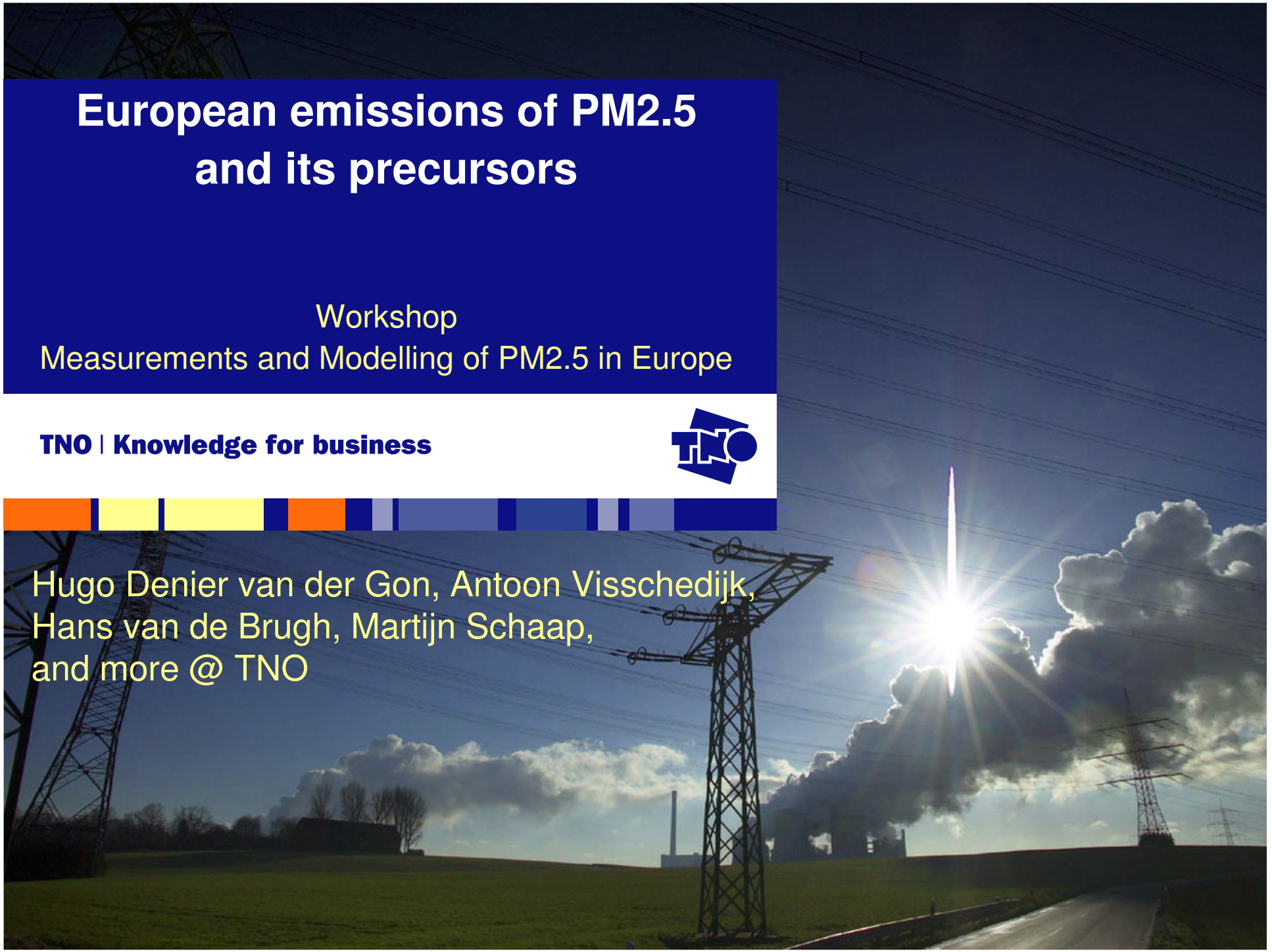
European emissions of PM2.5 and its precursors

Workshop
Measurements and Modelling of PM2.5 in Europe

TNO | Knowledge for business



Hugo Denier van der Gon, Antoon Visschedijk,
Hans van de Brugh, Martijn Schaap,
and more @ TNO

30 minutes to talk about emissions……

- What do we want to know and why?
- Progress in last 10 years
- European Emissions 2005
- Carbonaceous fraction of PM2.5 (EC and OC)
- Some additional comments
- The way forward……

What do we want to know and why?

- **Negotiations** to reduce environmental pressure (emissions) (e.g., NEC) – no spatial distribution required but transparency and acceptance of parties is the key
  - annual and within national borders is OK.

- **Air quality** - emissions become model input
  - Compliance with limit values has become the goal
  - Primary PM vs secondary PM (NOx, NH3, SOx)
  - Completeness, when and where more important

- **Exposure & health**
  - more accuracy in densely populated areas
  - Chemical composition, not all fractions relevant?
  - where and what more important

- **Climate** – see AQ but also size distribution, “color”

Less Covered By Reporting

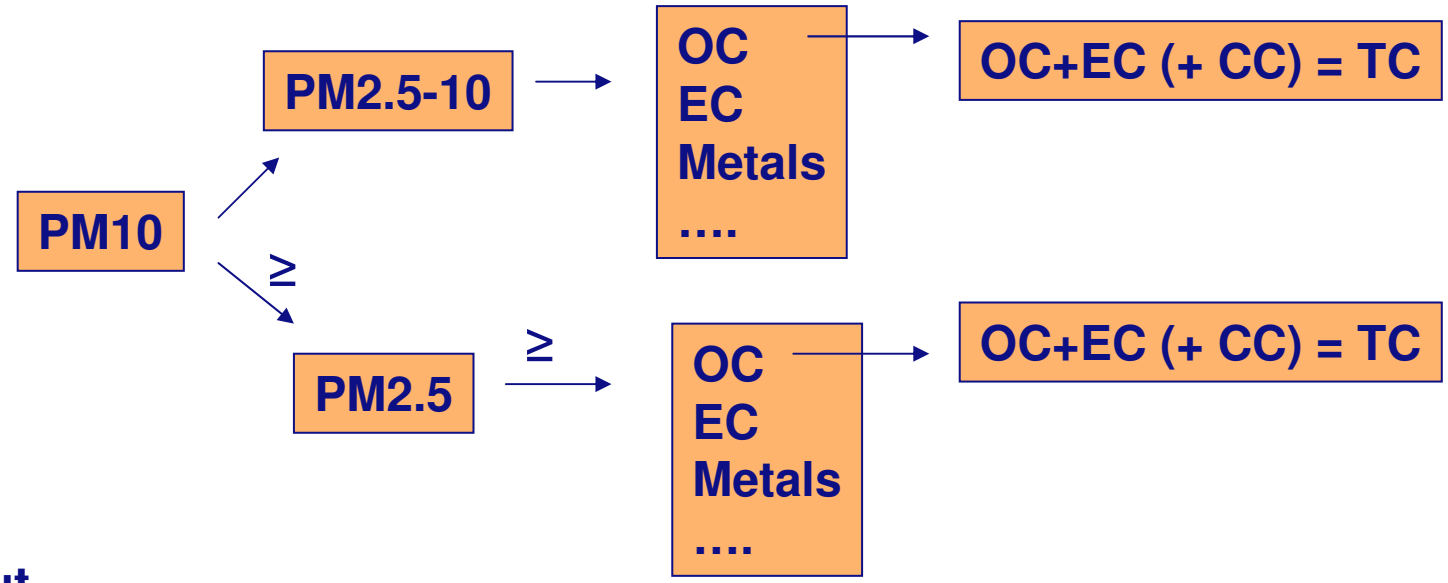
Progress in past years

- Quality of reported emissions improved (EMEP – CEIP)
- Good consistent sets of base year and projection data available e.g. IIASA RAINS / GAINS

- But…
- For modelling more than EU is needed
- Consistency between countries some times problematic
- Resolution of models has improved rapidly – asks for better resolution of emission data (national or 50 x 50 km not sufficient)
- Need for properties that are not reported
- Not all sources are (have to be) reported

A lid on the problems for PM

Emission = EF x Activity



But…

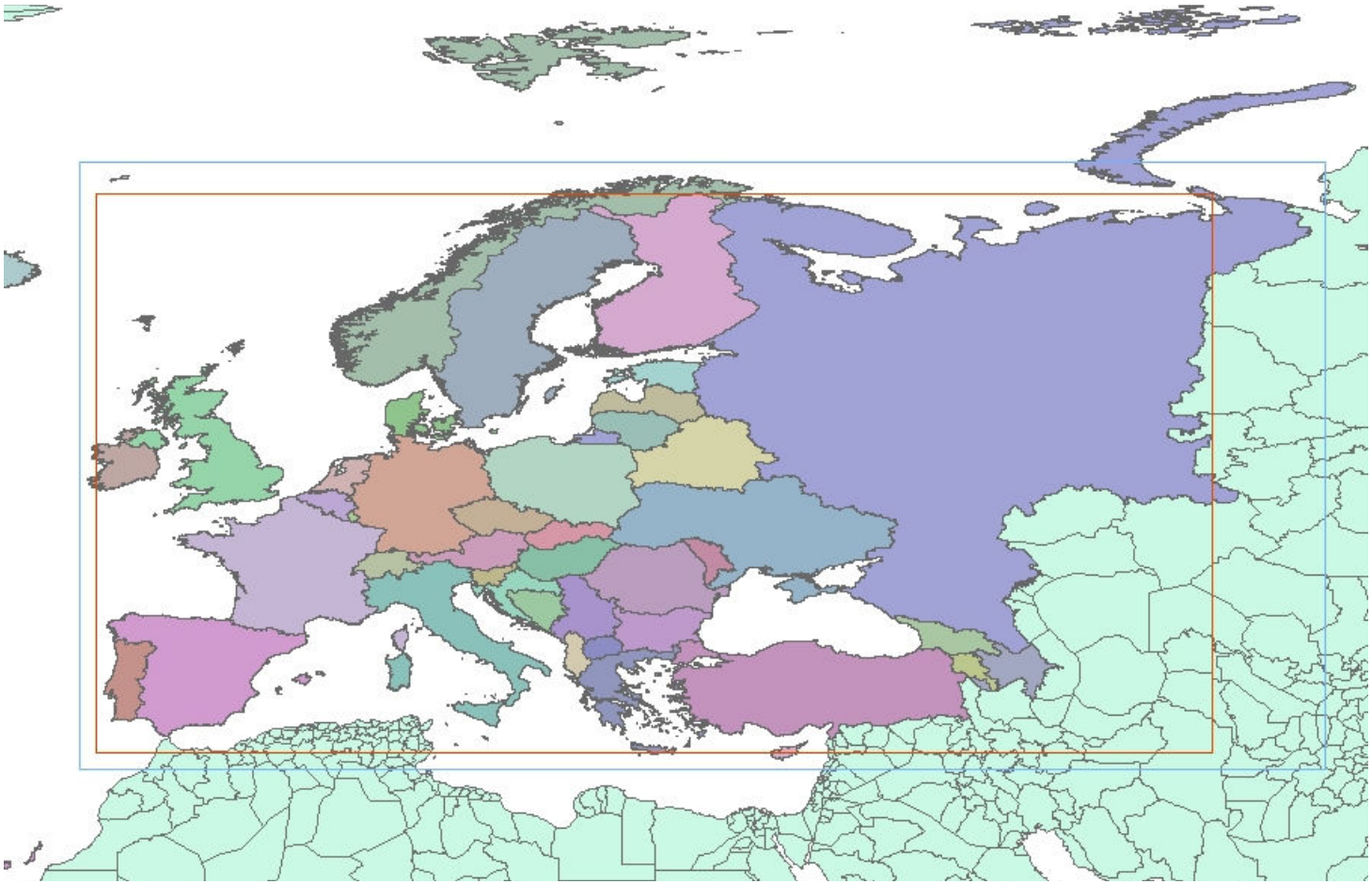
- **measuring techniques differ and cause uncertainty**
- **cars, boilers, stoves classified as one category may differ**

So, independently measured EFs may show PM2.5 > PM10; TC2.5 > PM2.5

By definition:
PM10 ≥ PM2.5 ≥ EC2.5+OC2.5 = TC2.5

→ **We calculate fractions!**

Study area: well beyond EU boundaries



To keep an overview, sources are aggregated by type:

Source sector as used for the gridded emission maps. Classification is based on the SNAP level 1 system with a more detailed split in SNAP 7 (road transport).

Source sectors	Description
1	Combustion Energy sector, utilities, refinaries
2	Combustion small sources (residential)
3	Combustion in industry
4	Process emissions (industry)
5	Mining and extraction of fossil fuels
6	Solvent use, use of products
7	Road transport
71	Road transport gasoline
72	Road transport diesel
73	Road transport LPG
74[1)]	Road transport non-exhaust (volatilization)
75[2)]	Road transport non-exhaust (tire, break and road wear)
8	Non-road transport
9	Waste processing
10	Agriculture

1) Relevant for NMVOC emissions

2) Relevant for PM emissions

Compilation of 2005 emission data

- Based on the new gap-filled EEA 2005 emission database, remaining gaps filled with TNO and/or RAINS estimates.
- sectoral data checked against IIASA Rains and/or TNO data.
- Extreme deviations adjusted - allows maximum use of official data while not hazarding the quality of the final result; Example for Romania;

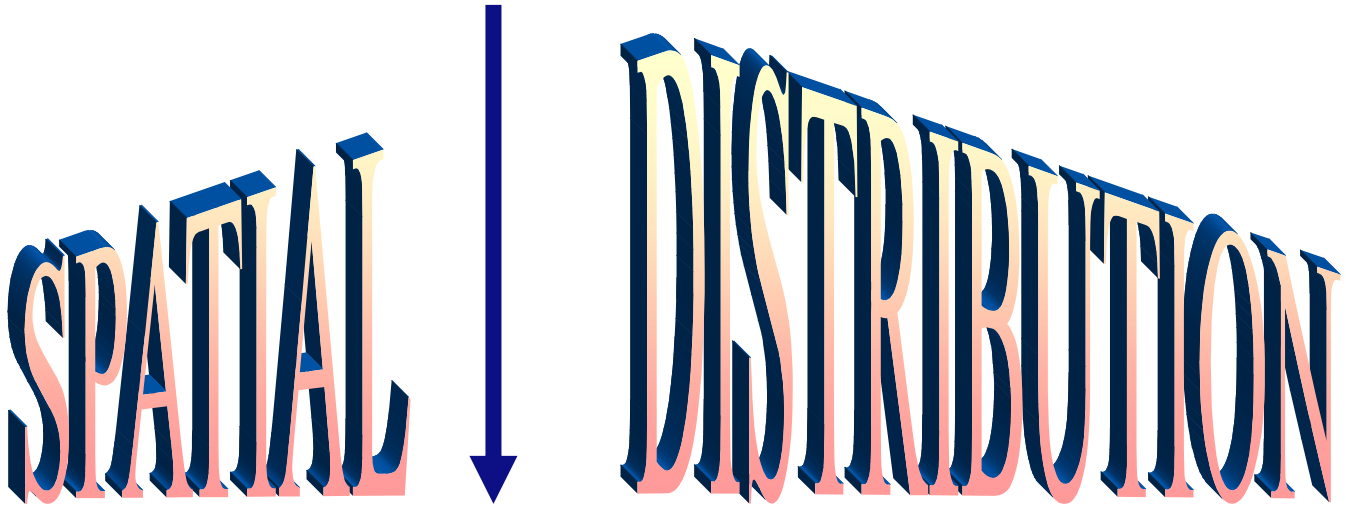
Substance	Units	SNAP	Emission	Data origin
NOx	Mg	1	100693	Reported by country
NOx	Mg	2	14931	Reported by country
NOx	Mg	3	42220	Reported by country
NOx	Mg	4	12720	Reported by country
NOx	Mg	5	804	Reported by country
NOx	Mg	7	107036	Reported by country
NOx	Mg	8	24806	Reported by country
NOx	Mg	9	26	Reported by country
NOx	Mg	10	4000	Gapfilled by EEA [1)]
PM10	Mg	1	43778	RAINS 2005 data used [2)]
PM10	Mg	2	26107	RAINS 2005 data used [2)]
PM10	Mg	3	11329	RAINS 2005 data used [2)]
PM10	Mg	4	26487	RAINS 2005 data used [2)]
PM10	Mg	5	850	RAINS 2005 data used [2)]
PM10	Mg	7	8444	RAINS 2005 data used [2)]
PM10	Mg	8	3572	RAINS 2005 data used [2)]
PM10	Mg	9	4808	RAINS 2005 data used [2)]
PM10	Mg	10	26481	RAINS 2005 data used [2)]

[1)] Emission value considered to equal the most recent reported emission value

[2)] No (gapfilled) country data available from EEA

UNECE-EUROPE EMISSIONS
PM2.5 + PRECURSORS

Emission	NH3	NMVOC	NOx	PM2_5	SOx
(ktonnes/yr)	6388	15363	17293	3264	16720



Updated and improved spatial distribution maps for emission sources
Point sources
Area sources

TNO updated and / or replaced point source data (location, capacity and fuel used) for the following branches

- Power generation
- Refineries
- Non-ferro industry
- Iron and Steel production
- Cement production (see map as an example)
- Ports and harbours (handling of bulk goods)

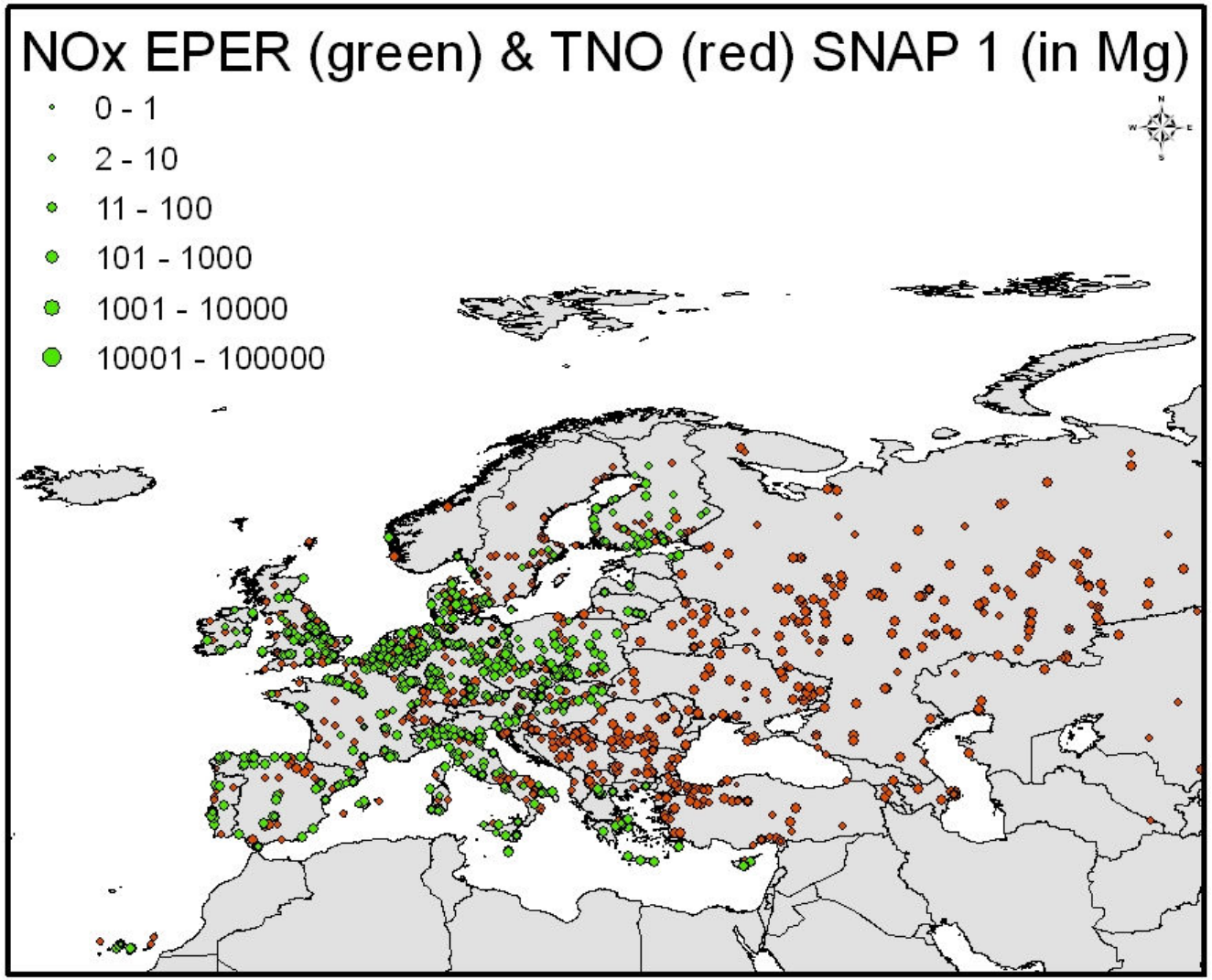
- **Other point sources, not updated**
- Waste Incineration
- Mining – oil and gas exploration
- Chemical Industry

  - Point source characteristics are used for properly distributing emissions e.g.
  - Capacity
  - Fuel use / type information

Example Power plants

- The new file contains 1823 point sources. (expansion of ~ 50%).
- Added new companies, remove closed installations,
- We added a lot of the smaller point sources to the file - new PS file is up to date and contains more detail than the old point sources file.
- Expanded the list of (large) point sources in the eastern European countries
- For the EU a match of 85 – 90 % with EPER reporting (see next slide) -> consistent!

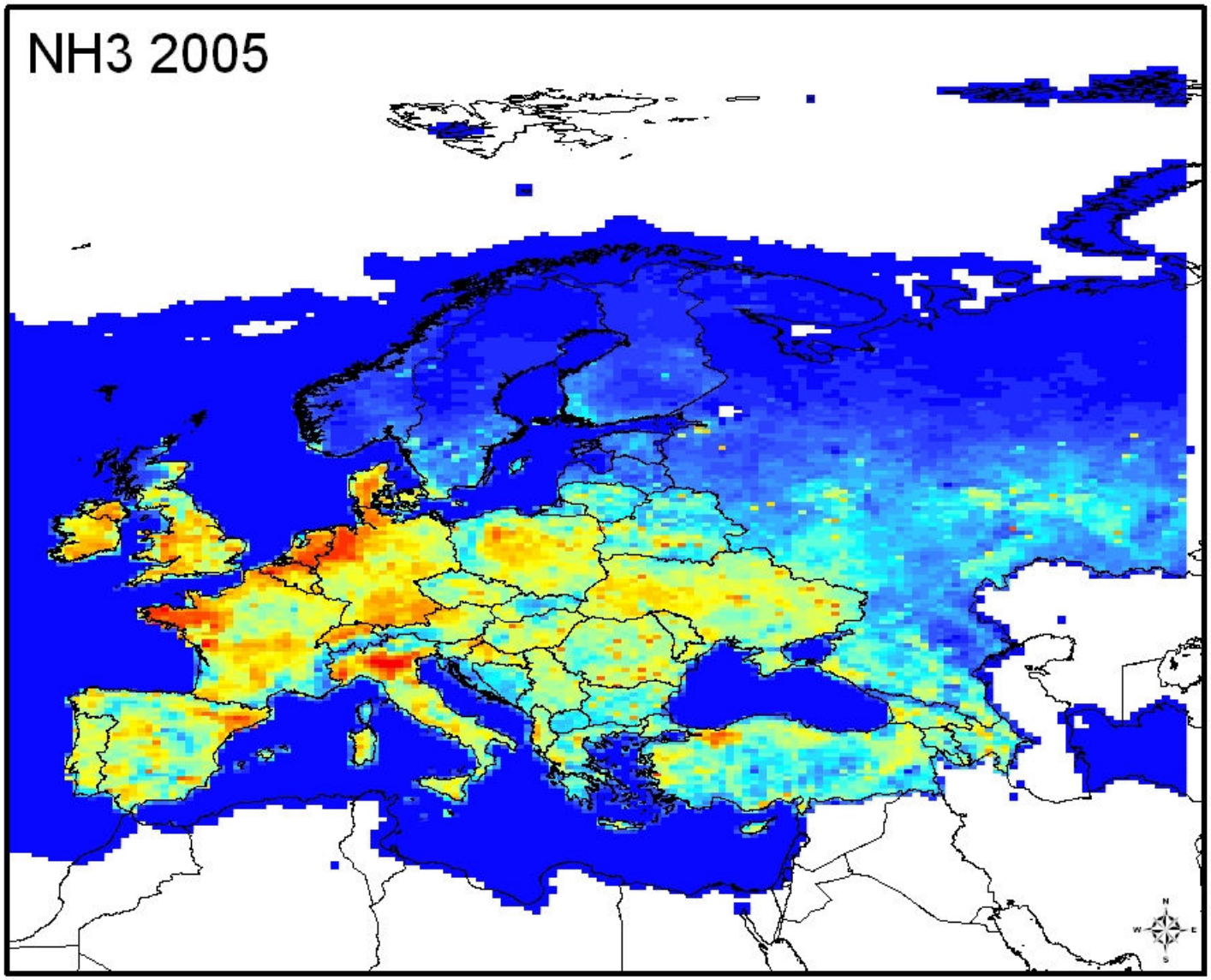
EPER reported power plants overlaying the TNO data base

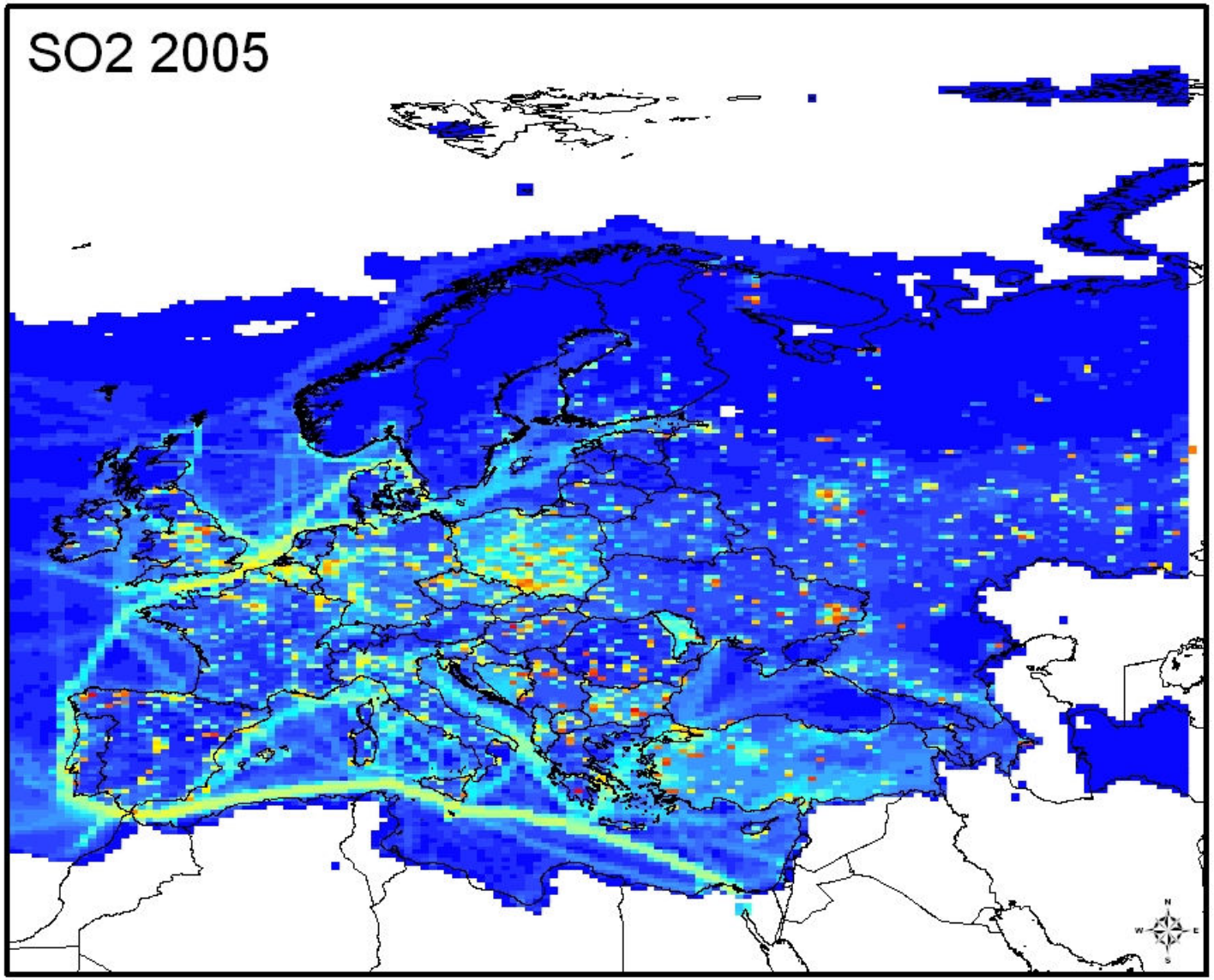


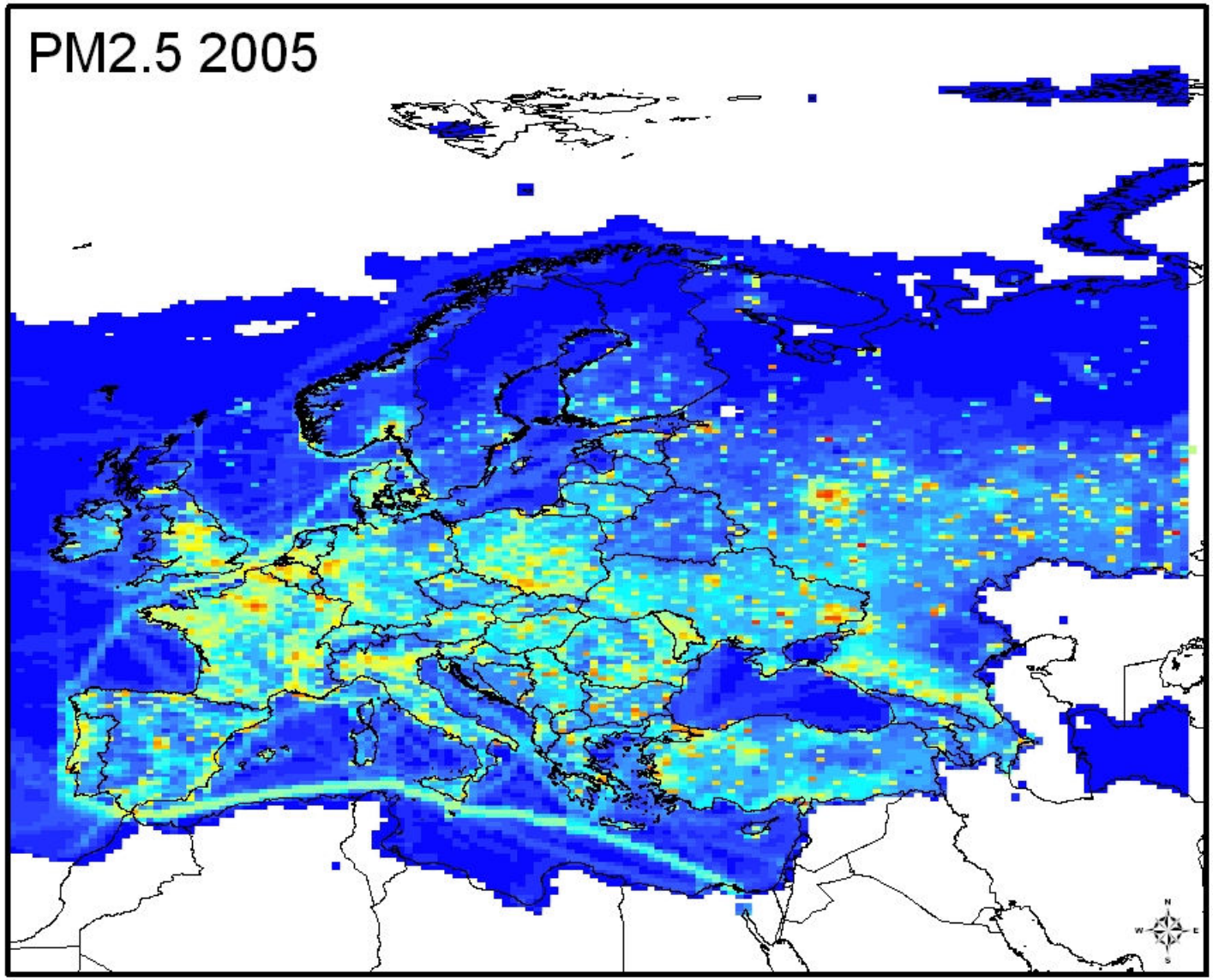
Diffuse and area sources

- Population is a default proxy for any anthropogenic source we do not have specific data for
- Derive a urban vs non-urban population map for some sources e.g. residential heating
- Agricultural emissions by animal location or by land use (we expanded the Corine LU map using other maps – not shown)
- Road transport - Make selective choices : urban traffic is gridded by total population, major road networks and intensity for non-urban traffic

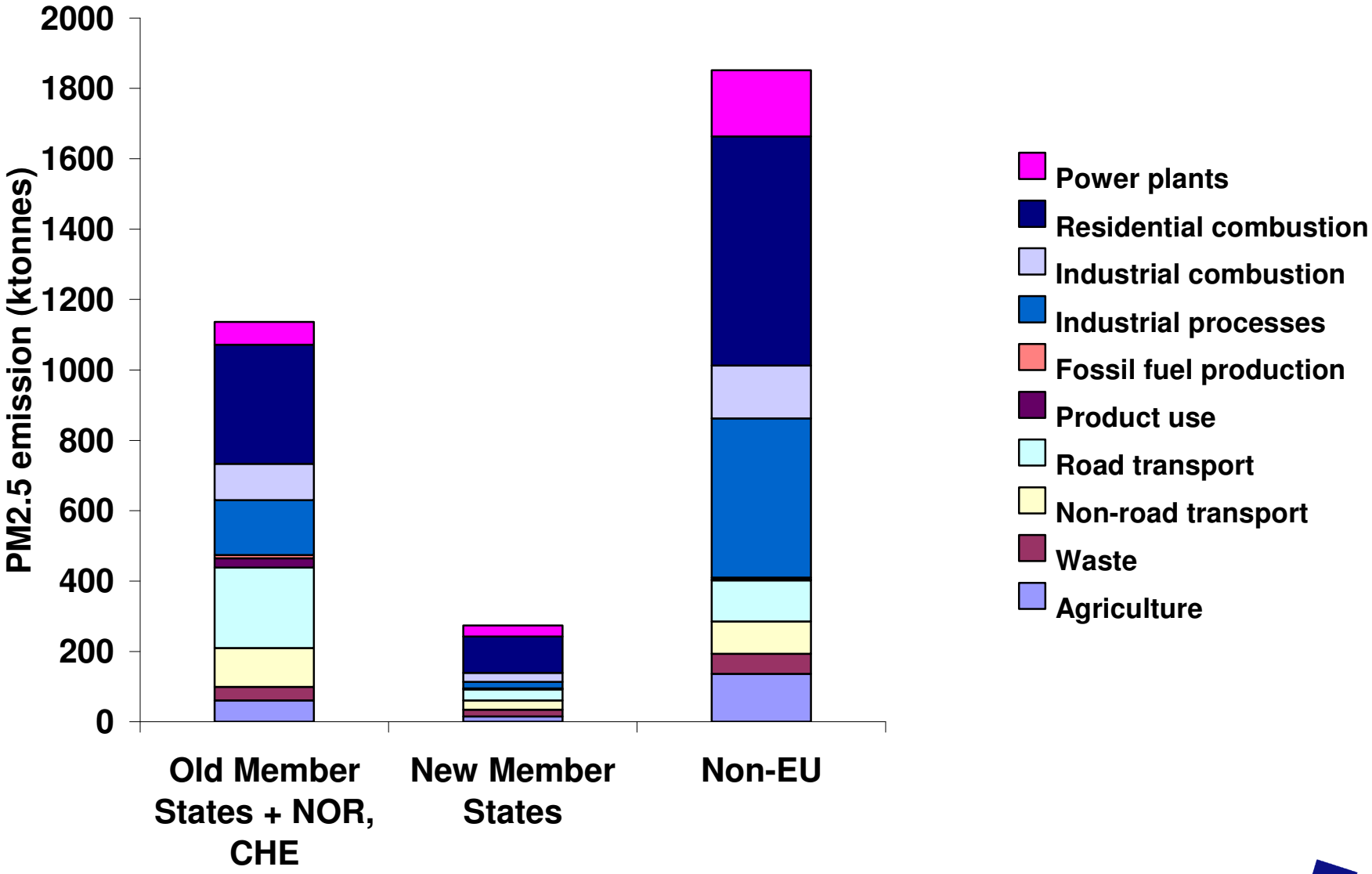
All sources…..



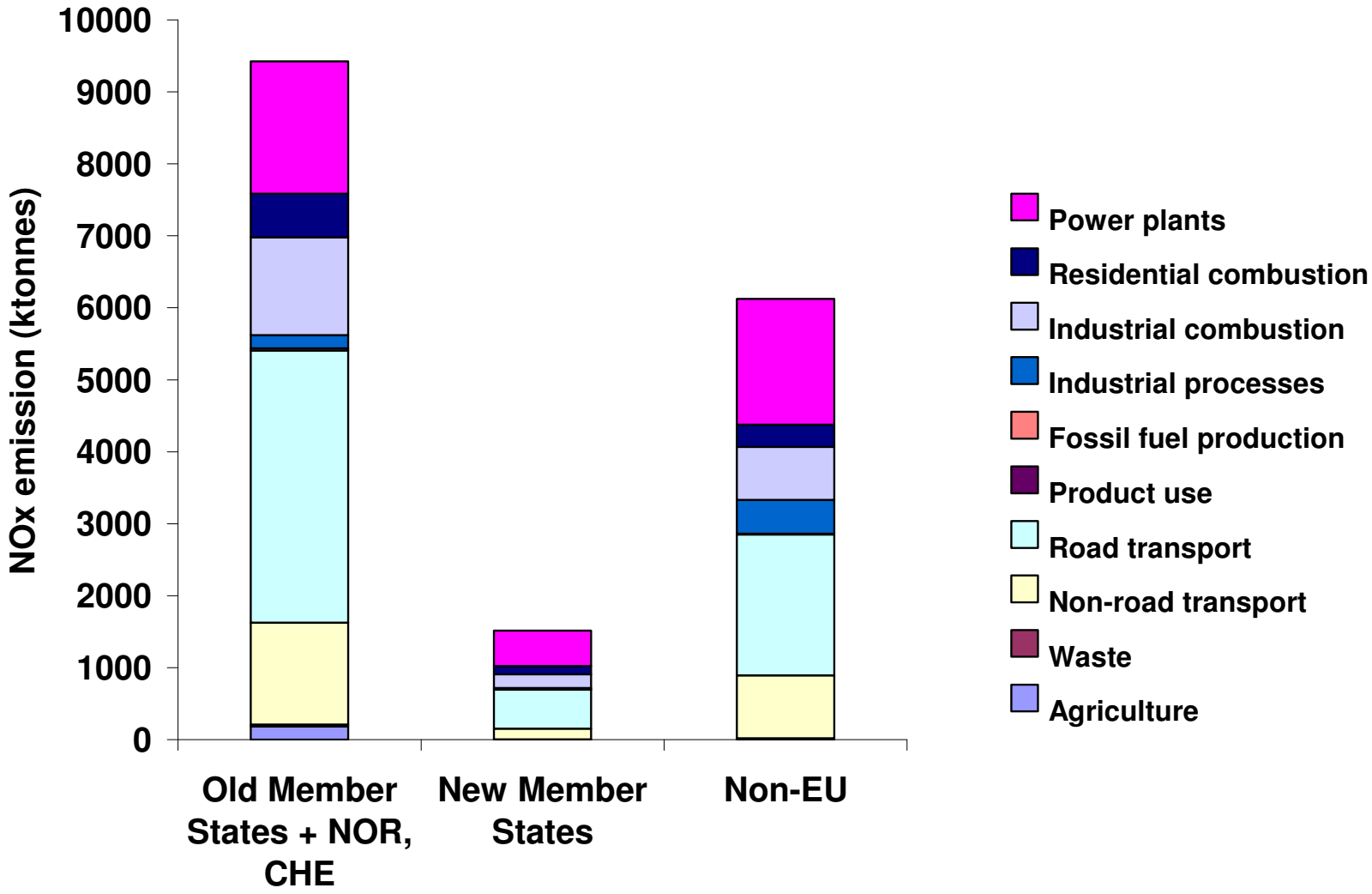

SO2 2005


PM2.5 2005

Sector contributions PM2.5



Sector contributions NOx

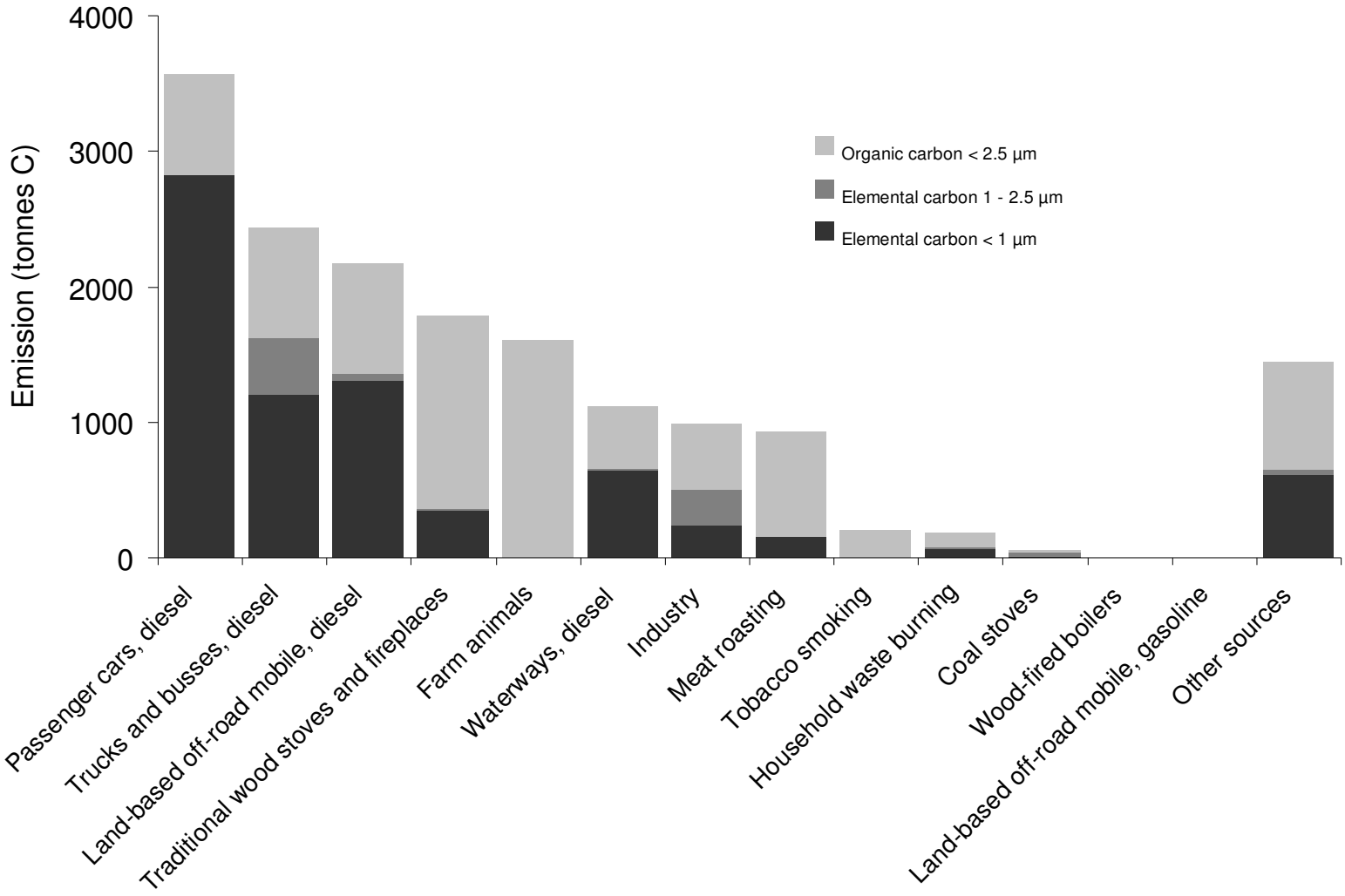


Anthropogenic primary Carbonaceous emissions in Europe 2005 (kt C) – based on fraction EC / OC in PM2.5

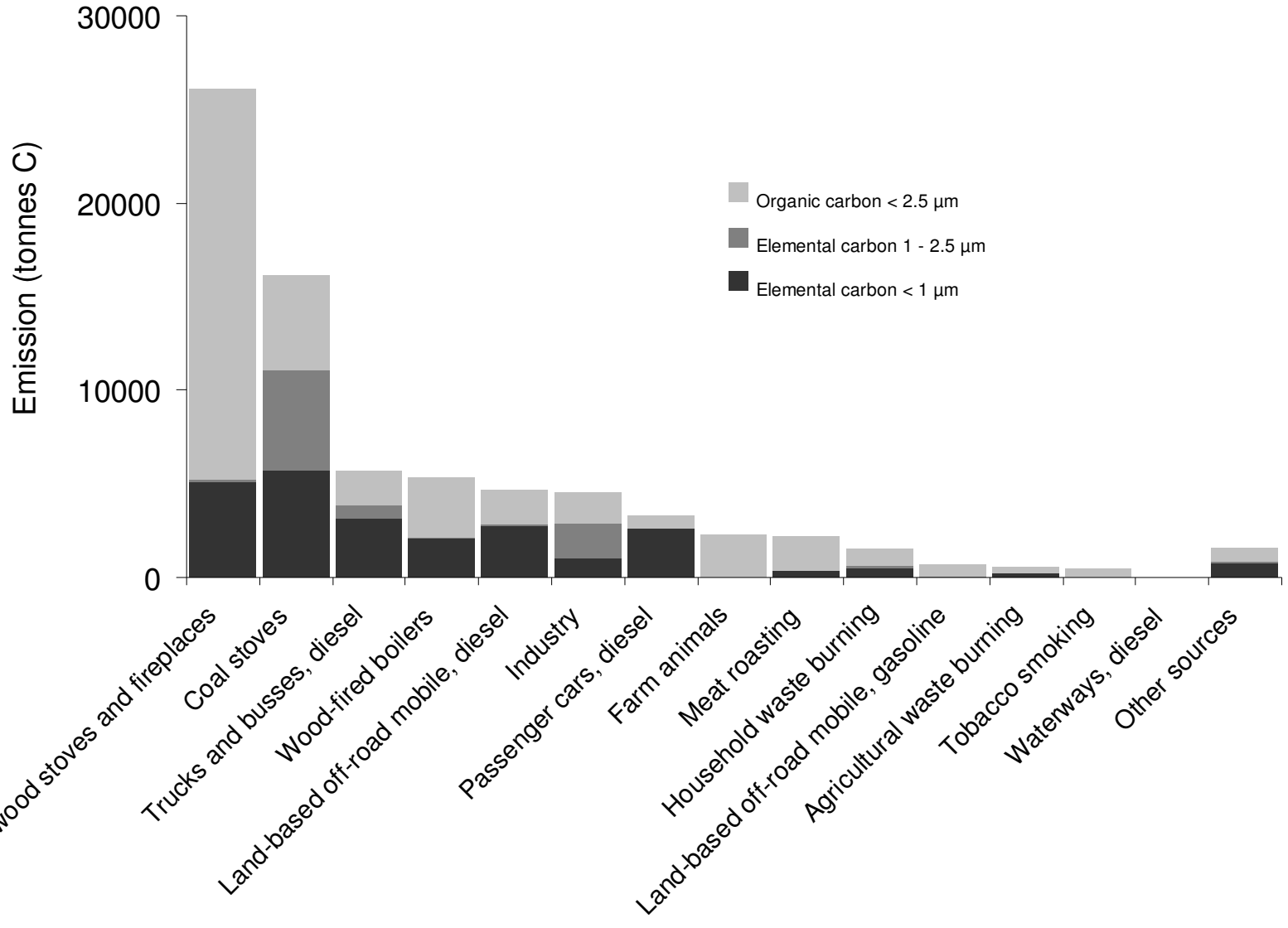
SNAP1	EC_1	EC_1-2.5	OC_2.5
1	2	18	11
2	143	43	395
3	2	4	9
4	32	4	81
5	1	3	1
6	0	0	0
7	184	17	104
8	90	5	71
9	35	2	63
10	35	1	112
Total Land based	525	96	847
International shipping	79	45	84
Europe	604	140	931

- Residential combustion dominates EC (coal) and OC (wood)
- Road transport dominates EC, also important for OC

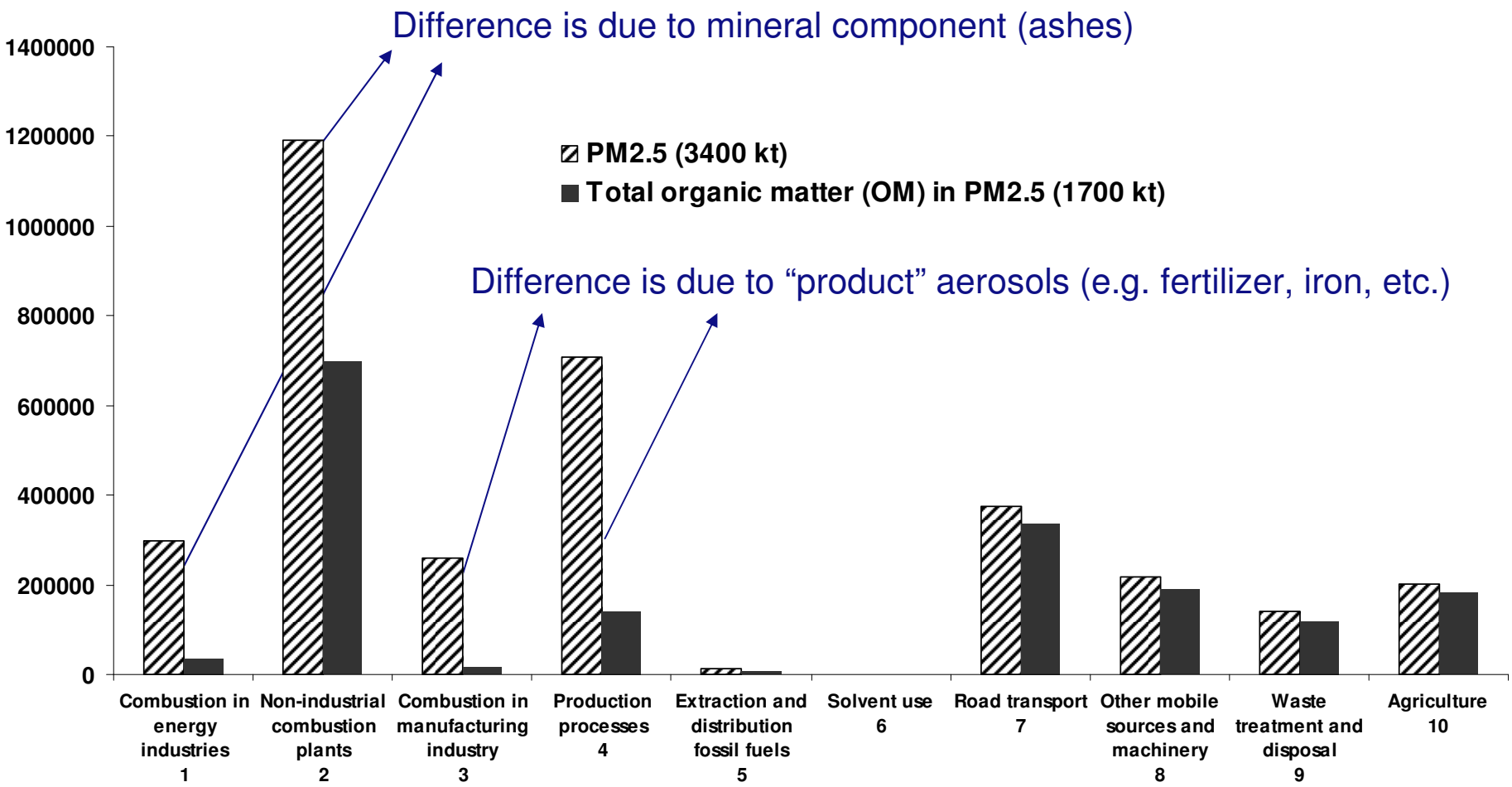
Netherlands

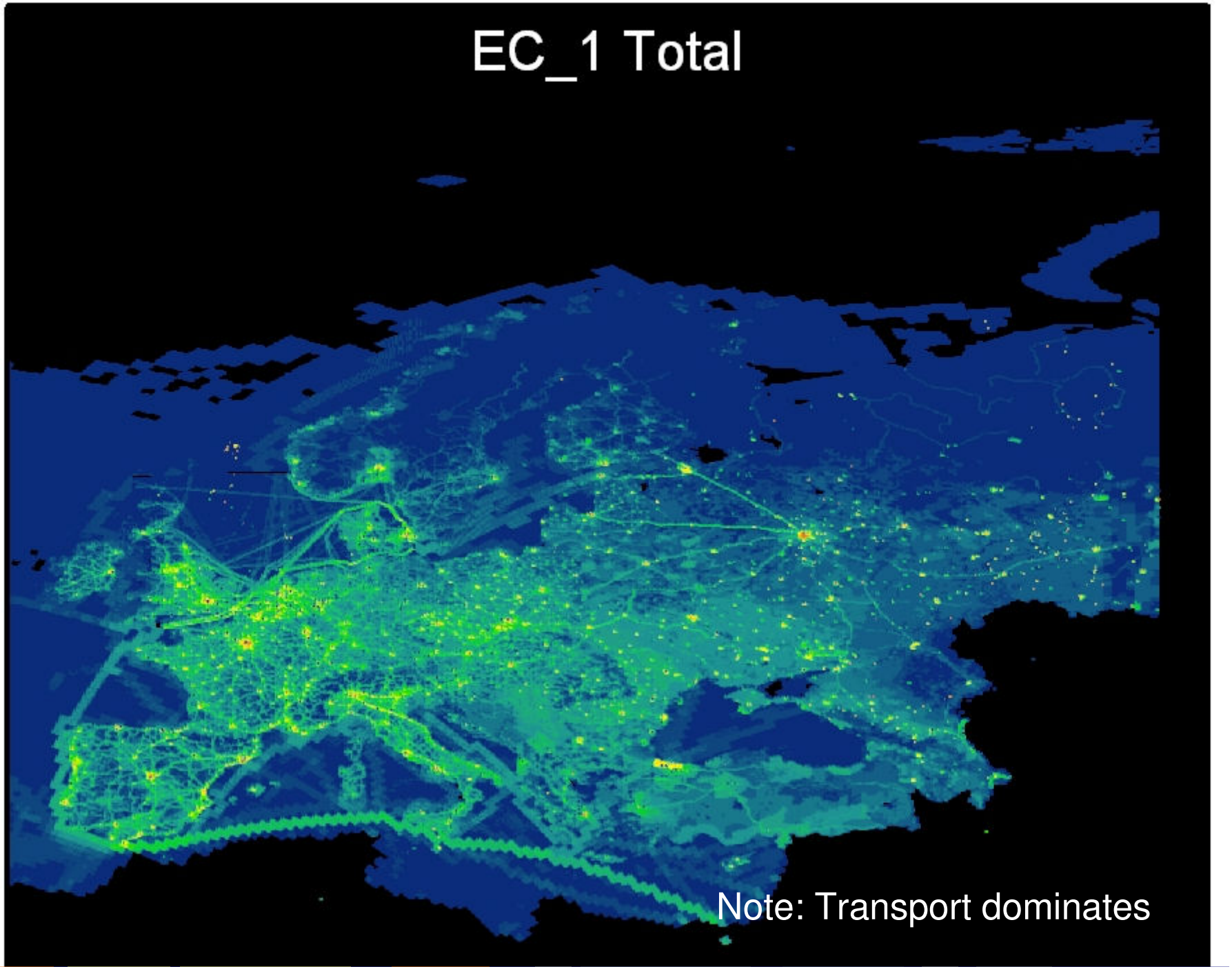


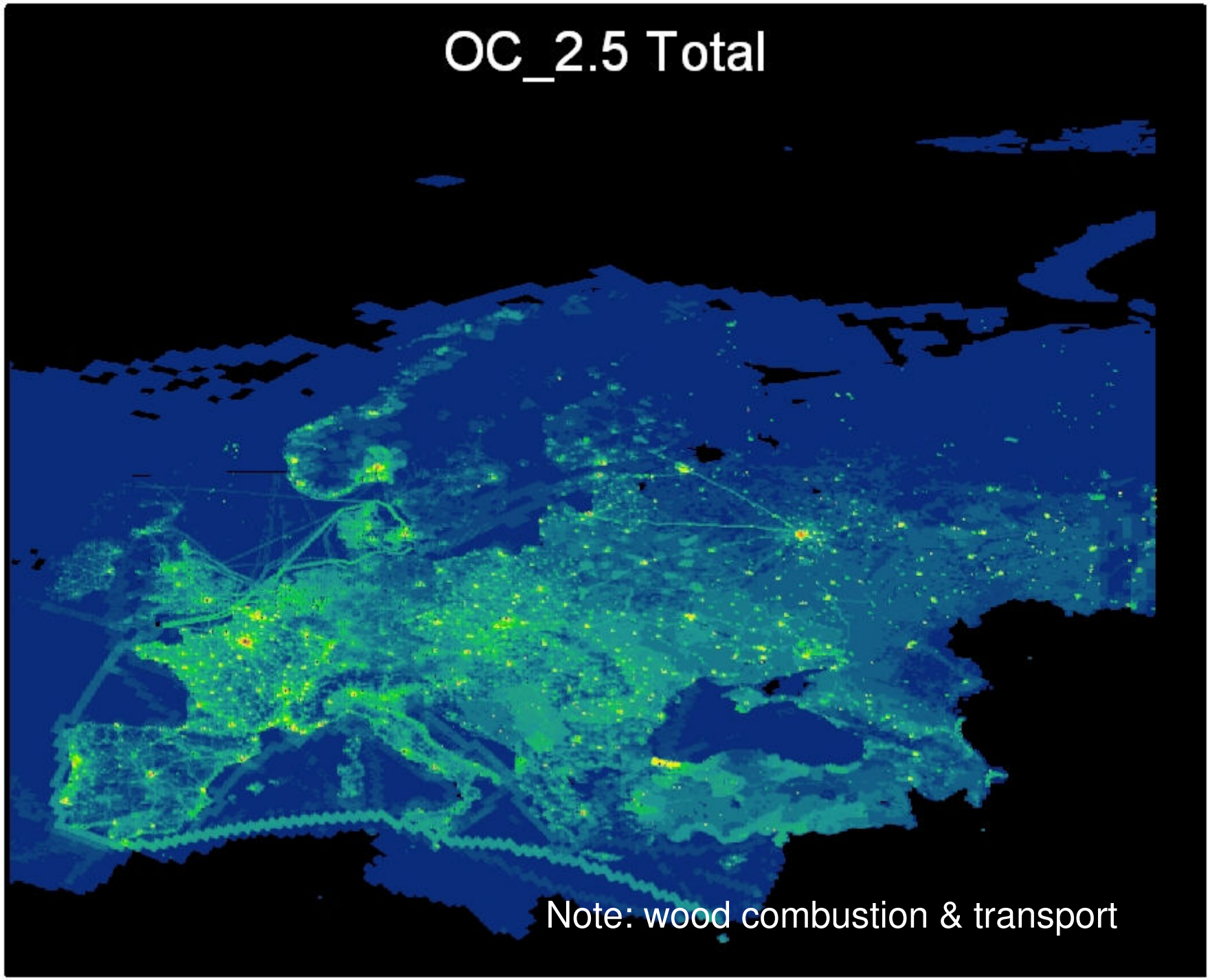
Poland


30000
20000
10000
0
Emission (tonnes C)
Organic carbon < 2.5 µm
Elemental carbon 1 - 2.5 µm
Elemental carbon < 1 µm
Traditional wood stoves and fireplaces
Coal stoves
Trucks and busses, diesel
Wood-fired boilers
Land-based off-road mobile, diesel
Industry
Passenger cars, diesel
Farm animals
Meat roasting
Household waste burning
Land-based off-road mobile, gasoline
Agricultural waste burning
Tobacco smoking
Waterways, diesel
Other sources

Emission of OM vs PM2.5 for Europe in 2005 by source sector




EC_1 Total
Note: Transport dominates


OC_2.5 Total
Note: wood combustion & transport

Conclusions European emissions 2005

- **Reporting is much better these days but also demands become more detailed and specific**
- **Base year 2005 maps developed for all substances**
- **The spatial distribution and allocation is greatly improved!**
- A European EC and OC emission inventory is compiled for the year 2005 that is consistent with particulate matter inventories.
- Total PM2.5 for UNECE Europe (excl. shipping) = 3400 kt and about half of this is carbonaceous aerosol (organic matter).
- Diesel use in transport and fuel wood by households are responsible for 70% EC_1 and 56% of OC in PM2.5.
- The high resolution inventories are “passed on” to Modelers (e.g. within the UBA PAREST, FP7 EUCAARI project…..The feedback should help in further improvements
- Working in this manner generates many ideas about further improvements, shipping, fire emissions, but funding work that is not directly linked to reporting requirements or limit values is difficult….
- The devil is in the detail……

Road transport

- Growth in volume
- Decreasing exhaust emissions due to cleaner technologies
- Non-exhaust emissions follow increasing volume
- Relative importance of non-exhaust en resuspension is growing

Relevance:

- X% reduction of exhaust emission does not result in X% reduction of road transport emission. (we tend to overestimate impact)
- Non-exhaust is more uncertain in terms of PM size but also in composition, when and where. -> Deserves more attention

- Validation of real-world emissions by measurements becomes more important to avoid ending up in a virtual world.

PM2.5 emission often calculated as a fraction of PM10

Iron & steel plants			
Technology level	**EF PM10 g/tonne pig iron**	**Fraction PM2.5**	**EF PMPM2.5 g/tonne pig iron**
Low	**1**	**0.5**	**0.5**
Medium	**0.192**	**0.63**	**0.121**
High	**0.038**	**0.95**	**0.036**

Emission decreases with higher removal efficiencies but PM2.5 fraction increases – smaller particles become relatively more important.

High removal is wonderful but ….
Assume unabated emission = 100/day
Removal = 99,5% -> emission = 0.5/day = 183/year
Assume 2 off-days, no removal – factory keeps going -> Emission = + 200!
So failure days may dominate the emissions – who reports this?

Measurement – Emission - Model

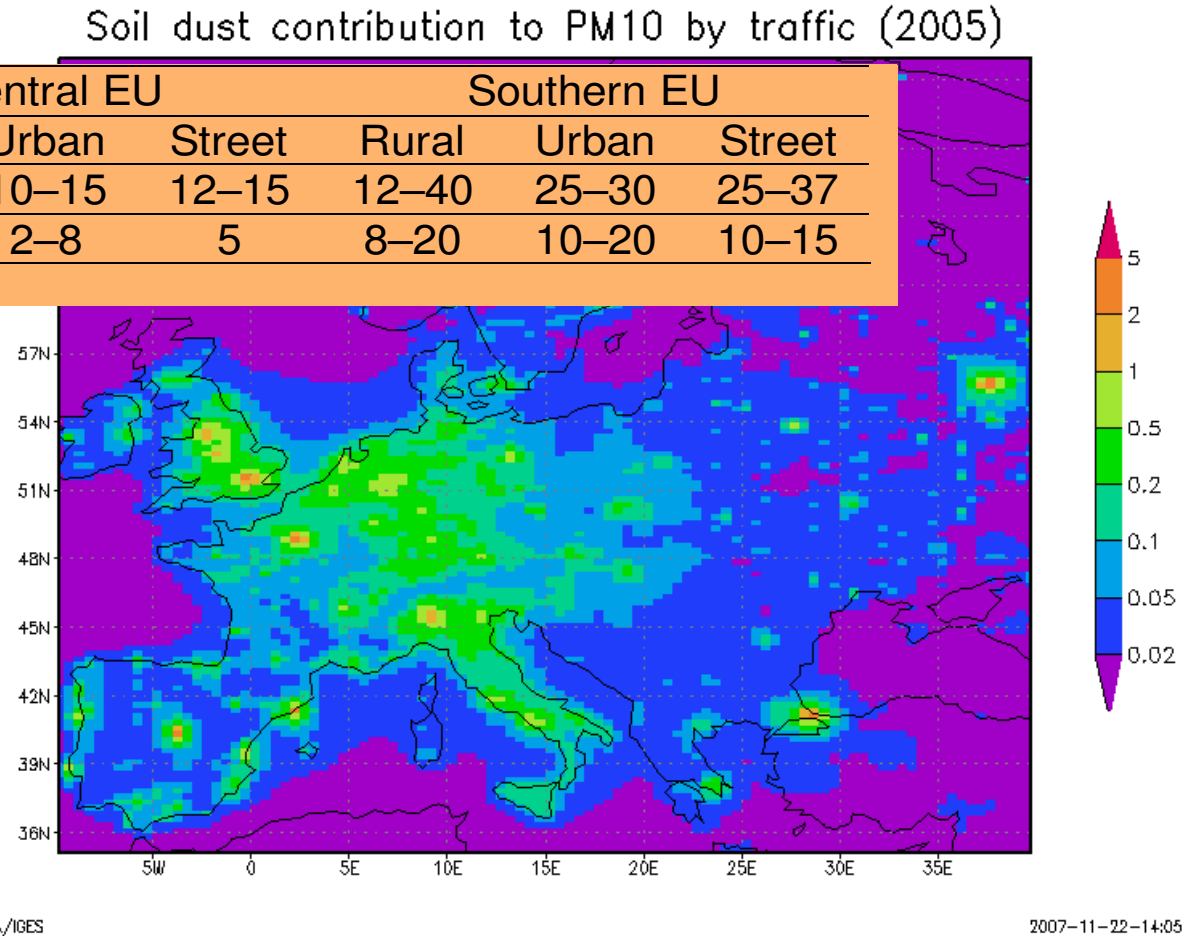
INTEGRATION

Is the way forward!

Predicted crustal PM10 due to resuspension by traffic

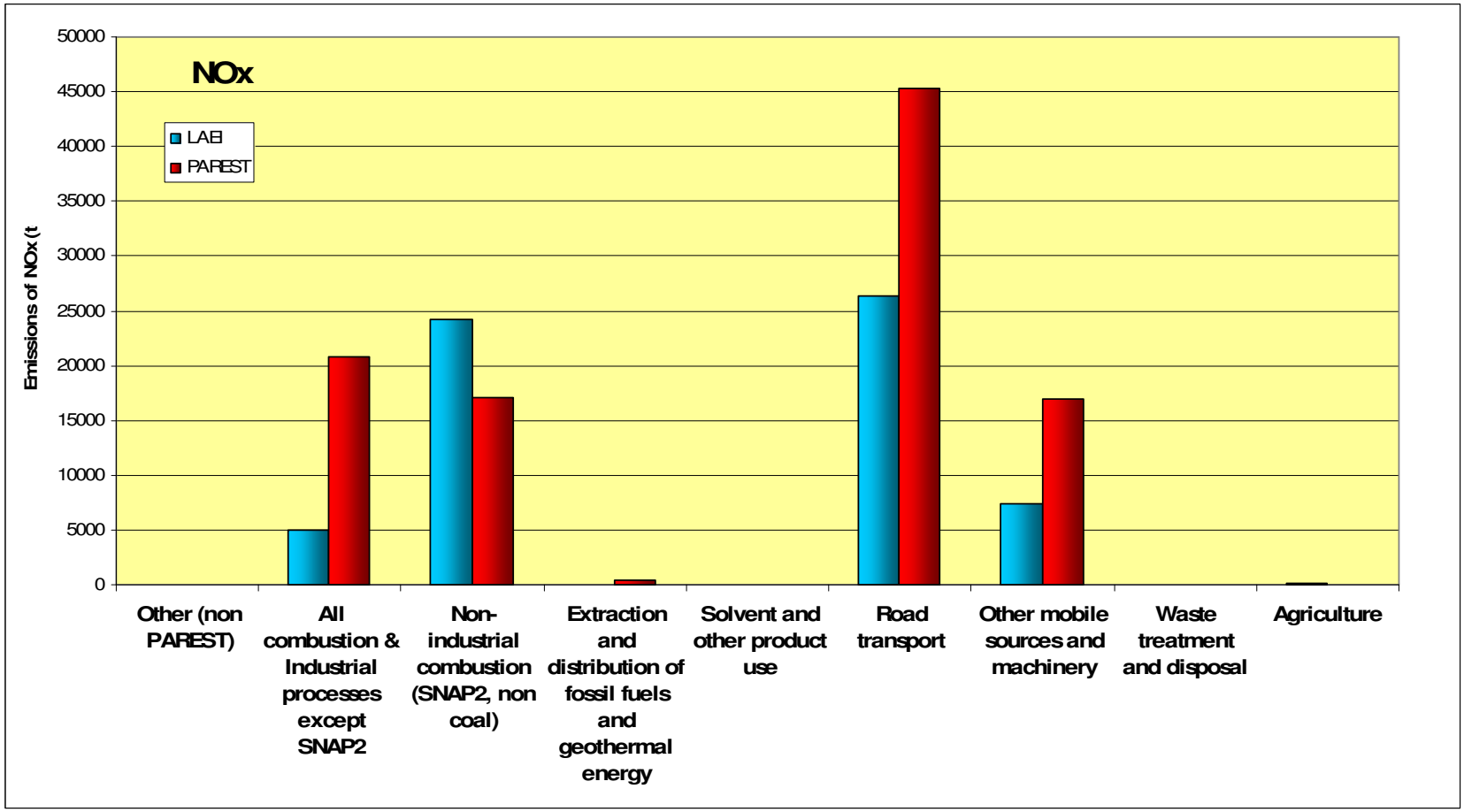
	Central EU			Southern EU		
	Rural	Urban	Street	Rural	Urban	Street
% CM inPM10	5–10	10–15	12–15	12–40	25–30	25–37
% CM in PM2.5	2–8	2–8	5	8–20	10–20	10–15

Source: Querol et al (2004)



Use our activity and distribution data to generate a hypothetical emissions map
Explore with modelers and observational data if this approach makes sense

In EU FP7 MEGAPOLI we will nest bottom-up city inventories in our top-down European EI



London – PRELIMINARY - : differences are large – both sides will learn

Remember?

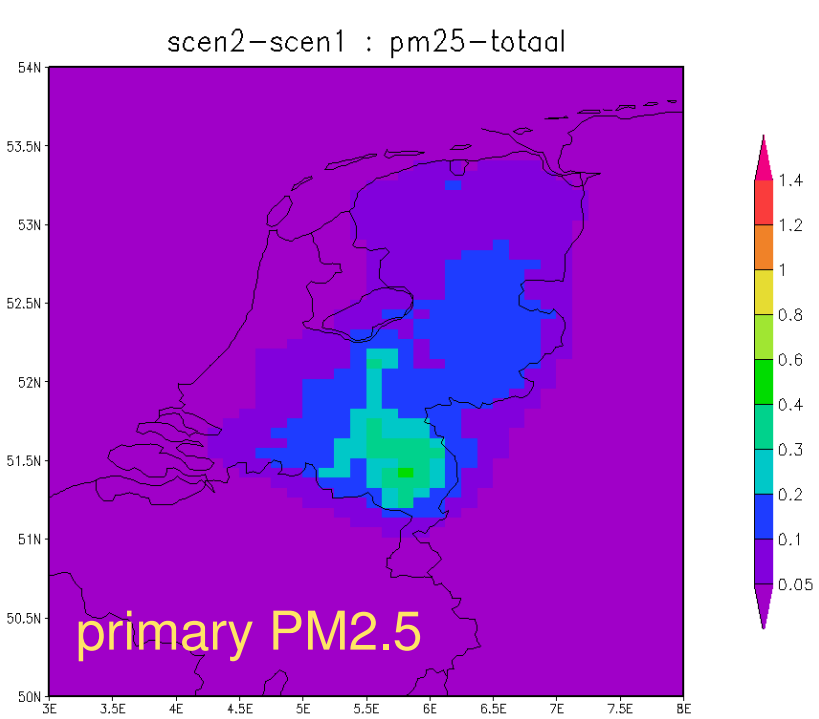
By definition:
PM10 ≥ PM2.5 ≥ EC2.5+OC2.5 = TC2.5

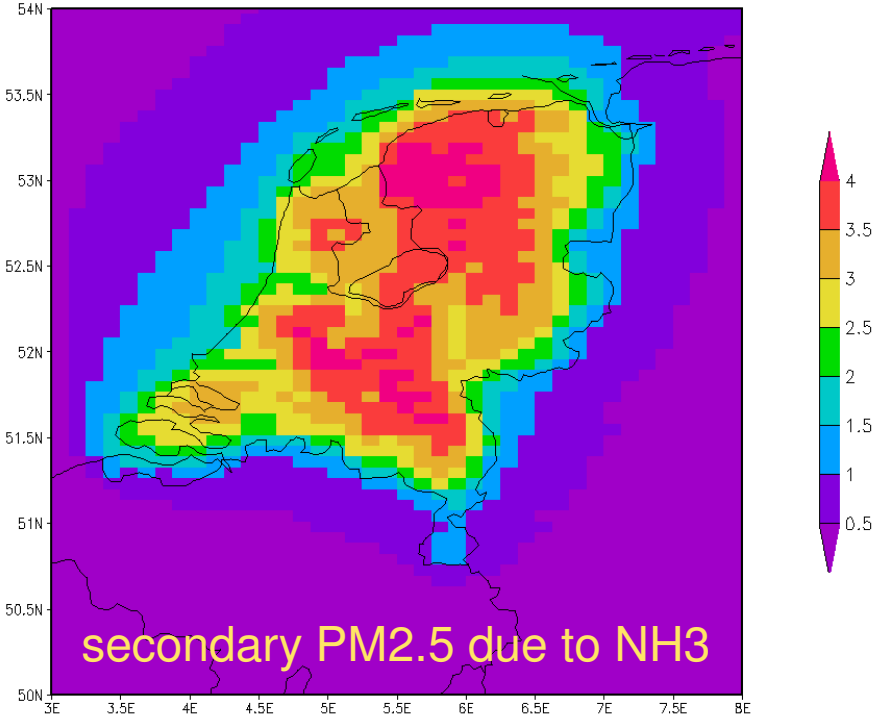
→ **We calculate fractions!**

- What happens when new findings suggest high fine OC for a source (e.g. wood combustion)?
- Only the share EC / OC would change since our PM10 fraction isn't changed
- New insights filter into EI's slowly because a new EF will be one on 10, 20 or more so impact is averaged out….
- Dialogue inventory people and measurement experts crucial!

Importance of precursors vs primary PM using Lotos-Euros model and emission scenario's

Name	Description	NH_3	NO_x	SO_2	PM2.5-10[a)]	PM2.5[a)]
		(tonnes/yr)				
S1	Agriculture = 0	-120000	-12660	0	-7013	-1821
S2	Precursor Agric. = 0	-120000	-12660	0	0	0





Importance of NH4NO3 due to Dutch agriculture for PM2.5 in NL is high – higher than all NL primary PM2.5 (Note: simplified version….)

Thank you for your attention

Acknowledgements

- BOP project and VROM
- UBA – PAREST project
- EU FP6 EUCAARI
- EU FP7 MEGAPOLI
- IIASA – RAINS / GAINS