dissolvers takes from 3 to 4 hours, depending on the type of clay. The amount of deflocculant is dosed according to necessity (0.1 to 0.5% in dry weight of the body). Before being transferred to the second phase dissolving, the clay dispersion is screened using vibrating screens (meshes 90 - 125 micron). This operation is necessary in order to eliminate impurities present in the material. The sieved slip is passed through magnetic separation to remove possible residual iron contamination.
b) second phase dissolving: the first phase clay dispersion, quartz, glass feldspar kaolin and, if used, pitcher are placed in sequence into turbo blunger.
c) second phase sieving and de-ironing process: the process examined in point a) is repeated;
d) mixing of the final slip: this operation is carried out in a pit fitted with a mechanical paddle stirrer. Once the body is homogenized, its main characteristics are checked:
- specific weight of about 1810 Kg/dm^3;
- viscosity of about 300° Gallenkamp;
- thixotropy of about 30°G;
- pH = 8.4 ;
- temperature of about 23°C.

Casting

a) The ready slip is transferred to the 2 pieces manual casting machine (plaster) where water is eliminated from the slip thanks to the plaster's absorption capacity.
b) emptying of moulds: once the thickness formation time has passed, the operator sends low pressure air (0.2÷0.3 bar) to reduce the time needed for emptying the moulds.
c) hardening of cast pieces: once the slip has been drained, compressed air is blown into the mould to reduce the time needed for completing the hardening of the cast pieces. Hardening takes 20÷30 min, depending on the bodies and the type of article.
d) demoulding: is carried out manually. Benches are very simple but almost all operations must be carried out manually.
At this stage in the pilot plant of the SE.TE.C.'s staff proceeds to the casting of a series of articles, starting from the basins, to identify how the Sanitser 13 body slip behaves with different shapes and different geometries, the deformations and defects that may be encountered.

The final stages of finishing, glazing and firing was made only on the best pieces and only after checking at least three different types of sanitary article.
Initially therefore the plaster moulds of different washbasin models were mounted, in a bank of automatic casting of casting which allows at the same time articles of different shape and size. The next phase has provided for the casting of WC pans and bidets, articles more complex than the wash basins from the point of view of the phase of casting, with a casting machine mechanized present in the pilot plant of SE.TE.C..
The phases of preparations of a mechanized casting vessel and bidet have essentially the same sequence of those already seen for the casting of semi-automatic and manual basins.

Drying

It was carried out in normal room condition experimenting different duration in order to achieve the required parameters for the green body.
Finishing or touch-ups
Finishing consists of a series of operations carried out manually, where operator corrects any moulding imperfections on the green body.

Glazing

Glazes prepared by Gemica are transferred in ready to use tanks to SE.TE.C. pilot plant. It is pulverized and manually spread over the green body in specific hutch, before firing.

Firing

Firing is carried out according to time-temperature profile which has to be fixed according to results from laboratory test described in Actions B2, B3 and C1.

The kiln present in our pilot plant, according to the type of heating system adopted, is gaseous fueled kiln and on it we decided the firing curve.
It is the most delicate phase of the whole manufacturing process. It is here that a combination of chemical and physical processes take place and give the product its functional, technical and aesthetic features which qualify it as belonging to a certain technical and commercial class of vitreous china 1 piece at a time are manually put and taken out of the 1 m^3 electric kiln. This type of kiln guarantees greater firing homogeneity.
In conventional production, the sanitaryware are fired at temperatures between 1230 and 1250 ° C with average cycles around 14/16 hours and with times of stays at the maximum temperature varying between 40 and 60 minutes. The firing temperature for our products is between 1165-1170 °C, with a decrease of about 80-100 °C compared to traditional cycles. The reduction in the firing temperature is also to be associated to a reduction in the residence

time at the maximum temperature. Expected savings in terms of thermal energy , are of about 15-18%.
Consumption rates are forecast to about 2,200÷2,300 Kcal/Kg of fired products. In this phase we recorded about 1850-2000 kcal/Kg for firing the sanitaryware product in our pilot plant.
The firing process can be regulated and controlled only if the chemical and physical features which "transform" bodies and glazes when they are subjected to a certain temperature cycle are completely understood. Most of the defects on the final pieces are due to the presence of strong thermal gradients inside the kiln. Therefore, the pilot plant has a GPL kiln that guarantees greater firing homogeneity.

The fired pieces have been checked after firing to verify the defects. In particular many different types of defects may be found on the fired pieces. These can be broken down into the following three categories:
- defects caused by the body/glaze non-compatibility;
- defects caused by the body;
- defects caused by the glaze.

The defects caused by firing or by the kiln shall be included respectively in these three categories according to the most obvious defect. The defect found on the body Sanitser 13 is related to the deformation and the swelling. We registered with photo this defect. The defect on the glaze was due to the loss of shine, glaze sagging and hammered surface. All these defects depend on the firing curve. Defects found on the enamel were thus eliminated by correcting the firing curve, increasing the final permanence to the maximum temperature and increasing the rise time of the temperature range to get to 1165 °C. On the body, defects were corrected by changing the rheology before casting and making changes in the modeling of the sanitaryware, which allowed a better production.In standard sanitaryware production the percentage of products without defects on finish products is of about 55%, while 10-12% of pieces are broken during casting, finishing or drying phases and 38% of pieces should be repaired or re-fired due to various defects.
In our pilot plant we first casted 75 pieces. 8 pieces broke during casting, finishing or drying phases (these pieces are reutilized for preparing the body in the pilot plant). We thus fired 67 pieces, 4 pieces presents defects (see deliverable B6), 3 pieces broke after firing. In total 60 pieces without defects, with a percentage of 89% on fired pieces..

By September 2015, 25 additional pieces were casted (but fired only in the following phases) and used for the glazing tests. 3 out of these 25 pieces broke during firing, while 5 showed light superficial defects, acceptable for a second choice piece.

Overall 100 pieces have been casted, of which 85 are first-rate pieces while 5 present pinhole defects. Defected pieces are thus 15, of which 10 to be discarded and 5 of second choice. The percentage of pieces “successfully produced” on the cast pieces is thus higher than that found in the conventional industrial cycle as in the phase of the pilot plant the operator places more attention and greater caution at every critical step of the process.

- *Progress and results achieved*

The test firing of ceramic articles of different types (wash basins, bidets and WC pans) different sizes and models, for the finalization of the body SANITSER 13 and the glaze PSI-103 in the pilot plant of SE.TE.C., ended in September 2015 with a three months delay.
First and most important reason was recorded at the time of preparation of larger amounts of SANITSER 13 body (1000 kg every time) in the pilot plant of SE.TE.C.. A particular effect was observed: the body during preparation, as indicated in Phase B2, with an amount of deflocculant (sodium silicate) equal to 0.08%, after one week shows a very low thixotropy (5-10° Gallenkamp). Also in the casting phase we realized that on the surface of the mould and

on the outer surface of the casted pieces there was dark film, almost certainly due to the organic substances present in clays dispersing in solution. We thought initially of dosage error, but the same problem was registered in the following trial. We thus thought it was a problem of over-flocculation of the body and we started to gradually decrease the concentration of sodium silicate, but the same phenomena repeated again. The subsequent tests were those to include in the formulation a Polyacrylate deflocculant, chemically different from the sodium silicate, at 50% (0.04%). The phenomenon of lowering thixotropic eased significantly. As a last attempt we made tests without the subsequent dissolving sodium silicate, only with the polyacrylate deflocculant coming to the optimal percentage of 0.025%. In these latter tests it was observed that the mixture after the second phase, in which all components are mixed, was not fluid as a standard VC mixture, but letting it rest and aging, after a day the optimal characteristics for the casting were measured. This phenomenon found in the test phase of the pilot plant will be further explored with the analysis to be carried out at the University of Milan (Action C1), as this discovery highlights the power of deflocculant of sodium present in glass for ceramic bodies.
It was anyhow not considered a problem to invest these three additional months to study the phenomenon described above, as Action B7 could not be started-up during July-August 2015, when the companies are closed, nor during September when important trade fairs were planned to show the results achieved (CERAMITEC and CERSAIE).
By the end of September 2015, expected results of the actions were achieved, both in terms of number of pieces produced successfully and as of compliance with quality requirements. However, as the start of the trials under action B7 was experiencing some delays, SE.TE.C. decided to use the remaining slip to cast some more pieces to tune the glaze which had been revised in the meanwhile.

Final results achieved are as follows:

- Technical features of the ceramic bodies assessed at pilot scale.
- ca. 100 pieces of large final ceramic bodies successfully produced with feldspar recovered SLG, pitcher and granite. As with SANITSER 13 we manage to find the right balance between the materials, the differentiated mixtures foreseen in the proposal are not needed anymore. Substitution values achieved are: Feldspar+SLG+pitcher: 43.62% (with 8% of pitcher)
- In total 85 pieces out of 100 without defects (corresponding to 85%; including second choice pieces 90%);
- Full correspondence of the ceramic body with principles of compatibility between bulk and glaze, durability, processability and compelling legal requirements, namely:

1. The thermal expansion of the bulk must duly match that of the glaze to avoid formation of cracks at the surface.
The dilatometric coefficients of the body and glaze are higher than the coefficients values found in a standard VC and in a standard glaze, but in agreement with each other.

2. Mechanical properties, expressed through Modulus of Rupture and Young Modulus, are in turn important to provide durability and assess fragility of a piece bearing a high level of non-crystalline phases.
The value obtained is in compliance with the norm UNI 4543 for the ceramic body (this norm required a value of 3950 N) and the SANITSER 13 body shows more resistance to bending compared with a standard VC body (+11%).

3. The shrinkage of a fired piece with respect to its size before firing may results in a relevant deformation of shape. The more complex the shape of a body, the more important such aspect becomes, as deformations depend on the position in a ceramic piece. Deformations do not

affect only the aesthetics of ceramic body, but they are also a source of tensions reducing durability and increasing fragility.

The shrinkages registered on the fired pieces are in compliance with the standard values found for vitreous china body, which is in the range 12-13%.
Subsequently on the fired pieces were measured the characteristic connecting dimensions for checking compliance with European standards. All the connecting dimensions measured are in compliance with the European Standard Norm.

4. Water absorption must stay below threshold fixed for VSW-bodies that convey organic liquids.
Water absorption average value found is 0.32%, in compliance with norm EN 997 and UNI 4543 for ceramic body.

- *Deliverables*

Interim report on the physical properties of large final ceramic bodies produced with SLG: 31/12/2014 , Annex 4 MR

Report on the physical properties of large final ceramic bodies produced with SLG, including pictures and technical performances. 30/09/2015 , Annex 5 MR

3.1.7 B7 Optimization of the slip design and process parameters choice in pre-industrial tests cycles

Foreseen timing: 01/07/2015 –31/12/2015
Actual timing:: 01/10/2015 (operational planning), 01/03/2016 (pilot trials) – 31/07/2016

- *Activities performed and problems incurred*

Preliminary contacts to identify the companies interested in running industrial and pre-industrial trials were taken already in 2014, starting with the companies who were involved at the proposal stage: Ceramica Globo and Ideal Standard. Among the other big producers contacted we can mention Villeroy&Boch and Keramag, both visited by Mr. Salvaia in March 2014 with the aim to present them the project and evaluate their interest in being involved in it. In the first months of 2014, Mr. Fortuna and Mr. Salvaia also met a representative from SIMAS, another important producer from Civita Castellana.

This activity resulted in the identification of two companies confirming their intention to participate to the project: SIMAS and Globo. In October 2015, upon completion of phase B6, MI and SE.TE.C. contacted them to arrange the operative planning to kick off the trials. The meeting to formalize the final cooperation agreement was expected to take place by November 2015.

However, both Globo and SIMAS withdrew their availability, motivating their choice with the unwillingness to assign staff and materials to the project and as they consider their plants (for casting and re-firing) to be oversized for the trials, which would have implied an excessive expenditure. It also has to be mentioned that in both cases internal issues and production difficulties unrelated to the project contributed to the decision.

The SANITSER partnership thus decided to move toward companies with a higher operational flexibility. It also took advantage of the situation to involve companies of different sizes and with different products, with the aim to test the transferability of the casting process under different production scenario.

During the presentation organized at Relais Fallisco to present the interim results achieved (see action D1), the first company suitable to replace Globo and Simas (Ceramica Scarabeo) was identified. Ceramica Scarabeo is a company of medium dimension, comparable to Globo. While the other two companies identified, Kerasan and Ceramica Amerina, are respectively a medium-large and a small company. This allowed a better and more meaningful assessment of the SANITSER process compared with the traditional one.

Cooperation agreements with Scarabeo and Kerasan, setting the cooperation framework and the duties of the parties, were signed in March 2016. Activities started right thereafter. Ceramica Amerina started its activities without a formalized agreement, reluctant to sign it.

The SANITSER slip was produced by SE.TE.C. in its pilot plant and transported to the ceramic producers, responsible for the casting phase. In the project proposal it was foreseen the intervention in this phase of a manufacturer of slips from Civita Castellana, Spica Ltd Part of the Imerys Group, Spica is always interested to new formulations that can lead to energy and cost savings. However, their involvement would have implied the disclosure of the Sanitser 13 formula, which we decided to avoid for IPR reasons. This choice required a greater effort on SE.TE.C. side, but did not cause any difficulty during the implementation phase. To produce the slip, SE.TE.C. bought the kaolin and the clay, normally used in conventional production while MI supplied the remaining non-plastic part of the materials necessary for the tests. GEMICA produced and supplied the necessary glaze.

Each pre-industrial test lasted from few hours to few days providing data related to the technical features and to the environmental and energetic aspects of the product and of the process. These data were analyzed to put in place the needed corrective actions aimed at improving the quality of the final testing phase. Corrective actions on firing curve, in production of the body or in casting phase were taken.

The cast ceramic pieces were the most suitable to meet the needs of the tests, requiring the production of articles of different types, size and shape. The articles cast by the ceramic producers were then dried and finished before being returned to SE.TE.C. for glazing and firing. The firing phase of the pieces was carried out in SE.TE.C. intermittent kiln, since the few cast pieces for each company could not be inserted in the industrial furnace together with the conventional production, as different firing temperatures apply.

SE.TE.C. has kept samples of the pieces obtained and has returned the remaining pieces to companies that have participated to this phase. The cast pieces are 220 in total, of which 20% toilets and bidets, while 80% sinks. The difficulties encountered by the companies in interacting with the new products, the results and the energy impacts of this phase were recorded and evaluated. This activity was completed in July 2016.

Operational difficulties were registered by companies, in particularly Kerasan srl and Ceramica Amerina, in the casting process of the new slip:

1) Slip rheological problems in casting: we noted the dark color and the formation of skin casting on the pieces surface. The problem was solved by simply eliminating the deflocculants that had been added by the companies according to the usual habits of their technical managers to do so for the latest corrections before casting.
2) The casting tests carried out allowed us to assess rheological and physical chemical characteristics of the body. In this phase, in fact, the first productive difficulties due to the fluidization of the mixture where we put the waste glass were found.

   The glass, in fact, acts on the clay in the slip like a deflocculant. In this way the slip Sanitser 13 at the time of casting assumes viscosity values in the standard, very low thixotropy values (around 10-5 °G), compared to the values recorded in a vitreous china equal to 25-20 ° G. For this reason the slip Sanitser 13 must be maintained at a higher specific weight (1820 to 1840 kg/cm3) than that of a VC (1800 to 1820 kg/cm3) to have the possibility of obtain the same thickness in the pieces (in mm) with respect to the VC standard.

3) After several studies conducted in our laboratory, in which the rheological characteristics trend (viscosity and thixotropy) was reported in function of slip aging and as the glass acts on the slip in which we use different types of clays, it was decided to proceed by changing the preparation of the first phase by directly entering the waste glass (GS-VF), and removing all deflocculants, such as sodium silicate and barium carbonate. This allowed obtaining a mixture (always with low thixotropy values 15-10°C) but which could be cast for several days (15 days), with no change in the rheological properties and especially in the value of the thickness formation, which could indicate a degradation of the characteristics of the slip itself.
4) Problems of pinhole on the enamel, which have been addressed and resolved by slightly changing the firing curve, increasing the residence time at the temperature in which the gas in the slip is formed to 850-1050 ° C, and changing the glaze formula.

Some difficulties were also registered to transfer know-how developed for simple-shape bodies to complex-shape ones. The biggest difficulties arise from the rheological problems recorded for the new raw materials introduced both in the dough and in the enamel.

The companies have faced the difficulties in different ways, which also reflect the different level of preparation of the technical staff involved in the trials.

- *Progress and results achieved*

About 220 pieces have been casted using the SANITSER body (Sanitser 13) and different formulation of glaze (PSI-103, PSI 111 and 113), producing 200 good quality pieces.

<omissis>

The flexibility in the production has been demonstrated obtaining 8 different types of articles. The reproducibility of the obtained product was demonstrated by inserting the slip and the glaze in different productive activities, different in structural size and with more or less qualified personnel. Compliance of the pieces, obtained by Sanitser 13 and PSI-113 enamel, is verified in correspondence with the standards EN 4543 and EN 997.

Expected	**Achieved results**
ca. 270 pieces of large final ceramic bodies successfully produced, in 3 different shapes.	ca. 220 pieces are casted, 210 pieces are fired and about 200 piece of good quality are obtained. They are successfully produced, in 8 different shapes.
The thermal expansion of the bulk must duly match that of the glaze to avoid formation of cracks at the surface.	OK, see the dilatometric analysis reported in deliverable.
Mechanical properties, expressed through Modulus of Rupture and Young Modulus, to provide durability and assess fragility of a piece bearing a high level of non-crystalline phases.	OK, see in the deliverable, the average value obtained on the pieces fired in this phase.
The shrinkage of a fired piece with respect to its size before firing may results in a relevant deformation of shape. The more complex the shape of a body, the more important such aspect	OK, see in the deliverable, the average value obtained on the pieces fired in this phase.

becomes, as deformations depend on the position in a ceramic piece. Deformations do not affect only the aesthetics of ceramic body, but they are also a source of tensions reducing durability and increasing fragility	
Water absorption must stay below threshold fixed for VSW-bodies that convey organic liquids.	OK, see in the deliverable, the average value obtained on the pieces fired in this phase.

- *Deliverables and annexes*

Optimization of the slip design and process parameters choice in preindustrial tests cycles: delivered on 31/07/2016, Annex 5 FR

3.1.8 B8 Sanitaryware final industrial production tests

Foreseen timing: 01/01/2016 - 30/09/2016
Actual timing: 01/09/2016 – 30/11/2016

- *Activities*

As in the final industrial phase the number of pieces to be produced is significantly higher, the manufacturers involved had the task of casting, enameling and firing the articles. At this stage, Ceramica Amerina decided to withdraw itself from the trials. Indeed due to its small productive dimensions and for internal reasons, it did not feel to go further with action B8, requiring the production of quantities significantly higher than those faced previously.

The project partners thus evaluated the possibility of inserting a new company substituting Ceramica Amerina, selecting it among those who had shown interest toward the project and had the required operational capacity. Ceramic Alice, a medium sized company similar to Scarabeo, was selected. As for B7, the Sanitser 13 body has been produced in the pilot plant of SE.TE.C. and delivered to the different companies selected. In parallel GEMICA produced the enamel. MI supplied the raw materials of its competence, the other being purchased as in B7. Companies then casted, dried, finished enameled and fired the pieces. Companies have chosen to produce small items, mostly washbasins, with manual and mechanized casting. The total number of good quality pieces produced is 1760, including 3.5% of pots and bins and the remaining 96.5% of washbasins. This activity was completed at the end of November 2016.
At the end of this phase the companies involved have delivered to SE.TE.C. two articles of each type produced in this phase, as was requested.
In total, Scarabeo casted, glazed and fired about 600 basins of different shapes. Kerasan casted, glazed and fired about 576 articles, of which 10 in WC pans and bidets and 566 in washbasins. The production of vases and bidet is more challenging with respect to the casting of washbasins, since they are obtained by automatic machines in which the supply lines are connected directly to the turbo in which the slip is matured. Not being able to place the slip in Sanitser ageing turboblunger, where there is the traditional mix, only WCs which allowed a manual casting were produced.
Ceramica Alice has produced 584 pieces, of which 50 childhood WC pans and 534 small washbasins. Also in this case the WC chosen to be cast with the Sanitser mix are small in size and cast in manually manner, so as not to put in the piping system our slip that might have created difficulties with the WC mix used in conventional production.
During this phase, companies were followed by technicians from SE.TE.C., which have gathered the data on electric and gas consumption for the environmental impact assessment.

In all the plants there is a litre-counter to verify the amount of water used and a counter for methane cm consumption.
Only Kerasan has a cubic meters counter attached to the oven used for firing, while Ceramics Alice and Scarabeo have general counters for the verification of the total methane consumption.

Overall, the Sanitser 13 slip produced and supplied by SE.TE.C. amounted to 30,000 kg, which is 10,000 kg average for each company. PSI-113 glaze was provided by GEMICA in a quantity of about 4,300 kg, corresponding to about 1450 kg of PSI-113 glaze delivered to each company.

Below details are provided on the number of trials.

Company	N° of fired pieces	N° firing processes	Number of fired pieces per process	N° of fired pieces GOOD QUALITY	Type of articles
Scarabeo	615	3	205	600	600 Wash-basin
Ceramica Alice	609	3	203	584	50 WCs + 534 wash-basins
Kerasan	600	3	200	576	10 WCs /bidet + 567 wash-basin
Total	1824			1761	1701 wash-basin + 60 WC/bidet

- *Problems*

The number of pieces produced is lower than the foreseen in the proposal, though a higher variety of pieces was achieved. (1760 pieces in 8 different types vs 3800-4000 pieces in 6 different types). This can be explained with the size of the companies involved and is backed by the fact that meaningful results does not effectively required that amount of pieces, while more representative results can be achieved by increasing the variety of the companies and shapes/types of products involved.

Despite the number of parts produced was lower, it was possible to test thoroughly project-related parameters such as energy consumption as well as environmental and socio economic impacts. Also the involvement of medium-sized businesses has allowed us to assess the ease of application of the project-related technology and to get to know which type of training is required when less expert staff is involved.

Furthermore, the flexibility in terms of process management and realization of ceramic pieces was evaluated and process parameters or slip/glaze compositions adjusted under different productive scenarios. The potential industrial difficulties listed below have been solved:

-Appearance of instability/fluctuations of slip on time, because of thixotropy boosted by contaminations in large production apparatuses;

-Development of pinhole on the glaze and continuous changes in the enamel to try to minimize the defect.

- *Progress and results achieved*

In the initial project	Actuated
ca. 3.800 – 4000 pieces of large final ceramic bodies successfully produced, in 6 different shapes by 2 different manufacturers.	1761 pieces of large final ceramic bodies successfully produced, in 8 different shapes by 3 different manufacturers.

Feldspar-SLG: minimum 50% of SLG Feldspar-SLG-pitcher: minimum 50% of SLG and 14% of pitcher Granite-pitcher-SLG: VSW produced with 100 % recovered waste products	43.62 % of Granite-pitcher-SLG insert in body formulation. 19.2% of SLG insert in glaze formula.
3.900 final ceramic bodies of diverse shapes ready to be demonstrated to, judged by and eventually sold to customers	1761 ceramic bodies of diverse shapes ready to be demonstrated to, judged by and eventually sold to customers

- *Deliverables*

Report on the sanitary ware industrial production tests, Annex 6 FR

3.1.9 B9 Design industrial VSW plant

Foreseen timing: 01/03/2016 - 30/09/2016
Actual timing: 01/07/2016 - 31/01/2017

- *Activities performed and problems incurred*

Once the production parameters for introducing the SLG and pitcher in sanitary ware were established, allowing for treatment in regime of lower temperature and shorter time, SE.TE.C. designed a plant for the production of VSW-pieces tailored to the new time-temperature parameters.

To this end all the plant units have been revised in order to match the requirements of the glass-based technology for sanitary-ware. The developed design allows improvements to the performance and production capacity of the plant as it has combined the process optimization lay-out, obtained from the pilot system's indications, with the traditional process characteristics (trialed in pre- Industrial and industrial). In this well-designed plant both conventional and SANITSER technology can be applied until the firing phase, while in this last stage an intermittent kiln is introduced specifically for Sanitser to allow for the lower firing temperature.

The new plant is provided with a slip preparation area; glaze preparation area; casting area; drying area; spraying area, firing area; quality check area.

The plant lay-out was produced by SE.TE.C. technical staff with 10 technical sheets and four project designs in 3D (autocad and pro-e).
The plants and the machines have been designed for a capacity of n° 300.000 pcs/year of production (equivalent to about 6.630 tons/year) of different types of end-product: washbasin - pedestal - water closet - bidet - water tank.
Project data, technical considerations, production planning, determination of quantities and description of the technological cycle are reported in detail in the deliverable (Annex

- *Results achieved*

- 1 design for industrial VSW plant with the following characteristics:

MECHANISED PLANT PRODUCTION PHASE	m^2 in the initial project	m^2 in lay out plant	Time in hours	No. of shifts
Storage of raw materials	1,000	1600	/	/
Preparation of bodies	350	340+430	/	1

and glazes				
Mould preparation and storage	500	580	/	2
Casting	1,400	1460	4	2
Drying	300	630	20	2
Inspection	150	230	/	2
Glazing	175	430	/	2
Drying of glazed pieces	500		6	2
Firing	1,000	1800	16	3
TOTAL	**5,375**	7500	46	15

- 2D and 3D pictures showing the plant's architecture (see deliverable, Annex 7).
- A notable CO2 emissions reduction was expected, along with a relevant energy saving. Calculations of these savings at proposal phase though have presented some errors.

Considering therefore the production of the plant, designed in the deliverable, of about 300,000 pieces/year. Every piece has a weight of about 20 kg. We obtain 6,000,000 kg of body SANITSER (6000 tons/year). Starting from data obtained during SANITSER project /which have also been used for LCA purposes within task C2 and for LCC purposes within task C3), firing the SANITSER body requires about 0.320 m^3/kg of gas (-18% less than an intermittent kiln of the traditional cycle, which is about 0.390 m^3/kg); this amount corresponds to around 2 940 kcal/kg. Thus, over one year of production with intermittent kiln, firing requires 17.6 $\times 10^{-9}$ kcal/year for all the pieces; this energy is supplied by around 1.9 million m^3 of methane and is related to a value of produced $CO_{2\ eq}$ equal to 5 144 ton $CO_{2\ eq}$ per year (for SANITSER sanitary wares).
Same calculations can be done for traditional cycle, with an annual energy need equal to 21.5 $\times 10^{-9}$ kcal/year for all the pieces supplied by 2.3 million m^3 of methane; this leads to 6 275 ton of $CO_{2\ eq}$ produced per year.
Compared with the traditional cycle, the energy savings associated with SANITSER firing process amounts to 0,4 million m^3 of methane per year (foreseen was 1,5 m^3) and $CO_{2\ eq}$ saving associated with SANITSER firing process is approximately 1 100 tons per year (foreseen was 210 tons), both about -18 %.

- *Deliverables*

1 design for industrial VSW plant, delivered 30/11/2016, Annex 7 FR.

3.1.10 C1 Determination of the time-temperature-composition parameters

Foreseen timing: 01/07/2013 – 30/09/2016
Actual: 01/07/2013 – 31/12/2016

- *Activities performed and problems incurred*

Action C1 aims at monitoring (i) the technical development of the project since its onset to end, (ii) the state of progressive advancement of the time-temperature-composition parameters' revision, crucial for formulation of slips in which SLG-granite-pitcher successfully replace feldspar fractions.

The activities, carried out on a laboratory scale by the University of Milan (Earth Sciences Department), have been steered to the following aspects:

(i) mullite growth kinetics, to determine how far activation energy is affected by the substitution of feldspar and this leads to a relevant contraction of time-temperature values;

(ii) as a consequence, definition of a new time-temperature interval for HT-ceramic process;

(iii) assessment of the macroscopic properties of final ceramic outputs to understand the principles underlying the changes of the fired body's physical properties induced by new composition-temperature-time parameters. The aim is to attain novel process conditions that guarantee the marketability of the product, i.e. such as do not worsen its performances with respect to the extant.

The phase/chemical composition and the relevant morphologic/micro-structural properties of the specimens covering the time-temperature-composition interval under investigation have been studied. Analysis have been carried out both on samples studied by university department and on those provided by SE.TE.C., with a continuous exchange of information to obtain a first-stage time-temperature-composition grid and determine a correlation between time, temperature and resulting phase composition. The results of this study are presented in the deliverable of the action C1 "First interim report on time temperature composition based on results of lab test" (version 1, 2 and 3) attached to the present document.
This study is closely related to the action B2 "slip-rheology adjustment strategy", since the results are the basis for subsequent tests.

The "2nd interim report on time-temperature composition based on results of pilot tests" aims to characterize aspects related to morphology, degree of homogeneity of chemical composition, phase composition and possible coating, in glaze samples that were designed to fulfill given technical requirements. In particular, we tackle the problems listed beneath:

I. Formation of anomalous black coating, as a function of the content of deflocculant agent;
II. Phase compositions that developed upon heating in the different glaze formulations (Sample PSI 97-100-101-202-103-104-105-106);
III. Bulk chemical composition, morphology of micro-structures in reference glaze samples (PSI 103-97);
IV. Spatial elemental homogeneity in reference glaze samples (PSI 103-97).

The phenomenon of the black coatings is ascribable to a change of viscosity that promotes separation of the organic component, occurring in clays, from the inorganic mineral part. UNIMI has by SEM analysed samples provided by SE.TE.C. with and without BC to make a comparison. These analysis confirmed that the black coating can be ascribed to an organic film, due to an organic-inorganic separation rendered possible by a decrease of viscosity, so as a consequence, we decided to reduce at the minimum level the content of deflocculant <omissis>

Figure. Black coatings on the surface of casted pieces (industrial tests)

From the results of phase composition upon heating study, we considered the ratio Integrated intensity-quartz/integrated-intensity-zircon (q=I.qz/I.zr) to highlight difference in terms of reactivity of different formulations with respect to temperature. The higher reactivity on heating is shown for PSI 105-106.
Glazes PSI_103 and PSI_97 do not show anomalous micro-structures, and both have in general homogeneous surfaces, although the latter exhibits a coarser texture than the former. The most relevant difference consists in that PSI_103 allows a better (more uniformly spread) distribution of zircon over its surface than PSI_97. This is likely related to a higher flowability of PSI_103 than the other one, at the same heating conditions. In particular, PSI_103 is more sensitivity to heating because of the presence of calcium, and also the presence of Zn can give a positive contribution to this higher sensitivity.

The "third interim report on time-temperature-composition based on results of pre-industrial trials" aims to characterise ceramic bodies produced by three industries, I1-I2-I3, collaborating in the SANITSER project. SE.TE.C. prepared slips for them following the indications developed in SANITSER, they casted them, and then SE.TE.C. fired them according to the newly developed temperature-time cycles. In the analysis we characterise the nature of the phases that appeared upon thermal treatment and the degree of homogeneity achieved for such ceramic bodies. The results are of interest in three respects:
(1) a comparison between bodies from the same company, in order to check the intrinsic stability of the slip against "physiologic" oscillations of a given process;
(2) a comparison between products from different companies, which use similar heating cycles and same traditional slip casting, in order to detect a possible sensibility of the slip to even small differences of process;
(3) a comparison between industrial output and laboratory output, in order to check the ''distance'' between wholesale production and small scale predictions/expectations. In the present study, we investigate a glaze sample, too. We can restrict our analysis to one glaze specimen only, as glaze is less sensitive to the rheology involving peculiarities of a process than slip.
The results of this studies show that the ceramic bodies provided by companies I1-2-3 are homogeneous with each other and also consistent with those produced by laboratory tests (within the precision achievable by the present X-ray powder diffraction experiments).

It is then possible to confirm that formulation SANITSER 13 is robust and portable from one plant to another. In such a view, it tolerates comparably small changes of thermal cycle (soaking temperature from 1170 to 1180 °C) and casting technology. To complete this action, the "Final report on the time-temperature-composition relationship" with an overview of the results obtained so far, aimed to define the firing behavior of glass-bearing slips and determined the relationships between the composition of the new slip and the new firing cycle, testing the processability of all vitreous china mixes formulated for the project and processed with different firing temperature, comparing them to standard VC formulation and cycle. In this study, ceramic bodies from industrial tests were also analyzed, for further revision of the time-temperature-composition variables highlighted in the previous stages.

- *Progress and results achieved*

Timing indicators:
The first deliverable was presented at due date of 31.01.2014 comprising the mineralogical analysis of the phases, to determine the composition of the contained mixtures baked at various temperatures in the range under study, the morphological analyses - microstructural and those of physical properties - of the specimens prepared at UniMi laboratories. In total about one hundred samples had been prepared to perform the various tests and report the

results in the deliverables, plus others that didn't give good results and were therefore discarded, altogether about 300 samples. This first version was shared with the monitor during his visit end of February 2014.

The first mineralogical analyses performed on specimens prepared by SE.TE.C. were performed in March 2014, then the analysis of all the samples was completed and the deliverable “1st interim report on time-temperature-composition parameters based on results of lab-tests” was updated and completed. The milestone "First stage of refinement of time-temperature-composition parameters, transferable to pilot scale of use" is considered achieved.

Since the pilot tests only ended in September 2015, the deliverable “2nd interim report on time-temperature composition based on results of pilot tests” was presented within 31/12/2015, with 6 months delay.
The results obtained by this study contributed to solve a technological problem encountered during casting (black coating) and to define the best glaze composition, based on the results achieved in terms of surface quality and homogeneity.

The deliverable “third interim report on time-temperature-composition based on results of pre-industrial trials” was completed at the beginning of August 2016, right after the end of the pre-industrial tests, with 7 months delay. The samples of ceramic bodies produced by three industries involved in testing, has been characterized, showing first of all a strong consistency between industrial output and laboratory output, and then confirming that formulation SANITSER 13 is robust and portable from one plant to another.

The Final report on the time-temperature-composition relationship was presented at the end of 2016, with 3 months delay. In this study we aimed to reconsider all outputs from previous studies, integrating them with the new results from industrial testing, and to further refine the relationships between time-temperature-composition, related to physical and rheological properties of the innovative ceramic product, always in comparison to a vitreous china standard composition and firing process. This work confirms the transferability of SANITSER innovation to an industrial scale also in terms of phase composition appeared upon thermal treatment, microstructures and degree of homogeneity achieved for such ceramic bodies and for their enamelled surfaces.

- *Results achieved*

The stated objectives for action C1 have been completed with the production of a number of specimens smaller than foreseen by the project, around 300 instead of 700, because sufficient to meet expected results.

The following results have been achieved:
- The phase/chemical compositions and the relevant morphologic/micro-structural properties of specimens covering the time-temperature-composition interval under study;
- An analysis of the correlation between time-temperature and resulting phase compositions, so as to be able to predict the role of T and t on the phases of the output;
- A determination of the kinetic parameters which control the mullite-formation reaction to monitor the state of evolution of a ceramic transformation and to set-up a model to predict time-temperature as a function of the SLG-content;
- Determination of the relationships between time-temperature-composition and physical properties (from B2), to steer new trials so as to formulate slips able to fulfill the physical properties requirements.

- *Deliverables*

- 1st interim report on time-temperature-composition parameters based on results of lab-tests - 31/01/2014 version 01; 28/3/2014 version 02 (Annex 8 IR); 31/03/2015 version 3 (Annex 6 MtR);
- 2nd interim report on time-temperature-composition based on results of pilot tests, 31/12/2015, Annex 8 FR
- 3° interim report on time-temperature-composition based on results of pre-industrial trials, 05/08/2016, Annex 9 FR
- Final report on the time-temperature-composition relationships 31/12/2016, Annex 10 FR

3.1.11 C2 Monitoring environmental impact: LCA

Foreseen timing: 01/01/2015 – 31/12/2016
Actual timing: 01/08/2013 – 30/03/2017

- *Activities performed and problems incurred*

The aim of C2 action is to evaluate the environmental performances of SANITSER system by carrying out a detailed benchmark between the innovative and the existing (traditional) technologies for sanitary ware production from an environmental point of view. All activities here reported are based on the four development stages of any ISO 14040 standardized LCA studies: goal and scope definition, inventory analysis, impact assessment and interpretation.

A. GOAL AND SCOPE DEFINITION

The goal of this study is to compare the existing traditional system for producing sanitary ware with the innovative SANITSER process, to identify pros and cons of the two systems from an environmental perspective

First of all, a literature research was done to find out other case studies and related standards:
- Assessment of Product Category Rules (PCR) for construction products and construction services (PCR 2012:01 version 2.0, downloadable from International EPD System website – www.environdec.com); the document provides the guidelines to perform an Environmental Product Declaration (EPD) for construction products; sanitary ware are included in the product group of this document.
- Analysis of the EN 15804:2012 (Sustainability of construction works – Environmental Product Declarations – Core rules for the product category of construction products), which represents the basis for the PCR 2012:01.
- Analysis of the main EPD published in this field (downloadable from International EPD System website – www.environdec.com).
- Analysis of ISO 14067:2013 (Greenhouse gases - Carbon footprint of products - Requirements and guidelines for quantification and communication).

After that, sanitary ware production system was studied for a better understanding of all processes:
- Visits of partners' sites/plants to understand the innovative production process respect to the traditional one (useful to prepare proper questionnaires for data collection and, in general, for LCA activities).
- Analysis of literature on sanitary ware production methods (D. Fortuna, Sanitaryware ceramic technology, Gruppo Editoriale Faenza editrice S.p.A., 2000).
- Different technical meetings aimed at deciding the main preliminary hypothesis for LCA and S-LCA study, both physical meetings (02/04/2015 and 25/01/2016) and skype calls.

These two preliminary activities allowed the definition of the scope of the analysis; main aspects are (all other decisions are reported in *Deliverable Life Cycle Assessment Report*):

- Definition of process stages to be comprehended within the cradle-to-gate analysis (system boundaries), with the division of production modules according to PCR (see next figures).
- Individuation of the declared unit[1] (1 ton of sanitary ware) to which refer all LCA inventory and analysis results;

Figure 1 Unit processes describing the stage of sanitary ware manufacturing included in LCA system boundaries.

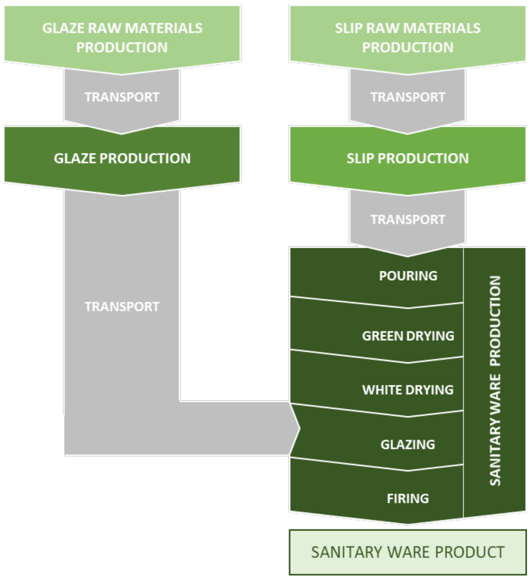
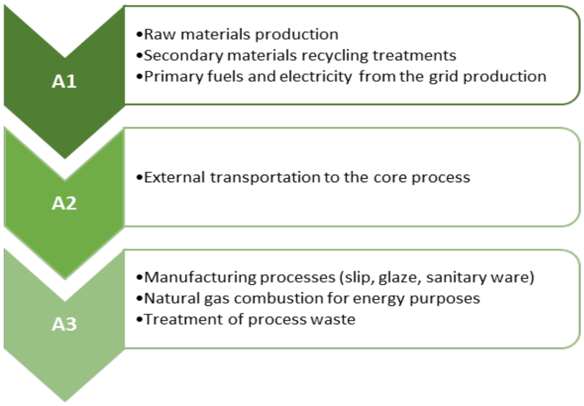


Figure 2 Boundaries for sanitary ware production divided in three modules according to PCR 2012:01 v2.01



The goal of the study was the comparison between the traditional and the innovative manufacturing systems (intended as the industrial production phase B8); however, LCE and project partners decided to analyses also the pilot phase (B6) and the pre-industrial phase (B7). This choice is due to:
- the utility of having a benchmark for a preliminary analysis of primary data, before starting further elaborations;
- the possibility to provide an environmental assessment of SANITSER upscaling process;

At this point, specific questionnaires for data collection were prepared on the basis of plant visits and decisions coming from technical meetings. Two kind of questionnaires were sent to partners:
- For raw material production;
- For slip, glaze and sanitary ware manufacturing.

In the meantime, other fundamental information was collected without using specific questionnaires: slip and glaze recipes, packaging specification, raw material suppliers localization. LCE tried to adapt data collection to every specific situation, using both Excel, Word and Power Point models.

Since LCA is an iterative technique, several aspects belonging to the scope required small modifications (e.g. system boundaries) to meet the original goal of the study after the preliminary data and information collection.

[1] It must be mentioned that the utilization of a declared unit, instead of a functional unit, is related to defined system boundaries: this study does not cover the complete life cycle of the sanitary ware product but only stages from-cradle-to-gate. For this reason, the further use and function of the product is not certain

B. INVENTORY ANALYSIS

Primary data collection was set up as a continuous exchange of information between LCE and partners: several versions of received data were analyzed and sent back to partners for further specifications or specific requirements, within an iterative process aimed at obtaining robust data. It is then clear that long time efforts were needed both to comply with the LCA nature as well as to meet the highest level of results reliability. Some unplanned events have then contributed to the LCA milestones repositioning, mostly due to the change of involved ceramic companies and to the refinement of initial recipes.

Once final data were validated by involved partners, the elaboration started with the normalization of all information to the selected declared unit. After this first step (performed on Excel calculation sheets) four different LCA models were implemented on SimaPro 8.3.0 professional tool, namely:

- Traditional production;
- Innovative industrial (B8) production;
- Innovative pre-industrial (B7) production;
- Innovative pilot (B6) production.

Models generation required the choice of appropriated datasets, were primary data was not available: for sake of robustness and coherence with the Webtool Database, Ecoinvent 2.2 was mainly taken as source of secondary data.

C. IMPACT ASSESSMENT

Due to the existence of a specific PCR for sanitary ware products, the environmental impact categories (and related indicators) were not deliberately chosen, but PCR rules were followed. Some of the analyzed potential environmental impacts are:

- Global Warming, kg CO2 equivalents (GWP100)
- Ozone Depletion, kg CFC-11 equivalents (ODP)
- Acidification of land and water, kg SO2 equivalents (AP)
- Eutrophication, kg PO43- equivalents (EP)

Other indicators were included in the analysis, as foreseen by PCR; some of them are:

- Total use of renewable primary energy resources ((MJ);
- Total use of non-renewable primary energy resources (MJ);
- Use of secondary material (kg);
- Use of net fresh water (m3);
- Hazardous waste (kg);

The classification and characterization method chosen was elaborated by LCE within the SigmaPro tool based on EN 15804 characterization factors (not specifically for this project, as it is a method frequently used internally). This method was applied to the four LCA models, generating four different groups of results for every category indicator: four different Life Cycle Impact Assessment profiles. Moreover, environmental impacts of the Ecoinvent operation *Sanitaryware, at plant/RER U* were calculated too, to be considered as reliable benchmark for the four SANITSER LCA models.

All results for the four models are reported in Deliverable Life Cycle Assessment report.

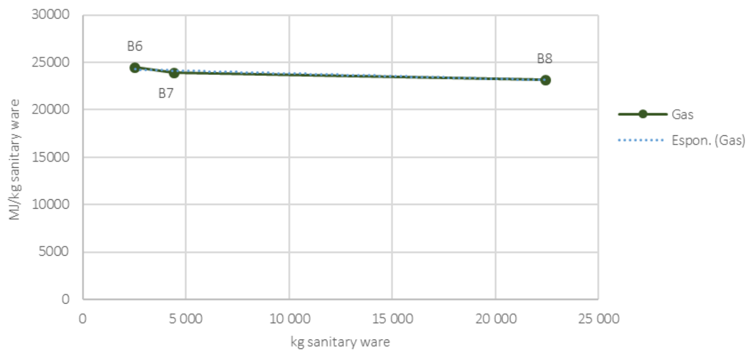
D. INTERPRETATION

At the end of impacts calculation, LCA analysts started the interpretation stage during which results of the four LCA models were compared among them and with the Ecoinvent operation ones. Other than impact indicators required by PCR, other kind of impacts were evaluated during this stage in order to put the focus on SANITSER benefits as much as possible. Hereby are reported some of the additional elaborations done:

- The recycled material content within SANITSER sanitary ware was calculated on the basis of slip and glaze dry recipes and production processes material efficiencies, for the industrial stage B8;
- Slip and glaze dry recipes were analyzed from the point of view of raw materials environmental impact, with detail of contribution to GWP of every single ingredient, for both the traditional and the two innovative SANITSER 13 and PSI 112 recipes;
- Raw materials transport from production sites to slip and glaze manufacturing sites was compared between traditional and industrial B8 processes, with detail of distances covered by truck and ship and with related environmental impacts (in terms of emitted CO2eq);
- Energy consumption of the sanitary ware production core stage, in terms of electric energy (for material handling) and gas consumption (for drying and firing), was compared between traditional and industrial B8 productions;

Finally, an evaluation of the upscaling process from pilot B6 to industrial B8 production stage was carried on the energy consumption of sanitary ware manufacturing core stage, showing trends of decreasing energy consumptions (in terms of MJ) and environmental impacts (in terms of CO2eq); an example is reported in next figure.

Figure 3 Relationship between production volume and gas consumption over SANITSER upscaling (both drying and firing stages are considered)



Once all results were calculated, they were submitted to internal verification made by an LCA expert from LCE. This kind of verification was useful for the individuation of analysis weakness and (in some cases) partners were involved in a last data collection stage, to finalize the LCA model with more robust data.

During the LCA development, LCA analysts started to create the related deliverable, on which every detail of the described operations can be found. Moreover, the draft EPD was prepared, following some example of verified EPDs available on Environdec website and other EPDs done based on EN15804 guidelines.

Both the deliverables were checked by different LCA experts and internally verified.

Design of a web – based tool

A web-based tool (hereafter "tool") was designed and developed with the following aims of:

- Collecting quantitative data from each partner involved in the project to feed Life Cycle Assessment (LCA) activities, such as the quantification of environmental performances related to raw materials, slips and glazes used for sanitary ware production;
- Comparing environmental performances related to different sanitary wares;
- Accepting the LIFE Project Monitor recommendation to deploy a tool to collect data and share environmental information among partners about materials, processes, etc.

Environmental performances are evaluated by means of the following environmental indicators:

- Greenhouse gases emissions;
- Use of net fresh water;
- Process energy consumption;
- Effect of recycled materials use.

Tool realization passed through the following steps:

A. Tool design;
B. Environmental database preparation;
C. IT web-tool development;
D. Tool release on www.sanitser-tool.eu.

A. TOOL DESIGN

Design is the key phase in tool development, when all functionalities are set: it usually ends with the preparation of a technical document (often called "software analysis"), describing all features (software technology to be used, users' enrolment, database properties and content, data collection procedures, report generation, etc.) by means of specific mockups, to give an overview of the whole tool.

The analysis represents the basis for dialoguing with Information Technology Department (after called "IT Dept.").

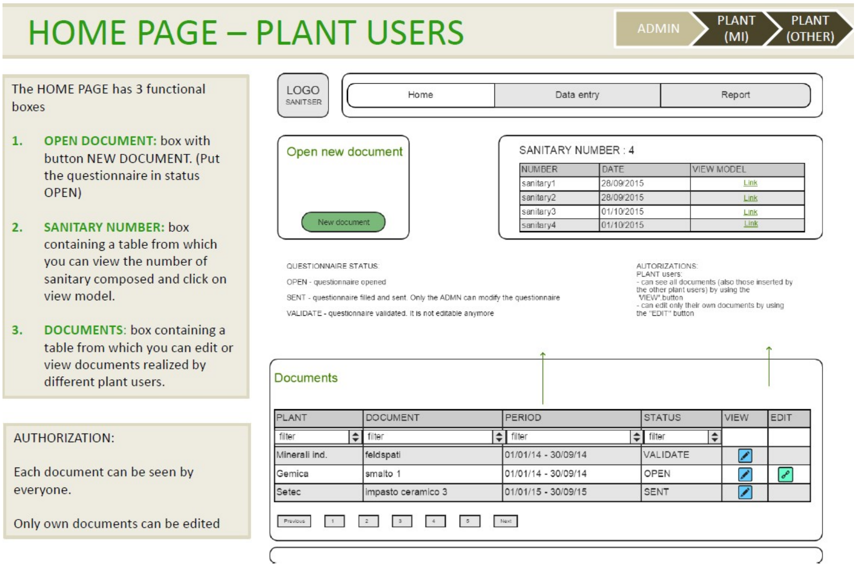
Hereby are reported some pieces of the analysis, to give an idea of the importance of this document.

Figure 4 Definition of authorizations and functionalities for all the users

USERS

USERS	AUTHORIZATIONS AND FUNCTIONALITIES
SUPER ADMIN	• User management (create/edit users; assignment of production process phase to proper user)
ADMINISTRATOR	• Documents mangement • Data Check and Validation • Database management • Users management • Creation of the Sanitary model • View reports
PLANT – Minerali industriali (MI)	• Filling in the questionnaire related to raw materials for slips • Building the primary data in enviromental database • View reports
PLANT – OTHER	• Filling out the questionnaire for collecting data other processing phases (slips, glazes, pilot plant) • Builduing the primary data in envoiromental database • View reports

Figure 4 Example of "home page" design with related mockups and explanation



B. ENVIRONMENTAL DATABASE PREPARATION

The tool is customized and tailored on SANITSER needs with a specific database. It consists of selected processes specific for sanitary ware production with related environmental performances.

Processes are grouped in seven main categories:

1. Raw and auxiliary materials (e.g. clay production)
2. Energy (e.g. electricity and fuel production)
3. Packaging (e.g. big bags production)
4. Water and air emissions
5. Waste
6. Transport
7. Natural resources (e.g, water)

The selection was made among various sources: commercial life cycle assessment database and scientific literature.

In the case of innovative raw materials (e.g. secondary raw materials produced by Minerali Industriali and used for SANITSER slip and glaze), a primary data collection was carried out to calculate specific environmental performances; results were included in the environmental database.

Figure 5 Overview of environmental database, inserted in the tool

	DB environment			Reference year	<year>	Selezionare gli Indicatori dal menu a tendina			
2	Section	Category	Element		Indicators	GWP	WATER	PROCESS ENERGY	SECONDARY MATERIAL
3			Code	Description	Units	kgCO2eq	l	MJ	%
4	MAT	Raw Materials	MP01	Clay	kg	0.00	0.00	-	-
5	MAT	Raw Materials	MP02	Kaolin	kg	0.15	8.44	-	-
6	MAT	Raw Materials	MP03	Talc	kg	0.26	1.92	-	-
7	MAT	Raw Materials	MP04	Quartz	kg	0.03	1.51	-	-
8	MAT	Raw Materials	MP05	Feldspar	kg	0.03	1.72	-	-
9	MAT	Additives	MP06	Sodium Silicate	kg	0.65	9.52	-	-
10	MAT	Additives	MP07	Sodium Carbonate	kg	0.40	29.40	-	-
11	MAT	Additives	MP08	Barium Carbonate	kg	1.55	6.56	-	-
12	MAT	Raw Materials	MP09	Calcium Carbonate	kg	0.02	0.29	-	-
13	MAT	Raw Materials	MP10	Zinc Oxide	kg	2.82	2.86	-	-
14	MAT	Raw Materials	MP11	Zircobit	kg	4.40	137.94	-	-
15	MAT	Raw Materials	MP12	Glass	kg	0.04	0.08	-	100.00
16	MAT	Explosives	MP13	Quarry explosives	kg	4.51	19.61	-	-
17	MAT	Raw Materials	MP14	BVC	kg	0.11	0.52	-	-
18	MAT	Raw Materials	MP15	GS-VF	kg	0.18	0.38	-	-
19	MAT	Raw Materials	MP16	VB-FF	kg	0.21	0.48	-	-
20	MAT	Raw Materials	MP17	VBI-FF	kg	0.12	0.29	-	-
21	MAT	Other	MP18	Plaster Gypsum for molds	kg	0.06	0.71	-	-
22	MAT	Raw Materials	MP19	Dolomite	kg	0.03	0.20	-	-
23	MAT	Other	MP20	Distilled water	kg	0.00	1.03	-	-
24	MAT	Film	MP21	LDPE Film	kg	2.73	6.86	-	-
25	MAT	Raw Materials	MP22	Feldspar F60P 0.1-0.7	kg	0.29	1.79	-	-
26	MAT	Expanding gas	MP23	Carbon dioxide	kg	0.79	8.17	-	-
27	MAT	Expanding gas	MP24	Nitrogen	kg	0.43	3.88	-	-
28	MAT	Expanding gas	MP25	Butane	kg	3.98	19.60	-	-
29	MAT	Expanding gas	MP26	Cyclopentane	kg	1.12	0.89	-	-
30	MAT	Raw Materials	MP27	Feldspar F60-PBVF	kg	0.09	0.43	-	-
31	MAT	Raw Materials	MP28	Seconday material	kg	-	-	-	100.00
32	MAT	Raw Materials	MP29	Glass scrap	kg	0.04	0.08	-	100.00
33	MAT	Raw Materials	MP30	Other scrap	kg	-	-	-	100.00
34	MAT	Raw Materials	MP31	Vetro Borico	kg	0.15	0.34	-	
35	MAT	Other	ENR01	Lubricating oil	kg	0.89	7.47	-	-
36	NRG	Combustion fuel	ENR02	Light fuel oil	l	3.31	4.27	40.18	-
37	NRG	Combustion fuel	ENR03	Gasoline	l	4.32	5.11	35.97	-
38	NRG	Combustion fuel	ENR04	Natural gas, boiler <100 kW	Nm3	2.84	0.86	38.80	-
39	NRG	Combustion fuel	ENR05	Natural gas, boiler >100 kW	Nm3	0.07	0.03	38.80	-
40	NRG	Electricity	ENR06	Electricity, medium voltage, France	kWh	0.05	7.34	3.60	-
41	NRG	Electricity	ENR07	Electricity, medium voltage, Germany	kWh	0.60	2.97	3.60	-
42	NRG	Electricity	ENR08	Electricity, medium voltage, Greece	kWh	0.80	4.94	3.60	-
43	NRG	Electricity	ENR09	Electricity, medium voltage, Italy	kWh	0.42	1.95	3.60	-
44	NRG	Electricity	ENR10	Electricity, medium voltage, Mexico	kWh	0.64	0.58	3.60	-
45	NRG	Electricity	ENR11	Electricity, medium voltage, Norway	kWh	0.01	0.04	3.60	-
46	NRG	Electricity	ENR12	Electricity, medium voltage, Sweden	kWh	0.03	3.87	3.60	-
47	NRG	Electricity	ENR13	Electricity, medium voltage, Turkey	kWh	0.66	1.98	3.60	-
48	NRG	Electricity	ENR14	Electricity, medium voltage, USA	kWh	0.68	1.67	3.60	-
49	NRG	Combustion fuel	ENR19	Diesel	l	3.13	3.80	43.30	-
50	NRG	Other	ENR21	Grease	kg	0.89	7.47	-	
51	PCK		PCK01	Paper label	kg	1.16	53.33	-	-
52	PCK		PCK02	Corrugated Board	kg	0.89	22.85	-	-
53	PCK		PCK03	Wood box	kg	0.23	2.19	-	-
54	PCK		PCK04	Glue	kg	1.40	161.28	-	-
55	PCK		PCK05	Stretch Film	kg	2.73	6.86	-	-
56	PCK		PCK06	Adhesive tape	kg	2.59	22.30	-	-
57	PCK		PCK07	Pallet	kg	0.23	2.19	-	-
58	PCK		PCK08	Steel wire (regetta)	kg	1.66	16.73	-	-
59	PCK		PCK09	HDPE Bags	kg	2.54	7.30	-	-
60	PCK		PCK10	LDPE Bags	kg	2.73	6.86	-	-

Section | Category | Indicators | UM | DB environment

C. WEB-TOOL DEVELOPMENT

During web-tool development, features designed during the first phase are developed by IT Dept. following four main steps:

1. Development of all the features listed in the technical documents and web-tool release in a development area;
2. Bug fixing of features developed;
3. Web-tool released in the official area (www.sanitser-tool.eu), where all partners could enter using their own login information;
4. Bug fixing of features released in the "official area".

In the following figures, some screenshots of the main functionalities are reported.

Figure 7 Data collection screen for plant user

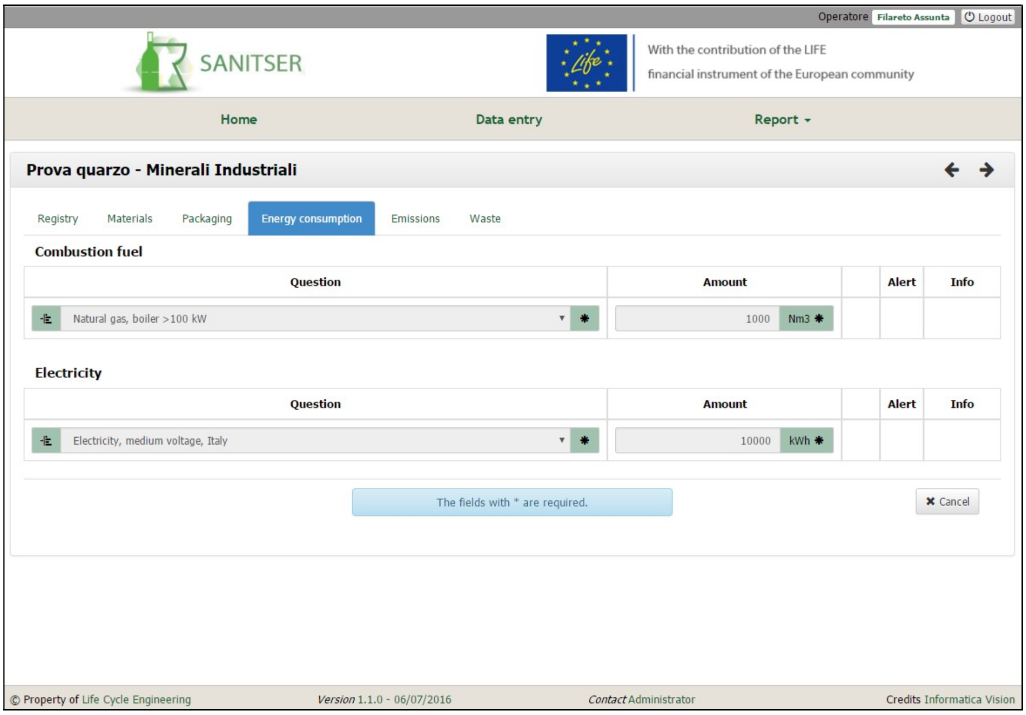
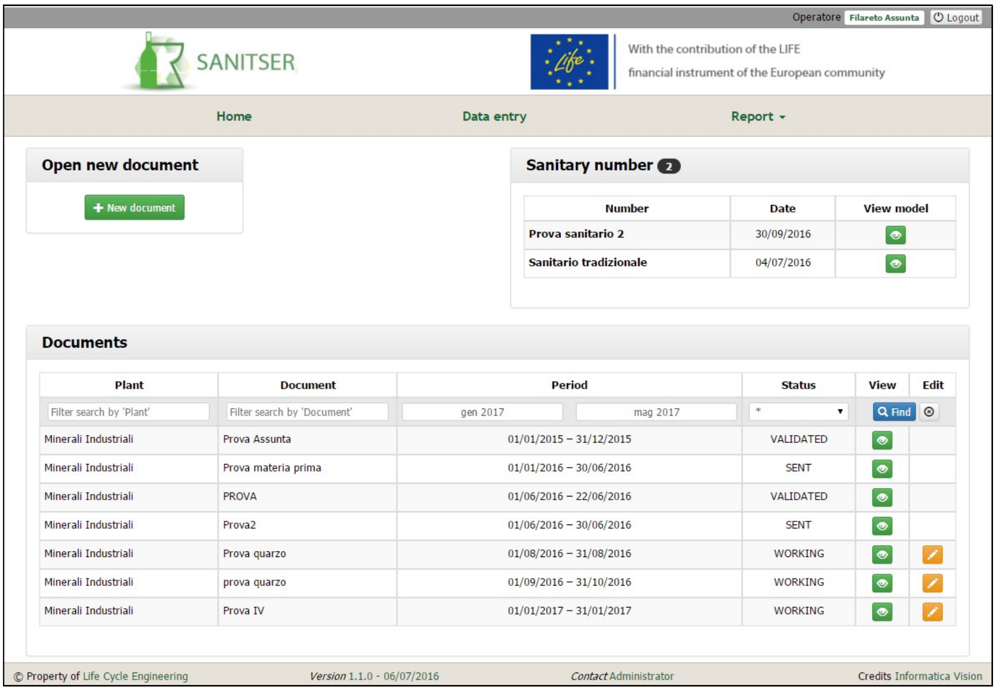


Figure 8 Questionnaire management for plant user



D. TOOL RELEASE ON www.sanitser-tool.eu

The web-tool was presented to all the partners during the consortium meeting held on 24th October 2016 in Civita Castellana and subsequently a delivery kit was released, containing the following documents:

- Tool release receipt, with the list of the documents contained in the delivery kit
- User manual, containing a general description of the tool and a specific description of each users 'functionalities (20161125 SANITSER TOOL user manual)
- User license, regulating data management, privacy, web hosting and security services.
- Excel file, for the collection of any observations/bugs coming out during its use (Mod21_SEGNTOOL_Sanitser)

- *Progress and results achieved*

The most important result of this LCA application is the availability of four detailed analogical models describing the considered systems: traditional system, pilot system (B6), pre-industrial system (B7), industrial system (B8).

All direct and indirect results achieved by the project and calculated by LCA application are reported in the following table.

Expected results	Actual (reached) results
Direct results	
Reduction of energy consumption thanks to the lower firing temperatures (-100/110°C) and 20% and to shorter soaking times.	Thanks to SANITSER process, energy consumption for 1 tonne sanitary ware production (excluding slip and glaze preparation) decreases of about 11% respect to the traditional process.

	The decrease is mainly due to a reduction of gas consumption for firing (-18%) and of electricity consumption (-11%) used all over the process for products and materials handling.
Valorisation of waste as secondary material and replacement of virgin raw materials (up to 40-50% in some cases).	Considering the final sanitary ware product, the contribution of secondary materials to the dry composition reaches 41% (8% from post- consumer and 33% from pre-consumer). This means that primary raw materials consumption of ceramic sector might be strongly reduced with the adoption of the new compositions.
Indirect results	
Reduction of maintenance costs	Maintenance and operative costs might be reduced thanks to the following issues: • Energy saving during sanitary ware production process (especially during firing process) • Higher quality waste (e.g. the absence of crystalline silica from the slip might decrease the level of risk of some waste, which might become non-hazardous, thus being recovered) • Minor quantity of waste to disposal • Longer machineries working life, thanks to a minor stress during the firing process Further considerations related to this issue are addressed in one of the deliverables of action C3 (Report on socio-economic impacts of the project).
Reduction of CO2 emissions in the atmosphere.	Energy saving related to the firing process generates an important benefit, other than reducing the primary energy need: the total CO2eq emission is lower for innovative industrial (B8) production, by 18%. This means a reduction of 19 $kgCO_{2eq}$ per ton of produced sanitary ware.
Raw material supply from long distance transport.	The use of secondary materials in glaze and slip compositions produced in Italy leads to reduce the distance covered for supplying raw materials to manufacturing sites of about 45% respect the traditional process. This reduction in distances leads to a reduction in sanitary ware transport environmental impacts.
Reduction of process waste per kg of product; Increasing of the production efficiency.	The implementation of the innovative SANITSER technology leads to a higher energy and material conversion efficiency. This is particularly true for the sanitary ware manufacturing stage, for whom it is possible to achieve the goal of a lower amount of waste generated. Due to the higher mechanical resistance of SANITSER 13 slip (both unfired and fired), which can reduce the number of broken products, a waste reduction of 2% was foreseen for the operations of sanitary ware production.

Design of a web – based tool

Although not foreseen, a web-based tool was implemented after the positive feedback of our monitor upon our suggestion to do so. The tool was used to collect data especially related to the innovative raw materials production, as well as to share environmental information among partners about materials and processes. It gave the possibility to calculate environmental performances of different process and compare results among the same product group in real time.

At present, the tool is employed by project partners only but it could be opened and shared with other interested stakeholder; to this aim among the afterlife activities a presentation of the tool with a specific training session is foreseen.

- *Deliverables and annexes*

- Analysis TEA for Sanitser (ITA) (Annex 7 MR).
- Life Cycle Assessment report (Annex 11 FR)
- Draft of an Environmental Product Declaration according to ISO 14025 (Annex 12 Final Report)
- Sanitser tool - Technical document and User's manual (Annex 13 Final Report)

4.1.12 C3 Assessment of socio-economic impacts

Foreseen and actual timing: 01/01/2015 – 30/03/2017

- *Activities performed and problems incurred*

The aim of C3 action is to evaluate the socio-economic impacts generated from SANITSER system compared to the traditional one. The Social LCA and the Life Cycle Costing were carried out by means of different methods, thus will be presented separately.

SOCIAL LIFE CYCLE ASSESSMENT

S-LCA is still at its younger stage of development, thus a standardized and internationally accepted methodology has not been defined yet. For this reason, LCE was firstly committed to the development of a customised methodological approach and only in a second moment to the actual S-LCA application: these two steps are reported in the two different Deliverables.

First of all, a literature review on existing S-LCA studies and related standards was carried out with detailed analysis of:

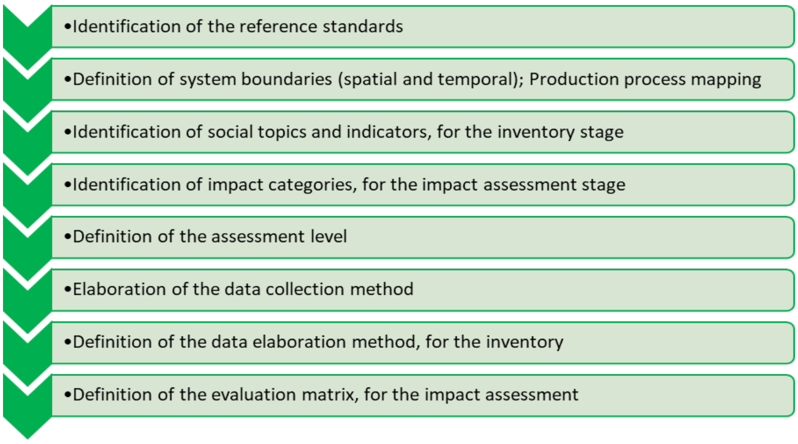
- *Guidelines for Social Life Cycle Assessment of products* provided by UNEP SETAC;
- *Handbook for Product Social Impact Assessment*, version 3.0 (Roundtable for Product Social Metrics 2016);
- an existing analysis of Social impacts from wind power;
- material from various conferences on Social LCA.

During this literature review, sanitary ware production process was analysed also by means of visits to production sites (as previously described for Task C2); a detailed process mapping was done by definition of:

- System boundaries (cradle-to-gate);
- Production stages;
- Temporal boundaries.

Once the process layout was clear, LCE proceeded with the customised methodology elaboration; the main steps are briefly reported in the following figure (for the complete description, please see *Deliverable Evaluation Matrix*).

Figure 1 List of the main steps for the definition of the evaluation matrix



The methodology was developed to be specific for the ceramic sector within Civita Castellana district: for this reason, sector expert' know-how was necessary all over the methodology development and some of the most important decisions were taken together with them:

- Technical meetings (02/04/2015 and 25/01/2016) aimed at deciding the main hypothesis for S-LCA study.
- Meeting with Civita Castellana district on 23/04/2015 aimed at getting in touch with companies involved in sanitary ware production to collect first impressions about socio-economic issues (see: http://www.osservatoriodistretti.org/node/320/distretto-industriale-della-ceramica-di-civita-castellana).
- Periodic skype calls for information exchange on the potential main social aspects of ceramic sector.

The definition of involved stakeholders (workers and local communities) was done with experts, while social topics and indicators were chosen by LCE among the ones suggested by literature based on received information; specific indicators were created following received indications on potential main social aspects of ceramic sectors, particularly related to silicosis diseases. In fact, the easy substitution of traditional recipes with innovative ones requires little modification of the manufacturing process, so that only some potential social impacts are touched by this innovation: LCE and partners had to put lots of efforts in the development of specific indicators, otherwise the literature ones would have not been able to highlight potential benefits generated by SANITSER innovation.

The data collection was organized through Excel questionnaires, prepared by LCE and sent to all chosen addressees by LCE, MI, GEMICA and SE.TE.C.. Since most of the involved actors live and operate in Italy, the chosen language was Italian. Models for subsequent data elaborations were prepared on Excel files, with a preliminary analysis of received data and then the application of the evaluation matrix.

The definition of evaluation matrix (reported below) was done, based on all collected data on social aspects of ceramic sector, by three LCA experts for sake of objectivity: social impacts are more qualitative than quantitative, so all the quantitative analysis is subjected to a high level of subjectivity, which was abated by the continuous interfacing among analysts during methodology elaboration.

Figure 2 The social evaluation matrix

Stakeholder Group	Social Topics	Performance Assessment	Impact Categories						Impact Assessment
			Human Rights	Working Conditions	Health and Safety	Cultural Heritage	Governance	Socio-Economic Repercussions	
Workers	Health and safety	-	0,5	1,0	1,0	0,0	0,5	1,0	-
	Fair salary	-	1,0	0,5	0,0	0,5	1,0	1,0	-
	Social benefits and social security	-	0,5	0,5	0,5	0,5	1,0	1,0	-
	Working hours	-	1,0	1,0	1,0	0,0	0,5	0,5	-
	Equal opportunities and discrimination	-	1,0	1,0	0,0	0,5	1,0	1,0	-
	Freedom of association and collective bargaining	-	1,0	1,0	0,0	0,5	1,0	1,0	-
	Employment relationship	-	1,0	1,0	0,5	0,0	0,5	1,0	-
	Training and formation	-	0,0	0,5	1,0	0,0	0,0	0,0	-
	Job satisfaction and engagement	-	0,5	1,0	0,5	0,0	0,0	0,5	-
	Total Impact category score		-	-	-	-	-	-	-
Local community	Safe and healthy living conditions	-	1,0	0,5	1,0	0,0	1,0	1,0	
	Access to tangible resources	-	0,5	0,0	0,5	0,5	1,0	1,0	
	Local capacity building	-	0,0	0,5	0,5	0,0	1,0	1,0	
	Community engagement	-	0,0	0,0	0,0	0,5	0,0	1,0	
	Local employment	-	0,5	0,5	0,0	0,0	0,0	1,0	
	Total Impact category score		-	-	-	-	-	-	-

The calculation model was finalized (together with Deliverable Evaluation Matrix) only once some filled questionnaires were received and evaluated to understand if the chosen methodology was compliant with received data.

Once the methodology was defined, it was applied to the S-LCA case study.

The analysis was done on both traditional and innovative processes: traditional process was analysed based on real experience of all addressees, while innovative system was analysed based on hypothesis of its effects on stakeholders and on the short production experience during the SANITSER project.

The first step was data collection, a long and iterative process made by LCE in collaboration with partners, which probably was the main obstacle for the assessment development:

- Stakeholder workers: data from partners were received in quite a short time, but those related to primary raw materials production were not received, thus requiring estimations made by LCE and partners' experience;
- Stakeholder local communities: the three actors to whom questionnaires were sent are local health authority (ASL), workers living in the neighbourhood of plants and local community associations. After some contacts, it was clear that the asked information was not available for these actors, being very specific and, in the case of innovative process, related to a hypothetical scenario. For this reason, the survey was mainly based on experts' judgement results of some surveys conducted by ASLs and other literature

All questionnaires were implemented in Excel sheet models, creating a Socioprofile for every stakeholder (a sort of average result of data collection). These Socioprofiles were used in input to the Evaluation Matrix, obtaining the social impact evaluation.

Every part of the social impacts calculation was verified, as well as the entire methodology and the two deliverables: since no benchmark was available for this kind of assessment, the aim of the verification was related to robustness of calculations and data and objectivity of the methodology.

LIFE CYCLE COSTING

The second part of C3 action is aimed at benchmarking the life cycle costing performance of the innovative technology for producing sanitary ware (SANITSER process) versus the traditional one.

The activities were performed using the Life Cycle Costing (LCC) methodology, regulated by the international standard ISO 15686:2008 "Buildings and constructed assets —Service-life planning".

All the activities reported hereafter follow the four development stages in which the LCC analysis was divided: goal and scope definition, LCC methodology definition, LCC Inventory, and final results.

A. GOAL AND SCOPE DEFINITION

The goal of the LCC analysis was to evaluate and compare the economic profitability of traditional sanitary ware production with innovative SANITSER system.

First of all, a detailed literature review was performed to generate a tailor made LCC model, suitable for the analysed systems. Among the others, the following standard and handbooks were considered:

- International Standard Organization (2008). ISO 15686-5:2008 - Buildings and constructed assets -- Service-life planning -- Part 5: Life-cycle costing
- Langdon, (2007). Life cycle costing as a contribution to sustainable construction. Guidance on the use of the LCC Methodology and its application
- Dhillon B.S. (2009) Life Cycle Costing for Engineers. CRC Press
- Farr J.V. (2011) Systems Life Cycle Costing. Economic Analysis, Estimation, and Management. CRC Press.

Then, the sanitary ware process was studied to gain a complete understanding of the differences between the state-of the art and SANITSER production processes. This included:

- The review and detailed study of the project documentation,
- Webinars with Consortium partners, aimed at defining the preliminary assumption for setting the LCCA scope and system boundaries;
- Technical meetings within LCE team, in order to guarantee the consistency of LCA and LCC scope and goal, as well as system boundaries and declared unit.

These activities led to the analysis scope definition, whose main features are presented hereafter.

- **System boundaries**

  The analysis focused on costs occurring during the operating and maintenance activities of a sanitary ware production system, including the following stages:

  - Ceramic slip production (STAGE 1);
  - Glaze production (STAGE 2)
  - Sanitary ware production (STAGE 3).

  In agreement with the Consortium partners, it was decided to focus the analysis exclusively on direct operating and maintenance costs, since these are the only cost categories for which a variation between the traditional and SANITSER process is foreseen. Fixed costs such as capital equipment and decommissioning, indeed, can be assumed equal for both traditional and innovative processes, as SANITSER technology can be adopted even by plants already operating with traditional system, with no need for additional investments.

- **Declared unit**

Consistently with the LCA analysis, the chosen declared unit was 1 ton of sanitary ware, produced either with the traditional or SANITSER process.

B. LCC METHODOLOGY DEFINITION

Cost categories identification

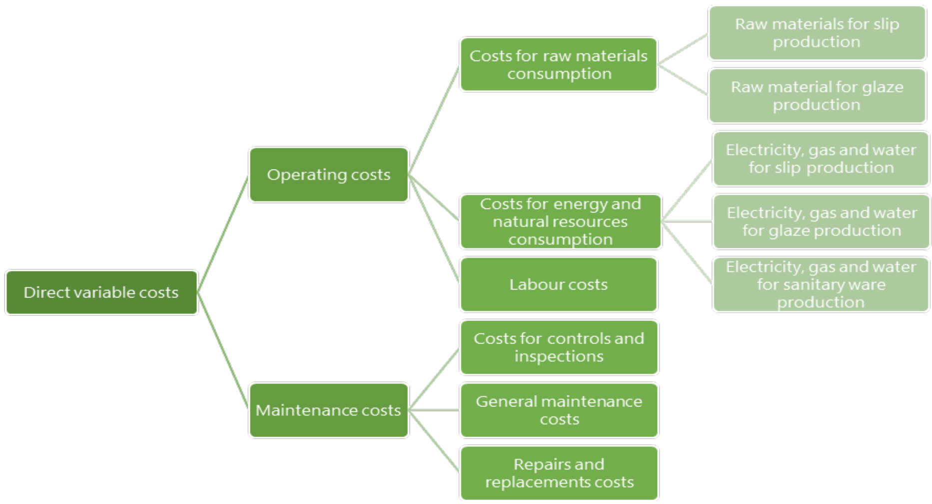
After the identification of the core processes and the definition of declared unit and system boundaries, the cost breakdown structure for the two systems was defined (figure 1).

The determination of costs incurred throughout the sanitary ware manufacturing was achieved by summing all several expenses inherent to three successive production stages (slip production, glaze production, sanitary ware production).

All the costs were aggregated into four main categories:

- Raw material costs, associated with the procurement of disposable raw materials used for slip and glaze production; (STAGE 1 and 2)
- Energy and natural resources costs, related with the amount of electric energy, water and gas consumed by the equipment during slip, glaze and sanitary ware processes respectively (STAGE 1, 2 and 3);
- Labour Costs (STAGE 1, 2 and 3);
- Maintenance costs (STAGE 1, 2 and 3).

Figure 6 – Cost breakdown structure



Discounting and investment appraisal technique

Project costs happening at different points in the life cycle of a system cannot be compared or summed directly, due to the varying time value of money. For this reason, the discounting technique was chosen to adjust future costs flows to their present value.

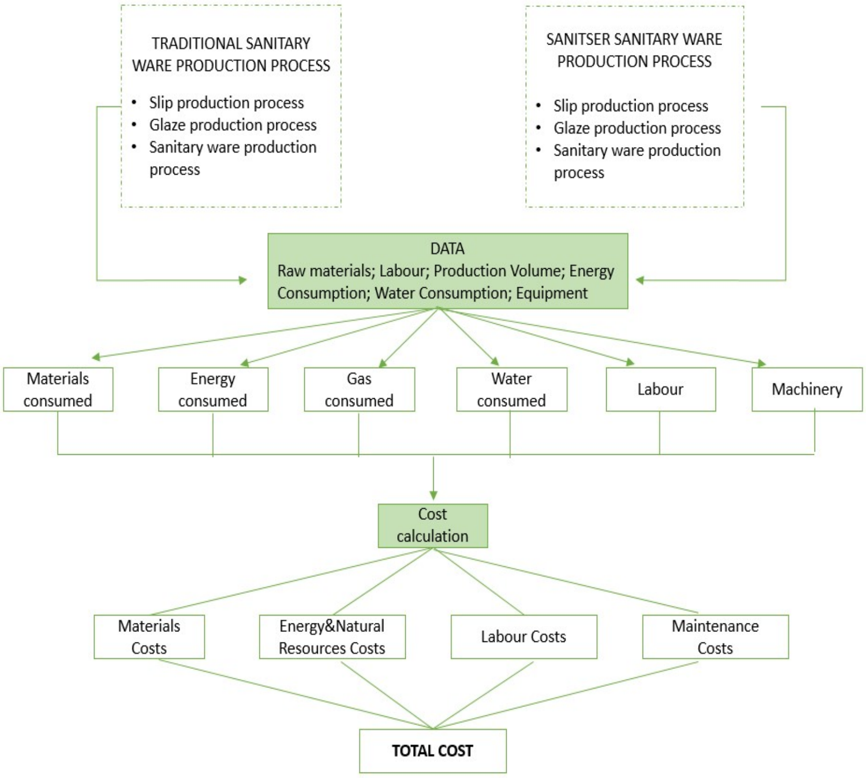
As results of the literature review carried out, it was decided to adopt a discount rate of **4%**, following the suggestions of the Swedish National Agency for Public Procurement's LCC guidance. Energy costs were assumed to remain unchanged. throughout the reference period.

To support eventual investment appraisal, the **Net Present Value** (NPV) approach was used to determine and compare the cost effectiveness of proposed options.

C. LCC INVENTORY

The following figure resumes the main stages required for an LCC analysis.

Figure 7 LCC process



Data collection

Data referred to the three production stages costs (slip, glaze and sanitary ware) were collected by means of a specific questionnaire, prepared by LCE and submitted to all project partners directly involved in the production. The questionnaire focused on the already-mentioned cost categories, and had field for collecting both traditional and SANITSER manufacturing data.

To increase the possibility of obtaining accurate data, guidance for compilation was provided to partners by means of written instructions and remote calls support (performed both before and during various stages of the data collection).

Data collection was carried out as a continuous and iterative process between LCE and Consortium partners, requiring significant time efforts for all the involved actors. To ensure the full reliability and robustness of data collected (and consequently, of the calculation model), further specifications on data collected were asked to partners. A technical meeting by remote was organized with SE.TE.C. to define and validate some assumptions on lacking data regarding SANITSER process.

LCC calculation model

Once collected and validated, data were normalized to the declared unit and then analysed through a specific LCC model. This latter was developed as an Excel spreadsheet, taking as a reference the Swedish National Agency for Public Procurement's LCC tool available on their website: http://www.upphandlingsmyndigheten.se/en/subject-areas/lcc-tools/.

The calculation model was structured so as to allow both cost comparison per declared unit and investment option evaluation covering the entire service life of a plant producing sanitary ware.

The model was changed considerably over time, being subjected to a simplification process which allowed to finally obtain a more user-friendly, replicable tool.

D. FINAL RESULTS

Once calculated, results were analysed to compare the economic performances of the two systems. The interpretation stage was structured in two different phases, presented hereafter.

Cost comparison per declared unit

In the first part, the economic comparison focused on the declared unit. The analysis was conducted without considering the timeframe, so costs occurring on yearly basis were reported to the declared unit by considering the yearly sanitary ware production.

To increase the added value of the study, the cost comparison was enriched by the analysis of contribution margin and break-even point of the two systems.

Total costs over plant service life

Then, the analysis was broadened to the investment appraisal on its entirety, thus considering all operating and maintenance costs occurring over the entire service life of a plant producing sanitary ware. A reference period of 40 years has been considered, representing the average use-life of a sanitary ware production process.

Furthermore, a cost-benefit analysis was performed using the Net Present value technique. To this aim, total costs occurring during the plant life cycle were compared with the expected revenues deriving from the sanitary ware sale.

- *Progress and results achieved*

The table below provides a concise summary of the main LCC and SLCA progress indicators set at the project beginning, the analysis phase to which they pertain, and some information about the current status. Due to some unexpected events and difficulties emerged throughout the project, LCC and SLCA milestones due dates had to be rearranged.

PROGRESS INDICATOR	PERTAINING ANALYSIS PHASE	DUE DATE	STATUS
SOCIAL LIFE CYCLE ASSESSMENT			
Stakeholder, subcategories, and socio-economic indicators definition	Methodology	30/09/2015	Achieved – February 2016
Socio-economic data collection	Assessment	01/01/2016	Achieved – December 2016
S-LCA Calculation model (matrix of evaluation)	Methodology	01/05/2016	Achieved – September 2016
S-LCA results	Assessment	01/06/2016	Achieved – December 2016
S-LCA report verification and final version approval	Assessment	30/08/2016	Achieved – February 2017
Integration with the environmental and economical results	Assessment	31/12/2016	Achieved – February 2017
LIFE CYCLE COSTING			
Case history definition (traditional technology) and equivalent	Goal & Scope Definition	*01/01/2016*	Achieved – February 2016

function system description			
Costs type definition and collection	LCC methodology definition.	*01/05/2016*	Achieved – From November 2016 to February 2017
LCC Calculation model	Inventory	*01/07/2016*	Achieved – February 2017
LCC results and breakeven point definition	Inventory	*30/09/2016*	Achieved -March 2017
LCC report verification and final version approval	Final results	*31/12/2016*	Achieved -March 2017

SOCIAL LIFE CYCLE ASSESSMENT

Most of the social topics were affected by only minor advantages, due to the fact that SANITSER does not change much in the production process and the supply chain is yet subject to EU minimum standards for social aspects, guaranteeing an average good social situation. A significant positive impact was though found related to the Silicosis issue. Silicosis is a form of occupational lung disease occurring after inhalation of crystalline silica dust, potentially present in all production processes involving materials containing silica. SANITSER process demonstrated to strongly cut down the social impact related to this disease due to the strongly reduced % of inhalable crystalline silica in the used materials.

LIFE CYCLE COSTING

The analysis confirmed that the adoption of SANITSER technology allows significant savings in operating costs, mainly due to the lower costs for raw materials and energy requirements. Maintenance costs are supposed to decrease as well, since SANITSER innovative slip and glaze are foreseen by experts to reduce the level of stress on machineries, thus decreasing all costs for maintenance and substitution. However, it was not possible to measure these benefits, since an estimation can occur only after a period of application equal to one year or more, while project production period took only some months.

- *Deliverables*

- S-LCA evaluation matrix, delivered 30/09/2016, Annex 14 FR
- Report on the socio-economic impacts of the project,delivered 30/03/2017, Annex 15 Final Report

3.2 Dissemination actions

3.2.1 Objectives

Dissemination **target groups** were mainly VSW producers from Europe and Third Countries, as well as research centres and industrial associations. Considering the wideness of the partnership involving relevant actors at all the stages of the ceramic production process, the project's audience was built starting from the already existing relations and networks. Other potential target groups were VSW clients and showroom owners, architects and builders interested in sustainable construction industry, local authorities (especially Municipalities), Ecolabel-Ecoaudit Committee at the Italian Ministry of the Environment, Universities, Research's Centres and Academic Institutions, and European Policy makers and experts engaged in ETAP and BREF updating. Particularly relevant could be the role played in providing visibility and spreading the project results to a wider, worldwide audience by the Green Building Council Italia. Confindustria Ceramica and Assomineraria, Italian representative associations of the industrial ceramic producers, chemistry and of the extractive companies respectively as well as ACIMAC (Italian Association Ceramic Machineries and Equipments Producers) were also to play a pivotal role for project results dissemination .

Dissemination and awareness raising activities were to be implemented in a **variety of approaches**, according to the different stakeholders and to their mission. We foresaw dissemination activities for the main national and international sector stakeholders (by presence of the partners in key fairs and conferences) and activities directed towards the general public aimed at demonstrating the relevance of matching better economic performances with environmental sustainability (by Open Days sessions and press). Stakeholders were to be kept continuously updated on the project status of implementation and invited to join seminars and dissemination events. Participation to international conferences, fairs and expos and targeted mailing of brochures and project dissemination tools and scientific publications was also intended to strengthen the impact at EU level.

3.2.2 Dissemination: overview per activity

i. D1 General dissemination

Foreseen timing: 01/07/2013 -31/03/2017
Actual timing: 01/07/2013 -31/03/2017

- *Activities performed and problems incurred*

A **corporate image** was realised by LCE's graphic designer in September 2013, and applied to dissemination materials, website and project documents formats. A A5 4 pages brochure was designed yet in early November 2013, in view of forthcoming first seminar (Annex 9 IR). Thought the project LCE has been taking care of realizing the posters and invitations required in occasion of the project events.

A **Stakeholders Mailing List** has been drawn up since project start and updated in occasion of project events, up to reach 116 contacts in occasion of the final conference. Among them: the end-users involved in the trials and other industry representatives as. Ideal Standard, Pozzi Ginori, Globo, Simas, Villeroy & Boch, etc.; institutional representatives at local, regional and national level (Comune of Civita Castellana, Comune di Gallese, Regione Lazio and National Ministry of Environment); LIFE monitoring and communication teams; Universities (UNIMI, Unimore, UNICAM, Federico II); representative associations and groupings at local national and European level (Centro Ceramica, Confindustria Ceramica, Assomineraria, Ceramie Unie, European Ceramic Society AISBL); related projects (see networking section for references); and the managers of the local schools.

Additional to the mailing list, SE.TE.C. disseminated the project and its events through its LinkedIn Group "Sanitary ware for passion", currently counting 1.036 members. Partners' own corporate websites were also used as multipliers to spread news on key project events. Besides receiving invitations to the events, stakeholders have been kept informed on project progress and achievements through **newsletters**, sent in May 2014, April 2015 and April 2016. The newsletters, drafted both in English and Italian, are available for download in project website and are attached to the present report (Annex 11 MR and Annex 16 FR).

A **half-day seminar** was organised the 4th of December 2013 close to Civita Castellana, anticipating the foreseen planning, as it was considered useful to present the start-up of the project and its first results to potential participants in industrial testing. In the afternoon a visit to Minerali Industriali's plant in Gallese Scalo was organised. Participants represented nearly all Italian producers of sanitaryware and related industries. Besides, project partners saw many of their employees and directors participating, which highly contributed to the promotion of the project amongst stakeholders and to sharing of competences amongst partners' staff (proceedings Annex 10 IR). The event was organised jointly by Minerali Industriali and SE.TE.C. and published at the LIFE website of the Italian Ministry of Environment. A press release was done before and after the meeting, that resulted in **2 articles published** in the "Corriere di Viterbo" on 4th and 7th of December (Annex 10 IR). Proceedings and pictures have been published on http://www.sanitser.eu/en/press.

On 26-28 February 2014 SE.TE.C. has participated in the **expo Indian Ceramics 2014**, where it exposed and disseminated informative materials about the SANITSER project. Indian Ceramics 2014 targets the international ceramic industry, and has presented a wide and broad spectrum of this industry including latest machineries, raw-material and innovative technologies. Pictures are provided in Annex 12 IR. During the fair SE.TE.C. registered distribution of about 50 project brochure and 50 one-to-one contacts.

On 25 September 2014 Minerali Industriali with support and participation of other partners organised the event "Presentation of the project SANITSER" during the **expo Tecnargilla 2014** in Rimini. The event gathered 29 participants. The decision to organize the seminar in the framework of one of the main fairs for the ceramic sector, instead of at partners' premises, was intended to encourage participation and maximize project visibility. The invitation was sent to the stakeholders contact list and published in the website of Italian Ministry of Environment. However, attendance to the event was low, mainly because the hosting entity forgot to include the event in the official program of the Fair (proceedings Annex 10 MR). During the same Fair, the SANITSER project has also been presented at SE.TE.C. stand, which registered about 60 one-to-one contacts and 100 distributed project brochures.

On 20-23 October 2015 SE.TE.C. has attended the **CERAMITEC fair** in Munich, exposing and disseminating informative materials about the SANITSER project. With 600 exhibitors from 37 countries attending the 2015 edition, CERAMITEC represent the main network connecting the entire sector, from manufacturer to suppliers and researchers. Pictures of the stand are provided in Annex 17 FR. During the fair SE.TE.C. stand registered about 70 contacts and 55 project brochure were distributed.

Minerali Industriali participated to the **2nd European Mineralogical Conference**, held in Rimini between the 11th and the 15th of September 2016, where it exposed and disseminated project materials (see picture). About 30 brochures were distributed among interested visitors. At this event Ms Tabacchi met Professor Paris from the University of Camerino, representing the first contact with the LIFE Ecotiles project (see action Networking).

As of open days and presentations targeting the local communities, a number of diverse events were organized with the aim to involve the widest possible audience:

The 10th of December 2015, an educational **presentation** was held at a local technical **high school**, the **ITIS Midossi** of Civita Castellana, reaching about 100 people among students and teachers. In this occasion Daniela Tabacchi (MI) illustrated the glass recovery process, Elisabetta Martini (SE.TE.C.) the preparation of the sanitary ware slip with recovered materials and Ermanno Gagliardi (GEMICA) the glaze production process. The same morning, SE.TE.C. plants remained open for visits of students, citizens and professionals. Despite the Open Day was announced through posters and an article on the local newspaper Corriere di Viterbo (see open days' proceedings Annex 18 FR), no one participated.

The following day, the 11th of December, another **presentation targeting the manufacturers of the ceramic district**, was held. Notwithstanding the choice of the location (a hotel in the centre of Civita Castellana, the Relais Fallisco) and the attention to shape the content of the presentation to the interest of a targeted and quite specific audience, the mid-term seminar did only attracted 11 participants, besides consortium members. Proceedings of both events are attached as annex 19 FR.

Following the encouraging results of the first contact with the local schools and given the difficulties to engage local citizenship in Open Days otherwise, SE.TE.C. decided to organize several **Open Days** dedicated to the high schools students, guiding them around the pilot plant and the laboratory. The following was achieved:

- 12/03/2016: 16 participants from ITIS Midossi (technical institute)
- 07/04/2016 and 11/04/2016: 30 participants in total from ITIS Midossi and Liceo Colasanti
- 23/02/2017: 32 participants from Liceo Scientifico Colasanti
- 03/03/2017: 28 participants from Liceo Classico Colasanti

All the open days were held at SE.TE.C. premises (and not also at Gemica's premises as initially foreseen) as they are the most interesting to visit, providing a wider overview of the production process. Proceedings are provided as annex 18 FR.

A presentation was also organized by Ceramica Scarabeo, one of the VSW producers participating to the industrial trials, at its premises, to present the project to its commercial network. After the presentation, about one hundred informative brochure of the project were distributed. Pics are available in Annex 20 FR.

Two **articles** on the project - jointly draft by SE.TE.C., MI and University of Milano – have been published on the specialized journal Ceramic World Review:

- n° 108/2014 (September 2014) - the first article titled "The use of waste materials in sanitaryware production." presents objectives, expected results and materials used in the project.
- n° 109/2014 (December 2014) - the second article titled "Project SANITSER" includes glass SLG and other recycled materials characterizations.

A third article was accepted for publication on the Journal Cerâmica:

- *01-Mar-2017, Cerâmica Journal, Decision letter relative to our Manuscript (ID CE-2017-0008.R1) entitled "“SANITSER”, AN INNOVATIVE SANITARYWARE BODY, FORMULATED WITH WASTE GLASS AND RECYCLED MATERIALS."*

Articles are bilingual, in Italian and English. They are available for download in the project website homepage and are attached to the present report (Annex 12 MR and Annex 21 FR).

A **closure event** was held the 10th of March 2017 in Civita Castellana, gathering 85 participants in total (71 without counting partners and subcontractors' representatives). To ensure for a significant participation, particular attention was paid to make the event dynamic and attractive. After the introductory remarks of the host (SE.TE.C.) and of the Mayor of Gallese (a nearby city where a Minerali Industriali plant is located), a brief presentation of the achieved results was held, immediately followed by a visit of the pilot plant. For the occasion, the plant was set up with a “guided tour”, with posters realized by LCE to illustrate the different stations, corresponding to the key production phases (raw material processing, body formulation, glazing and firing) and highlighting the environmental benefits brought with the project. Participants then moved to the Hotel Sabina for the networking lunch and the following session on the future perspective on the project, which saw the active participation of the audience that had the opportunity to take the floor to pose questions and discuss longer term perspectives opened with the project (see section 5.5 for a more detailed discussion on this issue). The presentations were held in Italian, with simultaneous translation in English offered to foreign participants by SE.TE.C. commercial staff. Overall, the balance of the event and the feedbacks received are extremely positive. The audience was variegated in terms of origin, both geographically and in terms of target groups represented. Final conference proceedings are provided as annex 22 FR.
The final press conference in Brussels, foreseen to mark project closure, was not held. Indeed, after a first analysis, Minerali Industriali realized that those kind of events are now far less popular than they were when the project was written, because of their past over-use, which led to a visible decrease of interest and impact. It was thus decided not to held the press conference and to opt instead for a e-mail distribution of the project conclusions (i.e. Laymans' report) toward organizations, representative at European level, operating in policy influence and sector representation.

- *Progress and results achieved*

- Corporate image designed in September 2013
- Stakeholders mailing list, updated up to reach 116 contacts
- 3 newsletters, distributed by e-mail and published on project website
- Project brochure, delivered on 08/11/2013 (due at 31/01/2014), printed in 250 copies by Minerali Industriali and 230 copies by SE.TE.C.
- 5 press articles on project events
- 3 Participations to international fairs and 1 presentation to international conference
- 5 open days for schools (106 participants in total) and 1 plant visit during the final conference
- 4 presentations / technical seminars: 1 launch event near Civita Castellana + 1 presentation in the framework of tecnargilla + 1 at the school ITIS Midossi + 1 midterm seminar in Civita Castellana (37 + 29 + 100 + 11 = 177 participants)
- 1 final conference: 71 participants (without counting partners and subcontractors) representating different stakeholders group targeted

- *Deliverables*

- Project Brochure - delivered at 13/11/2013 (due 31/01/2014) (Annex 9 IR)

- Proceedings seminar, including programme, presentations, participants list and press articles - delivered at 09/12/2013 (due 30/06/2015) (Annex 10 IR)
- Proceedings 2nd seminar (Tecnargilla) including programme, presentations, participant list – delivered at 25/09/2014 (Annex 10 MR).
- Proceedings mid-term presentation seminars in the Civita Castellana district (Annex 19 FR)
- Pictures open day at SE.TE.C. (Annex 18 FR), include press article.
- Proceedings Final Conference (Annex 22 FR)

- *Other Dissemination annexes*

Participation at Indian Ceramic (Annex 12 IR)
Newsletters 1&2 (Annex 11 MR)
Articles on Ceramic World Review (Annex 12 MR)
Newsletter 3 (Annex 16 FR)
Participation at Ceramitech 2015 (Annex 17 FR)
Article Sanitser on the Journal Ceramica (Annex 21 FR)

ii. D2 Mandatory dissemination activities

Foreseen and actial timing: 01/07/2013 -31/03/2017

- *Activities performed and problems incurred*

Considering the fact that LCE was responsible for development of the project's corporate image, it has been decided that it would take as well the responsibility for the design and updating of the website. LCE has specific competences on websites development whilst Minerali Industriali should have used an external society to realize the website because it doesn't have the required skills internally. In this way, all graphic works can be kept in the same hands, improving resources efficiency and quality.

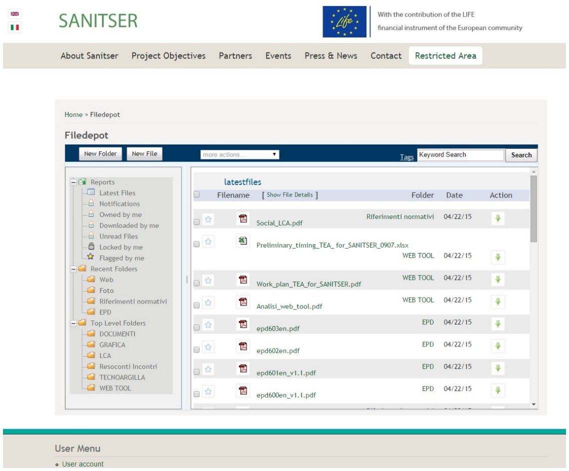
Notice Board
The Notice Board and the logo of the project were realized by LCE and provided to all the partners on 19/09/2013 (Annex 13 IR). Each partners placed the notice board within 30/09/2013.LCE realized also a drop flag in order to have a format easy to transport and so easy to be used. Notice boards were also placed at the premises of the companies participating to pre-industrial and industrial trials: in March 2016 at Scarabeo, Kerasan and Ceramica Amerina and in September of the same year at Ceramica Alice.

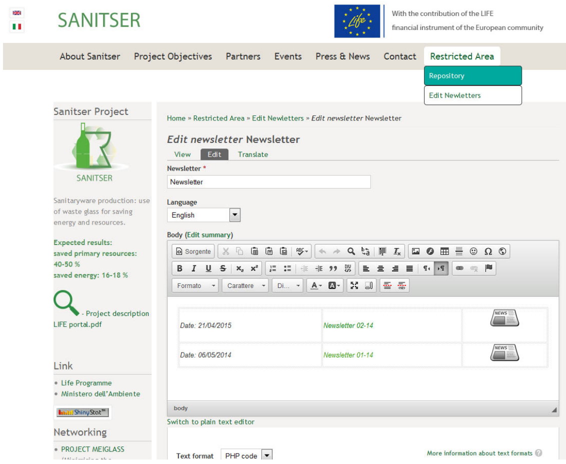
Website
The website was on line on 13/09/2013 at the address http://www.sanitser.eu. The website contents have been completed in October 2013, after which updates have been made. All partners placed a link to the SANITSER website on their institutional sites.
The website is accessible in Italian and in English and, after the last changes implemented by LCE to give more visibility to ongoing activities and impacts, has the following pages: About Sanitser (with a short synthesis of the project and its objectives); Partners (with short description of the partners and links to their websites); Press and Events (with announcements of project events, press articles and other downloadable materials); Results (with updated information on project achievements, including the Layman's report); Newsletters (summarizing project progress in yearly issues); Contact (with telephone, fax and email info@sanitser.eu references, connected to MI's Daniela Tabacchi). The key content is all featured in the home page as be easily accessible. It includes: news, newsletters, articles, link

to the LIFE projects we networked with, link to the LIFE and to the National Environmental ministry website. The acknowledgement of the LIFE programme support is also well visible.
A restricted area was designed and created by LCE in order to support:

- documents sharing among partners, in a dedicated repository
- newsletter creation

Each partner has the possibility to access to this area through his login information; after authentication, he is able to upload and download files in the repository and create newsletters. Figures below represent respectively the "repository" and the "edit newsletter" area.





The number of visitors of the website from its creation to the end of March 2017 is 2.914.
It's worth highlighting that the major number of visits (over 100 visits per month) occurred during specific dissemination events:

- April 2015 (154), after the meeting for networking with Delta srl
- December 2015 (115), after the Conference for the presentation of preliminary SANITSER results and the open day organized in SE.TE.C.
- April 2016 (111), after the project presentation in SCARABEO and other open days organized in SE.TE.C.
- March 2017 (109), thanks to the final conference

Layman's report

LCE coordinated the design and draft of the layman's report, which was ready by early March 2016 as to be printed for the final conference. The report features a total of 20 pages, written in a divulgative style. It is organized around the following sections:

- The sanitary ware production: facts, figures & challenges
- An innovative idea
- The SANITSER project (partners, objectives and the process)
- Project achievements (industrial results and environmental, societal and economic achievements)
- Dissemination and Networking
- Partnerships
- Further information & Contact details

The report has been printed by Minerali Industriali in 50 copies in Italian and 100 copies in English and published on the project website. Further copies were printed by SE.TE.C.

- *Results achieved*

Notice boards placed: 4 within 30/09/2013 (Annex 13 IR)

Web Site on line: 13/09/2013
The average number of monthly visitors of the website remained with 69 far below the goal of 200 monthly.

- *Deliverables*

Layman's report, Annex 23 FR

iii. E6 Networking with other Projects

Foreseen and actual timing: 01/07/2013 -31/03/2017and beyond

- *Activities performed and problems incurred*

The executive project manager Eugenio Salvaia participated to the Kick off meeting of Italian LIFE Projects 2012 on the 8th of November 2013. This represented the first occasion to identify content-related or complementary projects financed under the same call.
Following the event, a first screening of the LIFE project database was conducted, with the aim to indentify other project that could represent any added value to SANITSER, or vice versa. However, since the project was at a very preliminary stage, it was decided to wait to contact other projects as to be able to propose a more concrete exchange.

In April 2014 a second thorough inventory has been performed on the LIFE database. It still resulted that most of projects concerned with ceramics and glazes are related to tiles (CLAYGLASS - LIFE12 ENV/ES/000156 - use of any type of recycled glass; CERAM - LIFE12 ENV/ES/000230 - use of high content of ceramic waste; CERAMGLASS - LIFE11 ENV/ES/000560 - focusing new processing technique with laser; ZEF-tile - LIFE12 ENV/IT/000424 - proposing new firing techniques for NOx reduction), and only one of them, CLAYGLASS, concerned the use of recycled glass. The only project related to sanitaryware, ENVIP - LIFE12 ENV/ES/000598, focused on forming techniques, which is quite a different subject with respect to SANITSER.

Notwithstanding the partially different domains, in May 2014 Minerali Industriali contacted both the CLAYGLASS and the ENVIP projects, with the aim to get a deeper understanding of their activities and goals as to evaluate more properly potential opportunities for cooperation and exchange. However, the two projects did not reply to our e-mails.
At this stage, the inventory of running projects was also enlarged to projects financed under other funding programmes and namely the Eco-innovation Programme. Also in this case, the same difficulties in identifying related projects were encountered. Indeed, the only interesting project identified was ECO/13/630426/WINCER, to which Minerali Industriali participate as partner, which was involved with an exchange of visits (see details in Annex 9 MR and Annex 25 FR). WINCER also contributed to support SANITSER dissemination by linking to its project website from WINCER’s home page.

This led to a further extension of the scope of the search, beyond the ceramic and sanitary ware industries, to encompass other LIFE projects dealing more generally with the circular economy and with the reuse and recycling of various kind of materials. Among these, in March 2015 SANITSER representatives met the LIFE GREEN SINKS project - LIFE12 ENV/IT/000736, whose aim is to manufacture composite sinks made entirely of recovered materials. 2 Green Sinks representatives took also part to the SANITSER final Conference, engaging in a discussion on possible future cooperation for follow up projects (see details in Annex 9 MR and Annex 25 FR).

Networking opportunities were also sought with the LIFE FRELP project - LIFE12 ENV/IT/000904, which developed innovative technologies for the recycling of end-of-life photovoltaic panels in an economically viable way (see details in Annex 9 MR). In September 2015 Simone Salvetti, from Minerali Industriali, participated to FRELP midterm conference as to take first contacts. However, the early closure of the FRELP project led to the interruption of the relationship.

In September 2015, a new search on the LIFE database was performed, leading to the identification of some interesting projects financed under the 2013 call and namely: LIFE in SustainaBuilding, sustainable recycling in polyvalent use of energy saving building elements, LIFE13 ENV/IT/000535 and; LIFE + DIGITAL LIFE, a novel manufacturing process for photocatalitically activate ceramic tiles by digital printing, LIFE 13 ENV/IT/00140. The latter has been contacted by SE.TE.C. to establish a cooperation on TiO2 applications to ceramic products but the contact did not led to any concrete result or activity. Another potentially interesting project identified, LIFE NanoCeramicCO2 – Climate change prevention by the inclusion of nanoparticles in clays for the reduction of Ceramic Industry CO2 emissions, resulted to be closed in advance upon request of the beneficiaries. Among the new LIFE projects starting in summer 2016, the one offering the best opportunity for a concrete networking is the project LIFE15 CCM IT 000104, ECONOMICK, in which both SE.TE.C. and LCE are involved (respectively as lead partner and associate beneficiary). Therefore, the 24th of November 2016, SE.TE.C. and LCE took the occasion of a SANITSER's partner meeting to present to GEMICA and MI the ECONOMICK project, proposing them to test the SANITSER formulation within the new kiln which will be developed by ECONOMICK, as joint occasion to strengthen end-user engagement and resonance.

New contacts were also taken at the 2nd European Mineralogical Conference, held in Rimini between the 11th and the 15th of September 2016, where the staff of Minerali Industriali met Prof. Paris from the University of Camerino, involved in the LIFE ECOTILES project*, "ECO innovative methodologies for the valorisation of construction and urban waste into high grade TILES"* (LIFE14 ENV/IT/000801). 5 representatives of the LIFE ECOTILES project participated to the SANITSER final conference. Visit which has then been returned by Dr. Martini, who presented the SANITSER project at the conference "Environment and Waste: Innovation, Experiences and opportunities from EU projects", organized the 13rd of May 2017 by the University of Camerino and by Grandinetti srl in the framework of the ECOTILES project in occasion of the 25th anniversary of the LIFE programme.

Finally, the 11th of April 2017, Minerali Industriali and SE.TE.C. srl participated to the event Platform meeting organized by National Contact Point Life (NCP Life) in collaboration with Confindustria Ceramica and Laterizi and Centro Ceramica Bologna, and with the participation of EASME and the LIFE External Monitoring Team (Neemo GEIE-Timesis).
Following a list of LIFE Projects presented:
- **W-LAP** "waste eliminating and water-free new revolutionary technology for surface treatment of marbles, stones and tiles",
- **LIFE ReTSW-SINT** "Recycling of thermal spray waste in sintered products",
- **LIFE ZEF-tile** "Zero Emission Firing strategies for ceramic tiles by oxy-fuel burners and CO2 sequestration with recycling of byproducts",
- **LIFE in SustainaBuilding** "Sustainable recycling in polyvalent use of energy saving buildingelements",
- **LIFE HEROTILE** "High Energy savings in building cooling by ROof TILEs shape optimization toward a better above sheathing ventilation",
- **SILIFE** "production of quartz powders with reduced crystalline silica toxicity",

- **ECO TILES** “ECO innovative methodologies for the valorisation of construction and urban waste into high grade TILES”,
- **LIFE ECLAT** “New model of circular economy that also predisposes the use of waste materials in other industries”
- **WINCER** “Waste synergy in the production of INnovative CERamic tiles”, financed by CIP Eco-Innovation

- *Progress and achieved results*

- 5+ operational links established on ceramic and glass recycling related topics with other projects
- 9 LIFE/ECO-INNOVATION projects representatives taking active part to the SANITSER final conference and 2 paying a visits to the project partners in occasion of a dedicated networking event.
- 5 SANITSER project representatives taking part in dissemination events and meetings of other projects (3 of which after project closure).
- Networking reports
- Final networking list
- Indirect impacts of networking contacts on project development

- *SE.TE.C.Deliverables*

Networking report, delivered September 2015 (Annex 9 MR)
Networking report update, May 2017 (Annex 25 FR)

iv. E7 After-LIFE Communication Plan

Planned timing: 01/01/2017-31/03/2017
Actual timing: 24/11/2016-15/07/2017

- *Activities performed*

During the Management Board meeting of November 2016 the structure and object of the After-LIFE Communication Plan was shared amongst the partners, and the closure event formed a good occasion to discuss existing plans. The plan has been detailed with budgets and completed with the first section (overview of the project’s objectives, methodology and results, long-term benefits and sustainability of outcomes, transferability and replication potential and relevance to environmental policy and legislation) after completion of most part of the Final Report to assure coherence.

- *Deliverables*

After-LIFE Communication Plan, delivered 15/07/2017 (Annex 26 FR)

3.3 Gantt chart

Action short name		2013		2014				2015				2016				2017	
		III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II
Overall Project Schedule	Proposed																
	Actual				X						X						X
B1. Pilot plant for waste SLG preparation	Proposed																
	Actual	X	X	X	X	X	X	X	X	X	X	X				X	
B2: Slip-rheology adjustment strategy	Proposed																
	Actual	X	X	X	X												
B3 Glaze composition revision	Proposed																
	Actual	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
B4 Pilot plant for glaze preparation	Proposed																
	Actual	X	X	X	X	X	X					X	X				
B5 Pilot VSW production plant	Proposed																
	Actual	X	X	X	X	X	X	X	X								
B6 Assessment of the physical properties of large final ceramic bodies	Proposed																
	Actual				X	X	X	X	X	X							
B7 Pre-industrial tests cycles	Proposed																
	Actual										X	X	X	X			
B8 Final industrial production tests	Proposed																
	Actual												X	X	X		
B9 Design industrial VSW plant	Proposed																
	Actual													X	X	X	
C1 Determination the time-temperature-composition parameters	Proposed																
	Actual	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
C2 Monitoring environmental impact: LCA	Proposed																
	Actual	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
C.3 Assessment of socio-economic impacts	Proposed																
	Actual							X	X	X	X	X	X	X	X	X	
D1 General Dissemination	Proposed																
	Actual	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
D2 Mandatory dissemination activities	Proposed																
	Actual	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
E1-E4 Project management by MI / SE.TE.C. / GEMICA/LCE	Proposed																
	Actual	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
E5 Monitoring and evaluation of results	Proposed																
	Actual	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
E6 Networking with other projects	Proposed																
	Actual	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
E7 After-LIFE communication plan	Proposed																
	Actual															X	
E8 Audit	Proposed																
	Actual																X

3.4 Analysis of long-term benefits

Direct environmental benefits and relevance for environmentally significant issues and policy areas

As outlined in the project proposal, expected environmental benefits during project realization included: 120 ton of primary raw materials (feldspar, quartz) to be saved and the same amount of SLG waste recycled; 9500 Sm3 of gas to be saved with related CO2 reduction of 1,3 t, excluding the not estimable performances obtained by avoided transport of primary resources. The achievements were assessed with a LCA.

A) Recycled material

Considering pilot (B6), pre-industrial (B7) and industrial (B8) production phases, the number of produced articles is 2.081, of which 2060 of good quality. Total primary resources employed, except from water, amounted to 36,35 tons, of which 14.8 were constituted by recycled materials: 44% of the VSW body and 19% of the enamels, for an average of 41%.

The total amounts are much lower than expected (as explained in previous paragraphs), due to the following:

- involved companies were much smaller than those that were originally expected to participate, leading to a much lower (pre-)industrial production (220 instead of 270 in action B7 and 1.761 instead of 3.800-4.000 in action B8).
- the produced pieces were on average smaller than hypothised during proposal preparation: the forecasts worked with an average wage per piece of 30 kg, which was not conform reality: average was 25 kg in action B6, 22 kg in action B7 and only 13 kg in action B8. The smaller size of the chosen articles in action B8 permitted the producers to make a higher number of pieces, offering the wished variety needed for the assessments without employing too much resources.

Nonetheless, the amounts produced permitted the fine-tuning of lab results at the level of an industrial scale application, and the full validation of the feasibility to use the SANITSER 13 formula in industrial environment, which was the primary goal of performing the upscaling. From now on, all companies producing VSW are able to replace 41% of their primary resources - besides feldspar also quartz! - with recycled waste without renouncing to the quality or aesthetics of their products. The recycled waste used consists for about 20% of post-consumer waste and 80% of pre-consumer waste.

B) Firing: saved energy

The most important benefit generated by SANITSER process is the energy consumption reduction in the firing stage. Pieces were fired at a temperature of 1150-1170°C instead of the 1250°C required for traditional formulations, 14,5% lower. This brought to a decrease in methane consumption of 18%, impacting on total energy consumption with a saving of 11%. Compared to traditional system natural gas consumption, the amount of saved natural gas per each produced ton of sanitary ware is equal to 70 m^3, corresponding to 1.5 m^3 saved for an average article weighting 22 kg. This saving generated a total saving of natural gas equal to 2.044 m^3 all over the three production phases of the project. This amount is lower than was foreseen in the proposal due to the reduction in produced amounts of VSW.

C) Firing: avoided emissions

The energy saving over the firing process generates an important benefit, other than reducing the primary energy need: the total CO_{2eq} emission of SANITSER industrial VSW production is 18% lower than conventional production. This means a reduction of 188 kgCO_{2eq} per ton of produced sanitary ware, and 4.1 kgCO_{2eq} avoided per each article of average weight (22 kg). For the overall sanitary ware production during the SANITSER project, the reduction of GWP emission related to firing process is equal to 5.5 ton CO_{2eq} and would have been equal to 16.4 ton CO_{2eq} in case of realization of all the 4330 pieces foreseen.

This is exponentially higher than was foreseen in the proposal, mainly due to errors in the calculation methods.

EU relevance

SANITSER achievements are important for the implementation of EU environmental policies set up in the 6th and 7th Environmental Action Plans, as well as of great relevance for the implementation of circular economy principles in the sanitary ware industry and of the Roadmap for a Resource-Efficient Europe.

Specifically, the project contributed to the following environmental objectives and priorities:
1. Improved management of waste materials (recycling, minimization of waste for disposal);
2. Savings on raw materials (re-entering a waste material into the production process);
3. Improved energy efficiency and consequent reduction in CO2 emissions (the possibility to fire ceramics at a significantly lower temperature thanks to the re-entry of waste glass into the production process);
4. Reduction in the energy consumption for transportation of raw materials actually bought on external markets (mainly Turkey) and consequent reduction of CO2 emissions.

The results achieved can be taken into account in the update of the Ceramic BREF that is foreseen for the current year. To this end they have been shared with CERAME UNIE, the European Ceramic Industry Association involved in this exercise. The BREF has gained more importance as it becomes, with the IED Directive, the legal base for the factory permits in the EU.

In SANITSER was demonstrated that the joint efforts of material suppliers and ceramic VSW producers in a single value chain characterized by a strong focus on sustainability is able to produce significant results in the improvement of the environmental footprint of VSW production while at the same time providing the opportunity to lower significantly production costs. Herewith it can be considered an excellent example of how to merge European targets on sustainability and competitiveness.

Long-term benefits and sustainability

a) Environmental. The project will significantly improve the environmental footprint of Vitreous Sanitary Ware production. Considering a current production of about 50 million pieces of Vitreous Sanitary Ware in Europe and Turkey annually, to which the technology could be applied in the future, the following very considerable impacts on Europe and Turkey's environment can potentially be envisaged:

- Reduction in methane consumption of 77 million m3 (18% of 428 million m3)
- Reduction in CO2 emissions due to the lower methane consumption of 206.8 million kgCO2eq (18% of 1.149 million kgCO2eq)
- Reduction in the use of primary raw materials of 557.169 ton (41% of 1.361.722 of dry material consumption). This includes the total elimination of primary Quartz and Feldspar from the slip (was ca. 46,5%).
- Employment of glassy waste that cannot be employed by the glass industry: about 442.127 ton of pre-consumer waste (80%) and 115.042 ton of post-consumer waste (20%).

An additional environmental asset is provided by the successful tests with glazes enriched with TiO_2, that provides the pieces with a high anti-bacterial and air-cleaning action, reducing the use of water and domestic cleaning agents (both the natural and synthetic ones) by households.

b) Economic. For several reasons, the proposed innovation is expected to boost competitiveness of the European VSW sector:

- Firstly, by making use of SLG waste, raw materials cost for sanitary ware industries are reduced by around 15%, with further possible cost savings related to lower distances for materials transportation. Moreover, the proposed technology limits significantly production costs of VSW by reduction energy consumption for the VSW firing process: the operative energy cost reduction has been estimated equal to 9.8%. Due to the easy applicability of SANITSER innovative process, maintenance and labour costs are unvaried, although the kiln operation at lower temperatures is expected to improve its lifetime and reduce maintenance.
- Secondly, SANITSER technology permits the production of higher quality VSW thanks to: a) more performing new materials developed by the introduction of SLG, b) more attention paid to critical process segments exploiting the time spared because of a contraction of soaking time.
- Thirdly, the improved environmental footprint will have a positive impact from a marketing point of view because the new sanitary ware products can comply with LEED specification (Leadership in Energy and Environmental Design points 4.1 and 4.2 “Recycled material content”). The availability of easy access to an Environmental Product Declaration (EPD) for environmental communication purposes, provided by the works of our partner LCE, will furthermore allow companies to strengthen this competitive advantage.

c) Social. It is likely that local populations will not immediately realize the positive impact SANITSER activities may provide, apart from employment chances. However, in the mid-long-term the mentioned environmental benefits will become apparent. Workers of sanitary ware plants and of companies producing materials for sanitary ware instead will have immediate awareness of the benefits of the strong reduction of Silica exposure, which will lead (as long-term benefit) to a lower number of Silicosis cases: this was confirmed by results of Social – LCA, which highlighted a lower impact value for the stakeholder workers thanks to Sanitser application.

The precise calculation of this unforeseen benefit requires future more in-depth analyses: for the moment we can evince that the amount of inhalable crystalline silica, the origin of this disease, is present in quartz for about 13% of its weight, due to which it is qualified as hazardous material (qualified as STOT RE 1). Ordinary VSW contains about 27-28% of quartz. Instead, of the recycled materials used in SANITSER 13 only one product, employed for a large percentage in SANITSER 13 slip, contains this inhalable compound at only 2,18 %, (qualified as STOT RE 1). This implies that the amount of inhalable crystalline silica in the raw materials for VSW production can be reduced with about 84% !

d) Continuation of project actions

The technical and monitoring project activities do not need to be continued now the project is completed as the achieved results are very satisfying. Partners will now concentrate on future industrialisation and commercialisation of the achievements. LCE will keep the website maintained until 5 years after the end of the project and will provide the necessary maintenance to the web tool (web hosting, server, security certificate, etc).

Replicability, demonstration, transferability, cooperation

The following initiatives are planned to assure future **replication** of the achievements:

Minerali Industriali will start with the design of an industrial line for the milling of waste soda lime glass and treatment and milling of ‘special glass’ (fiber glass, boron-glass and barium glass) for large introduction into VSW production. Such a line will probably be realized in the North of Italy, in Cacciano Minerali Industriali's plant, near to the plants where SLG, pitcher and F60P are actually produced. Plans for replication in Egypt, Messico, Bulgary and Czech Republic are being assessed, all places where MI has mineral treatment plants and VSW districts. The plant should be able to work in continuous and have a capacity of several tons per hour, to be established as a function of the expectable market share which differ from location to location.

SE.TE.C. will promote the new formulation and dedicated plant design amongst its customers by instruction of sales staff, update of its catalogue and participation to fairs. As soon as clients have been found the plant design will be customised to scale and specific needs. The dedicated plant will amplify the results achieved in the project in terms of energy consumption and permit a reduction in building costs due to reduced temperature of the kiln that require less advanced heaters, while materials are expected to have a longer lifetime.

SETEC will also start sales of the SANITSER 13 formulation to customers and intends to develop similar formulations in forthcoming years tailored to its clients.

GEMICA, with the experience gained by SANITSER, will be able to define an industrial process for the production of flexible engobes and glazes, suitable for VSW ceramics containing glass cullet. The development of such full range of glazing and decorating materials will meet the new needs expressed by the end-user ceramic industries. The productive capacity of this new production line will be defined on the basis of the acquired requests of VSW producers.

LCE is available to support and provide specific technical assistance to any companies interested in the development and publication of a verified Environmental Product Declaration (EPD) for communication purposes. During the last phase of the project, some companies (Kerasan and Scarabeo) asked for additional details how to draft and publish an EPD, showing a clear interest to innovative tools for environmental communication and green marketing initiatives.
LCE will also provide technical support in case any interested stakeholder would like to access the web tool for environmental performance evaluation purposes, guiding them in using the tool and analyzing results. The tool provides a user-friendly platform to simulate the environmental impact of a Sanitary ware product, per production stage, with different slip and glaze compositions and energy consumption values. This kind of evaluation could be useful for research and development purposes, for assessing the environmental performances of new products, or even for production process analysis, with the individuation of environmental hotspots.

Several **Transferability** opportunities have emerged that are currently subject to feasibility assessments:
An unexpected application of SANITSER 13 emerged during project implementation. SE.TE.C. sent some samples of the material to a company producing ornamental articles for graveyards, that produces China and Vitreous China products. The first are fired at 1165°C, the latter at the usual 1230 °C. It would be highly convenient for the company if it could fire all its products at the lower temperature to be able to merge production processes. It used our SANITSER 13 in the production of about 100 items (small jars and plates, candleholders) of Vitreous China, firing it at only 1165 °C. Results were positive, no deformations or cracks were registered (items are of small dimension). They thus show great interest toward implementing our formulation in the near future, which would enlarge the application field of SANITSER technology to a first not VSW ceramic field.

SE.TE.C. is also evaluating the opportunity to apply the knowledge acquired through the Sanitser project in valorisation of basalt powders, produced as mining waste materials. The knowledge is also used to study the use of new recovered waste materials in ceramic slips, glass spheres, pumice, insulating ceramic refractories, etc..

SETEC and MI are assessing the transferability of results to ceramic fire clay and vitreous ceramic slips with low silica concentration, used for casting of big pieces, like shower trays and washbasins, ceramic panels for stoves and dishes. These ceramics, as in the SANITSER project, could be made from at least 30-40% of recovery materials with low-content of inhalable SiO2, with lower firing temperatures of at least 80-100 °C and a 10% reduction in CO_2 emissions in the entire process .

In both last two cases the knowledge built up would strongly boost a quicker introduction of high amounts of glass waste in the slip, although further study is still required do to the different characteristics of these products and their applications.

Best Practice lessons learned

The application of a thorough Life Cycle Assessment provided the unique opportunity to obtain reliable knowledge on the impacts of the VSW production process, information that is up to now not publically available. This difficulty caused indeed a series of wrong presumptions that were written in the project proposal. A significant part of the production process is still performed manually and producers usually don't calculate the environmental and economic impact of their production modalities. In case some producer is in possession of this kind of data, they are strictly kept for internal use. Indeed, Centro Ceramica Civita Castellana, that represents the operators in this district, was unable to offer significant data to sustain the LCA. The data on standard VSW production will thus be very useful for other kind of innovation related activities, performed by project partners like SETEC, but also by other stakeholders that can be provided with access to the LCA tool.

The development of a complete LCA on sanitary ware product increased LCE's knowledge on the sector, becoming a useful resource for future projects. In particular, LCE already started to exploit the new knowledge within the LIFE project Economick (LIFE15 CCM/IT/000104).

Leading to Social LCA and LCC, LCE recognized the importance of stakeholders' involvement since the very first assessment steps: this is connected to the lack of a standardized methodology for both S-LCA and LCC, thus requiring customized data collection and elaboration to obtain a good quality assessment.

The experiences with local awareness raising activities were of great importance for SETEC and may be useful for other LIFE projects especially those concerning industrial processes. We learned that citizens are not easily made interested in visiting an industrial environment, even if they are invited by depliants and newspaper announcements. Instead, high schools are an excellent vehicle to improve environmental awareness related to industrial production amongst the local population, being highly interested in such topics and able to insert plant visits and presentations in the students' curriculum as long as such events are planned well in advance. Moreover, the activities permitted to increase students' interest in the production of sanitary ware, the biggest economic activity in the Civita Castellana district. This may not only be favourable to their future employment choices but also to the sector's need for qualified labour force.

Innovation and demonstration value

EU funding added value mainly lies in 1) allowing the realization of a project involving representatives of the whole supply chain for the ceramic industry, and 2) strengthening the impact of initiatives to showcase innovations towards stakeholders and target groups, which is expected to boost project long term sustainability and replication of the innovative solution here proposed.

Long term indicators of the project success
Project success is defined for each partner by different performance indicators:
LCE:

- Utilisation of acquired knowledge in one or more new projects in the following 2 years, as evidence of our company's benefit. Technical knowledge on the glass scraps valorisation technology is useful to discuss similar issues in different industrial sectors.
- Incoming number of clarifications about the web tool use and any requests to access platform functionalities by other companies and stakeholder in general, as indicator of the relevance of the performed activity for the sector.

SETEC:

- 2 more intermittent and tunnel furnaces sold every year in the period 2017-2020 specifically for SANITSER slips.
- SANITSER 13 formulation sold to 2 customers every year in the period 2017-2020
- 2 new articles published in International journals between 2017 and 2020 to keep attention o the SANITSER achievements

MI:

- 3 Industrial production plants erased within year 2024, 5 within year 2027
- sold amount of SANITSER mix (SLG+F60P+pitcher) to VSW Italian sector above 1500 ton/year from year 2018 onwards, with the aim to raise the quantity with plant replication abroad.

GEMICA:

- Industrial production line realized within 2019
- sold amount of SANITSER enamels above 300 ton after year 2018