WG1 - Source apportionment

Exercise SA

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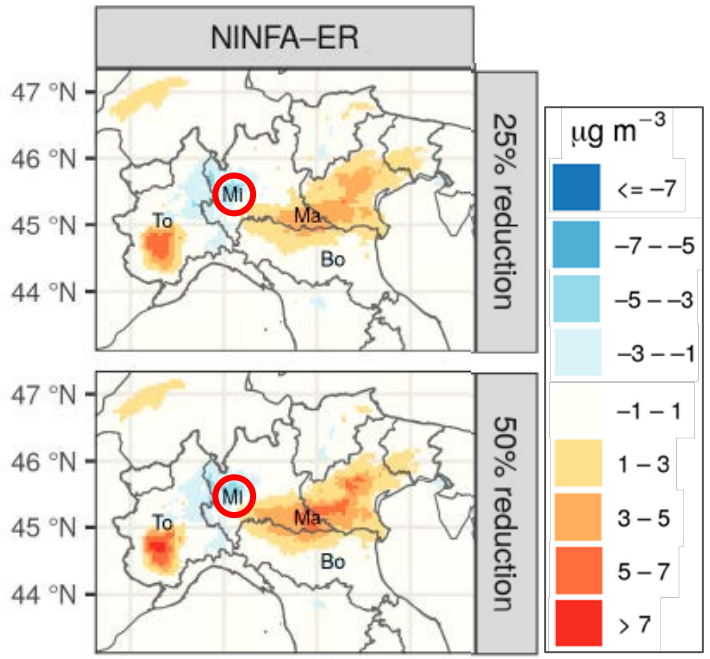
Exercise 1

Chemical Regime NOx vs. NH3



Atmosphere **2023**, *14*, 762. https://doi.org/10.3390/atmos14050762

atmosphere

MDPI

Article

Impact of NO_x and NH_3 Emission Reduction on Particulate Matter across Po Valley: A LIFE-IP-PREPAIR Study

Giorgio Veratti [1,2,*], Michele Stortini [2], Roberta Amorati [2], Lidia Bressan [2], Giulia Giovannini [2], Stefano Bande [3], Francesca Bissardella [3], Stefania Ghigo [3], Elisabetta Angelino [4], Loris Colombo [4], Giuseppe Fossati [4], Giulia Malvestiti [4], Alessandro Marongiu [4], Alberto Dalla Fontana [5], Barbara Intini [5] and Silvia Pillon [5]

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4 ARPA Lombardia, Regional Environmental Agency of Lombardia, 20162 Milano, Italy; e.angelino@arpalombardia.it (E.A.); lo.colombo@arpalombardia.it (L.C.); g.fossati@arpalombardia.it (G.F.); g.malvestiti@arpalombardia.it (G.M.); a.marongiu@arpalombardia.it (A.M.)
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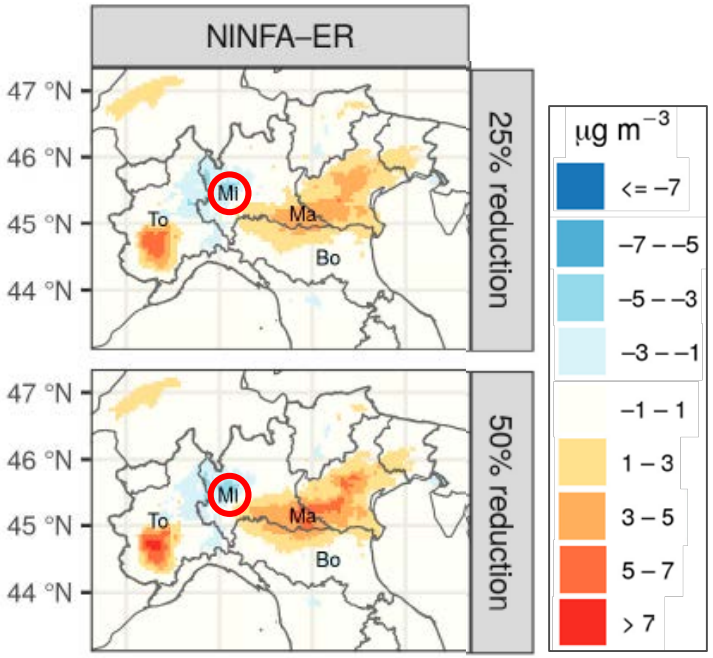
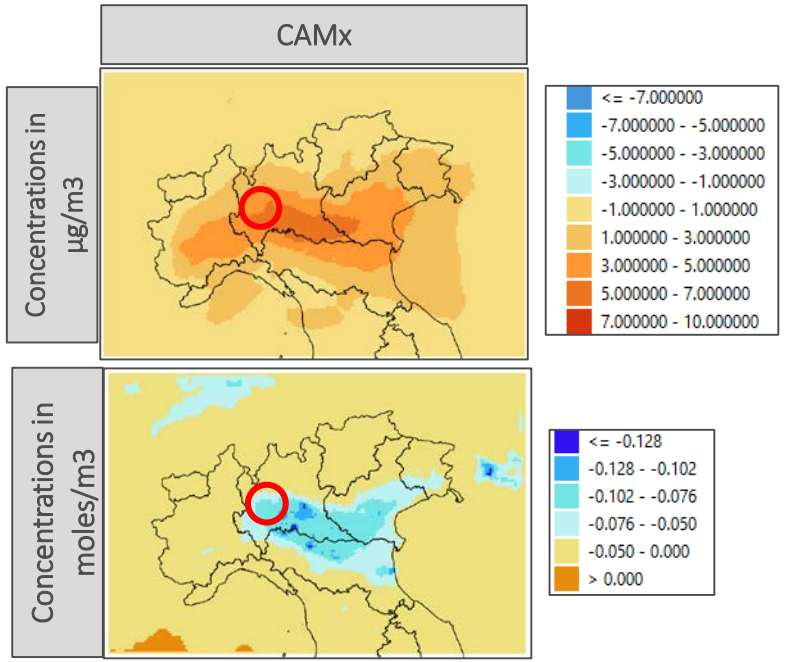
Chemical Regime NOx vs. NH3

Difference $P^{\alpha}_{NOX} - P^{\alpha}_{NH3}$ based on NINFA/Brut Force for α=25% and α=50%



Difference Cnt_{NOX} (NO_3^-) – Cnt_{NH3} (NH_4^+) based on CAMx/PSAT



Which precursor would you recommend to reduce in priority in the Milan area to abate PM2.5 concentration?

NH3 because its reduction impacts more the PM concentrations than the reduction of NOx

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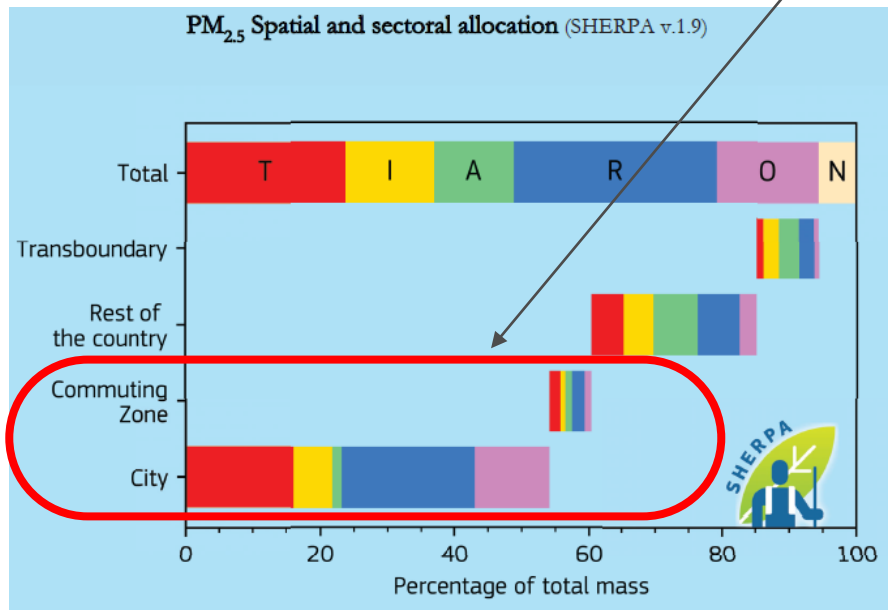
Spatial Scale and Sectorial Impacts

The decision maker, who mandates you, can only take decision in the area of Milan



Which activity sectors should be reduced to produce the largest impact on PM abatement (in the city and commuting zone)?

Residential and transport have the highest impact
Other sources and Industry have a lower impact
Agriculture have the lowest impact

Could this recommendation be in contradiction with the previous one?

NH3 is mainly emitted by Agriculture, while NOx is mainly emitted by Transport and Industry. A reduction of NOx should lead to a higher reduction of PM than a reduction of NH3 which seems to be in contraction with the previous conclusion.

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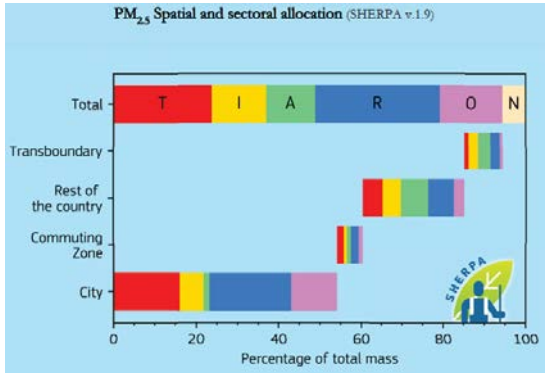
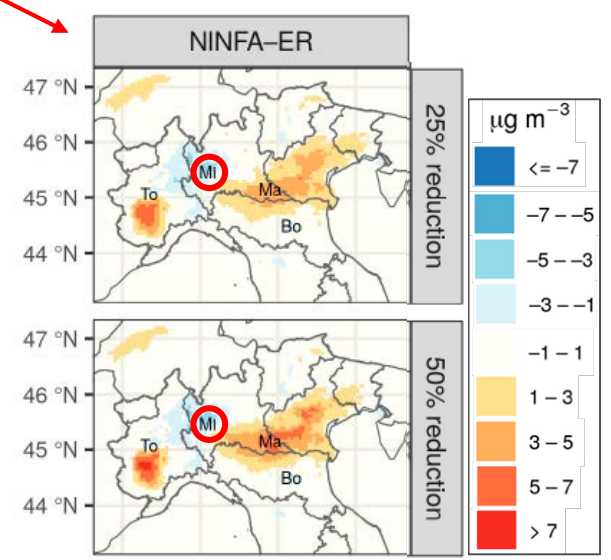
Why?

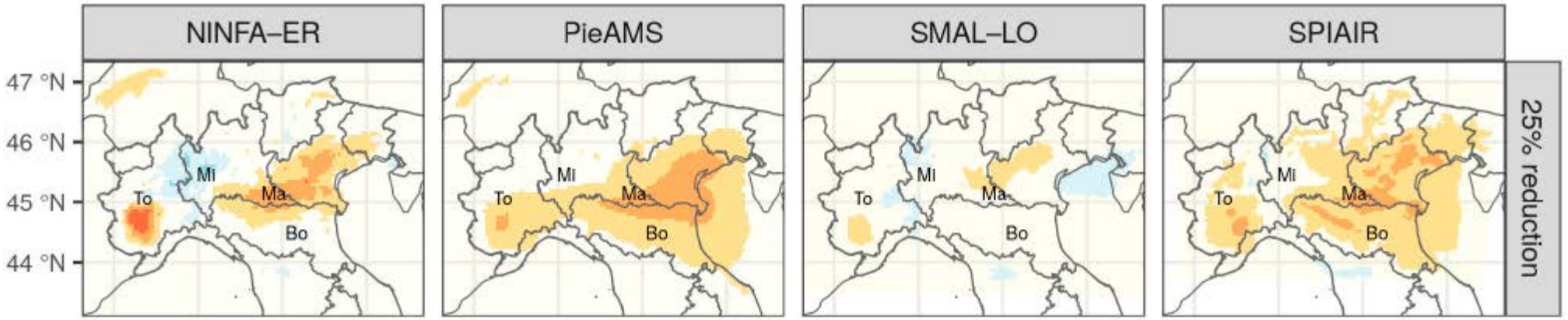
- « Model systems » are different

SHERPA based on EMEP





Comparison between different models



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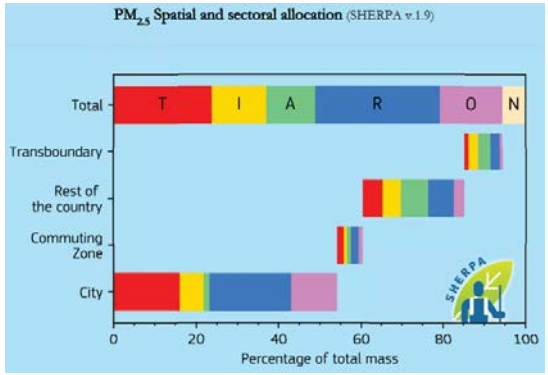
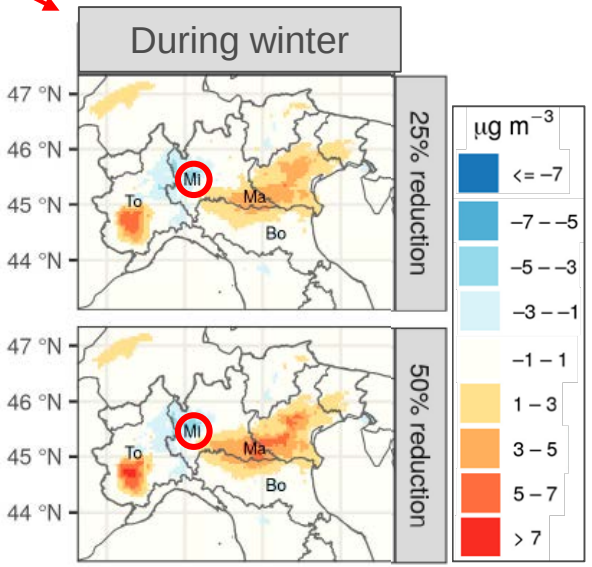
Why?

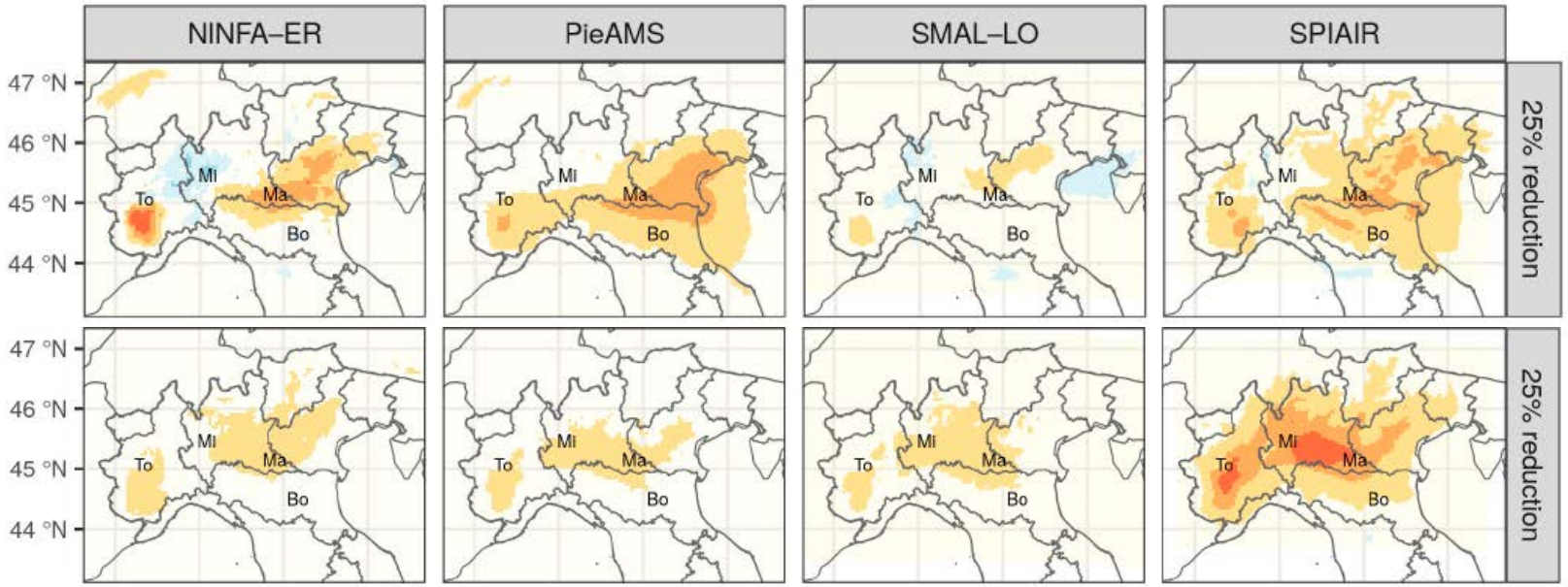
- « Model systems » are different
- Time scale are different
  (was not indicated in the exercise)

During one year



During winter





WINTER

SUMMER

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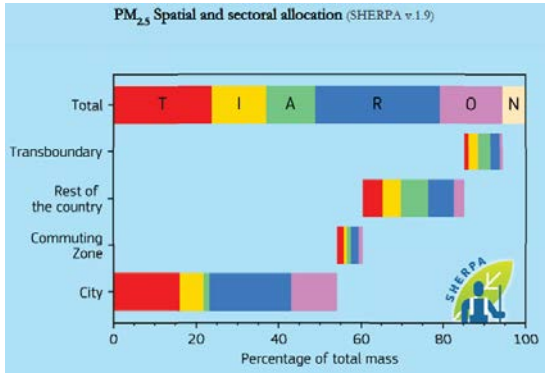
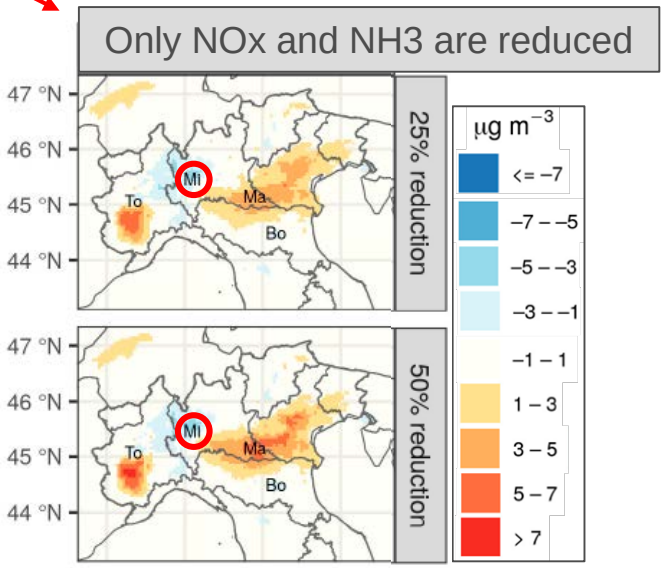
Why?

- « Model systems » are different
- Time scale are different
  (was not indicated in the exercise)
- Reductions affect different precursors

All precursors are reduced



Only NOx and NH3 are reduced



We could imagine that the PM in Milan are composed by a large amont of PPM emitted in their majority by the Residential and Transport sectors and not by Agriculture.

Then, the reductions are mainly driven by PPM and not by NOx or NH3.

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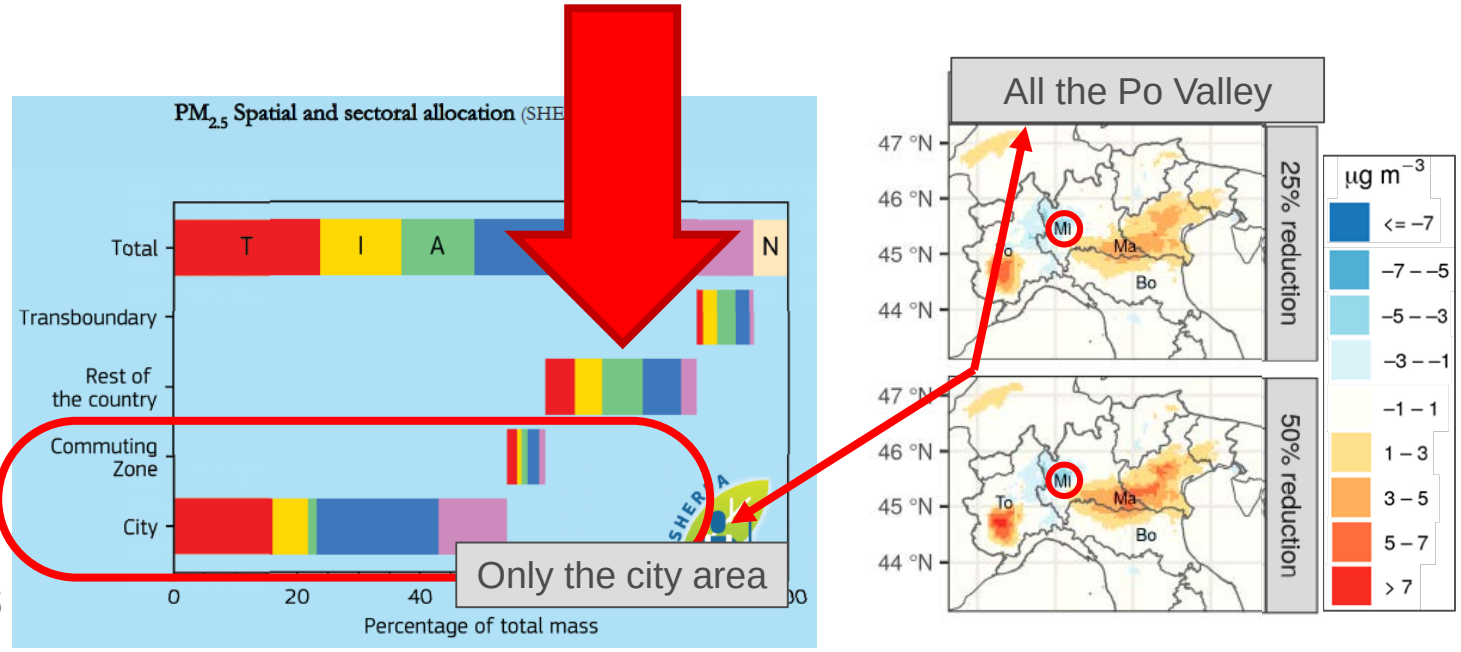
Why?

- « Model systems » are different
- Time scale are different
  (was not indicated in the exercise)
- Reductions affect different precursors
- Spatial scales of the reductions are different



In SHERPA's results, the most significant impacts of agriculture come from reductions on a national scale.

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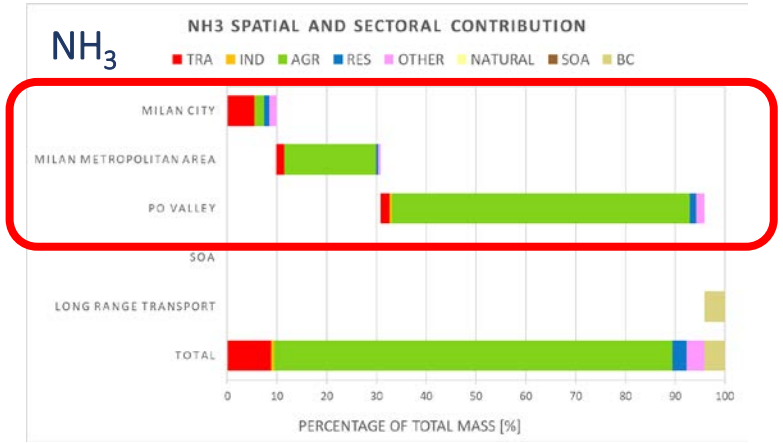
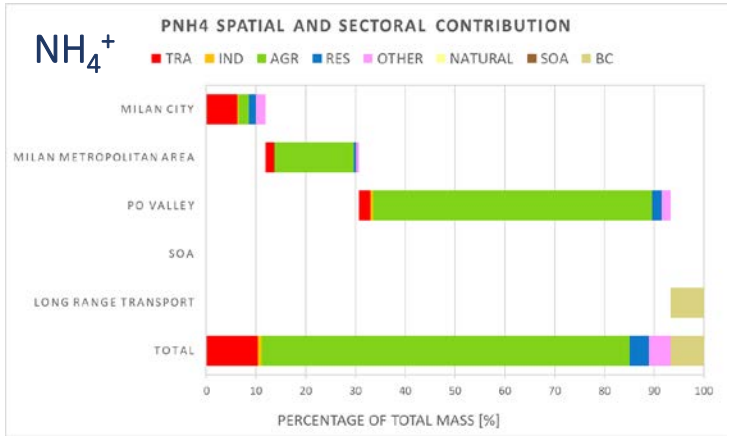
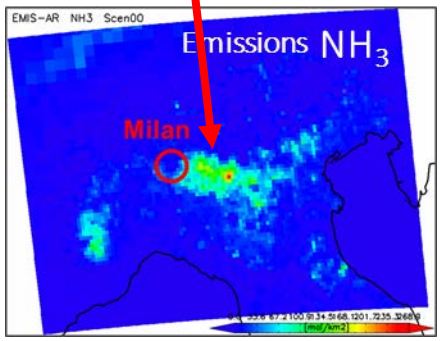
Spatial Scales and Tagging

MILAN receptor: Sectoral and spatial contributions based on CAMx/PSAT







NH3 is emitted mainly by the agriculture at the scale of the Po Valley outside the city

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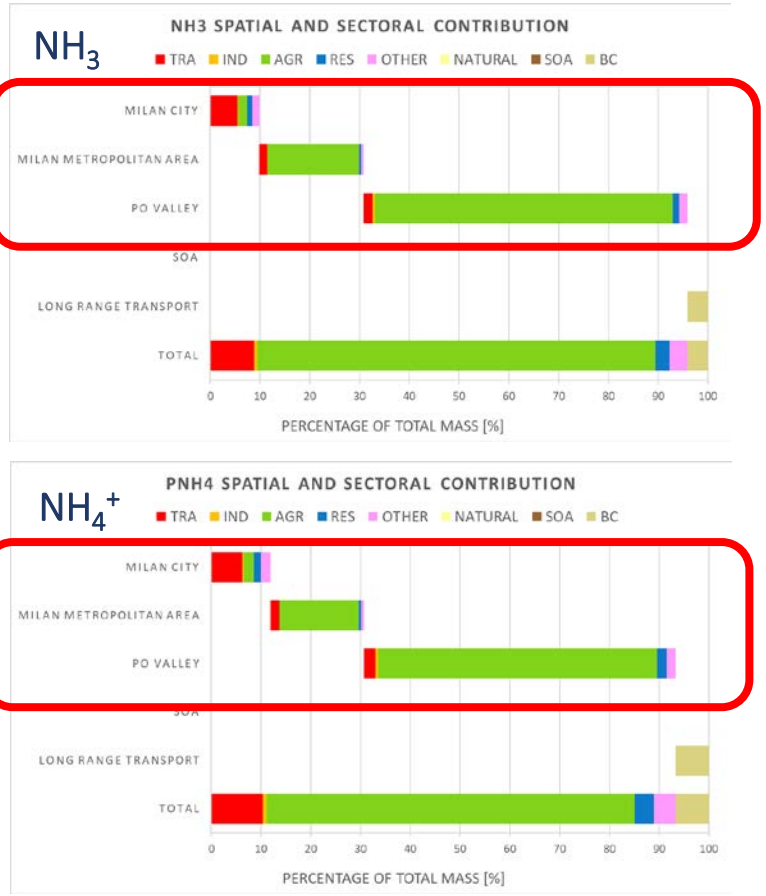
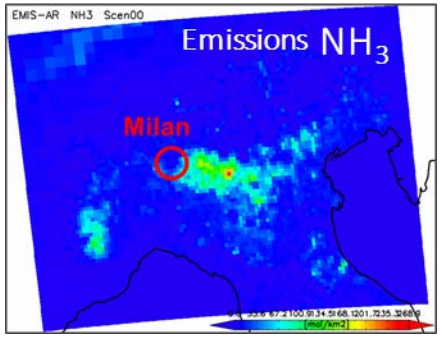
Spatial Scales and Tagging

MILAN receptor: Sectoral and spatial contributions based on CAMx/PSAT

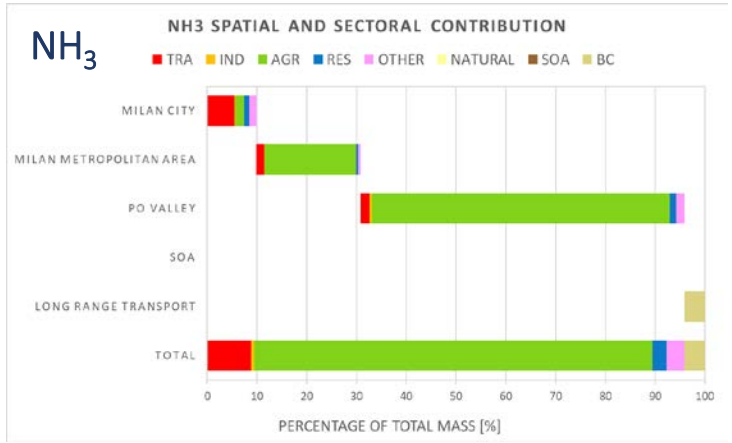


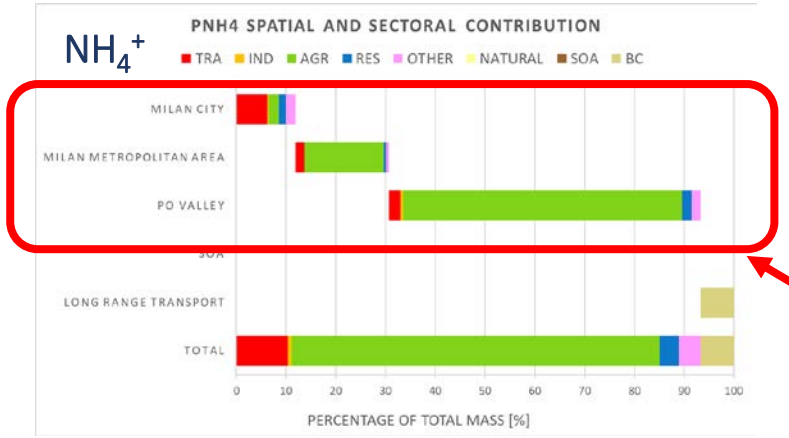


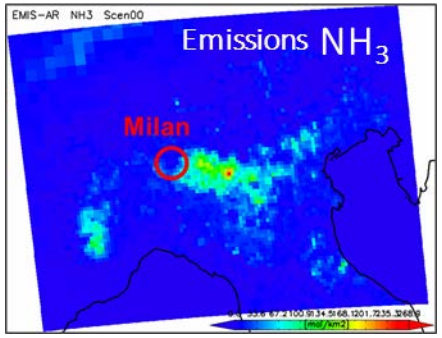
NH4 is produced from NH3, it comes, like NH3, mainly from the scale of the Po Valley.

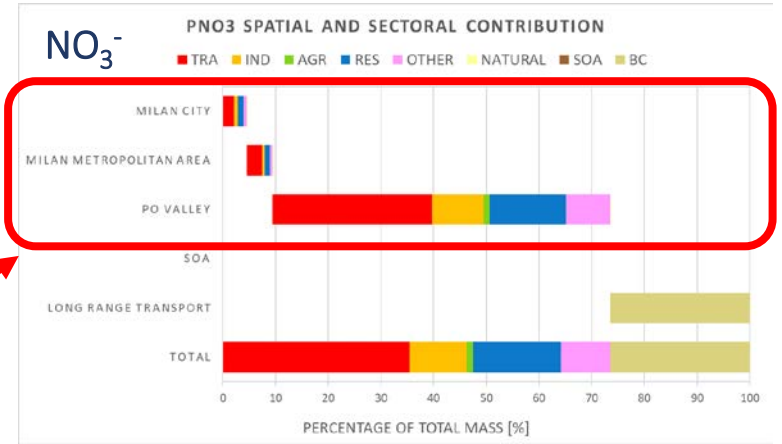
Spatial Scales and Tagging

MILAN receptor: Sectoral and spatial contributions based on CAMx/PSAT









The formation of NH4 from NH3 requiered the presence of NO3 and vice versa.

NO3 comes, like NH4, mainly from the scale of the Po Valley.

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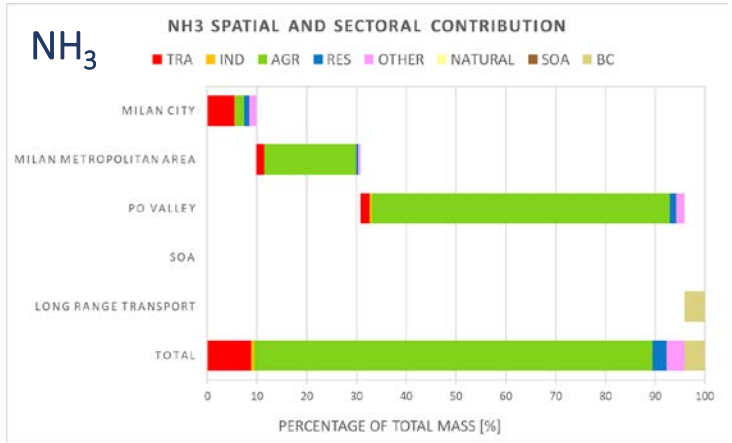
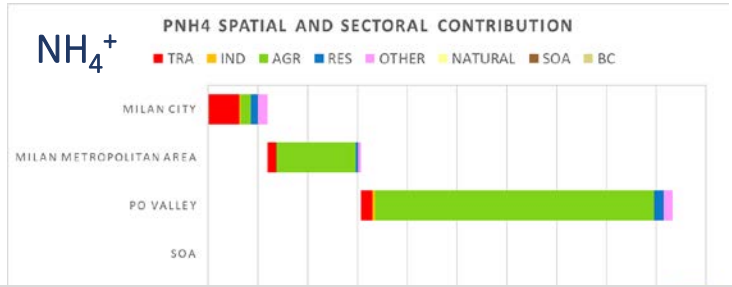
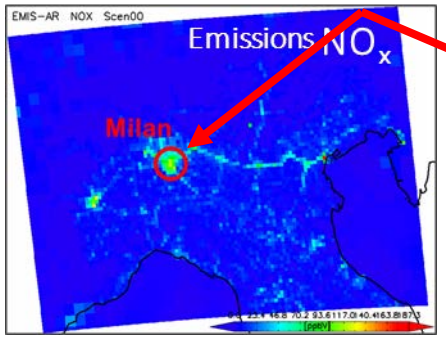
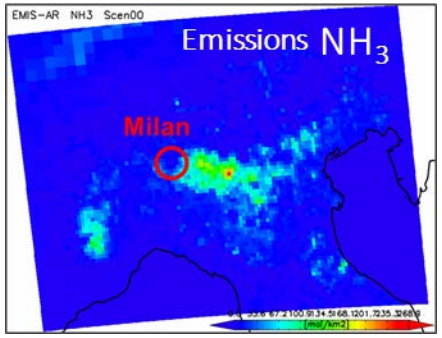
Spatial Scales and Tagging

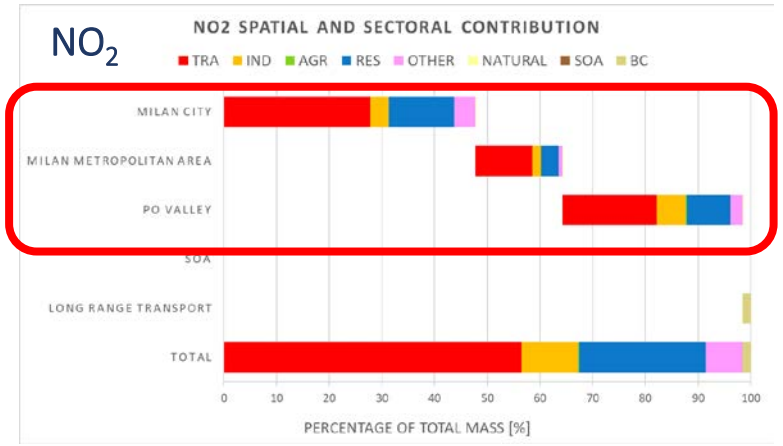
MILAN receptor: Sectoral and spatial contributions based on CAMx/PSAT

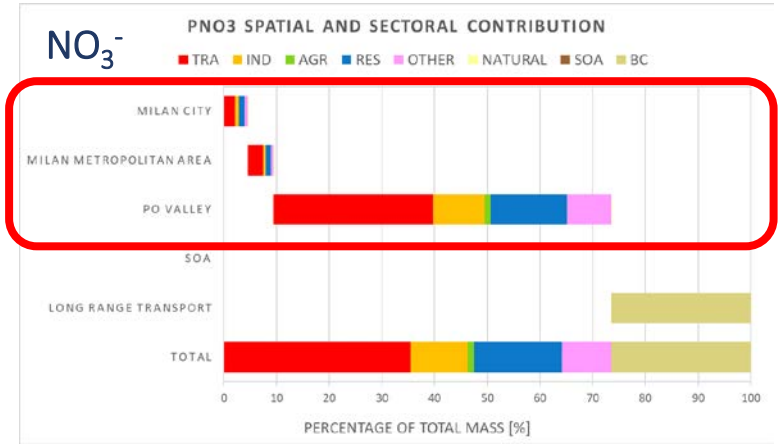












NO3 is produced from NO2 in presence of NH4.

The PSAT results show that main part of NO3 is chemically formed at the scale of the Po Valley while a large part of the NO2 comes the emissions at the scale of the city..

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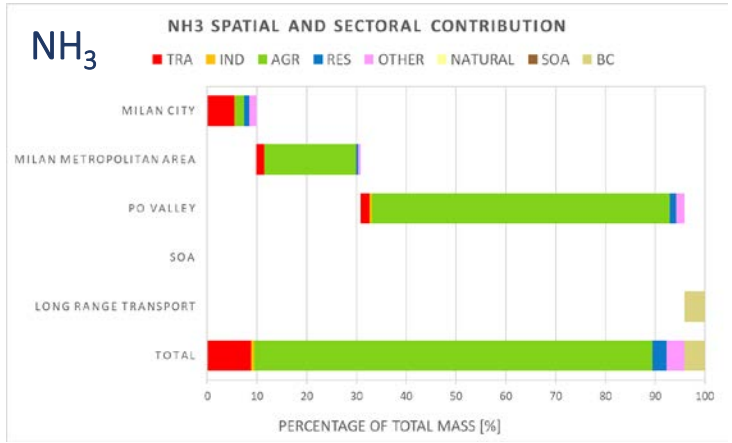
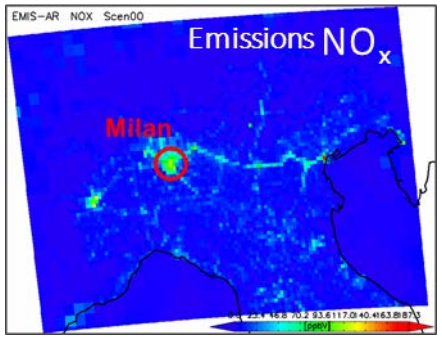
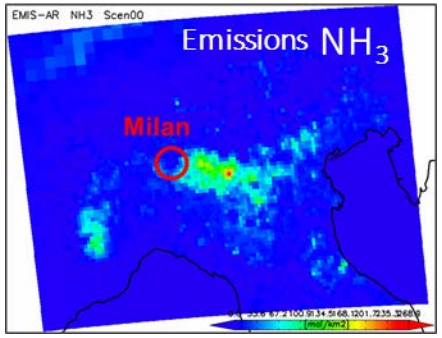
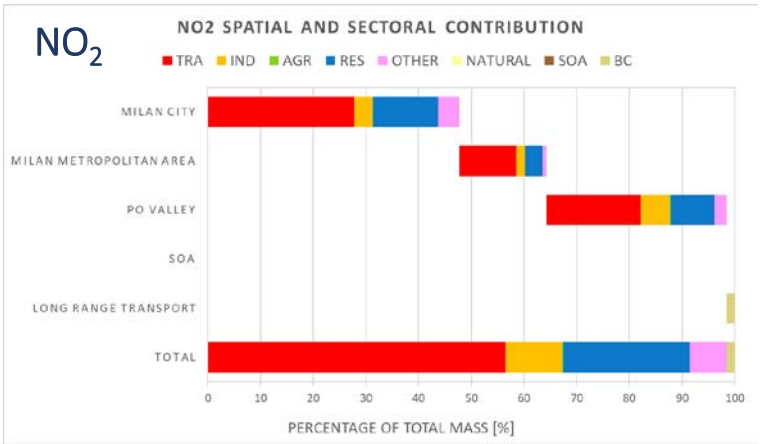
Spatial Scales and Tagging

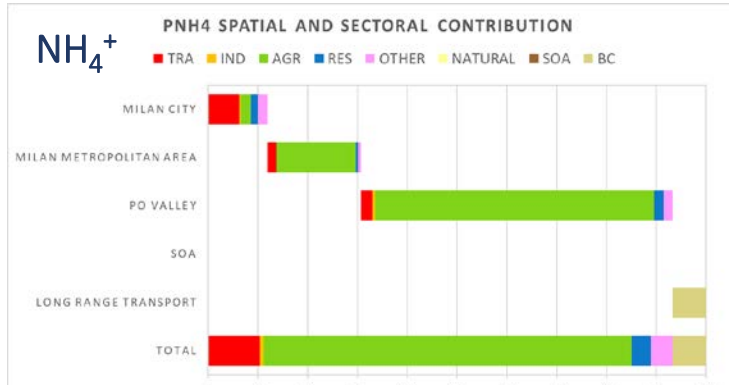
MILAN receptor: Sectoral and spatial contributions based on CAMx/PSAT

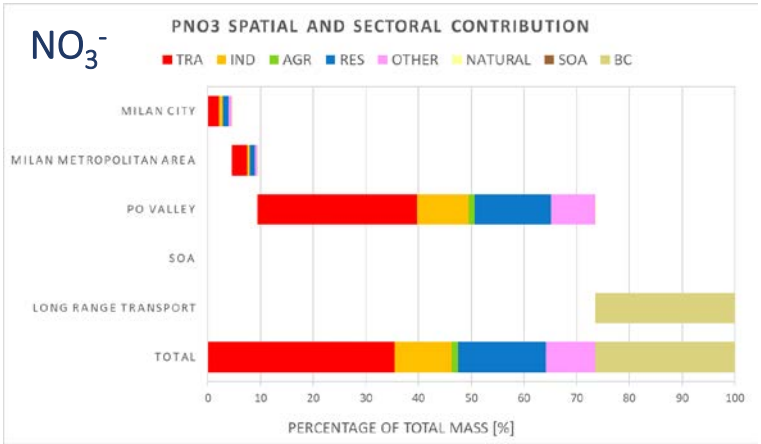












Milan's atmosphere is saturated with NO2 emitted mainly inside the city, so NO2 reductions have less impact than NH3 reductions, but NH3 comes from outside the city, so NH3 reductions confined to the city can be important.

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Exercise 2

Two Different Goals

- Reduce concentrations on average over the year,
- Reduce concentrations when an excessively high daily threshold is reached.

Each of these goals can lead to choosing completely different strategies.

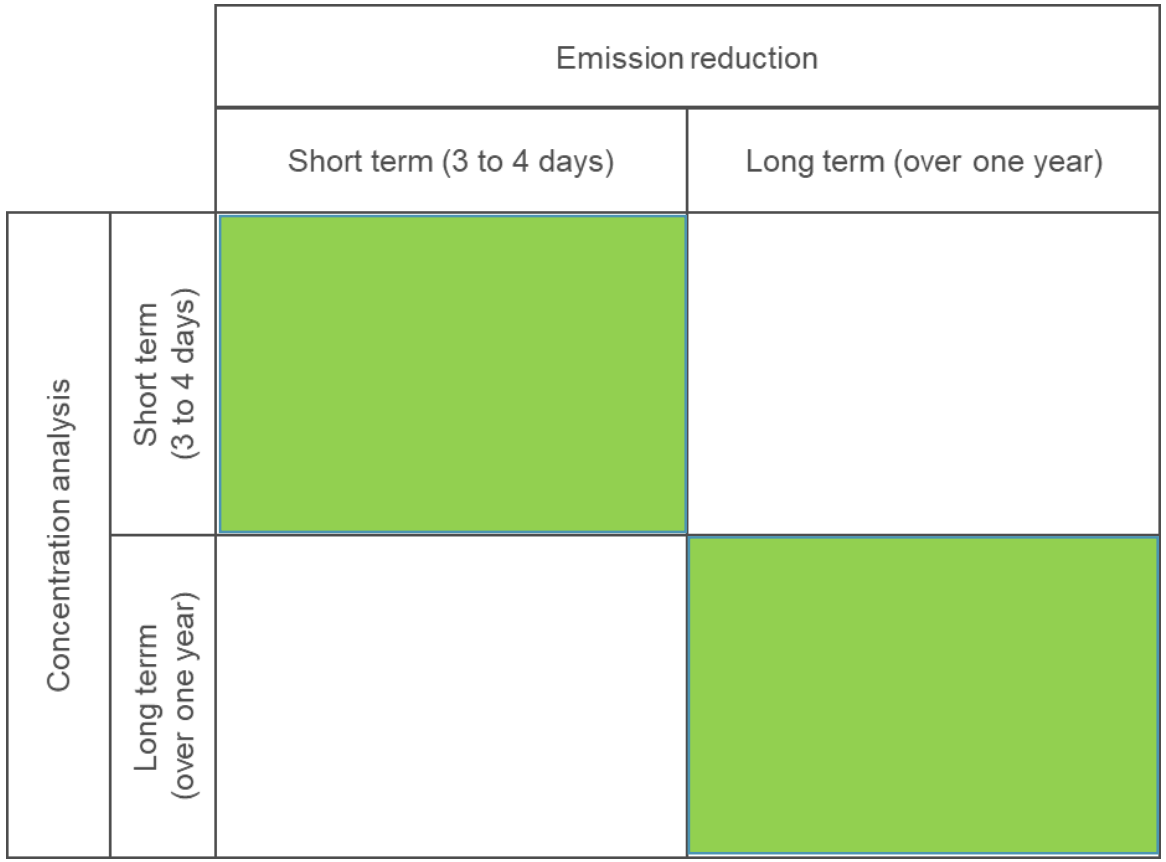
How to use models to design strategies able to reach these two goals?

Time Scale

Reducing peaks of exceedance requires the implementation of immediate reduction measures during (or before) the period of exceedance, while reducing annual averages requires implementing strategies over the entire year.

Models should to simulate these two situations which correspond to the two green square

BUT...



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Time Scale

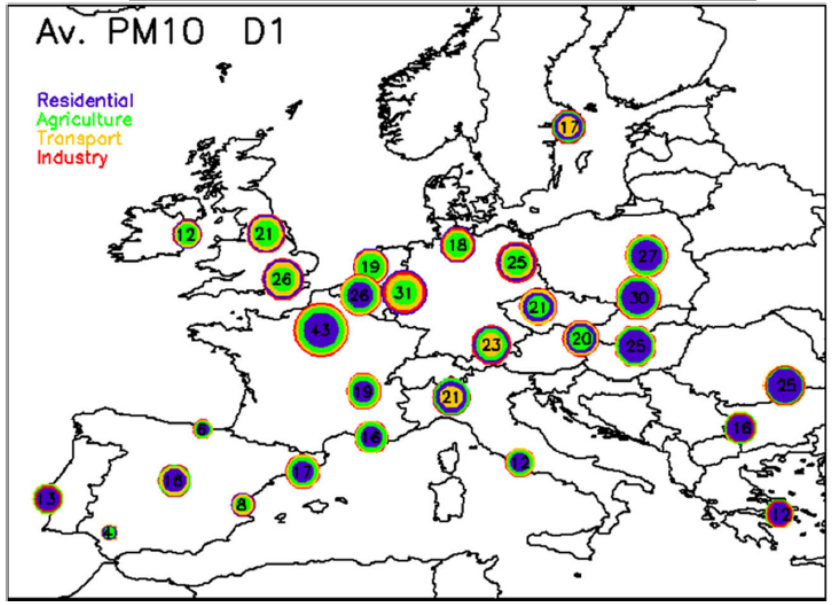
Air Qual Atmos Health (2017) 10:235–248
DOI 10.1007/s11869-016-0427-y

Analyzing the efficiency of short-term air quality plans in European cities, using the CHIMERE air quality model

P. Thunis[1] · B. Degraeuwe[1] · E. Pisoni[1] · F. Meleux[2] · A. Clappier[3]

... reducing emissions over a long period always has an impact over a limited period, depending on the « residence time of the reductions ».

Reduction over 1 day



Reduction over 3 day

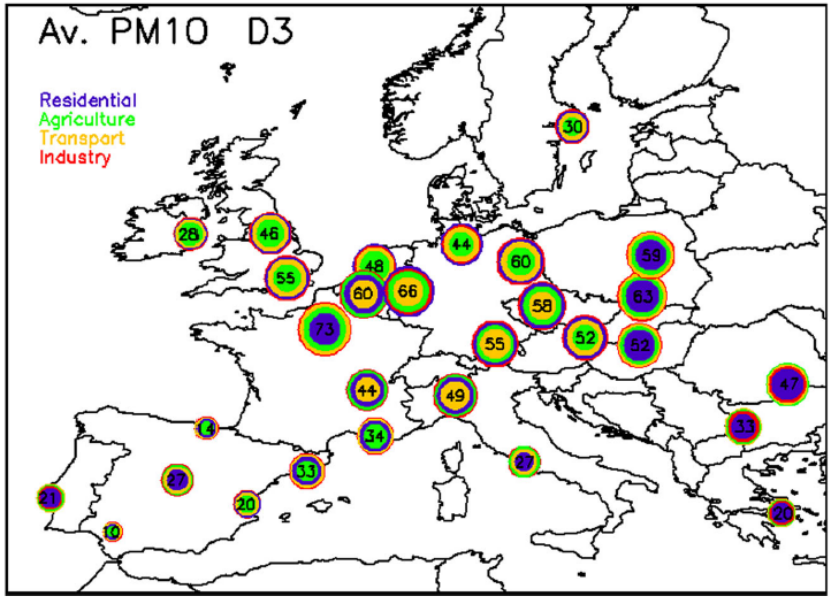


Fig. 1 Map of relative potentials (i.e., $\Delta C/\alpha C$) at $D_{AQP} = 1$ for PM_{10}. The *circled area* is proportional to the potential with the most important contributors placed from center to outwards. The four activity sectors are represented by *different colors*. The *number in each circle* is the overall potential (i.e., corresponding to all sectors reduced simultaneously)

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Time Scale

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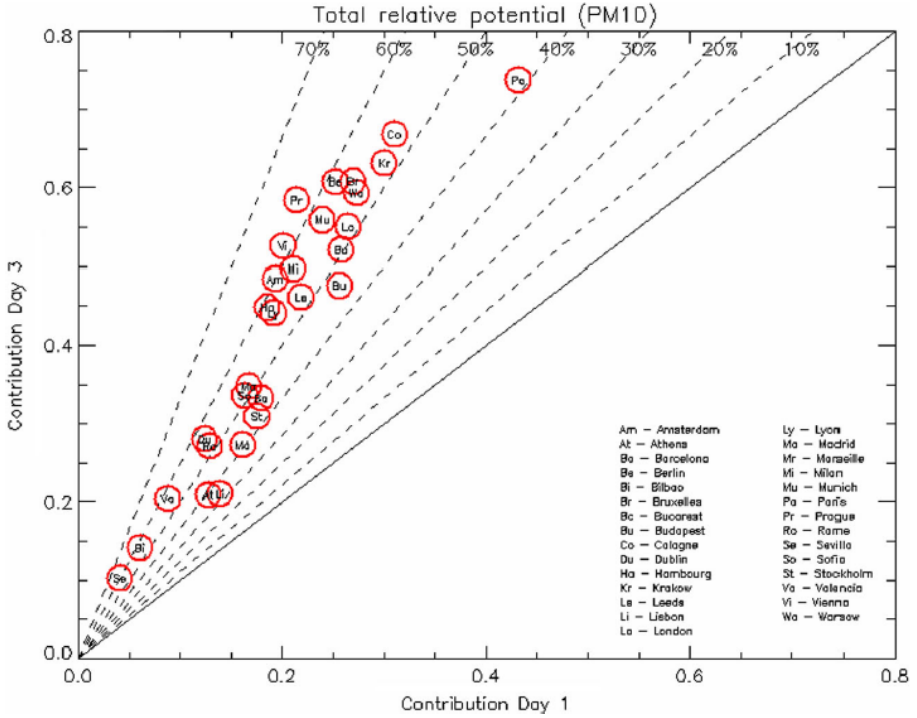
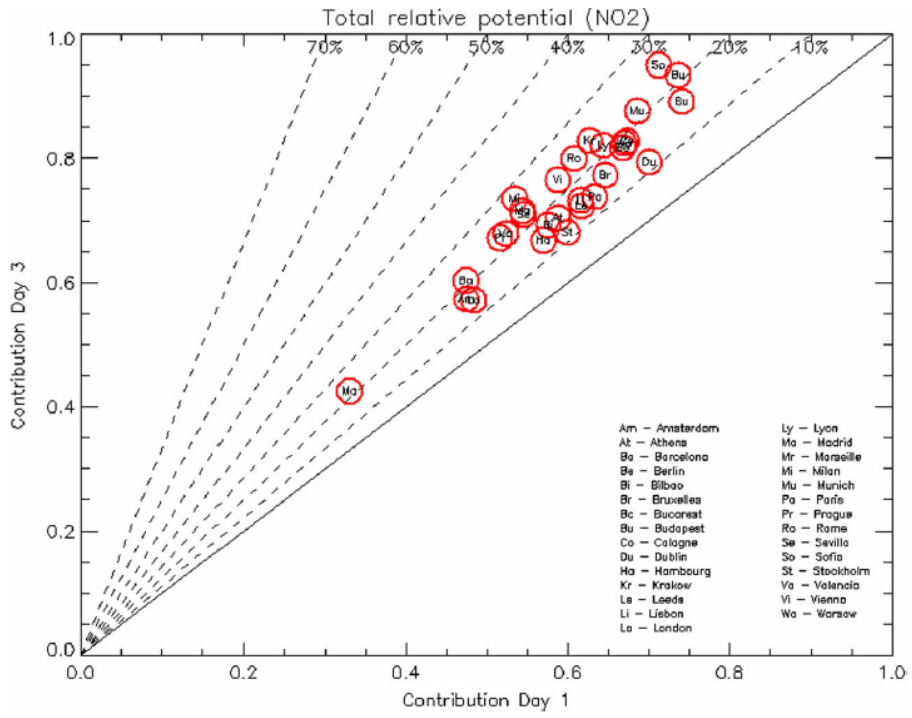
P. Thunis[1] · B. Degraeuwe[1] · E. Pisoni[1] · F. Meleux[2] · A. Clappier[3]

The residence time of reduction dependes from the pollutants concern...

Day3 vs. Day1 for different European cities





... but also from the area which is reduced.

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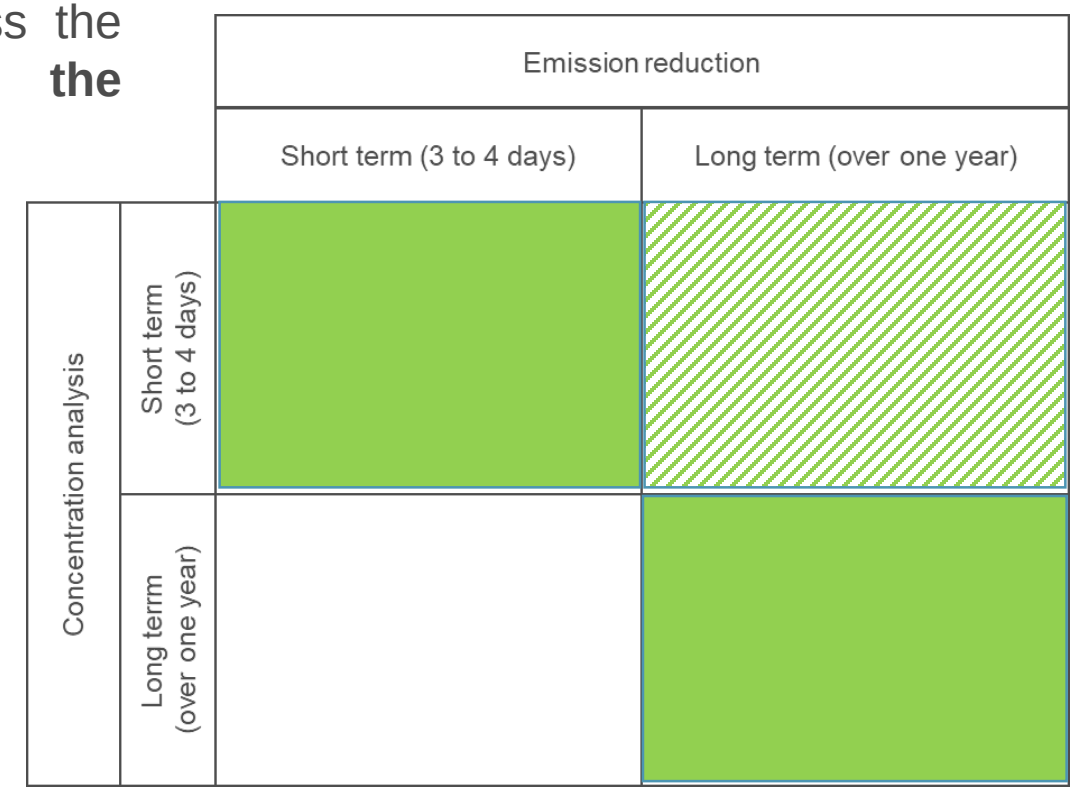
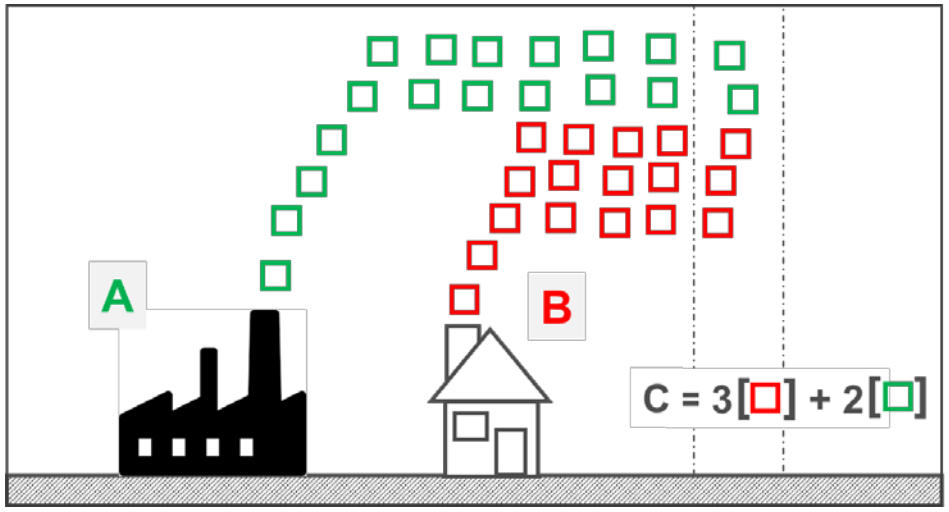
Time Scale

Long-term emission reductions could be used to assess the impact of shorter-term strategies, **provided that the « residence time of reductions » is verified.**

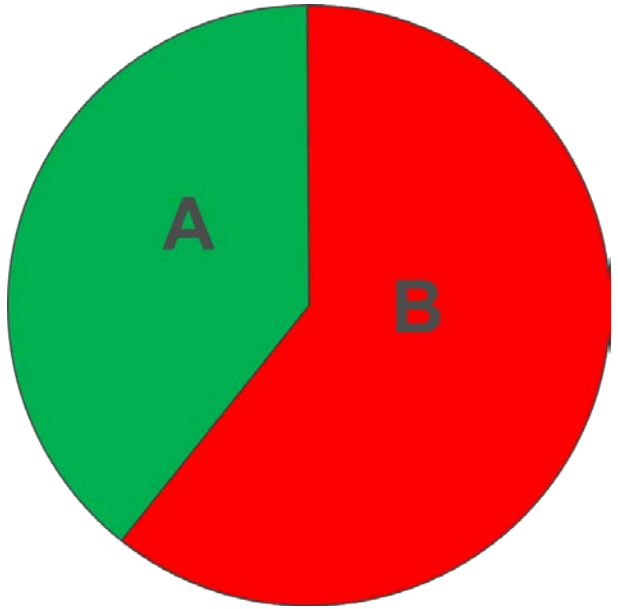


Exercise 3

Ideal Situation



Easy to explain and to understand, ideal for the comunication



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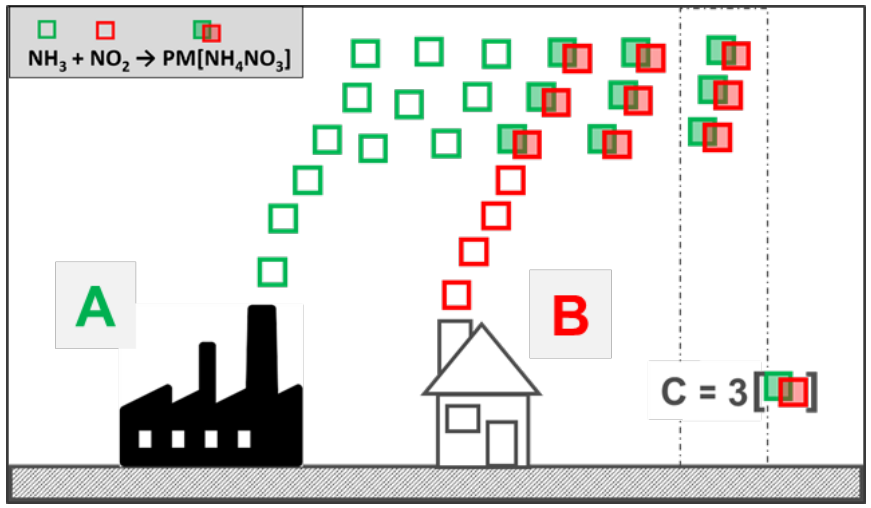
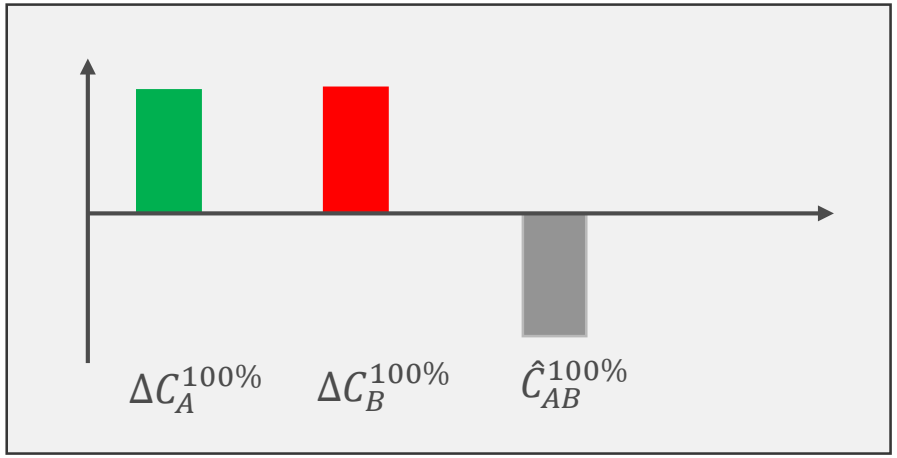
Real Situtation





Concentration changes resulting from an emission reduction:

$$\Delta C_A^{100\%} = 3 \qquad \Delta C_B^{100\%} = 3 \quad \Rightarrow \quad \Delta C_A^{100\%} + \Delta C_B^{100\%} = 6$$

$$\Delta C_{AB}^{100\%} = 3 \quad \Rightarrow \quad \Delta C_{AB}^{100\%} \neq \Delta C_A^{100\%} + \Delta C_A^{100\%}$$

$$\Delta C_{AB}^{100\%} = \Delta C_A^{100\%} + \Delta C_B^{100\%} + \hat{C}_{AB}^{100\%}$$

$$\hat{C}_{AB}^{100\%} = \Delta C_{AB}^{100\%} - \Delta C_A^{100\%} - \Delta C_B^{100\%} = 3 - 6 = -3$$

Interactions between sources and precursors can lead to negative terms and terms which can not attributed to only one unique source

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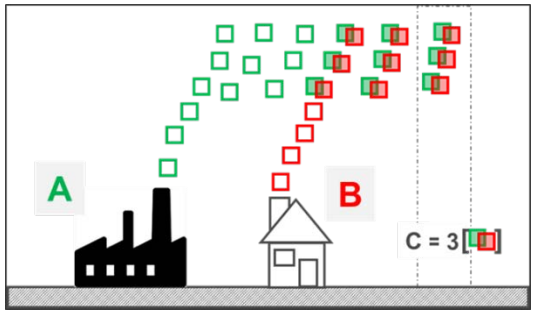
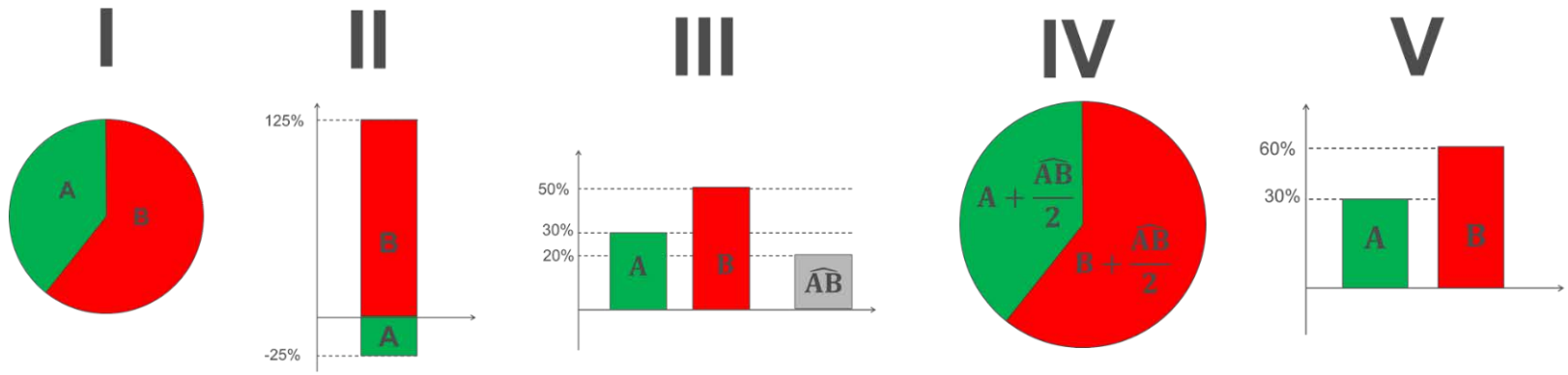
Real Situation



- Should the sum of the terms calculated by a SA method always be equal to 100%?
- Should an SA method produce only positive terms?
- Should an SA method only produce terms that can be attributed to a single source?



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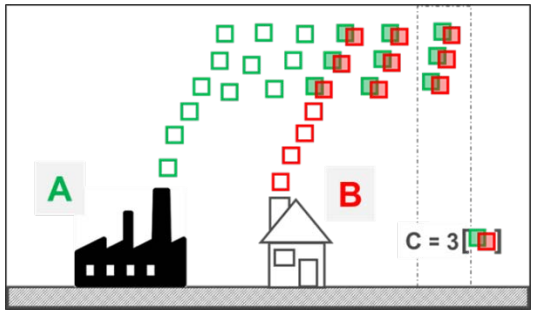
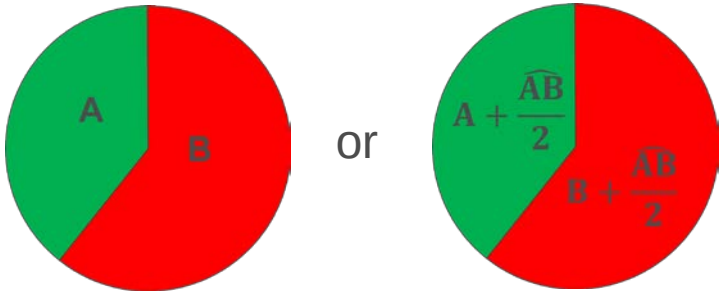
Favor simplicity



If we favor simplicity, we would answer YES to all the 3 questions

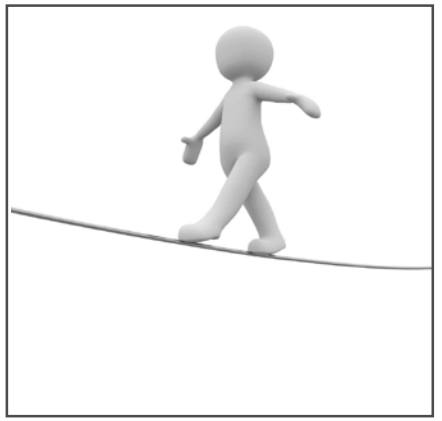
- Should the sum of the terms calculated by a SA method always be equal to 100%?
- Should an SA method produce only positive terms?
- Should an SA method only produce terms that can be attributed to a single source?

The most suitable representation is then the pie chart

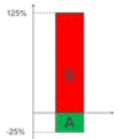
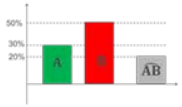
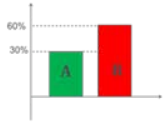


It is a simple representation but we lose the possibility of communicating on the negative impacts (e.g. increases in O3 linked to reductions in NOx) and different terms could be different than the impacts resulting emission reductions (impacts ≠ contributions).

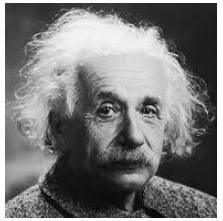
A matter of compromise?



Your answers reflect a willingness to compromise between a complete representation and a simplified representation.

		Yes	No	?	Why
I			X		no need to add up to 100%
II			X		too confusing
III		X			
IV			X		no need to add up to 100%
V		X			

« Everything should be made as simple as possible, but no simpler »
A. Einstein



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Thank you for your attention

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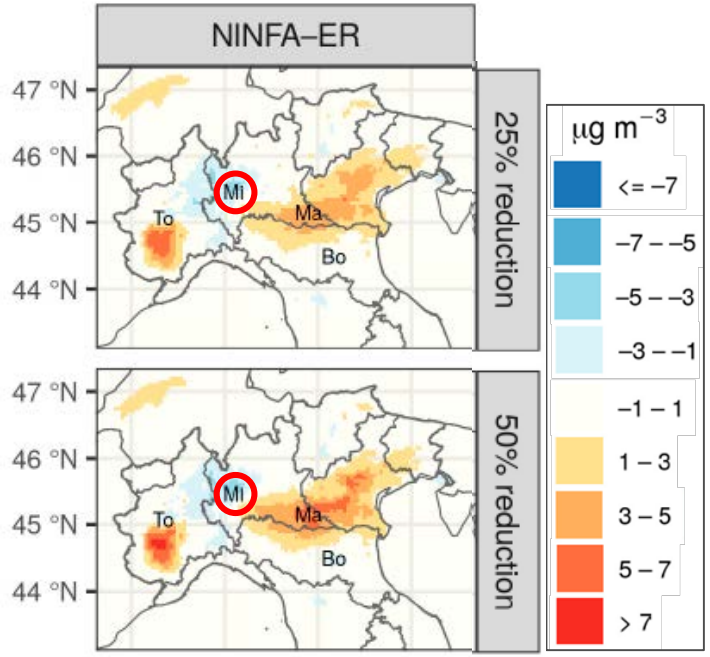
Which precursor would recommand to reduce in priority, why?

First question: chemical regimes NH_3 vs. NO_x

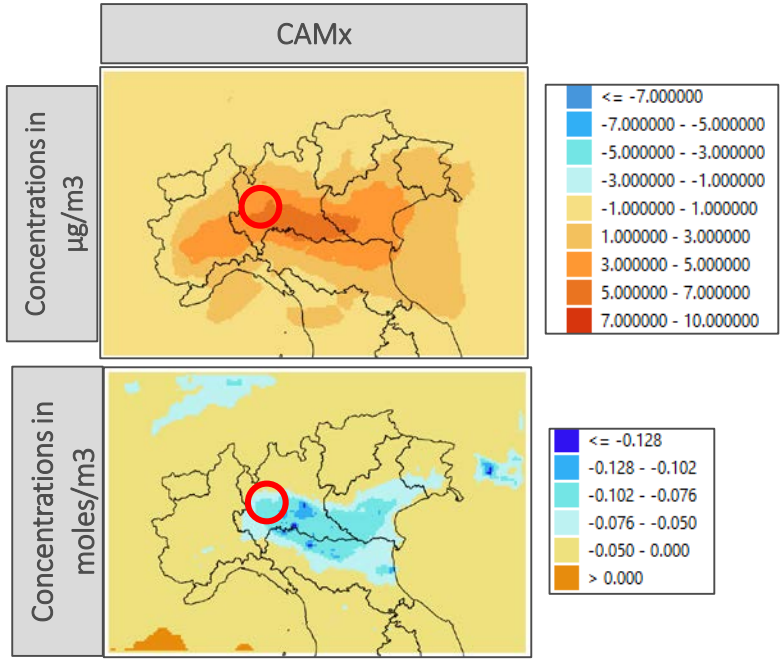
You have acess to the following maps which give information about the sensitivity to NO_x and NH_3

Difference $P^{\alpha}_{NOX} - P^{\alpha}_{NH3}$ based on NINFA/Brut Force for α=25% and α=50%



These maps show simulated results obtained reducing independently NO_x and NH_3 of 25% (map above) and 50% (map below) over the all Po Valley with the NINFA-ER model. Blue color shows areas where the impact of NH3 over the PM concentrations is higher than the impact of NOx reduction. Orange and red color show the opposite.

Difference Cnt_{NOX} (NO_3^-) – Cnt_{NH3} (NH_4^+) based on CAMx/PSAT



These maps show the fraction of NH4 and NO3 composing the Amonium Nitrate PM obtained with the CAMx model and SA module PSAT. The map above shows mass fraction while the map below shows moles fraction. Blue color shows aeras where the fraction of NH3 is higher than the fraction of NOx reduction. Orange and red color show the oppposite.

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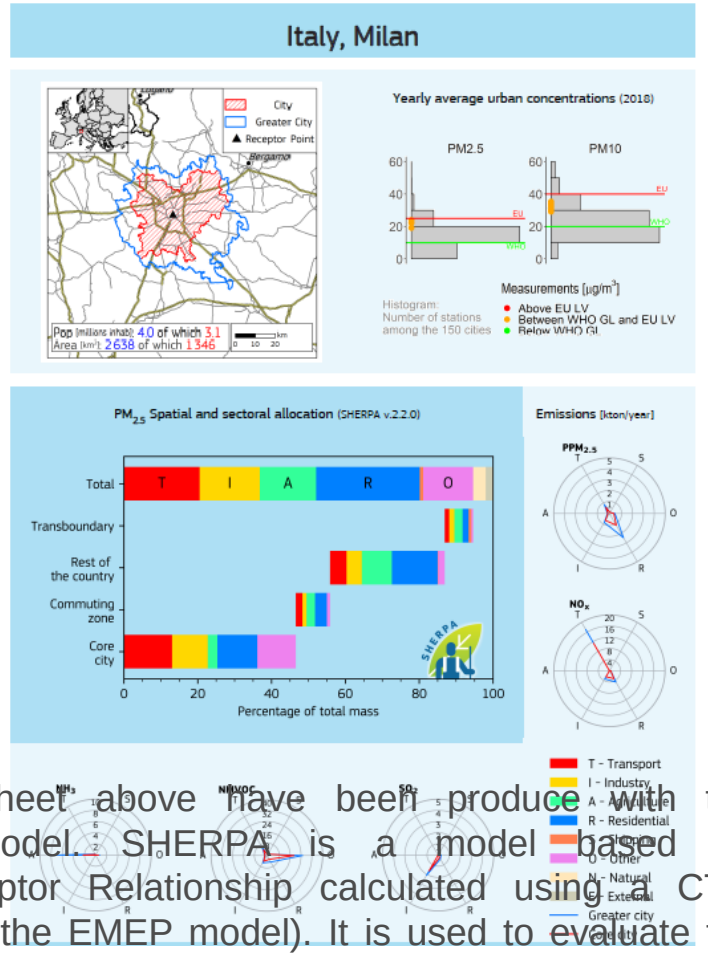
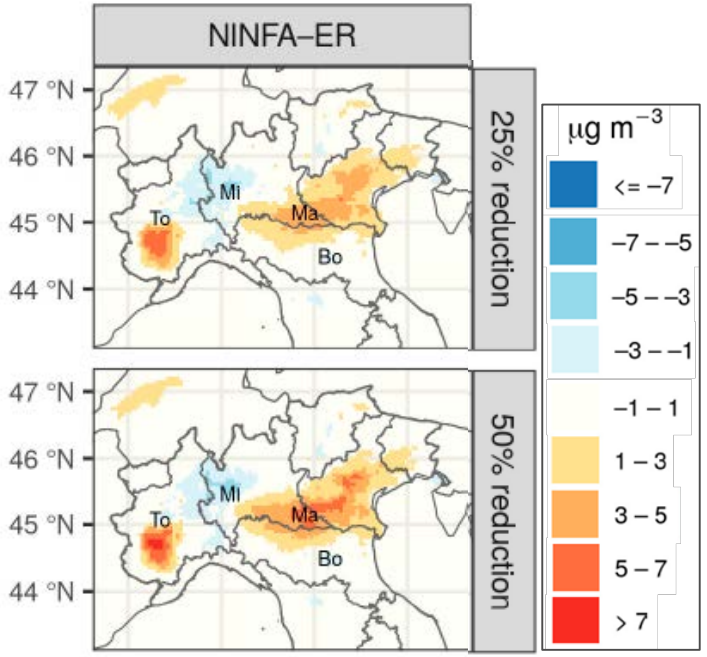
The decision makers who mandate you can only take decision in the area of Milan. Please use the SHERPA results concerning Milan core city and Commuting zone to recommand which activity sector sould be reduced to produce the highest impact on PM abatement ?

Could this recommandation be in contradiction with the following one? Why?

Second question: Spatial Scale

Additionnally to the prewiews maps you have acess to the following graphics:





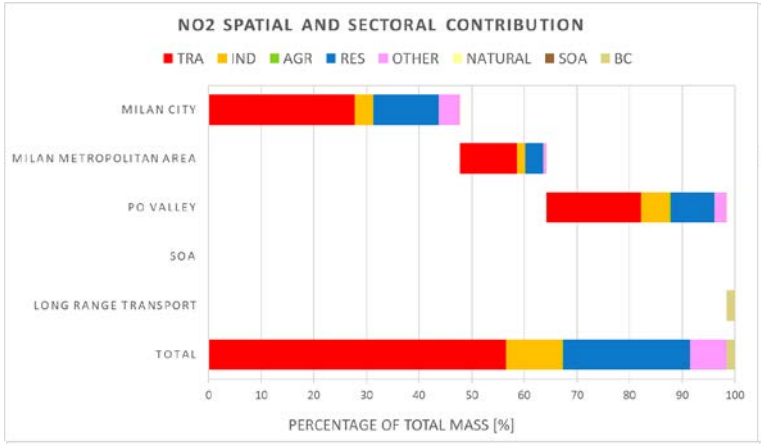
The data sheet above have been produce with the SHERPA model. SHERPA is a model based on Source/Receptor Relationship calculated using a CTM model (here the EMEP model). It is used to evaluate the impact of emission reductions

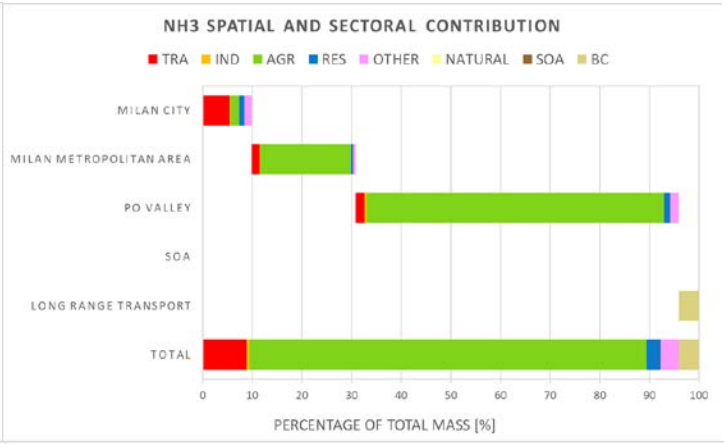
Third question: Spatial Scales

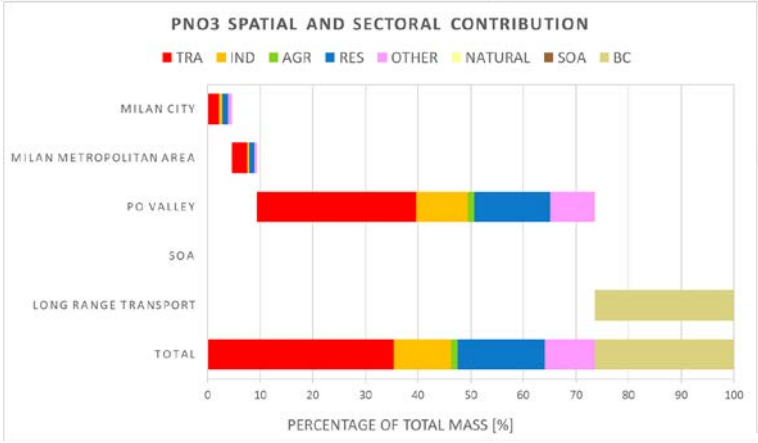
These graphics show the mass fraction of NO2 and NO3 coming from different spatial scales.

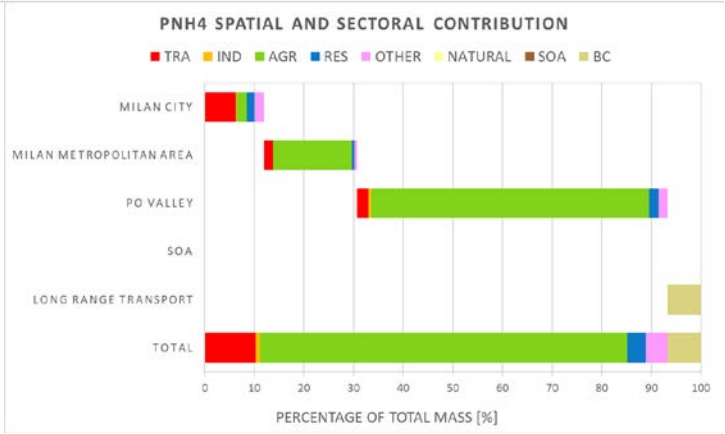
MILAN receptor: Sectoral and spatial contributions based on CAMx/PSAT

NO_2 and NO_3^-









NH_3 and NH_4^+

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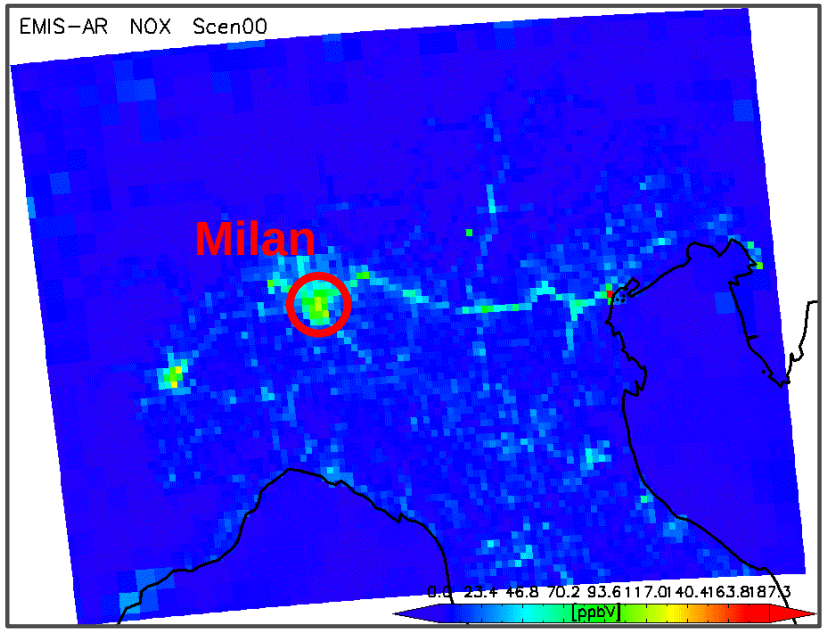
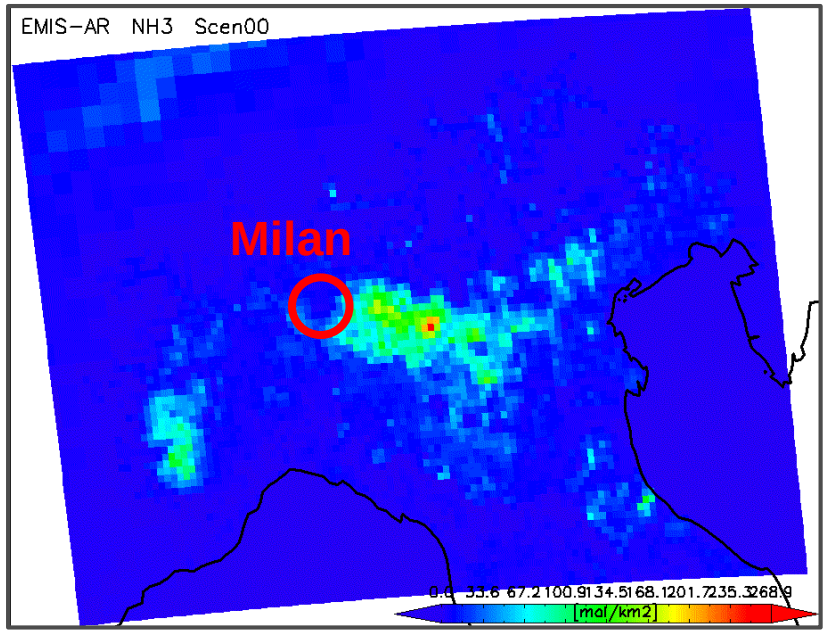
Third question:





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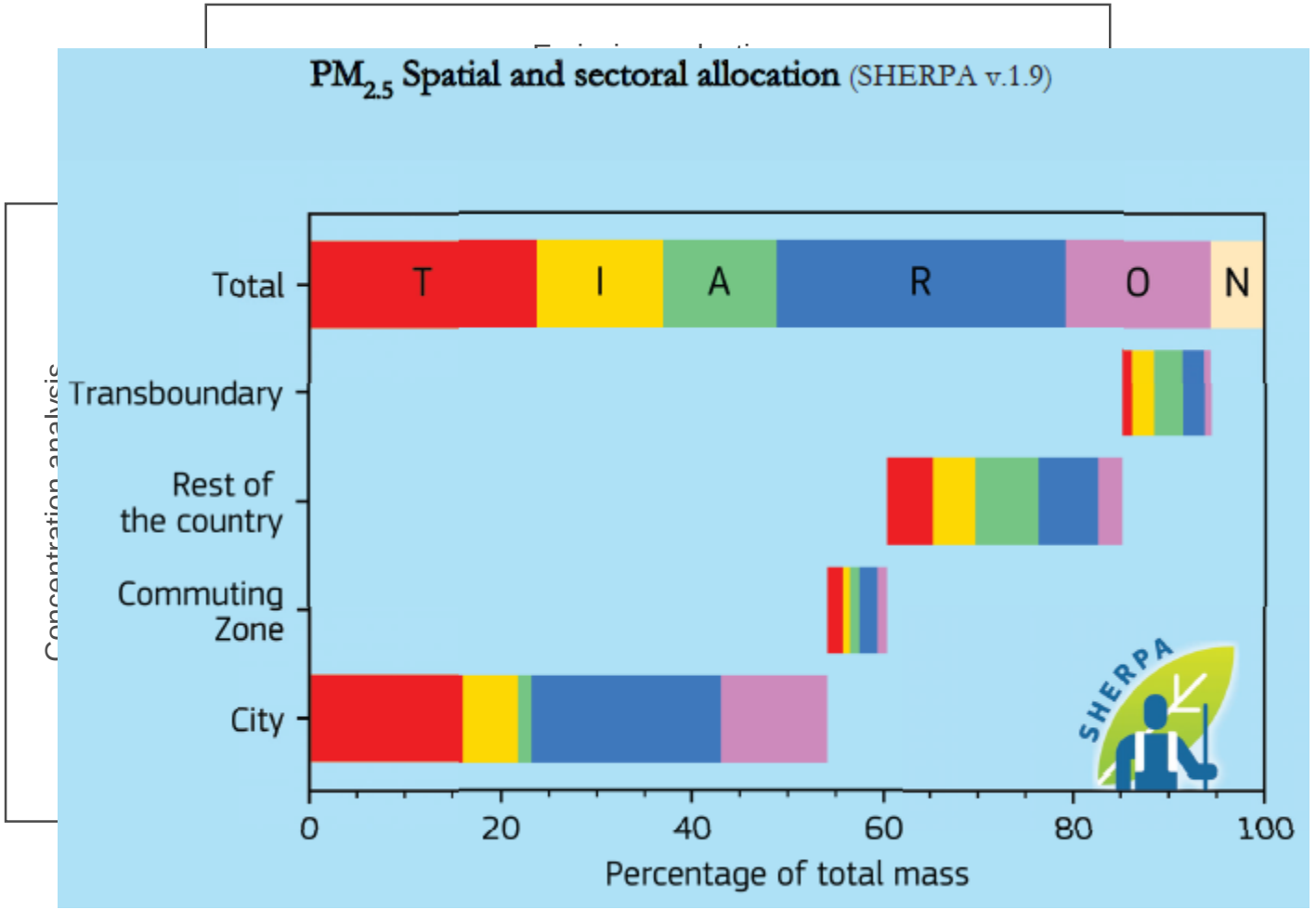
Exercise 2



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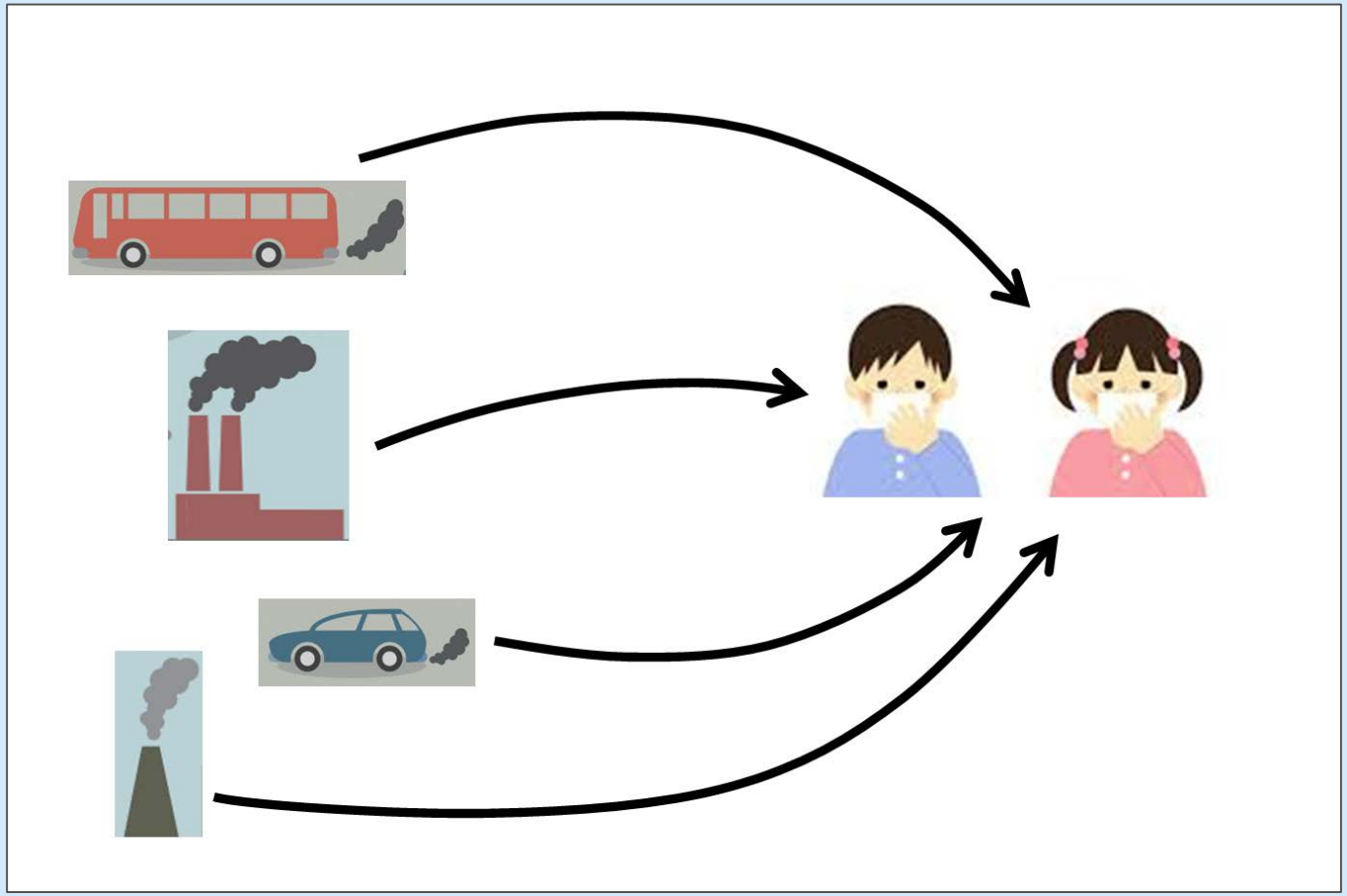
		Emission reduction	
		Short term (3 to 4 days)	Long term (over one year)
Concentration analysis	Short term (3 to 4 days)		
	Long terrm (over one year)		

Exercise 3

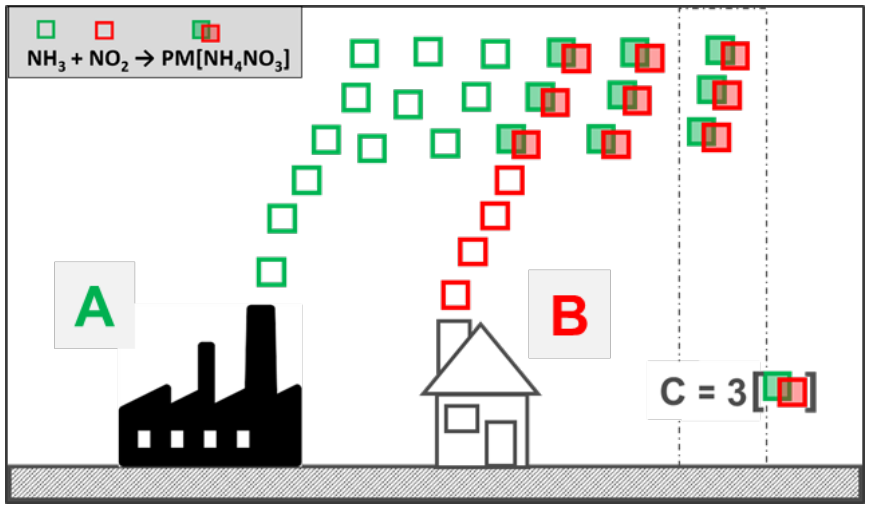
SA Method: Definition

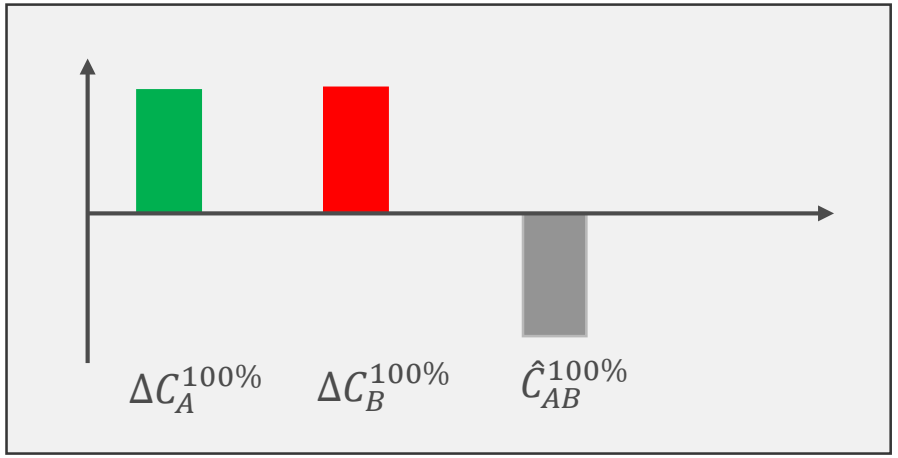
Source apportionment is a technique used to **relate emissions from various pollution sources to air pollution concentrations** at a given location and for a given time period.

but what does « relate » means?



Impacts of Emission Reductions





Concentration changes resulting from an emission reduction:

$$\Delta C_A^{100\%} = 3$$

$$\Delta C_B^{100\%} = 3$$

$$\Rightarrow \quad \Delta C_A^{100\%} + \Delta C_B^{100\%} = 6$$

$$\Delta C_{AB}^{100\%} = 3 \quad \Rightarrow \quad \Delta C_{AB}^{100\%} \neq \Delta C_A^{100\%} + \Delta C_A^{100\%}$$

$$\Delta C_{AB}^{100\%} = \Delta C_A^{100\%} + \Delta C_B^{100\%} + \hat{C}_{AB}^{100\%}$$

$$\hat{C}_{AB}^{100\%} = \Delta C_{AB}^{100\%} - \Delta C_A^{100\%} - \Delta C_B^{100\%} = 3 - 6 = -3$$

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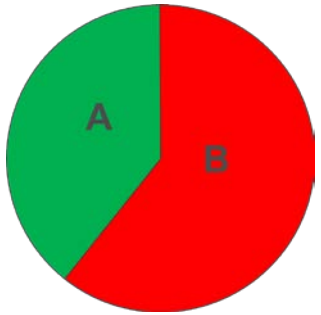
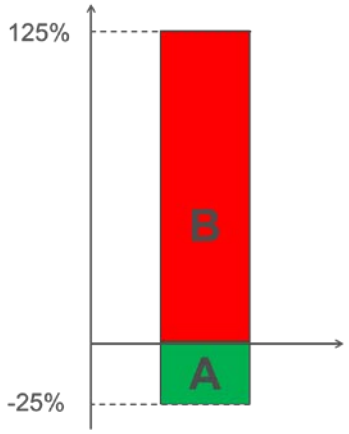
to be SA or not to be SA ?

5 methods produced the following results for two sources A and B?

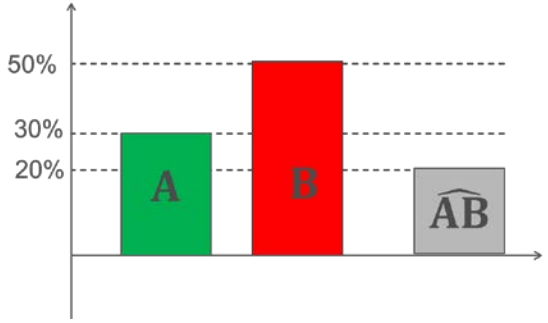
I



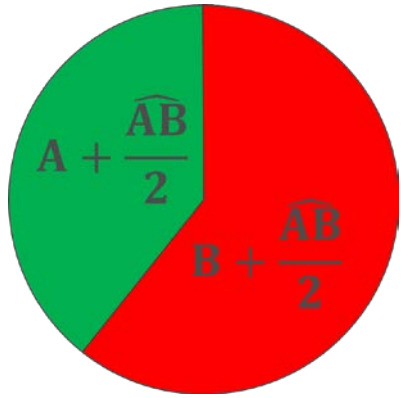
II



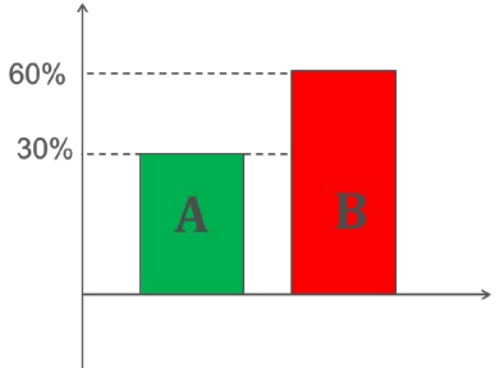
III



IV



V



which of these methods can be considered as a SA method?

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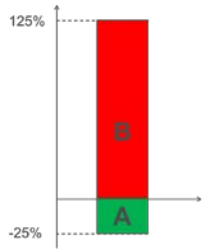
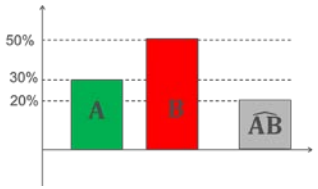
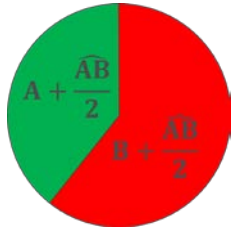
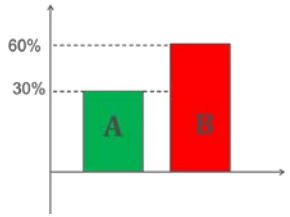
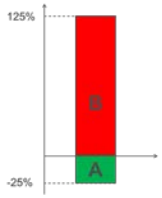
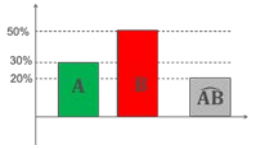
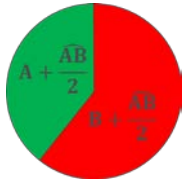
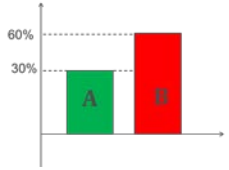
to be SA or not to be SA ?

	I	II	III	IV	V
					
Yes					
No					
?					

		Yes	No	?	Why
I					
II					
III					
IV					
V					

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Thank you for your attention

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The aim of this exercise is to analyze how to use SA results to design specific and efficient reduction scenarios.

In Milan, PM concentrations quite regularly exceed the thresholds specified by the European directive. Decision-makers want to reduce exceedances, but only have the authority to act on the city's emissions and don't know which are the best measures to take. They mandate you to help them to use SA results to design specific and efficient reduction scenarios.

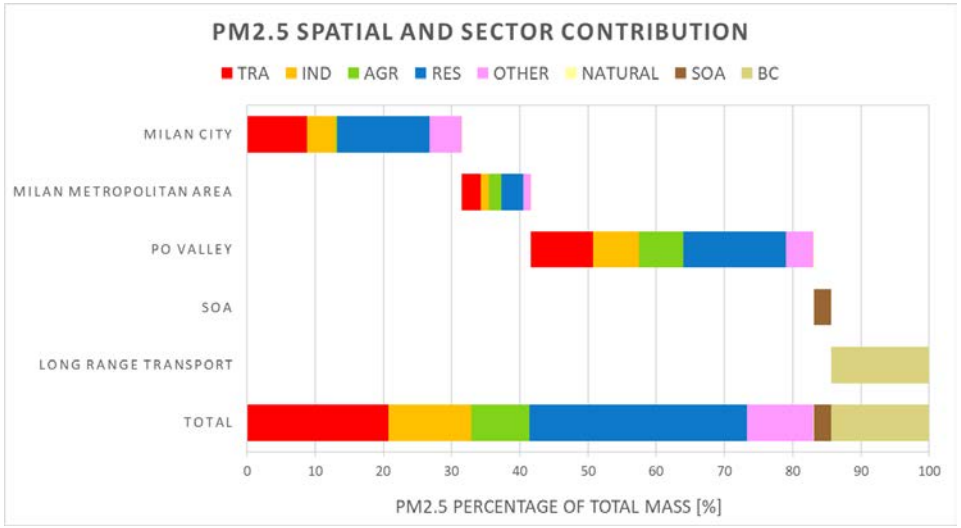
you answer to the two following questions:

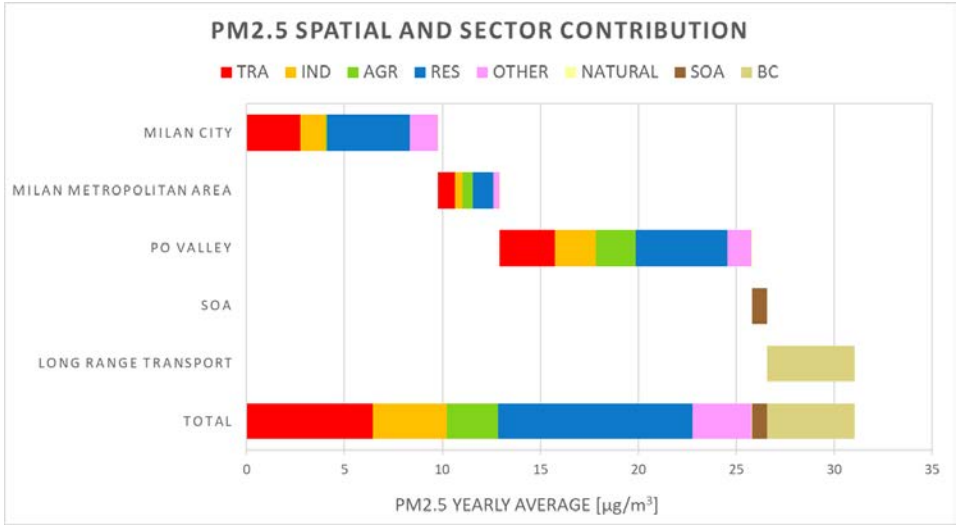
1) which precursor should be target in priority
2) at which activity sector should be targeted in priority

Second question: target an activity sector

MILAN receptor

PM2.5 - Sectoral and spatial contributions based on CAMx/PSAT





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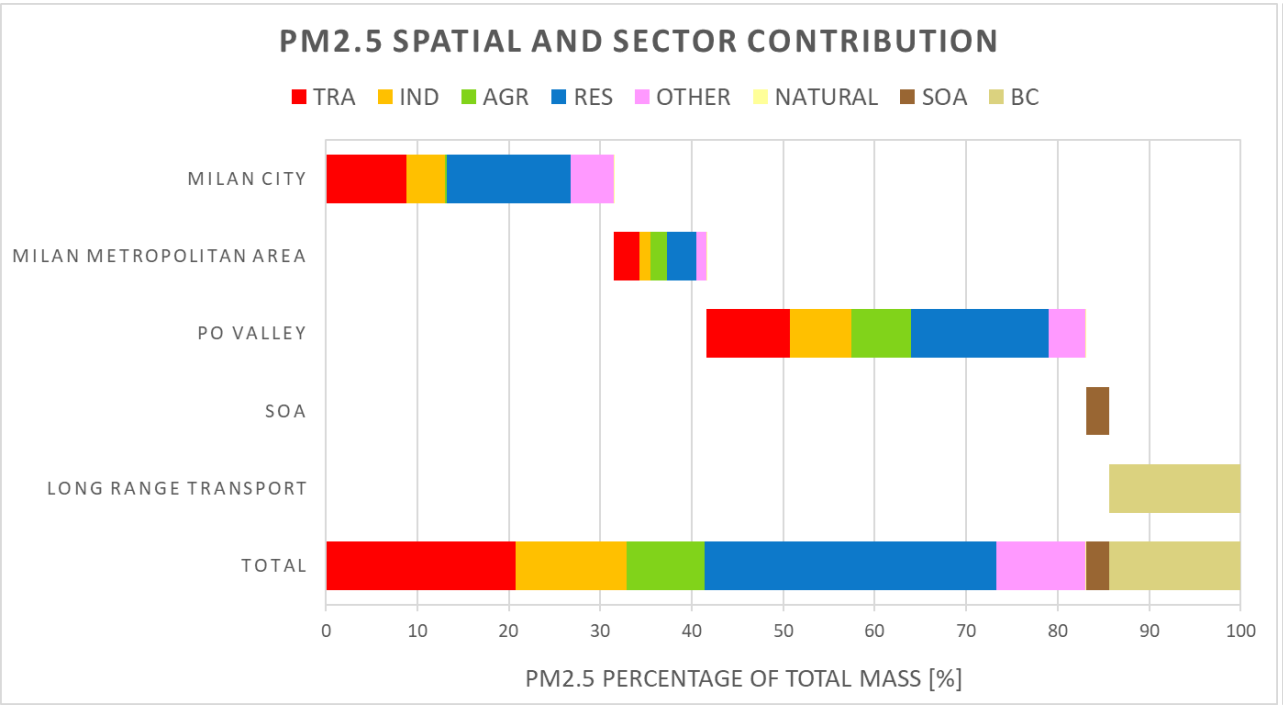
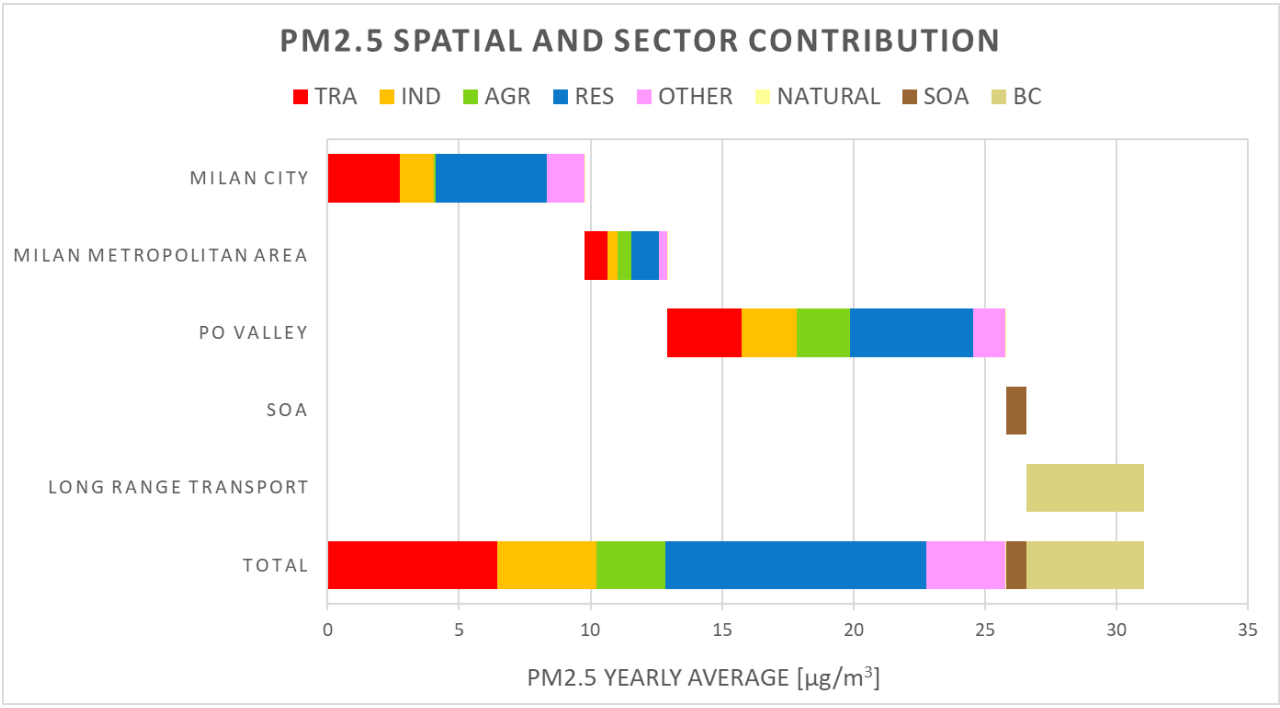
MILAN receptor

PM2.5 - Sectoral and spatial contributions based on CAMx/PSAT





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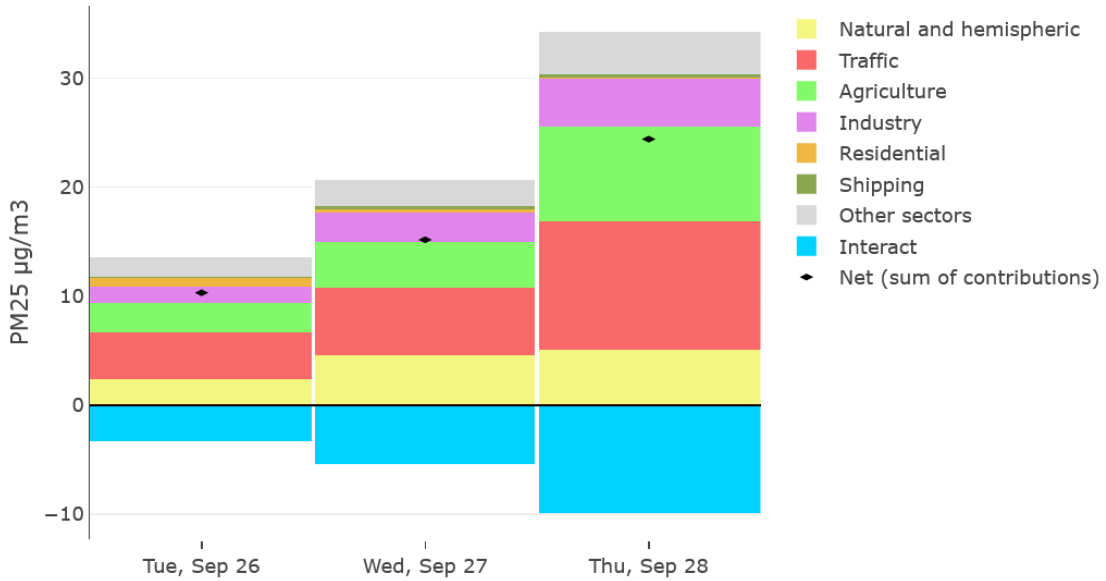
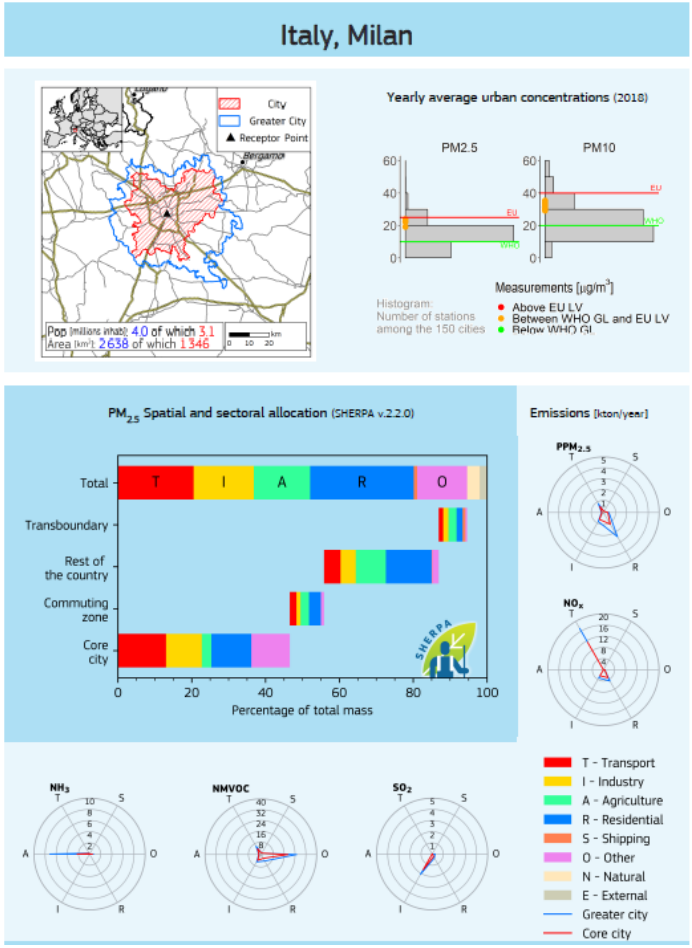
B. **In a second step**,

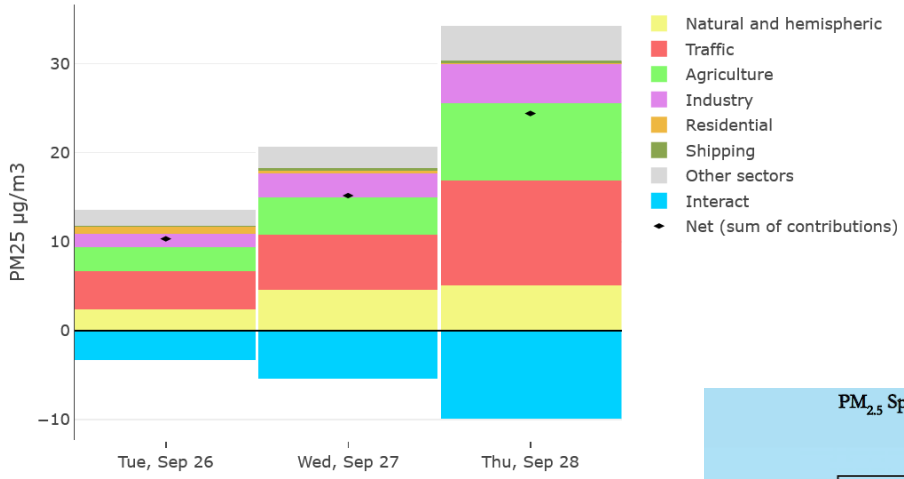
1. Reduction scenarios to be implemented throughout the year.
2. Reduction scenarios to be implemented for a limited period on days when concentrations exceed limits

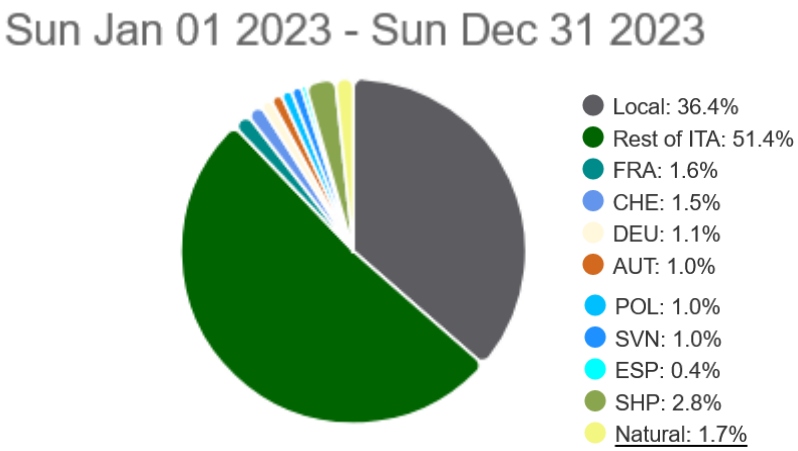


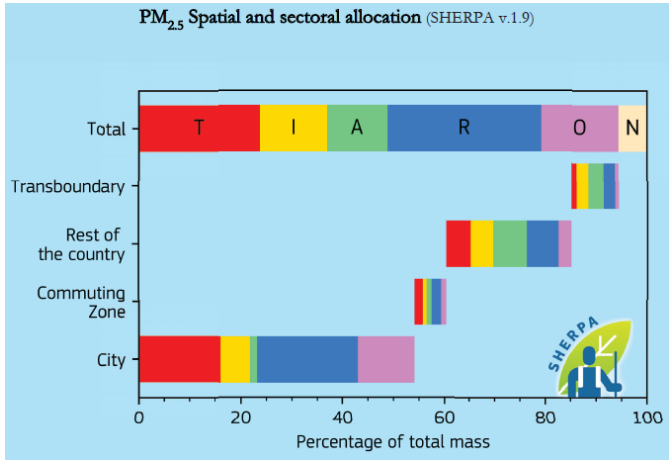
Second question: target an activity sector

you have acess to the following maps:

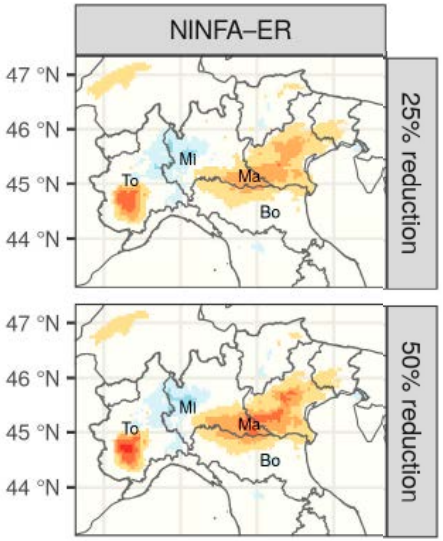


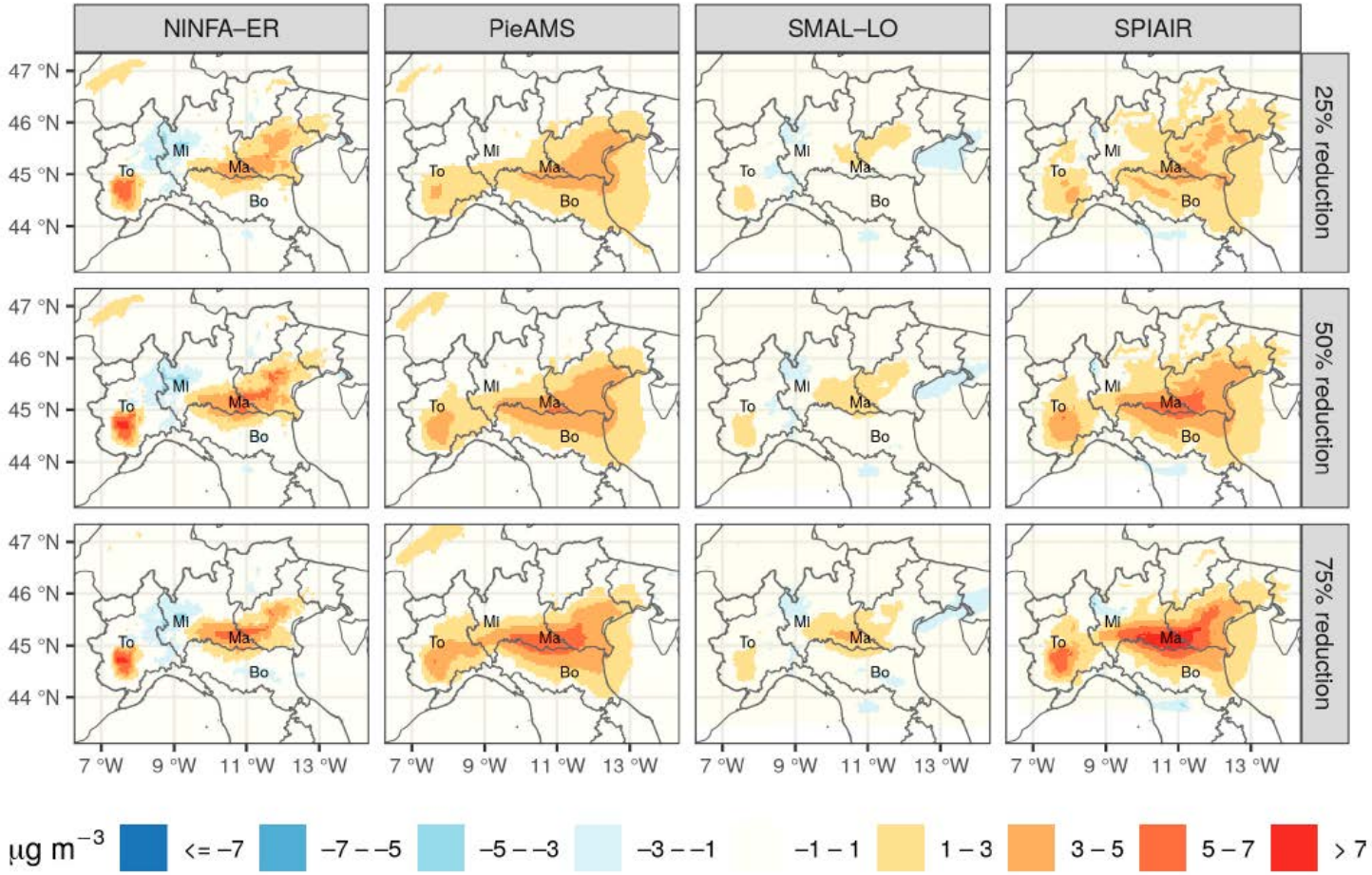






A. **In a first step**, you have acess to





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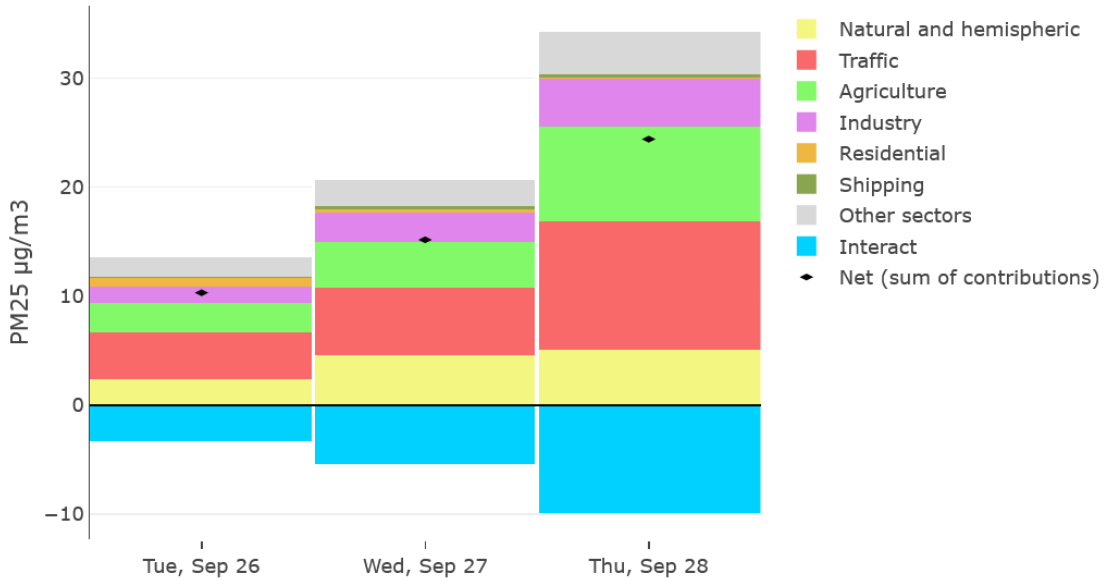
B. **In a second step**,

1. Reduction scenarios to be implemented for a limited period on days when concentrations exceed limits



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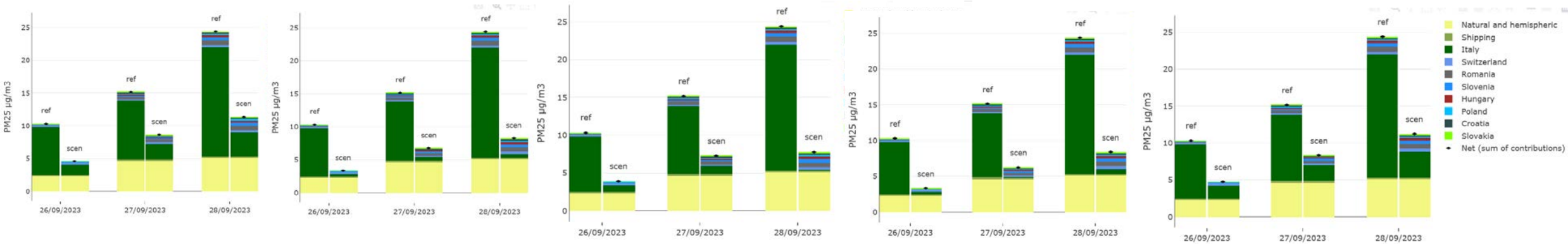

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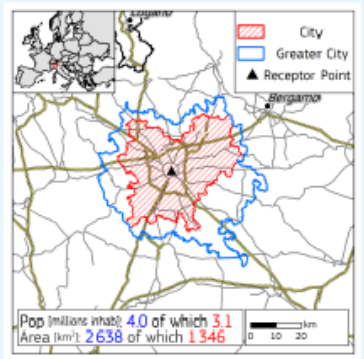
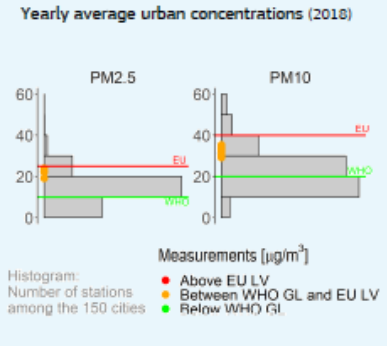
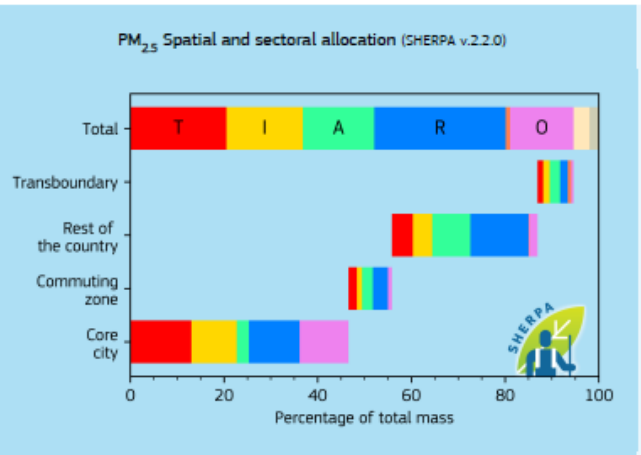
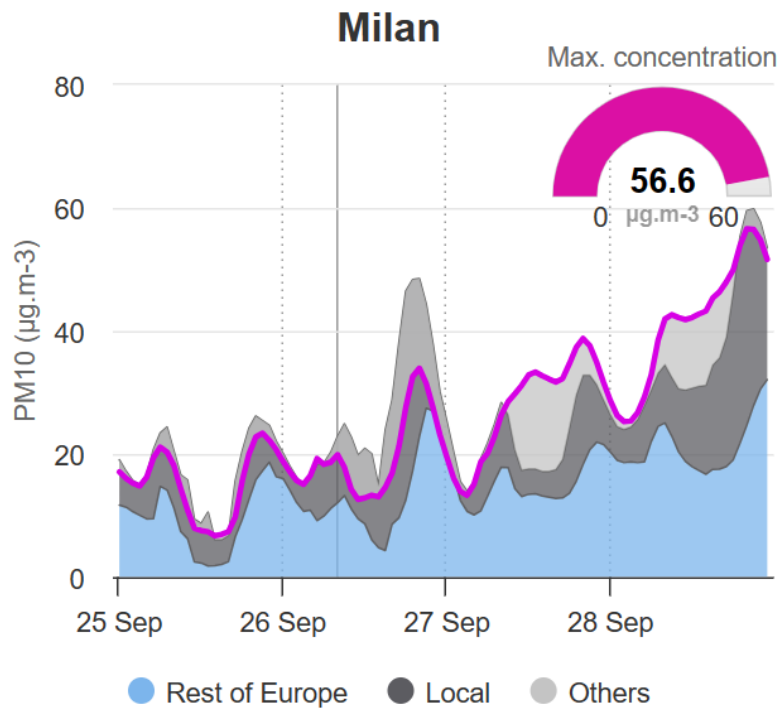
Italy, Milan







T - Transport
I - Industry
A - Agriculture
R - Residential
S - Shipping
O - Other
N - Natural
E - External
Greater city
Core city



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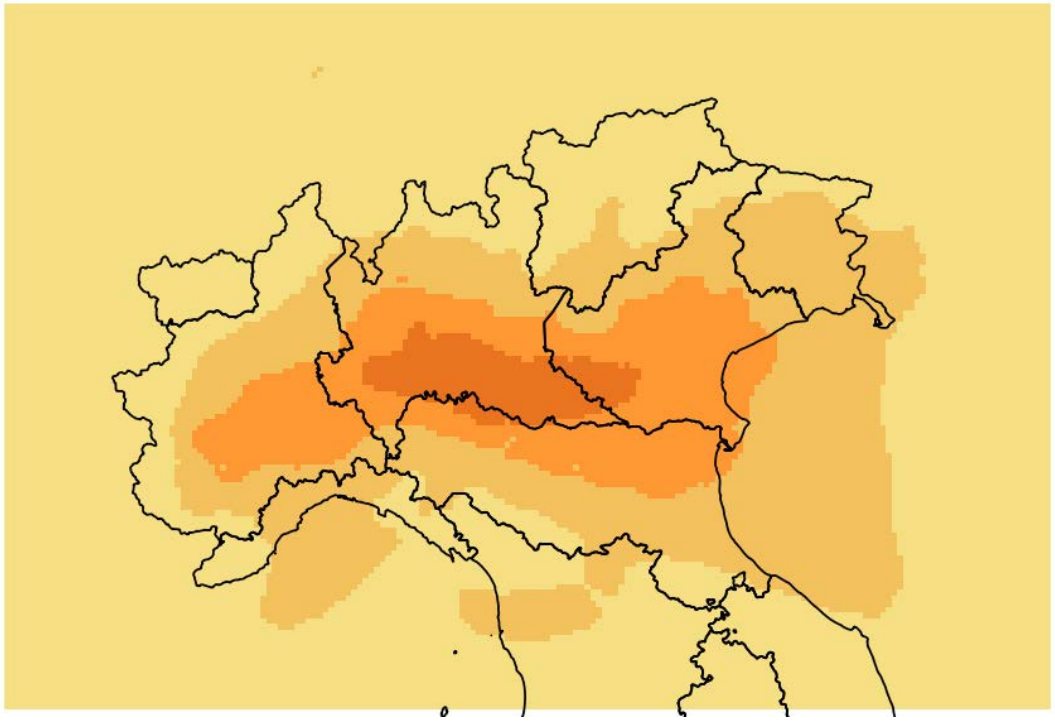
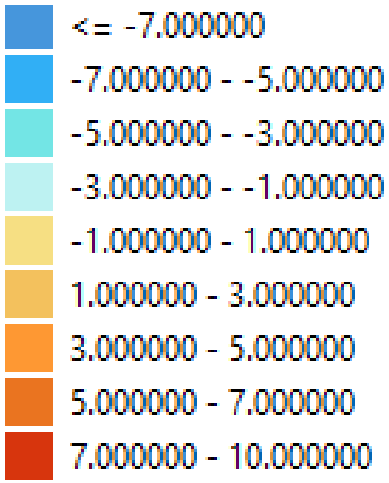
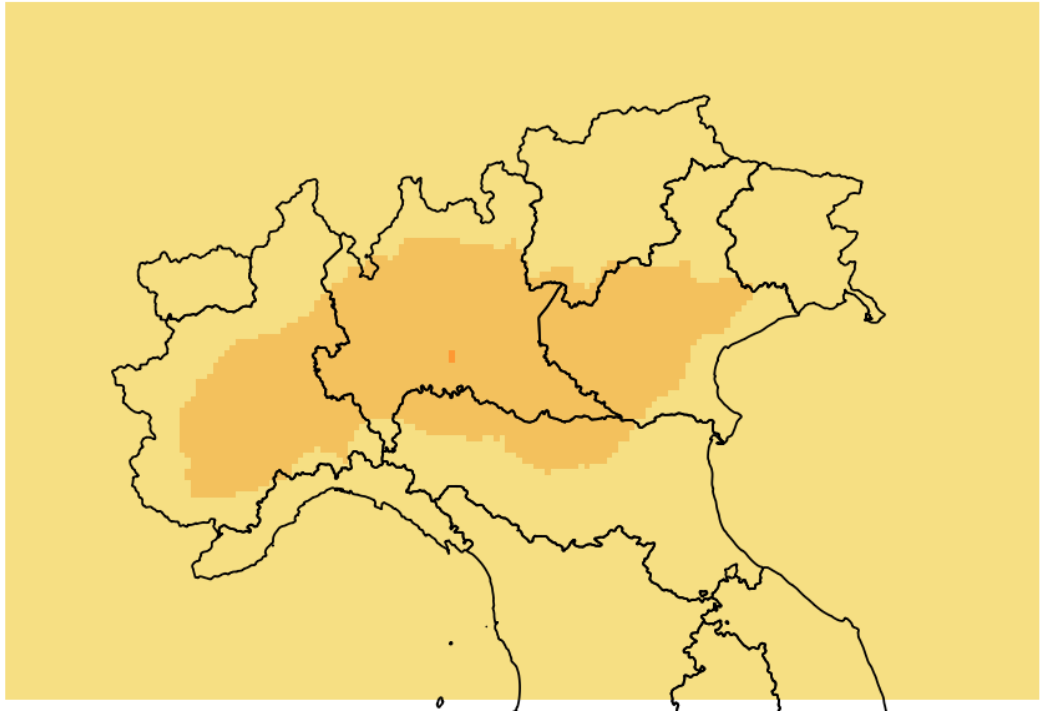
Difference $P^{\alpha}_{NOX}(NO_3^-)$ – $P^{\alpha}_{NH3}(NH_4^+)$ based on CAMx/PSAT







WINTER

SUMMER

Concentrations in µg/m3

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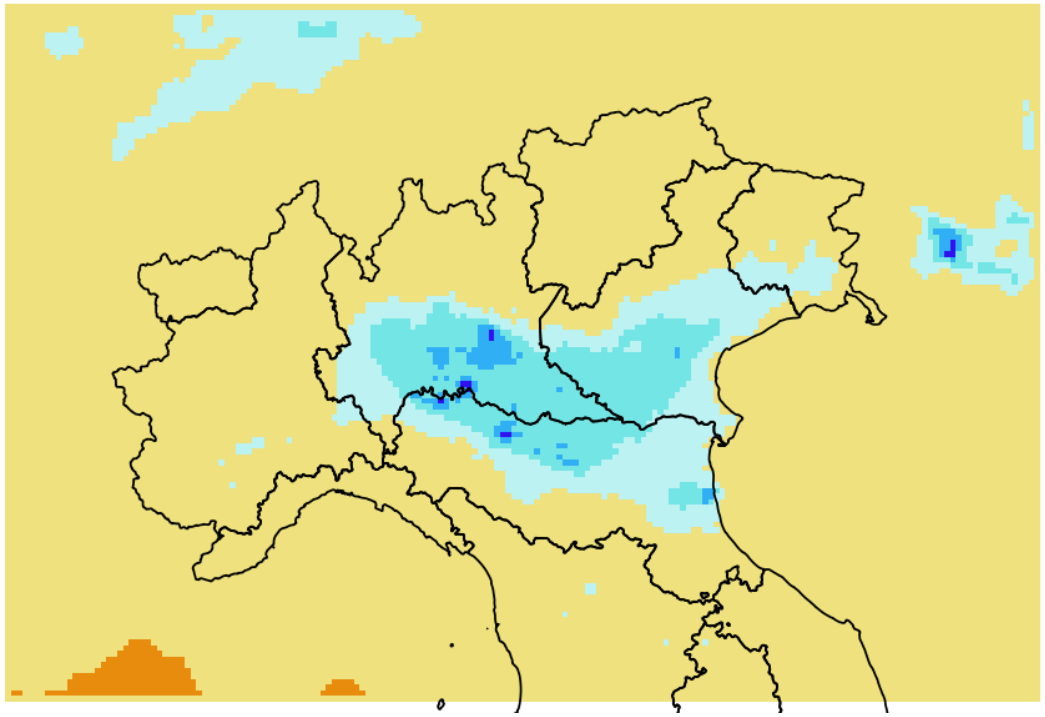
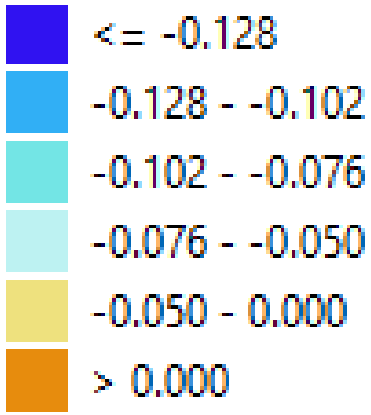
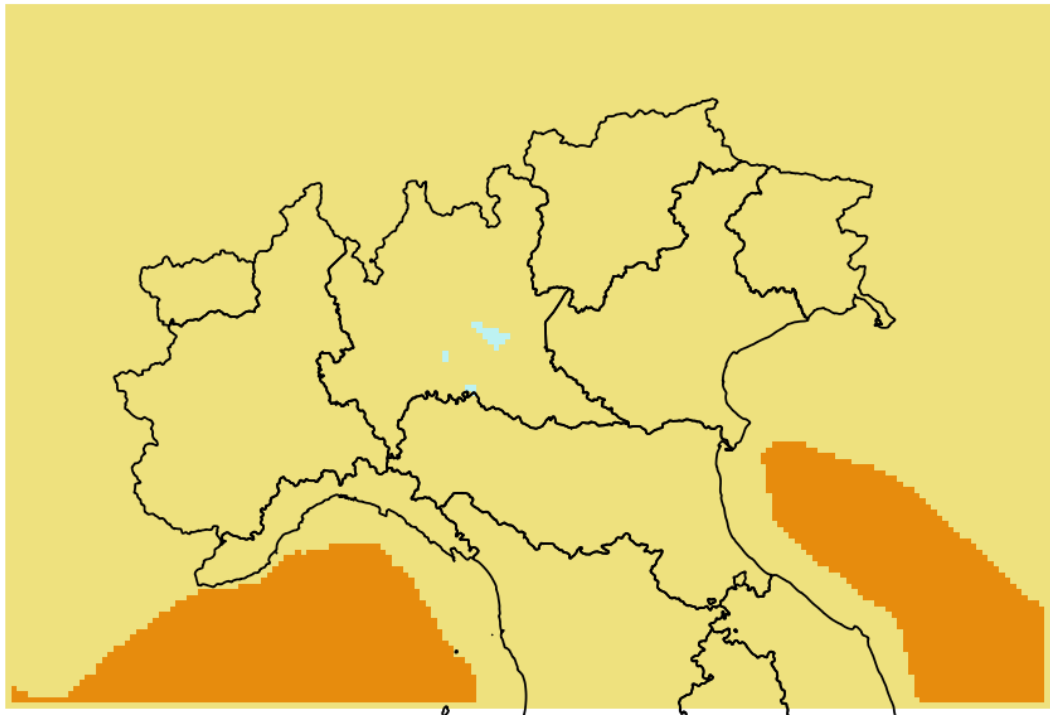
Difference $P^{\alpha}_{NOX}(NO_3^-)$ – $P^{\alpha}_{NH3}(NH_4^+)$ based on CAMx/PSAT







WINTER

SUMMER

Concentrations in moles/m3

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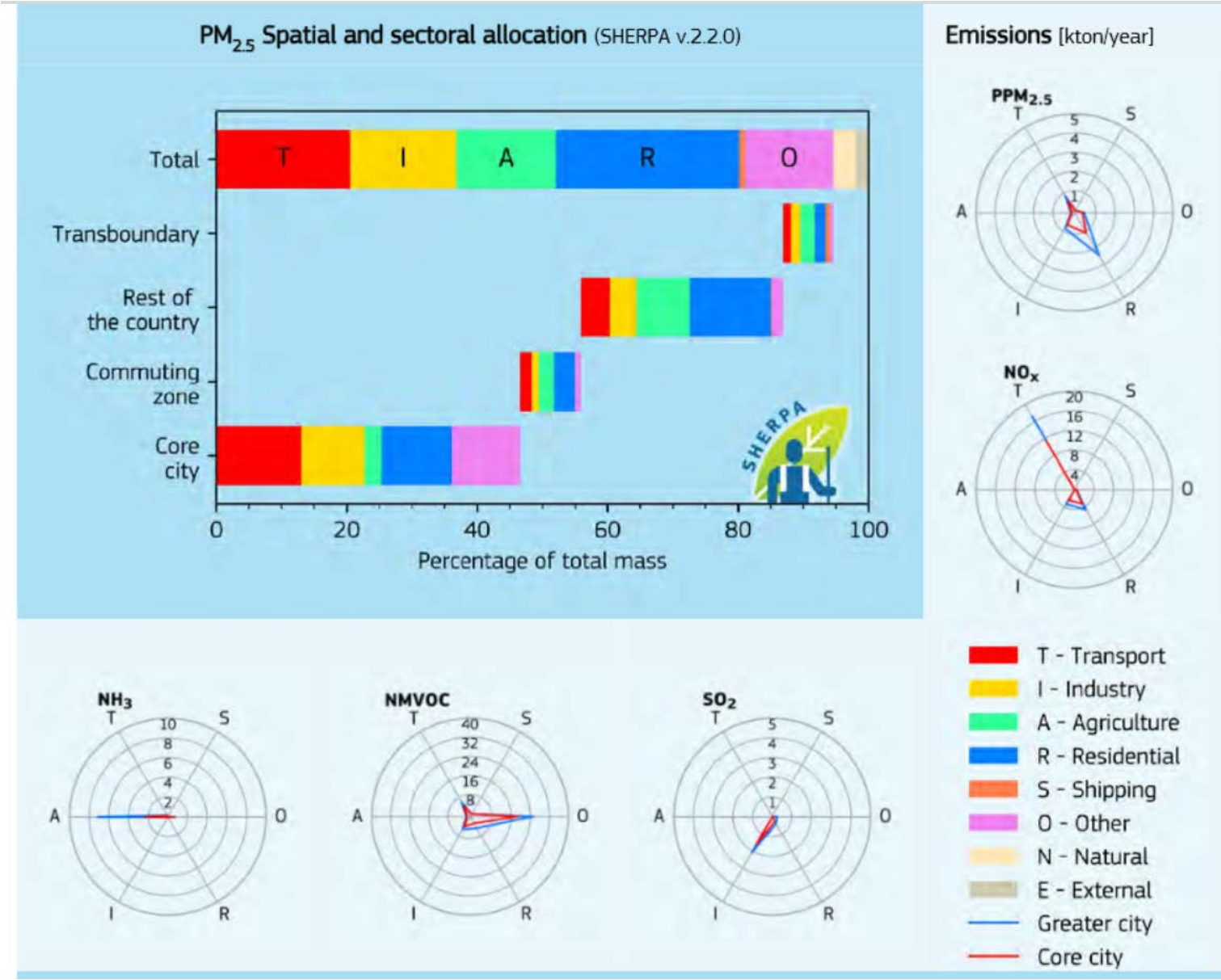
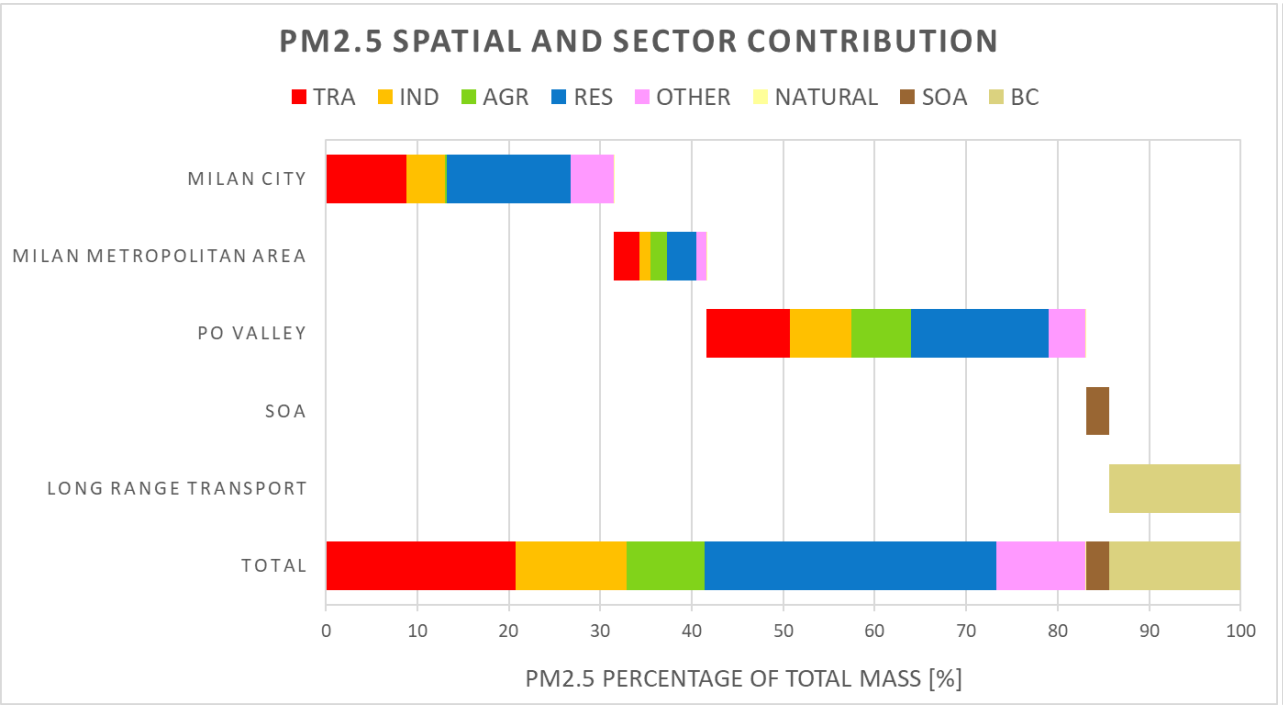
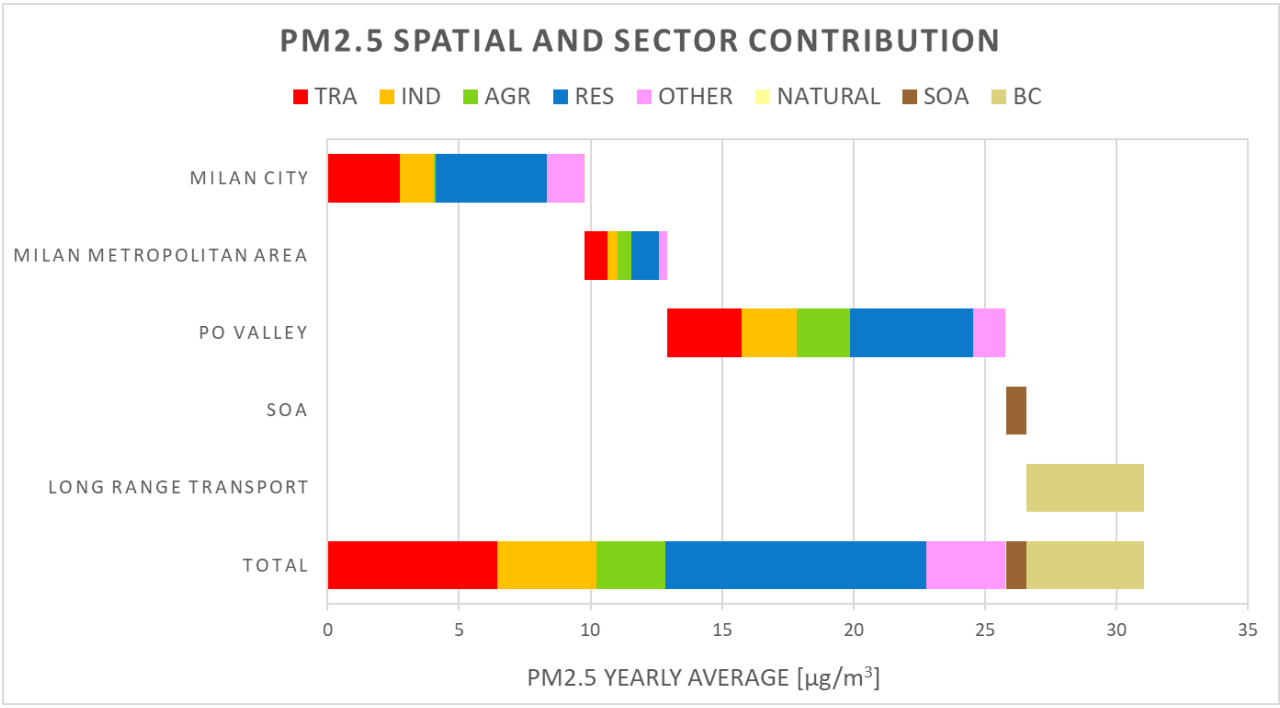
MILAN receptor



MILAN receptor

PM2.5 - Sectoral and spatial contributions based on CAMx/PSAT





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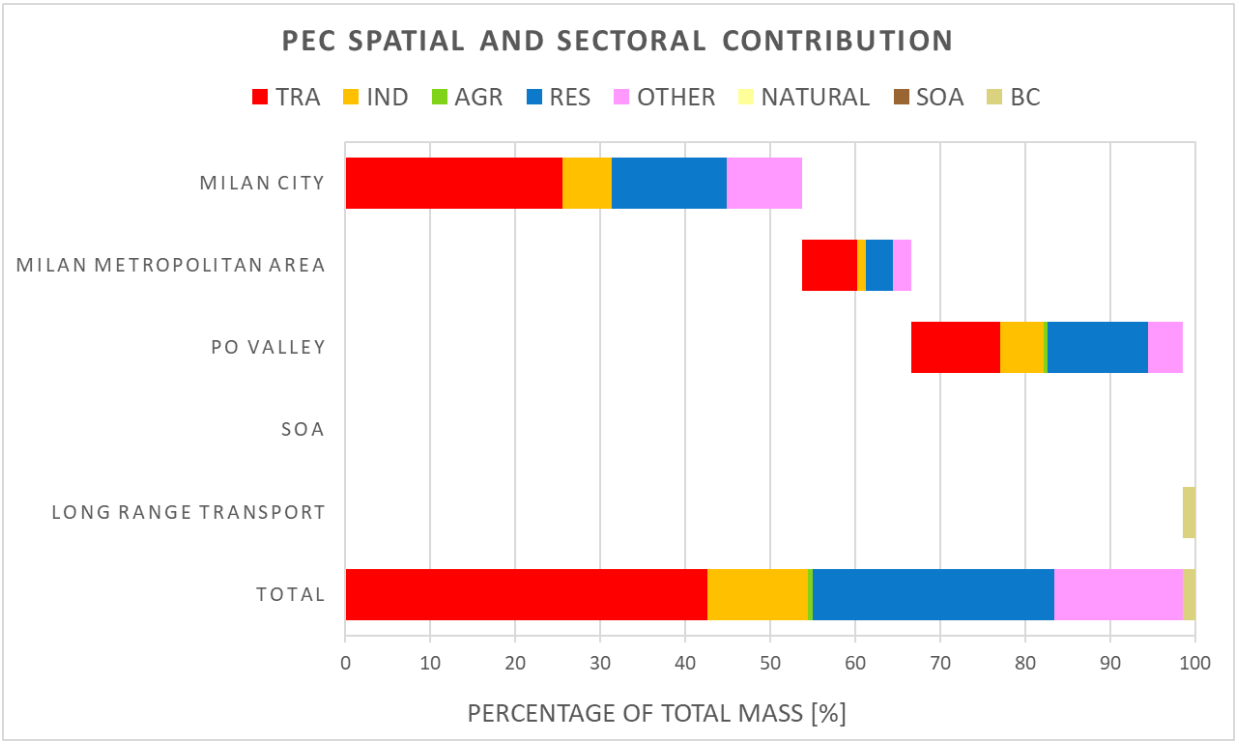
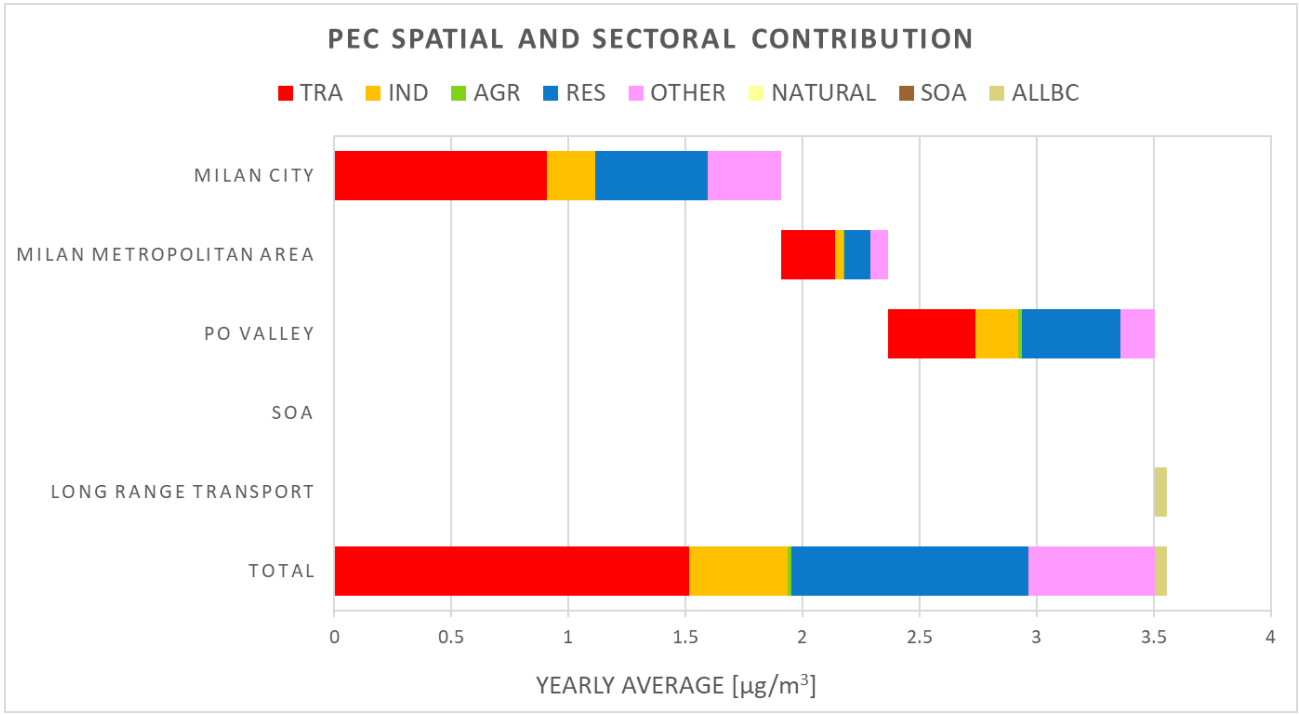
MILAN receptor

EC - Sectoral and spatial contributions based on CAMx/PSAT





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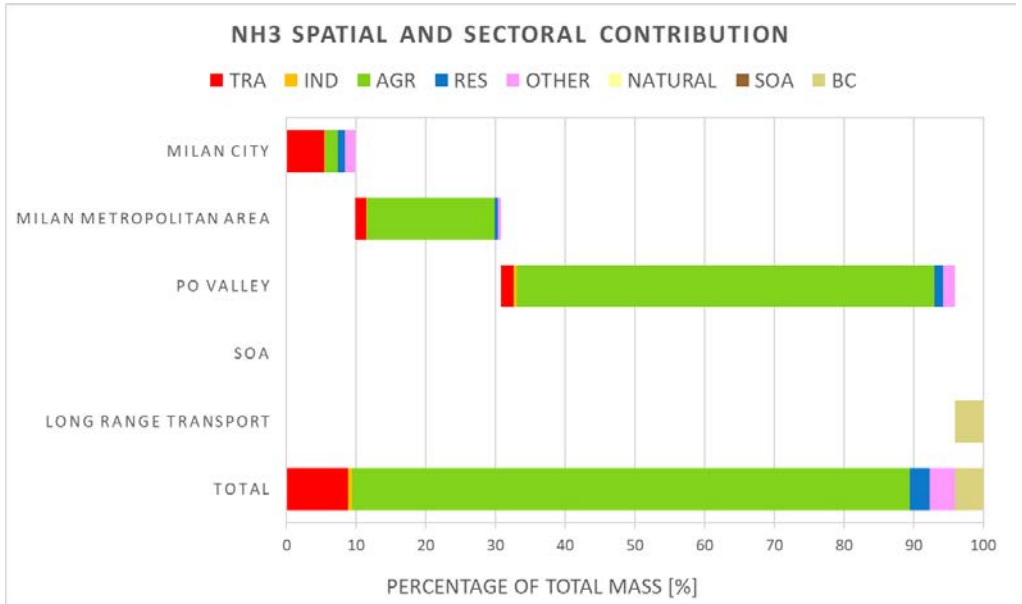
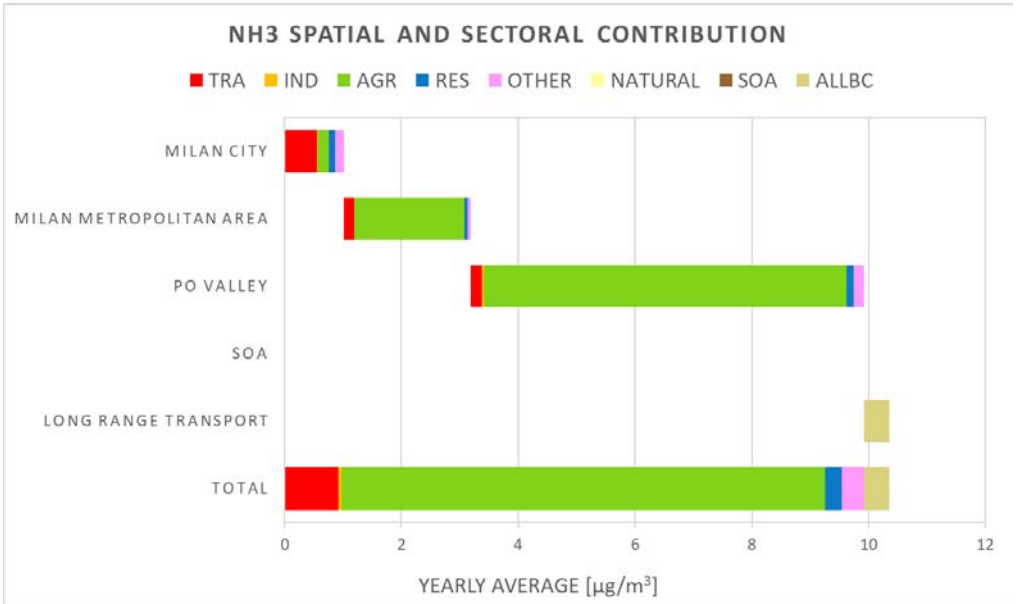
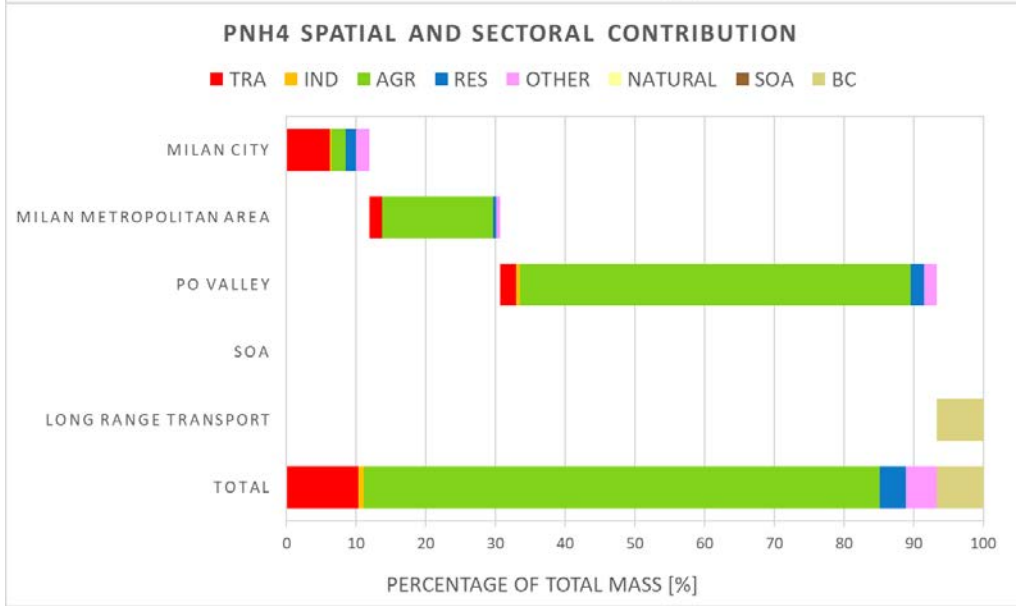
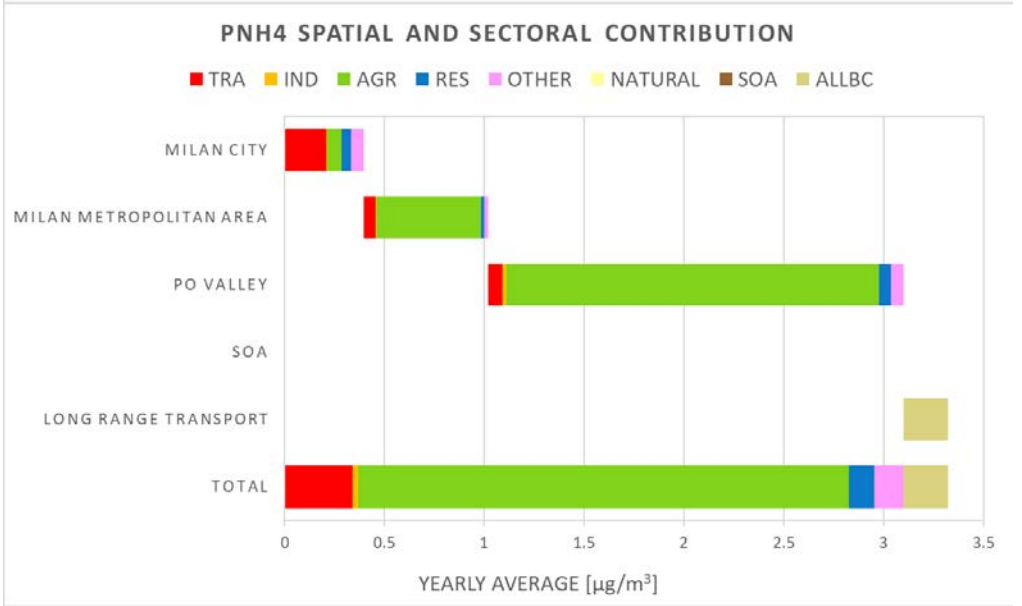
NH_3 and NH_4^+ - Sectoral and spatial contributions based on CAMx/PSAT



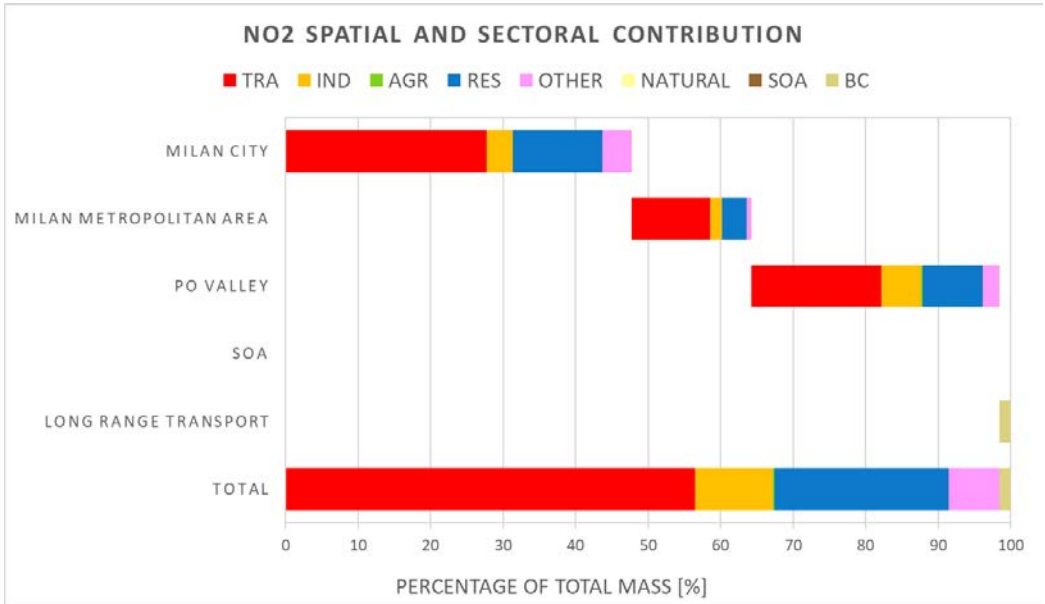


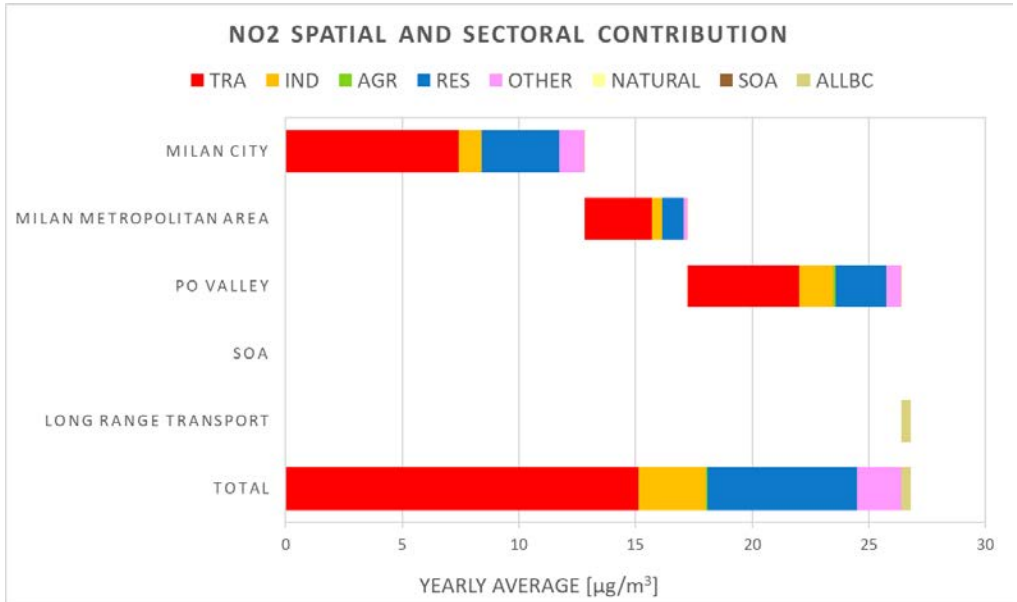


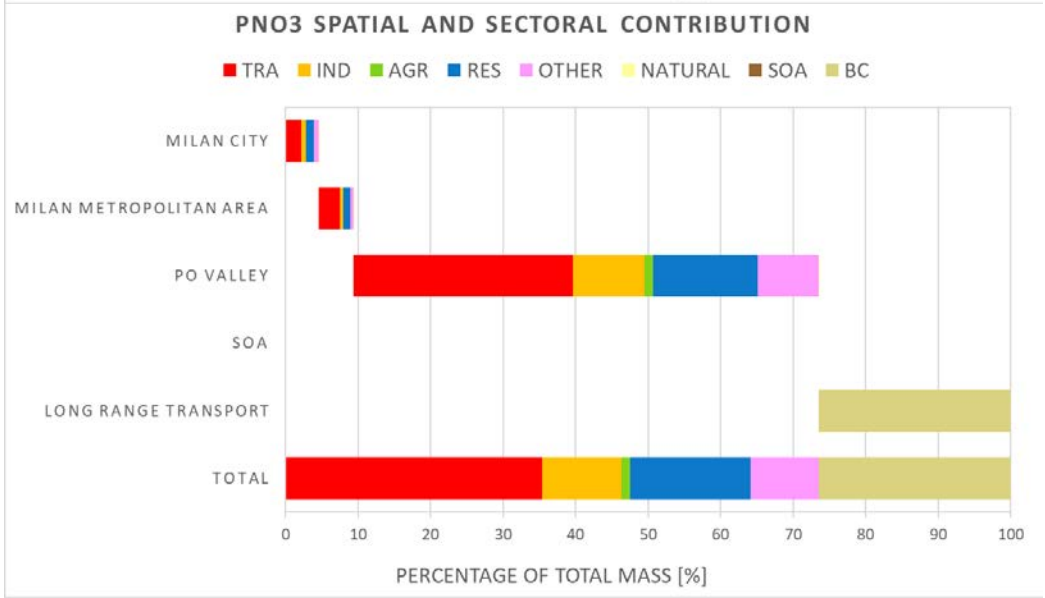


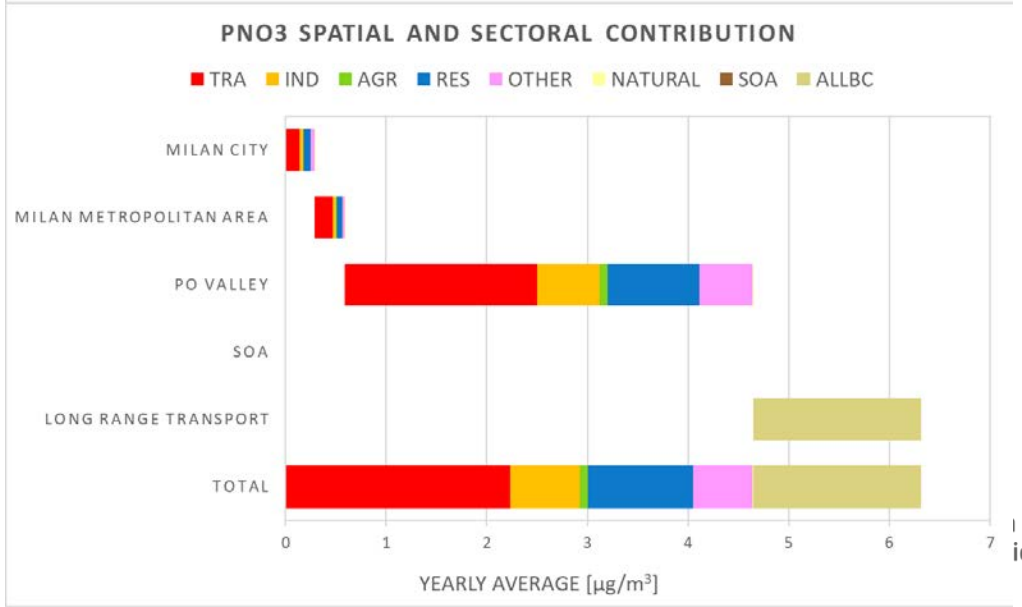
MILAN receptor

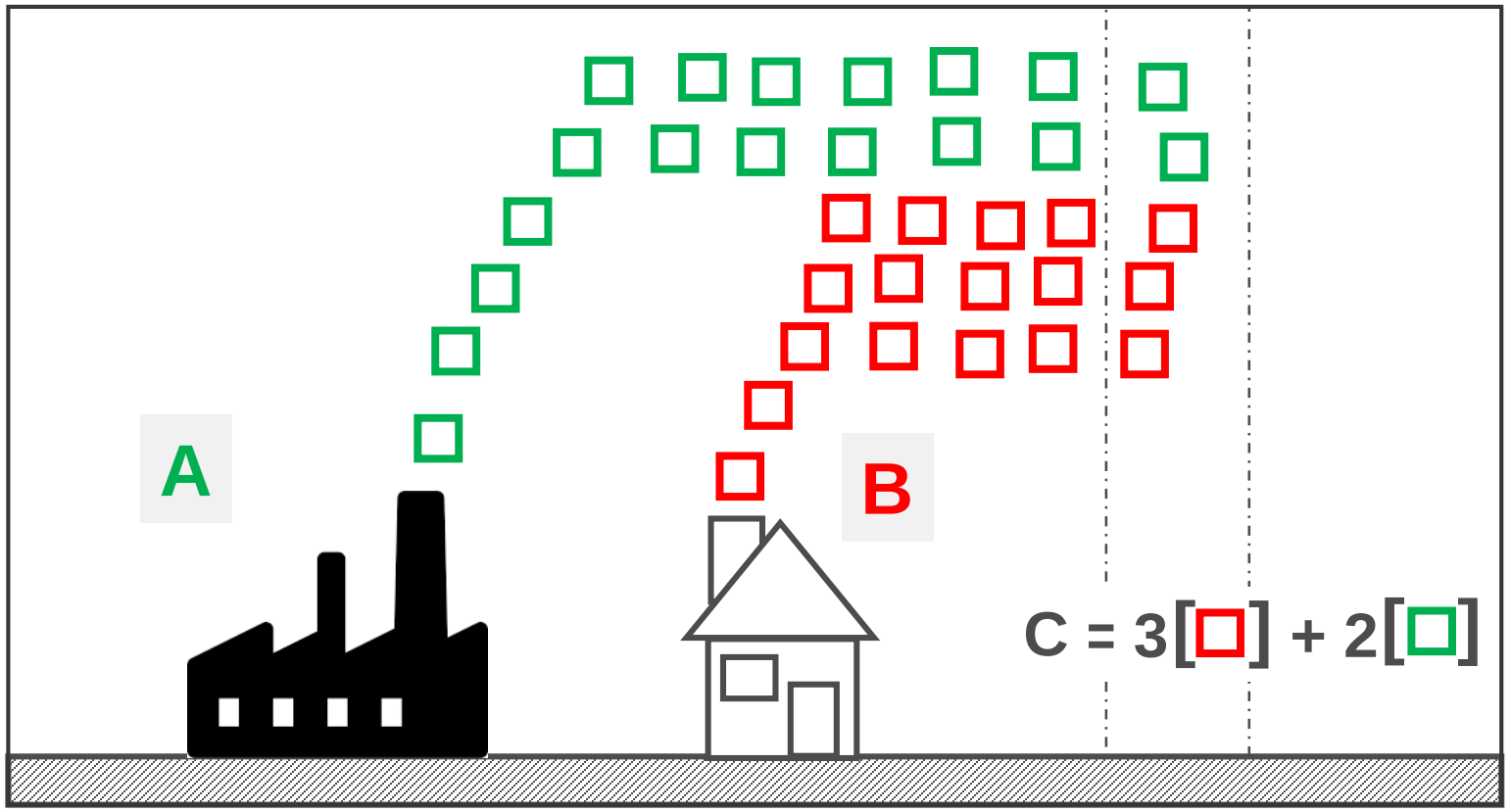
NO_2 and NO_3^- - Sectoral and spatial contributions based on CAMx/PSAT











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for the temporal analysis, exercise 2, we discussed as follows:

1) at first, one should think about the domain under study, in this case, Milan...the knowledge of the domain under study is very important as a starting point

2) then we discussed PM. For PM:

- in general, for Milan, winter period is the focus, as PM is high in winter. But the analysis on the temporal scale cannot be considered separately from the geographical dimensions (that means, it is important to know if pollution depends on local or background sources. The same for sources). It means, to perform a temporal analysis and take decisions on this, one needs also to take into account geographical and sectoral dimensions, to have the full picture

- to reduce PM yearly averages, an annual approach to source apportionment is sufficient

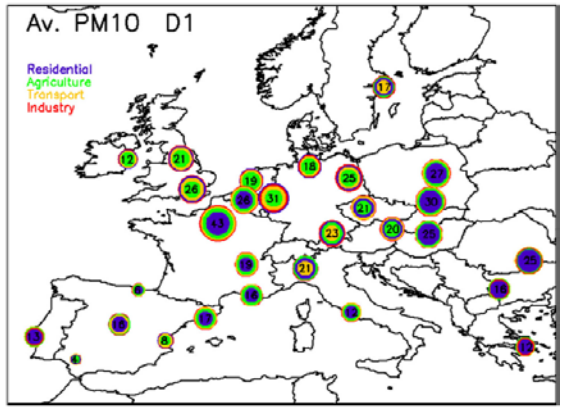
- to reduce PM exceedances, one could also use source apportionment techniques, but a similar information can be derived through simpler approaches, as i.e. correlation analysis, etc...

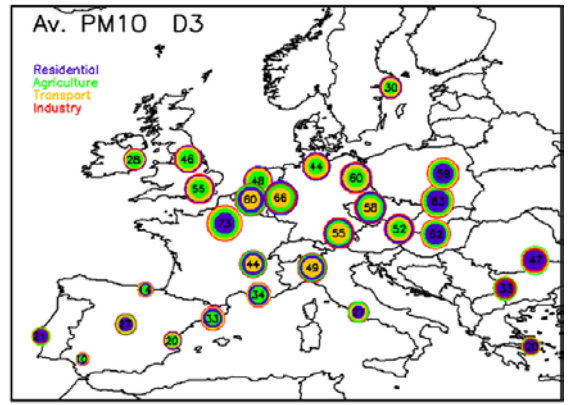
3) for NO2

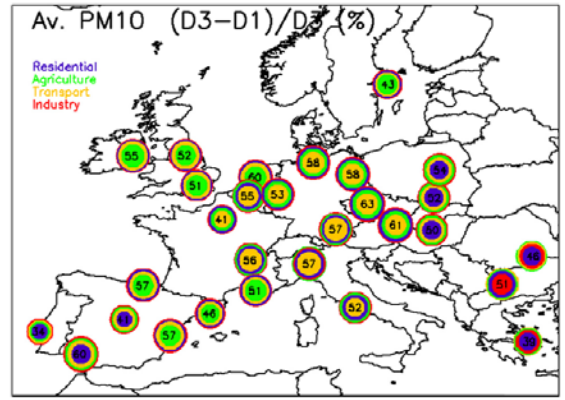
- this pollutant is much more local and much more short term, so in principle source apportionment can be done in an easier way

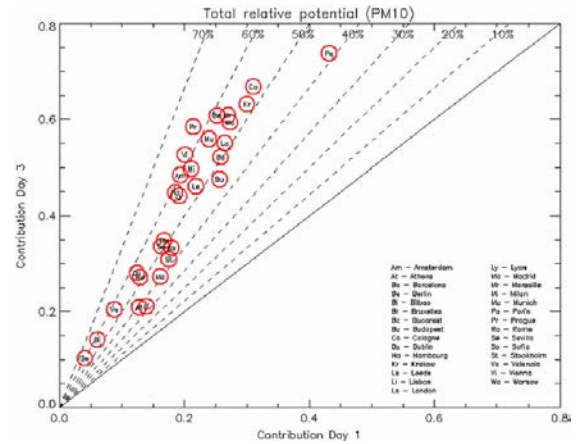
- in this case, an annual approach to source apportionment is already sufficient, both to control averages and exceedances

4) in any case, all the tools available are useful to support decision makers, but then final decisions will be taken by policy makers, also considering other factors









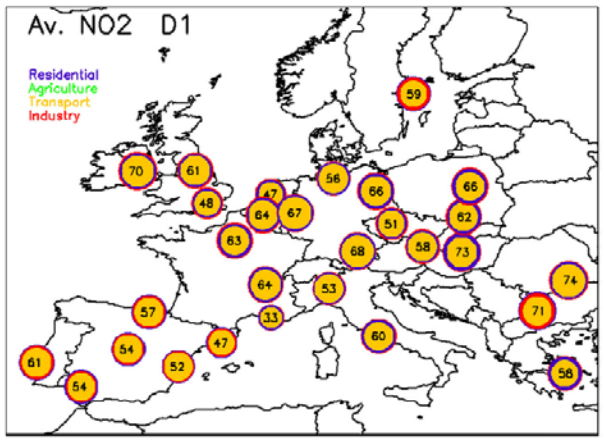
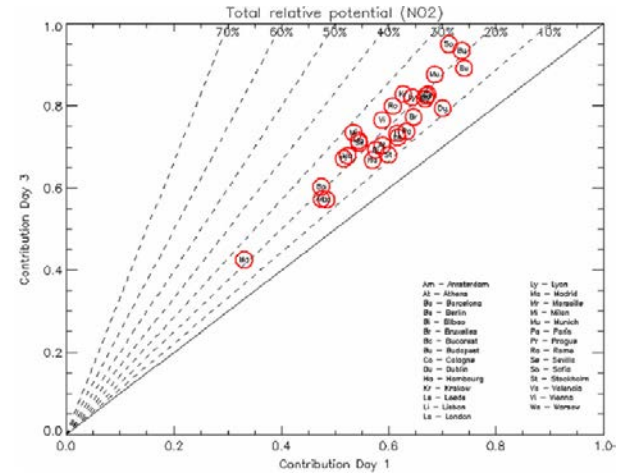


Fig. 1 Map of relative potentials (i.e., $\Delta C/\alpha C$) at $D_{AQP} = 1$ for PM_{10}. The *circled area* is proportional to the potential with the most important contributors placed from center to outwards. The four activity sectors are represented by *different colors*. The *number in each circle* is the overall potential (i.e., corresponding to all sectors reduced simultaneously)



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