PhotoCityTex

Air pollution treatment in European urban environments by means of photocatalytic textiles

LIFE "ENVIRONMENT & RESOURCE-EFFICIENCY" TRAINING

PHOTOCITYTEX PROJECT

Amalia Muñoz,
CEAM

http://www.ceam.es/PHOTOCITYTEX

LIFE13 ENV/ES/000603
With the contribution of the LIFE financial instrument of the European Union

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Air pollution treatment in European urban environments by means of photocatalytic textiles

Reference: LIFE13 ENV/ES/000603

Budget: 1.297.105,00 € (1.177.880 elegible costs)

% UE Co-funding 50% (of elegible costs)

Length: Start 01/07/2014 **End** 30/06/2017

Project coordinator:

CEAM
FUNDACIÓN CENTRO DE ESTUDIOS AMBIENTALES DEL MEDITERRÁNEO

AJUNTAMENT DE Quart de Poblet

LEGAMBIENTE emilia-romagna

aitex textile research institute

NEXT TECHNOLOGY TECNOTESSILE

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Project Background

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1. Air pollution

(Wikipedia)

Air pollution is the introduction of particulates, biological molecules, or other harmful materials into **Earth's atmosphere**, causing **diseases**, **death to humans**, **damage to other living organisms** such as animals and food crops, or the natural or built environment

- Air pollution may come from ***anthropogenic*** or **natural** sources
- It could be local or planetary

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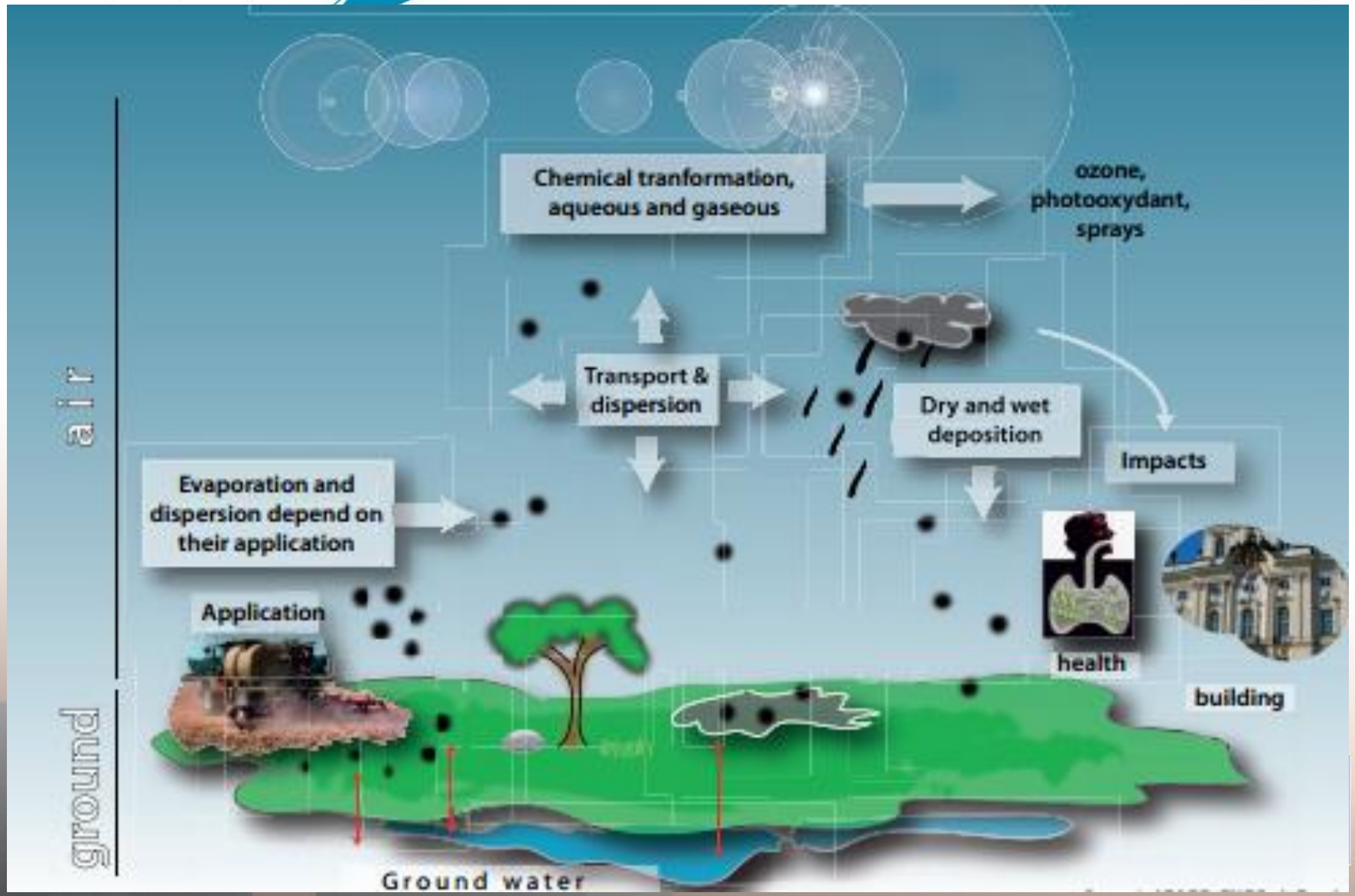

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1.Air pollution

European legislation: Emission and level of air pollutant concentration

Policies \ Pollutants		PM	O_3	NO_2 NO_x NH_3	SO_2 SO_x S	CO	Heavy metals	BaP PAH	VOCs
Directives regulating ambient air quality	2008/50/EC	PM	O_3	NO_2	SO_2	CO	Pb		C_6H_6
	2004/107/EC						As, Cd, Hg, Ni	BaP	
Directives regulating emissions of air pollutants	2001/81/EC	(a)	(b)	NO_x, NH_3	SO_2				NMVOC
	2010/75/EU	PM	(b)	NO_x, NH_3	SO_2	CO	Cd, Tl, Hg, Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V		VOC
	Euro standards on road vehicle emissions	PM	(b)	NO_x		CO			HC (hydrocarbons), NMHC (non-methane hydrocarbons)
	94/63/EC	(a)	(b)						VOC
	2009/126/EC	(a)	(b)						VOC
	1999/13/EC	(a)	(b)						VOC
	91/676/EEC			NH_3					
Directives regulating fuel quality	1999/32/EC	(a)			S				
	2003/17/EC	(a)	(b)		S		Pb	PAH	C_6H_6, HC (hydrocarbons), VOCs
International conventions	MARPOL 73/78	PM	(b)	NO_x	SO_x				VOC
	LRTAP	PM (a)	(b)	NO_2, NH_3	SO_2	CO	Cd, Hg, Pb	BaP	NMVOC
		Secondary pollutants		Primary pollutants, antropogenic					**Primary** and secondary pollutants, Biogenic and **antropogenic**

Source: EEA Report No 9/2013

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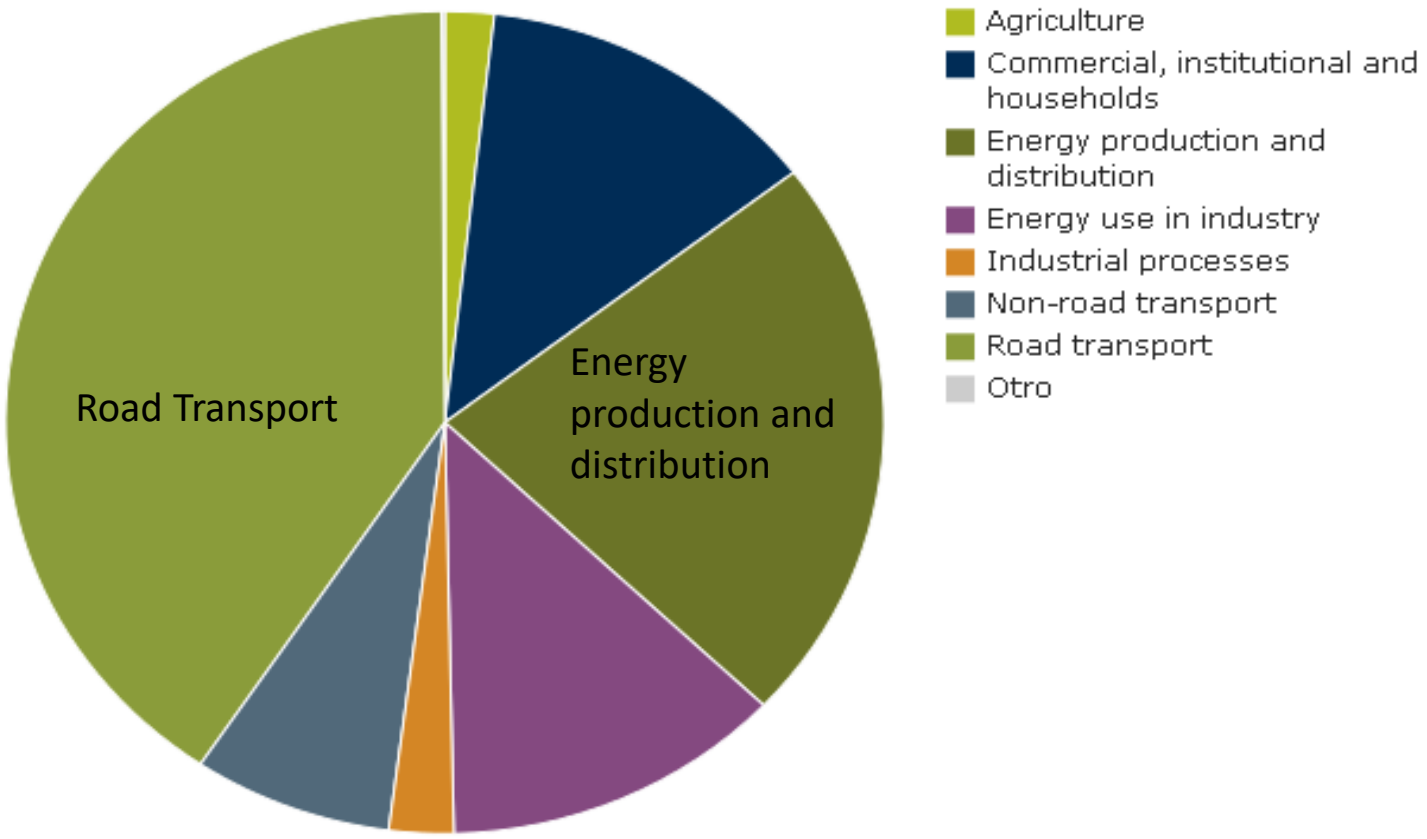
1. Air pollution: NO_2



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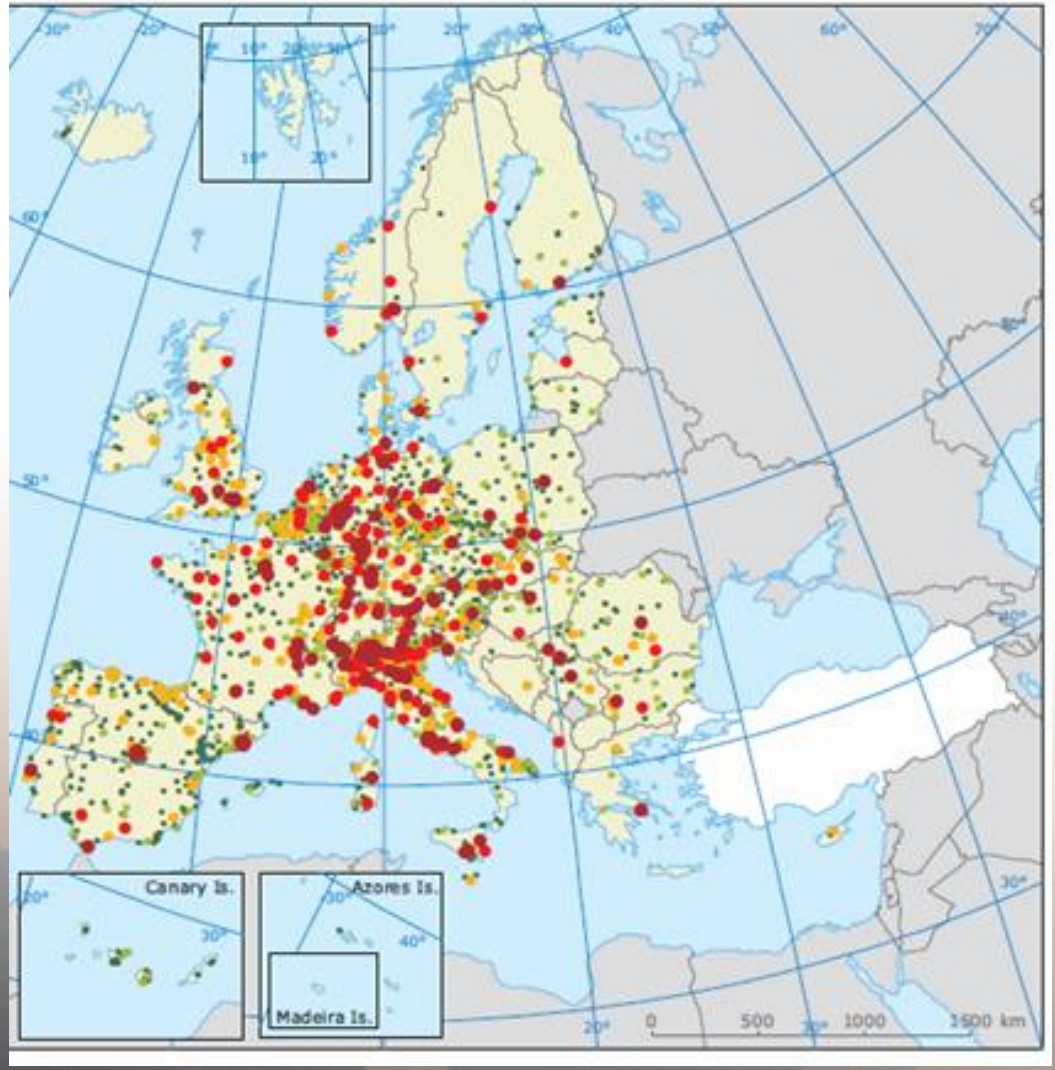
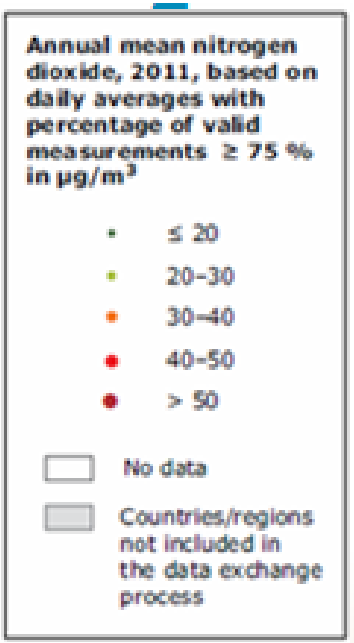
1. Air pollution: NO_2





Fuente: EEA-Report 9/2013 Air quality in Europe.pdf

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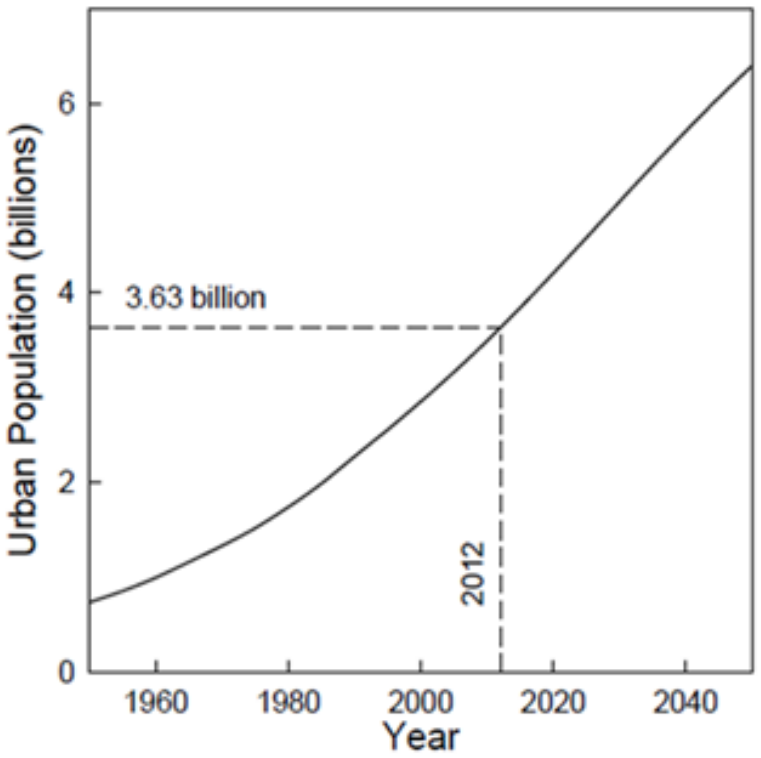
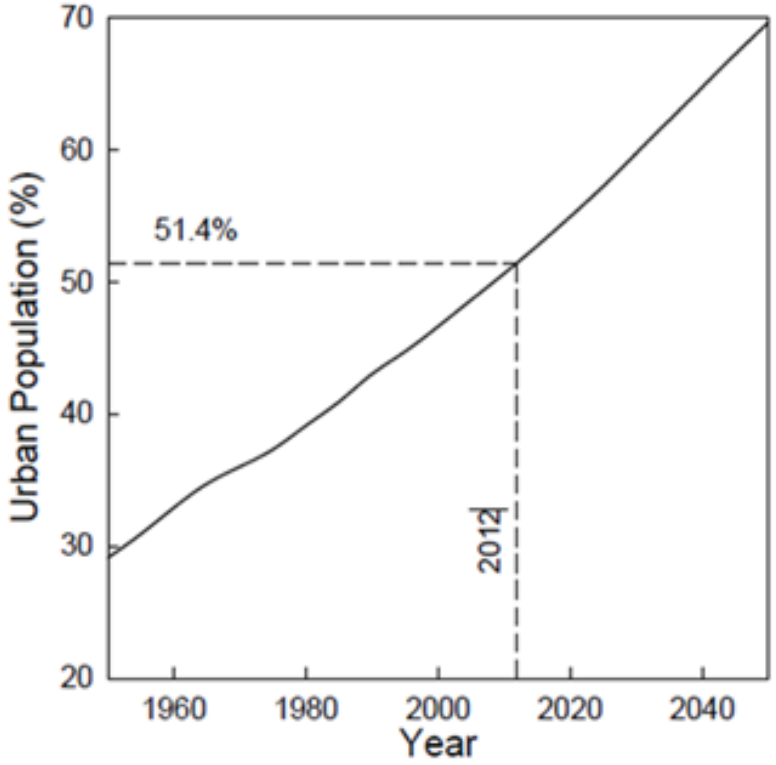
1. Air pollution

“Urbanization”





Source: UN Population Division http://esa.un.org/unup

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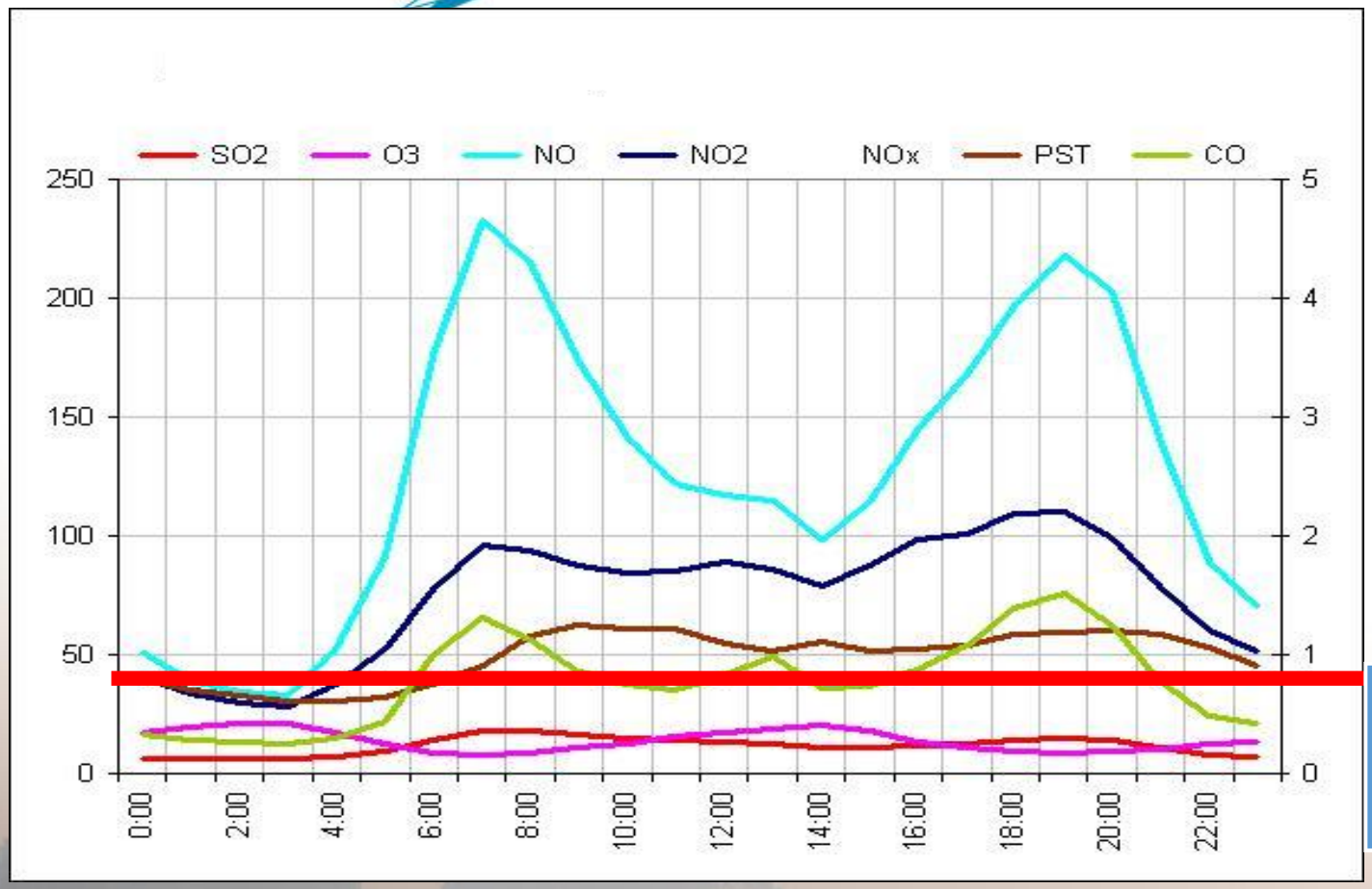
1. Air pollution: NO_2



Limit Level (annual average): NO_2 : 40 µg/m³

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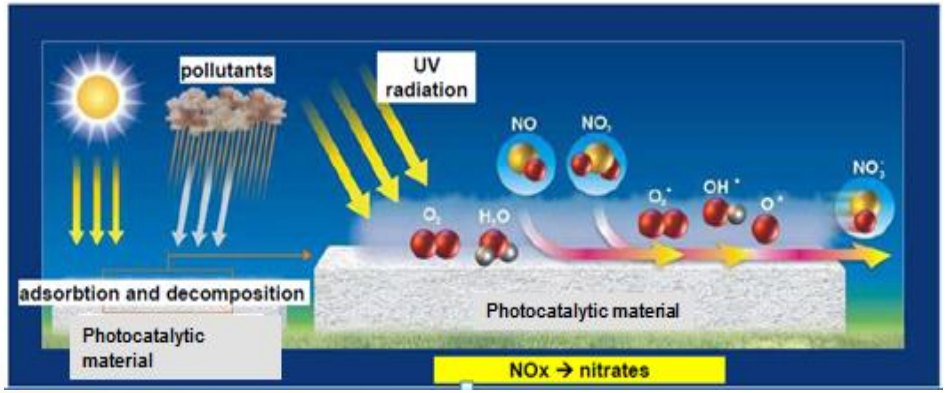
2. Available technologies: Photocatalysis

Photo: light induced phenomenon caused by absorption of ultraviolet or visible light around 400 nm (natural or artificial light)
Catalyst: A substance that causes or accelerates a chemical reaction without itself being affected.

Photocatalysis can be defined as the acceleration of a photoreaction by the presence of a catalyst. In most of the cases the catalyst is made from TiO_2 particles



Source: ITALCEMENTI

When the light of the appropriate energy illuminates the sensitizer, an electron from the valence band promotes to the conduction band, leaving an electron deficiency or hole, h+ , in the valence band and an excess of negative charge in the conduction band, e− , which are oxidizing and reducing equivalents respectively and can participate in redox reaction

Advantages of TiO_2: high chemical stability, nontoxicity, relatively low cost and its highly oxidizing power.

It can be used for **self-cleaning surfaces**, **decomposing atmospheric pollution** and **self-sterilization**

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3. TEXTIL ARCHITECTURE

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Objectives

Generic

To demonstrate the environmental possibilities of textiles with photocatalytic activity in terms of decontamination of urban atmospheres

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PARTNERSHIP

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Partners

The importance of a good and complementary Consortium

Core partners (from Spain)

Coordinator: **CEAM (Mediterranean Center for Environmental Studies)**

Center for research, development and technological innovation to improve the natural environment in the Mediterranean. Activities focused on providing comprehensive proposals for environmental management in the domain of the **atmosphere, ecosystems, human activities and their interactions**.

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Partner 2: **AITEX (Textile Research Institute)**

Center for research, innovation and advanced technical services available to the textile, manufacturing and technical textile sectors

aitex
textile research institute

A first proposal was submitted in LIFE+ 2012 call with other partners, but rejected

Life

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Partners

The importance of a good and complementary Consortium

Complementary partners (Italy and Spain)

Partner 3: **NTT (Next Technology Tecnotessile)**

Research Centre in the textile sector with experience in photocatalysis in other materials

Partner 4: **Quart de Poblet City Council**

Local Public Authority. Demonstration to be held in the town

Partner 5: **LEGAMBIENTE Emilia Romagna**

Non-profit association. Mission: to make the environmental culture the centre of a new kind of development and diffused well-being

Complementary transnational approach

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BUDGET

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Budget

The importance of a balanced and clearly justified budget

The budget needs to be fully justified. All costs have to be reasonable

(In the past, all the partners divided up the total budget "equally". It is not affordable any more).

The costs items needs to be sufficiently detailed or supported by the project description to allow proper assessment of their relevance and added value to the project

It could be difficult for **local** and regional authorities and Public Bodies, but it is necessary to make a great effort to have a credible budget and during the implementation of the project, to make a good justification of all costs.

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SPECIFIC OBJECTIVES

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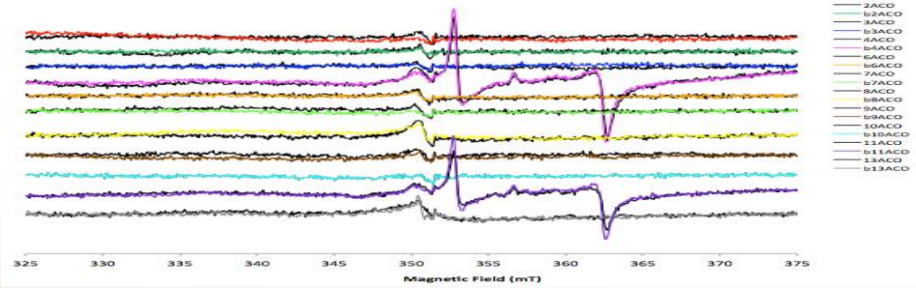
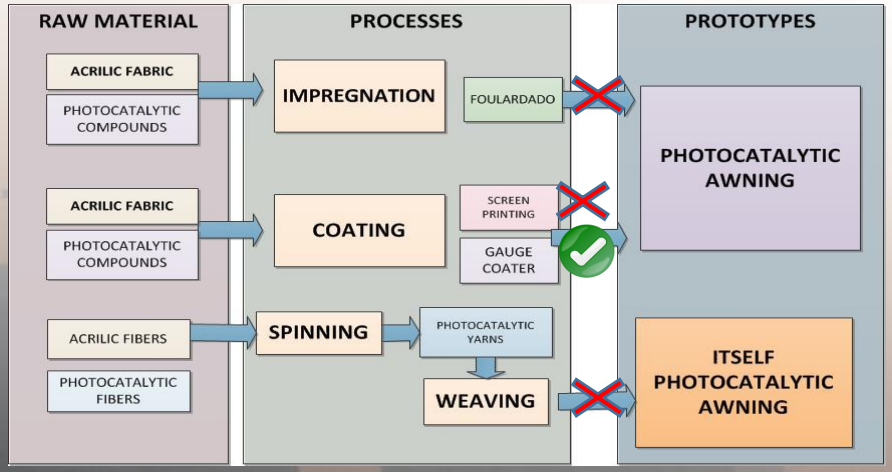
PROJECT Objectives

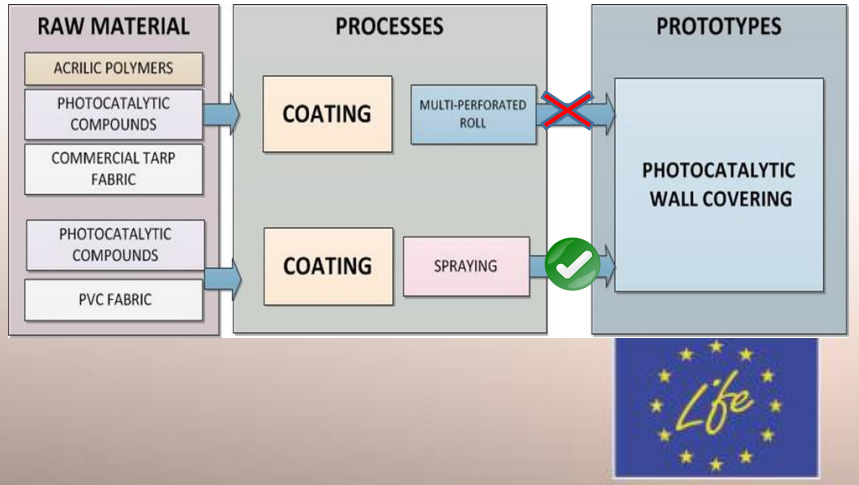
Specific

- To **manufacture photocatalytic textile demonstrators** in order to be applied as depollution systems in urban environments.

- To study the **photocatalytic properties at laboratory and semi-industrial** scale of two types of textile based architecture elements: **awnings and wall coverings**.







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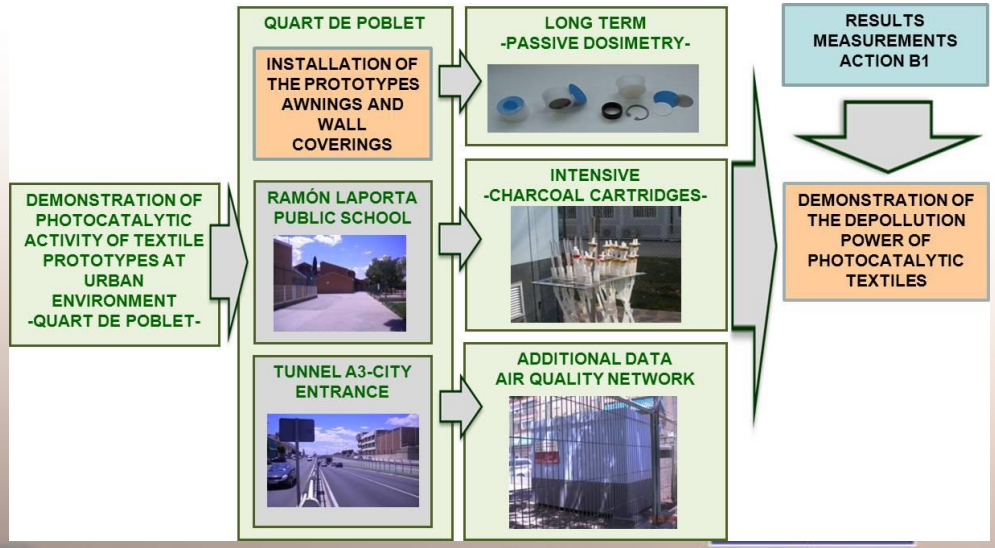
Objectives

Specific

- To demonstrate their application and to estimate its efficiency by **testing the photocatalytic textiles** in a higher scale but **under atmospheric controlled conditions at EUPHORE simulation chamber**.

- **To demonstrate its application in a real polluted environment** by installing some of the photocatalytic textiles in different urban locations at **Quart de Poblet City** (Valencia, Spain) and conducting field measurements before and during the prototypes installation.

- **Provide a basis** to encourage local authorities and stakeholders **to adopt a more integrated approach to urban air quality management** and to implement the techniques and methods successfully tested in PHOTOCITYTEX project.



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Expected results

Demonstration of the effectiveness of photocatalytic textile in order to **reduce the atmospheric concentration of nitrogen oxides (NOx)** to a limit lower than 40 mg/m^3 established by European law.

A maximum reduction rate of 30% in NOx concentration is expected in the chamber tests, whilst a maximum of 20% of reduction is expected in the field campaigns (in the vicinity of the sampling points).
(It must be noted that such NOx depollution is an important figure: **20% NOx reduction will be a very successful result for most of the polluted scenarios considered**)

Benzene, VOCs (Volatile Organic Compounds), HNO_3 (compound related to acid rain), O_3 and **other pollutants will be measured** as an added value to the project. **Reductions in at least one of the compounds** in amounts around 15-20% below the concentrations measured before the application of textile are going to be considered as an **added value benefit**

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Stakeholders and target audiences

- **Industry:** Textile companies, chemical industry
- **Research Centres:** textile, building and environmental sector
- **Regional, national and European Environmental Organizations:** focuses to air pollution, air quality treatments and green solution
- **Platforms and Associations** in which beneficiaries are involved
- **Municipalities and Governments at Regional, National and European Level**

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Implementation activities.

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ACTION B.2:

PHOTOCATALYTIC TEXTILES PROTOTYPING

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SUB-ACTIONS

2.1. Elaboration of technical data sheet for textile elements to be manufactured and employed in demonstration tests

2.2. Manufacture of photocatalytic textiles prototypes at lab scale

2.3. Characterization of photocatalytic textile prototypes developed at lab scale

2.4. Manufacture of photocatalytic textiles prototypes at semi-industrial scale

2.5. Characterization of photocatalytic textile prototypes developed at semi-industrial scale

2.6. Technical report elaboration with all the information generated in previous sub-actions (AITEX).

2.7. Translation of the relevant documents (AITEX).

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SUB-ACTION 2.4-2.5

PHOTOCATLYTIC AWNING: IMPREGNATION PROCESS

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SUB-ACTION 2.4-2.5

PHOTOCATALYTIC AWNING: COATING PROCESS – SCREEN PRINTING

- EXPENSIVE PROCESS.
- TIO2 ON SURFACE DEPENS ON SIZE MESS
- NO POSSIBLE TO INCREASE THICKNESS OF COATING

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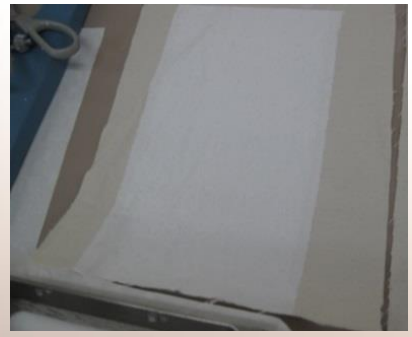
SUB-ACTION 2.4-2.5

PHOTOCATALYTIC AWNING: COATING PROCESS – GAUGE





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SUB-ACTION 2.4-2.5

PHOTOCATALYTIC AWNING: SPINNING PROCESS

Photo-catalytic rayon fiber
SUNDIA
Remarkably Increased Capabilities after Sunlight Exposure

Life

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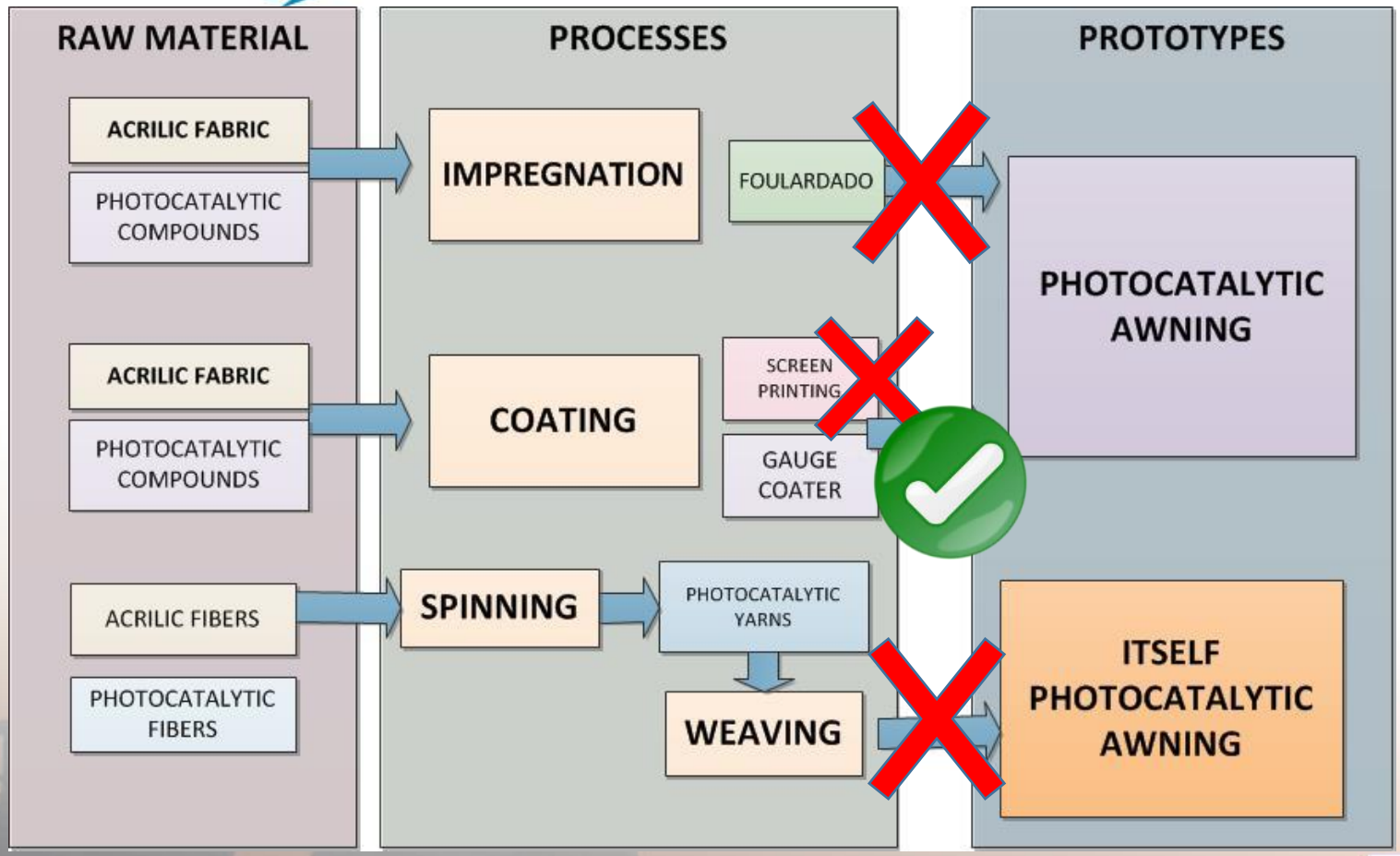
AWNING



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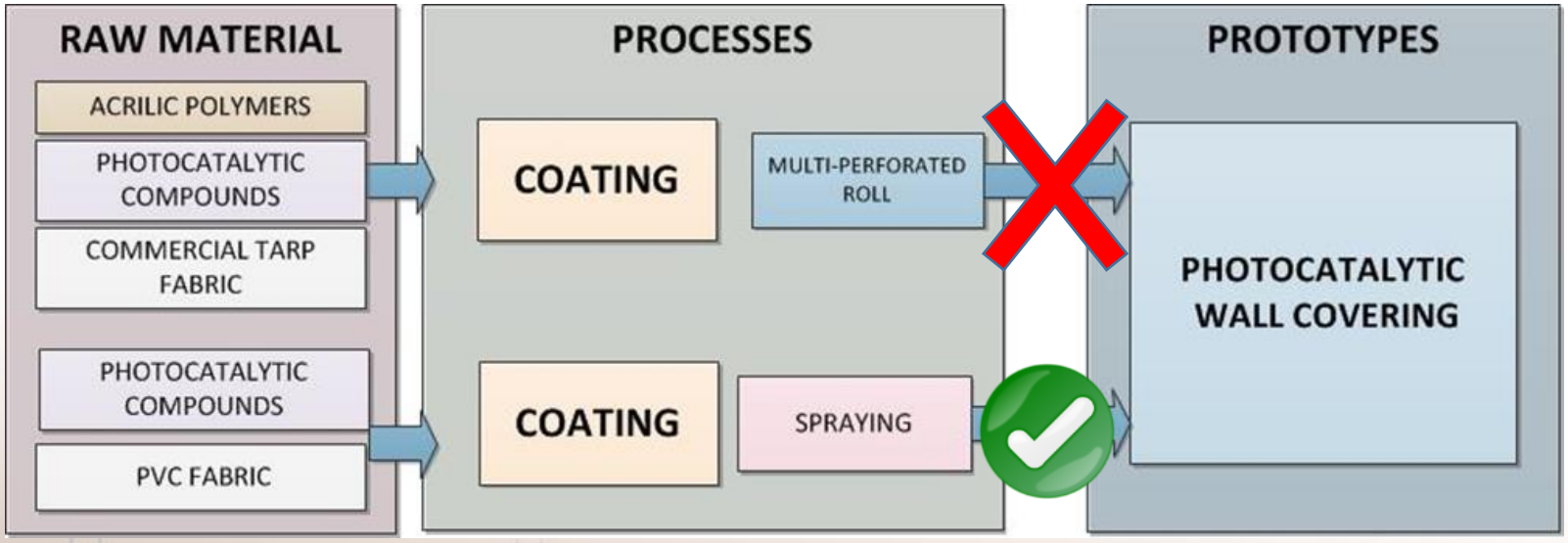
SUB-ACTION 2.4-2.5

WALL COVERING



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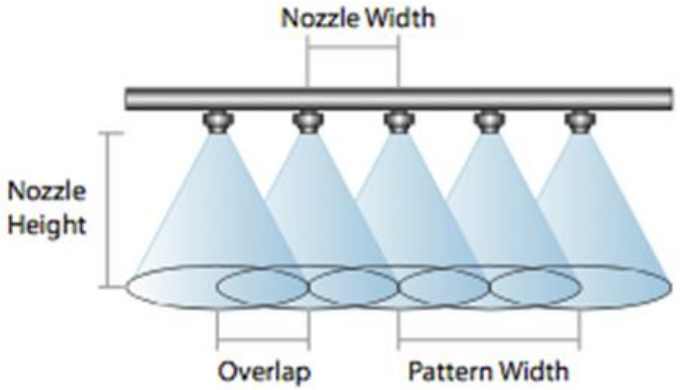
SUB-ACTION 2.4-2.5

WALL COVERING: SPRAYING PROCESS



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CHARACTERIZATION TESTS

- MORFOLOGY(SEM)
- WATER PENETRATION RESISTANCE
- MASS PER UNIT AREA
- DETERMINATION OF TEAR RESISTANCE
- DETERMINATION OF BREAKING STRENGTH AND ELONGATION
- LIGHT EXPOSITION TEST
- FT-IR
- EPR SPECTROSCOPY

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B3. Demonstration of the photocatalytic activity of functional textile prototypes at the EUPHORE simulation chamber

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Foreseen implementation actions

(a) Constant NOx concentration at atmospheric levels
→ to test the NOx retained by the functional prototypes and its potential effect on formation of secondary pollutants. To demonstrate the reduction effectiveness

(b) Daily NOx profiles representative of European polluted environments (A.1): **Bologna, Paris and Quart de Poblet** → to compare with action B4

(c) VOCs/NOx ratio and RH typical conditions representing European scenarios
→ to demonstrate the effect of the photocatalytic textiles on VOCs and NOx reduction and the influence on secondary pollutants formation

Experiments at EUPHORE

B3

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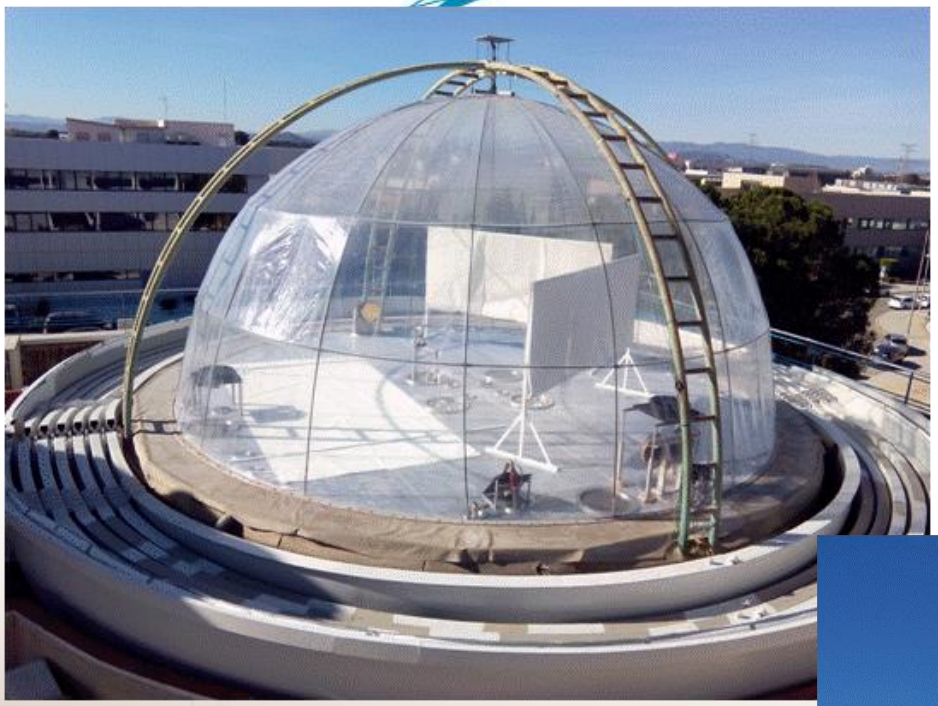

Air volume : 200 m^3

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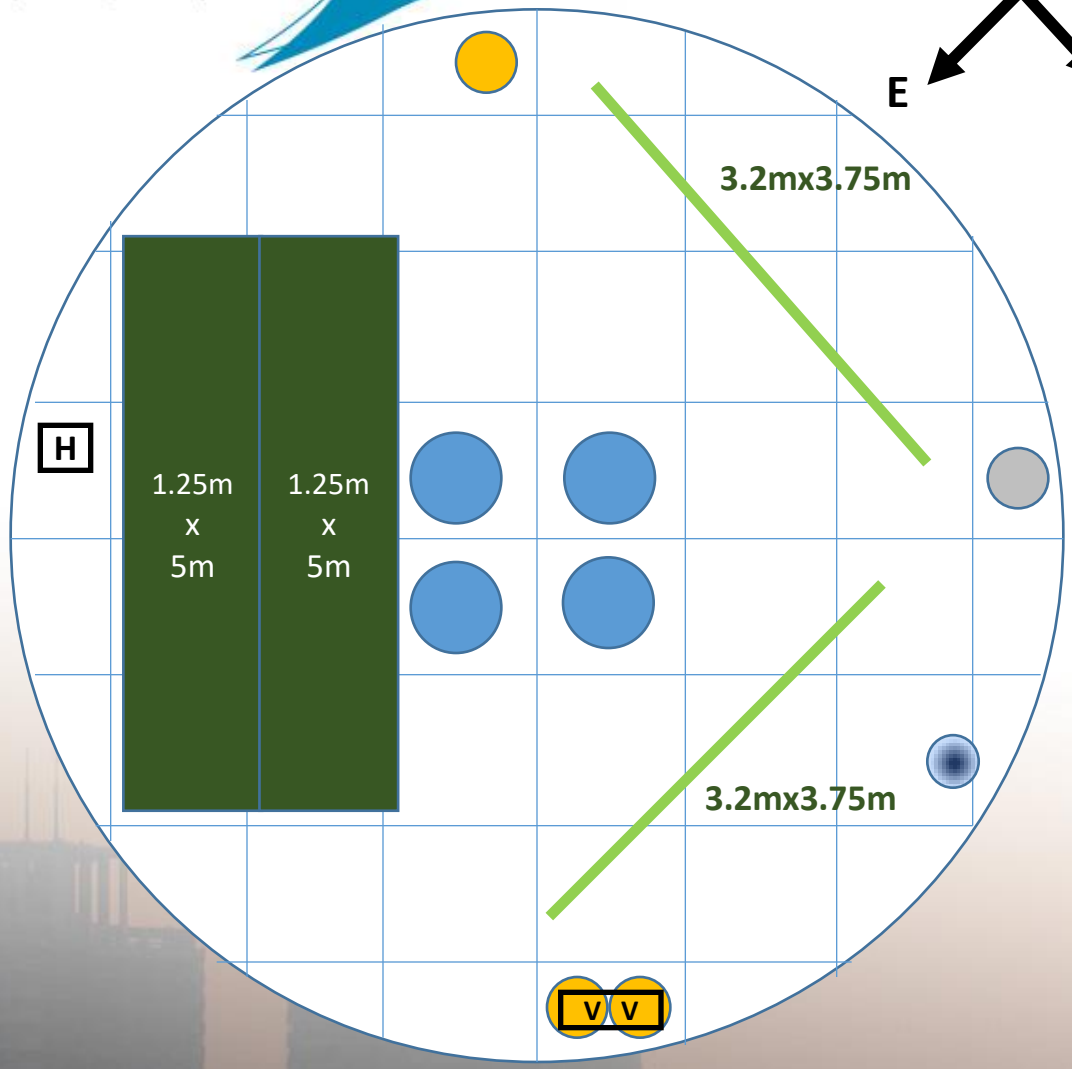
B3

Chamber B

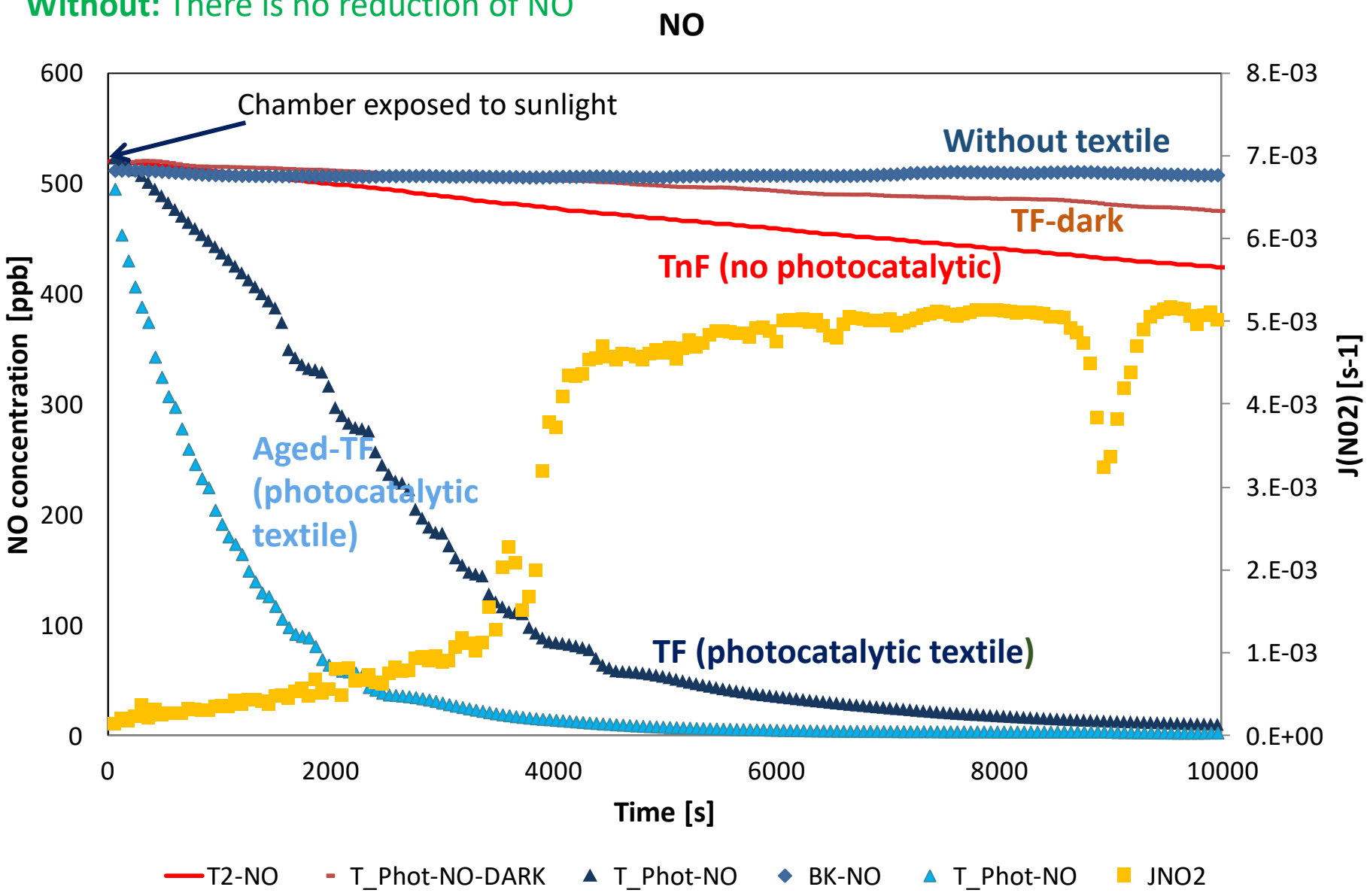


Horizontal area:	12.5 m^2
Vertical area:	24 m^2
TOTAL:	36.5 m^2

RESULTS: Tests with NO addition. School textile NO

TF: Sharp NO reduction due to the textiles, even under very low radiation

Without: There is no reduction of NO

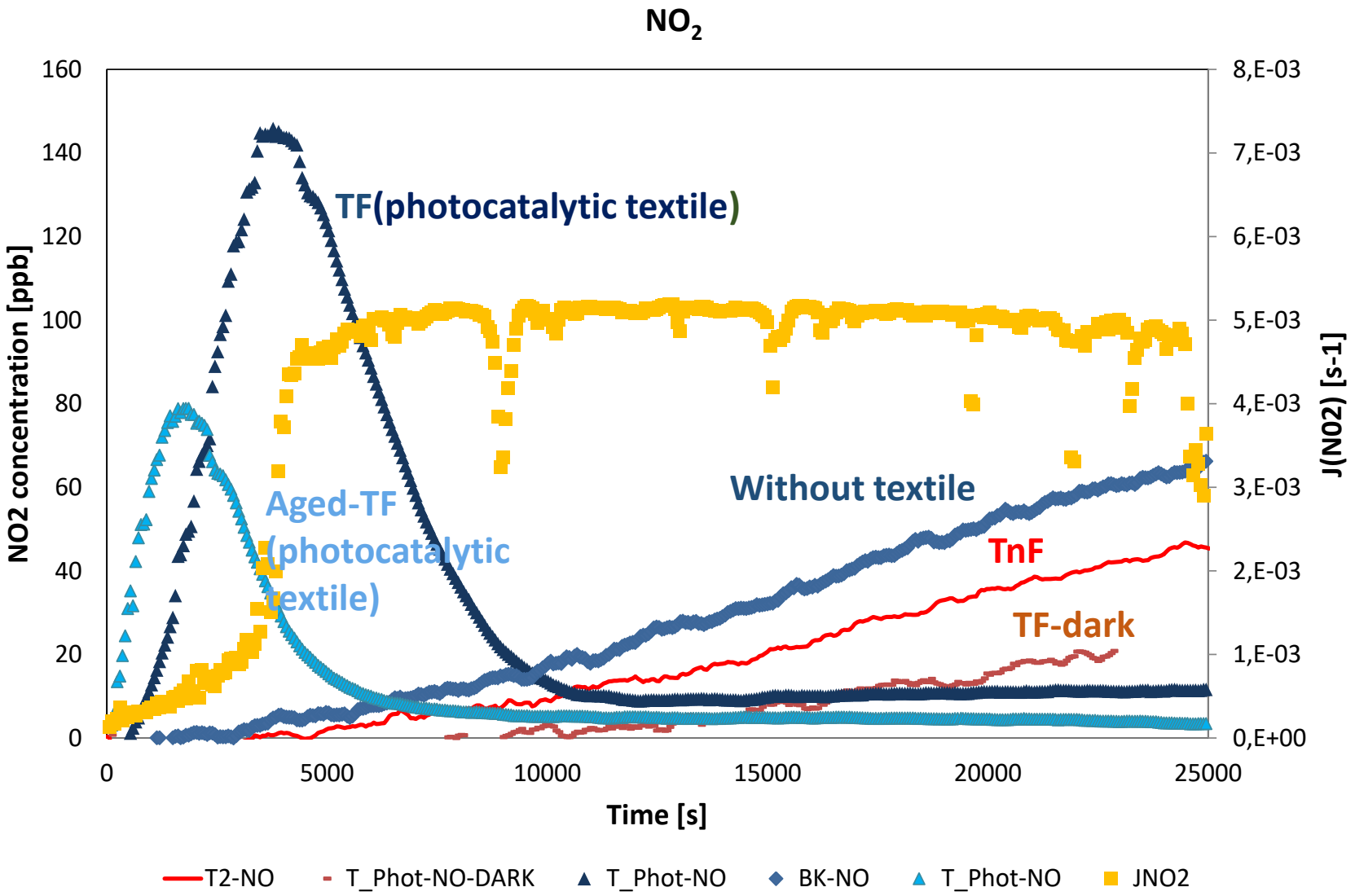


RESULTS: Tests with NO addition. School textile

NO2

TF: NO_2 initially formed but reduced later

Without: NO_2 increases continuously with time



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Activity B1. Environmental measurements of contaminants in selected urban locations before the installation of the photocatalytic textile prototypes

Activity B4. Demonstration of photocatalytic activity of textile prototypes at urban environment-Quart de Poblet

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ENVIRONMENTAL MEASUREMENTS AT URBAN ENVIRONMENTS BEFORE AND AFTER THE INSTALLATION OF THE PROTOTYPES

QUART DE POBLET

RAMÓN LAPORTA PUBLIC SCHOOL

TUNNEL A3-CITY ENTRANCE

LONG TERM MEASUREMENTS

INTENSIVE MEASUREMENTS

ADDITIONAL DATA

PASSIVE DOSIMETRY

CHARCOAL CARTRIDGES (Tenax, XAD-2, DNPH, C18)

GENERALITAT VALENCIANA AIR QUALITY NETWORK

CHARACTERIZATION OF THE AIR POLLUTANTS AT THE AREA OF STUDY

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TEXTILES IN THE TUNNEL

Name: TIO-PVC
Material: PVC FABRIC
Surfactant: SILCOSPERSE
Photocatalytic compound: SIGMA ALDRICH TiO_2

Wall coverings installed in 11th February 2016

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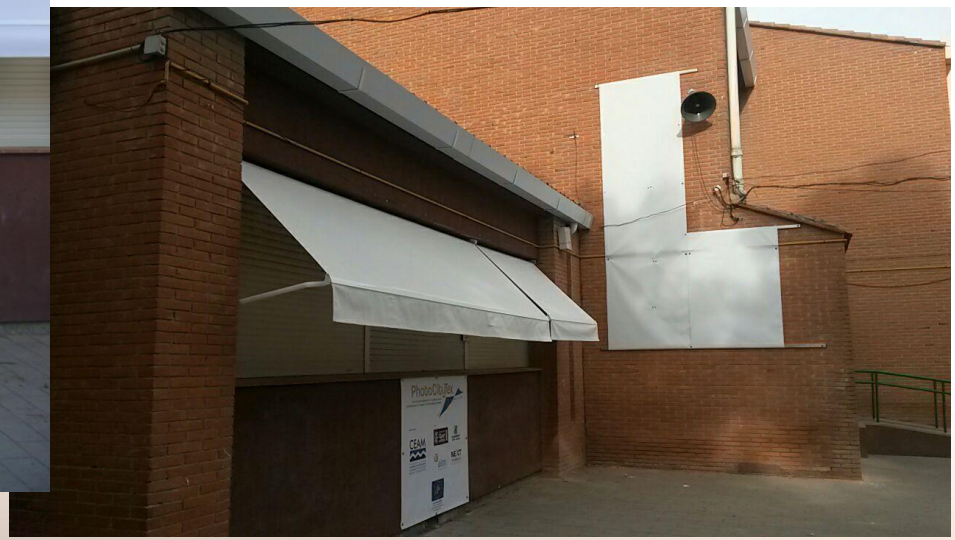
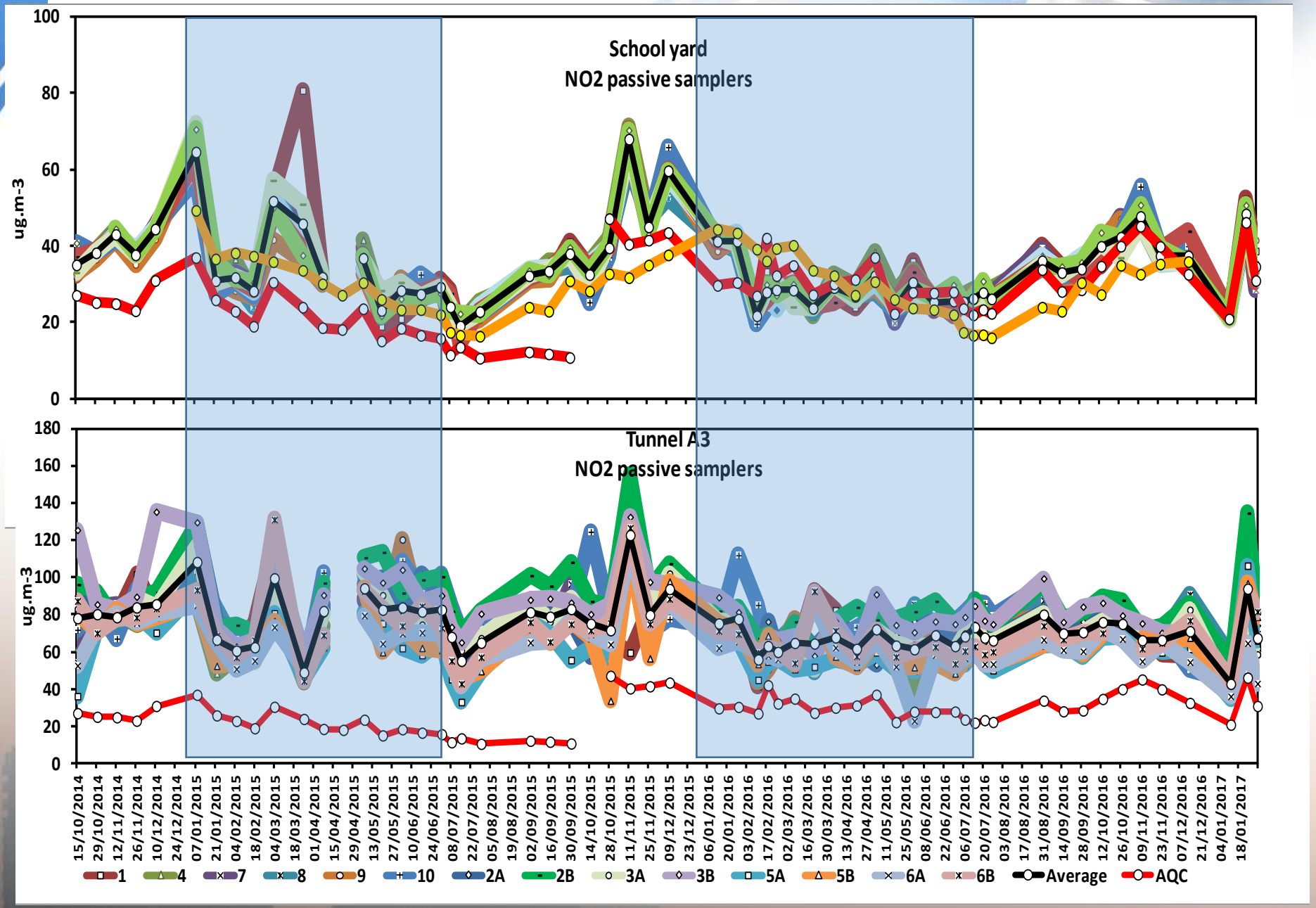
TEXTILES IN THE SCHOOL

Name: PA-F
Substrate: ACRILIC FABRIC
Photocatalytic compound: WD AERODISP W740X

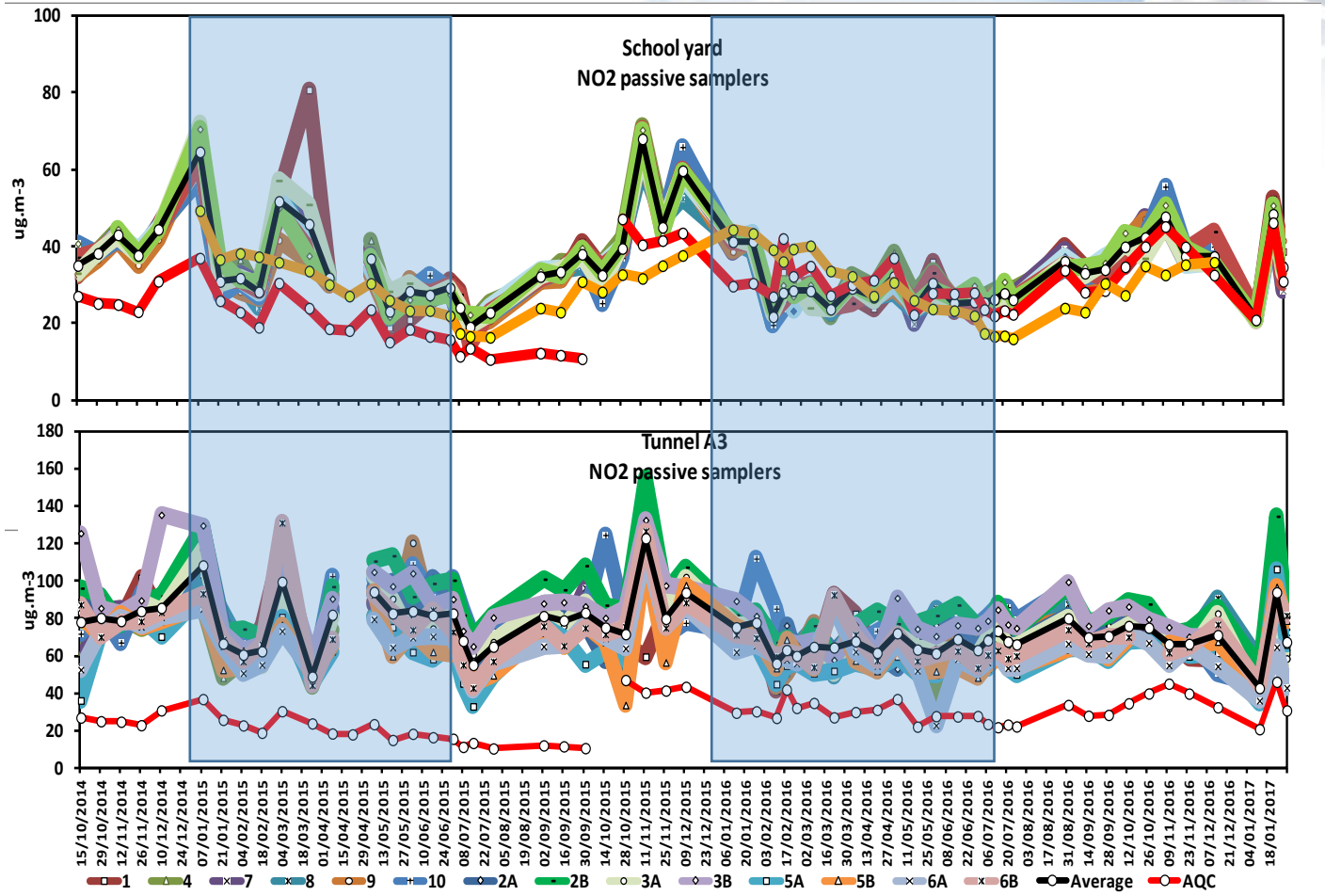


Installed 10th Dec 2015 awning and 17th Dec 2015wall covering

RESULTS. NO2 dosimetry. Extensive campaigns

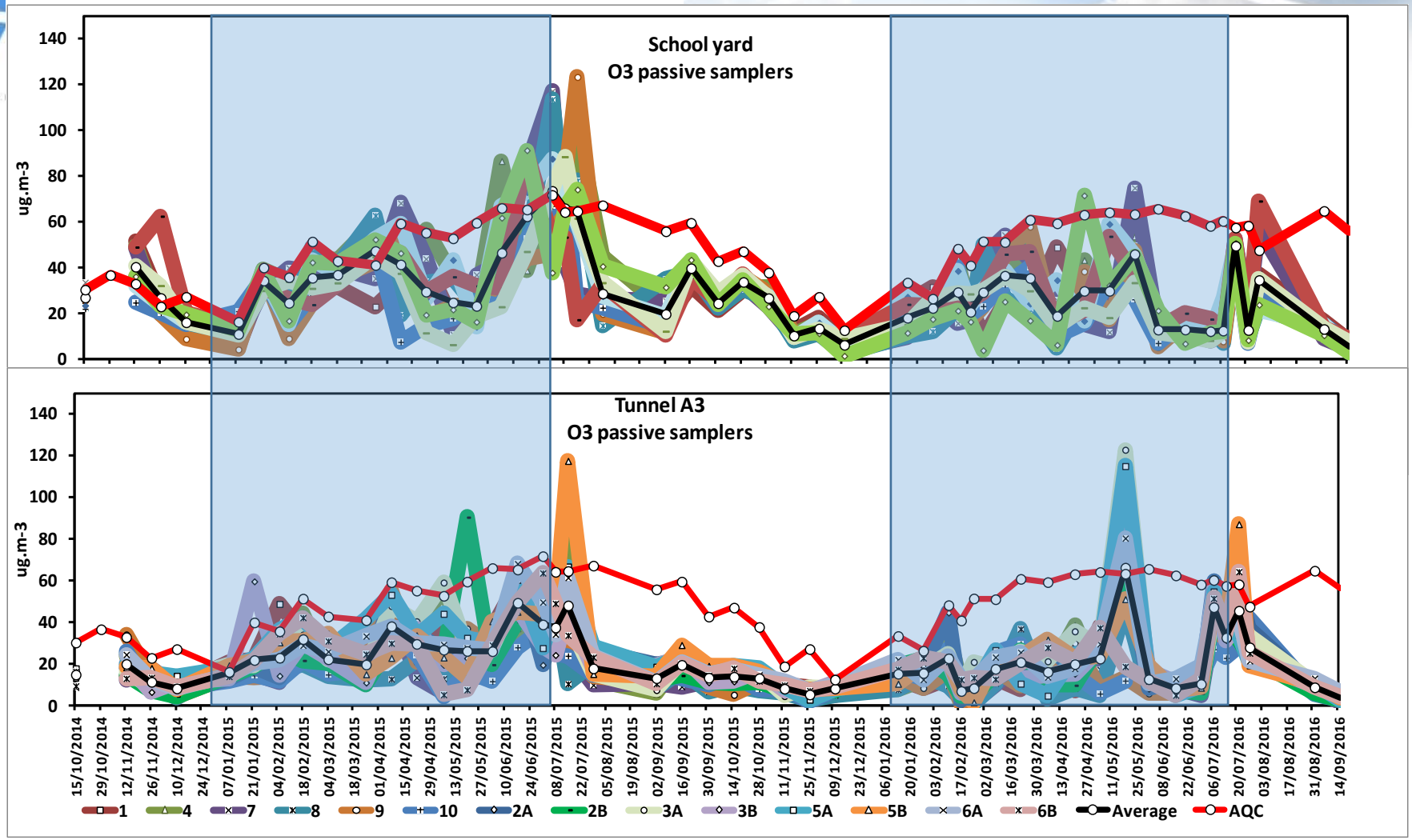


RESULTS. NO2 dosimetry. Extensive campaigns



Textiles	Initial	End	AQC Stat NO2 (ug/m3)	School NO2 (ug/m3)	School NO2 (ug/m3)	Tunnel NO2 (ug/m3)	Tunnel NO2 (ug/m3)
NO	06/01/2015	06/07/2015	20.5	33.6	39.5	76.1	3.7
YES	07/01/2016	08/07/2016	24.1	28.9	28.9	65.9	2.7
Reduction			17.5%	-14.0%	**-26.8%**	-13.4%	**-26.3%**

RESULTS. Ozone dosimetry. Extensive campaigns



Textiles	Initial	End	AQC Stat O3 (ug/m3)	School O3 (ug/m3)	School-norm O3 (ug/m3)	Tunnel O3 (ug/m3)	Tunnel_norm O3 (ug/m3)
NO	06/01/2015	06/07/2015	56.9	43.2	43.3	32.2	0.6
YES	07/01/2016	08/07/2016	57.0	26.4	26.4	24.2	0.4
Reduction			0.2%	-39.0%	**-39.1%**	-24.8%	**-24.9%**

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Conclusions on Implementation activities.

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- Measurements are being taken regularly at the installations to determine levels of air contamination before and after installation, to evaluate the prototype's effectiveness.

- The results obtained, both in the EUPHORE simulation chamber and in the real urban environments in the A3 tunnel and the school are certainly promising:

  - 90% reduction in NOx in an hour, under controlled conditions in at EUPHORE: 35m2 of photocatalytic awning installed in a volume of 200m3 of air; significantly better than expected from initial previsions, which indicated a 30% reduction over 8 hours.

  - 25% reduction in NO2 near the textile in a real environment: Annual readings before and after installation returned reductions of NO2 of 25% near the installation, which is a real improvement over the calculated reduction of 20%.

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- Reduction in the ozone levels:

  An additional reduction of ozone was reported near the awnings, which is a definite benefit to health given the irritation that ozone causes to the upper respiratory system.

- It has been successfully demonstrated that the use of a photocatalytic compound on a textile substrate significantly improves the results previously achieved on other types of material such as cement and paint. The implications for health and air quality are clear: the use photocatalytic textiles is an effective component in the fight to reduce NOx levels and should be combined with other, less popular measures such as reducing the use of private cars, lessening the severity of these unpopular measures on road users. We should be urging local authorities to adopt their use and adapt them to their plans for environmental improvement.

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Social-economic impact.

Long-term benefits

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C.2 Monitoring the socio-economic impact

Investigation on social impact of air quality improvement on:

A. **Citizens awareness**

B. **Productive and business sector** (production increasing for the technical textile sector and awning solutions producers)

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C.2
A. Investigation on citizens awareness -

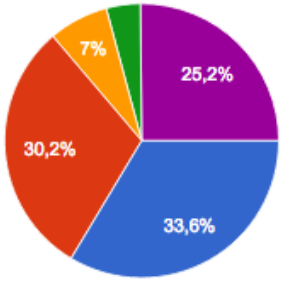
- For designing the tool to be used in QDP, **it has been realised in Italy and Spain an activity of data collection** focusing on a specific target of people (students aged 14-18), citizens (18-99)

More than 700 questionnaires collected

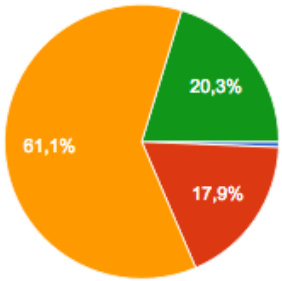
Italy – The results

DOMANDE RISPOSTE

Quali sono le fonti di maggiore inquinamento

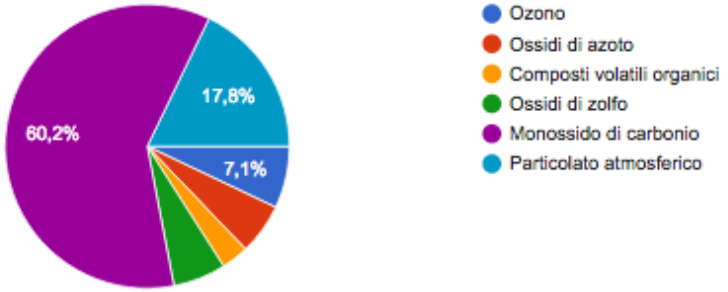


Cos'è il particolato atmosferico? (458 risposte)

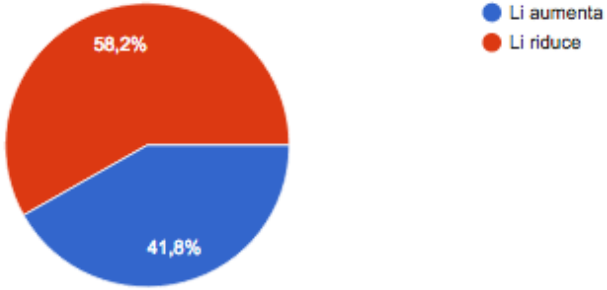


DOMANDE RISPOSTE 504

Quale tra le seguenti sostanze inquinanti è quella che ha maggior impatto sulla salute dell'uomo?
(482 risposte)



Secondo te, la pioggia aumenta o riduce gli effetti nocivi del particolato?
(481 risposte)



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C.2
B. Impact on productive and business sector

Investigation on economic benefits regarding PhotoCityTex results exploitation, through **an estimation of**:

production/sales increasing for chemical/technical textiles/awnings sector.

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Variable costs evaluation -

COSTS	Variable Costs in € for the production of 1 m^2 of photocatalytic fabric
PVC fabric	€ 2,68
TiO_2 Sprying	€ 0,76
Depreciation Sprying machinery and drying	€ 0,81
Personnel	€ 0,95
TOTAL	€ 5,20

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Market targets previsions - Italy

Textile tested by NTT

Market Targets	Production (m^2/year)	Price (€/m^2)	Turnover (million €)
2019	100000,00	8,40	0,84
2020	130000,00	8,40	1,092
2021	180000,00	8,40	1,512

- According to TIE SpA annual production capacity (stable for the years 2018 and 2019)
- Inflation rate computed according to BCE estimation till 2021: 1.6% (2018); 1.8% (2019); 2.0% (2020); 2.2% (2021)

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Profits and Losses Forecast - Italy

	2019	2020	2021
Revenues	**€ 840.000**	**€ 1.092.000**	**€ 1.512.000**
Sales Revenues	€ 840.000	€ 1.092.000	€ 1.512.000
Costs	**€ 489.000**	**€ 603.044**	**€ 794.511**
Operating Costs	€ 369.000,00	€ 481.144,00	€ 670.478,85
PVC fabric	€ 268.000,00	€ 355.368,00	€ 502.873,06
TiO2 Sprying	€ 76.000,00	€ 100.776,00	€ 142.605,79
Depreciation Sprying machinery and drying	€ 25.000,00	€ 25.000,00	€ 25.000,00
Personnel	€ 95.000,00	€ 96.900,00	€ 99.031,80
Profit/loss before tax	**€ 351.000**	**€ 488.956**	**€ 717.489**

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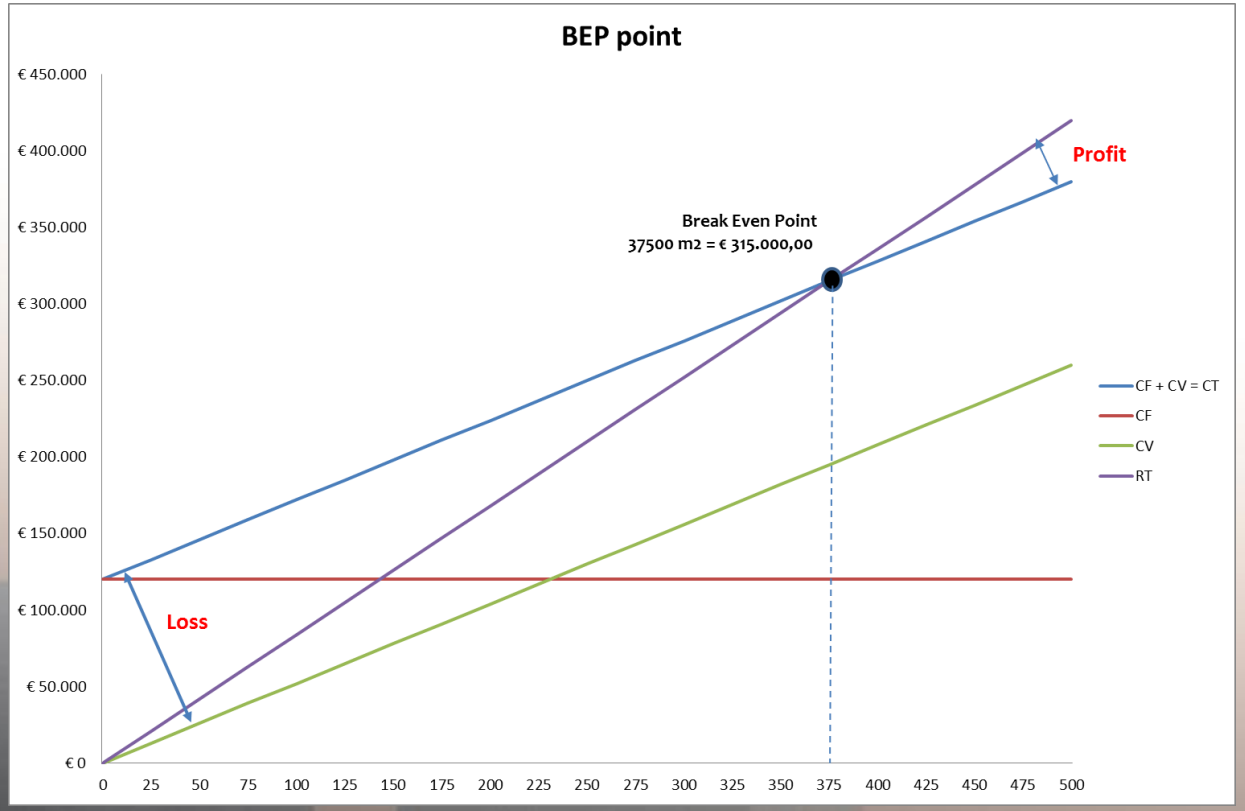
Break-even analysis - Italy

The break-even point is the time when costs equal revenues and the costs are revenues values for this parity. Break-even analysis is a useful tool to provide a dynamic view of the relationships between sales, costs and profits for different price levels.



CF = fixed costs
CV = variable costs
CT = total costs
RT = total revenues

Q = break even point = CF/(Selling Price – CV)

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Market targets previsions

- To reach the goal of Action C.2 partners met one of the biggest producers of awnings and outdoor fabrics for sun protection and furnishings: “PARA’ spa” http://www.para.it/

- “PARA’ spa” already took part into an Italian project on photocatalytic applications (pavements, ceramics, other) but appreciated very much the monitoring campaigns and results of PhotoCityTex project.

- The Italian partners and the company agreed to exchange data and information about the costs of the textiles in order to check the possibility to work on a market prevision based on PARA’ market model.

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Problems encounterd during project implementation

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Problems encountered

- **Overall, the project is progressing adequately**.
- No management problems have been encountered and communication among the partners runs smoothly to date. **Partner roles are clearly defined** and to the largest extent they are executed as described in the technical annex of the project.
- Although a **delay in the completion of activity B2** with respect to the scheduled program has been encountered, it will not affect the overall aim of the project and does not require any modification of the expected finalization time as the project, and specially activities B3 and B4, were planned taking into account possible delays in the previous activities, and a **buffer time was considered in the proposal**.

Such six-months shifted have been due to:

- The main conclusions from Activity A1 is that January and July are more suitable to represent the average winter and summer conditions, respectively for the active campaigns in B1 and B4 and some of the tests in B3, instead of November and May, previously foreseen.
- Final delivery of the prototypes, foreseen on the 31th August 2015 was finally achieved in December 2015 for awning prototype and January 2016 for wall covering prototype.

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Problems encountered

- Final delivery of the prototypes, foreseen on the 31th August 2015 was finally achieved in December 2015 for awning prototype and January 2016 for wall covering prototype.

Awning prototype:

- **Acquisition of raw material**: the photocatalytic fiber was acquired from Japan and some delays occurred during transport.
- **Identification of spinning technological partner**: finding **an external service** for spinning process at lab scale was very difficult, actually, it was decided to look for an industrial supplier, in order to spin the Sundia fiber at semi-industrial scale directly.

Wall covering Prototype:

- Problems were faced with the **pilot production of TiO_2 coated PVC**: Although the wall covering prototype at semi-industrial scale was initially manufactured in **November 2015, degradation of the textile was observed, so** changes in the manufacturing process were necessary in order to manufacture the wall covering prototype with the needed Quality. Due to the availability of the manufacturing company for carrying out these changes in the productive process, the wall covering prototype to be installed a Quart de Poblet was supplied at the end of January 2016.

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¡Thanks!

http://www.ceam.es/PHOTOCITYTEX

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