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LIFE13 ENV/IT/000140

LIFE Project Number
LIFE13 ENV/IT/000140

FINAL REPORT
Covering the project activities from 01/07/2014 to 31/12/2017

Reporting Date
15/03/2018

LIFE+ DIGITALIFE
A novel manufacturing process for photocatalytically activate ceramic tiles by digital printing

Project Data

Project location	ITALY – Emilia-Romagna
Project start date:	01/07/2014
Project end date:	31/12/2017
Total Project duration (in months)	42 months
Total budget	€ 2.930.845
Total eligible budget	€ 2.647.139
EU contribution:	€ 1.323.568
(%) of total costs	45.16%
(%) of eligible costs	50%

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Beneficiary Data

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Project Website	http://digitalife.active-ceramic.com/

LIST OF ABBREVIATIONS

PM	Project Manager
TM	Technical Manager
QM	Quality Manager
GF	GranitiFiandre SpA
UMIL	Università degli Studi di Milano
PROJECTA	Projecta Engineering Srl
TiO_2	Titanium dioxide
Active	*Active Clean Air & Antibacterial Ceramic*^{TM}
MRSA	Methicillin-Resistant *Staphylococcus Aureus*
PSB	Project Steering Board
DB	Dissemination Board
IPRs	Intellectual Properties Rights
sqm	square meter

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1. List of contents

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2. Executive Summary

2.1 Brief description of the project aims and results

Environmental purification is a necessary aspect of scientific research to improve human life quality. Studies on the properties of TiO_2 have been known since the 1980s, but only a few years ago, research has turned industrial applications and, therefore, into commercially available products on the market. The action of TiO_2, light (solar or artificial) and humidity, naturally present in the air, is called photocatalysis and is capable of triggering a series of oxidation reactions on the surface of materials where TiO_2 is present, which can destroy polluting molecules, including smells, and have antibacterial action, even against the most dangerous strains. Finally, dirt adheres less tenaciously, allowing cleaning with water and damp detergents.

The research project entitled "A novel manufacturing process for photocatalytically activate ceramic tiles by digital printing" aims to modify the current process of deposition of the photocatalytic titanium dioxide (TiO_2) on the ceramic material. The traditional spraying technology has to be changed with an innovative methodology, which is based on the digital decoration using inks containing micrometric titanium dioxide and additives, necessary in the final process to vitrify the ceramic surface and stabilize the photocatalytic TiO_2 particles.

GranitiFiandre (GF) has developed, over the years, suitable manufacturing techniques that have allowed them to produce, with the designation "Active Clean Air & Antibacterial Ceramic™", an innovative ceramic product fixing on the tiles TiO_2 at high temperature. With the exposure to both natural and artificial light, TiO_2 activates the photocatalysis process, which favors antipollution, antiodor and bactericidal action that characterizes this product for which in April 2014 the European Patent Office has approved the patent EP2443076. GF has already implemented in its productive sites industrially production lines, with the traditional spraying process for deposition of titanium dioxide.

<u>The Life “DIGITALIFE” project confirms the following items:</u>

• A novel system for manufacturing high quality photocatalytically active tiles up to 150x300 cm and different thicknesses is feasible. The new system uses the digital printing technology, where a TiO_2-based ink is directly deposited on the tiles surface highly reducing TiO_2 excess and waste, and drastically reducing energy and water usage. The results on the built prototype equipment confirmed the expected results with an increasing of the photocatalytic efficiency of the produced activated slabs.

• The performances of the tiles produced with the novel process have been validated and assessed with Erythrosine tests and according to the EU and ISO standards (e.g. ISO 10678, ISO 27448-1, ISO 27447, UNI 11484). The photocatalytic performances of the slabs prepared by digital printing are higher than the tiles produced by spray method.

• A novel ink based on water able to provide similar performances to the ones of the currently used solvent-based ink is formulated with a water content of 30%. The presence of water in the ink formulation further strengthens the positive environmental impact of the project, by eliminating petrochemical-based substances.

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• Life Cycle Assessment (LCA) calculations were carried out to assess the environmental impact of all phases of the project: from preparation to the development of components used to produce ink, from "digital printing to the final stage of firing to stabilize TiO_2.
Adjustments have been made at each stage to make the whole product "green" not only because its function will be to reduce pollution in buildings but also for a precise check that every production passage impacts little on the environment. One short example of the LCA conclusions: the carbon footprint of the entire manufacturing process was evaluated and, as expected, has a greater impact on the traditional process than on digital printing processes. The Kg of CO_2eq in the three production processes are respectively: 1.62 kg for digital printing with water-based ink, 1.63 kg for digital printing with solvent ink and 3.42 kg for the traditional process.
• The size of the prototype system is such as to allow the production of about 100 square meters of ceramic slabs per day. It is a small prototype dedicated primarily to the purpose of testing and internal evaluation of the quality of the final product and that allowed in 2017 to build a new industrial plant that produces about 1000 square meters per day of large photocatalytic ceramics.
• Nowadays we are no more talking about tiles, but ceramic slabs and digital technology allows "activating" them in a very flexible way in terms of production of different sizes and thicknesses. During the final industrial validation test, about 1000 sqm tiles were produced from the traditional 30x60 and 60x60 cm to the innovative 150x300 cm and with thicknesses from 6 mm to 20 mm in order to go meet all the needs of architects and designers.

2.2 Environmental and socio-economic benefits

The environmental and socio-economics benefits of the DIGITALIFE project are not changed from the original proposed in the Grant Agreement:
• Availability of cost-effective and sustainable products that improve air quality.
• The demonstration of a technology able to avoid potentially harmful nanometric powders, further pushing the market towards sustainable and safe solutions. In fact, the TiO_2 powder dispersed in the ink is in the micrometric range, in comparison with nanometric powders present in all the photocatalytic products present in the market today [2011, NIOSH, Occupational Exposure to Titanium Dioxide].
• Reduction of the pressure on water resources, with the consequent benefits for citizens and economy.
• Reduction of TiO_2 waste and excess.
• Reduction of energy consumption.
• Stimulating citizens to the adoption of photocatalytic tiles having sound positive anti-bacterial and anti-pollution properties.
• Raising the wide public awareness on sustainable manufacturing solutions.
• A novel ink formulation containing water is the first example of water-based ink usable in industrial heads.
• The photocatalytic properties of the digital printed Active achieved important increases of the efficiency towards the pollutants degradation, due to a more homogeneous dispersion of the TiO_2

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particles at the tiles surface. NOx and several VOCs (toluene, acetone, acetaldehyde, and ethanol) revealed a high efficiency of the ceramic to abate these pollutants. Dedicated measurements were also performed on formaldehyde and on alpha-pinene as reference molecule for odors. The new photocatalytic slabs are active also in water in the degradation of solved pollutants such as drugs.
Moreover, tests performed on several strains of bacteria, the so-called super bug included, highlighted the high efficiency of the digital printed slabs to destroy all kind of tested bacteria.
The self-cleaning action is maintained with an important decrease of the time necessary to degrade the reference molecule for the ISO test, oleic acid, passing from 70 h for the spray-coated tile to 28 h for the new digital printed one.

Thanks to the Digitalife project we have an increase in the interest of the new product with +29.06% of users who visited the web pages dedicated to Digitalife and the prospect of maintaining and progressively increasing the interest of users towards web pages as a vehicle for communication and dissemination of culture and news. Moreover, in the first months of work of the new industrial plant, built with company funds based on Digitalife project research, we observed an increase of + 348% in production and marketing of large Active slabs. The great interest of the stakeholders in the development of the new Active products led to the drafting of several new properties (for a total of over 30,000 square meters in various formats and finishes) and the opening of the health / hospital sector in which the group started to invest by sponsoring a master's degree in hospital planning.
A further possible development of Active coating on large slabs is the furnishing sector. Thanks to the new possibilities, contracts have been possible with both direct customers and third parties for the development and supply of tables with various sizes starting from 100x100 cm slabs, with a perspective of several hundred square meters for 2018 and a more important perspective for the years to follow.

2.3 General comments

The Digitalife project is therefore positively concluded from the technical and scientific point of view and was nominated "Project of the Month" in October 2017 by the Italian Ministry of Environment.
http://www.minambiente.it/notizie/progetto-life-del-mese-di-ottobre-2017-digitalife

For this particular award and in general for the good progress of the project the whole team must publicly thank our external monitor Ing. Mengali for the help and valid suggestions that he gave us during the three years of work.

A new approach to the formulation of water-based inks must not only involve a green-vision of the process to avoid VOC or CO_2 emissions but also better product efficiency and this may be the scientific basis for promoting the production of 2.0 inks, on a tomorrow that must be very close.

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We are still working on new formulations for new types of GF / UMIL inks. The original solvent – based ink, used for the first industrial test, was labelled as 181, while the water-based one was named 257. We are now working on number 304.
The new generation of inks foresees the presence of metals to decorate the surface of the TiO_2 and allows its activity even in the visible light region, mainly with the LED lightning. Moreover, particular metals allow the antibacterial activity even in the dark and this makes the product even more interesting in hospital applications, resting clinics, and so on.
We have received information requests to use the activated slabs in very different sectors such as stables, bovine births or pigsties, in this latter case for the containment of odours, as well as inquiries for the use of photocatalytic ceramic products for the abatement of particular aggressive contaminants indoor.

Indoor pollution remains our main goal and we are becoming the benchmark in the area of photocatalysis as recently quoted on the blog of the Italian Chemical Society that mentioned one of our papers on the contamination of aldehydes inside confined spaces and the possibility of photocatalytic technologies in the actual remediation of contaminated sites.
https://ilblogdellasci.wordpress.com/2017/11/01/strategie-contro-linquinamento-indoor/

However, we cannot forget the excellent performance of the Digitalife slabs in water. A case-by-case trial, just to make sure that the photocatalytic coating did not detach itself even in an insidious environment such as inside the water, has yielded totally unexpected and appreciated results in the field of industrial water purification.
In particular, the possibility of using our photocatalytic ink on other substrates such as glass has turned the attention of some companies specialized in the recovery of water contaminated by industrial dyes.

2.4 Milestones

The following milestones, foreseen in the GA, were achieved:

Milestones	**Action**	**Foreseen date**	**Actual date**
Preparatory phase: successful completion of parameters, measurements and regulations assessments, laboratory tests	A1	31/12/14	28/02/15
Pilot plant design and engineering: the engineering of the pilot plant is completed and it is within the expected requirements and regulations	A2	31/10/14	30/06/16
Realization of the pilot plant: The pilot plant is successfully realized in compliance with European and national regulations	B1	31/08/15	30/04/16
Water-based ink: successful use of the water-based ink	B2	31/12/15	31/03/17

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Prototypes testing and validation	B3	31/12/16	31/05/17
Industrial validation	B4	31/12/16	31/07/17
Life Cycle Assessment	C1	30/04/17	30/06/17
Market analysis completed	C2	30/06/16	31/07/17
Dissemination and communication	D1	30/06/17	31/12/17
After-LIFE Communication Plan realised	D2	31/12/17	31/12/17
Auditing	E1	31/12/17	28/02/18
Networking activities	E2	30/06/17	31/12/17

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2.5 Summary of the chapters present in the present report:

- Ch.1: List of contents

- Ch.2: Executive summary
  A brief summary of the project reports a description of the objectives, key deliverables, outputs and milestones together with a detailed point-by-point summary of the chapters present in the Mid-term report.

- Ch.3: Introduction
  A one-page introduction to the project is reported highlighting objectives, present results and environmental problems that are solved with the Digitalife project.

- Ch.4: Administrative part containing a schematic presentation of the working method, including an overview of project phases, activities per phase and planning as well as a full description of the management system, organigram of the project team and project management structure with indications of the names of the three financial project assistants (one for each partner). Moreover, details about the project management process, the problems encountered, and the communication with the Commission and Monitoring team are also described in this section.

- Ch.5: Technical progress per task
  In this chapter, a full description of the technical progress achieved in each Action were fully reported.
  The present project is composed by 5 main phases, labelled with from the letter A to E, divided in 12 actions. Action by action, a technical report of the main tasks is reported, taking into account the several deliverables prepared on each task.
  At the end of each Action, the “Indicators of progress” is also reported.

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3. Introduction

Air pollution has been one of European Union's main environmental policy concerns since the late 1970s. Despite the efforts to reduce emissions of air pollutants in the EU, air pollution remains the number one environmental cause of death in the EU, still leading to about 400.000 premature deaths each year in the EU due to elevated levels of fine particles and ozone. As secondary organic aerosols represents one of the main particle matter (PM) constituents, the ability to break down its precursors, NOx for example, certainly leads to a reduction of PM concentration in the air.

As reported in 2017 Air Quality in Europe report www.eea.europa.eu/publications/air-qualityin-europe-2017, air pollution continues to have significant impacts on the health of the European population, particularly in urban areas. It also has considerable economic impacts, cutting lives short, increasing medical costs and reducing productivity through working days lost across the economy. Europe's most serious pollutants in terms of harm to human health are PM, NO2 and ground level O3. Air pollution also can damage vegetation and ecosystems. It leads to several important environmental impacts, which affect vegetation and fauna directly, as well as the quality of water and soil, and the ecosystem services they support. The most harmful air pollutants in terms of damage to ecosystems are O3, ammonia (NH3) and nitrogen oxides (NOx). Reported map shows that the stations with concentrations above the annual NOx limit value were widely distributed across Europe in 2015. Air pollution is the single largest environmental health risk in Europe and the disease burden resulting from air pollution is substantial (Lim et al., 2012; WHO, 2014). Heart disease and stroke are the most common reasons for premature death attributable to air pollution and are responsible for 80 % of cases; lung diseases and lung cancer follow (WHO, 2014). In addition to causing premature death, air pollution increases the incidence of a wide range of diseases (e.g. respiratory and cardiovascular diseases and cancer), with both long- and short-term health effects, including at levels below the existing World Health Organization (WHO) guideline values (WHO, 2016a, and references therein). The International Agency for Research on Cancer has classified air pollution in general, as well as PM as a separate component of air pollution mixtures, as carcinogenic (IARC, 2013).

The EU's clean air policy framework sets EU air quality standards, implements the EU's international obligations in the field of air pollution, and integrates environmental protection requirements into other productive sectors. Therefore, environmental purification is a necessary aspect of scientific research to improve human life quality.

In this context, photocatalytic surfaces might play an important role in cleaning both indoor and outdoor environments. Photocatalysis is a chemical reaction mediated by light, humidity and by the so-called photocatalyst and it is important for the oxidation of pollutants, biological toxic agents, and volatile organic molecules. TiO_2 as photocatalyst exhibits high activity and offers an economically and technically practical means to clean air and water. GranitiFiandre (GF), global leader in porcelain gres tiles, developed state-of the art photocatalytic tiles called Active Clean Air & Antibacterial Ceramics™ (hereinafter named Active) able to effectively remove pollutants and volatile organic substances in air and several organic compounds (dyes, drugs) in water, transforming the traditional ceramic in one advanced ecoactive material, able to improve the environment where we live.

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The original Active tiles coating process consisted in spraying a mixture of a commercial titanium dioxide powder (~100 nm), water and silica-based additives over the ceramic surface, and in a firing cycle followed by a brushing step to remove titania particles in excess. Such a process presented several drawbacks: a large consumption of water, energy, and titania. Photocatalytic results are good but an accurate surface characterization revealed a strong inhomogeneity of the TiO2 distribution at the tiles surface.
The DIGITALIFE project is overcoming all these drawbacks by using the digital printing technology, able to coat ceramic slabs (up to 150x300 cm). Active tiles are highly efficient on the degradation of NOx and VOCs molecule confirming the improvement of the air quality in the confined environment where Active is used as coverings or floors.

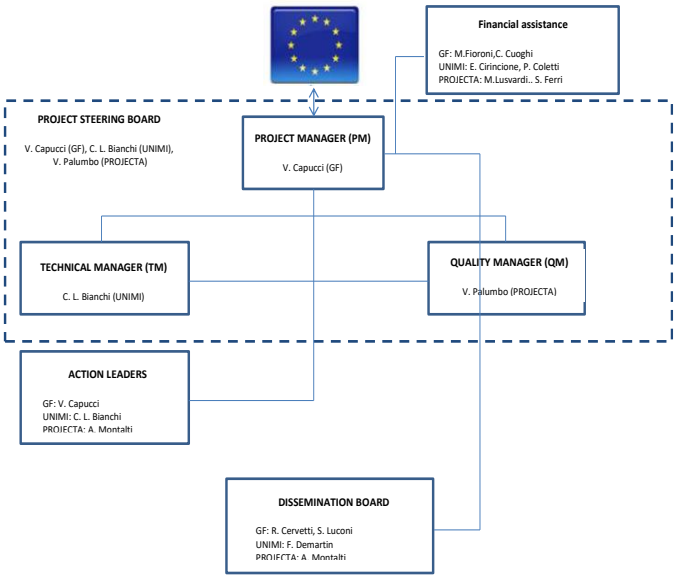
4. Administrative part

4.1 Description of the management system

The project has been developed enhancing an in depth, continuous and previously defined collaboration between every function involved in the project realization.
The DIGITALIFE consortium is composed by GranitiFiandre as Coordinating Beneficiary and by University of Milan and Projecta Engineering as associated beneficiaries.

The overall organisational management structure of the DIGITALIFE Project is shown in the diagram in Fig.1: it is aimed at ensuring the fulfilment of project objectives, by allowing a good communication among beneficiaries and the most valuable and cost effective management of the project. PM, TM and QM are also members of the Project Steering Board (PSB) chaired by the PM. Main task of the PSB is to ensure that project objectives are met in a timely and efficient manner, as well as to ensure that possible problems are discovered early and dealt with in a timely manner.

Fig.1 - Organigram of the project team and Management Structure



A Dissemination Board (DB) is also present and is represented by a representative from each beneficiary. The DB is responsible of the coordination of the dissemination activities in accordance with the dissemination plan that was prepared and released in Sept 2014.
Since the beginning of the project, GranitiFiandre identified a financial project assistant, Dr. M. Fioroni, responsible for managing the financial administration of the overall project expenses,

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reporting the overall budgetary situation of the project to the PM, monitoring cost declarations of the partners and taking appropriate action, if necessary (in consultation with PM), and answering questions from the partners and the EC with respect to administrative/financial matters. However, all partners are responsible for the administration of their own project expenses and each beneficiary identified its own financial assistant: Dr. E. Cirincione for UMIL and Dr. S. Ferri for Projecta.
The overall organizational management structure of the DIGITALIFE Project did not change during the project except for a member of the Board Steering Committee, Eng. V. Palumbo, who has been replaced by Eng. A. Montalti in all his function in February 2017.
Moreover, UMIL financial responsible Dr. E. Cirincione was replaced in all her function by Dr. A. Magrone in July 2016.
The project manager Mr. V. Capucci together with the other two members of the Project Steering Board (PSB) were continuously in contact by Skype calls every week and TM visited at least once a month the factories and laboratories of the other two partners to check the progress of the research on both ink formulation and prototype assembly and installation.

Reports submission: the following reports were sent to the Commission:

- Inception Report (March 2015)
- Midterm Report (February 2016)
- Progress Report (July 2017)
- Final Report (the present document)
- Monthly Reports (sent to the MT every month with a summary of the main activities carried out).

4.2 Evaluation of the management system

Since the starting of the project, the management process has been implemented and continued at a satisfactory level. The Partnership Agreement was definitely signed by all the beneficiaries on January 14, 2015. Each beneficiary has an original copy of the document signed by all beneficiaries. The arrangements contained in the Partnership Agreement have been maintained since its entry into force without any deviations. The Consortium faced different types of issues described in detail in the Chapter 5 of the present report and briefly reassumed here below:

– Some delays in the preparation of the list of equipment and in general materials to buy, which were partly different from the ones listed in the original project budget.
– difficulties in the formulation of the ink due to the presence of the solid particles of TiO_2.
– difficulties in the formulation of the water-based ink due to technical problems connected with the heads compatibility.
– an increase of the total commitment on the project dissemination to enforce the Action D1 in terms of time efforts and quality of the communication.

All of the above-mentioned issues have been promptly analyzed in depth by the PSB. The Coordinating Beneficiary, as responsible for the project management, has been leading all the activities at the technical, financial and administrative levels. All critical issues have been dealt with

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and there have been no effects on the project implementation effectiveness.
Prof. Claudia Bianchi, TM, coordinates the technical management.
For the financial management and tracking of the project, the PM has been strongly supported in these activities by the Financial Manager and his team. The PM accurately controls the financial situation of the Beneficiaries in order to assure that the project's costs are in accordance with the budget foreseen in the GA. A request for budget amendment was prepared and submitted to the EC at the end of September 2015 although it was considered not justified and thus refused by the Commission. This refusal did not however affect the technical project progress. All changes in the budget are analyzed in details in section 6 of the present report.
The reporting of the project development and the financial results has been followed in accordance to the EC and Life+ guidelines. All project costs have been collected and recorded (working hours dedicated to the project, travel and subsistence costs - in cooperation with HR dept., archive of invoices strictly pertinent to the Digitalife Project) – and the budget schedule monthly updated. From the financial side, the PM checks the costs sustained for the Project. Each month all beneficiaries have updated their financial reporting .xls file and uploaded them in the project online repository together with a scanned copy of all accounting documents justifying the declared expenditures.
The PM submitted to the Monitoring Team a monthly report in Italian with a summary of the main activities carried out in each action in the month taken into account.

5. Technical part

5.1 Technical progress, per task

In this part, a short description of the technical progress achieved in each Action is here reported. The DIGITALIFE demonstration project is organized in six different phases, divided in 12 actions, labeled with from the letter A to E. Action by action, a short technical report of the main tasks is reported, with the addition of the explanation of results achieved.

Actions can be divided as:
1) preliminary actions
2) realization of the digital printing pilot
3) novel water-based print heads will be substituted into the system.
4) validation of the new technology
5) assessment of the environmental parameters (LCA) and market studies.
6) the new technology has been disseminated to the project's stakeholders and the wider public.

The list of the deliverables, that mark the end of each action, is here reported:

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Deliverables	Foreseen date	Actual date
A1.1 - Equipment, materials and regulations: details on standards, materials and equipment to buy from suppliers for the project demonstration and testing activities	31/12/14	28/02/15
A1.2 - Laboratory tests: details on the measurements, specifications and standards that will be conducted on preliminary samples	31/12/14	19/12/14
A2.1 - Design and layout of the pilot plant	31/10/14	28/10/14
A2.2 - Engineering of the pilot plant and blueprints: report on the engineering phase. Description of the mechanical properties and workflow of the novel digital printing system	31/10/14	28/10/14
B1.1 - Procurement report	31/08/15	30/09/15
B1.2 - Start-up of the pilot plant, tests and specifications	31/08/15	31/12/15
B1.3 - Pilot plant manual	31/08/15	30/04/16
B2.1 - Water-based ink substitution	31/12/15	31/03/17
B2.2 Testing and fine tuning	31/12/15	
B3.1 - Results of tests	31/12/16	31/05/17
B3.2 – Validation	31/08/16	31/05/17
B4.1 – Industrial validation report	31/12/16	31/09/17
C1.1 – LCA	30/06/17	31/07/17
C2.1 – Market introduction scenarios report	30/06/17	31/07/17
D1.1 – Dissemination Plan	30/09/14	29/09/14
D1.2 - DIGILIFE project website	31/12/14	22/12/14
D1.3 - Mid-term conference	30/06/15	30/09/15
D1.4 - Brochures, newsletters and final poster	30/06/15	30/06/17
D1.5- Publications and conferences	30/06/17	31/12/17
D1.6 - Conferences	30/06/17	
D1.7 – Layman's report	30/06/17	30/06/17
D1.8 – After-Life+ Communication Plan	30/06/17	30/06/17
E1.1 Audit	31/12/17	28/02/18
E2.1 – Networking activities	30/06/17	31/12/17
D1.9 – Final conference	30/06/2017	06/07/17
Analytics Digitalife website		
Analytics Digitalife Facebook		
AWARD -Progetto mese Ottobre 2017		
Answers to EC letters		
Outcomes final tables		
Leaflet Digitalife		
Table 6.5 Financial section		

The actions overview has been reported as follows:

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Action	Target	Achieved results	Indicator of progress
A.1	**Preparatory actions** **Foreseen: 1 July 2014/December 2014** **Actual starting date: 1 July 2014** **Actual end date: end of February 2015**	• Full list of targets, material, equipment and regulations. • Laboratory tests successfully completed. • Measurements on TiO_2 coating homogeneity, surface photocatalytic activity fully respects the requested final values in lab tests. Standards (ISO 10678, ISO 27448-1, ISO 27447) for both air purification and anti-bacterial activity were chosen). A new standard for NO degradation UNI 11484 was chosen to bypass the problems encountered using the ISO 22197-1, as reported in several papers in the literature by C. Minero et al (Int. J. of Chem React. Eng., 11 (2013), DOI: 10.1515/ijcre-2012-0045).	• Report of the results on the pilot plant readiness and preliminary tests at the laboratory level. • Quantity of data coming from tests and trials (see action B.1).
A.2	**Design of the pilot plant** **Foreseen (project document): 1 July 2014/ 31 October 2014** **Actual starting date: 1 July 2014** **Actual end date: 30 June 2016**	- Full design of both the pilot plant and the digital printing machine according to EU and national regulations - Layout of novel digital printing system - Several modifications of the print heads depending on the complexity of the water-based ink formulation.	- Full design of both the pilot plant and the digital printing machine. - Parameters of the plant are all well-defined.
B.1	**Realization of the pilot plant**	• Purchase of all needed equipment, instrumentations and materials,	• Realization of the pilot plant • Start-up of the pilot line

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	Foreseen (project document): 01 November 2014/ 31 August 2015 **Actual starting date: 01 November 2014** **Actual end date: 30 April 2016**	• Assembly of the mechanical parts, programming of control system. • Successful realization and testing of the pilot plant. • Conformity with applicable regulations. • Plant Manual and Safety manual, risk assessment and working procedures of the pilot line following local and EU regulations.	• Performance indicators give expected results: - Processing time and speed: on August 3rd, we produced 900 sqm of photoactive slabs. This has to be compared to the real sized production capacity of 1500 sqm in 8 hours long cycles. - Very homogeneous TiO_2 distribution - Surface completely covered with TiO_2, as homogeneously as possible, using the low amount of TiO_2 so to have a very thin thickness of the photocatalytic layer. The surface homogeneity was checked by HR-SEM - Photocatalytic properties. The new material has better photocatalytic performance than the tiles produced now with the spray technology - Printing quality. It is difficult to give an indicator of the printing quality as no one has never prepared and tested digital inks with photocatalytic properties. An important goal reached is to have obtained the nowadays quality that we have with the digital print using the digital ceramic inks, completely different in composition from the target of our project that is a digital ink with photocatalytic properties.

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			- Manufacturing parameters: the new digital machine operates with a fixed bar of 160 cm equipped with 6 print heads under which the tile flows. Firing cycle: 80 min (cold entrance and cold exit) with max temperature of 680°C.
B.2	**Substitution with water-based ink** **Foreseen (project document): 01 September 2015 - 31 December 2015** **Actual starting date: 01 September 2015** **Actual end date: 31 March 2017**	• Activated slabs can be produced with the new formulation. • Performance and quality testing. • Fine-tuning and optimization of all parameters and specifications for the process and the products. • Identified areas for improvement of design reliability, costs, and feasibility.	• Slabs produced. • Performance tests completed. • Manufacturing and testing cycles completed. • Firing cycle: 80 min (cold entrance and cold exit) with max temperature of 680°C. Photocatalytic properties and printing quality acceptable.
B.3	**Prototype testing and validation** **Foreseen (project document): 01 January 2016 - 31 August 2016** **Actual starting date: 01 January 2016**	• prototype perfectly working • no cracks of the slabs are present • the ink is uniformly distributed	• Production of slabs with no defects in size, color, shape, etc.

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	Actual end date: 30 April 2017		
B.4	**Industrial Validation of the pilot plant and final refinement** **Foreseen (project document): 01 September 2016 - 31 December 2016** **Actual starting date: 01 March 2017** **Actual end date: 31 July 2017**	• Suppliers, industry and relevant stakeholders are actively involved • Final tests give expected results.	• Production of slabs with different sizes and thickness and complete absence of defects in size, color, shape, etc. • good photocatalytic efficiency in all the photocatalytic properties
C.1	**Environment impact assessment of the novel photocatalytic tiles** **Foreseen (project document): 1 July 2014 - 31 April 2017** **Actual starting date: 1 July 2014**	• Comparison of the environmental impact of the three main productions: from the old spray method to the new one with water-based ink. • Final calculations demonstrates the new production is greener. For example, the carbon footprint of the entire manufacturing process was calculated, having a great impact on the processes where a firing step is present. The obtained Kg of CO_2 eq are respectively: 1.62 kg for digital printing with water-based ink, 1.63 kg for digital printing with solvent ink and 3.42kg for the traditional spray process.	• All LCA calculations performed on the three-photocatalytic tiles production systems have allowed, through the iterative method, to optimizing the manufacturing chain. • Production processes, when optimized from the point of view of energy consumption and resources used, have been compared to highlight the differences in environmental impact. • The traditional method has been most impacting in every

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	Actual end date: 31 May 2017		category of calculation considered. • The two digital printing processes are comparable but, definitely, much easier to perform due to the lowest number of steps in manufacturing production. • In addition, considering that the system under investigation is the production of photocatalytic tiles, one of the most interesting results is the lowest NOx value associated with innovative production (digital printing) processes compared to traditional one.
C.2	**Socio-economic impact of the project** **Foreseen (project document): 1 March 2017 - 30 June 2017** **Actual starting date: 1 March 2017** **Foreseen end date: 31 July 2017**	• Increasing interest in the new Active (+29,06% visits in Active website) • Increasing in production and commercialization of big slabs with Active (+348% in first 4 months) • Drafting of at least 4 specifications for big projects with new Active (around 30.000 sqm of tiles to supply) • Opening of new opportunities in socio-medical area (hospitals and care facilities)	• Monitoring Digitalife and Active website (users access and clicking on the pages) • Sponsorship of a master course for professionals in the social and medical field at Milan Polytechnique • Technical dissemination to sales department and support in big projects decisions • Technical dissemination to clients to highlight the advantages of the new product
D.1	**Communication and dissemination of results**	See Section 5.3	- logo and headed notepaper - website - four different notice boards - dissemination through social: LinkedIn and Facebook

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	Foreseen (project document): 1 July 2014 - 30 June 2017 Actual starting date: 1 July 2014 Foreseen end date: 31 December 2017		- mid-term conference on June 4th 2015 - Presentation of project's results to several international conferences and international fairs. - dissemination via media - 10 papers in International Scientific Journal with Impact Factor. - final conference in Milan on July 6th 2017
D.2	**After LIFE+ Communication Plan** **Foreseen (project document) and Actual: 1 July 2017 – 31 December 2017**		
E.1	**Project Management**	See Section 4.2	
E.2	**Networking with other EU projects Foreseen (project document) and Actual: 1 July 2014 / 31 December 2017**	See Section 5.4	We establish three important collaboration with other EU Life funded projects. • PM and TM attended two other Life projects events • Two EU funded project representative attending DIGITALIFE events.

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5.2 A brief summary of the main steps of the project

The prototype was assembled on the production line GF, as per the original design, during the summer stop and routine maintenance of the plants in GF in August 2015. On September 3, 2015 the first tests of the prototype were carried out. Slabs of 150x300 cm were coated with the TiO_2-based ink using the prototype with seven bars containing the print heads.

Fig. 1 - Group photo with present PM and TM as well as managers and technicians involved in the Digitalife project (group GF and Projecta and PhD students UNIMI).

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Fig. 2 - In the picture the detail of a print head bar containing the formulation based on TiO_2

Fig.3 – slabs manual loading

As it is a prototype, the slabs (300 x 150 cm) have been loaded, one by one, thanks to a forklift, on a roller conveyor of the normal production line.
The measurements conducted with the electron microscope HR-SEM of the University of Perugia (Fig. 4) allowed us to verify that the digital printing technique leads to a uniform distribution of the TiO_2 particle on the surface of the ceramic tile.

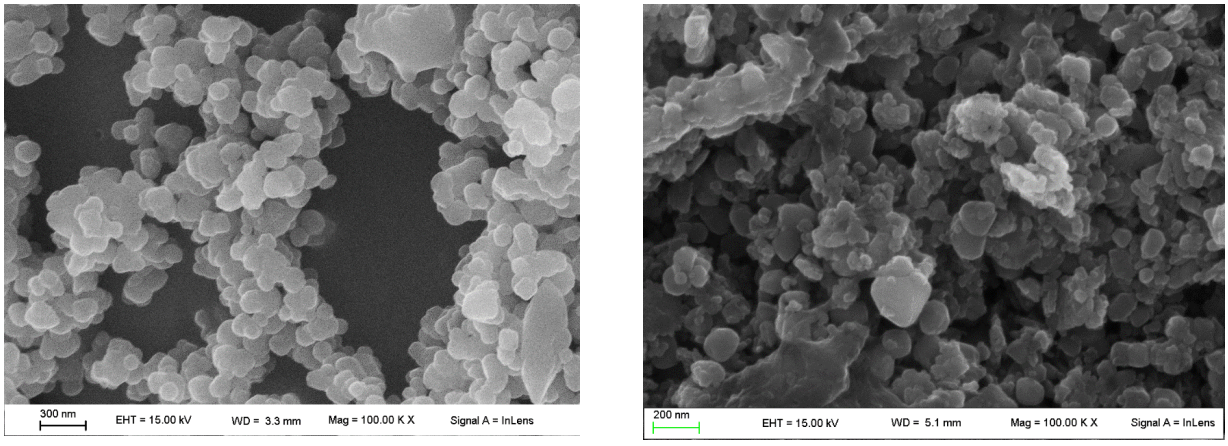

Fig.4 - HR-SEM a 100000X: sprayed product (left), digital printed slab (right)

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Tests were performed in accordance with ISO for verifying photocatalytic activity by degradation of methylene blue (ISO 10678) and of the property of self-cleaning by degradation under UV lamp for 76 hours of a layer of oleic acid placed over the surface of the ceramic material (ISO 27448). In both cases, the material has passed the test being able to boast once again of international certifications.
The data obtained showed higher photocatalytic activity than the samples produced with the old technology spray, probably due to the better uniformity of the titanium dioxide at the surface of the ceramic slabs.
Similarly, the tests conducted by independent laboratory Artest of Modena for the antibacterial action have confirmed the effectiveness of the new digital product against *Escherichia coli* (ISO 27447). In this case, the product prepared with the digital printing prototype obtained even better results compared with the old Active product, with a percentage of bacterial reduction of 99.99% as in the previous preparation, but with a higher ΔR (the photocatalyst antibacterial activity value with UV irradiation, according to ISO 27447 standard).

The first industrial test with the water-based ink was performed on August 2016. The slabs showed a poor homogeneity of the TiO_2 particles distribution on the ceramic surface. This fact brought to an insufficient photocatalytic efficiency of the coated material. Heads had problems of piezoelectricity and this produced ink drops randomly in size and quantity of ink. Moreover, the binder used in assembling the heads had been chemically attached (loose) by the formulation present in the pan.
For this reason, a new formulation of the water-based ink was prepared: Diethylene glycol was completely removed, identified as the component with the highest chemical aggressiveness, as well as other dispersants. Moreover, LCA calculations highlighted the environmental problems due once more to the presence of the glycol.
In March 2017, final tests were carried out to verify the compatibility of the new water ink containing 30% of water from both the rheological point of view of the formulation itself and the mechanical seal of the heads. The industrial validation confirmed the possibility to work with an ink with a partial formulation with water.
We can conclude that at present, technical limits do not allow to avoid completely the use of petroleum-based solvents. Head prints present nowadays on the market have not the necessary features to work with a full water ink.

Many process parameters were tested and verified during the prototype validation and optimization.
Tuned parameters:
- Loading speed of the various slabs, size by size;
- Depending on the firing cycle and the size, the rates of transport and consequently the amount of ink to be deposited on the slabs are determined by varying the surface coverage percentage, (usually working between 50 and 100%), and the size of the droplets in picolitre;
- Brush pressure parameter that cleans the material before being decorated with the digital ink;

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- Product dimensions and thicknesses. The higher the thickness the longer is the firing cycle. In fact, being a vitrified product time may be longer than the firing cycle used to produce the ceramic slabs from the raw materials.
- Constant and repeated checks are carried out on the ink drawing so that some head or parts of the ink may be jammed, creating lines or disparities on the application of digital ink.
- Despite the modern temperature control technology, Seger cones are occasionally introduced into the production baking cycle, which, despite being a technology of the last century, is still today able to determine the actual firing of materials taking into account the two fundamental parameters temperature /time.
- Temperature control in the cooling zone and at the kiln outlet. At this point the amount of titanium dioxide attached to the surface of the materials in a more or less tenacious way is also checked;
- All sizes must run on the rollers as centrally as possible to keep the tiles always towards the centre of the digital machine.

All details about number of produced tiles, tests and results, production tests such as kiln cycle, temperatures, etc. are reported in Deliverable 4.1, in order to have the possibility to link results and production parameters.

Bearing in mind all the above-mentioned parameters, we must not forget that the heads need not exceed the temperature of about 40 ° C in any way. In this regard, the digital machine is in a closed and air conditioned environment.

The final test in GF plant was scheduled for the middle of June to allow the project to be definitively validated from the industrial point of view by operating on traditional and innovative formats:
- Thickness 9 to 10 mm, Formats 60 x 60.cm - 60 x 30 cm – 60 x 120 cm: 1500 sqm produced during the test.
- Thickness of 6 mm sizes 100 x 300 cm and 150 x 300 cm: 2100 sqm produced during the test.
- Thickness 20mm for 60 x 120 cm: 400 sqm produced during the test.

These series of tests allowed the evaluation of the entire process from the heads of the digital printer, the kiln curve, and the final brushing. We carefully checked not to have broken products or with an uneven distribution of ink on the surface.

In addition, the timing required bringing the kiln to the right curve during shaping changes and thickness changes was also evaluated.

In the following some pictures of the produced tiles.

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LIFE13 ENV/IT/000140

30 x 60 cm: 9 mm

60 x 60 cm: 9 mm

60 x 120 cm: 9 mm

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LIFE13 ENV/IT/000140

60 x 120 cm: 20 mm

300 x 100 cm: 6 mm

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300 x 150 cm:6 mm

With this wide variety of sizes, we have verified the cycle and temperature of the kiln with results, technically, very satisfactory.

Based on the amount of produced slabs during the industrial validation test, we optimized the firing kiln cycle reducing the requested time of about 20%. Therefore, it is possible to estimate the possible quantities of slabs activated by digital technology (they are based on the size of the slab that enters the kiln's mouth):

-Size 60x60 cm at 9 mm thickness: estimated production 1700 sqm in 9 hours
-Size 60x120 cm to 20 mm thickness: estimated production 900 sqm in 9 hours
-Size 300x100 cm at 6 mm thickness: estimated production 900 sqm in 9 hours
-Size 300x150 cm to 6 mm thickness: estimated production 1350 sqm in 9 hours

It is very difficult to make a serious comparison between the old production with spray technology and the new digital one. In the latter case, we changed the type of kiln modifying both the length and mainly the entrance size of the kiln. The new firing cycle is reduced of about 20% and this means reducing more or less 20% of the pristine amount of consumed methane per year. Considering a possible annual production of 200000 sqm, this means we economize 100000 cubic meter/y of methane.
Moreover, we have to consider that in the new technology, we removed the dryer, and we are actually economizing another 100000 cubic meter/y methane.
To better represent this saving, 200000 cubic meters of methane is equal to the consumption of about 200 houses of 100 sqm inhabited by families of four people in northern Italy (https://luce-gas.it/faq/costo-consumo-medio-gas-metro-quadro-riscaldamento).

Even in the case of electric energy saving, we can estimate a reduction in consumption of about 15%, because the new application often requires lighter brushing in relation to the type of product surface.

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The photocatalytic characteristics of the products are given here. The table shows average values on tests carried out on almost all the sizes and thicknesses listed above:

	NOx	Ethanol	Oleic acid (self-cleaning ISO27448)	Antibacterial activity (ISO 27447)
Old spray production	56%	20%	70 h	ΔR = 3.3
DIGITALIFE solvent--based ink	91%	100%	28 h	ΔR = 4,0
DIGITALIFE water--based ink	95%	100%	26 h	ΔR = 4,0

A superficial characterization was necessary to understand the further improvement of the measured photocatalytic properties, already increased thanks to the introduction of the digital technique.
The samples were analyzed by HR-SEM electron microscopy at the University of Perugia to verify the surface uniformity of the coating and compare it with the measurements carried out on the samples produced with solvent-based ink.

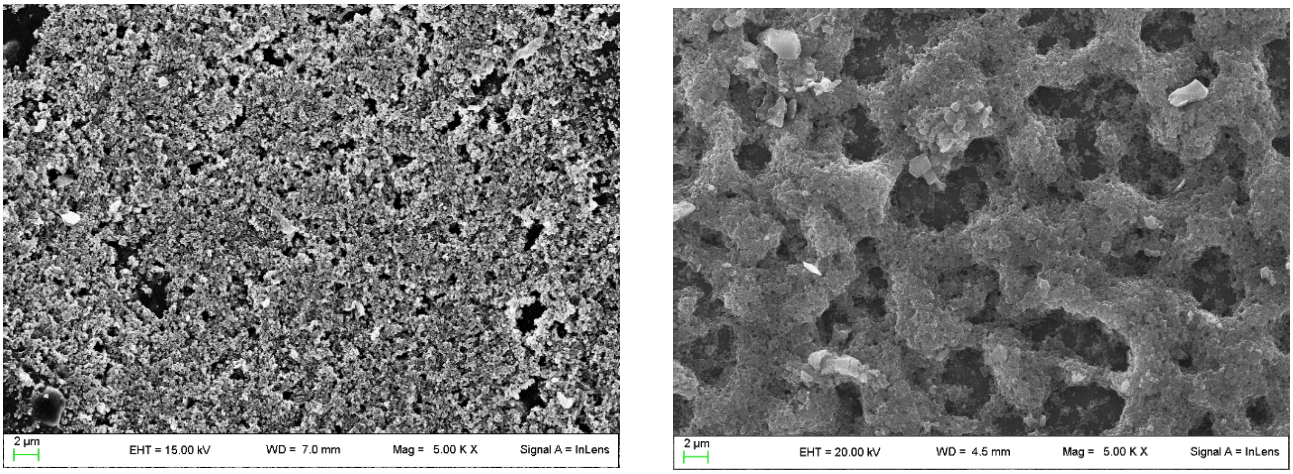

Fig. 5 – surface feature of the different inks: water-based (left picture) and solvent-based (right picture)

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It is possible to observe how the water ink allows a perfect surface uniformity of the particles of TiO_2. In addition, in the photographs at higher magnifications (50kX and 100kX), you can notice the perfectly clean and well-defined photocatalyst particles.

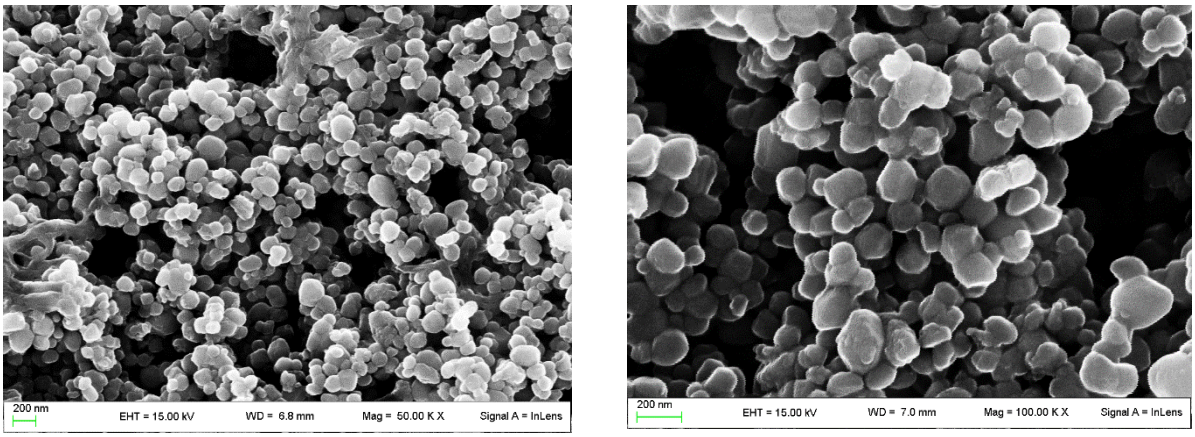

Fig. 6 – samples from water-based ink at two different magnifications (10k and 100kX)

Conversely, the photos, obtained from the characterization of the sample obtained with solvent-based ink, showed a much less homogeneous structure.
There were no longer any voids typical of the surfaces produced with spraying technology, but the sample was still partially uneven with areas with variable TiO_2 thickness

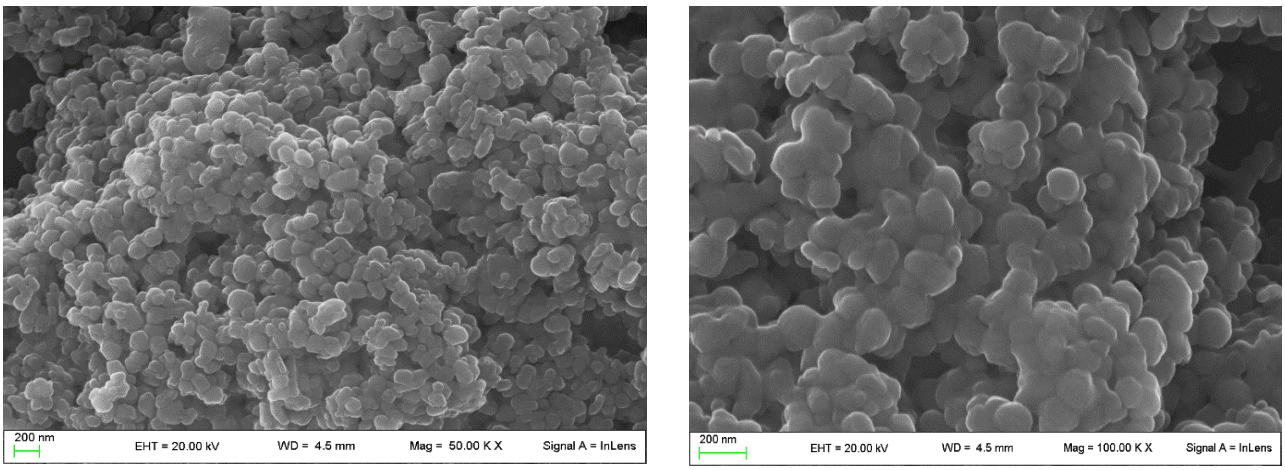

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Fig. 7 – samples from solvent-based ink at two different magnifications (50k and 100kX)

The particles (see magnifications 50kX and 100 kX) were less sharp, as covered by a slight veil, probably due to the formulation of the ink completely solvent, not yet completely degraded.

This slight surface film, impossible to characterize due to the sub-nanometric thickness, could be the cause of the lower efficiency of the samples produced with solvent ink compared to those produced with water ink.

Despite the considerable difficulties in the formulation of water ink and in its use with the heads currently on the market, we can still conclude that water not only benefits from the environmental point of view (see Conclusions of LCA calculations), But also benefits from the point of view of the photocatalytic efficiency of the product.

5.3 Dissemination actions

5.3.1 Objectives

In the present action, the three partners are proceeding with the dissemination of the project's achievements to the widest possible audience. A Dissemination Plan (Deliverable D1.1) was prepared and released on 29/09/2014, according to the timetable indicated in the Grant Agreement.
The target of the Digitalife communication is the full dissemination of the project results at different levels in order to cover different kinds of target-persons:
a) a more detailed scientific communication in international scientific journals devoted to scientific researchers interested in advanced research of photocatalysis;
b) a spread communication in open access journals devoted to people involved in the production of ceramic tiles with particular interests in advanced coatings;
c) an educational communication to the society to spread the importance of pollution for our health and the possibility that photocatalysis materials can help us to clean our world (air and water).

5.3.2 Dissemination: overview per activity

Activities to ensure wide visibility and identification of the project have been planned as part of the dissemination campaign, including the following actions:

a. design of the DIGITALIFE corporate identity (logo, colour scheme, style sheets). The logo was chosen by all beneficiaries during the first Kick Off Meeting organized in July 2014 conveying the idea that DIGITALIFE project is focused on precise, small drops, containing the photocatalyst that can be precisely placed on the tiles surface to ensure a coating with new

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photocatalytic properties. The logo is present on the official letterhead, used by all the partners for official communications with suppliers.

b. set up of a website completely devoted to the project and presence of the project on the main social networks, online since the end of December 2014 with the following url: http://digitalife.active-ceramic.com. The website is monthly updated and it is a valid instrument for all beneficiaries to disseminate their results and to organize the dissemination activities complying with the Grant Agreement and the LIFE + program obligations. In the website, links to other Life projects are also present.
c. Four notice boards reporting all the most important information about the project were created and placed in the main site of the three beneficiaries, in UMIL lab and in GF outside the Iris showroom.
d. a Facebook page (Fig. 9) was created: https://www.facebook.com/pages/Life-Digitalife-Project/1795898290634422 (online since February 23rd, 2015). Facebook page is updated one a month at least. Our target is to include information not only on the project developments, but also on the problems of air pollution in general including video or articles taken from the international media.
e. 1 LinkedIn profile
f. 1 Leaflet
g. 10 publications in International Scientific Journals with IF
h. more than 20 speeches or posters in International conferences around the world (often invited lectures)
i. 6 papers in specialized journals on architecture and design (attached in the final report as digital documents)
j. Final conference in Milan on July 6, 201)
k. Dissemination via media like the website www.floornature.com: Floornature is an international design and architecture portal with a focus on porcelain stoneware materials for contemporary architecture, exclusive interviews with great masters of international architecture and the most interesting new developments in the world of architecture (Fig.8).

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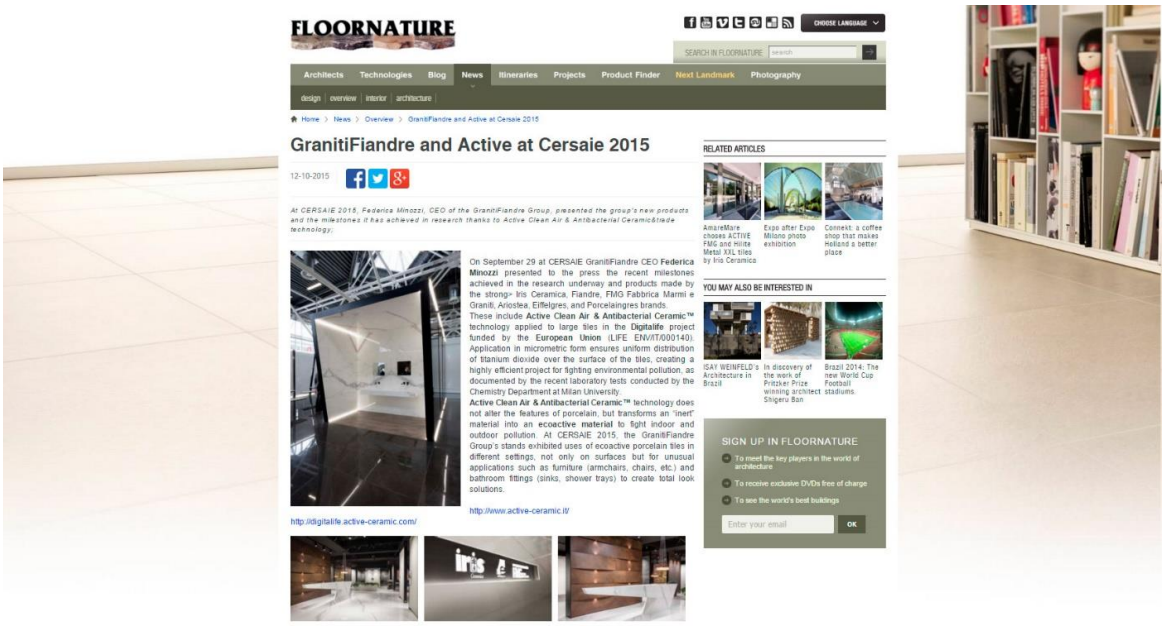

Fig. 8 – Example of dissemination via media

Fig. 9 – Facebook page of our Digitalife project

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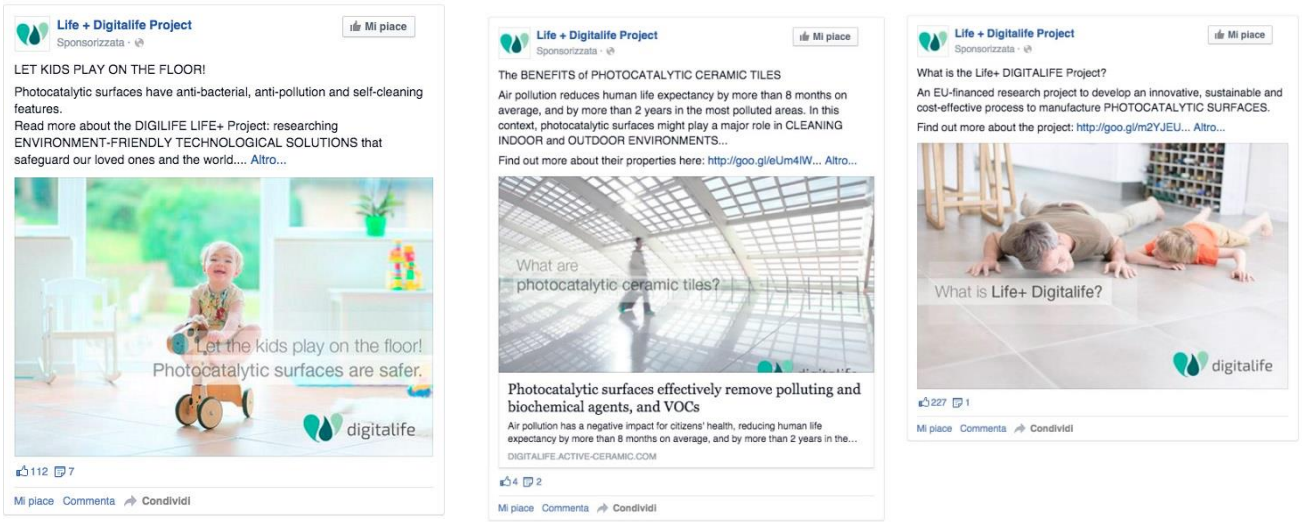

Fig. 10 – Facebook updates

l. The LinkedIn page:
Fig. 11 – LinkedIn Digitalife page

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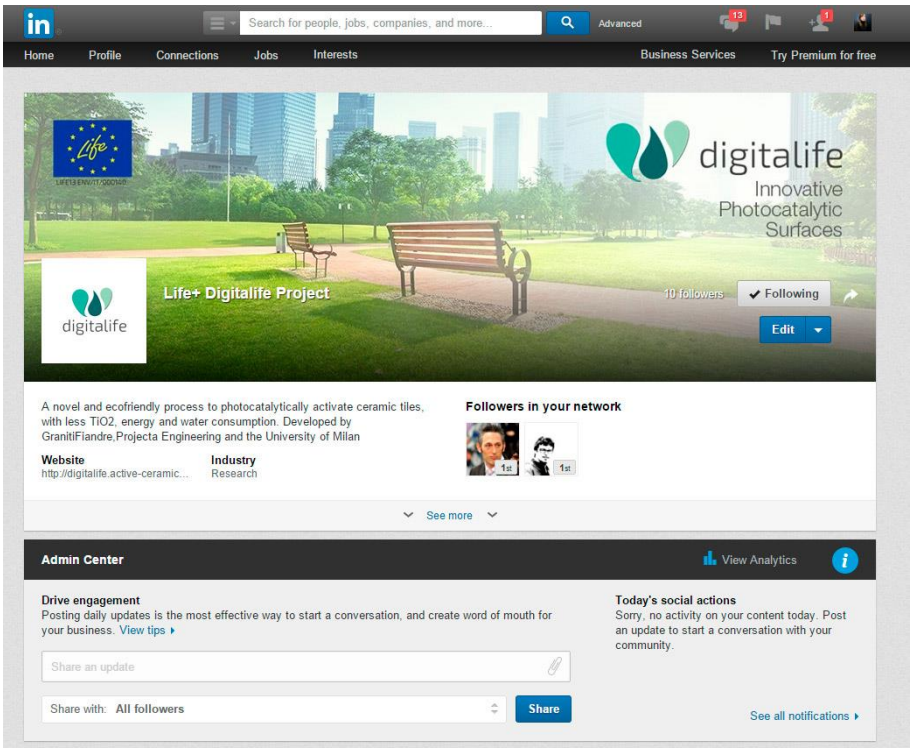

m. The mid-term conference of the Digitalife project was held in Castellon (Spain) on the June 4th 2015. The decision to hold the conference at the headquarters of the Spanish Matimex was dictated by greater promotion of the event and the need to consolidate and develop links with other LIFE Spanish projects with whom we were in contact. In fact, at the event dr. Teresa Moreno, PM of the project LIFE13 ENV/ES/000263 and dr. Marta Castellote, PM of the project LIFE13 ENV/ES/001221, were present to the event and both of them gave a talk on their Life projects, as already reported in 5.1.5.2.

   We wanted to increase the impact of the event by having a large number of architects (about 50) interested in photocatalytic ceramics in a booming market like Spain.

n. The photocatalytic slabs prepared during the project, where shown during the Fair “Cersaie” - Salone Internazionale della Ceramica per l'Architettura e dell'Arredobagno – in Bologna (Italy) at the end of September 2015, 2016 and 2017. The official website of the events indicated more than 100,000 participants from each event. Registered people: more than 3,000 people for each brand both in fair and in the showrooms (FAB in Castellarano or Iris Showroom in Fiorano Modenese).

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Fig. 12 – photocatalytic slabs during Cersaie in Bologna (2015 edition)

o. The project was always presented in all the occasions where official delegations come to visit our showrooms.
Delegations from Singapore, Tunisia, Hong-Kong, Mexico, China, Malaysia, etc..

p. Oral or poster presentation in several International Scientific congresses all over the world often as invited speakers.

q. Scientific publications in International Scientific Journals with Impact Factor:

i. M. Stucchi, C.L. Bianchi, C. Pirola, S. Vitali, G. Cerrato, S. Morandi, C. Argirusis, G. Sourkouni, P.M. Sakkas, V. Capucci, "Surface Decoration of Commercial Micro-sized TiO2 by means of High Energy Ultrasound: a Way to enhance its Photocatalytic Activity under Visible Light", Applied Catalysis B: Environmental, 178, (2015) 124–132
ii. C.L. Bianchi, C. Pirola, F. Galli, M. Stucchi, S. Morandi, G. Cerrato, V. Capucci, "Nano or micro-TiO2 for the photodegradation of ethanol: experimental data and kinetic modelling", RSC Advances, 5 (2015) 53419-53425
iii. C.L.Bianchi, C. Pirola, F. Gallia, S. Vitali, A. Minguzzi , M. Stucchi, F. Manenti, V. Capucci, "NOx degradation in a continuous large-scale reactor using full-size industrial photocatalytic tiles". Catalysis Science & Technology, 6 (2016) 2261-2267
iv. M. Stucchi, C.L.Bianchi, C. Pirola, G. Cerrato, S. Morandi, C.Argirusis, G. Sourkouni, A. Naldoni, V. Capucci, "Copper NPs Decorated Titania: A Novel Synthesis by High Energy US with a Study of the Photocatalytic Activity Under Visible Light ", Ultrasonics-Sonochemistry, 31 (2016) 295-301

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v. C.L. Bianchi, B. Sacchi, C. Pirola, F. Demartin, G. Cerrato, S. Morandi, V. Capucci, "Aspirin and paracetamol removal using a commercial micro-sized TiO2 catalyst in deionized and tap water", Environmental Science and Pollution Research, 24(14) (2017) 12646-12654

vi. C.L. Bianchi, M. Stucchi, C. Pirola, M. Lanza, G. Cerrato, L. Cappellin, F. Biasioli, V. Capucci, "TiO2 photocatalysis for the abatement of ubiquitous indoor pollutants: study of the simultaneous degradation of aldehydes", Trends in Photochem & photobiol, 17 (2016) 31 – 43

vii. C.L. Bianchi, G. Cerrato, B. Sacchi, S. Capelli, V. Capucci, "Micro-sized TiO2 as photoactive catalyst coated on industrial porcelain grès tiles to photodegrade drugs in water", Environmental Science and Pollution Research, DOI 10.1007/s11356-017-9066-6

viii. C.L. Bianchi, M. Stucchi, C. Pirola, G. Cerrato, S. Morandi, B. Sacchi, S. Vitali, A. Di Michele, V. Capucci, "Micro-sized TiO2 catalyst in powder form and as coating on porcelain grès tile for the photodegradation of phenol as model pollutant for water phase", Adv Mater Sci, 2(2) (2017) 1-6

ix. M. Stucchi, C.L. Bianchi, C. Argirusis, V. Pifferi, B. Neppolian, G. Cerrato, D.C. Boffito, "Ultrasound assisted synthesis of Ag-decorated TiO2 active in visible light", Ultrasonics-Sonochemistry, 40 Part A, (2018) 282–288

x. M. Stucchi, F. Galli, C.L Bianchi, C. Pirola, D.C. Boffito, F. Biasioli, V. Capucci, "Simultaneous photodegradation of VOC mixture by TiO_2 powders", Chemosphere, 193 (2018) 198-206

r. Final conference: held in Milano at the University of Milan main site in Milan downtown. Participants: 78 signed persons (architects and ISO members).

All info about the project, papers, posters, certificates with photocatalytic tests results and leaflets were added to a USB card given as present to all participants at the final conference nd to the stakeholders visiting the sites of the three partners.

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Logo color:
Full Color
Shell color:White
Shell size:83x52mm

Front

Logo color:
Full Color
Shell color:White
Shell size:83x52mm

Back

Date:2017.06.28

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www.ACTIVE
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Fig.14 – pictures form the final conference

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At present, we can conclude that all the planned activities have been successfully performed. The objective to disseminate the project and the obtained results is achieved. Both at scientific and consumers level, we can declare that the Digitalife project attracts attention. The scientific community is very interested in industrial products that are really effective in improving the air quality, especially in confined rooms where we stay many hours of our day. Daily GF receives requests of information about the digital photocatalytic products to be installed in hospitals, retirement homes, hospices, public offices, nurseries, etc.

5.4 Action E.2 Networking with other EU projects

In the present Action, we implemented networking activities and established links with key actors from past and on-going EU funded projects. The consortium ensured a seamless information flow of information with other EU-funded projects.

The mid-term conference of the Digitalife project was held Castellon (Spain) on the June 4th 2015. As previously announced, the decision to hold the conference at the headquarters of the Spanish Matimex was dictated by greater promotion of the event and the need to consolidate and develop links with other LIFE Spanish projects with whom we were in contact.
In fact, at the event dr. Teresa Moreno, PM of the project LIFE13 ENV/ES/000263 and dr. Marta Castellote, PM of the project LIFE13 ENV/ES/001221, were present to the event and both of them gave a talk on their Life projects. -

Picture as Fig. 15

The logos of the both Spanish and Slovenian Life linked projects are present in our website (see Fig. 16):

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Fig.15 – logos of the projects linked to the Digitalife project

In particular, with Spanish project life-photoscaling, we sent our activated slabs prepared by digital technique for their project aiming to compare the activity in real condition of photocatalytic building materials. It is important to underline that the Spanish project coordinator, Dr. Castellote, confirmed that our slabs are the only photocatalytic material produced by digital technique among all the products they have selected for their test.

5.5 Evaluation of Project Implementation

In the following tables, the objectives and the results have been compared and evaluated by using the methodology detailed here below (from "a" to "f"):

a) Comparison of the results vs the objectives – evaluation;

b) Objectives met: successes and lesson learned;

c) Quantitative and qualitative information about the actions;

d) Project results immediately visible and other coming out later;

e) Effectiveness of the dissemination.

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The general project objectives shall be attained through the intermediate objectives and actions achievement that are reported and explained with more details in the previous chapters of this report. The following list, with comments and grades (grades from 1 to 5 where 5 is the best result), summarizes the project objectives vs results.

Preparatory actions

a	b	c	d	e
4	The present action was aimed at finalizing the research conducted by the three project partners on the photocatalytic activity of micro-TiO2 powders (also compared to nanopowders), digital printing, solvents and water-based inks (including suitably designed modifiers). Problems were encountered in the preparation of the list of equipment and in general materials to buy with some updated differences with the list proposed to the Commission during the project submission.	The pilot plant was designed in compliance with EU and national regulations and laws. All the plant parameters were well-defined.	Two deliverables were prepared.	Indications on website structure Facebook and LinkedIn pages were scheduled.

Implementation actions

a	b	c	d	e
4	The pilot plant was built and installed inside the existing GF production line. Solvent-based ink was prepared. Problems faced to use water-based ink due to piezoelectric mechanism of the print heads.	The pilot plant was validated already on several sizes and thicknesses.	Photocatalytic slabs showed at Cersaie fair each year.	Results reported in the website and in the social media (see details in Fig. 21).

Monitoring of the photoactivity of the new slabs and environment impact of the novel products

a	b	c	d	e
5	Slabs prepared by digital printing with the Digitalife prototype were tested to verify and quantify the photoactivity both on the pollutants degradation in water and on the antibacterial activity.	The new photoactive slabs are more efficient than the old prepared by spray method. The tiles characterization revealed a more	Quantitative data were previously reported.	New results reported in International congresses and in Scientific

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	LCA calculations were performed comparing past and new coating procedure.	uniform distribution of the TiO2 at the ceramic surface. We almost completely reduced the water consumption, energy of about 15%, TiO_2 of over 50%.		journals with IF.

Communication and dissemination of results

a	b	c	d	e
5	Communication of the project aims and results is considered an important aspect of the Digitalife project. The constant update of our social media and the planning of the dissemination events have been useful to achieve the goal of raising awareness on the project and reaching a wide and diversified range of interested stakeholders and audience However, the effort spent in the dissemination of the project were much higher than foreseen as indicated by the excellent results obtained and described in Chapter 5.3 The costs for the dissemination of the project (especially for the constant update of the project website) revealed to be higher than foreseen and this was in fact reported in the request for amendment.	A dedicated website together with Facebook and LinkedIn pages, continuously updated. Parallely full information using scientific channel such as international congresses and high level scientific journals. Problems to create a Wikipedia page.	1 website 2 social 2 events (mid-term and final conference) 3 fairs 80 external events involving stakeholders 4 notice boards 10 scientific papers.	All the pre-established objectives concerning the communication and dissemination of the results both to scientific community, to general public and to the stakeholder have been successfully completed.

Project management

a	b	c	d	e
4	The DIGITALIFE consortium is composed by GF as Coordinating Beneficiary and by UMIL and Projecta as associated beneficiaries. An amendment to the	PM, TM and QM are also members of the Project Steering Board (PSB) chaired by the PM.	Partnership Agreement definitely signed on	Monthly reports are sent to the Monitoring Team. Inception report submitted in March 2015 and positively evaluated. Mid-term report submitted in February 2016

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	Project budget was submitted in September 2015 but refused since the proposed changed were not considered substantial.	A dissemination board is also present.	14/01/2015.	Progress report submitted in July 2017. The present Final report submitted in March 2018.

Link to other EU Life projects

a	b	c	d	e
5	Participation to events and links with other Life projects with similar aims.	Three important connections with Life ENV projects	Talks inside our mid-term conference. Exchange of samples. More link and exchanges of documents and best practices will be activated and done in the future	Three projects logo in our website.

5.6 Analysis of long-term benefits

The project is currently in the middle of its path with a good maintenance of the expected timing and targets unchanged.

1) Environmental benefits:
   a. the new slabs produced with the digital prototype have a large positive impact in improving air quality. Test on different air pollutants showed an excellent efficiency of the material towards the complete degradation of the pristine molecules. Both NOx and VOCs are strongly degraded, 95% and 100% (on ethanol) respectively. Formaldehyde is photodegraded as well by the new material.
   b. Antibacterial properties are confirmed even on MRSA strains.
   c. New prototype allowed preparing a new generation of photoactive ceramic surfaces reducing the amount of TiO_2 lost during the preparation stage. Wastes of photocatalysts are completely avoided.
   d. Thanks to the uniformity of the TiO_2 at the tiles surfaces, we can now use 50% less of photocatalyst obtaining better photocatalytic results compared to the traditional technique.
   e. The new coating procedure using the digital printing machine allows reducing the use of water, necessary in the spray plant to mix the silica-based materials with the TiO_2. In addition, to clean all the tanks. All these procedures are no more necessary in the new digital printing method.
   f. The water consumption for the entire process was drastically reduced remaining only a very small quantity present only in the water-based ink formulation.

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g. Overall energy consumption is reduced (estimated in about 15%).
h. LCA results confirm the new environmental benefits especially in terms of carbon footprint (reduced of about 89% in terms of CO_{2eq}).
i. A new water-based ink was formulated and tested containing up to 30% water with excellent photocatalytic results (NOx degradation over 90%).
j. A completely new plant paid by GF own funds was built on the basis of the results obtained by the Digitalife project and started its work on October 2017 with the production of activated large slabs.
k. The industrial validation of the entire project was performed between June and July 2017 testing the photoactivation on different slabs sizes and thicknesses.

2. Long-term benefits and sustainability:
   a. Long-term / qualitative environmental benefits:
      i. the new product prepared by digital printing showed excellent results in terms of long-term environmental benefits solving serious environmental problems such as the air quality both outdoor and in confined rooms.
      ii. All the functional uses of the new product, fighting air pollution and antibacterial activity, are well-confirmed.
      iii. Odor degradation is also confirmed lowering the costs due to the abatement of these unpleasant molecules in hospitals, restaurants, etc.
      iv. No toxic or harmful molecules were used to prepare the photocatalytic slabs.
      v. The produced photocatalytic ceramic slabs can have a great impact on the nowadays problems given by a high level of pollution in our EU cities. The last weeks of 2015 can be remembered as a terrible time where the levels of pollution in many European cities had pollution levels extremely above the EU regulatory limits.
      vi. the novel photocatalytic tiles nowadays represent a valuable product that can reduce the concentration of pollutants (chemicals, VOCs and bacteria) up to 100% even in water phase (both distilled and tap water) where drugs where degraded (e.g. aspirin, ibuprofen, paracetamol). Consequently, citizens will highly benefit from the DIGITALIFE photocatalytic tiles, which will contribute to the “Thematic Strategy on air pollution” objective of 47% reduction in life expectancy loss by 2000 with respect to 2020 values.
      vii. In the light of the results of the Digitalife project, if we could assume that all the millions of sqm of tiles produced in 2016 (more than 13 billion) were treated with the technique and the TiO2-based ink developed during this project, the environmental pollution issues would drastically decrease, especially as far as indoor pollution is concerned. Based on our results, 13 billion of sqm of Active slabs means the destruction of 48 million-kg of NOx in one year of work. Considering a Euro 6 diesel car, the average NOx emission

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is 0.07 g/km, we can calculate that we could compensate the emission of about 46 million cars, travelling for 15000 km in one year.

b. Long-term / qualitative economic benefits: All the benefits of which we speak are given from a material that does not require energy to exert its properties.
Thanks to the self-cleaning properties, we can use milder cleaners avoiding the use of biocides, which leads to pollution of surface waters. The surfaces are always well cleaned and sanitized.

c. Long-term / qualitative social benefits: great impact on public health and thus great benefits in term socio-economic impact on the budget of the Public Health.
Our new digital printed product was selected among different photocatalytic building materials for an on-site test in one area to improve the air quality of Madrid (Spain) (LIFE13 ENV/ES/001221 – Photoscaling).

d. Continuation of the project actions by the beneficiaries: the transformation of the solvent-based ink into the water-based one is in progress increasing the environmental benefit of the final ceramic product.

e. The production of digital Active has made it easy to find great enthusiasm among our stakeholders right away. In particular, the excellent results shown on all the photocatalytic properties tested have allowed proposing a new product with high efficiency. At present, we are developing new kind of inks containing a TiO_2 doped with metals in order to enhance and improve the photoactivity even in the visible region, mainly under LED light.

f. Due to the limitations in the GA for which GF were not allowed to sell the new photocatalytic slabs produced with the prototype DIGITALIFE, GF property has decided to build a new industrial plant that exploits the pre-industrial studies and results obtained in the DIGITALIFE project, before the end of the Life project. The GF property has provided a funding of more than 7 million€ and at the end of November 2016 the new digital Active Digital production was started with a digital machine that is the industrial evolution of the prototype developed during this project. This Company choice is based on the idea of providing large slabs with photocatalytic features to give to the market not only sustainable products but also active in terms of slabs which can exploit in real conditions all the properties of the photocatalytic materials. The market seems to respond in more favorable terms than in the past.

g. The new prototype working with the digital printing methodology assures a better replicability and a fast transferability of the production sites compared to the old process via spray method based on the specific knowledge and experience of the people directly involved in the production. With the new process, the production costs are evaluable with a higher precision than with the old spray technology.

h. The new plant has the capacity of 220000 sqm/year to photoactivate large slabs.

3. Best Practice lessons:

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1) it was necessary to formulate in a different way the TiO_2 ink to obtain the expected results considering the vitrified surface on which the ink has to be coated.
2) during the preparation of the project, the personnel costs wrong.
3) the number of personnel hours was underestimated for the construction of the prototype.
4) the present project can increase the development of the large slabs technology.

4. Innovation and demonstration value: The project innovation is really high.
   i. No other EU or international company is able to prepare photocatalytic slabs using the digital printing technology.
   ii. The preparation of the solvent-based ink containing a photocatalytic powder as body is an absolute innovation.
   iii. The preparation by digital printing of large slabs (150x300 cm) coated by the photocatalytic layer, fired and brushed, is unique in the world.
   iv. The level of photoactivity efficiency reached by the new slabs is higher than all the other building materials present in the market at present, worldwide.
   v. The use of micro-sized TiO_2, not toxic and harmful, is once more confirmed in the new ceramic surface as well.
   vi. The peculiarities of these photocatalytic slabs are receiving great attention by architectures especially as "worktop" for kitchens in both EU and the USA thanks to their self-cleaning, anti-odor and antibacterial properties.
   vii. inks were completely formulated in-house exploiting and increasing all the competences present in both GF and UMIL labs.

5. Long term indicators of the project success will be presented at the end of the project including LCA calculations and quantification of the benefits of the new technology. Quantitative data on TiO_2, water and energy consumptions will be also calculated and compared with the old process. Other possible indicators:
   - SQM of photocatalytic tiles produces with the new technology
   - New inks formulations
   - Number of other companies that decided to exploit photocatalysis to improve environmental quality
   - Number of new publications on photocatalytic building materials
   - Number of people requesting information on our new technology

The European industry is an important actor for the development of the EU areas as whole, and it is at the same time responsible of a large part of the energy (25,3%), water (40%) and materials (12% in relation to manufacturing) consumption [2012, EUROSTAT, Consumption of energy; 2008, EEA, Water use by sectors; 2010, C. Heidhorn, Are we heading to a real European Recycling Society?]. In this context, the ceramic industry is a strategic enabler for growth, innovation and sustainability. A

thriving ceramic industry in the EU is vital to achieve a competitive low-carbon and resource-efficient economy.

After an essentially stationary 2015, 2016 saw a recovery in global production and consumption of ceramic tiles with growth of 5.7% and 5 % respectively. World tile production passed the 13 billion-sqm mark to reach 13056 million sqm, 5.7% up on 2015. Asia resumed growth, up from 8631 to 9331 million-sqm equivalent to 71.5% of global production [Acimac Research Dept.]. The European continent produced 1887 million sqm (14.4% of world production), including 7.1% growth from 1218 to 1304 million sqm in the European Union (EU-28). However, world exports is almost entirely attributable to EU which rose from 856 to 903 million-sqm (+5.5%), one third of total world exports. About Italy, Concorde Group remains at the top of the rankings. Iris Ceramica Group is in second place with an export share of 80%. Italy is at the third place of world exporting countries after China (first place) and Spain, but it is interesting to compare the average export price (€/sqm) from these three actors: China 4.9, Spain 6.5, Italy 13.8. It is really clear the role of leader of the Italian companies in this sector and that the Italian products are fully appreciated in terms of quality and beauty notwithstanding a price the highest price.

In this scenario, the DIGITALIFE project is pure innovation and complies with the regulations and strategies in terms of air quality, sustainability, job growth and environmental impact. In particular, important repercussions are expected at the societal level. Such repercussion will span from better air quality, reduced GHG emissions and mitigation of water use, to the chemicals exposure, to the possibility of providing photocatalytic, self-cleaning and anti-pollution cost-effective products.

In fact, the novel photocatalytic tiles nowadays represent a valuable product that can reduce the concentration of pollutants (chemicals, VOCs and bacteria) up to 100% even in water phase (both distilled and tap water) where drugs where degraded (e.g. aspirin, ibuprofen, paracetamol). Consequently, citizens will highly benefit from the DIGITALIFE photocatalytic tiles, which will contribute to the “Thematic Strategy on air pollution” objective of 47% reduction in life expectancy loss by 2020 with respect to 2020 values.

In the light of the results of the Digitalife project, if we could assume that all the millions of sqm of tiles produced in 2016 (more than 13 billion) were treated with the technique and the TiO2-based ink developed during this project, the environmental pollution issues would drastically decrease, especially as far as indoor pollution is concerned.

Based on our results, 13 billion of sqm of Active slabs means the destruction of 48 million-kg of NOx in one year of work. Considering a Euro 6 diesel car, the average NOx emission is 0.07 g/km, we can calculate that we could compensate the emission of about 46 million cars, travelling for 15000 km in one year.