

## Experiences from photocatalytic films in urban domains

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<b>Short Description</b>	This report describes the test made in the Campus of the University of Bologna, Italy about the application of PURETi Coat a photocatalytic surface treatment manufactured in EU by Nanoair Solutions. The development of Nanoair Solutions in providing direct or indirectly services and new products or solutions to municipalities is as well described..		
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## List of abbreviations

NO <sub>2</sub>	Nitrogen dioxide
NO <sub>x</sub>	Nitrogen oxides
NO	Nitrogen oxide
CO <sub>2</sub>	Carbon dioxide
CO	Carbon oxide
TiO <sub>2</sub>	Titanium dioxide
UV	Ultraviolet
O <sub>2</sub>	Oxygen
O <sub>3</sub>	Ozone
SO <sub>2</sub>	Sulfur dioxide
H <sub>2</sub> O	Water
ZN	Zinc
Ag	Silver
Cu	Copper
VCOs	Volatile organic compounds
PCO	Photocatalytic Oxidation
PC	Photocatalysis
NASA	National Aeronautics and Space Administration
OEM	Original Equipment Manufacturing
CDTI	Center for Industry Technological Development
OEM	Original Equipment Manufacturing
SME	Small and Medium Enterprise
CFD	Computational Fluid Dynamics
PCS	Passive control system
FIFA	International Federation of Association Football
ACS	Active control system
SNCF	National Society of French Railways
ISO	International Organization for Standardization
WHO	World Health Organization

## 1 Executive Summary

While being involved in the iSCAPE project, a Nanoair Solutions<sup>1</sup>, a Spanish SME, exclusive distributor of PURETi in European Union has evolved from a start-up importing the photocatalytic technologies into the European market to a company producing the state-of-the-art photocatalytic technologies in Europe. Now, the company also dedicates significant efforts to research and development activities such OEM, research of new products not only activated by light and developing new services with other iSCAPE partners to municipalities.

The iSCAPE project has also helped the company to achieve greater visibility and gain remarkable exposure to various stakeholders from private industries, the academic world, semi-public institutions and municipalities.

From a startup to scale, producing new jobs, services, products and citizen engagement to urban domains that helps to reduce pollution in the EU.

Several new social and urban success have been achieved during the iSCAPE project such as the results of the Lazaretto test (UNIBO), D3.8, D3.6, D3.7 followed with citizen engagement activities in Bologna, D5.5. Therefore new services alliances to assist municipalities, new urban domain deployments (applications, pilot tests, etc.), new products research, new uses of PURETi coatings in urban environments (OEM´s), new international clients and new ways to apply PURETi Coat have been developed during the iSCAPE project timeline.

The Lazaretto test has proved results of reductions of NOx between 10% to 20%, while being as high as 40% close to the walls where PURETi Coat was applied. A higher reduction was found in the first 50 cm, which is the height of small children that can be most affected by the exhaust pipes of cars.

Regarding new services, alliances several contracts have been signed with public construction firms with strong liaisons and city works experience with different municipalities in order to apply PURETi Coat on the streets and façades of cities in Spain. This has opened a wider path in which photocatalysis as a PCS can provide significant reductions in urban air pollution.

Several municipalities in Spain have tried in some streets the PURETi Coat photocatalytic solution as a first experience and have gained knowledge of this new technology as a tool to reduce pollution.

An industrial approach to manufacturers of products that are usually bought by city hall such as urban furniture, sport domes and stadiums has been made in an OEM strategy where different firms incorporate a final PURETi Coat treatment in the products to be offer at municipal markets.

The knowledge gained in the iSCAPE project has helped Nanoair Solutions in researching new formulations in a recently acquired laboratory with other nanotechnologies compatible with TiO2 such as Zn, Cu or Ag.

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<sup>1</sup> <https://nanoair.es/>

## 2 Introduction

In the following sections the evolution the evolution of Nanoair Solutions from a start up to a scale up firm will be described. From importing technologies such as PURETi Coat and distributing them in Spain to produce them in a toll agreement with a pharmaceutical firm, in order to develop new nanotechnologies and finding new services and products of the urban domain that can apply and use PURETi Coat.

## 3 From startup to a scale up

### 3.1 iSCAPE as a ramp-up for PURETi products

The iSCAPE project has enabled Nanoair Solutions to rump up its commercial activities by producing scientific results and evidence-based data. For example, the field campaign conducted in Lazaretto, Bologna (Italy), described at the reporting of D3.7 during the iSCAPE project, was the first experimental campaign run in the real-world conditions comprehensively.

Although some tests such as those reported by Maggos et Al. (2008) and Jeanjean et Al. (2017) were carried out in urban domains before, in those tests it was not :

- Applied state -of-the-art-modelling approaches such as Computational Fluid Dynamics (CFD) to assess the effectiveness of the photocatalytic coating, measuring with two ARPAE mobile laboratories. This mobile units were equipped for a continuous measurements of air pollutants such as nitrogen oxides (NO<sub>x</sub>, NO, and NO<sub>2</sub>), carbon monoxide (CO), ozone (O<sub>3</sub>), sulfur dioxide (SO<sub>2</sub>) with a 1-min time resolution. Additionally, daily averages of particulate matter in the form of PM<sub>10</sub> and PM<sub>2.5</sub> were also monitored.( described at the reporting D3.8).
- Used a photocatalytic coating product of the 3rd generation such as PURETi Coat<sup>2</sup>.

In addition, it is also worth noting that the field campaign activities conducted in Bologna, Italy were coupled with various citizen engagement activities in Bologna Living Lab, which led to an increased awareness of the role that passive control systems play in reducing the exposure to air pollution.

The results obtained in the Lazaretto test, Bologna Italy have been significant promising. Reaching levels of reduction of NO<sub>x</sub> near the walls of the street canyon where it was applied of 40% and having the major reduction in the first 3 meters of height. Computational Fluid Dynamics approach to model the effect of PURETi Coat as a photocatalytic coating on the local distribution of NO concentration within a real street canyon was tackled. Overall results of NO<sub>x</sub> reduction in Lazaretto were found between 10%to 20%.

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<sup>2</sup> <http://www.pureti.es/en/productos/pureti-coat/>



Being under the umbrella of the iSCAPE project and actively collaborating with reputable academic institutions and governmental organizations also helped Nanoair Solutions to enhance the credibility of the technology into the market, which now requires testing and validation of the technology's performance at a large-scale. In retrospect, before joining the iSCAPE project, it was a challenging task for Nanoair Solutions (PURETi) to penetrate the municipal market given that other products from the previous generations of the photocatalytic world (Generation 1 and Generation 2) described in D 3.7 produced not significant results Gallus et Al (2015). That however, changed with the results produced during the iSCAPE project, essentially enabling the company to create a unique value proposition and separate its products from alternative solutions produced by the competitors.

Zhu et Al. (2017) compared the performance of PURETi Coat with probably the standard photocatalytic product in the market called Degussa P25. PURETi Coat was found between 10 times to 25 times stronger than Degussa P25 destroying pollutant gasses in different humidity and temperature scenarios .

TiO<sub>2</sub> Photocatalysis was discovered in 1968 by Fujishima et Honda. Basically Generation 1 products arrived to market during the 70 's. these products consist in photocatalytic powders mixed with cement and other construction materials. In Generation 1 products most of the particles of TiO<sub>2</sub> were covered from the materials in which they were embedded.

Generation 2 products arrived to market after wet photocatalytic process was discovered in 1998 in Saga, Japan. Generation 2 products expanded the potential of photocatalysis to a higher level of performance and contribute to the development of photocatalytic paintings, most of them of pastel colors since TiO<sub>2</sub> is a white pigment.

In 2004 PURETi a Generation 3 of surface treatments, arrived to market with an aqueous totally transparent nano coating where all the particles of the coating are activated and not covered by secondary substances.

Throughout the project implementation and especially, during the last year of iSCAPE project, Nanoair Solutions dedicated significant efforts to share the project learnings and experiences with prospective customers and built a business case for its product-as-a-service offering.

## 3.2 From product to product-as-a-service

The cost-benefit analysis reported in D7.2 & D5.3 & D5.4 for photocatalytic coating indicates that photocatalytic coating is one of the most cost-effective passive control solutions. For example, in Bologna, Italy, the cost of air pollution reaches the figure of 300M € per year while the cost of applying PURETi there would not exceed €15M per year which equals in pollution reduction to planting one million trees. NO<sub>x</sub> reduction by trees depend on the species, temperature, relative humidity and meteorological conditions. In addition, studies carried out in the northern part of the world (near polar region) shows no effect of vegetation on gaseous pollution, Yli-Pelkonen et Al. (2017).

One of the studies by Takahashi et Al. (2005) reported NO<sub>2</sub> reduction of 9.4kg/year for 100 trees (*R. pseudo-acacia*). Similarly, the work of Nowak et Al. (2002) reported 4.5kg/year for an urban forest. Each m<sup>2</sup> of applied Pureti on concrete destroys in lab tests (QIPS University of

Belfast<sup>3</sup>) circa 140 gr/NOX/year which compared with the results of Takahashi et Al. (2005) each m<sup>2</sup> of Pureti Coat applied on concrete would destroy NOX more than a tree (R. pseudo-acacia). According to FMI (iSCAPE final event Dublin 2019) low boundary walls have shown no effect on average concentration levels of NO<sub>2</sub> in Dublin City.

A holistic approach of gathering different passive control systems is a must in urban environments. A combination of different PCS and ACS are needed to tackle urban pollution. PURETi Coat, the photocatalytic coating that has been tested in Lazaretto, (Bologna), is a one-step professional application that transforms concrete, roads, and building facades into self-cleaning air scrubbers. PURETi Coat is a cost-effective solution for reducing many facility maintenance problems. A unique spray application on a cement surface uses the energy of natural sunlight to break down organic dirt and pollution. High pressure washing is no longer necessary because sticky organic particles break down before getting stuck to treated surface.

PURETi Coat, has shown significant results destroying NOX in the Lazaretto Campaign, that can be added to other passive and active control systems to undertake within an urban domain, such as the right urban planning, better use of public transportation, car restrictions, green areas and trees, citizen engagement and education among others .

PURETi Coat have been applied in some of the streets of several cities in Spain with only some third-party sampling tests required. The test process has been based on sending a sample of the applied asphalt or concrete to a third-party laboratory/university to check the photocatalytic activity under ISO 22197-1:2007 and ISO 10678:2010 norm/test in laboratory conditions.

The cities of Seville, Malaga, Murcia and Arroyomolinos have already 200.000 sqm of PURETi Coat on some of their streets but without a real world/continuous measuring of the results.

A real-world study was needed for the 3rd Generation of photocatalytic products. The test carried in Lazaretto is bringing extraordinary results. An important door has been opened that gives the iSCAPE credentials and achievements to PURETi Coat a 3rd Generation photocatalytic product. This is an important help to offer PURETi Coat to other municipalities and articulate the SME it is with large service providers to municipalities.

Madrid City's Hall as a local example has decided that all new tender for maintenance and re-asphalting works on its streets must have photocatalytic coatings that complies with the norms ISO22197-1:2007 and ISO 10678:2010. Those norms were made for the 1st and 2nd Generation of photocatalytic coatings. It is expected soon an update of these norms for the improved technologies that already exist in the market. The duration of different photocatalytic products ranges from months to years depending on the product that makes the re-application a new service to renovate the initial applications on streets. In the case of PURETi an application lasts for 2 years on roads and sidewalks. Other cities in the EU are expected to follow this path and undertake similar solutions likely after the results published by iSCAPE project in the 'Generalized Recommendations Regarding Passive Control Systems for Improved Air Quality and Climate Change Mitigation'. So a new service for public facility management

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<http://pureti.com/content/documents/QIPS-NOx-report---PURETi-Coating-on-Concrete-modified-ISO-10-22-13.pdf>

and construction firms has arisen recently : Applying photocatalytic coatings on top on existing, new streets or re- asphaltting.

In order to inform the different stakeholders of the application of PURETi Coat which is a transparent surface treatment some advertising and signalling ideas have emerged. Besides public relations and media coverage (press releases) some street signaling have been designed in order to inform the different stakeholders of the actions and services made with this passive control system. In this way, the impact and information on stakeholders could last longer. This could be made as follows: in the below figures 1 and 2.



Figure 1: Street sign



Figure 2: Street signaling

### 3.3 Prospective customer and end-user engagement

It has been identified by Nanoair Solutions after several meetings that city halls in general prefer to deal with already certified suppliers. Most of them usually are big public construction firms which is better for SME such as Nanoair Solutions to articulate with by selling them PURETi t

in order that these firms can apply it after a re-asphalting or refurbishing some urban spaces such as bridges, sidewalks, roads, streets, bicycle lanes and roundabouts. The shortfall is that those firms do not look for the best quality photocatalytic product, instead these firms search for the cheapest in the market. Parallel to that the urban decision makers lack, for the time being, a solid knowledge of the differences of the 3 generations of the several photocatalytic solutions in the market. This behavior is confusing the market and harms the right development of the photocatalysis industry in general.

Several partnerships have been developed with some public construction firms that know how to introduce in municipalities an ultimate technology to the different decision makers and stakeholders in urban domains. Direct contacts and contracts were made with Eiffage and Augusta Asphalts to provide knowledge services to different municipalities. A paper was submitted to the Spanish National Congress in Jaen in 2016<sup>4</sup> which mentions the participation of Nanoair Solutions in the iSCAPE project.

Urban furniture is an important opportunity for marketing new functionalities to existing products that are being affected by fierce competition from Asia. Benches, children's playgrounds, artificial turf, streetlights and signaling, basket papers can become urban pollution scrubbers and self-cleaning surfaces while becoming disinfected by the photocatalytic reaction. Negotiations between Nanoair Solutions and urban furniture manufacturers are being taken in order that new functionalities can be added to the products made for municipalities by applying PURETi Coat in their production lines to that is produced and sold. Figure 3. A typical bus stop can have a coatable area of 10m<sup>2</sup> approximately, this according to the studies mentioned in this report can equal to the destruction capacity of pollution of 10 trees, Nowak et Al. (2002) and Takahashi et Al. (2005). Besides reducing pollution urban furniture can be self-cleaning reducing the use of chemical cleaning products that also affect pollution. The previous approach was an innovation OEM. Regarding existing urban furniture it can be coated after a pressurized water cleaning providing a new service to municipalities. This kind of services are been offered per example through a service/advertising firm called Clear Channel in Madrid. Clear Channel apply Pureti in the urban furniture advertising.

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<sup>4</sup> <https://29semanadelacarretera.aecarretera.com/>





*Figure 3: METRO Brescia, San POLO Station, Italy*

Several bus fleets are testing PURETi in different countries such as RENFE, (Spain) ,Bus Italia (Italy), SNCF, (France). The access to this firms has been made directly in the case of RENFE and indirectly through the German multinational Aunde, which is already a supplier of this public transportation firms.

Public transportation and delivery fleets can take advantage of the photocatalysis, by applying PURETi outside of a bus, tram or train can be a self-cleaning one while cleaning the air of the city. Figure 4. PURETi can be applied inside the vehicle enhancing the internal air quality as well for the sake of the better health of the passengers. For cleaning maintenance PURETi Coat only needs water to remove the small remaining dirtiness on the surface where it is applied, so less consumption of chemical products such as detergents and solvents are needed in maintenance/cleaning. Photocatalysis destroys by oxidation bacteria, virus and mold. So better health for passengers is expected in areas where people sit or hold his hands once treated with Pureti Coat.



Figure 4: A bus informing stakeholders about its new functionalities

## 4 Real-life testing

### 4.1 Pilot Study: Bologna Case

The application of PURETi in Bologna was carried out at the University of Bologna Lazzaretto Campus and its technology and methodology can be seen in the deliverable D3.7('Report on technical advancements for photocatalytic coatings').

The objective of the experimental program was to measure and compare the effectiveness of photocatalytic coatings in reducing the concentrations of NO<sub>x</sub> pollutants in urban street canyons, the environmental performance and durability of the methods proposed for application of PURETi Coat to concrete pavement and facades.

At the pilot stage in Bologna, the first requirement was the approval by the City Council of Bologna, once the City Council approved the works, the appropriate location was chosen. The maximum collaboration by the client was sought, to support points of water, electricity and access to the premises at any time to perform the tasks. These tasks had to be coordinated with the ARPAE and IAAC air quality stations and sensors suppliers.

This whole process took two years of time since the Iscape project was approved. The main objective was to carry out the application of PURETi Coat in Summer 2017 but finally had to be moved to the Summer of 2018. Coordination with different institutions and clients are not always the best scenario. Different cities and locations were asked to allow the deployment, but unfortunately only the Lazzaretto area located in the Municipality of Bologna was available.

For this purpose two similar street canyons were selected between the University buildings with the same geographic NW orientation and affected by the same pollution.

One street canyon was cleaned and applied with PURETi Coat, and the other street canyon was untouched and used as control to understand the differences between the two in order to evaluate the effectiveness of the surface treatment.

The method consisted of cleaning and applying a water-based TiO<sub>2</sub> surface treatment, commercially known as PURETi Coat. This treatment is applied to facades and road of the street canyon to form an invisible ultra-thin coating.

The efficiency was measured using a newly developed sensors provided by IAAC and the mobile measurement stations from ARP AE.

Two laboratories from ARP AE were displaced and equipment from IAAC are installed in both street canyons.

These units were equipped for a continuous measurements of air pollutants such as nitrogen oxides (NO<sub>x</sub>, NO, and NO<sub>2</sub>), carbon monoxide (CO), ozone (O<sub>3</sub>), sulfur dioxide (SO<sub>2</sub>). Described at the reporting D3.8('Report on deployment of neighborhood level interventions') and D3.6 ('Report on photocatalytic coating')

## 4.2 Key learnings and takeaways

Important takeaways are learned in the Bologna pilot test. Weather forecasts are sometimes very difficult to predict, and it is important to have at least 24 hours without rain to ensure proper adhesion of PURETi Coat to the surfaces. The only limitation that must be respected is the non-application when it rains and make sure that it does not rain for the next 24-48 hours after application.

As it was a pilot test, to move all types of additional machinery such as back up generator sets and water tanks was a bit difficult.

All PURETi applications require a good pre-cleaning, to ensure the correct adhesion of the product on the original surface and not on the dirt that may be on the surface.

Logistics was a great challenge, since move all cleaning and application equipment from Barcelona to Bologna.

Ground transportation was chosen, availability and easy to be anywhere in Europe in hours time.

In the whole process, two points are the most critical and that would need support, pre-cleaning, and energy to perform the application.

In the same equipment it can be adapted to be able to perform both the pre-cleaning of the surfaces and the subsequent application of PURETi Coat as the final product.

Lifting machines were hired to reach the entire facade of the buildings, for cleaning and for the application of PURETi Coat throughout the facade (figure 9).

According to the results of the measurements and predictions, shows that it was not necessary to apply on an entire facade of 10, 15 or 20 meters. With only the first three meters of height on

the facades, it is possible to reduce the pollution of the cities. Described at the reporting D3.6 ('Report on photocatalytic coating').

The advantages of the equipment consist in an application with electrostatic gun, achieving a 100% coverage of the surfaces.



*Figure 5: Manual Application*

Evaluations of the data (based on Deliverables D3.6 ('Report on photocatalytic coating') and D3.8 ('Report on deployment of neighborhood level interventions')) conclude that NOx reduction was clearly taking place. Scale or size is important – thousands not hundreds of square meters should be treated in order to obtain better results.

In the process that encompasses the application, The best scenario to perform the correct cleaning and drying and subsequent large-scale application should be supported by industrial and autonomous machines, instead of relying on an outlet or a water outlet is important to move forward without obstacles.(figure 10)





*Figure 6: Manual Application with autonomous machine*

Once the PURETi photocatalytic product is applied, a completely transparent structured net is created that is highly effective and durable thanks to the PING. Described in the deliverable D3.7('Report on technical advancements for photocatalytic coatings').

Unique: A water based solution – no powders- Its mineral, no chemicals involved.

Versatile: Can be spray applied to all existing road or building surfaces, the product goes on so thin that it cannot be seen, even on glass

Effective: The PURETi solution produces better dispersion of the nano-sized anatase crystals at the surface, when it is applied to, 100% of the surface is functional and active.

Durable: The product is its own binder. One application lasts 5+ years on vertical surfaces. 2-3 years on road borders, 2 years on traffic roads.

Safe: In solution, in application and in use, quick in implementation and with measurable results immediately

## 4.2.1 Application planning

PURETi is the state-of-the-art photocatalyst that makes large-scale application of TiO<sub>2</sub> in a highly-polluted urban environment feasible and cost effective.

PURETi can be spray applied on almost any building material: Horizontal and vertical surfaces – anywhere that gets light.

It is a water based solution, dries in seconds, cures in 24-48 hours

Ideal application conditions are right after a pressure washing or other cleaning. PURETi itself is not a cleaner – it is a keep it-cleaner. PURETi can be spray applied manually or with automated equipment, such a cleaner and sweeper trucks.(figure 6,9,10)

Low risk. No economic disruption or behaviour change required on the part of the public. No visible change to the surfaces after application. Large areas can be treated in a single night in public spaces: roads pavements, barriers, signs, benches, private buildings can add surface area, if permission is obtained.

## Implementation

The steps below identify the implementation method with PURETi product described at the reporting of D3.7 ('Report on technical advancements for photocatalytic coatings').

The conditions and forms of application have been adjusted by establishing a protocol. Based on the need to create a deployment in a canyon street, that generates an air flow that allows a better measurement of the decontaminating effect of the product. Different tests of application procedures were carried out to guarantee the correct function of the TiO<sub>2</sub> nanoparticle red.

Step 1: Pressure Wash or clean surface to best-possible condition.

Step 2: Spray apply PURETi product.

Step 3: Allow product to dry (10 seconds) and fully cure (24-48 hours) without disruption.

Step 4: Modify cleaning protocol after application to use less water pressure and no chemicals.

## Validation method

Within WP3 IAAC has developed the Living Lab Stations, an environmental sensor aimed at researchers to monitor their interventions. The solution bridges the gap between ultra-low-cost air quality sensors and high-end instrumentation. The goal is to provide a system cheaper and more robust than traditional instrumentation but more accurate than other low-cost solutions to measure the performance of interventions on the field for more extended periods. That features makes it perfect for assessing the performance of photocatalytic coatings over long periods (1-18 months). With it, the absorption of PM<sub>2.5</sub> and NO<sub>2</sub> can be measured, and better understanding of positive effects on air pollution as well as the drift on performance over time. That makes it extremely suitable to monitor an already coated area to know when a new application of PURETi is required. In a nutshell, offering customers an effective yet not expensive monitoring solution when deploying PURETi can help increase their trust and the long term effectiveness.

The studies of simulations made by UNIBO in D3.6 ('Report on photocatalytic coating'), describe the functionality and effectiveness of photocatalytic coating and reducing NO<sub>x</sub> concentrations in urban street canyons by an experimental field campaign to study the different air circulation in the 2 canyons and its impacts on pollutant concentrations.

The simulations showed that the potential of photocatalytic coatings in reducing NO<sub>x</sub> concentrations depends on the meteorological conditions affecting the street canyon. The highest reductions were observed when the walls and the street were exposed to maximum ultra-violet (UV) radiation. The reduction was also depending on the distance from the treated surfaces, with the greatest reductions occurring in the first 25-50 cm from the treated surfaces. Average NO<sub>x</sub> reductions are in the range of 10-20%, but also up to 40-50% near the treated surfaces.

Height: the largest efficiency in NO<sub>x</sub> reduction appears in the first 3 meters height

Distance: the largest efficiency on NO<sub>x</sub> reduction appears near the treated walls (25 – 50 cm)

Reductions of 50% should be achievable with sufficient surface area treatment

No construction activity required. The total area can be fully used by the public within hours.

## 5 Service development with other iSCAPE partners

Packages of different combinations can be developed and standardized in which some services from the iSCAPE Project members can add value to urban domains. As an example to a city hall an initial pilot test can be offered of different PCS such as applying PURETi Coat + monitoring results (IAAC) + Analyzing results (UNIBO) and advising of the best urban vegetation (Surrey University) for the area where the PCS are going to be deployed. Another example could be only monitoring and analyzing results, etc.. It is not easy to quote for Nanoair the cost of this packs. Price per m<sup>2</sup> is easy to bring to a standard quoting and it is scalable while services such as modelling, monitoring and others, are more related to the scope of the project and availability of abroad resources from other members of iSCAPE project.

A definition of the size of an intervention could be a first step to budget the different pack-services from some members of the iSCAPE to enhance their efforts and create a new scope of different services that can initially and quickly being quoted to municipalities. Some work is being done by Nanoair Solutions to add to the photocatalytic application of Pureti Coat the potential new services that could be available from some of the iSCAPE project partners.

There is a project at Harbor of Barcelona which has been introduced to other iSCAPE partners. If results of the pilot test are acceptable the Port of Barcelona will do a large application of PURETi Coat, IAAC Stations and contract the modelling and analyzing of UNIBO. in reference of the reports D.3.6, D3.8, D3.7, D7.2, D3.3, D3.1, D3.5.

Nanoair Solutions is a SME. The application in Lazaretto was made by hand but in order to apply PURETi Coat in large urban areas a spray truck was designed by Nanoair Solutions and a public construction partner called Eiffage to quickly deploy a photocatalytic coating on roads and streets. Eiffage is the 5th largest public construction companies in EU. Fig 5.

It has also been identified during the iSCAPE Project different machinery already existing in the market that could easily apply PURETi Coat in large scale deployments with only adapting few parts for the proper application.

PURETi Coat needs to be applied on a clean surface and with the right nozzle and pressure. Not any spray or pressure works for that. In that sense the 2 steps process cleaning one interesting product has been identified so trucks for applying PURETi have not to be custom made. This identification has been made among several typical road sweeper and washer machinery for urban cleaning existing in the market.

An example of this is a Dulevo model that vacuums the dust of the streets while filtering the dust it vacuums in PM<sub>2.5</sub> size. This way while cleaning not secondary products are created and spread in the city. Figure 6.

The use of machinery for applying PURETi Coat can reduce the cost of applying PURETi cost down to 1€/sqm which makes the PURETi Service application as one of the most cost-effective passive control system solutions for pollution. If this figure is divided by the guarantee of the product for roads and streets which is 2 years, the cost per sqm goes down to 0.5€/sqm. One of the following machines can easily apply 15.000 sqm in one hour.



Figure 7: Eiffage truck and the first prototype made in USA for LSU



Figure 8: Dulevo sweeper and washer truck



### Keep the buildings cleaner and reducing pollution

For applying façades mobile platforms can be used and one person can apply from level 0 to 3 meters height an average of 150 sqm/hour. Costs arise depending the country labor costs but PURETi coat in façades is guaranteed for 5 years at 100% capacity and 10 years at 80% capacity which makes it still a competitive cost-effective solution see Figure 7. In order to penetrate into the building façades industry an agreement have been signed with the 2 leader firms of façades maintenance in Spain IMFALÚ and DREYSER.



*Figure 9: Façade application*

### Maintaining Urban Furniture cleaner by making them cleaner and air scrubbers for pollution, Children's grounds:

While cleaning the air of the city every sqm of a Surface treated by PURETi Cleans the air more than planting a tree Nowak et al. (2002) and Takahashi et al (2005) . Moreover, the Surface remains disinfected by the power of light. This is especially important for children's Parks. A new service for disinfecting surfaces of the children's Parks while contributing to clean the air of the cities is being developed by partnering with the service firm Synthelast in a CDTI<sup>5</sup> EU program. Figure 13. Bacteriological and NOX reduction laboratory tests are currently being made.

<sup>5</sup> <http://www.cdti.es/>

Other services to municipalities and stakeholders can be made in the form of digital screens connected to the iSCAPE stations to prove to the different stakeholders the results of the active and passive control systems against pollution. Figure 8. In this way the virtuous circle can be closed and PCS and ACS can be made and showed its results to stakeholders on real time. This is one of the objectives that the Harbor of Barcelona is considering after the potential success the pilot test explained before and detailed in section 6 of this document.

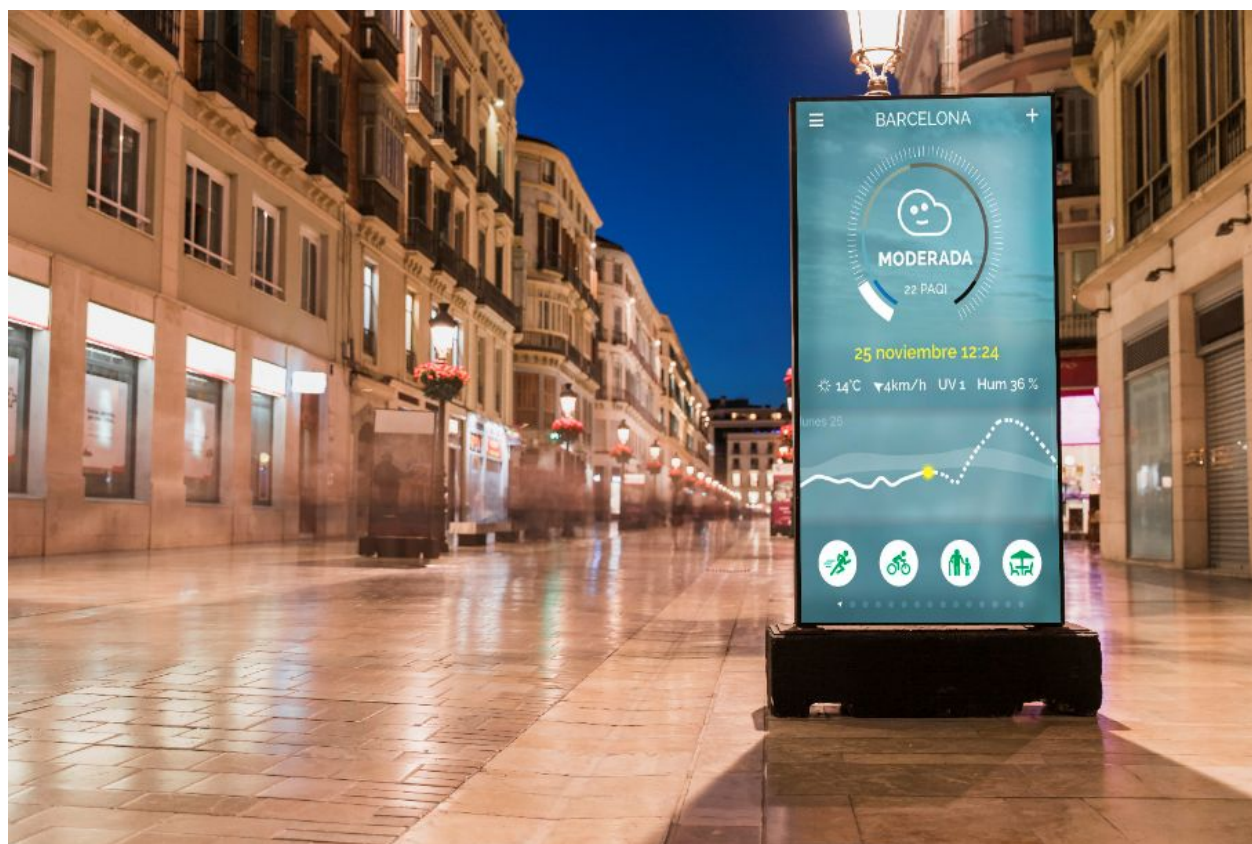


Figure 10: Urban digital signaling with information of nearby pollution.

## 6 Commercial Opportunities

### 6.1 Cities and Public Authorities

There has been until recently advances in studies of photocatalytic coatings, some reluctance from City Halls to use a technology with which there was not a deep knowledge and some frustrating experiences with the first and second generation of photocatalytic products.

Some tests have been made in several cities but the impact on the stakeholders has vanished in favor of other more visible control systems (active and passive). iSCAPE results and methodology are expected to change this mindset.

An important opportunity has been identified with the Harbors in Spain. Due to increase of global trading Spanish harbors have experienced an important activity growth during the last 20 years. This has been translated into important economic benefits for the Harbor Authority but important increase in producing pollution in the city as well. Cities that have the harbor in its downtown are very affected by the presence of this kind of infrastructures in an urban environment. Barcelona is an example of it. According to several sources the harbor of Barcelona which is located in the most transited (by car or pedestrian) area of the town is producing between 20% to 30% of the pollution of the city. There is strong interest in reducing such a negative impact. Barcelona City Hall and Government of Catalonia wants to diminish this effect by taxing the Harbor authorities while not solving the problem of pollution. There is structural limitation to plant trees or vegetation in the premises due to structural reasons (concrete).

Besides Barcelona Harbor is one of the most transited technical stops for Mediterranean cruises. Cruises once parked in the Port of Barcelona are using their diesel generators 24/7 to work their hospitality and travelling tenants/clients. Therefore, trade and tourism are increasing the levels of pollution in the port and in the right next city area.

Another harbor in Catalonia, Tarragona Port, has a similar situation, an important stop for cruises but worsened off because is the exit route of the largest petrochemical plant in Spain. According to some sources pollution in Tarragona is supposed to affect the endocrine system of human beings so much that the quality of the sperm in its citizens is considered the worst in Spain<sup>6</sup>.

Both Harbor authorities in both meetings with the Chairwoman of Port of Barcelona and the Chairman of the Port of Tarragona has expressed their interest in doing a pilot test which must involve some of the iSCAPE partners such as UNIBO, UCD, IAAC and Nanoair Solutions. In that sense the following replica of the Lazaretto iSCAPE Trial has been submitted to them. If the results are the same or better of the UNIBO ones the Harbor authority has expressed its desire to become the largest photocatalytic area in the world treating with PURETi Coat buildings and streets with a large deployment of IAAC Stations and academic advising to analyze results will be required in a provided continuous service.

Green light has been given to start a pilot test as soon as the members previously mentioned are ready to start.

Below is a picture Figure 11 of the area that is going to be treated and its results measured, analyzed and modelled.

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<sup>6</sup> <https://institutomarques.com/reproduccion-asistida/la-esterilidad/disruptores-endocrinos/>



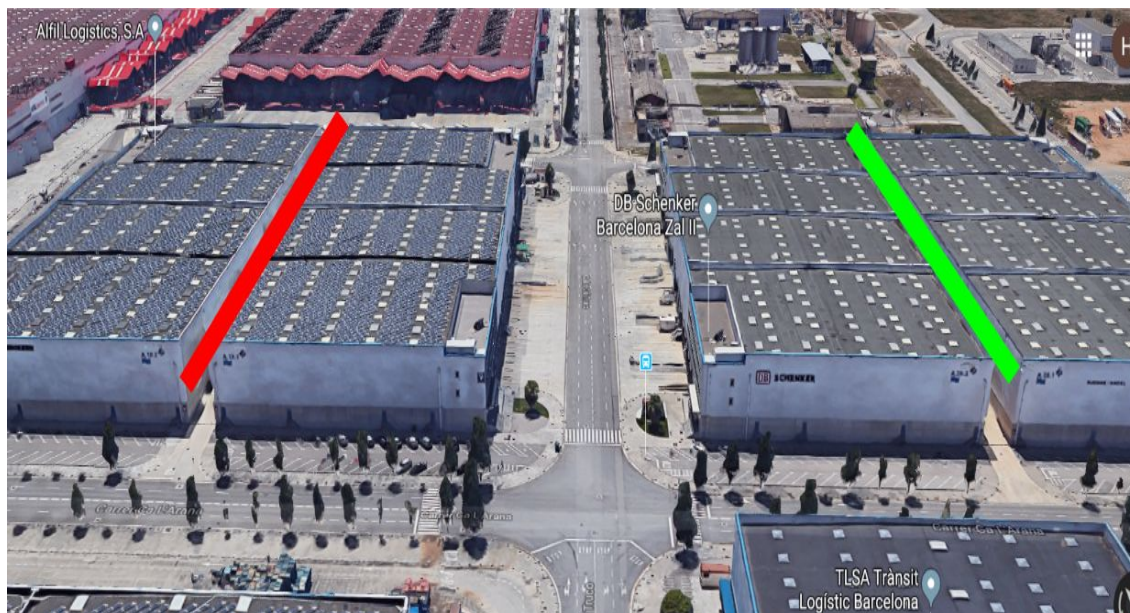


Figure 11: Port of Barcelona

Green Color: area to be treated.

Red Color: control area.

AREA: 3,000 m<sup>2</sup>.

AREA TO TREAT: Both facades and floor.

PURETi leaves no marks and is completely transparent. It can be applied on crystals without reducing transparency.

The red zone without treatment will be the one that serves as an element of comparison.

AREA TO TREAT AND CONTROL AREA: Installation of air quality meters. (The meters will be installed at a considerable height to avoid subtraction and vandalism over them).

The Iscape project air station will be installed, which are statistically correlated with the official EU air quality Station that is already installed in the Port of Barcelona, under a triangulation system.

Air quality monitoring station will be installed in the treated area.

Air quality monitoring station will be installed in the control area.

Air quality monitoring station is installed in the current air quality measurement zone.

If the results of such a vast area are positive as it is expected the Harbor of Tarragona is second in the list and few other harbors in Spain or EU could be as well targeted and some urban areas could also be included in large scale deployments of PCS.

## Outdoor parkings

Outdoor parkings are places where car traffic accumulates in cities and where pollution is intense. Ikea applies PURETi Coat through the public works company Eiffage, with the aim of minimizing the impact of cars' pollution that park in its shopping centers. Figure 12. It took 3



hours to apply in 2017 30.000 sqm of PURETi Coat in the Ikea located in Alcorcón, Madrid, Spain.



Figure 12: Ikea Parking

## 6.2 Innovative partnerships

While working within the scope of the iSCAPE project some opportunities in urban domains have been identified and nowadays are in a partnership agreement status, industrial testing, market testing or matured and successfully being accepted by the different markets of the industries that can affect the urban domains. Unfortunately the municipalities contacted to be involved in the ISCAPE Project, were reluctant to test 3<sup>rd</sup> Generation photocatalytic products since too much time was spent with low results with previous technologies of Generation 1 and Generation 2.

The private industry is more open to quickly test results and put in value new functionalities for their products (OEM) Original Equipment Manufacturing addressed to urban domains such as sport fields, urban landscape, urban furniture, suppliers to transport authorities, urban furniture, etc.

### Children's Playgrounds

The playgrounds are small places sometimes placed in the middle of the city and used by the most sensitive population to pollution (children). Children play and breathe a highly polluted air in some of the EU cities. The fact of applying PURETi in areas treated with cement or building materials or recycled rubber tires typical of EU children parks improves the quality of outdoor air at a height where PURETi is more active, the first 50-70 cm. The children's street furniture is also treated with PURETi because of its long duration once applied on surfaces where there is

no car traffic or strong abrasivity, in this way the spaces where children play become disinfected surfaces, self-cleaning and cleaning the air of the city.



*Figure 13: PURETi in Parks*

## Stadiums

### Artificial turf

In most of the EU northern cities artificial turf is a substitute for ground hockey and football fields. Easier to maintain becomes a high user of difficult to recycle materials. Nanoair Solutions PURETi has developed an exclusivity partnership in 2018 with the Belgian firm SLG DOMO SPORTS, number one European manufacturer of artificial turf for sports and landscape uses.

The UVA filter of PURETi Coat helps artificial turf to last longer avoiding the excess of using unnecessary chemical resources. The turf stadiums become urban pollution scrubbers while avoiding the growth of molds and bacteria on it. SLG DOMO SPORTS is a leading firm in recycling all his products from their clients. Tests studies made on their artificial turf with Pureti in IST Fraunhofer Laboratory reached 48% NOX destruction levels .



Figure 14: SLG artificial turf in stadium

## Stadium Seats

Once the opportunity in the OEM market was detected in the artificial turf industry, the rest of the stadium could become an interesting place to avoid the use of chemical products in its cleaning processes while cleaning the air of a sport area which gathers during sport events significant amount of spectators and stakeholders. In this way a partnership program has been developed with the European leader of seats for stadiums FIFA certified firm called DAPLAST.

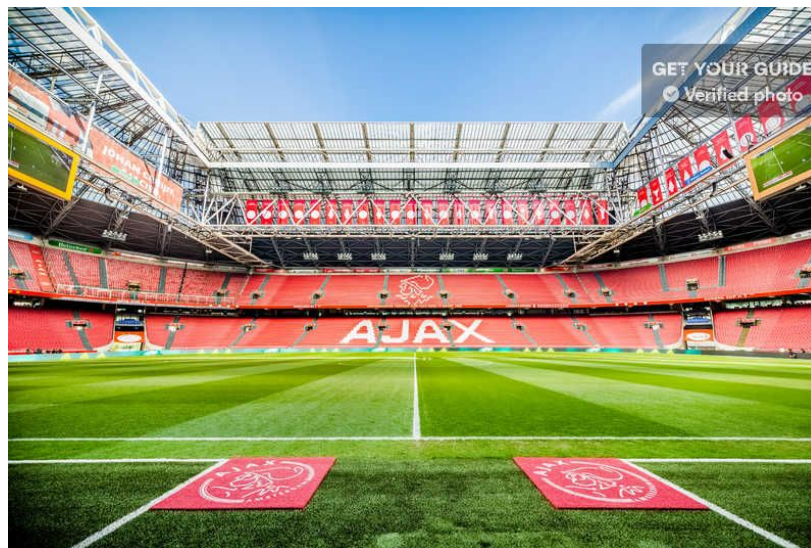


Figure 15: Ajax Stadium



## Advertising

Advertising is an industry with strong links to the degree of the consumption economy. In that sense doing good by doing business has moved them into the use of more environmentally friendly ways to address their communications to consumers. City billboards use large amounts of resources while bringing little back to cities. Several partnerships have been made with local urban advertising firms that apply PURETi Coat on their billboards after printing their communication messages. Toyota has made an advertising campaign which has offset the pollution caused by 5825 cars in one year. Several canvas advertisements have been installed in some cities in the EU giving a strong sustainable message to stakeholders while supporting the photocatalytic coatings making them “somehow” visible. Figure 16.

Most of the bar and restaurant terraces in southern countries of UE are covered with umbrellas. A contract with the firm Ezpeleta has deployed 250.000 umbrellas in Spain that destroys pollution as much as planting one tree does. Figure 17.



Figure 16: Toyota and Cabify billboard

## Awnings

Awning and dome canvas cover significant areas in southern cities of UE. Textile industry is among the major sources of pollution. A global exclusivity has been signed with the second largest manufacturer of awnings in the world, a Spanish firm called Saulea. Saulea is planning to produce in 3 years 1 million sqm of photocatalytic awnings and sport domes that probably will destroy pollution as much as have planted 1 million trees in EU.



Figure 17: Photocatalytic parasols by Mahou San Miguel



Figure 18: Green by Sauleda & PURETi

### Smart fabrics for public transportation - AUNDE

Public Transportation seats usually are not in the best hygienic conditions while internal air quality is affected by outdoor pollution once doors are opened within the city. Accumulation of people in public transportation makes transmission of diseases easier. According to WHO 90%

of diseases are transmitted via airborne. Aunde has developed a new service besides their fabrics production which consist in applying PURETi not only on the fabrics of the seats by applying PURETi Coat to all the inside and outside of the urban public transportation fleets. Figure 19.



*Figure 19: Aunde (Smart fabrics for public transportation)*

### **Ceramics for façades- The Neolith Case**

In 2017 a relationship started with Neolith a Spanish manufacturer which is one of the world leaders in large size ceramics for façades. At the end of 2017 Neolith was launching worldwide a new ceramic collection called Skyline by PURETi Figure 20. At the beginning of 2018 Neolith launched their self cleaning and anti pollution façades concept in USA and got the most important architectural and innovation awards such as:

- 2018 Neolith SKYLINE +PURETi Gold Edison Award.
- November 2018 (Special IAQ Indoor Air Quality) Edition D'A of Architecture FR.
- BUILDINGS *Money-Saving Products 2018* (Skyline + PURETi).
- Architectural Products *Product Innovation Awards 2018* (Skyline + PURETi).
- Architectural Record *2018 Products of the Year* (Skyline + PURETi).
- Architectural Digest 2018 AD Great Design (Mirage).

After the success of the media coverage of SKYLINE , Neolith decided to apply PURETi Coat in all its production by default.

Corporate Video of Neolith + PURETi SKYLINE<sup>7</sup>

<sup>7</sup> <https://www.youtube.com/watch?v=NxfUDGTd0nc&t=11s>



Figure 20: Neolith (2018 Edison Awards)

## 7 Outreach activities and synergies

### Promotional events and other dissemination activities

The new concept of public transport has been introduced by the German firm AUNDE. Coating from outside and inside public transportation. Applying PURETi Coat to the outside of the bus to destroy outdoors pollution while applying it in the inside of the bus the internal air quality can be significantly improved according to several studies<sup>8</sup>.

The following firms have been contacted by Nanoair Solutions to introduce the new concept for public transportation:

- RTTP Transportation Authority of Île de France. Meetings in Paris and Barcelona. Pilot test to be made in 2020.
- Bus Italia-Ferrovie dello Stato. Pilot tests made in 2018.
- TMB-Transports Metropolitans de Barcelona. Pilot tests made in 2017.
- EMT-Empresa Municipal de Transportes de Madrid. Meeting in 2017 No interest.
- RENFE- Spanish Railway Authority. Pilot tests made on 2018.

### Other outreach activities:

- Presentation of PURETi in Florida International Construction Trade Exhibition. 2017. Conference organized by Neolith. Largest USA trade exhibition of construction materials it has helped Nanoair Solutions to gain exposure in the USA market.

<sup>8</sup> <http://pureti.com/resources/testing-studies.html>

- Top 10 Finalist in the AKZONobel contest Paint the Future 2018, 150 start ups participating, 2018. Paint the Future is the ecosystem for accelerating new innovations in paints and coatings developed by Akzo Nobel . Through a platform and programs, innovators get access to resources to help commercialize their solutions. Rest of information available at<sup>9</sup>. Current status under confidentiality agreement.
- “Semana de la Carretera” submission of Paper in the National Congress of Roads in Jaen, Spain. Following this activity 200.000 m<sup>2</sup> of PURETi Coat were applied in different cities of Spain  
<https://www.aecarretera.com/congresos/congresos-y-jornadas/congresos-celebrados/2692-29-semana-de-la-carretera-innovacion-para-una-movilidad-segura>
- Press release in The Economist  
<https://www.economist.com/science-and-technology/2017/11/09/smelly-farms-may-succumb-to-subtle-science>) based on publication in the air quality scientific Journal Atmosphere of an study (<https://www.mdpi.com/2073-4433/8/6/103/htm>). The Economist is one of the most prestigious non academic magazines , the fact of being mentioned there helped Nanaoair Solutions to target indoor air quality in urban environments.
- Press release in The Wall Street Journal. “Façades that Clean the air of the Cities” (<https://www.wsj.com/articles/a-condo-facade-that-cleans-itself-and-the-air-around-it-1527602400>).
- Interview in Bloomberg TV to Glen finkel, founder and Chairman of PURETi USA (<https://www.bnnbloomberg.ca/video/company-develops-solution-that-makes-surfaces-act-as-air-purifiers~1416007>)

### Promoting technological integration with other EU funded platforms

- IFAPA-Junta de Andalucia. Government of Andalusia, Spain. PURETi is in a ongoing study to evaluate its incidence on plant growth. An increase in greenhouse production is expected to grow by 25% and reduce the use of pesticides by 70%.
- AITEX-CEDETI (Government of Spain) Grant on study of PURETi on urban playgrounds for children. While cleaning the air of playgrounds an aseptic environment for children can be provided.

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<sup>9</sup> <https://www.letspaintthefuture.com/>



## 8 Conclusions

Several pilot tests were made in the EU before the Lazaretto campaign D.3.6, D3.8, D3.7 on application and measuring the effectiveness with old technologies of photocatalytic products and never on a real street canyon. A Computational Fluid Dynamics modelling as was made by UNIBO during iSCAPE project. The results of the UNIBO, IAAC, UCD and FMI WP 3 and WP 7 have proved significant results and improvements in the fields of photocatalytic coatings as a pollution PCS, low cost measuring stations and new modelling approach.

The results and experiences of photocatalytic films of Nanoair Solutions with Pureti Coat product in urban domains have reached outstanding levels based on a cost effective analysis compared with other PCS. As an example developed by FMI the Bologna city cost of pollution is at €300M per year while this cost could be significantly offset by €15M/year cost of Pureti applied all over the city.

Reductions between 10% and 20% of NOX were achieved in the Lazaretto campaign while reaching 40% reduction of NOX nearby the surfaces treated with PURETi Coat (50 cm distance) and being the photocatalysis of PURETi Coat more effective in the first 3 meters of height.

Based on these results a wide opportunity of new services and products for municipalities are already reaching the market pushed mainly by private firms. The results of the Lazaretto campaign could open a new path to directly engage urban decision makers in order to embrace technologies that although invisible produce a significant effect on urban pollution and health of the stakeholders.

The evolution of a 3 partners start up to a scale up firm during the iSCAPE project has been mostly through collaborations with private firms that are either service providers or product providers of municipalities. New ideas on where apply PURETi photocatalytic coating are step by step happening. New products are being developed to combat pollution in the cities by Nanoair Solutions in order to make a better urban environment.

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