

# Urban Air Quality Management

What is expected in the next future?

Clappier A.

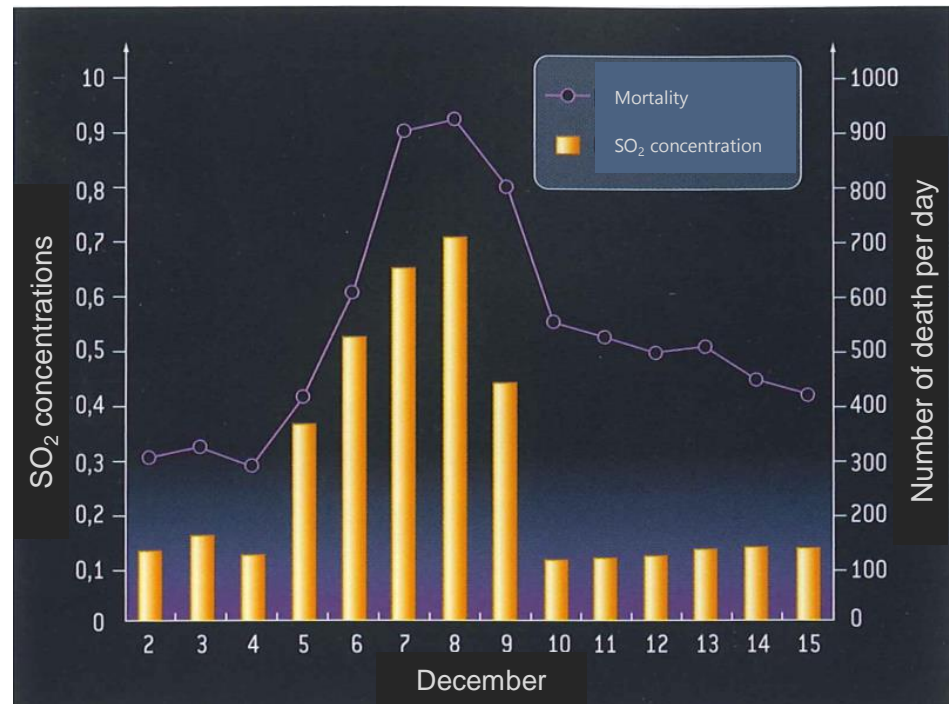


# PRIMARY POLLUTANTS

# Primary Pollutants

## 1952 – The London SMOG

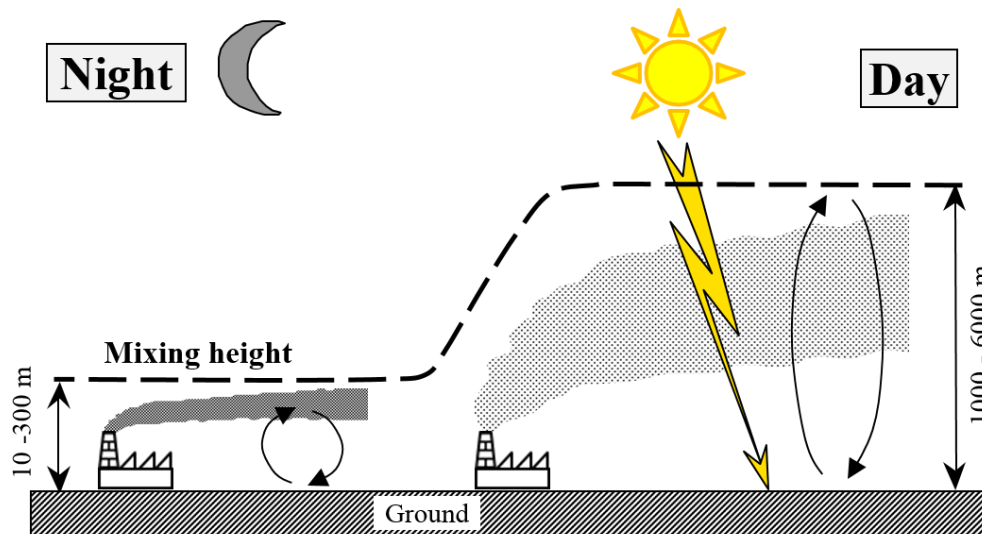
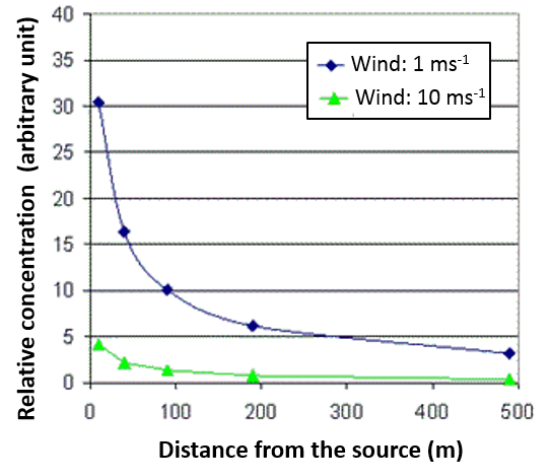
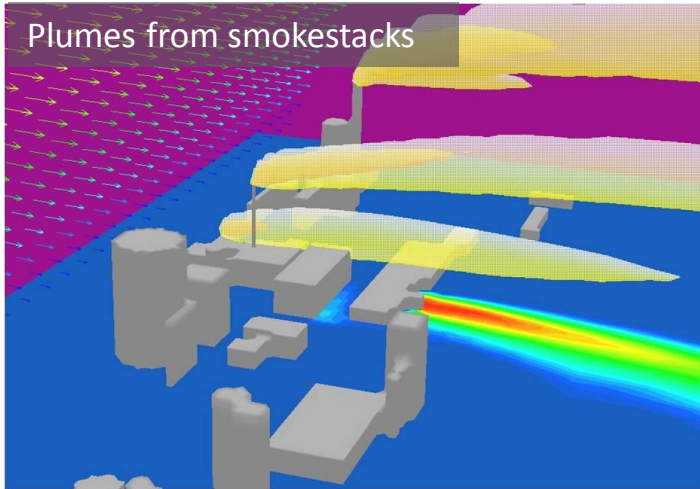
In December 1952, heavy fog persists for 5 days and **kills more than 4,000 people** in London.



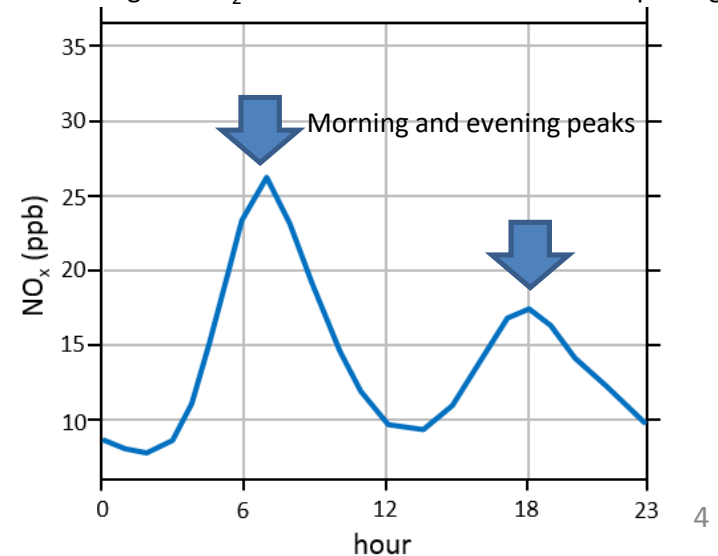
The SMOG is due to high concentrations of **sulfur dioxide (SO<sub>2</sub>)** and **nitrogen oxides (NO and NO<sub>2</sub>)** have been released in the atmosphere by coal combustion (heating system and electric power plants).

# Primary Pollutants

Primary pollutants affect mostly areas close to the sources that emit them.



Annual average of NO<sub>2</sub> concentrations over all Rhone-Alpes region.

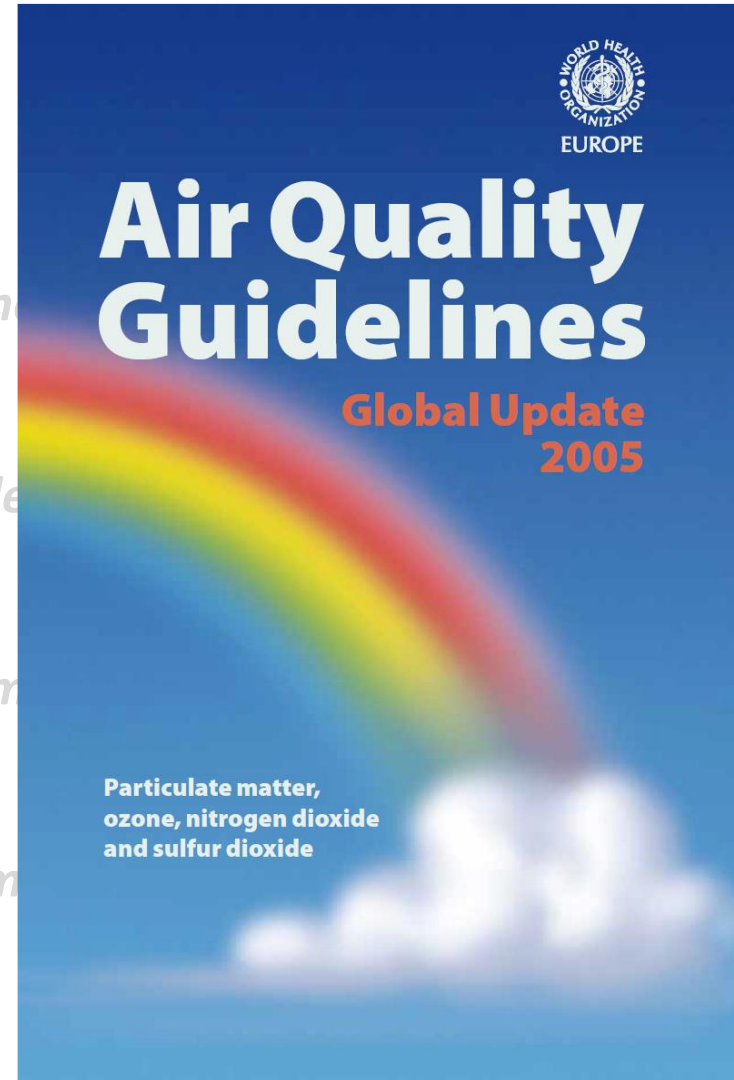


# Urban Air Quality Management

## ❑ Set threshold concentrations



Guideline levels for each pollutant ( $\mu\text{g}/\text{m}^3$ ):		
PM <sub>2.5</sub>	1 year	10
	24 h (99th percentile)	25
PM <sub>10</sub>	1 year	20
	24 h (99th percentile)	50
Ozone, O <sub>3</sub>	8 h, daily maximum	100
Nitrogen dioxide, NO <sub>2</sub>	1 yr	40
	1 h	200
Sulfur dioxide, SO <sub>2</sub>	24 h	20
	10 min	500



# Urban Air Quality Management

*Set threshold concentrations*

*Observations to identify the locations of the exceedances*

*Quantification of the emissions*

*Evaluation of the area of influence*

*Choose the most appropriate*



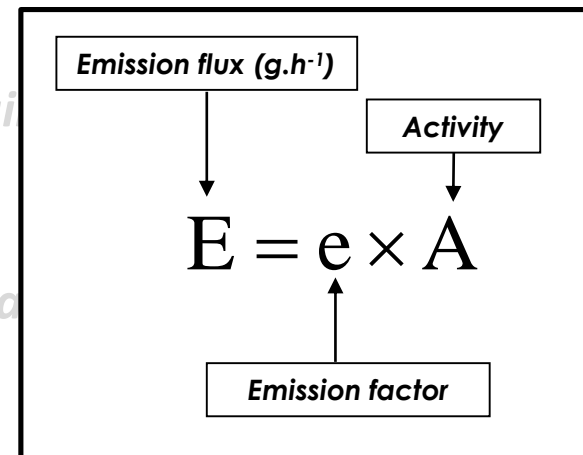
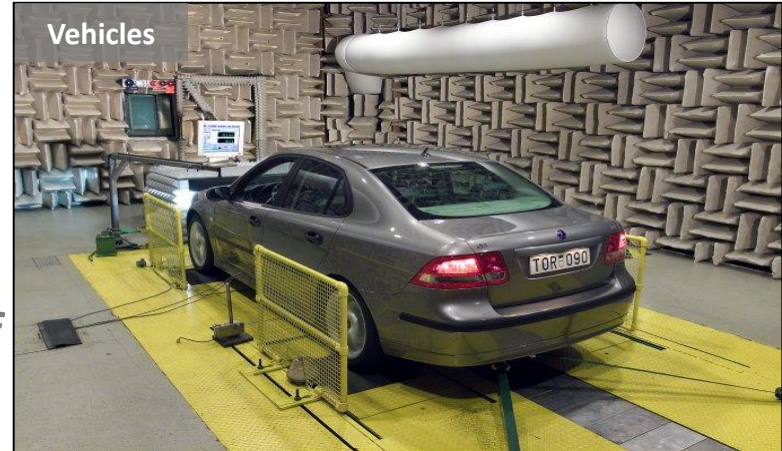
Measurement station in Strasbourg

# Urban Air Quality Management

*Set threshold concentrations*

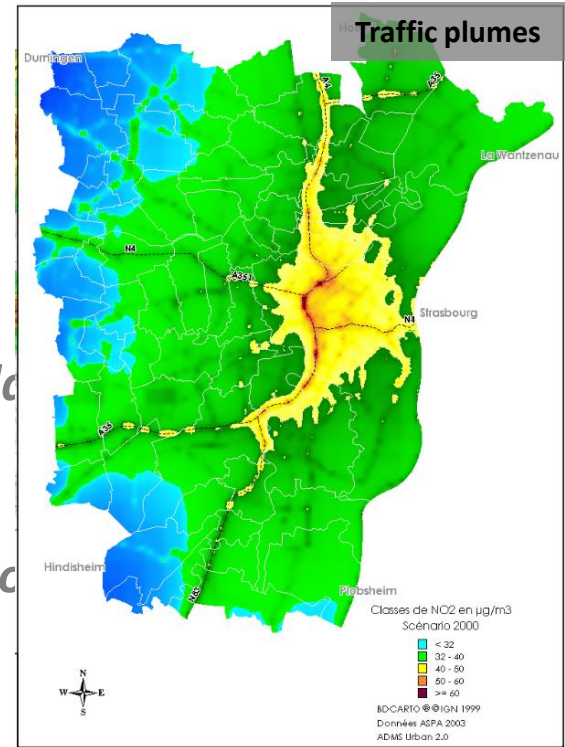
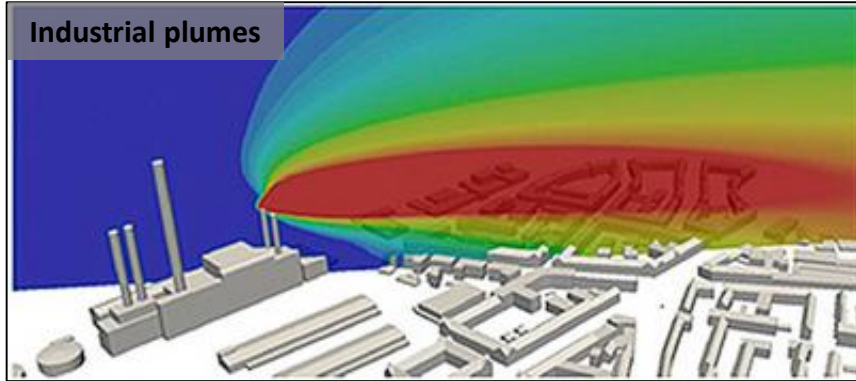
*Observations to identify the locations of*

*Quantification of the emissions sources, identification of the main contributors*



# Urban Air Quality Management

## Numerical modelling



ns of the exceeded

rs

Quantification of the emissions sources, identification

Evaluation of the area of influence of the main sources

Choose the most appropriate abatement measures



# Urban Air Quality Management

- ❑ *Set threshold concentrations*
- ❑ *Observations to identify the locations of the exceedances*
- ❑ *Quantification of the emissions sources, identification of the main contributors*
- ❑ *Evaluation of the area of influence of the main sources*
- ❑ ***Choose the most appropriate abatement measures***

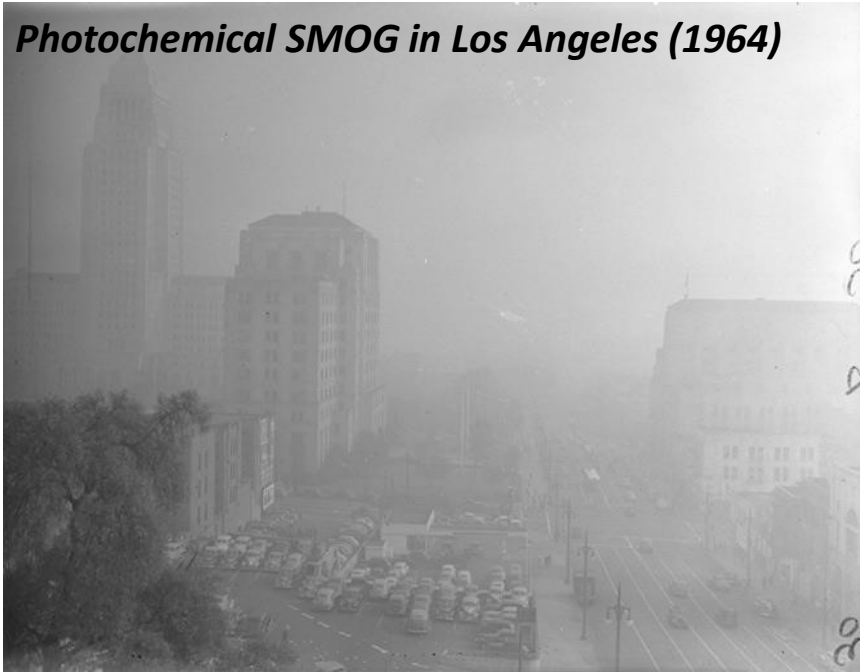
# SECONDARY POLLUTANTS

# Secondary Pollutants

## In the 60's – The photochemical SMOG

In summer, when the sun is strong, visibility decreases, people experience eye irritation, respiratory diseases such as asthma increase.

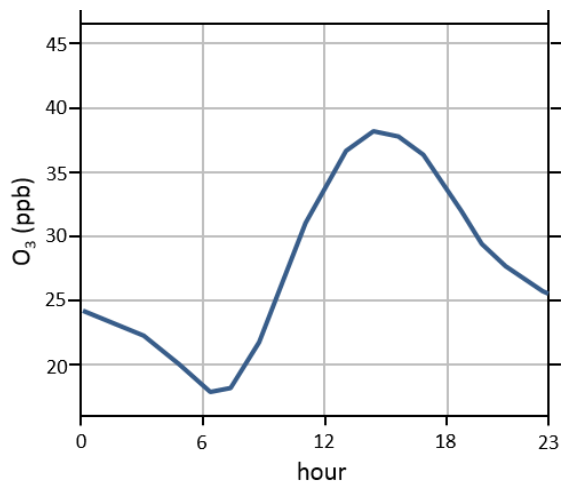
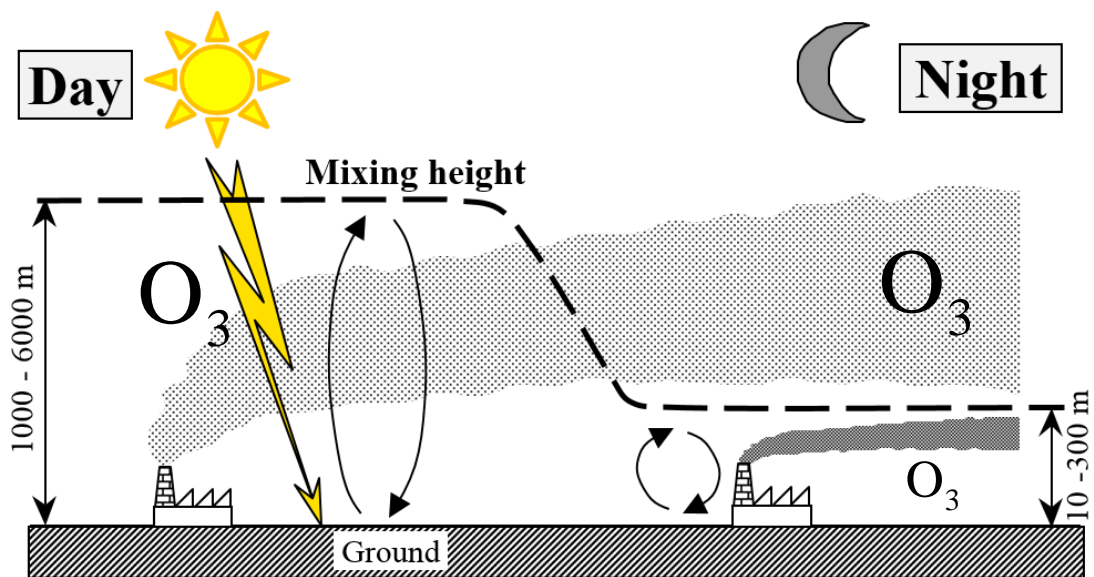
*Photochemical SMOG in Los Angeles (1964)*



The photochemical SMOG shows high concentrations of photochemical pollutants like **ozone**.

# Secondary pollutants

Ozone



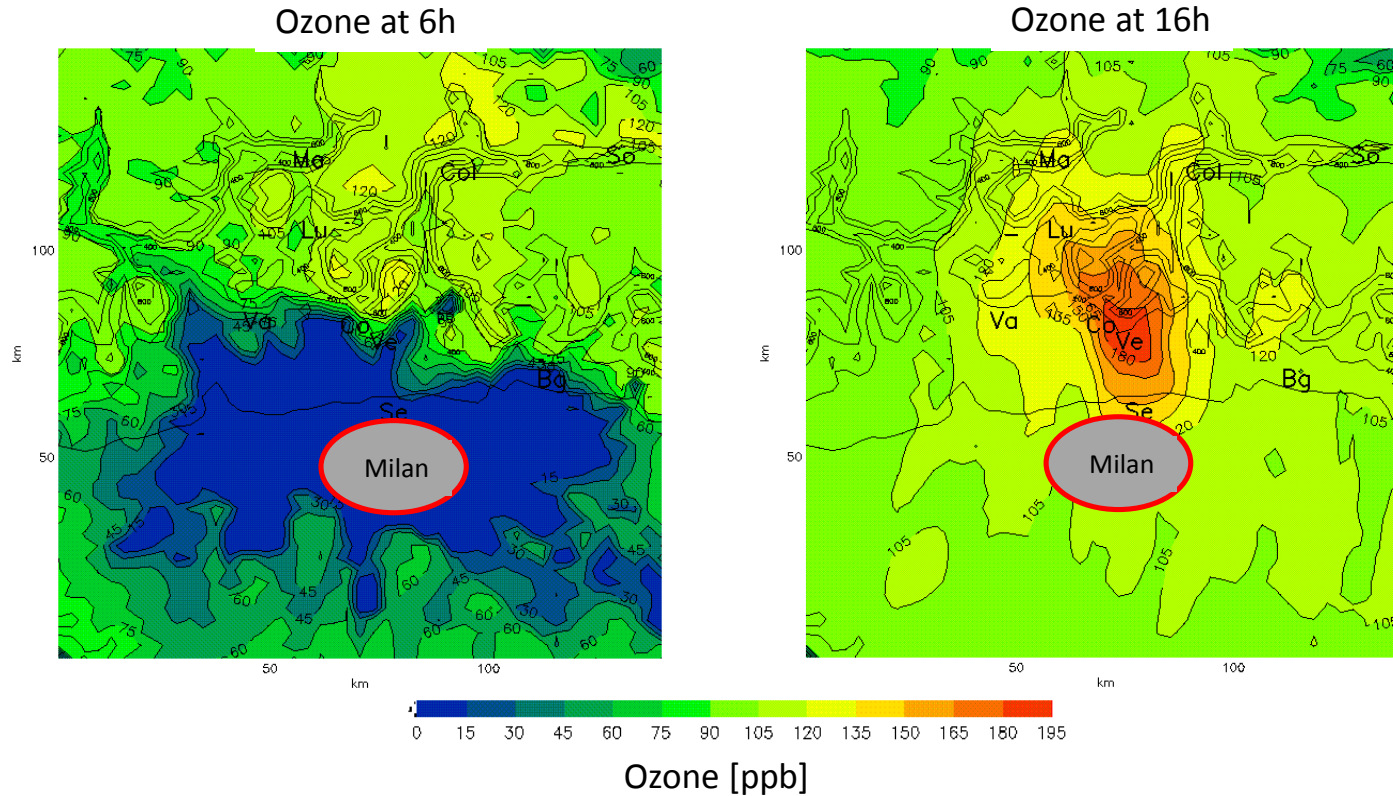
Annual average of O<sub>3</sub> concentrations over all Rhone-Alpes region.

# Secondary Pollutants

## Ozone

Maximum ozone concentrations are generated during the afternoon outside cities.

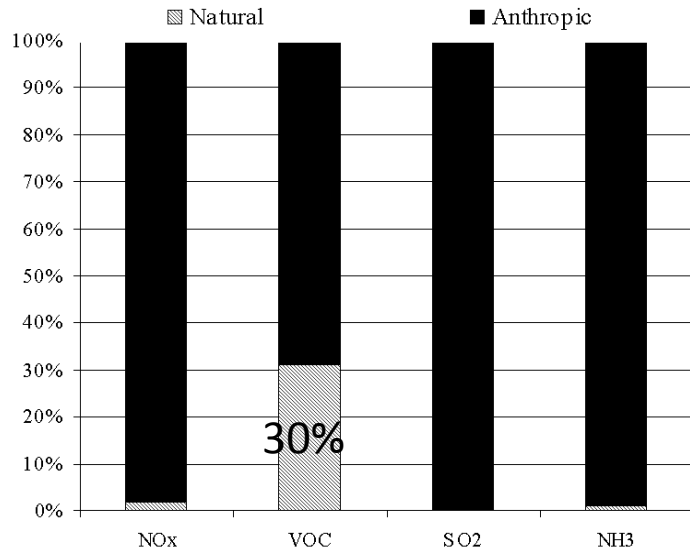
### Example of Milan



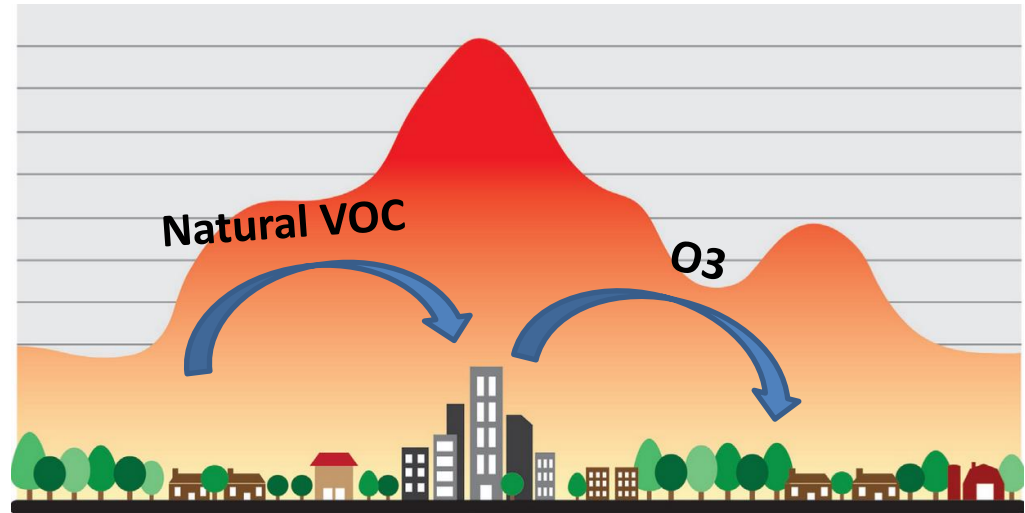
# Secondary Pollutants

## Interaction between city and rural area

Natural and anthropogenic emissions in Switzerland



Mix with anthropic NOx  
the Natural VOCs  
contribute to Ozone  
formation



Ozone affects  
agricultural  
production yield



Each spot on this leaf indicates  
the location of a stoma that has  
been adversely affected by  
ozone

# Primary & Secondary Pollutants

In the 90's: Particulate Matter (PM)

Primary PM:

PPM

Secondary PM:

*Nitrogen dioxide*

$\text{NO}_2$

*Ammonia*

$\text{NH}_3$

*Sulfur dioxide*

$\text{SO}_2$

*Hydrocarbons*

VOC



$\text{PM}[\text{NH}_4\text{NO}_3]$

$\text{PM}[(\text{NH}_4)_2\text{SO}_4]$

$\text{PM}[\text{VOC}]$

*Ammonium nitrate*

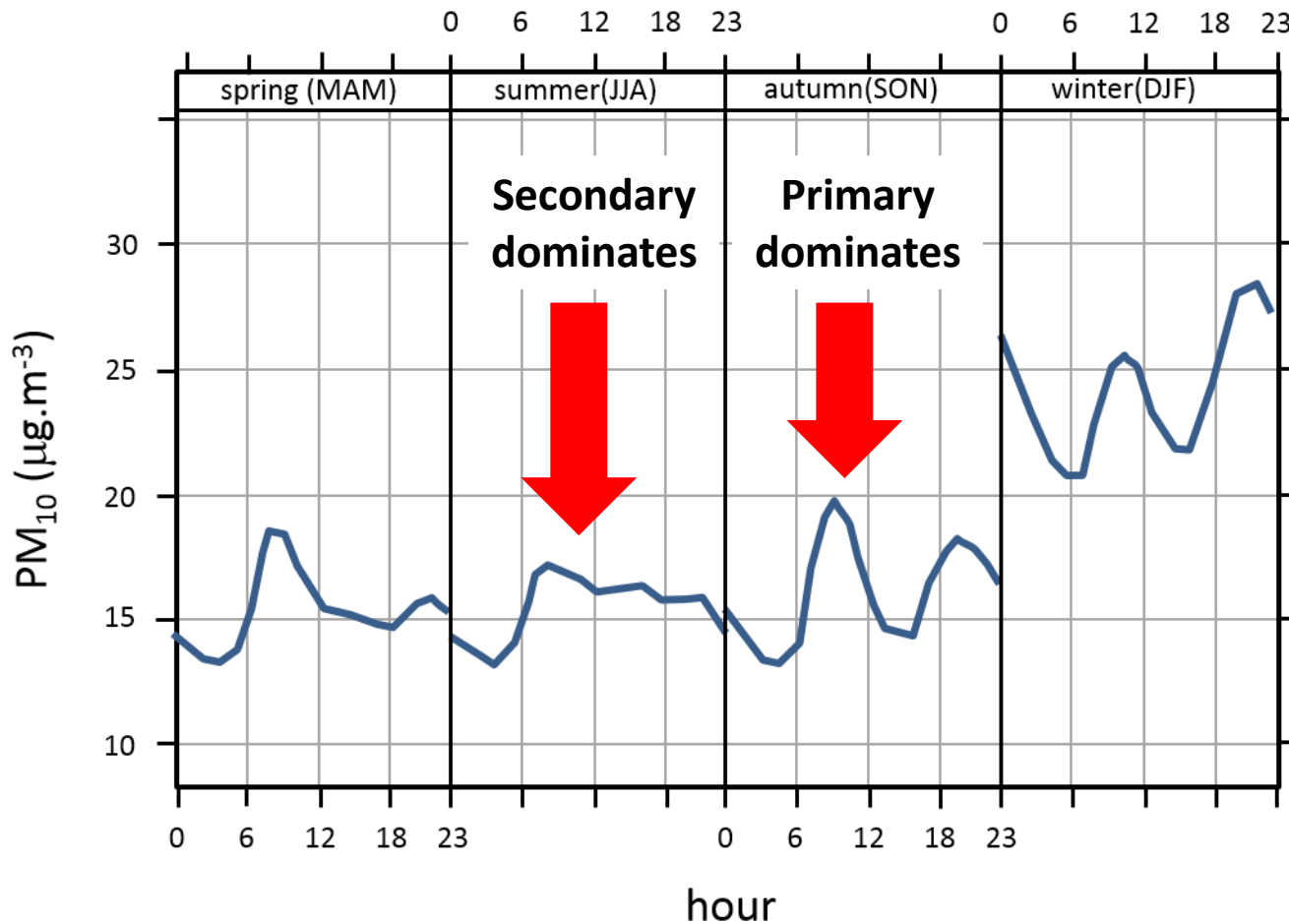
*Ammonium sulfate*

*Organic PM*

# Primary & Secondary Pollutants

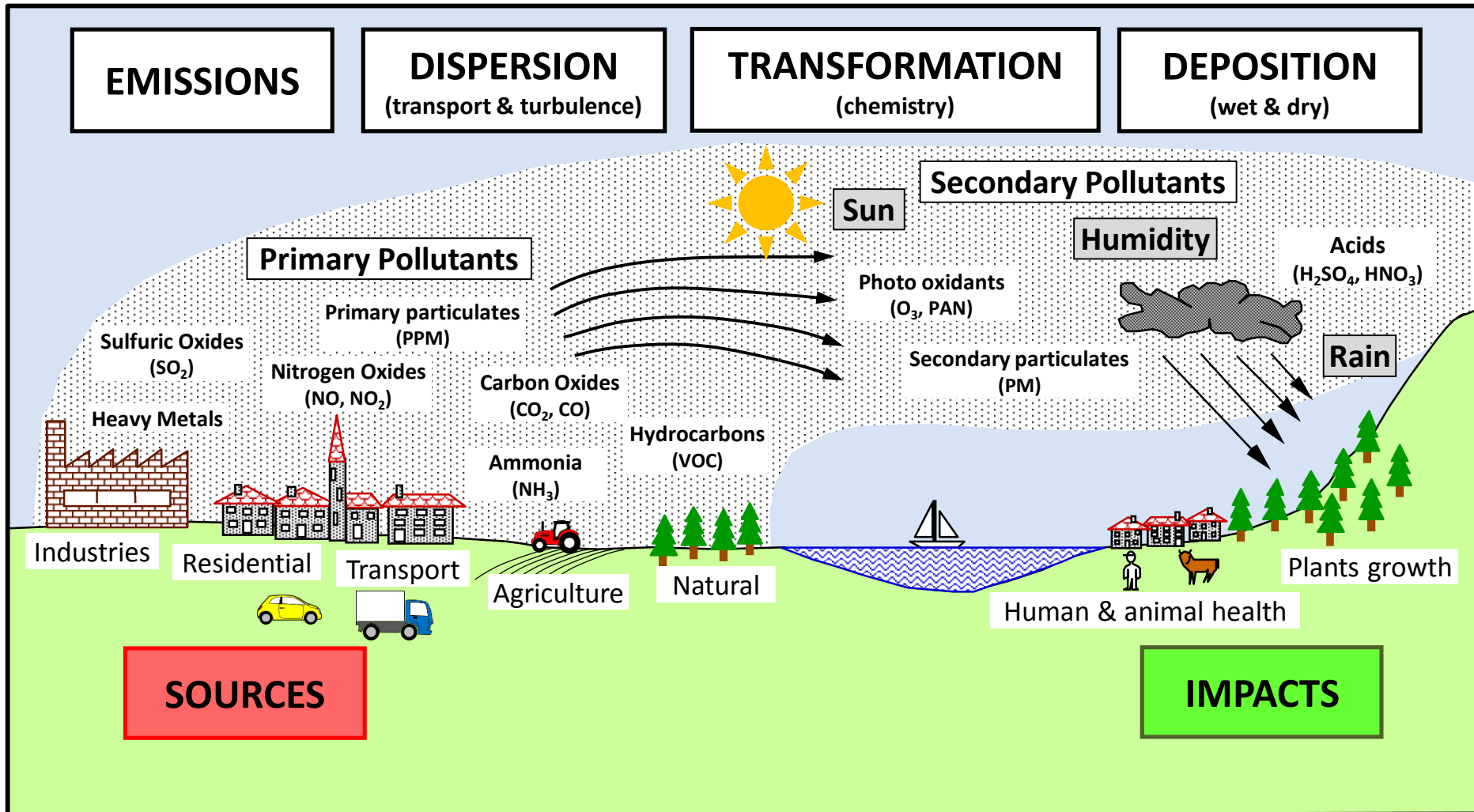
## Particulate Matter (PM)

Seasonal average of PM concentrations over all Rhone-Alpes region.





# Urban Air Quality Management

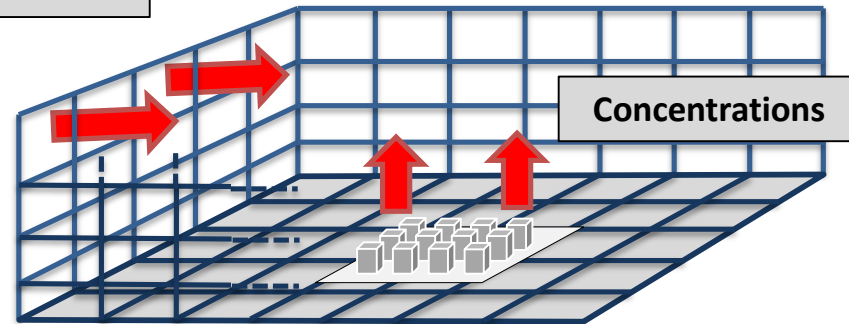


# Urban Air Quality Management

## Chemical Transport Model

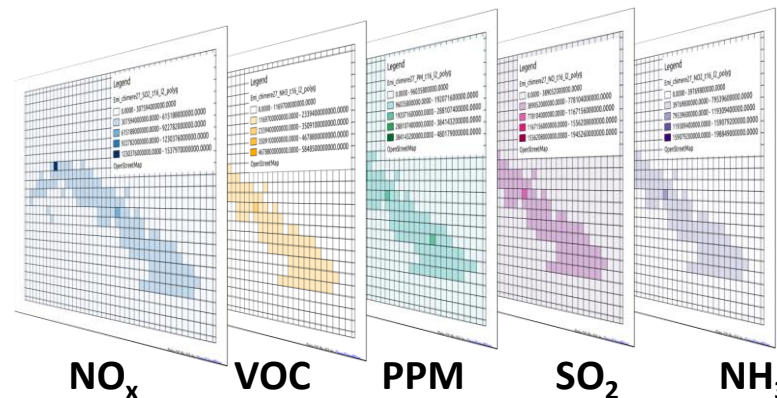
Boundary conditions

Meteorological conditions simulated by a **Meteorological Model**:  
Wind, Temperature, Solar radiation

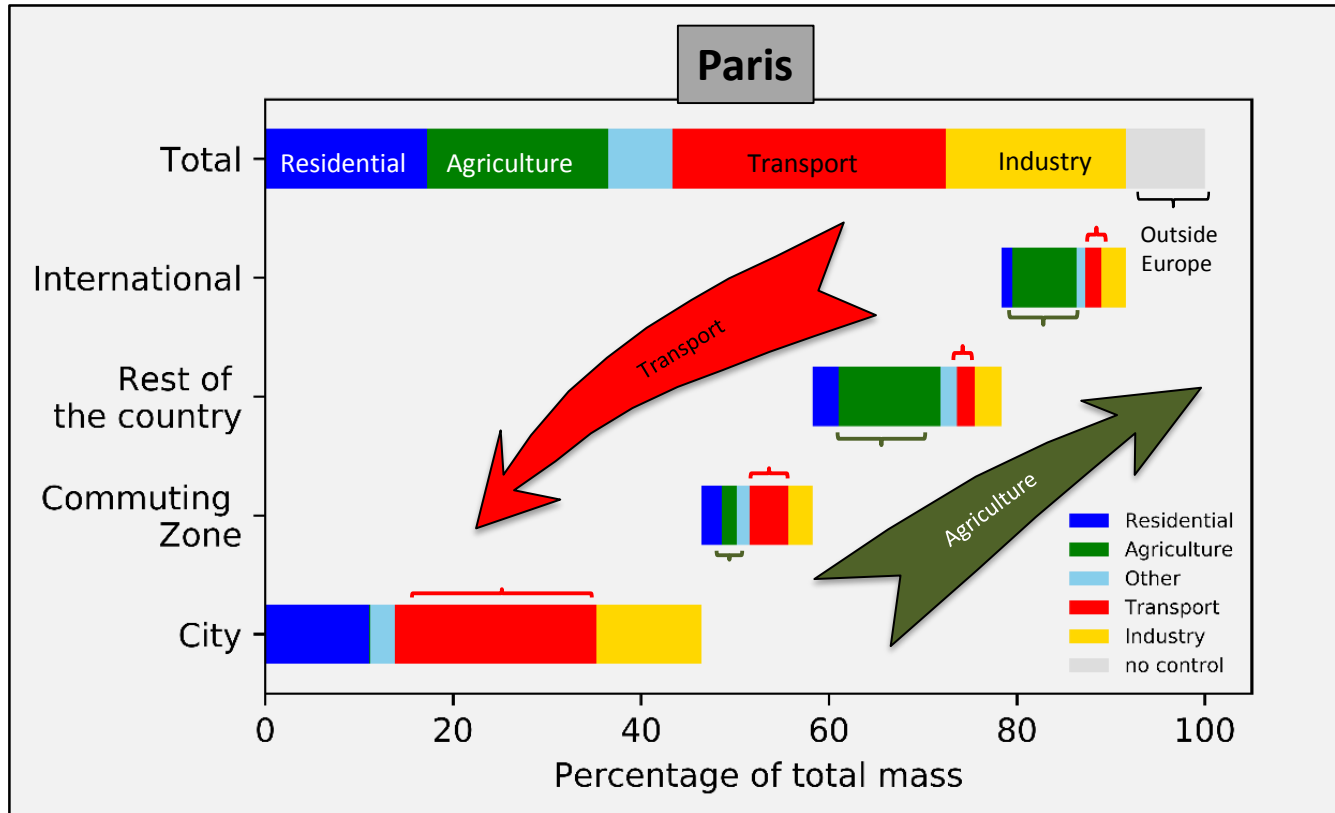


Complex Air Quality Models requiring significant CPU and comprehensive emission inventories are needed.

Emissions

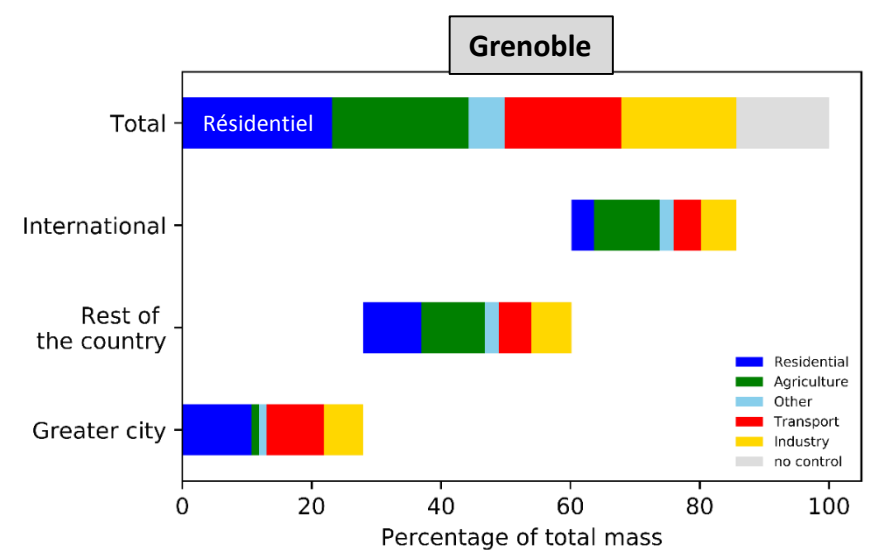
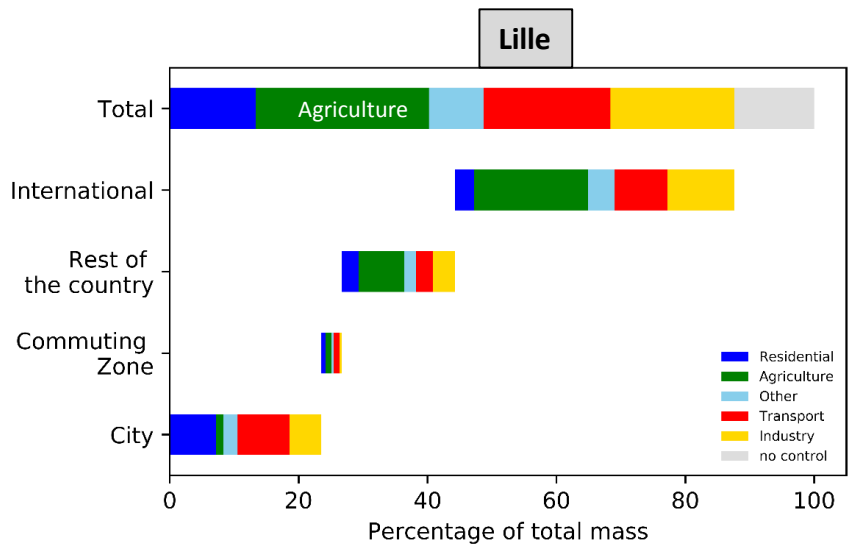
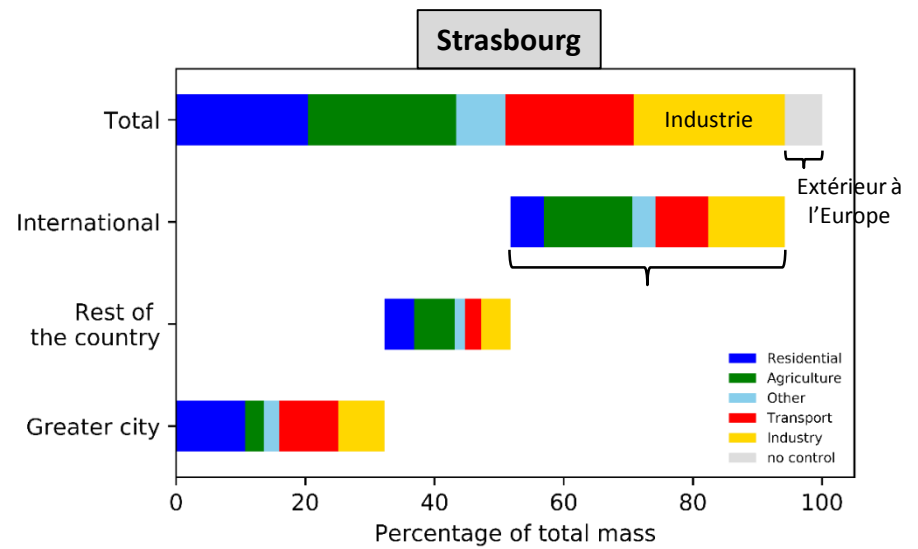
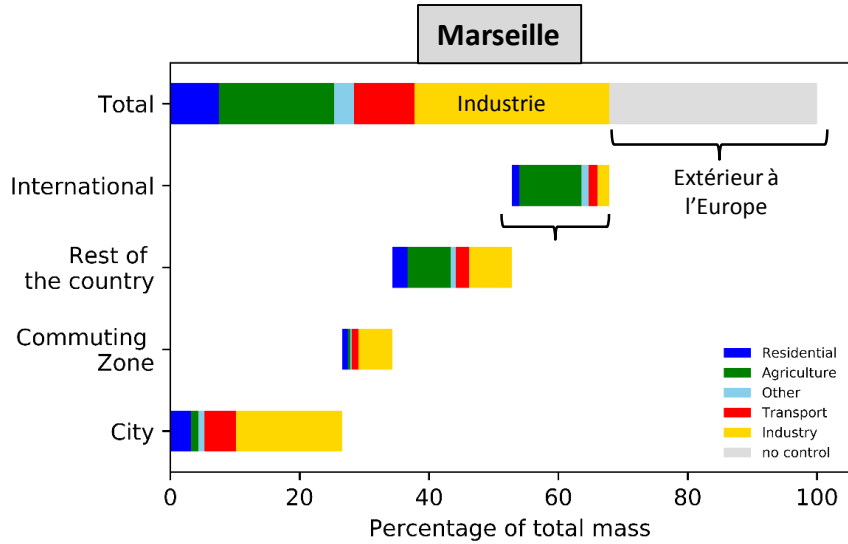


# Urban Air Quality Management

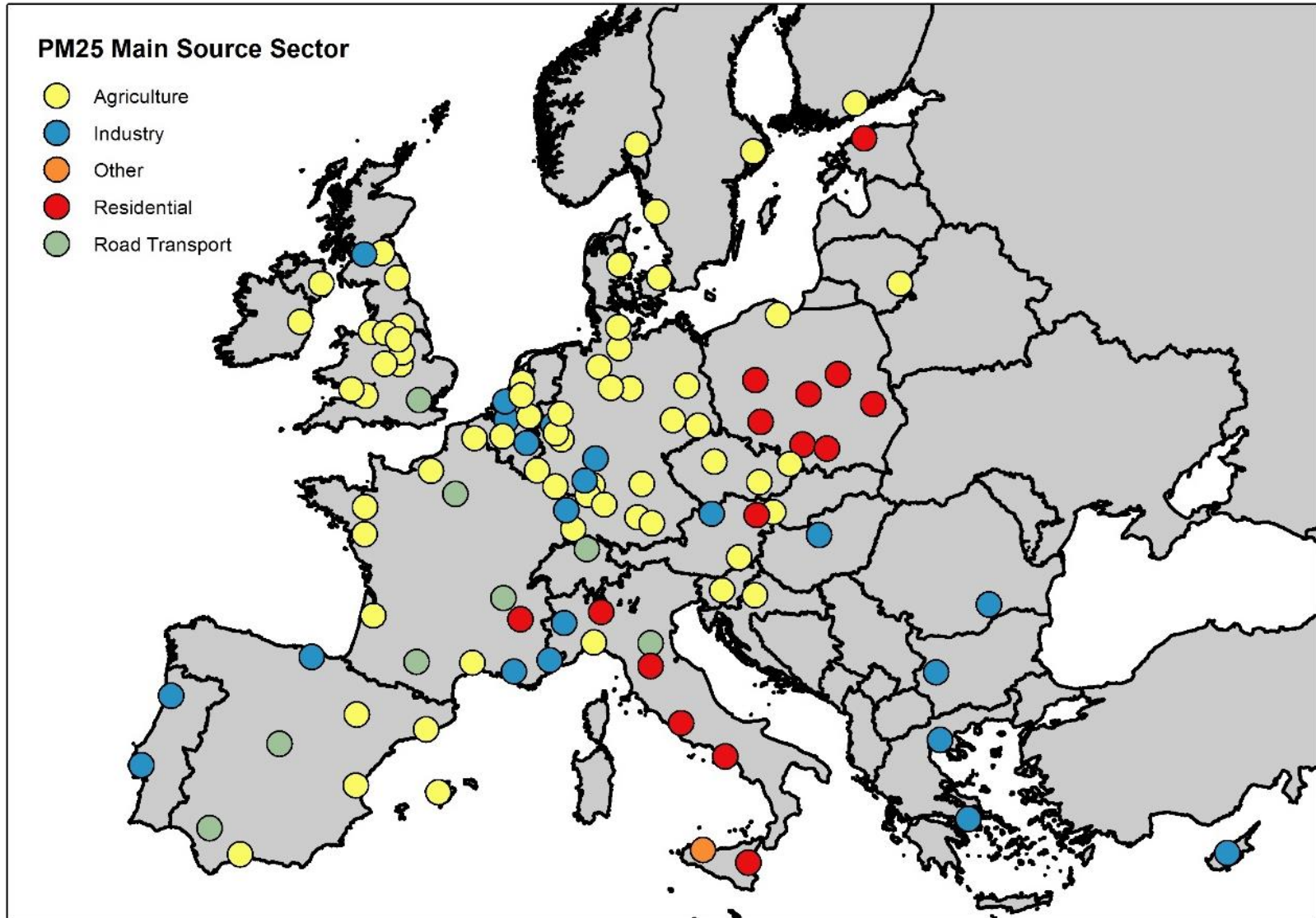


- Agriculture source should be regulated at European scale
- Transport, residential and industry could find solutions at the city scale.

# Urban Air Quality Management



# Urban Air Quality Management

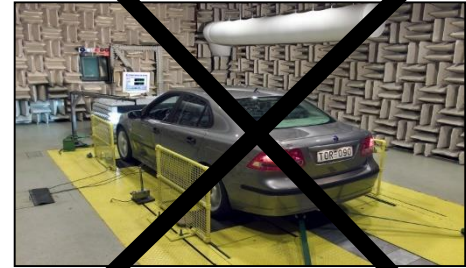


# **SIMPLIFIED PROCEDURES**

# Example of Cuba

Target the uncertainties before the accuracy.

1'000'000 \$



15'000 \$

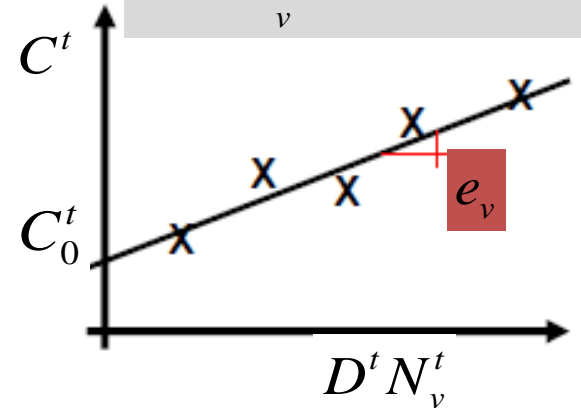
Measurements of concentrations



Traffic counting

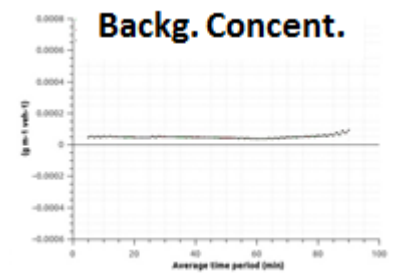
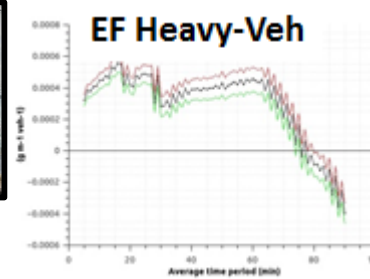
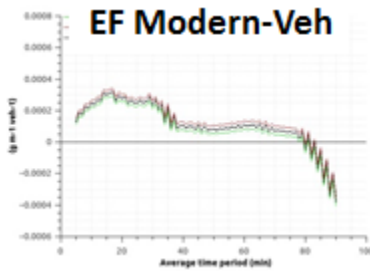
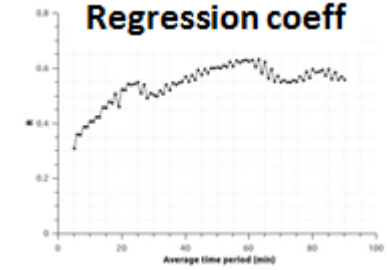
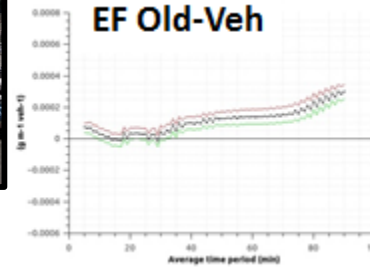
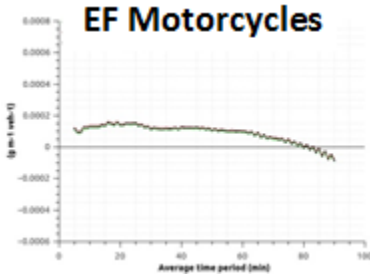


$$C^t = \sum_v D^t N_v^t e_v + C_0^t$$



Bulk emission factors

# Example of Cuba

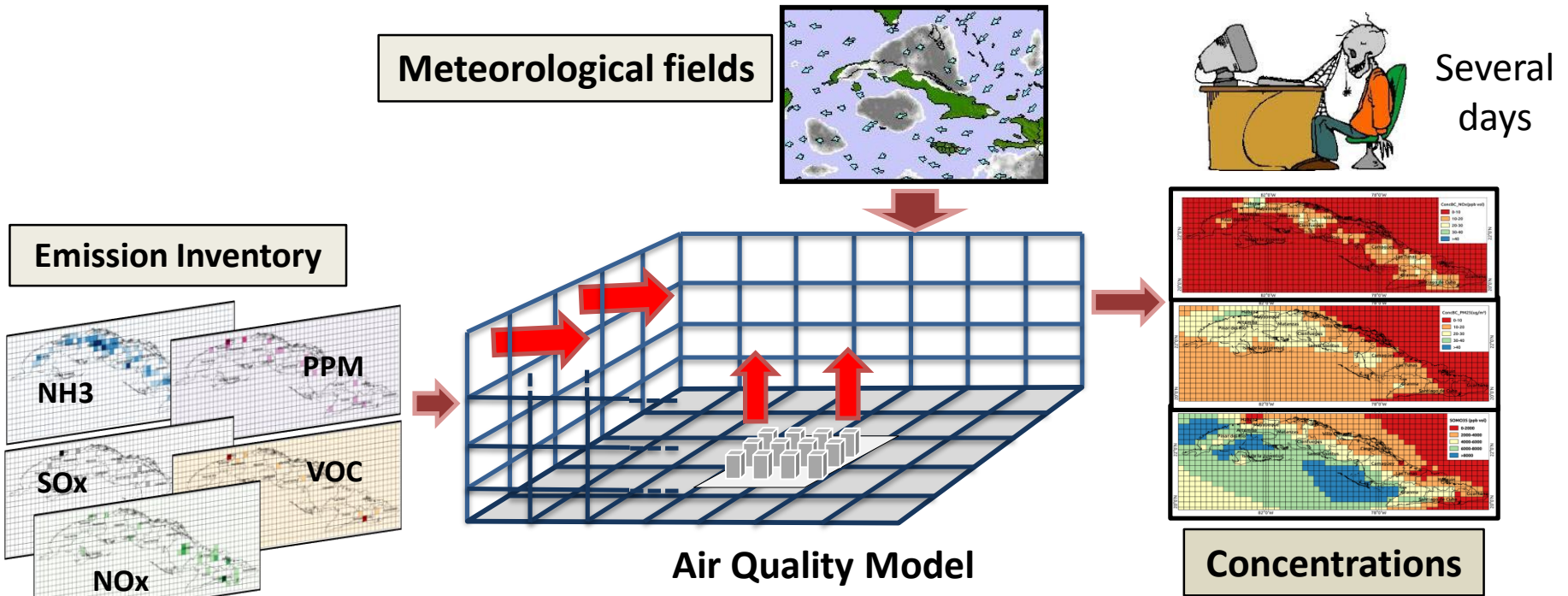


	Emissions (mg/km)	Std. Dev 95% Confid	Emis. (mg/km/ pers)	Concent. ( $\mu$ /m <sup>3</sup> )
Motorcycles	111.8	2.7	<b>55.9</b>	4.4
Modern vehicles	91.3	11.2	22.8	9.6
Old vehicles	124.2	18.5	31.1	<b>26.7</b>
Bus	<b>413.8</b>	31.25	3.5	14.9

1. Identification of time-averaging
2. Principal Component Regression (PCR) instead of Multi Linear Regression (MLR)



# Example of Cuba



Few minutes

**Emissions**

Set of scenarios results

$$C_i = f_i(E_1, E_2, \dots, E_n)$$

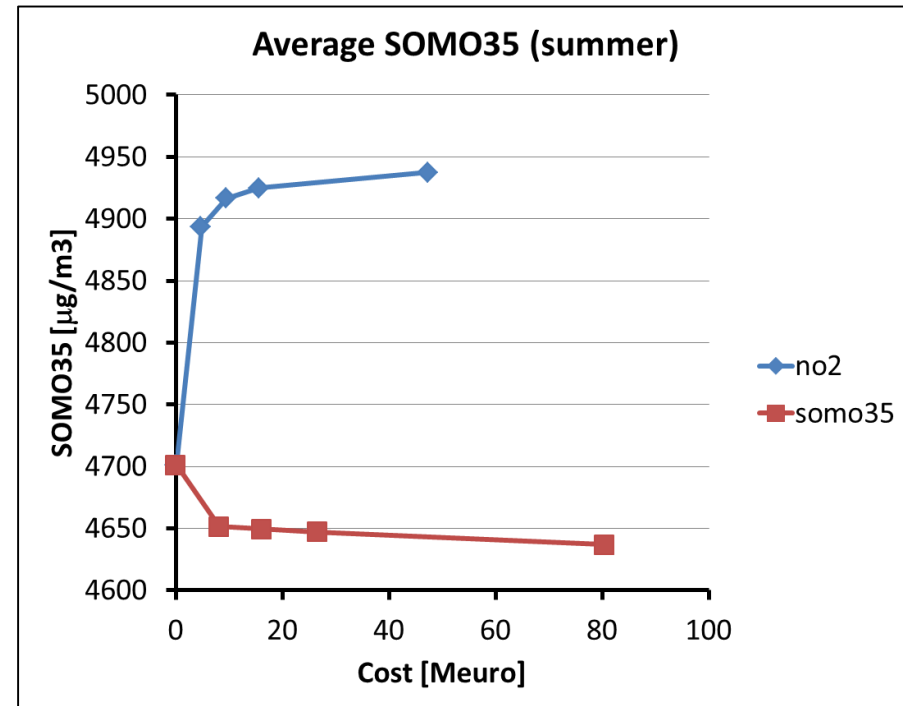
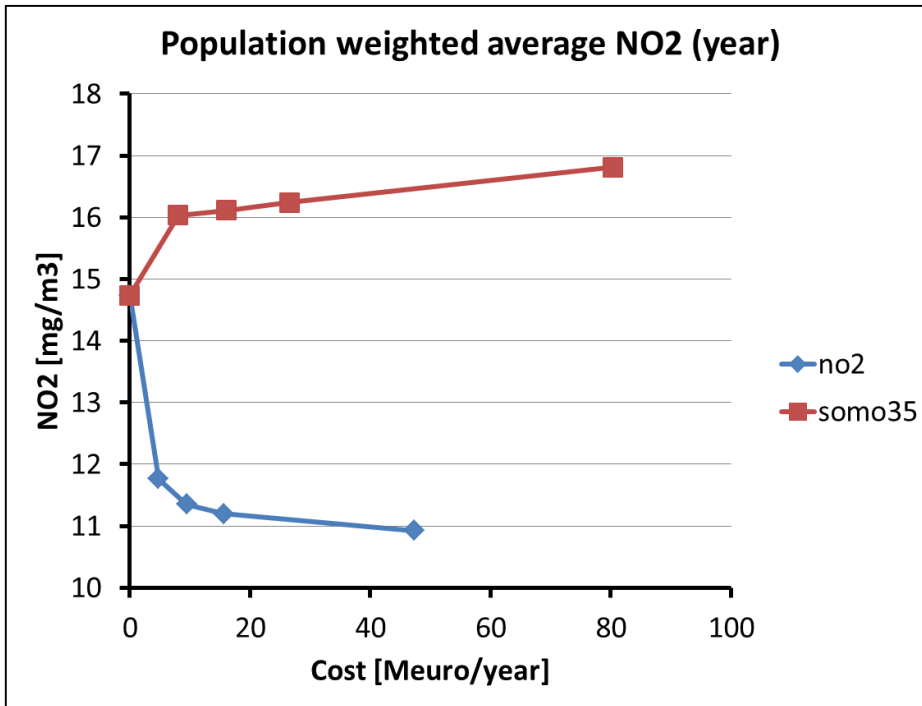
**Concentrations**

*Source-Receptor Relationship - SRR*

# **HOW TO DEAL WITH MULTIPLE OBJECTIVES?**

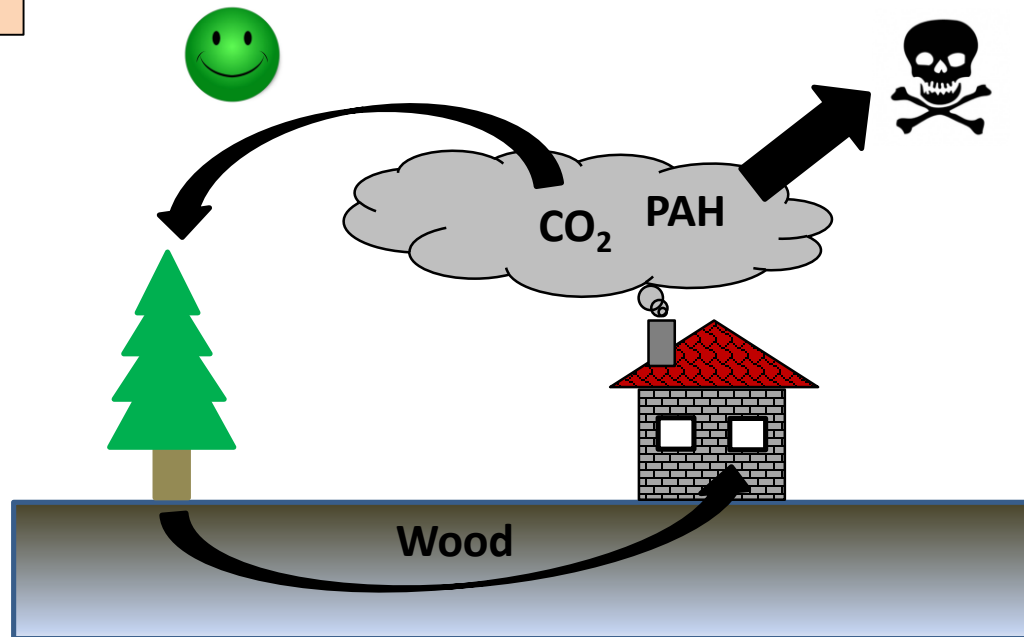
# Multiple Objectives

## O<sub>3</sub> & NO<sub>2</sub> over Alsace



# Multiple Objectives

Wood burning

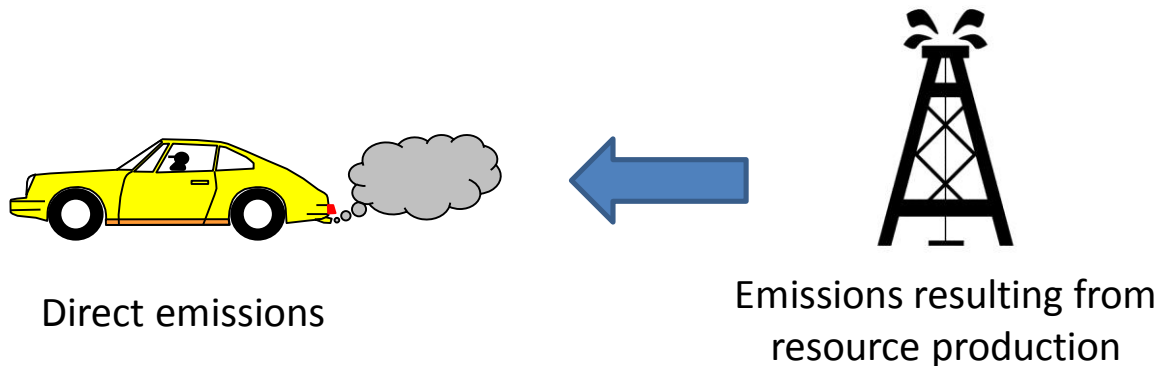


Burning wood in residential heating systems contributes to reduce the emissions of greenhouse gases but it releases harmful pollutants.

# Multiple Objectives

Air quality degradation and climate change are two related issues as they are caused by fossil fuels combustion. The reduction of harmful pollutants ( $\text{NO}_x$ ,  $\text{SO}_2$ , PM, CO, VOC,  $\text{O}_3$  ...) should be considered together with the reduction of greenhouse gases ( $\text{CO}_2$ ,  $\text{CH}_4$  ....).

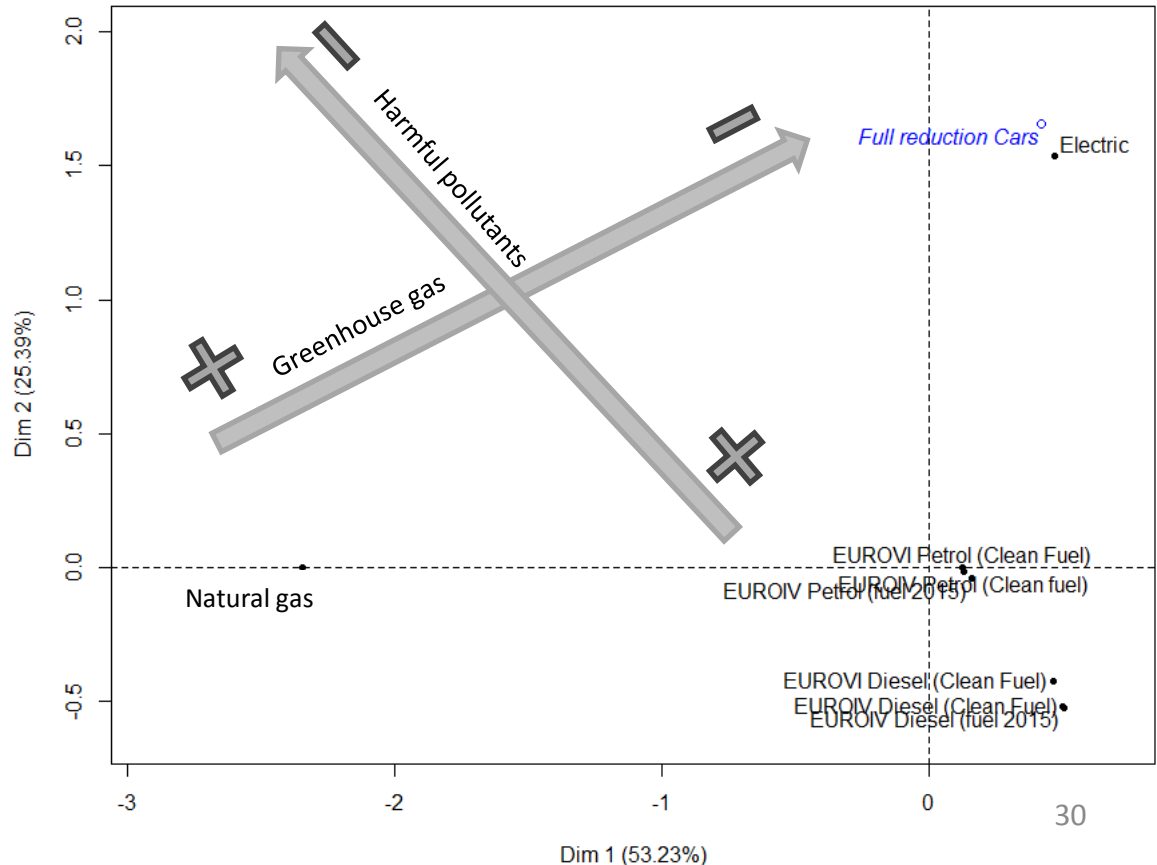
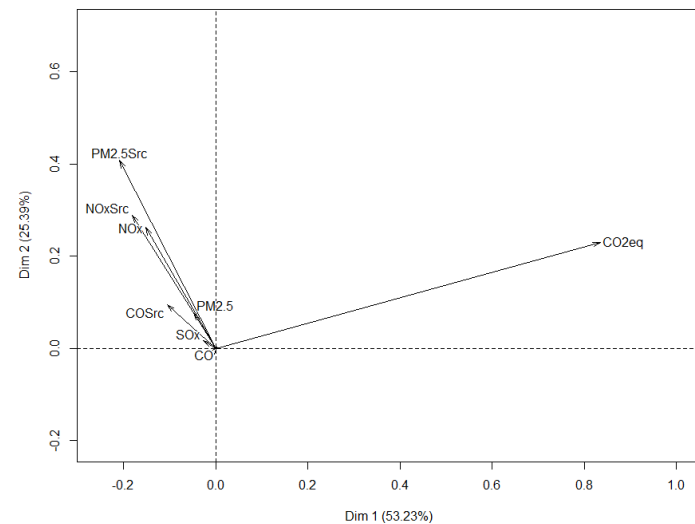
All activity sectors should be considered:



# Multiple Objectives

## Private cars in Bogota (Colombia)

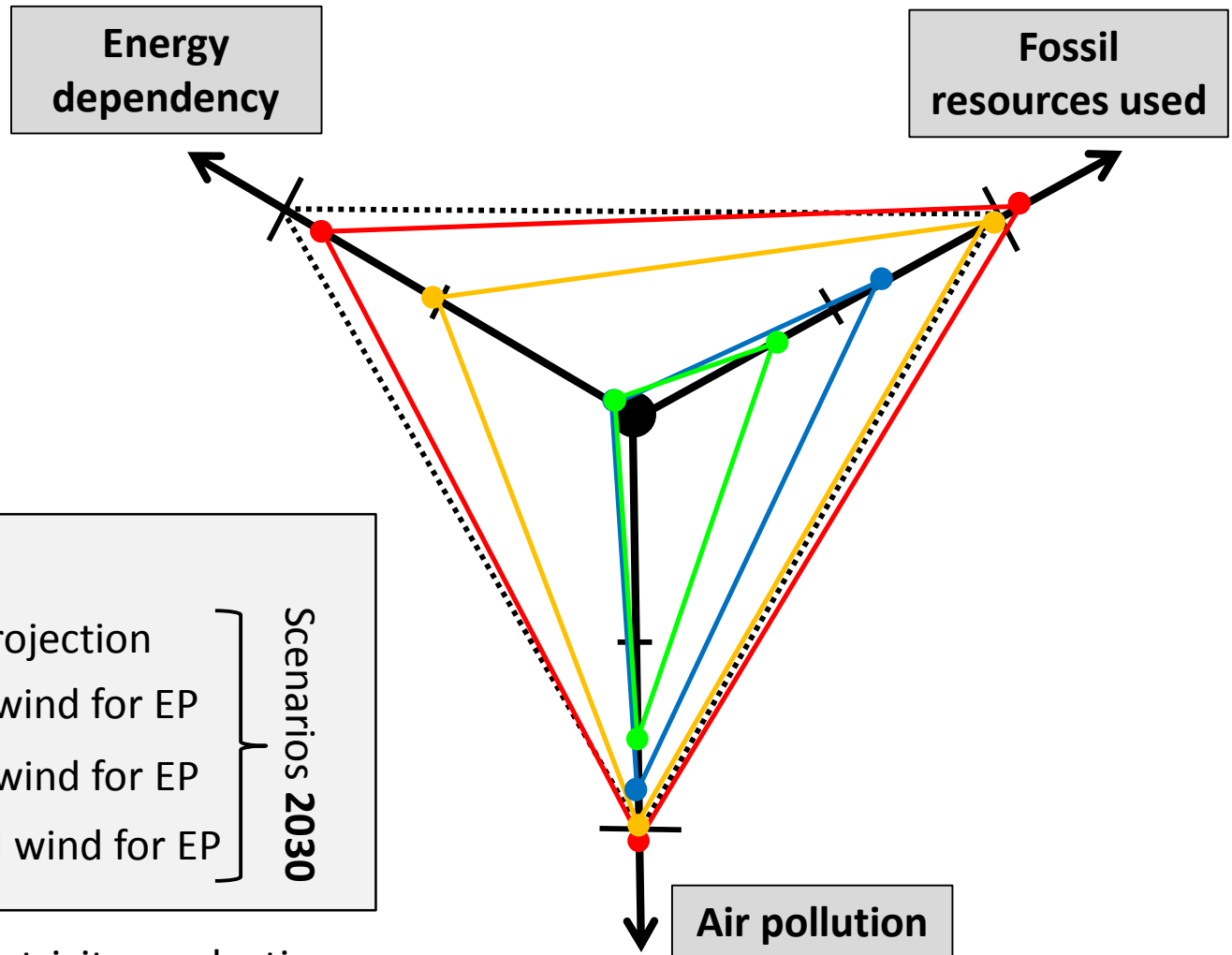
Direct emissions + Emissions resulting from resource production  
for CO, NO<sub>x</sub>, SO<sub>2</sub>, PM and Greenhouse gas (CO<sub>2</sub> equivalent)



**70% of Colombian electricity is hydroelectricity**

# Multiple Objectives

Cuban energy mix



- ..... Situation **2015**
  - Government projection
  - 20% solar and wind for EP
  - 50% solar and wind for EP
  - 100% solar and wind for EP
- Scenarios **2030**

EP = Electricity production

# **TRENDS FOR URBAN AIR QUALITY MANAGEMENT**

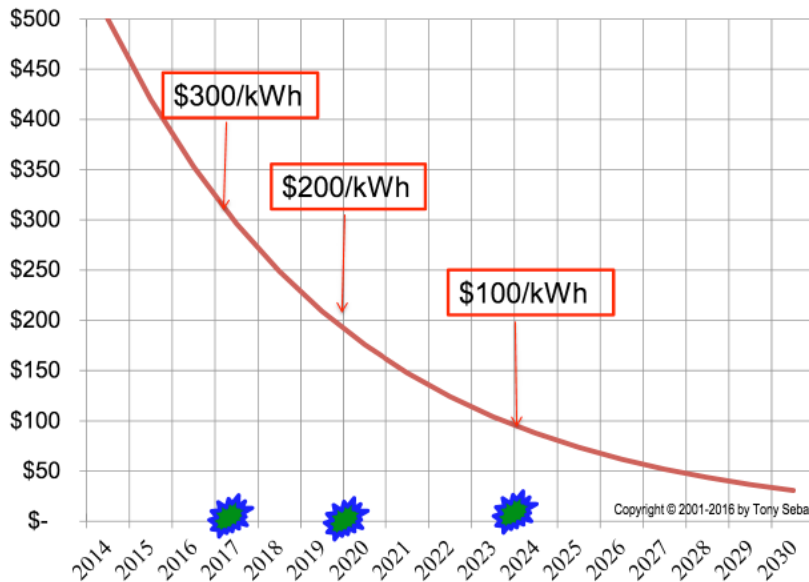


# Electric cars

An electric car is easier to build than a thermal car but it is **more expensive to buy** because of the price of the batteries.

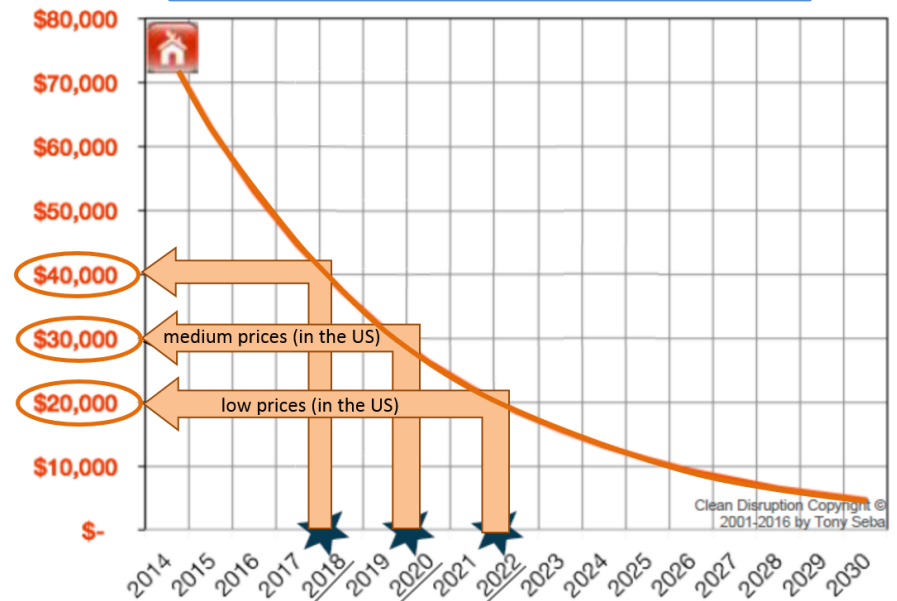
The price of batteries is constantly decreasing, the price of electric cars also decreases.

Projected Cost of Li-On Battery Storage (\$/kWh)



Assumption: 16% /year Technology Cost Curve

Projected Cost of Electric Vehicles



# Electric cars

Electric vehicles use less energy than thermal vehicles



		Cons.	Weight	Autonomy
		liters/100km	kg	km
VW Golf	Gasoline	8,30	1378	600
	Diesel	6,60	1378	750
	Electric	2,00	1553	200
Softcar	Electric	0,80	500	300

Maintenance costs of electric vehicles are lower than for thermal vehicles

more than 2'00 moving parts in an internal combustion engine

18 moving parts in an electric engine

→ an electric vehicle is 10 to 100 time chipper to maintain.



Electricity is cheaper to transport than fuels

Cost of Use of Electric Vehicles are already lower than for Thermal Vehicles

## Norway's electric cars zip to new record: almost a third of all sales

Camilla Knudsen, Alister Doyle

OSLO (Reuters) - Almost a third of new cars sold in Norway last year were pure electric, a new world record as the country strives to end sales of fossil-fueled vehicles by 2025.



Electric cars are parked in Oslo, Norway January 1, 2019. Picture taken January 1, 2019.  
REUTERS/Alister Doyle

# Secondary PM vs. Primary PM

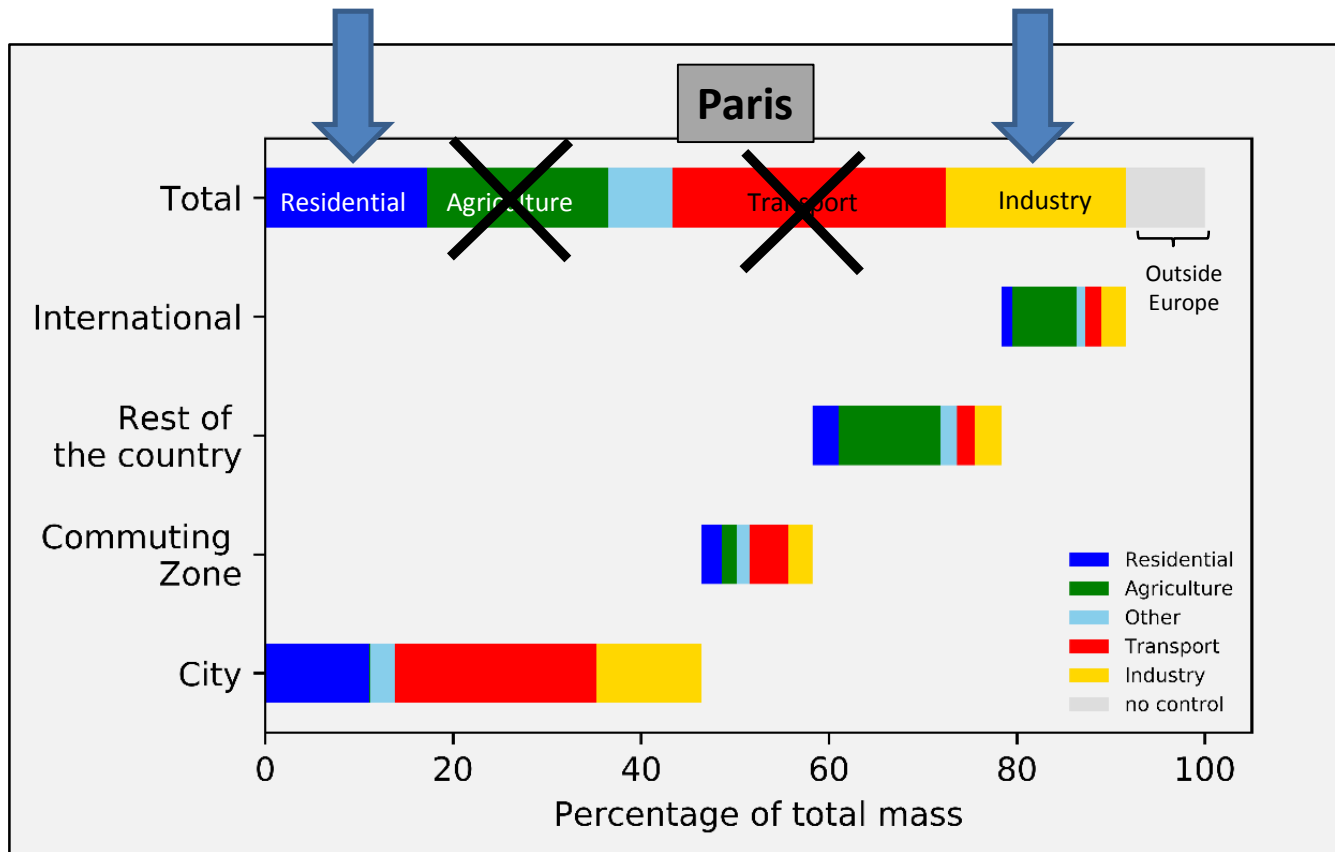
SCIENTIFIC REPORTS

## Differential toxicities of fine particulate matters from various sources

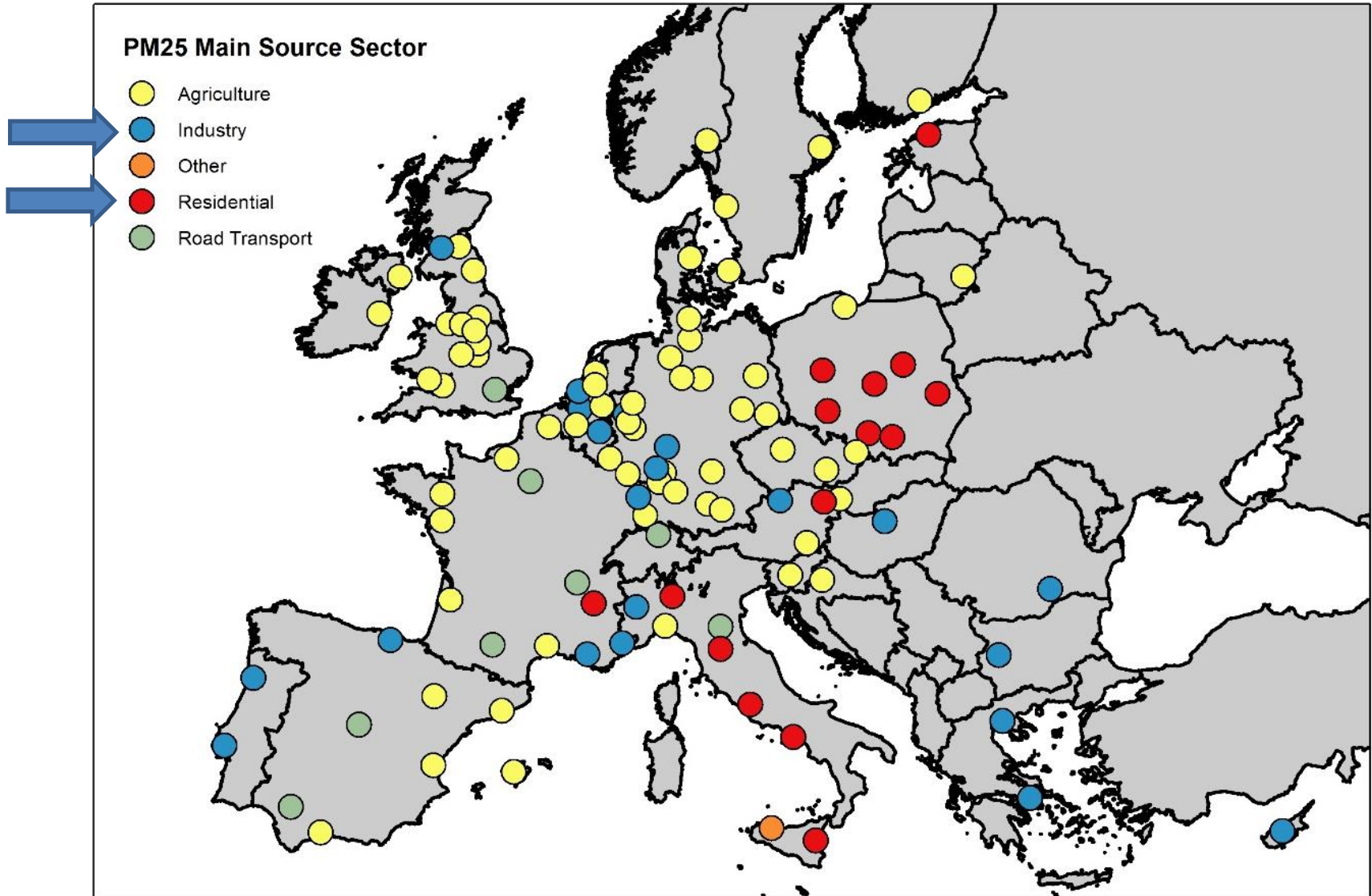
Minhan Park<sup>1</sup>, Hung Soo Joo<sup>1,2</sup>, Kwangyul Lee<sup>1</sup>, Myoseon Jang<sup>3</sup>, Sang Don Kim<sup>1</sup>, Injeong Kim<sup>1</sup>, Lucille Joanna S. Borlaza<sup>1</sup>, Heungbin Lim<sup>4</sup>, Hanjae Shin<sup>5</sup>, Kyu Hyuck Chung<sup>6</sup>, Yoon-Hyeong Choi<sup>7</sup>, Sun Gu Park<sup>7</sup>, Min-Suk Bae<sup>8</sup>, Jiyi Lee<sup>9</sup>, Hangyul Song<sup>1</sup> & Kihong Park<sup>1</sup>

Recent publications have shown that secondary PM (like ammonium nitrate) are much less harmful than primary PM.

# Urban Air Quality Management



# Urban Air Quality Management



An aerial photograph of a European city street. The street is lined with multi-story buildings, some with half-timbered facades. A large church spire is visible in the background. The text "MERCI DE VOTRE ATTENTION" is overlaid in the center of the image.

**MERCI DE VOTRE  
ATTENTION**