

Evaluation of measures for air pollution abatement in Pamplona, Spain

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- Effect of urban vegetation on air quality.
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 - CFD simulation
 - External cost (health)
- Effect of traffic rearrangements:
 - CFD simulation
 - External cost (health)



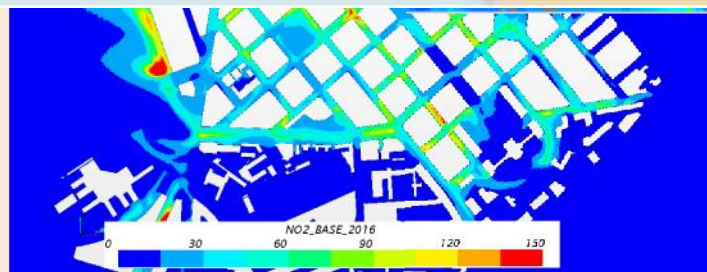
LIFE-RESPIRA project

- ❑ 2014-2017
- ❑ **Participants:** Universidad de Navarra, CIEMAT, GANASA
- ❑ **General objective:** Assessment of cyclists and pedestrians exposure to urban air pollution.
- ❑ **Some specific ob**

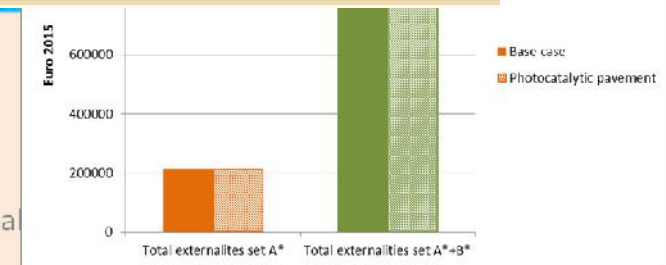
- High resolution
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Investigating effect of urban vegetation

- Experiments in street canyons.
 - Two streets. One with trees and other without trees.
 - Simulations with CFD model.
- Experiments in roads crossing urban parks:
 - Effect of trees
 - Effect of shrubs hedge in the sidewalk
 - Simulations with CFD model.

Effect of street trees on air pollution dispersion

Field campaigns Pamplona



Tafalla st



San Fermín st

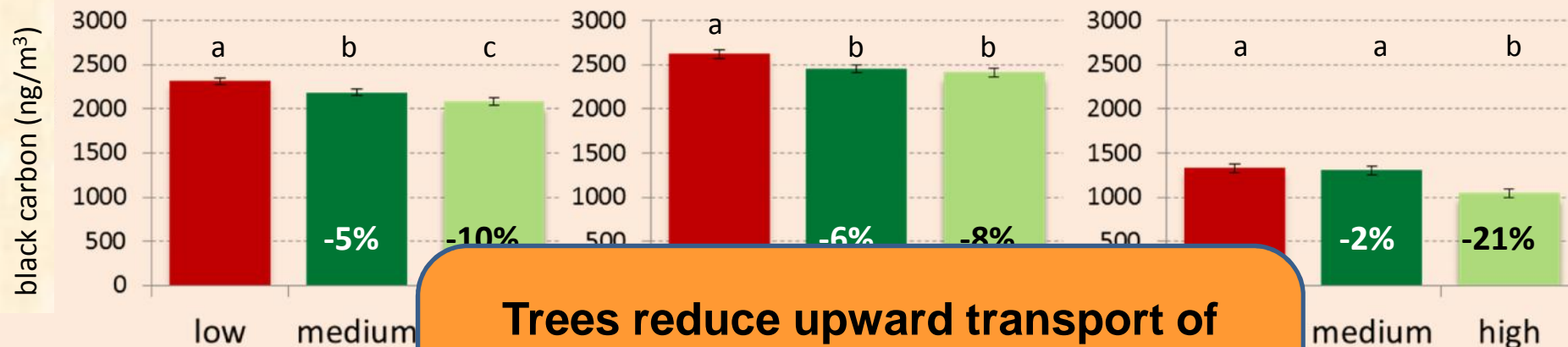


Effect of street trees on air pollution dispersion

19 July- 2 August 2016, Field experiments

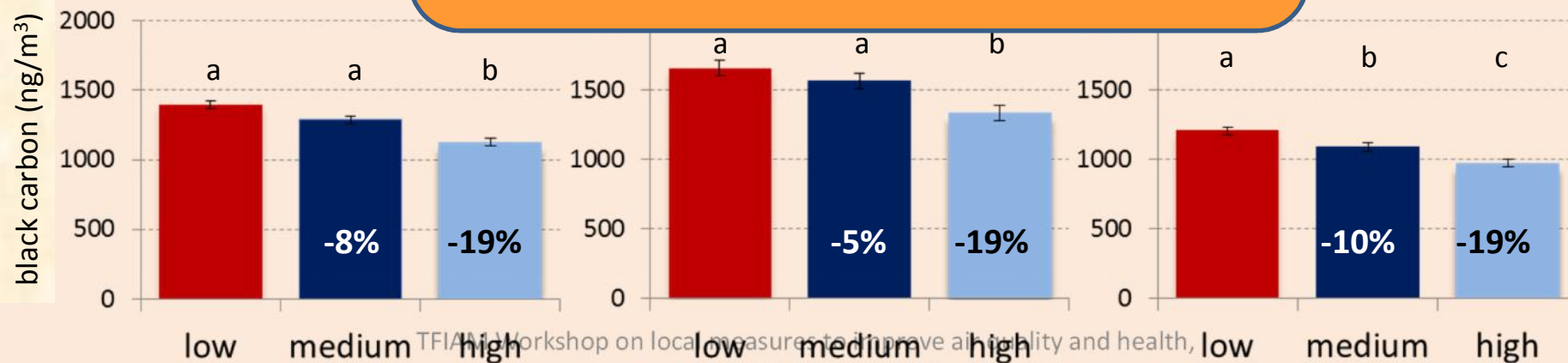


San Fermín st, with trees



Trees reduce upward transport of vehicle emissions and increase air pollution within canopy

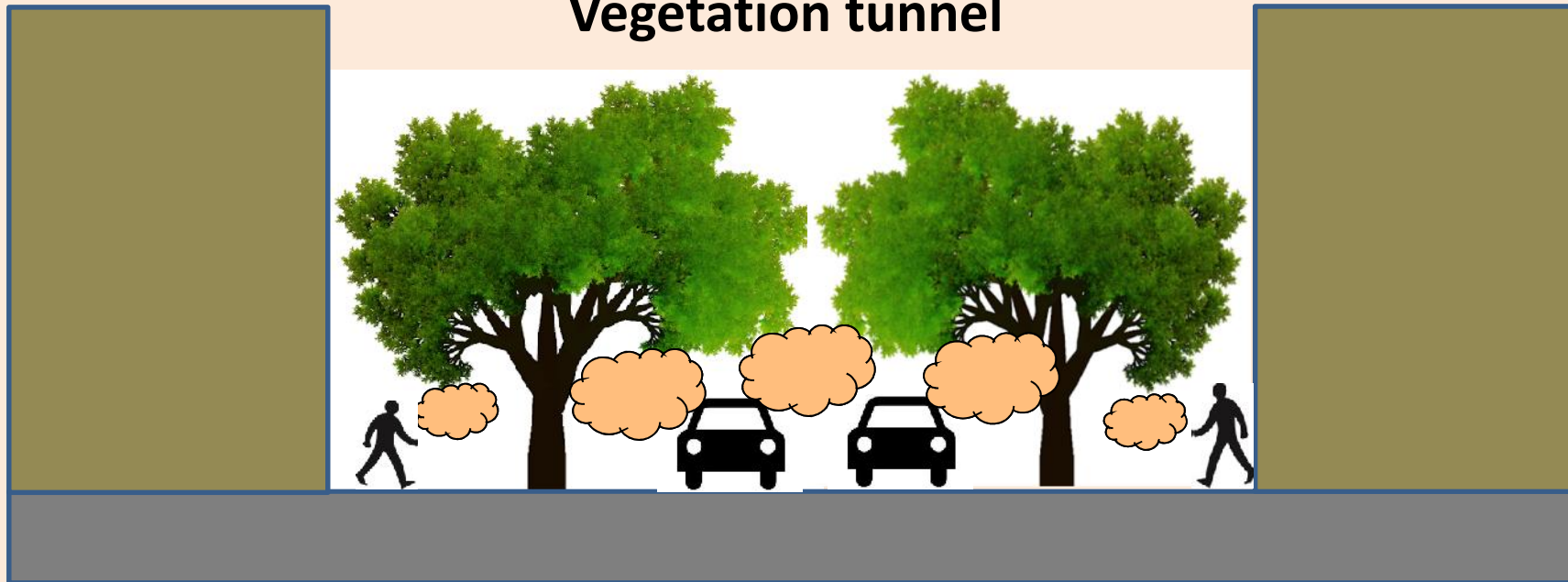
Tafalla st, no trees



Effect of street trees on air pollution dispersion



Vegetation tunnel



Effect of street trees on air pollution dispersion

Model simulations

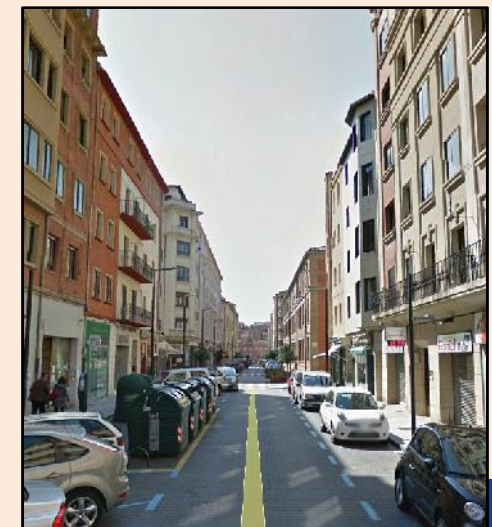
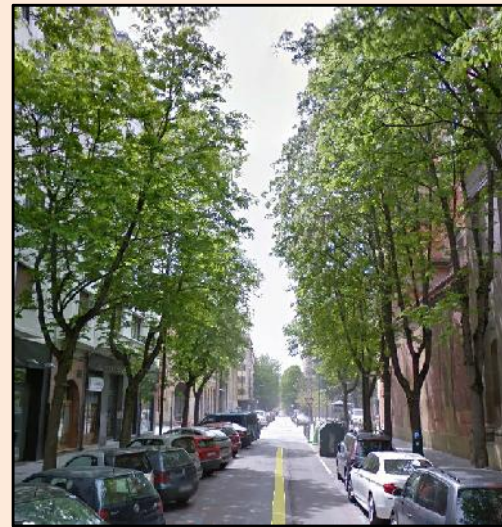
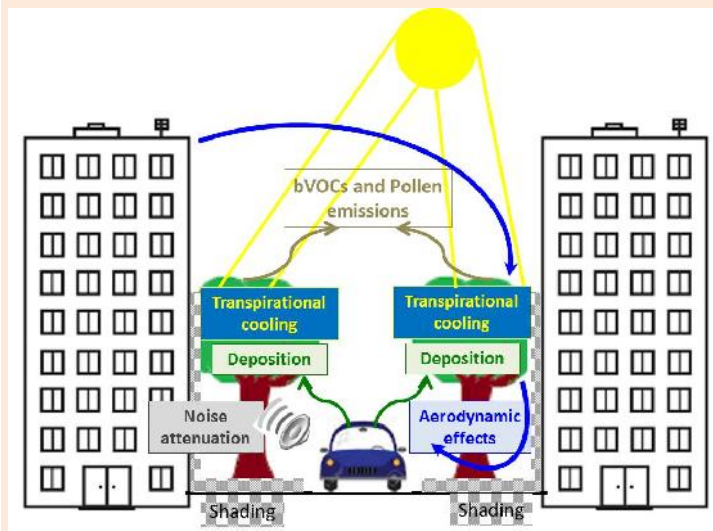
Main objective:

Estimate effect of street vegetation on air quality taking into account two important aspects:

- Dynamical effects (modifying air flows, turbulence and ventilation)
- Removal effects (vegetation is a sink of air pollution by deposition).

Studied:

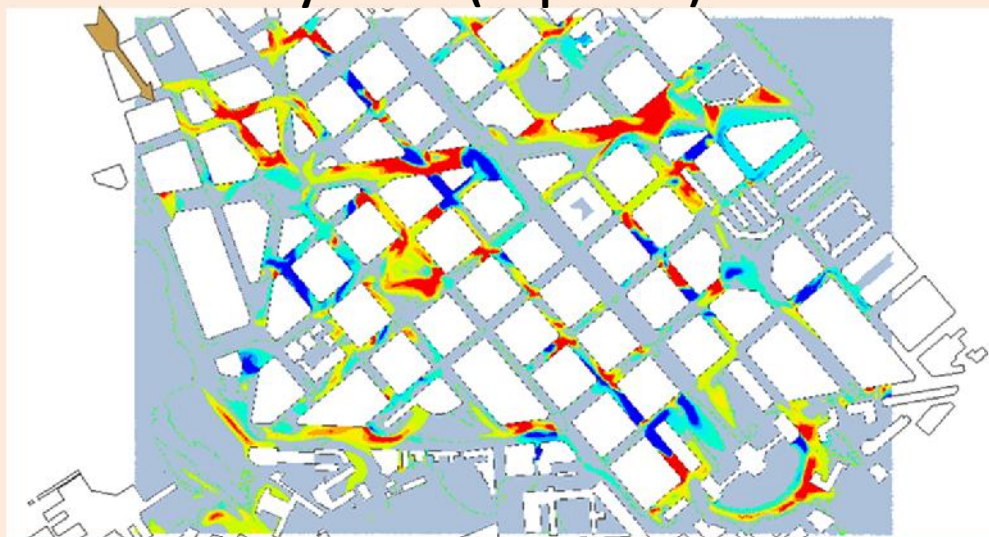
- ✓ How do trees affect NO_x distribution in an urban district at pedestrian level?
- ✓ What happens if trees are planted in the free-tree street?



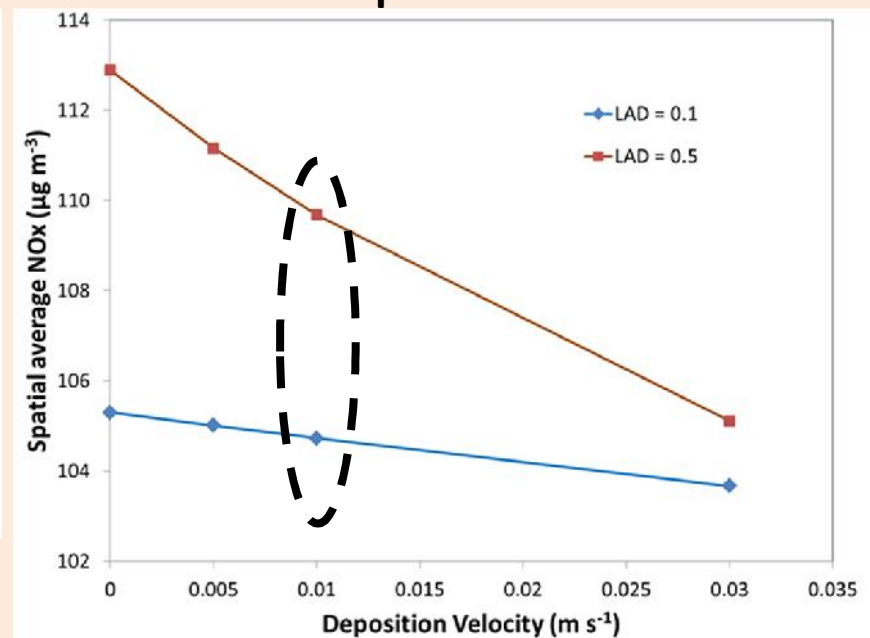
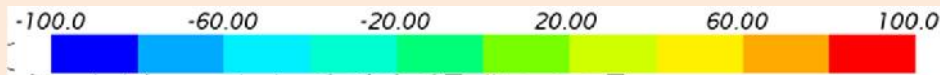
Effect of street trees on air pollution dispersion

CFD simulations

- What happens if the foliage is more dense (increasing Leaf Area density, LAD)?
- What happens if the deposition velocity of pollutants captured by trees increases?
- Several high resolution CFD-street canyon modelling for a dominant wind direction (NNW) and for several scenarios of deposition velocity and LAD
- **Aerodynamics (dispersion) effects seem to dominate over deposition effects.**



NO_x (LAD=0.5) – NO_x(LAD=0.1) ($\mu\text{g m}^{-3}$)



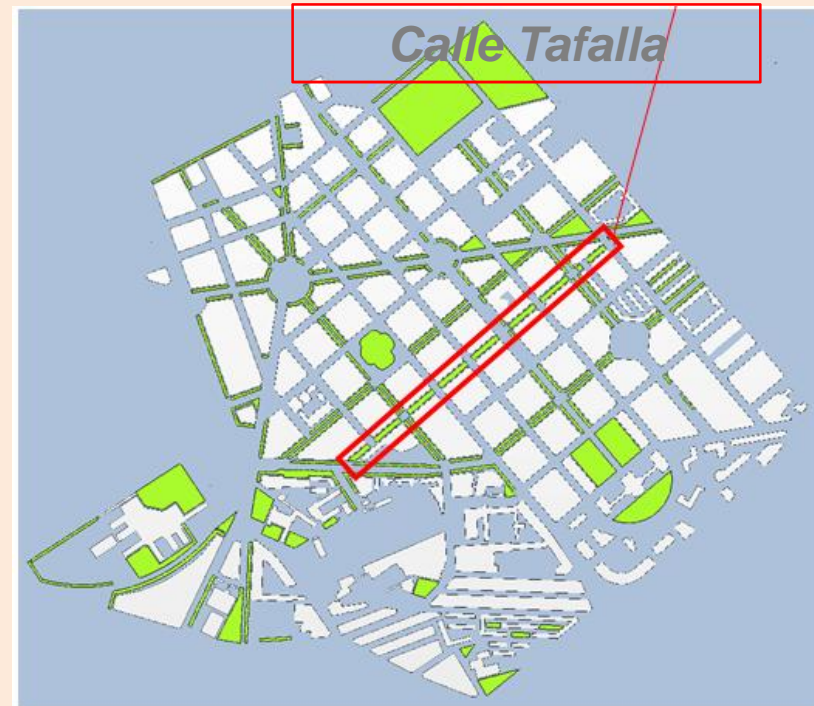
Effect of street trees on air pollution. CFD simulations

What happens if trees are planted in a tree-free street?

High resolution CFD-street canyon modelling for a dominant wind direction (NNW)



Real case



Scenario with new trees in Tafalla street

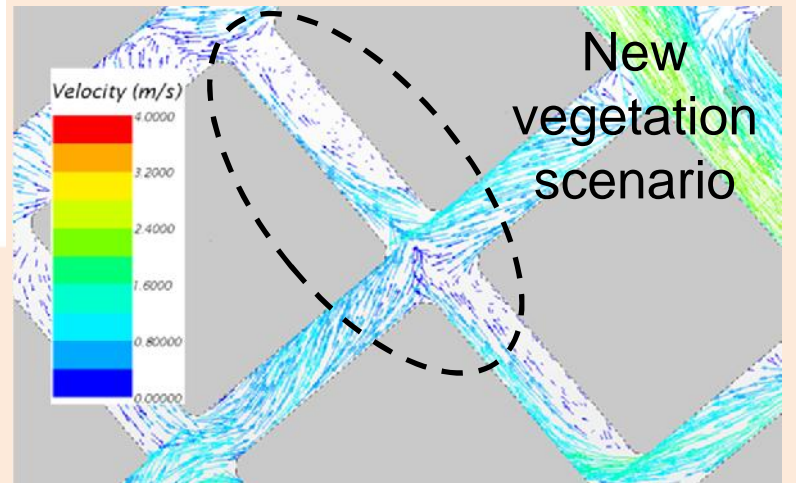
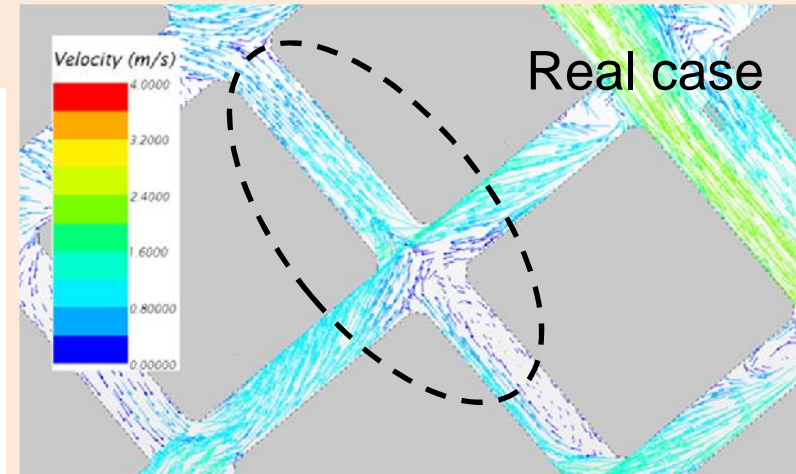
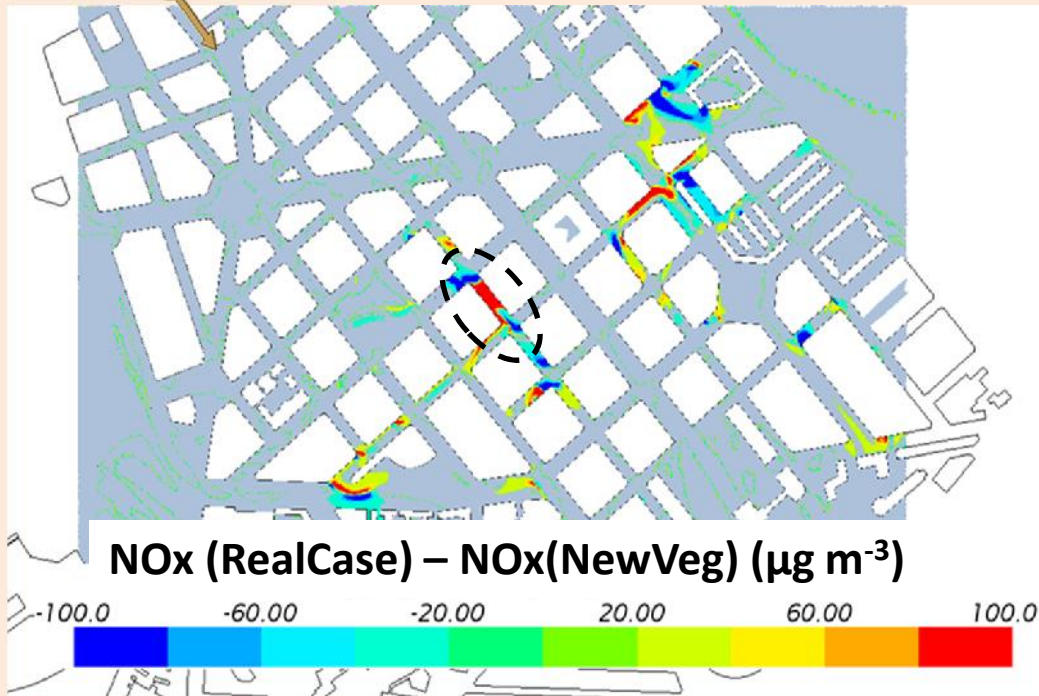
Effect of street trees on air pollution dispersion

CFD simulations

What happens if trees are planted in a tree-free street?

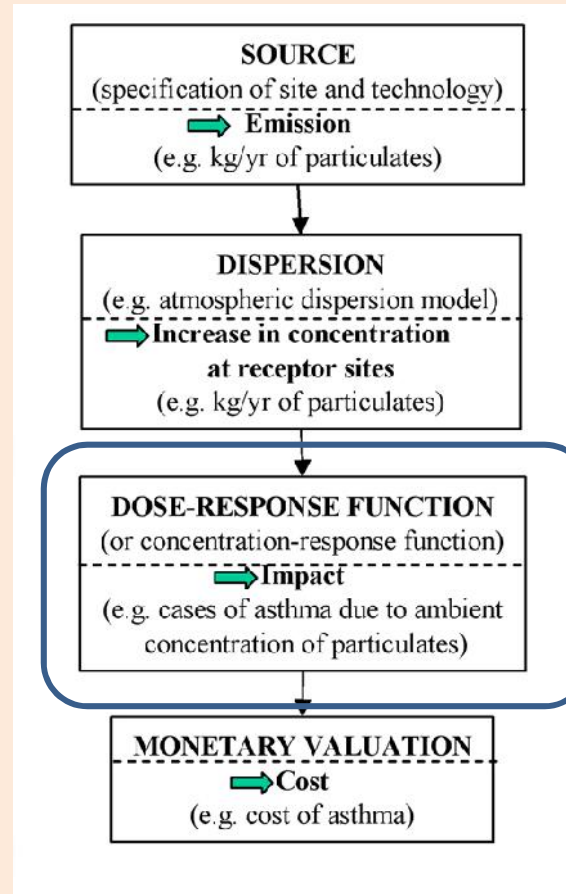
High resolution CFD-street canyon modelling for a dominant wind direction (NNW)

LAD=0.5 m⁻¹; vdep= 1 cm/s



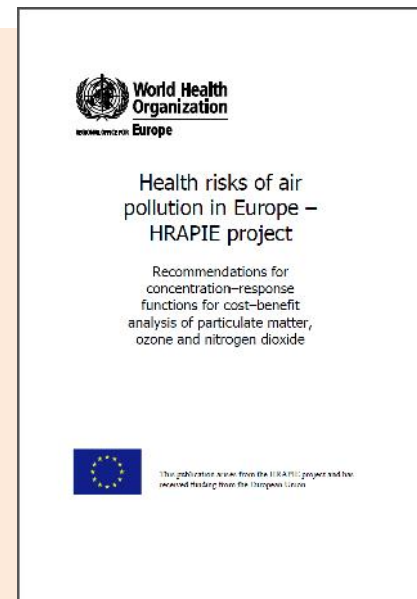
The inclusion of new trees in one street modifies significantly pollutant distribution not only in that street, but also in nearby streets.
Global effects in pollutant concentration are small

External Cost (health) of mitigation measures. Effect of street trees on air pollution dispersion



Concentration-response functions

WHO, 2013. Health risks of air pollution in Europe – HRAPIE project
Recommendations for concentration–response functions for cost–benefit analysis of particulate matter, ozone and nitrogen dioxide



We were focused on NO₂

External Cost (health) of mitigation measures. Effect of street trees on air pollution dispersion

Monetary values

Holland, M. Cost-benefit Analysis of Final Policy Scenarios for the EU Clean Air Package. Version 2. Corresponding to IIASA TSAP Report 11, Version 2a October 2014

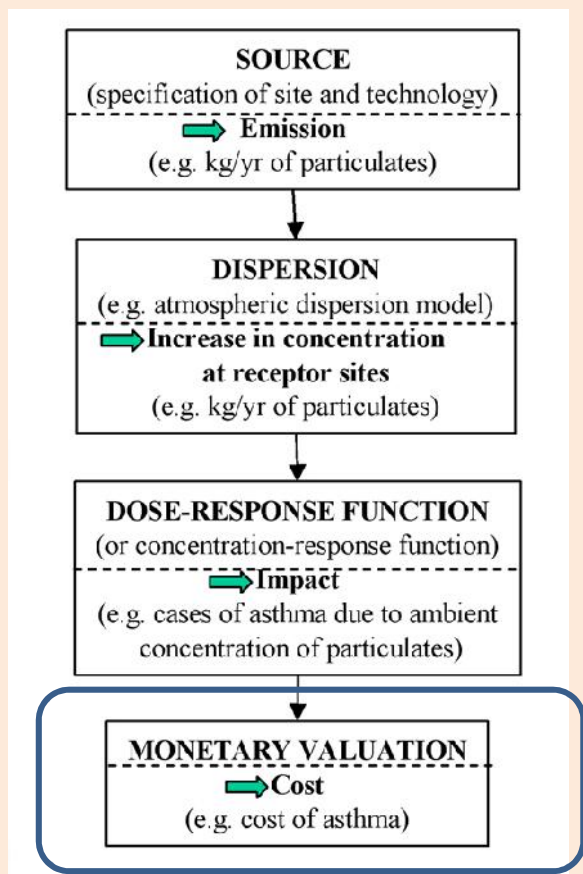


Table 2.4. Updated values for the health impact assessment (price year 2005)

Impact / population group	Unit cost	Unit
Ozone effects		
NO₂ effects (though not quantified in this report)		
Mortality from chronic exposure as: Life years lost, or Premature deaths	57,700 / 133,000 1.09 / 2.22 million	€/life year lost (VOLY) €/death (VSL)
Mortality from acute exposure	57,700 / 138,700	€/life year lost (VOLY)
Bronchitis in children	588	€/case
Respiratory Hospital Admissions	2,220	€/hospital admission

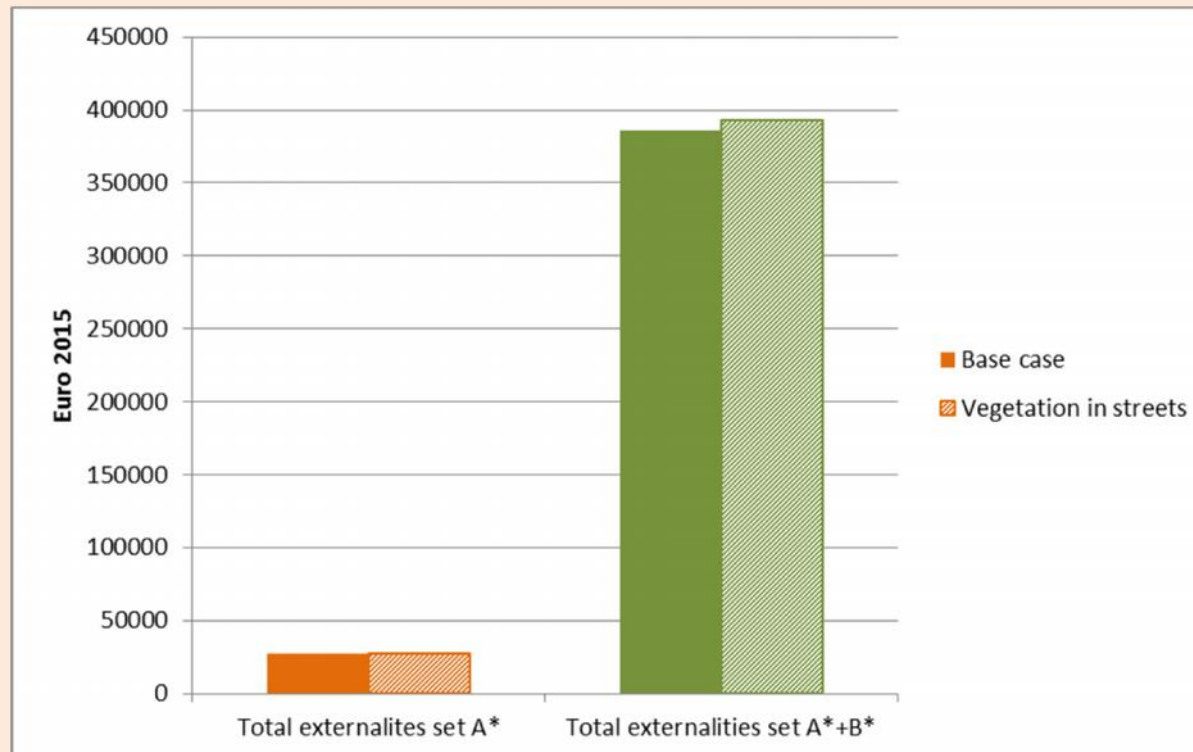
Updated for inflation to 2015 prices

	Monetary value	Unit
Mortality	68,143.70 €	Euro ₂₀₁₅ /life year lost
Bronchitis in children	694.43 €	Euro ₂₀₁₅ /case
Respiratory hospital admissions	2,621.82 €	Euro ₂₀₁₅ /case

External Cost (health) of mitigation measures. Effect of street trees on air pollution dispersion

What happens if trees are planted in a street without trees?

High resolution CFD-street canyon modelling + concentration-response functions + monetary valuation

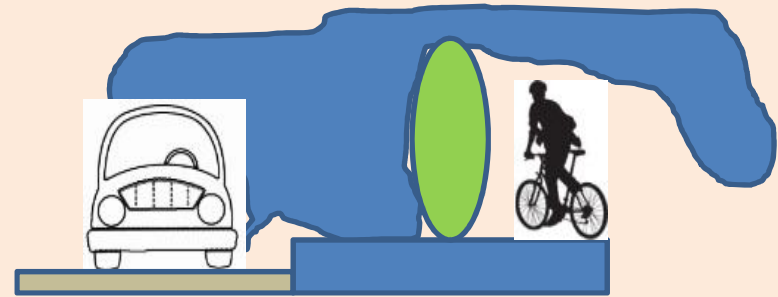


Group A* (pollutant-outcome effects for which enough data are available for a reliable quantification)
Group B* (pollutant-outcome effects for which there is more uncertainty) effects are quantified.

Experiments in streets crossing urban parks:

Effect of shrubs hedge in the sidewalk

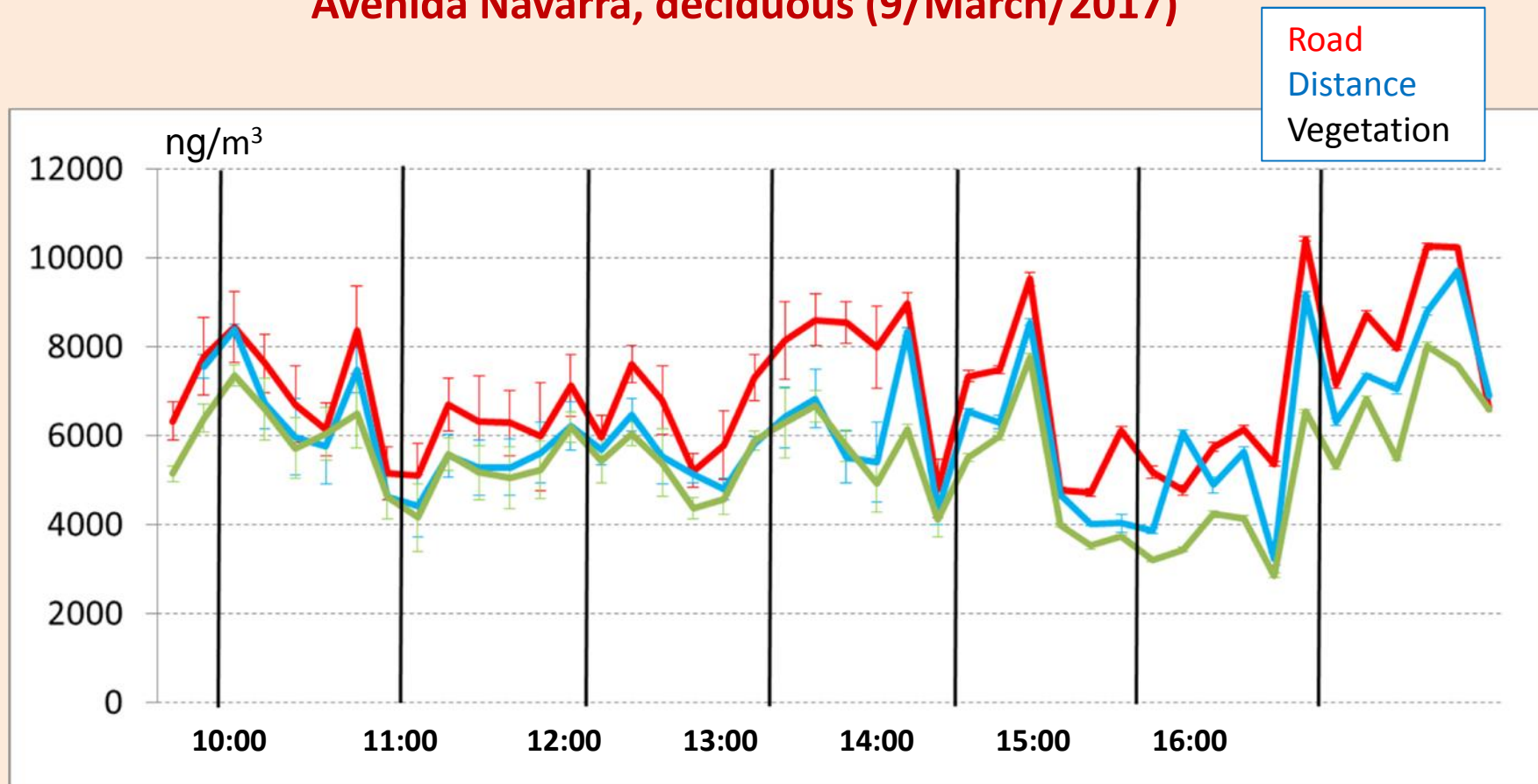
Black carbon



Effect of shrubs hedge in the sidewalk. Field Experiments

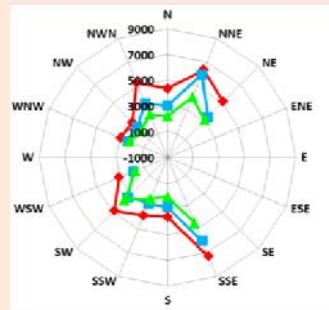
Black carbon

Avenida Navarra, deciduous (9/March/2017)

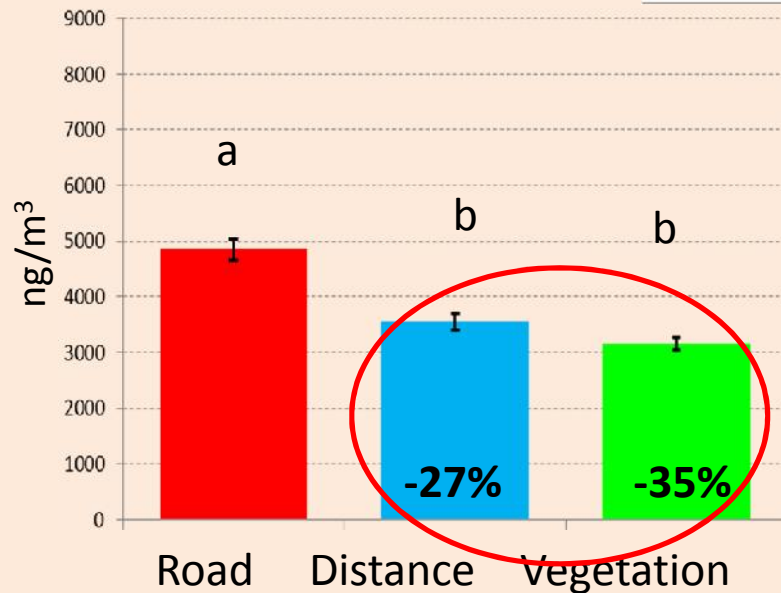


Effect of shrubs hedge in the sidewalk. Field experiments

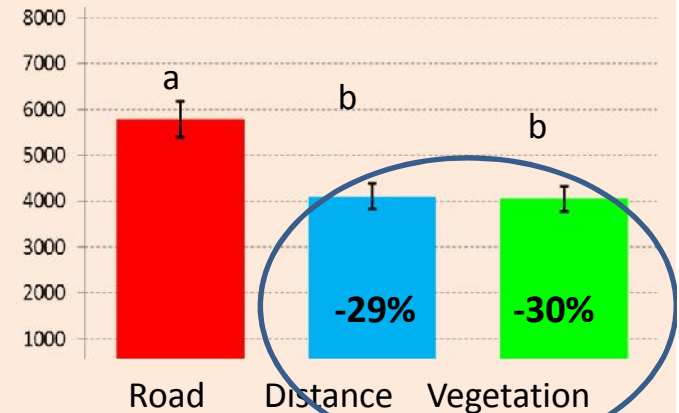
27/June/2017



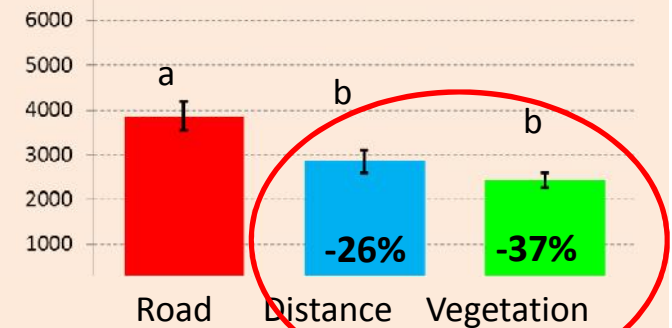
Black carbon



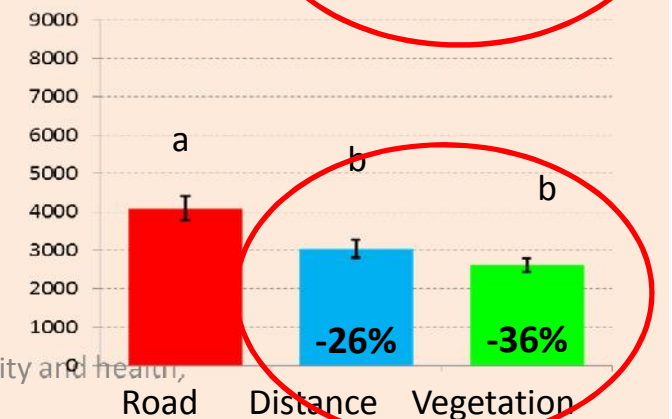
Calm
($v < 0.5$ m/s)



From road
(SW)



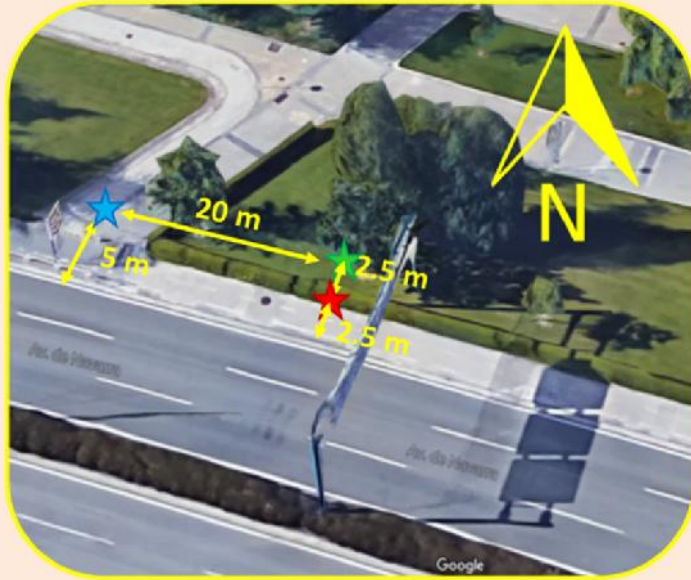
Parallel to road
(NW/SE)



Vegetal barriers are effective for reducing air pollutant exposure

Effect of vegetation (shrubs/trees) barrier. CFD simulations

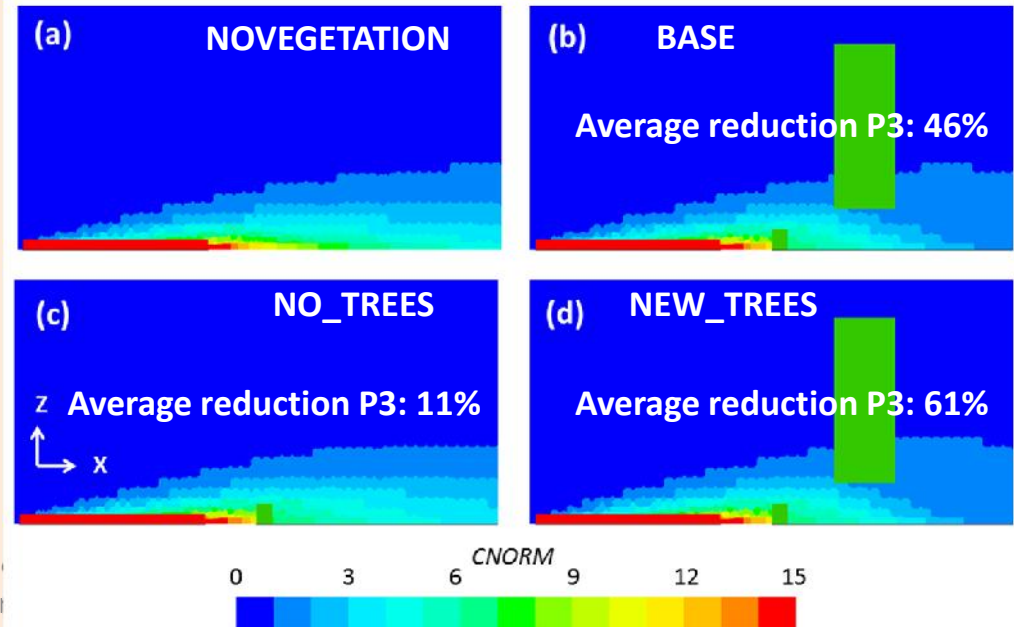
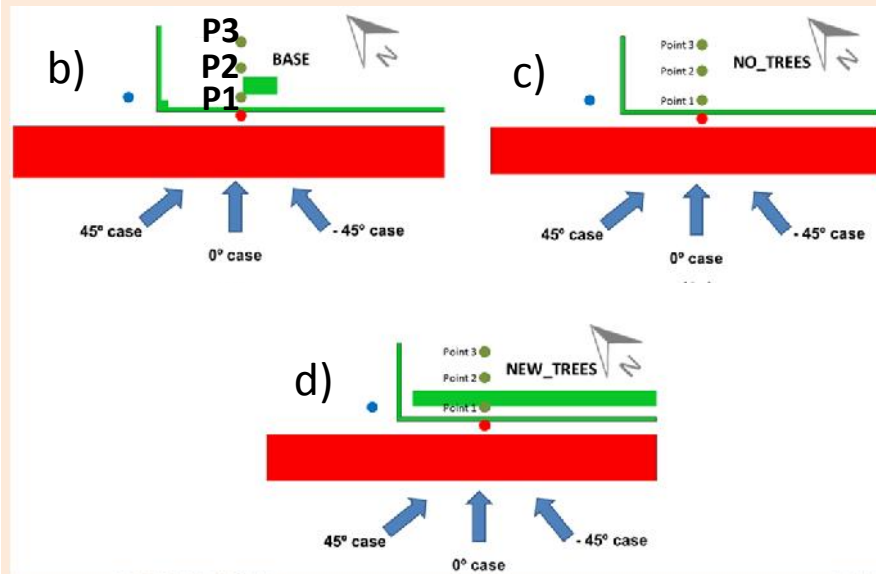
Actual vegetation barrier characteristics



Hedgerow (He)	Tree T	Tree small Ts
Height (He_H) = 1 m	Horizontal dimensions (T_hd) = 6 m x 3 m	Horizontal dimensions (Ts_hd) = 2 m x 2 m
Width (He_W) = 0.8 m	Base (T_b) = 2 m	Base (Ts_b) = 2 m
LAD (He_LAD) = 4.29 m ² m ⁻³	Top (T_t) = 10 m	Top (Ts_t) = 4 m
	LAD (T_LAD) = 0.5 m ² m ⁻³	LAD (T_LAD) = 0.5 m ² m ⁻³

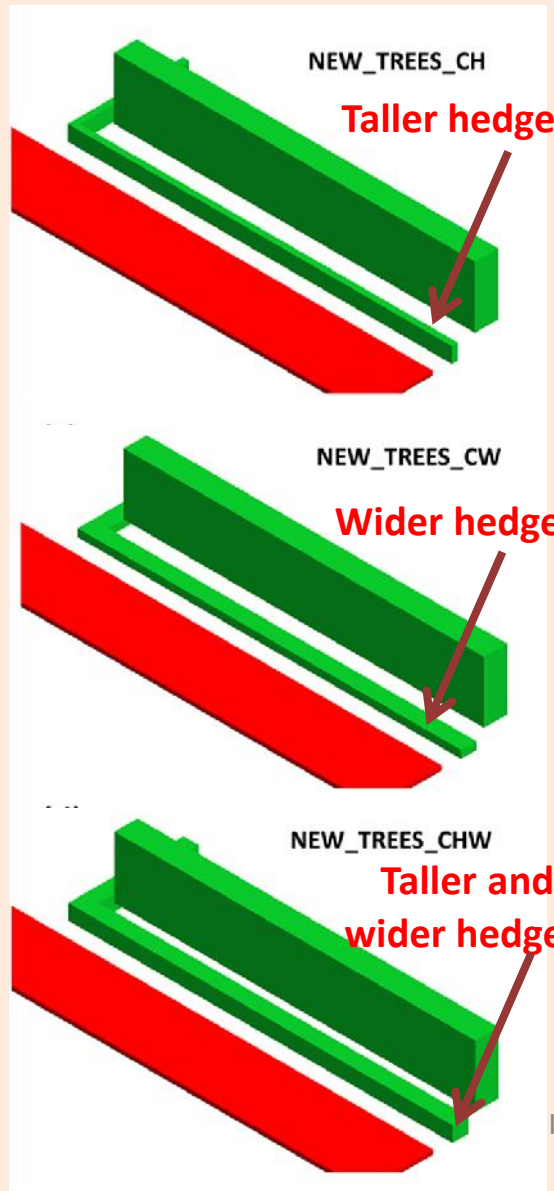
Evaluation

Exp./CFD	Wind direction	BC Concentration Reduction Percentage	
		Blue point	Green point (P1)
Exp.	0°±30°	20.0%	44.3%
	0°	26.5%	44.6%
CFD	45°	21.5%	46.1%
	-45°	31.9%	45.1%

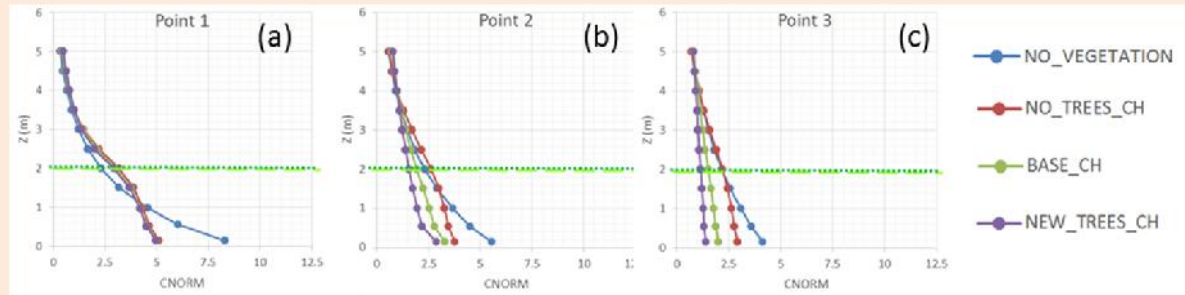


Effect of vegetation (shrubs/trees) barrier. CFD simulations

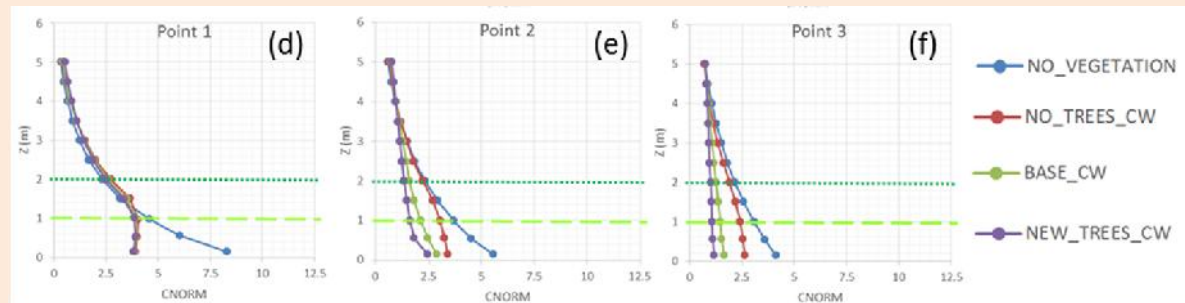
Hypothetical vegetation barrier scenarios:



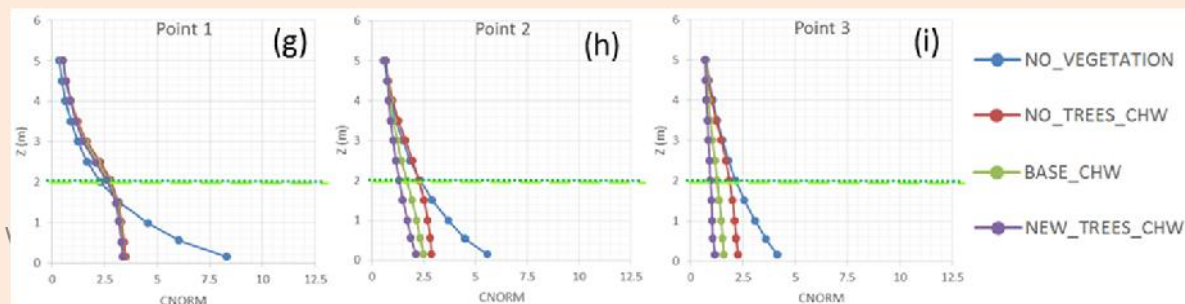
Average reduction of **taller-hedge + trees** vs NO_VEGETATION below the tree base at **P3 = 59%** (16% for taller hedge and without trees)



Average reduction of **wider-hedge + trees** vs NO_VEGETATION below the tree base at **P3 = 65%** (24% for wider hedge and without trees)

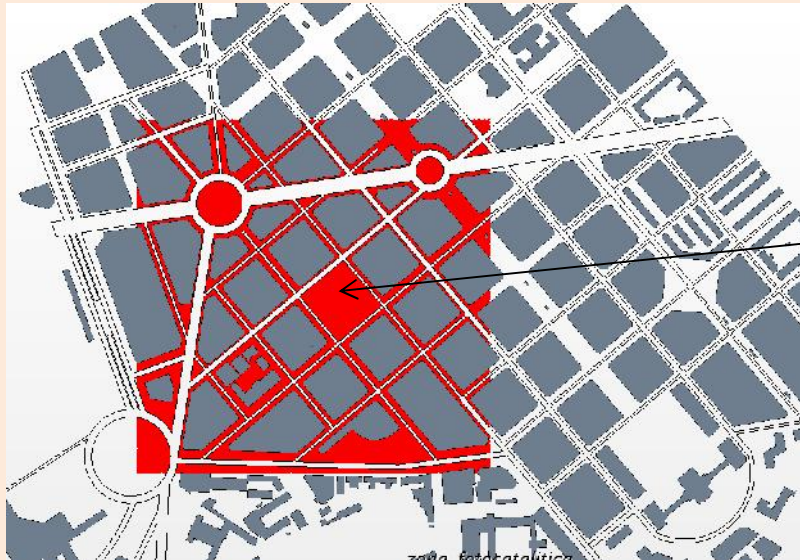


Average reduction of **taller-wider-hedge + trees** vs NO_VEGETATION below the tree base at **P3 = 66%** (33% for wider hedge and without trees)



Effect of photocatalytic pavements. CFD simulations

2016 NO₂ annual average concentration

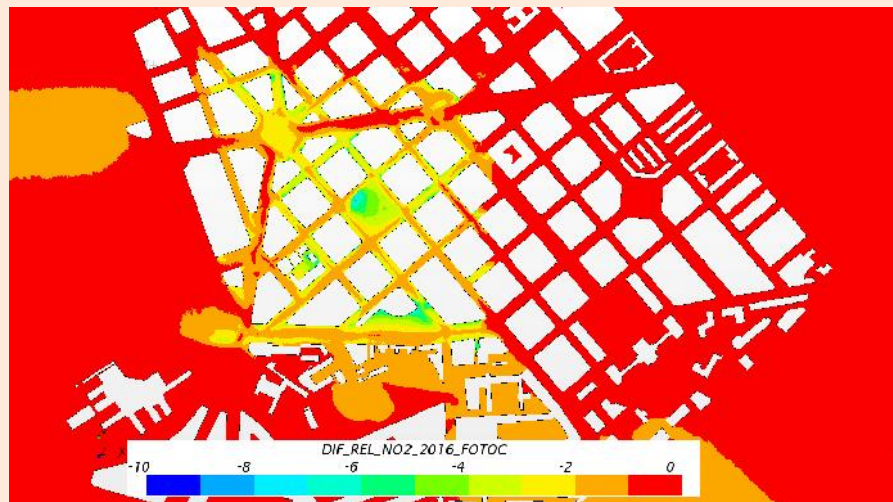
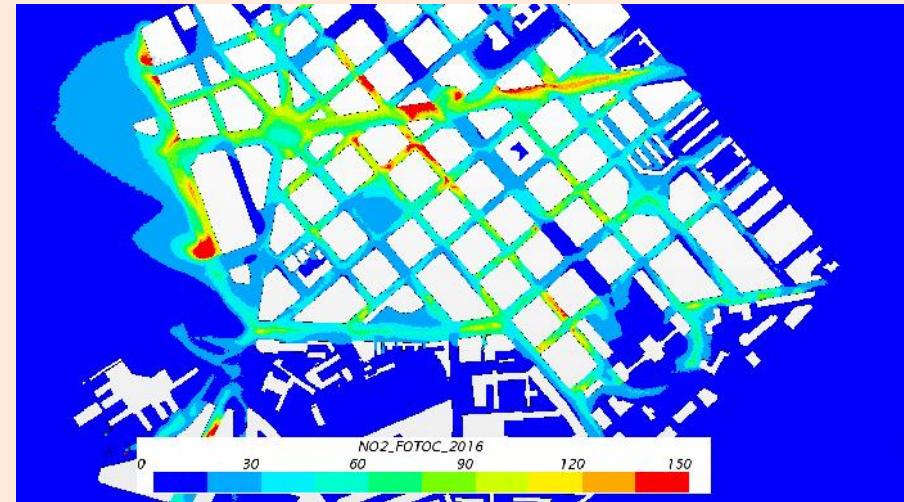
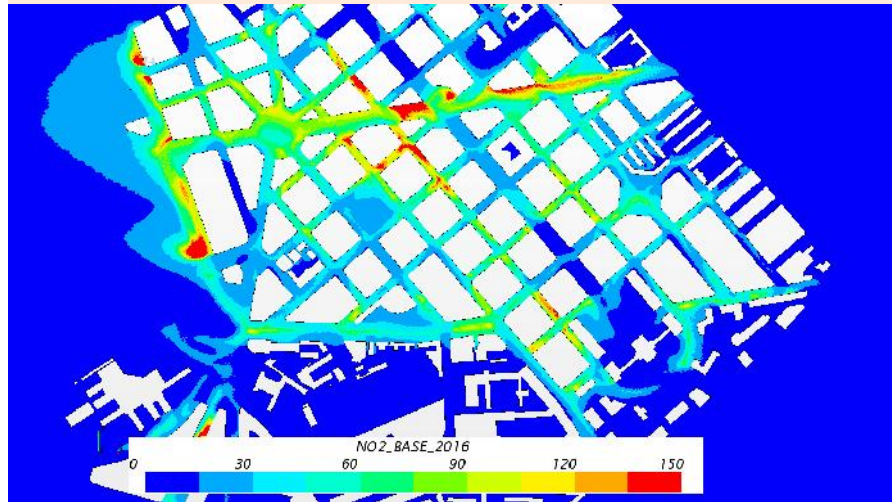


Assumptions:

- Photocatalytic pavement (only sidewalks) 400m x 400m around Plaza de la Cruz square.
- Always is photactive and deposition velocity (applied to NO₂) 0.5 cm/s (In real case, it happens only in daytime).

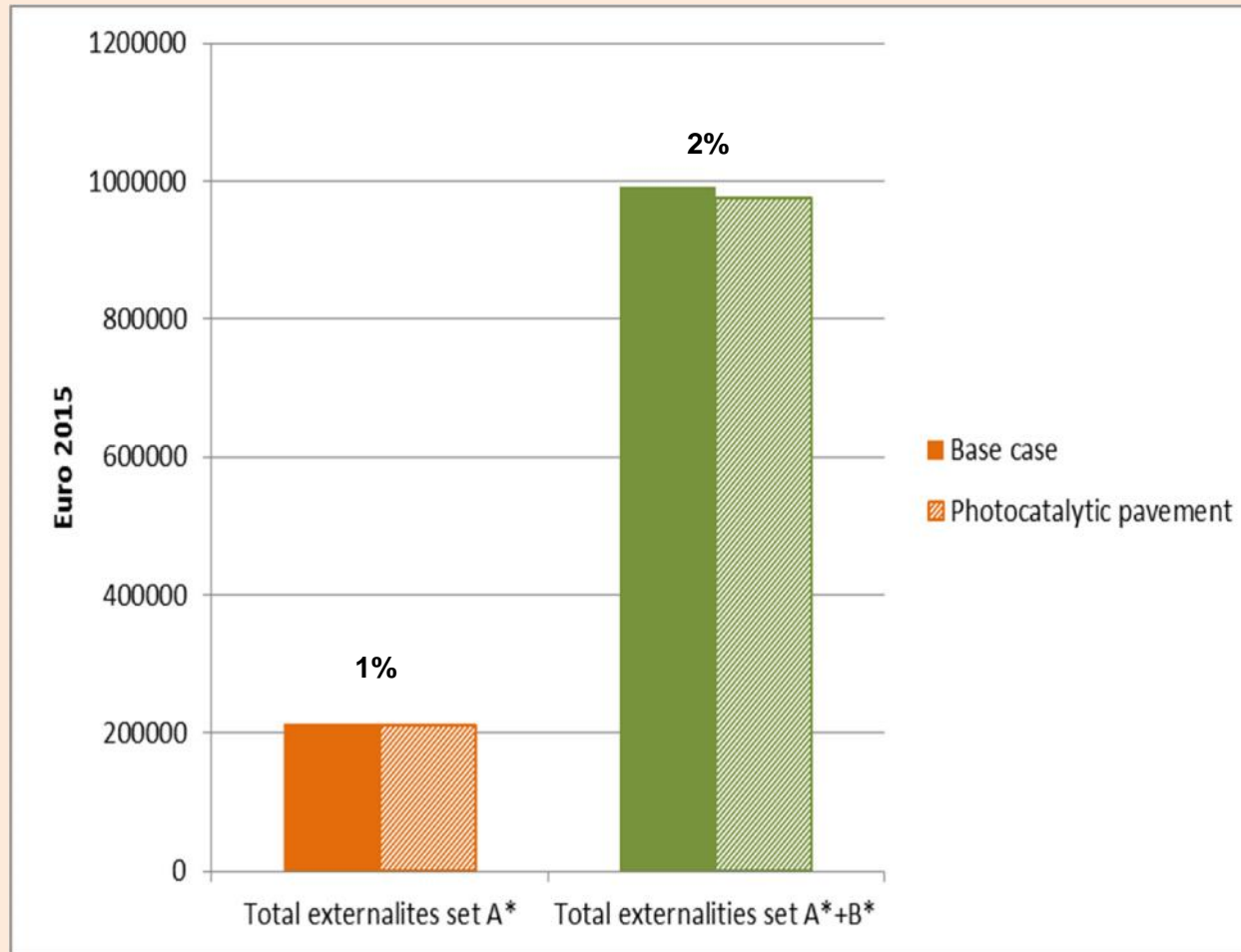
Compared with base scenario without photocatalytic materials.

Effect of photocatalytic pavements. CFD simulations



- **Relative differences of averaged concentrations around 2% in the photocatalytic area.**
- However, model assumptions are overestimating the photocatalytic effect.

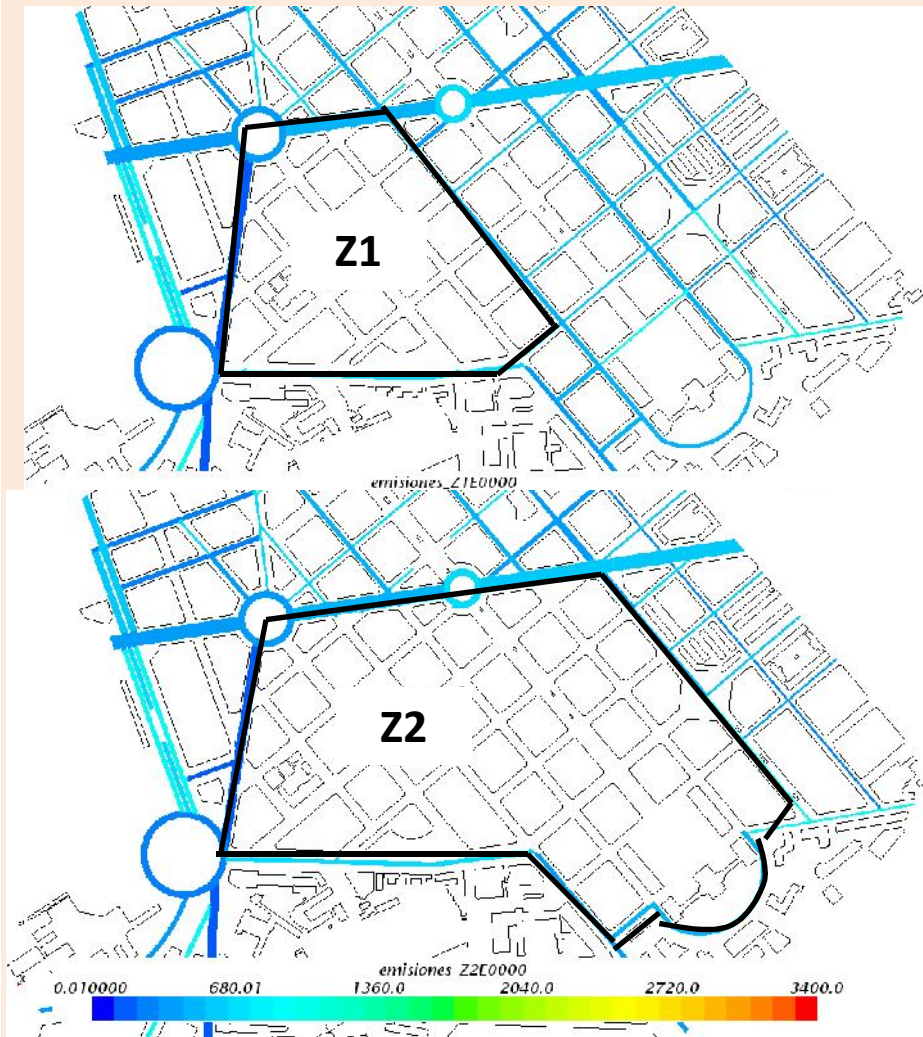
Effect of photocatalytic pavements. External Cost (health)



Effect of photocatalytic pavements in sidewalks



Effect of traffic rearrangements. CFD simulations



2016 NO₂ annual average concentration

Scenarios (BASE+12new scenarios):

Restriction zones (Z1 and Z2)

6 scenarios per zone, combination of:

- Traffic inside restriction zone reduced to:
 - 0% (no traffic)
 - 20% (few traffic)
- Traffic increases around restriction zone:
 - 0% (no traffic diversion),
 - 30% (some traffic diversion),
 - 60% (important traffic diversion)

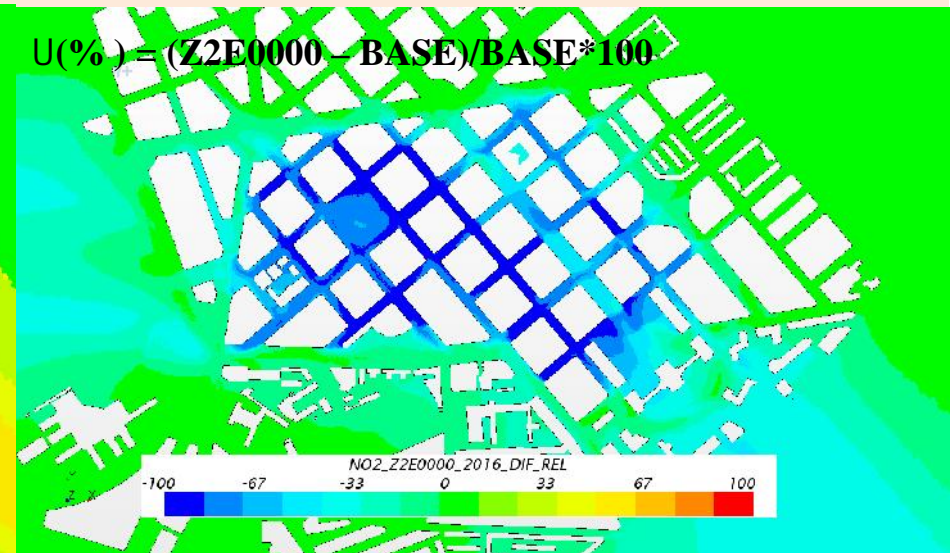
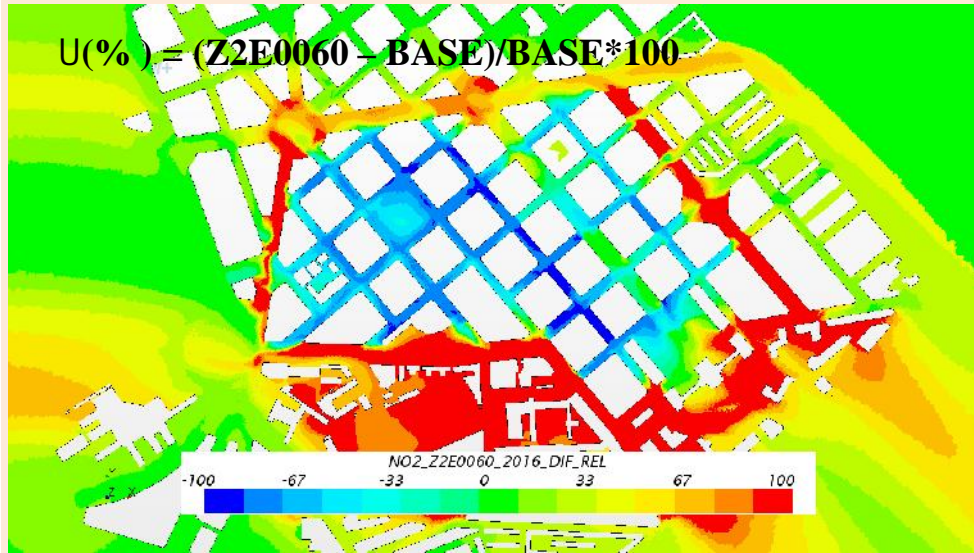
Measures to improve air quality and health,

Tallinn, 28-29 June 2018

Effect of traffic rearrangements. CFD simulations

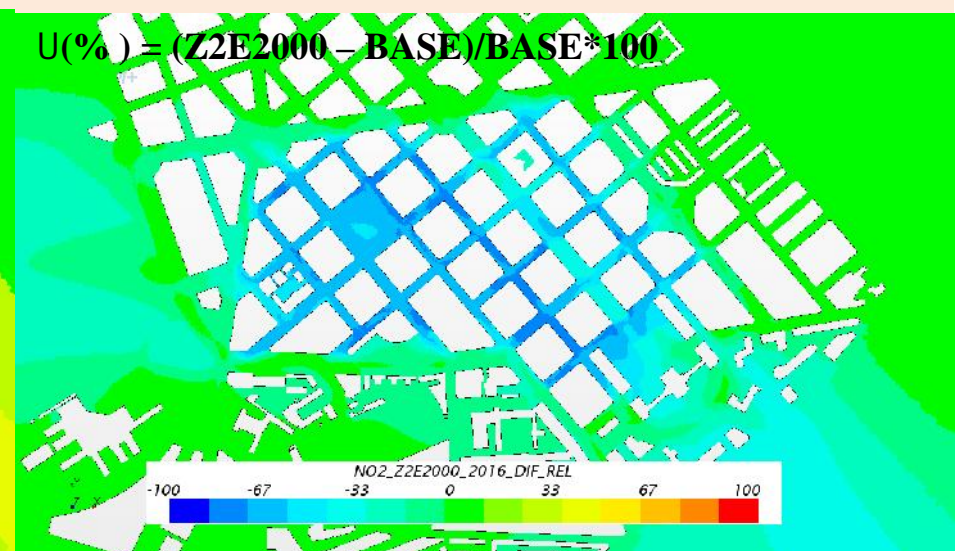
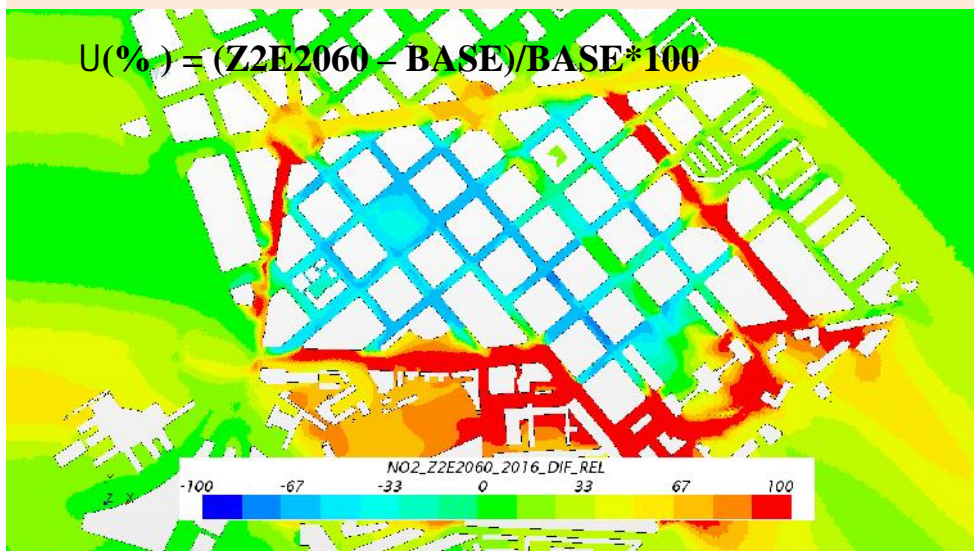
No traffic inside, strong traffic diversion

No traffic inside, no traffic diversion

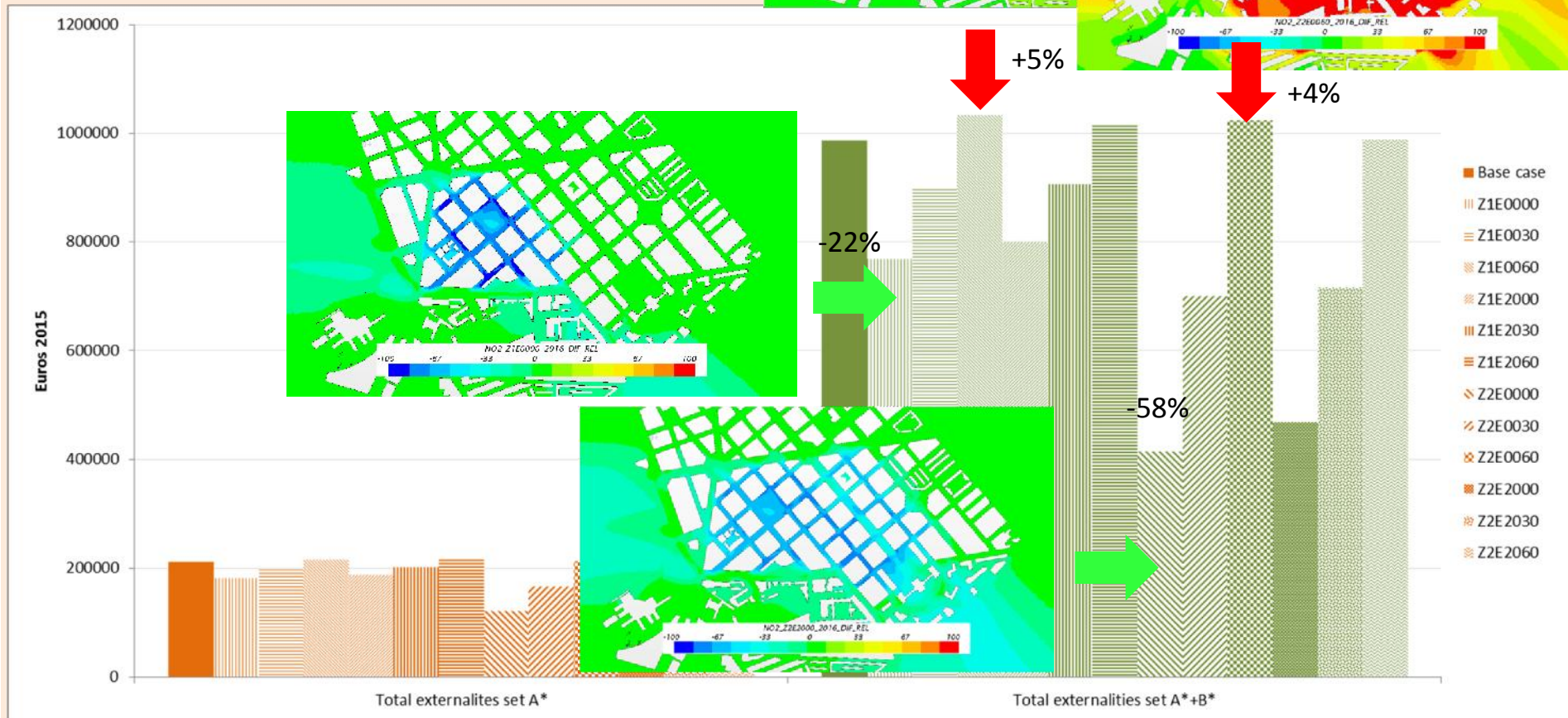
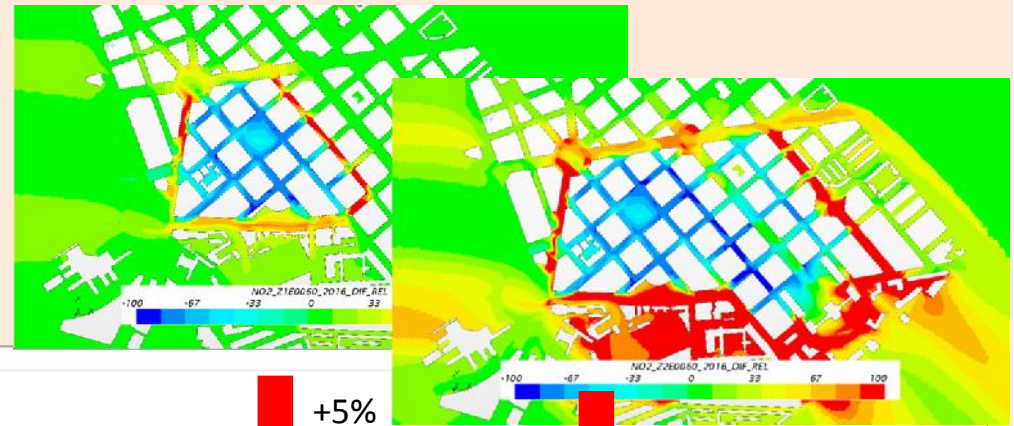


Few traffic inside, strong traffic diversion

Few traffic inside, no traffic diversion



Effect of traffic rearrangements. External costs



Conclusions

- Trees reduce dispersion of traffic emissions in streets and increase air pollution within canopy
- Aerodynamics (dispersion) effects seem to dominate over deposition effects.
- The inclusion of new trees in one street modifies the distribution of pollutant, not only in that street, but also in nearby locations, but total effects in pollutant concentration and health cost savings are small
DO NOT BLAME THE TREES! Traffic has to be removed from streets!
- Vegetal barriers are effective for reducing air pollutant exposure, especially when combined hedges and trees forming wide barriers.
VEGETAL BARRIERS CAN ISOLATE PEDESTRIANS FROM ROAD TRAFFIC!
- **Effect of photocatalytic pavements is negligible.**
- **Redistribution of traffic in the city might produce important reductions in air pollution and health impacts but only if there are no significant traffic diversion**