Recent experiences in Spain

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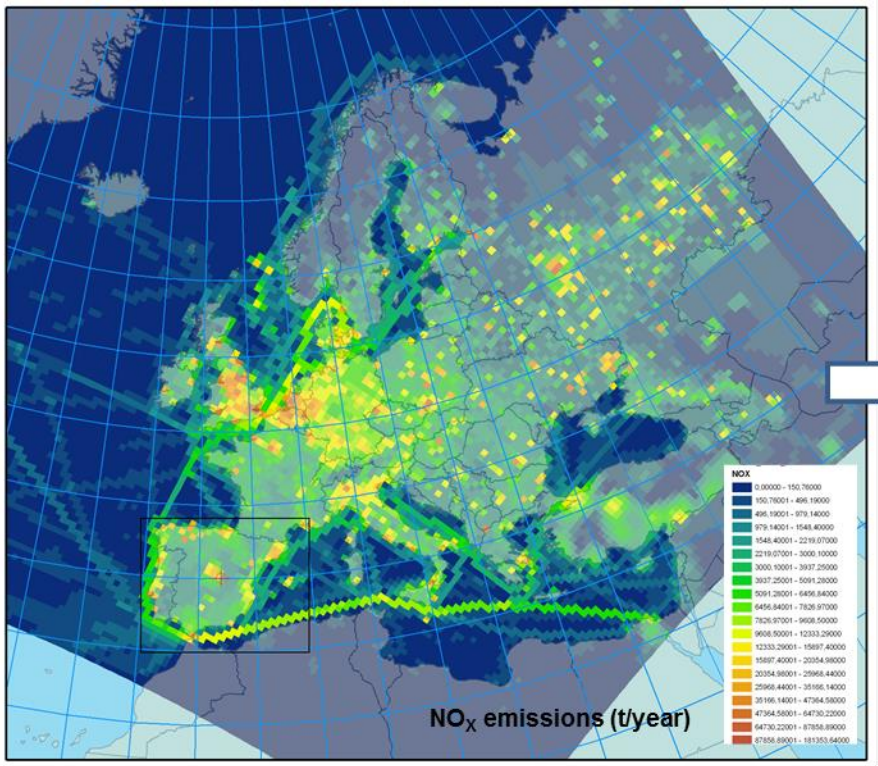
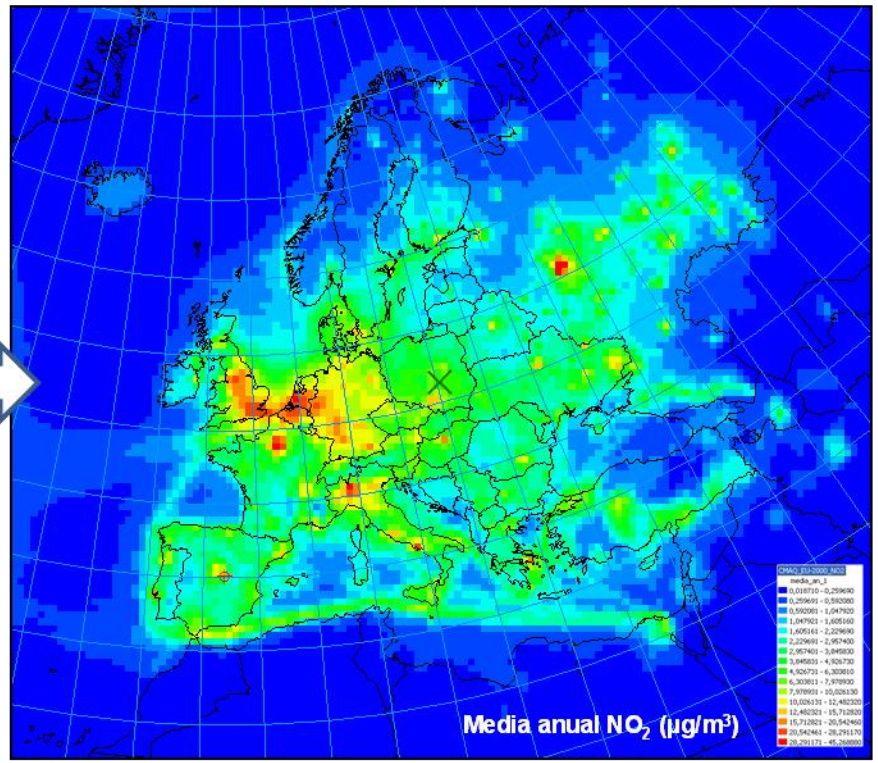
OUTLINE

1. Introduction (city focus)
2. Domestic heating inventory in Madrid
3. Indirect emissions in Madrid
4. Mesoscale parameterization for urban areas
5. Microscale simulations in Madrid
6. Population exposure through mobile data
7. Future Madrid AQ Plan
8. Protocol for high pollution episodes
9. Urban freight distribution
10. Other work (clean cookstoves and NECD)

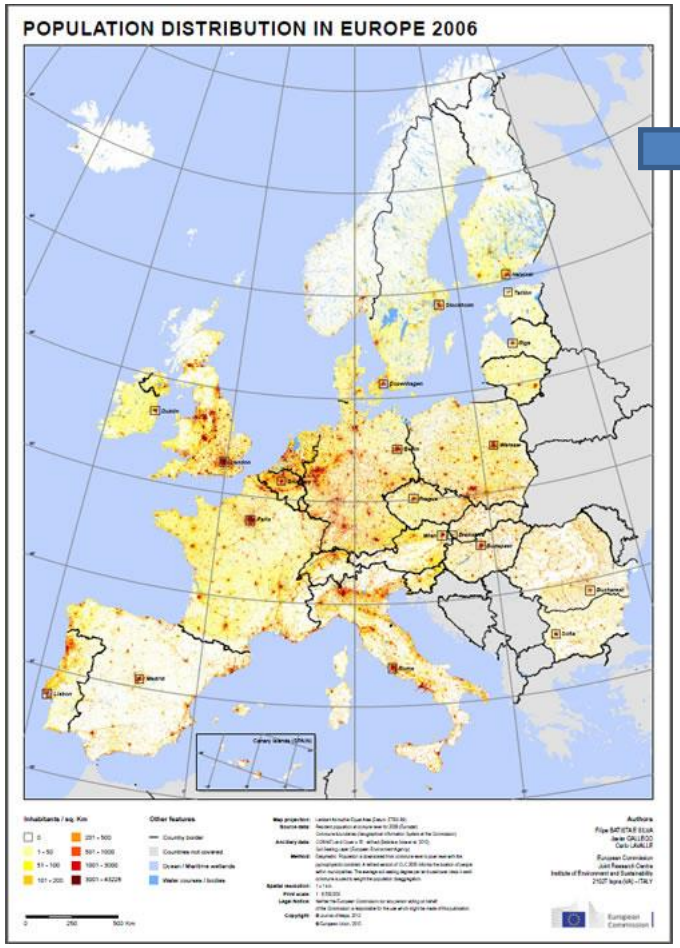
1.- Introduction

- The most important air quality issues occur in urban environments due to (two factors):





1. High emission intensity → High pollution levels



Source: JRC 2013

Table ES.1 **Percentage of the urban population in the EU-28 exposed to air pollutant concentrations above certain EU and WHO reference concentrations (2011–2013)**

Pollutant	EU reference value	Exposure estimate	WHO AQG	Exposure estimate
$PM_{2.5}$	Year (25)	9–14	Year (10)	87–93
PM_{10}	Day (50)	17–30	Year (20)	61–83
O_3	8-hour (120)	14–15	8-hour (100)	97–98
NO_2	Year (40)	8–12	Year (40)	8–12
BaP	Year (1 ng/m³)	25–28	Year (RL, 0.12 ng/m³)	85–91
SO_2	Day (125)	<1	Day (20)	36–37

Key: < 5% | 5–50% | 50–75% | > 75%

Notes: The estimated range in exposures refers to a recent three year period (2011–2013, except for SO_2 WHO AQG, 2011–2012) and includes variations due to meteorology, as dispersion and atmospheric conditions differ from year to year.

The reference concentrations include EU limit or target levels, WHO air quality guidelines (AQG) and estimated reference levels.

The reference concentrations in brackets are in µg/m³ except for BaP in ng/m³.

For some pollutants EU legislation allows a limited number of exceedances. This aspect is considered in the compilation of exposure in relation to EU air quality limit and target values. The comparison is made for the most stringent EU limit or target values set for the protection of human health. For PM_{10} the most stringent limit value is for 24-hour mean concentration and for NO_2 it is the annual mean limit value.

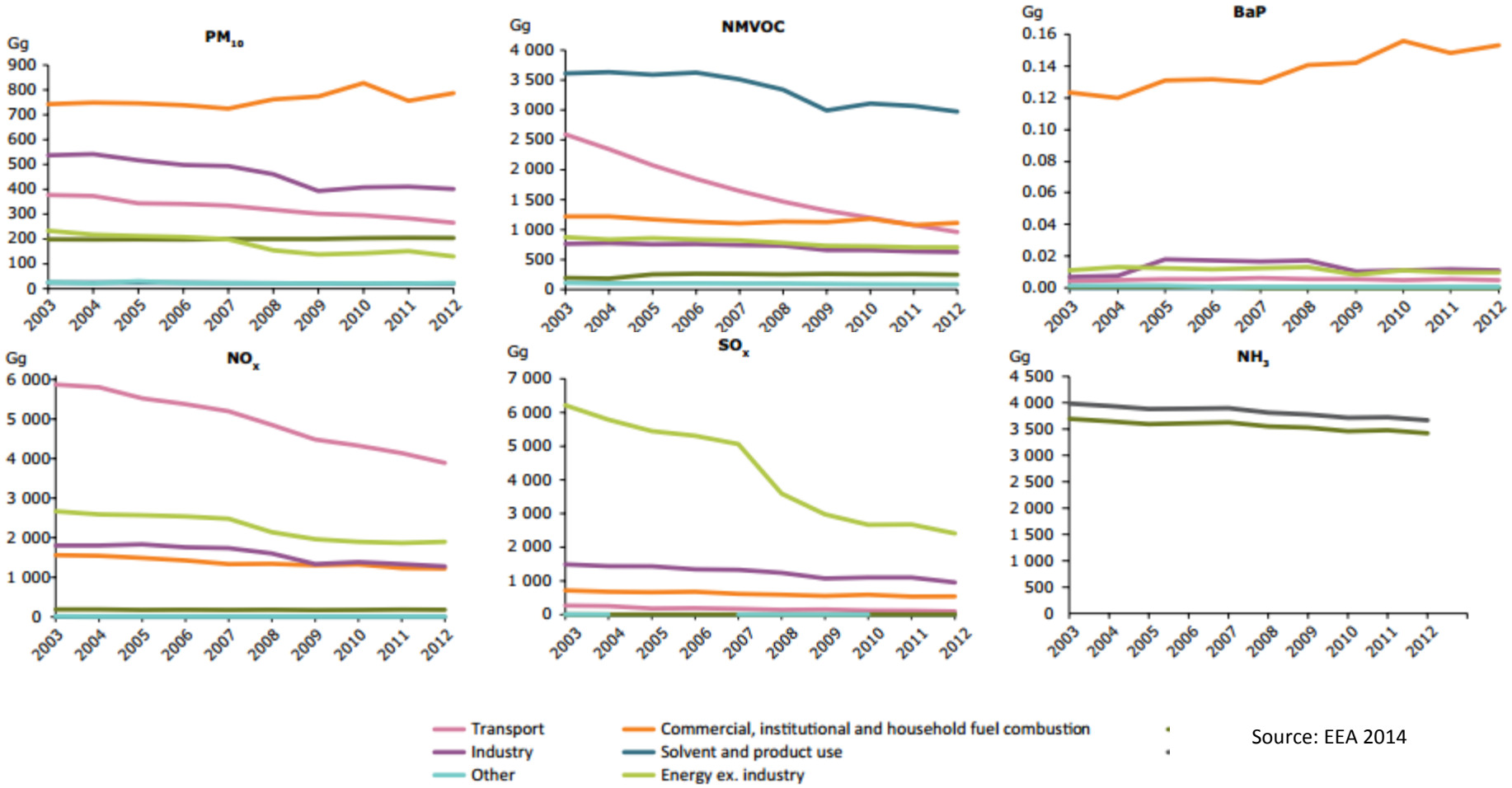
As the WHO has not set AQG for BaP, the reference level in the table was estimated assuming WHO unit risk for lung cancer for PAH mixtures, and an acceptable risk of additional lifetime cancer risk of approximately 1 x 10^{-5} (ETC/ACM, 2011).

Source: Based on EEA, 2015d.

Source: EEA 2015

2. High population exposure

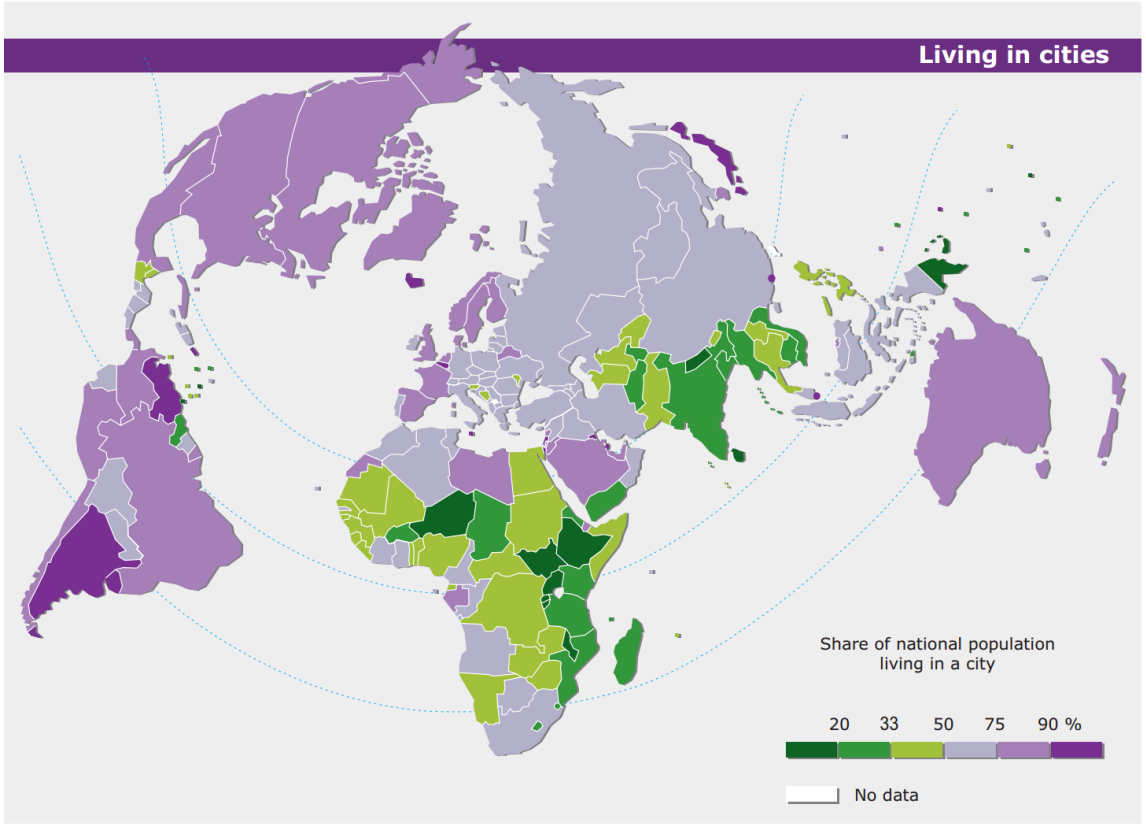
- Urban air quality issues remain even in areas where significant emission reductions have been achieved (e.g. EU-28 emissions in the last decade):



Source: EEA 2014

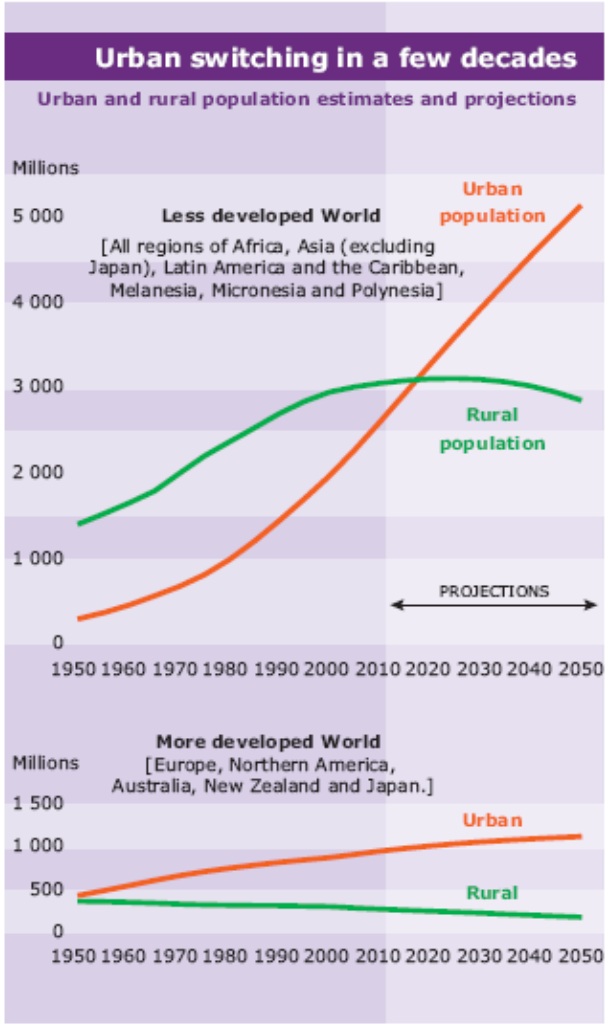
- This is and will be very relevant due to urban population growth

Figure 2.2 National urbanisation levels in 2010



Source: UN Population Division, World Urbanization Prospects (2011 revision).

Urban population in 2010, Source: EEA, 2014



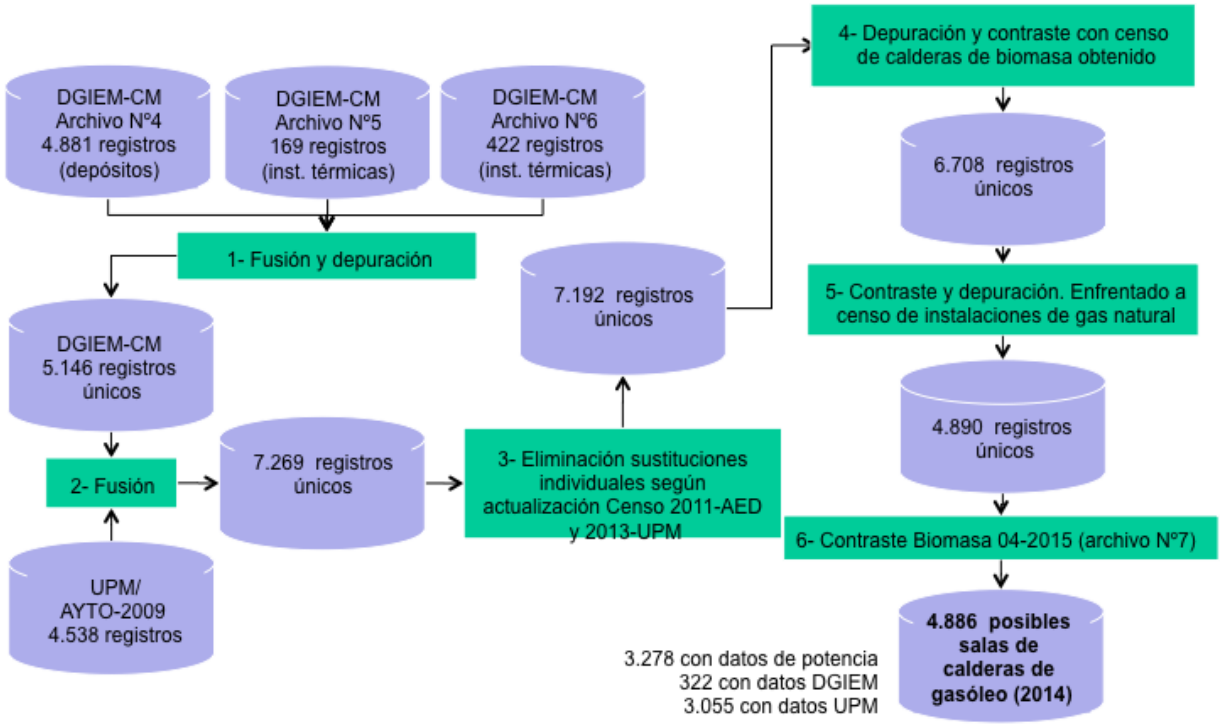
•Urban emission and dispersion is particularly complex:

- Built areas generate their own meteorological conditions with a clear impact on pollutant dispersion

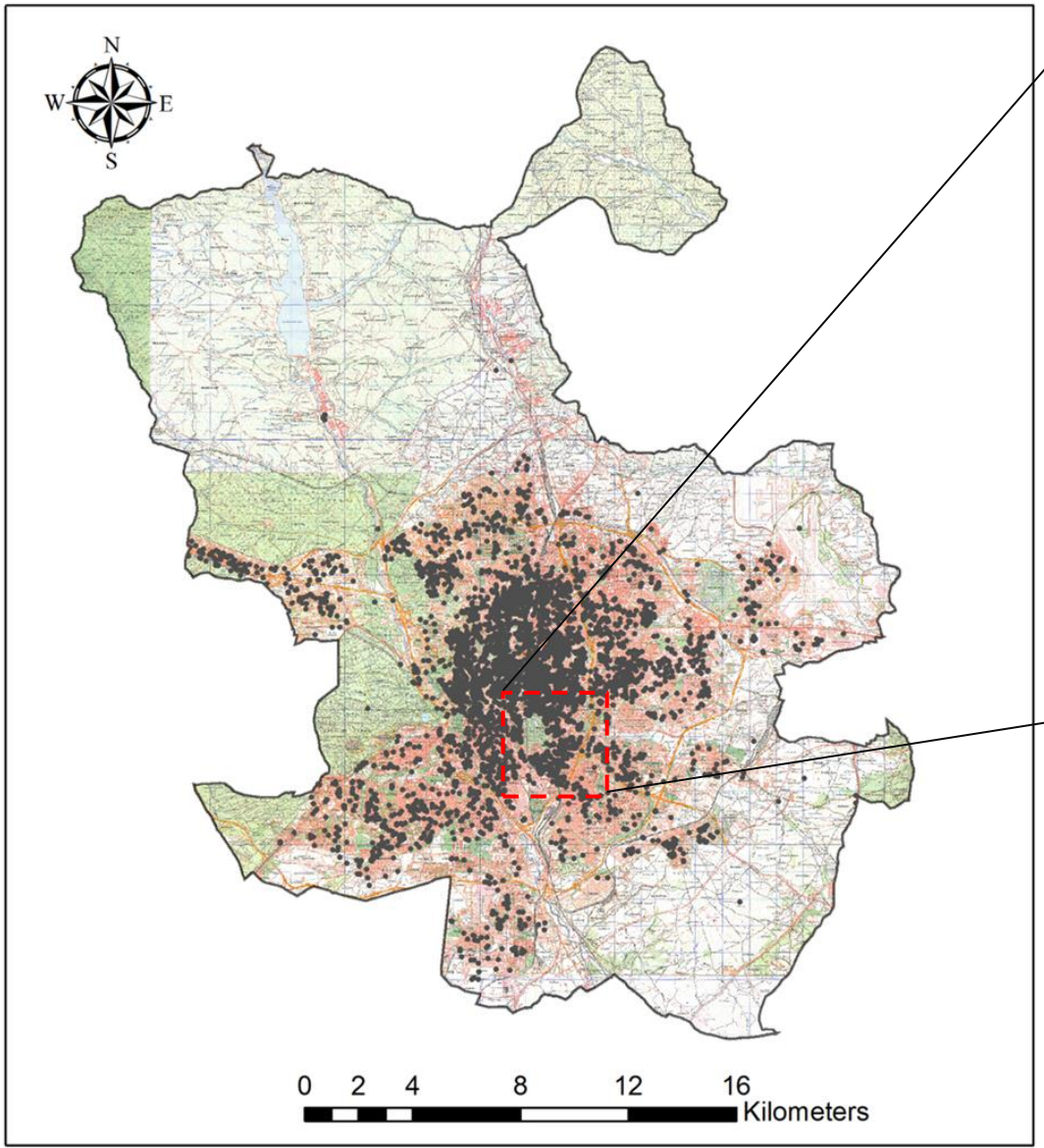
Parameter	Air Quality	Urban Climatology	Urban Planning
Wind speed	Very important	Important	Very Important
Wind Direction	Very important	Important	Very Important
Temperature Humidity	Important	Extremely important	Very Important
Pollutant Concentration	Extremely important	Very important	Very important
Turbulent Fluxes	Very important	Very important	Very important

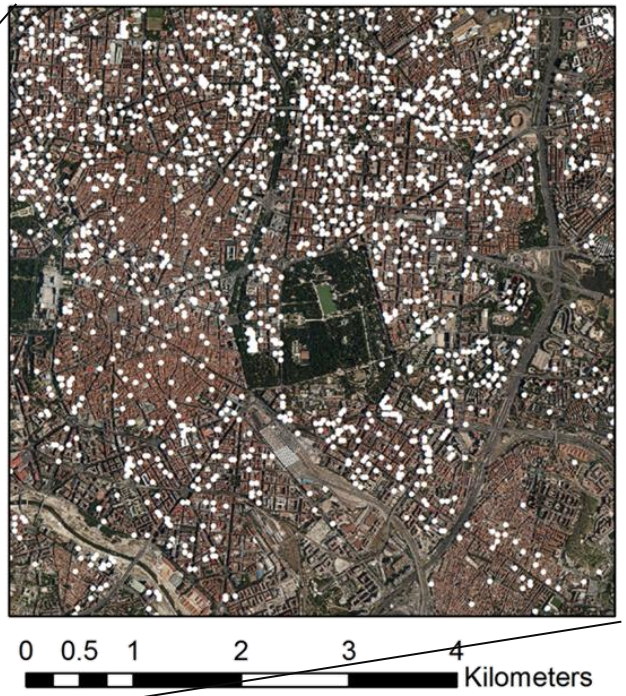
Source: Srivastava and Rao, 2011

2.- Domestic heating inventory

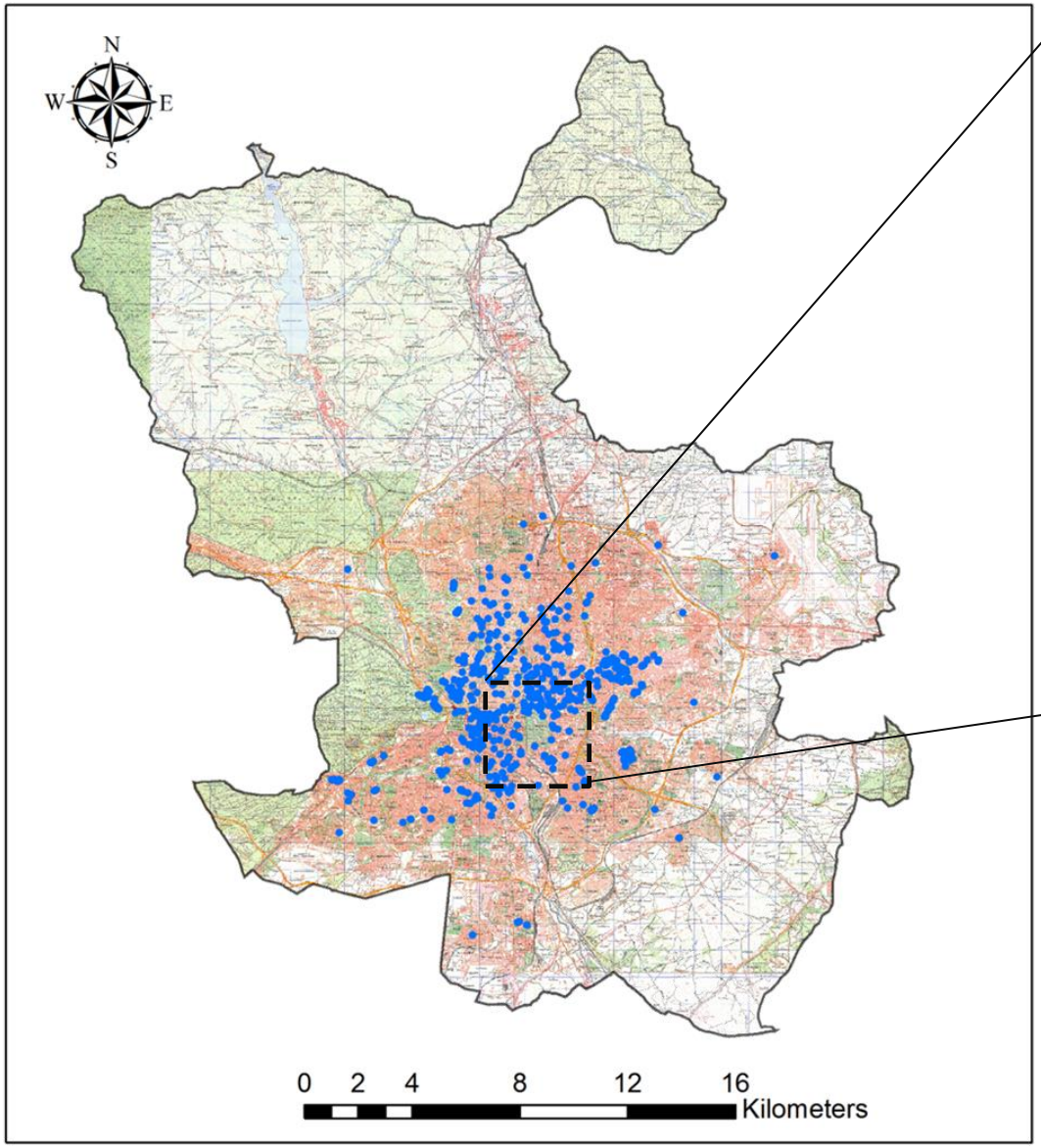


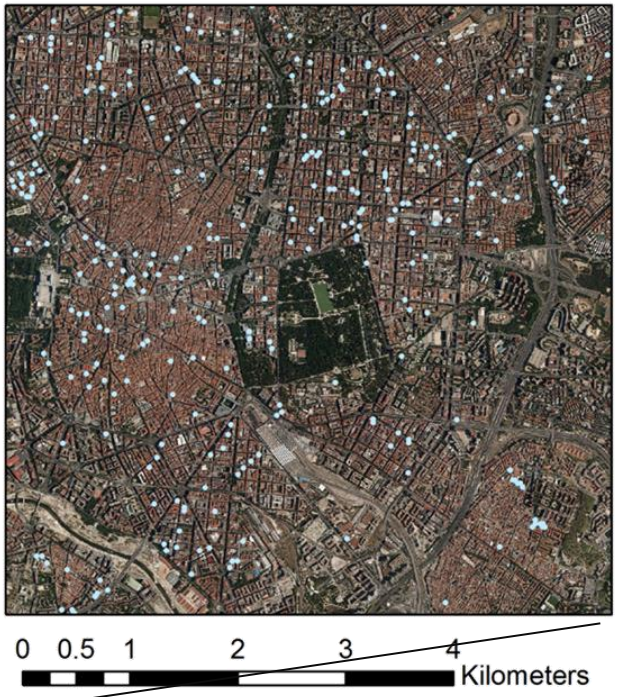
Fuel	Number of facilities	Number of facilities with specific data associated
Biomass	178	109
Coal	656	389
Diesel	4,886	3,278



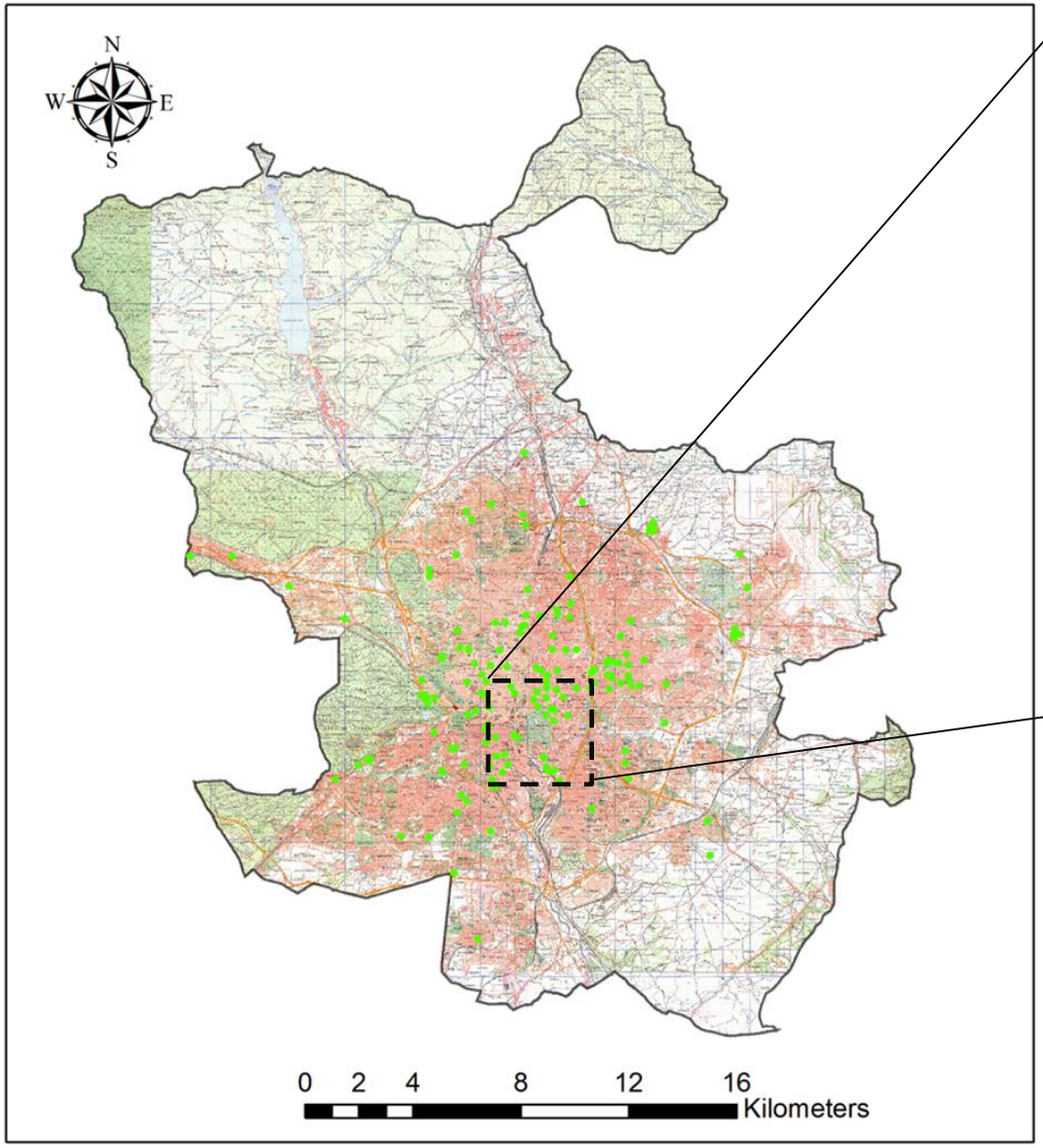


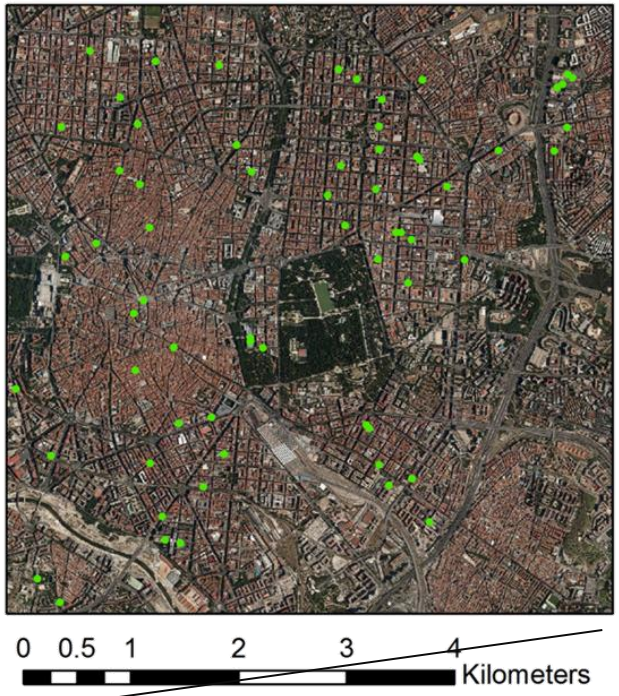
Diesel boilers





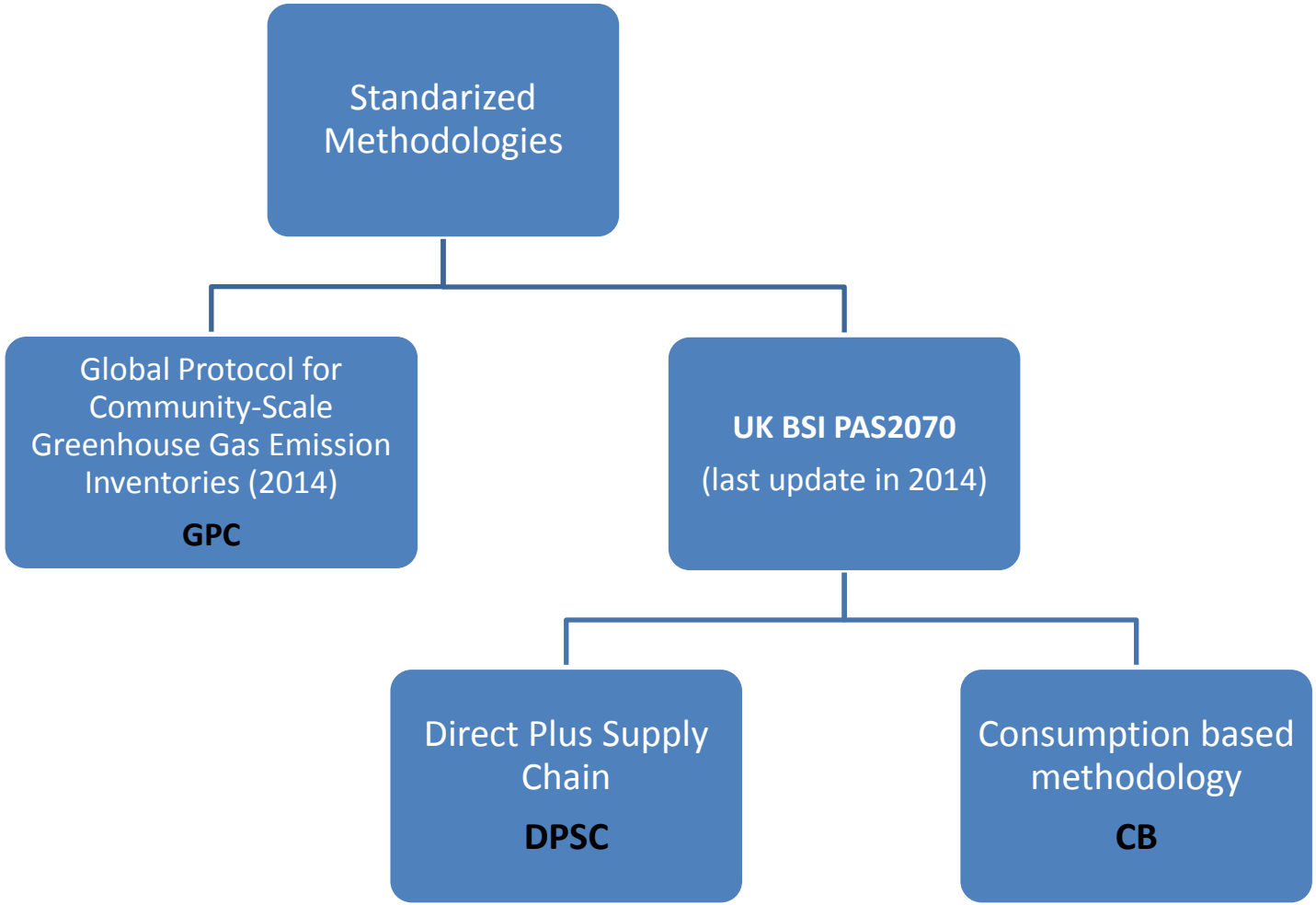
Coal boilers

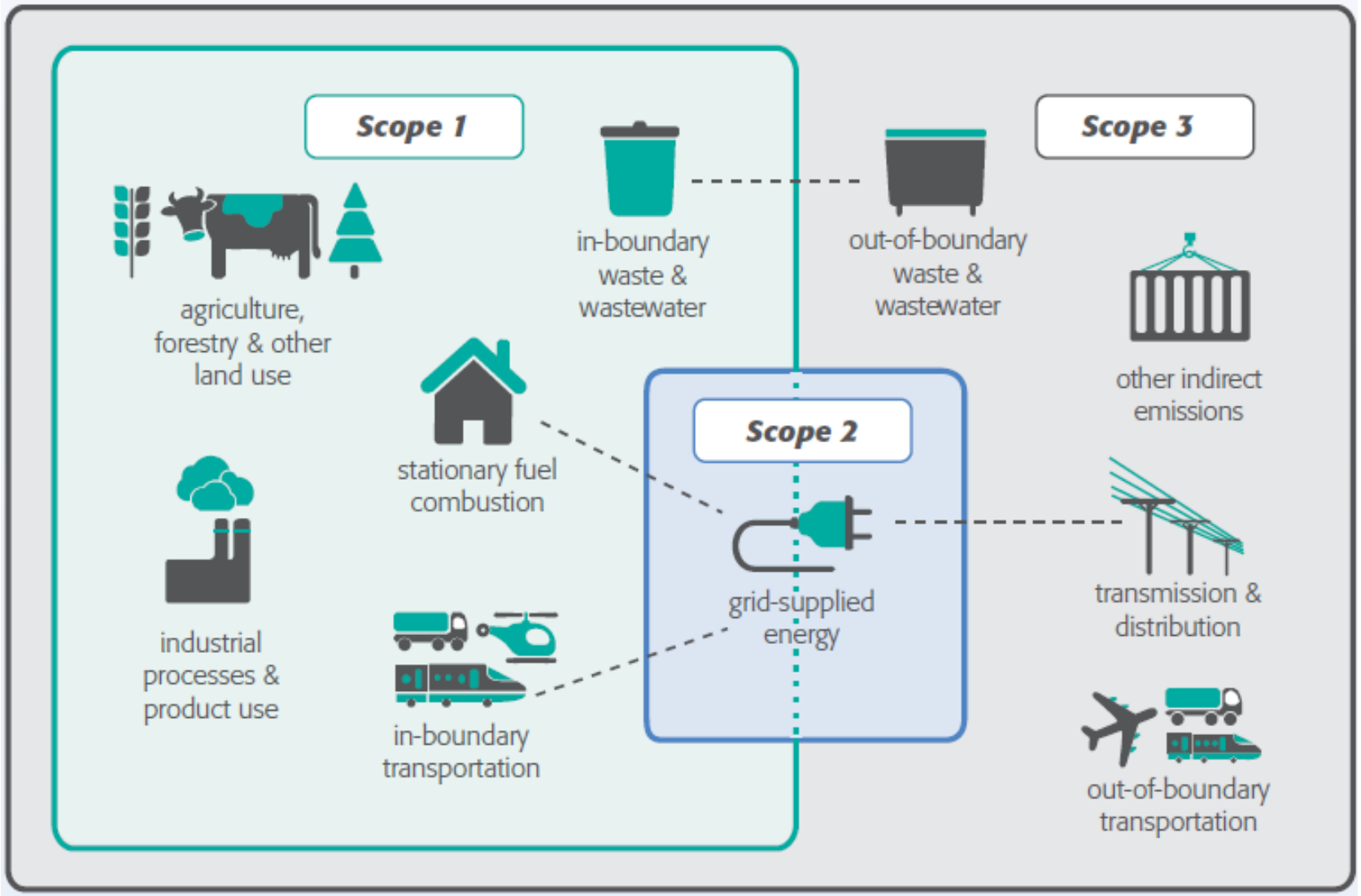




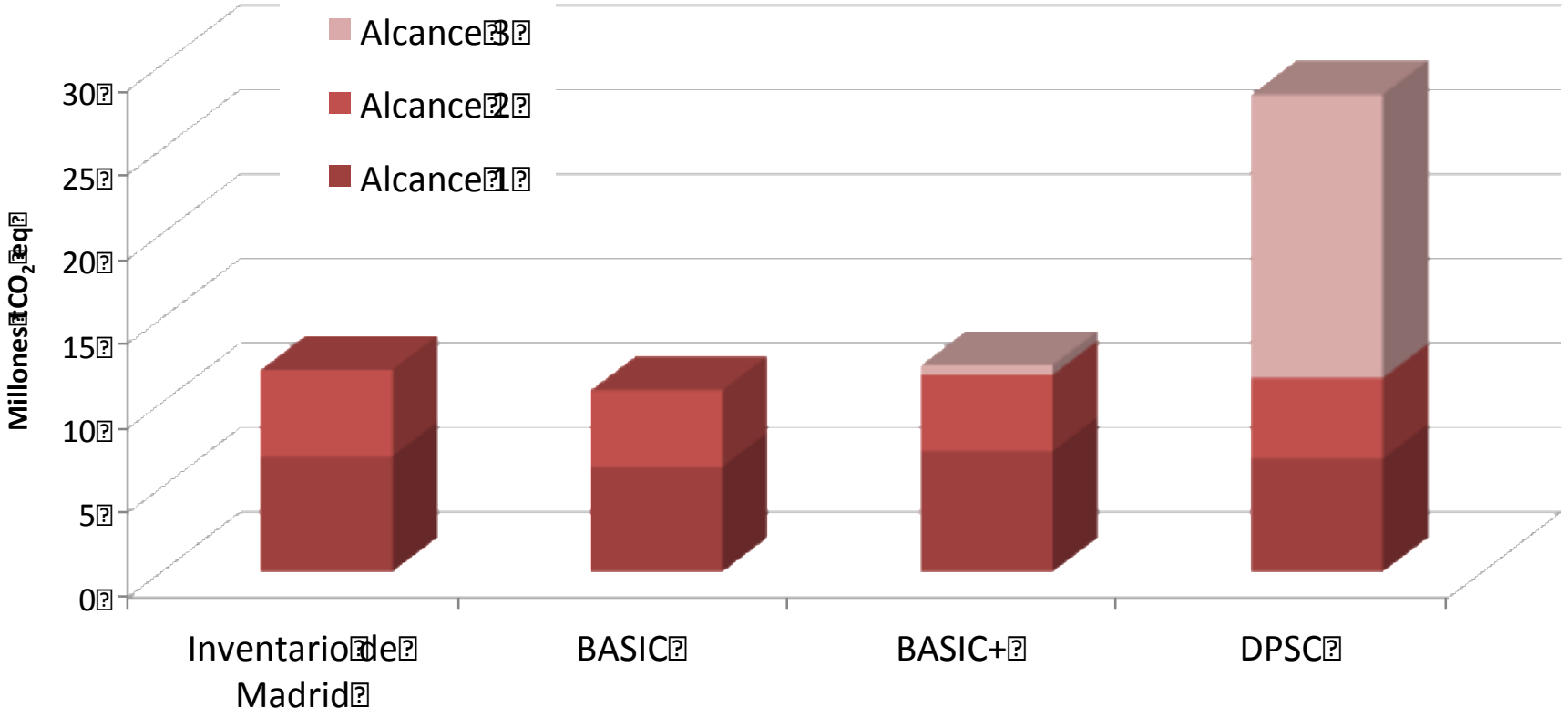
Biomass boilers

3.- Indirect emissions

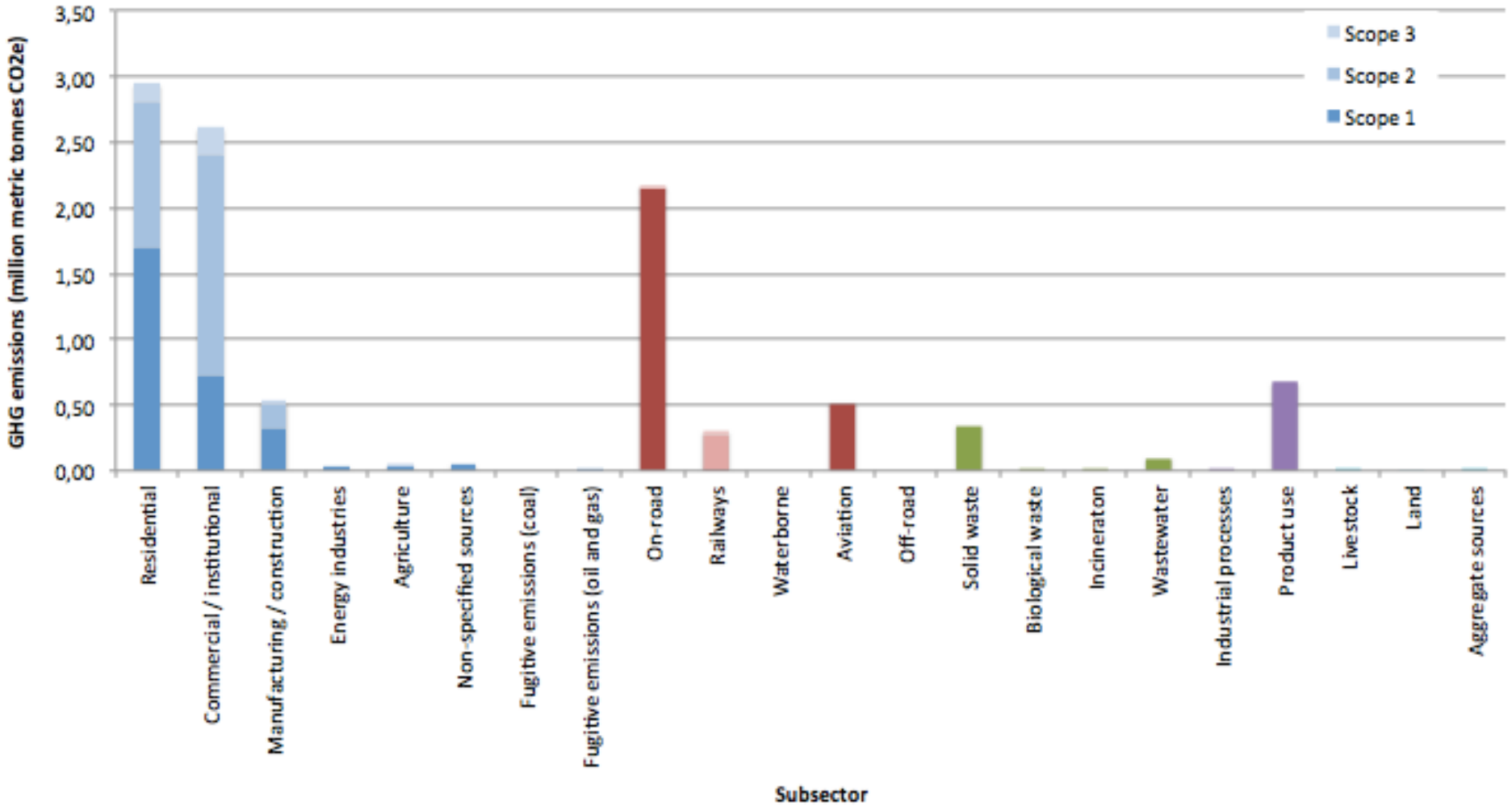


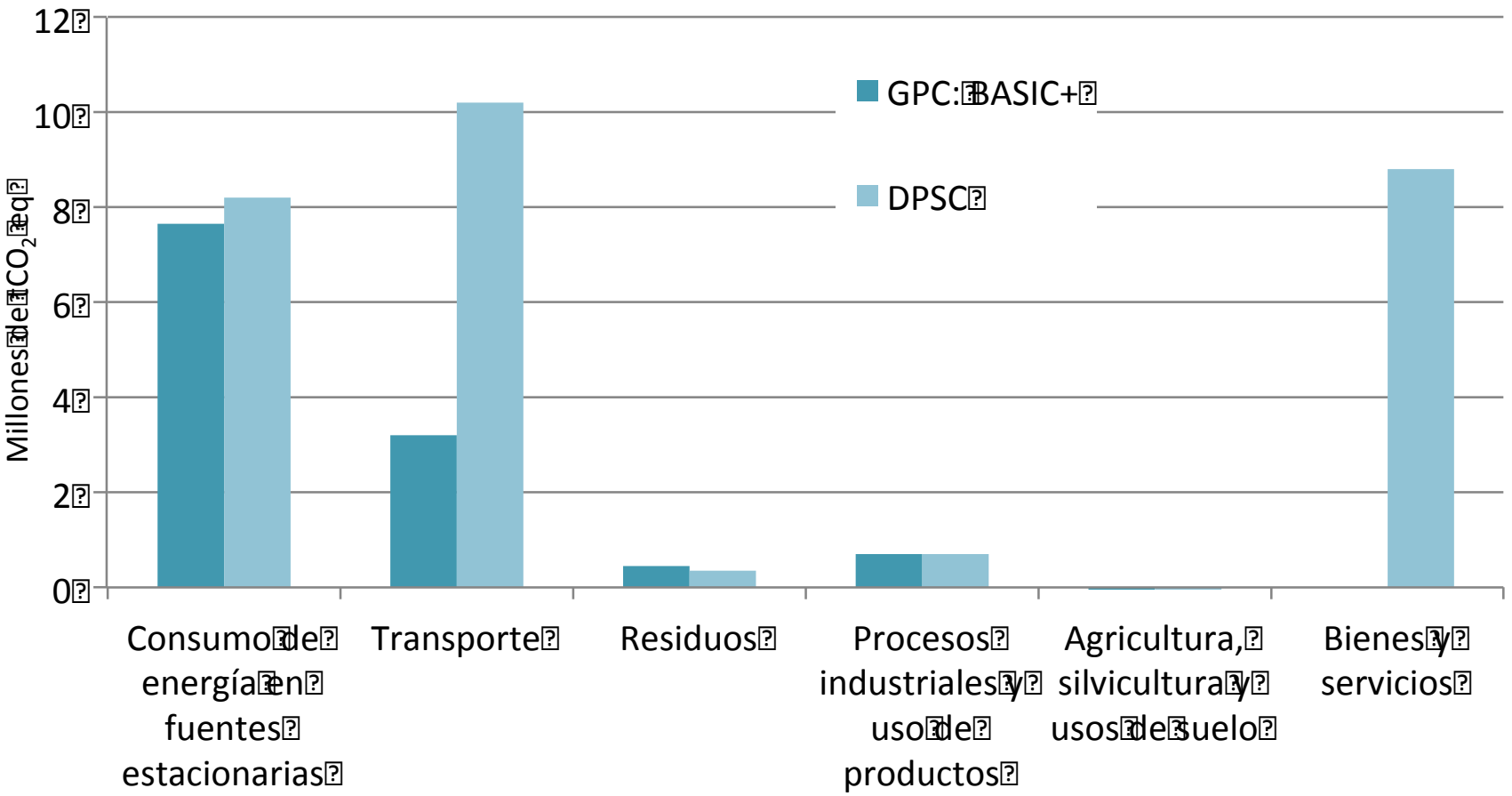

Scope 1
Scope 2
Scope 3
agriculture, forestry & other land use
in-boundary waste & wastewater
out-of-boundary waste & wastewater
other indirect emissions
stationary fuel combustion
grid-supplied energy
transmission & distribution
industrial processes & product use
in-boundary transportation
out-of-boundary transportation

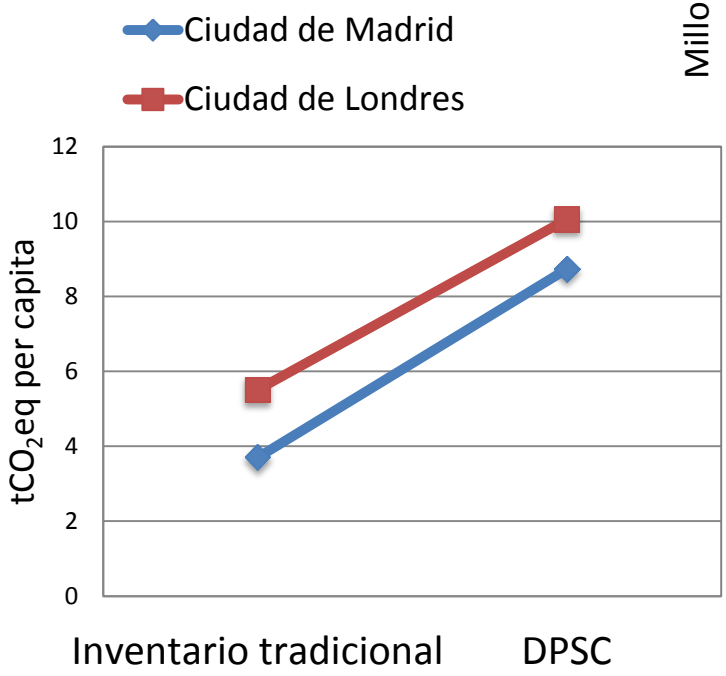
Madrid Emission Inventory ($ktCO_2eq$)	GPC: BASIC ($ktCO_2eq$)	GPC: BASIC+ ($ktCO_2eq$)	PAS2070: DPSC ($ktCO_2eq$)
11.980	10.773	11.998	28.266

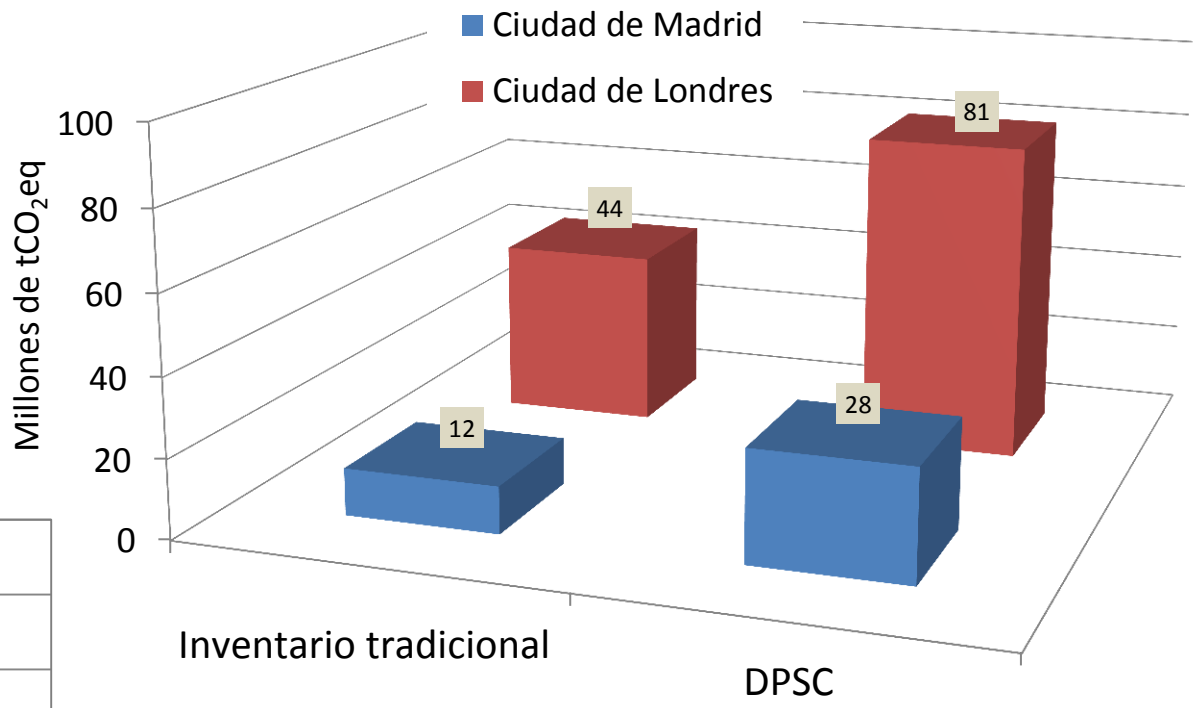


BASIC/BASIC+ by subsector and scope

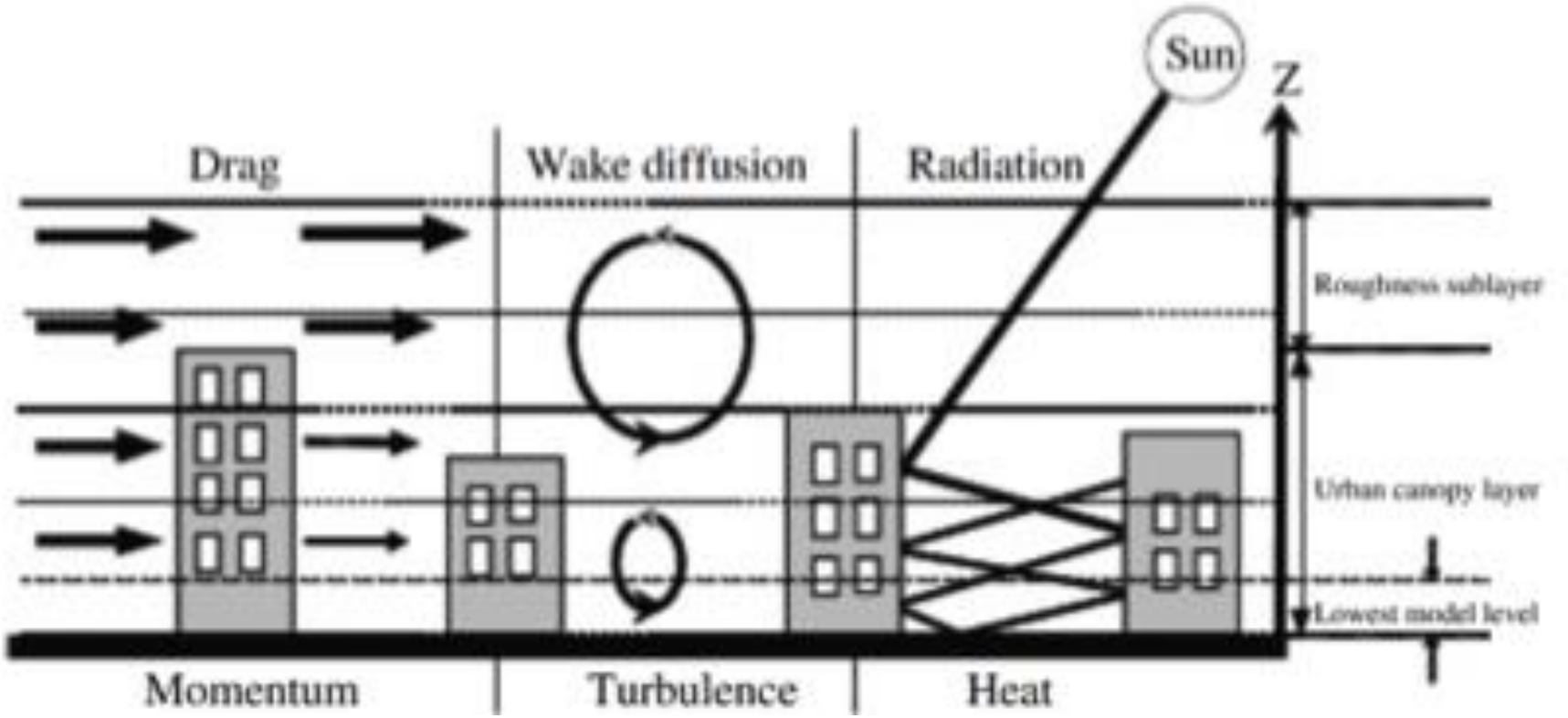



12
10
8
6
4
2
0
Millones de t CO_2 eq
GPC: BASIC+
DPSC
Consumo de energía en fuentes estacionarias
Transporte
Residuos
Procesos industriales y uso de productos
Agricultura, silvicultura y usos de suelo
Bienes y servicios


Ciudad de Madrid
Ciudad de Londres
12
10
8
6
4
2
0
tCO2eq per capita
Inventario tradicional
DPSC


Ciudad de Madrid
Ciudad de Londres
100
80
60
40
20
0
Millones de tCO2eq
44
81
12
28
Inventario tradicional
DPSC

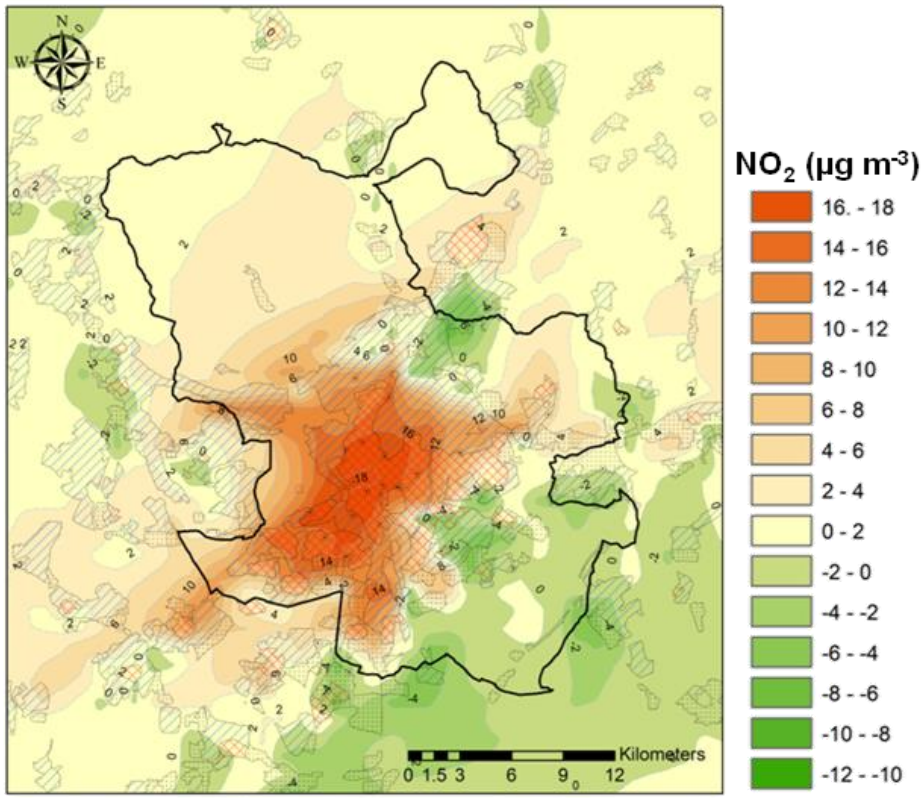
4.- Mesoscale parameterization for urban areas

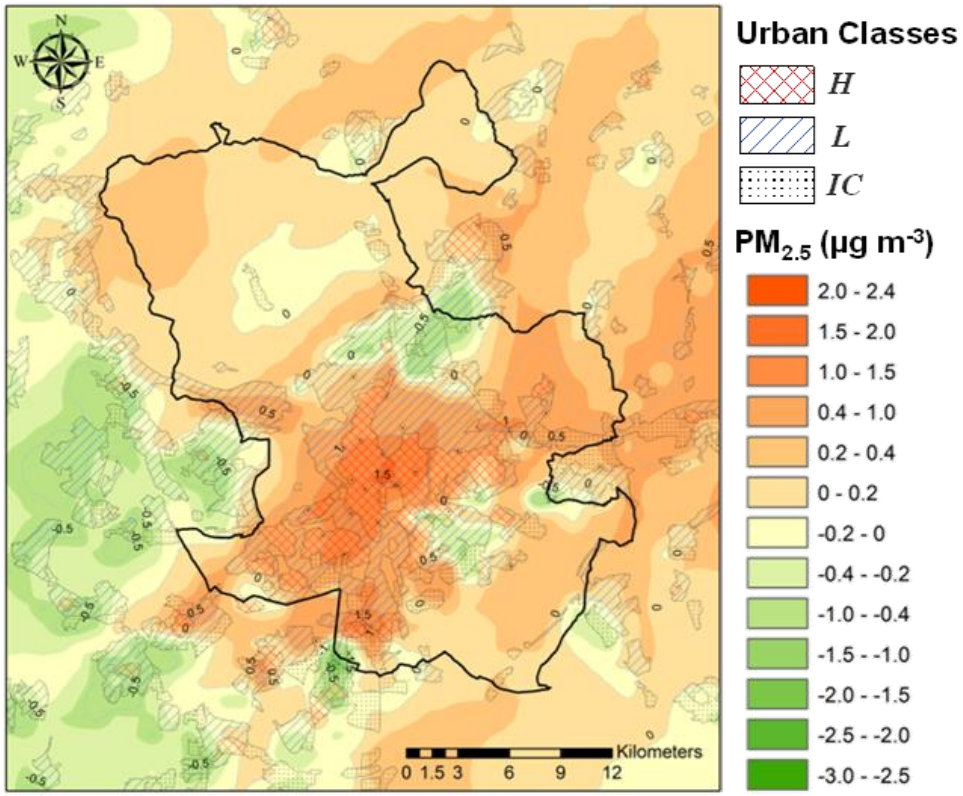


Source: Chen et al., 2010

- Temperature
- Wind speed
- Wind direction

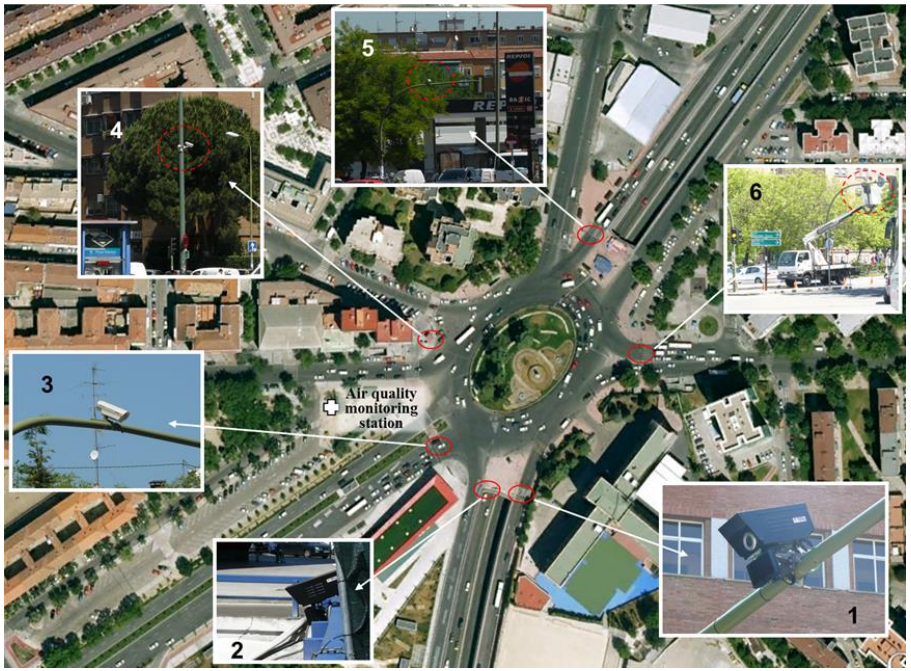
Annual mean


N
W
E
S
Kilometers
0 1.5 3 6 9 12
NO2 (µg m-3)
16. - 18
14 - 16
12 - 14
10 - 12
8 - 10
6 - 8
4 - 6
2 - 4
0 - 2
-2 - 0
-4 - -2
-6 - -4
-8 - -6
-10 - -8
-12 - -10


N
W
E
S
Kilometers
0 1.5 3 6 9 12
Urban Classes
H
L
IC
PM2.5 (µg m-3)
2.0 - 2.4
1.5 - 2.0
1.0 - 1.5
0.4 - 1.0
0.2 - 0.4
0 - 0.2
-0.2 - 0
-0.4 - -0.2
-1.0 - -0.4
-1.5 - -1.0
-2.0 - -1.5
-2.5 - -2.0
-3.0 - -2.5

5.- Microscale simulations in Madrid

Measurement campaign

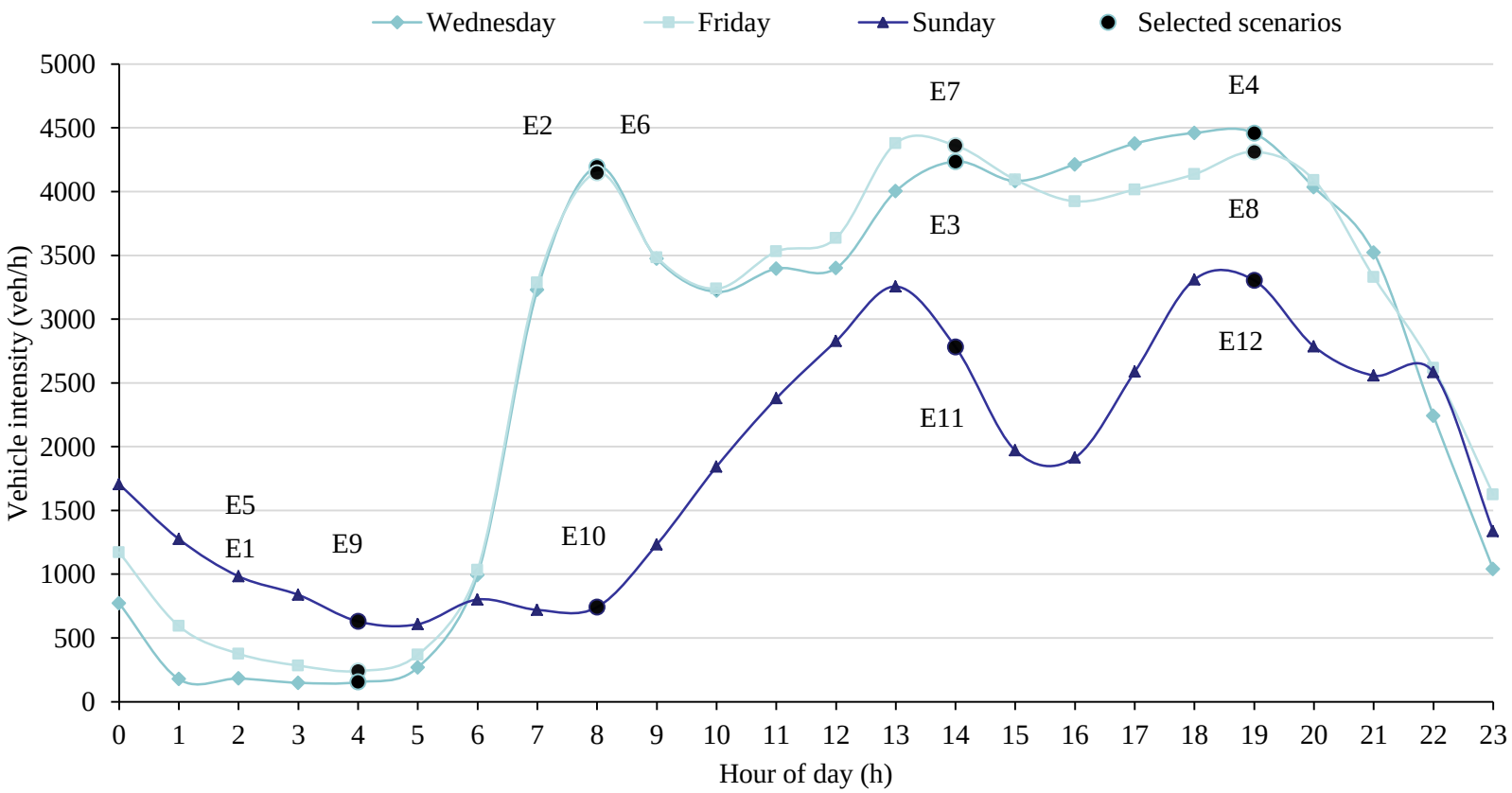


Between May, 23-27th 2013

Recompilation of traffic data was done with **2 fluxes** and **11 movements** cameras to define **fleet composition**, **traffic volume** and vehicle **routes**

Scenarios

- 12 scenarios were selected to perform 1-h length simulations
- Representative of a weekly pattern



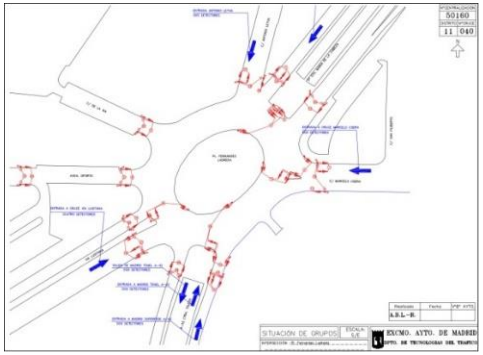
Modelling system: Microscale Traffic simulation model PTV VISSIM

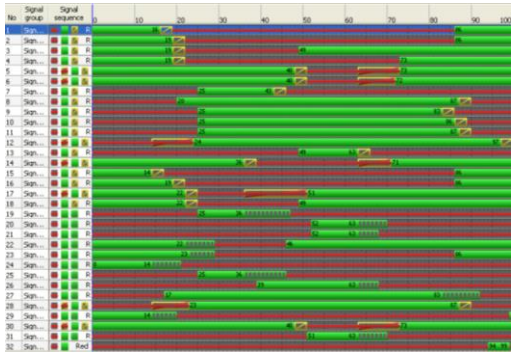
Real world

Scenario simulation

Traffic volumen, composition and routes

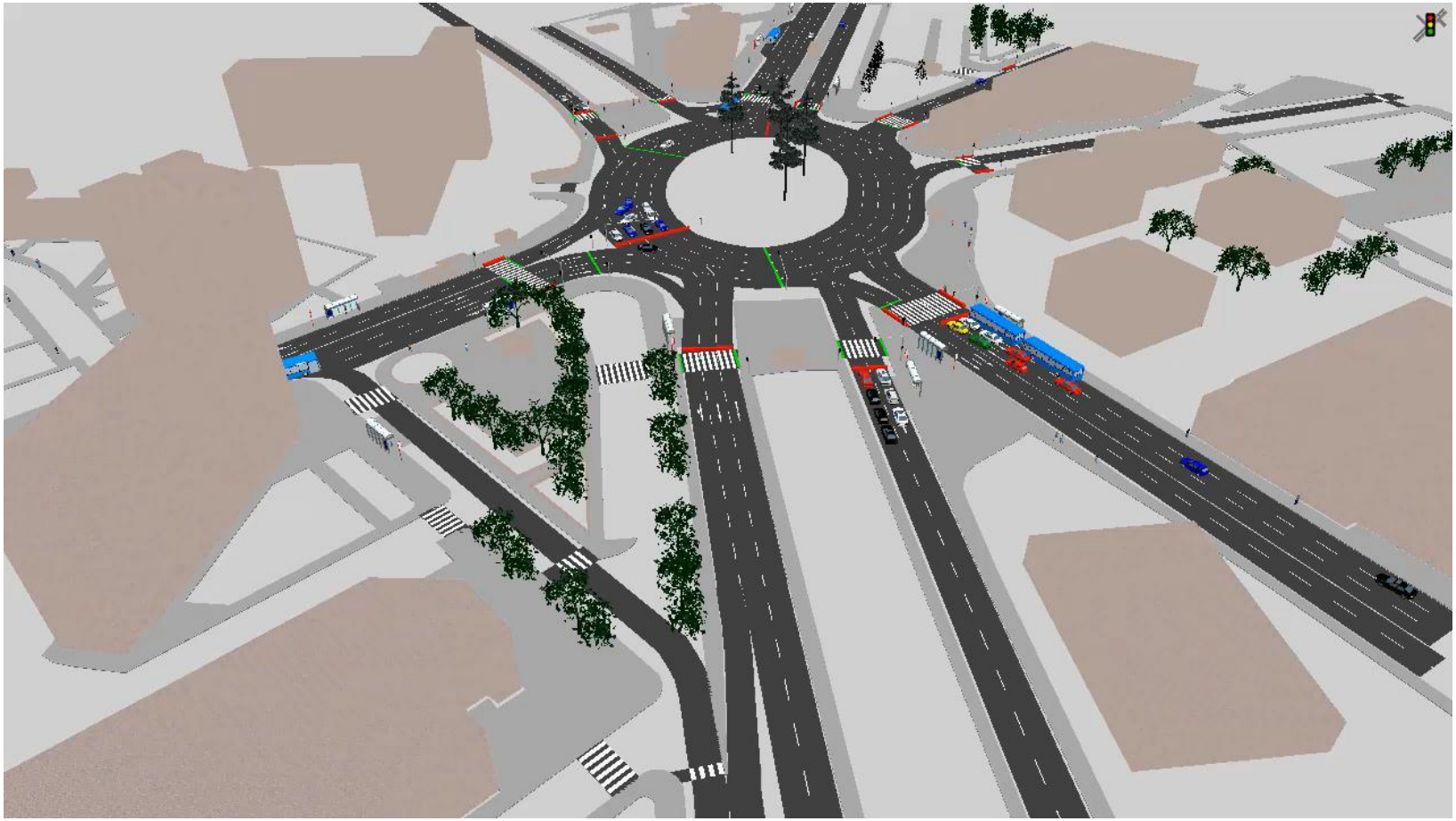
Bus lines and stops



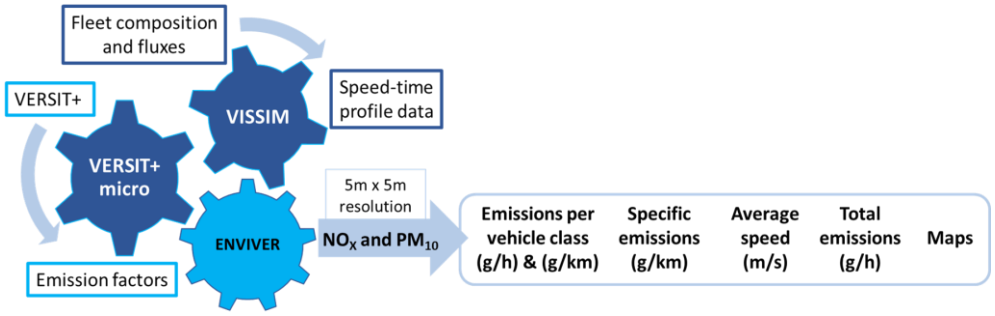


Position of traffic lights and phases

Modelling system: Microscale Traffic simulation model PTV VISSIM



Modelling system: Microscale emissions model VERSIT+micro/ENVIVER



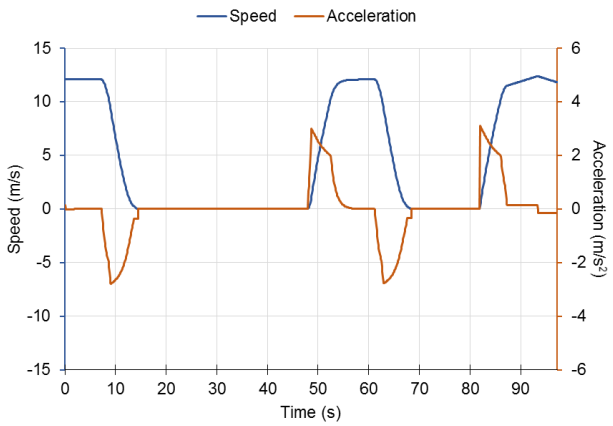
Emission factor · Traffic volume · Section lenght

$$TE_j = \sum_{k,m} \left(E^F_{j,k,l} \cdot TV_{k,m} \cdot L_m \right)$$

Emissions

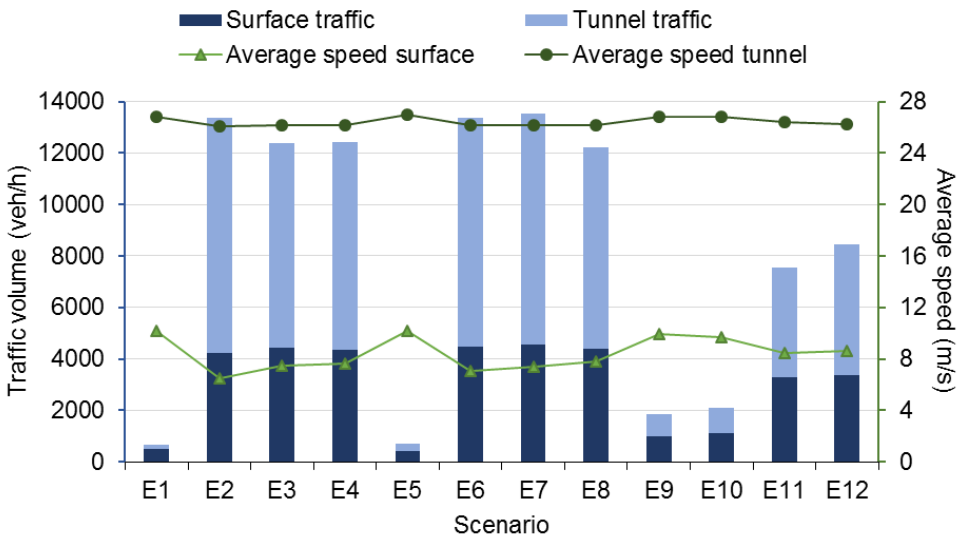
pollutant · Vehicle class · Speed-time profile · Road section

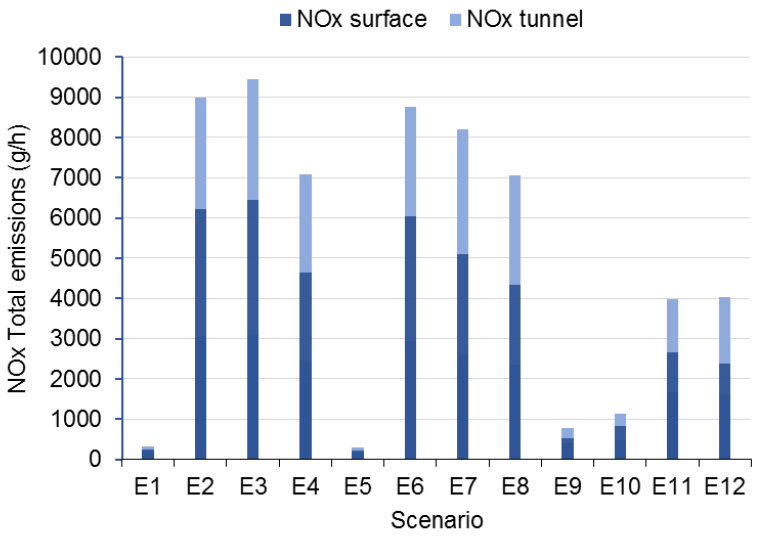
Area	Road type	VISSIM customized classes	VERSIT+ customized vehicle class name
Surface	Urban	Car	Urban_Car_2013_FL
		Taxi	
		Truck	Urban_HGV_2013_FL
		Bus	Urban_Bus_2013_FL
		Motorcycle	Not assigned
Tunnel	Highway	Car_tunnel	Highway_Car_2013_FL
		Truck_tunnel	Highway_HGV_2013_FL
		Bus_tunnel	Highway_Bus_2013_FL
		Motorcycle_tunnel	Not assigned



Total emission results

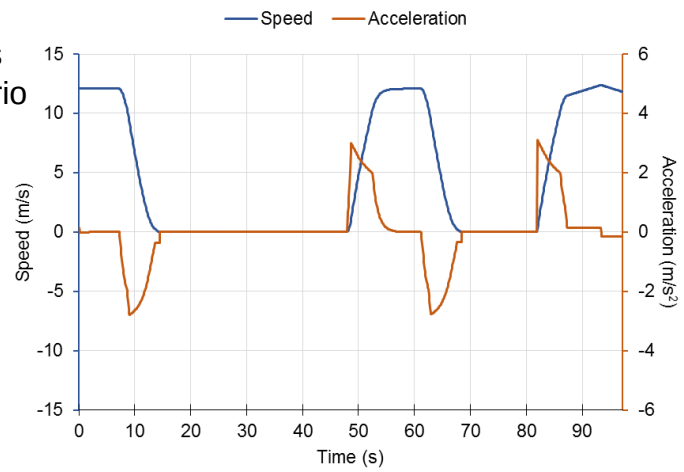
- NO_X hourly emissions in the square range from 100 to more than 9000 grams
- Maximum traffic intensity and emissions do not correspond because of congestion and total traveled distance





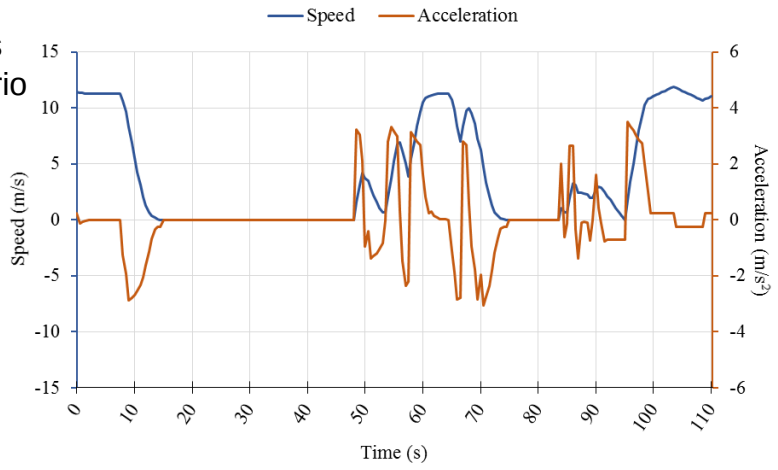
Emission factors and congestion

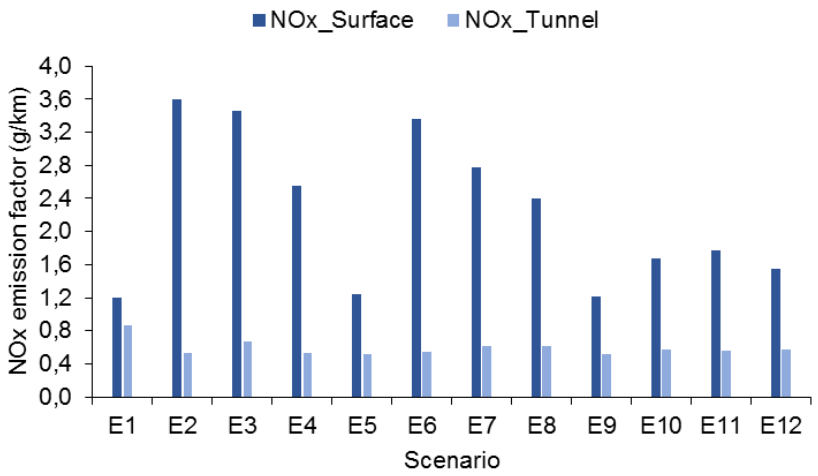
Free flow conditions E1 scenario



- Emission factors presents huge differences due to congestion, up to 65% for NO_X

Saturated conditions E2 scenario





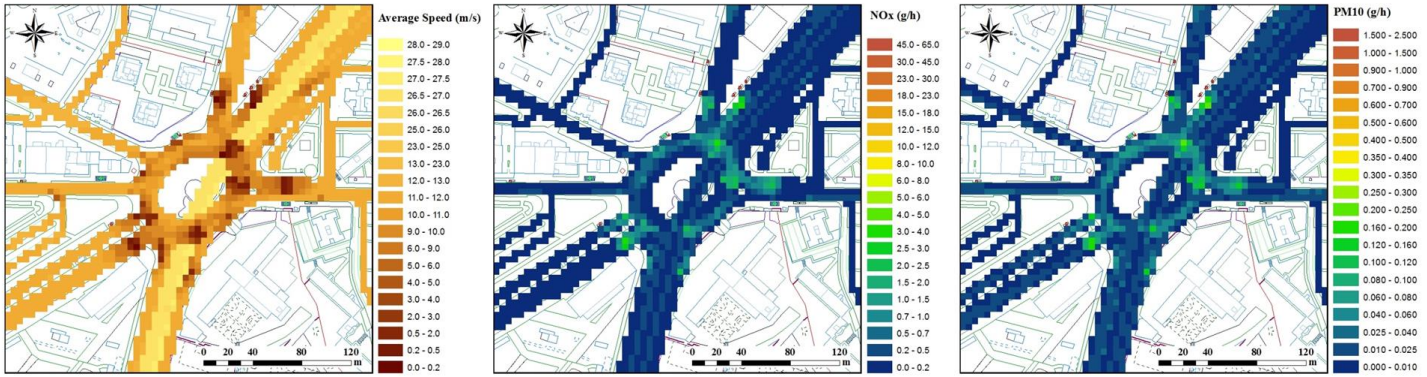
Spatial distribution of emissions

Free flow conditions

E1 scenario
Average speed surface: 5.58 m/s (20.1 km/h)
Average speed tunnel: 27.01 m/s (97.2 km/h)

NO_x: 248.50 g/h surface
84.45 g/h tunnel
1.20 g/km surface
0.87 g/km tunnel

PM_{10}: 18.47 g/h surface
5.47 g/h tunnel
0.09 g/km surface
0.06 g/km tunnel

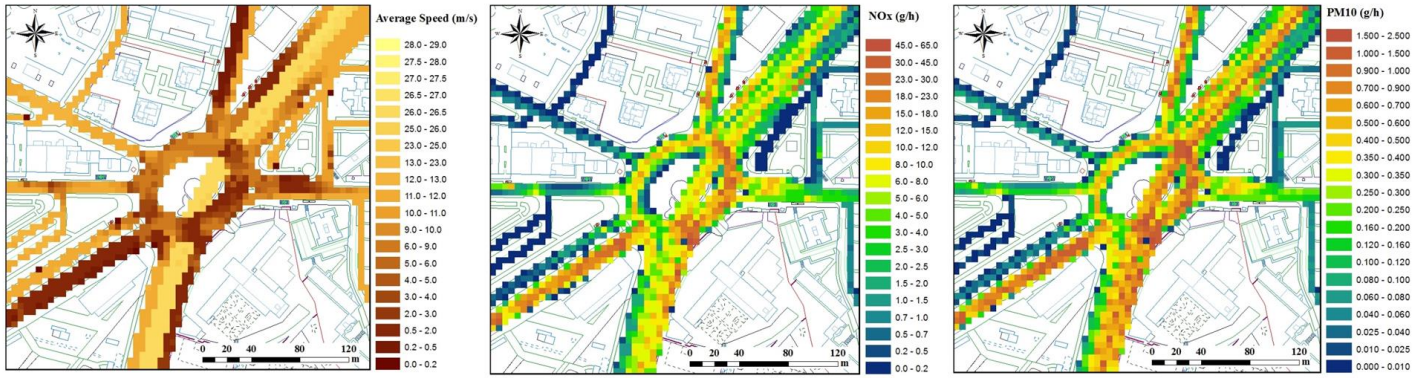


Saturated flow conditions

E3 scenario
Average speed surface: 5.02 m/s (18.1 km/h)
Average speed tunnel: 26.17 m/s (94,2 km/h)

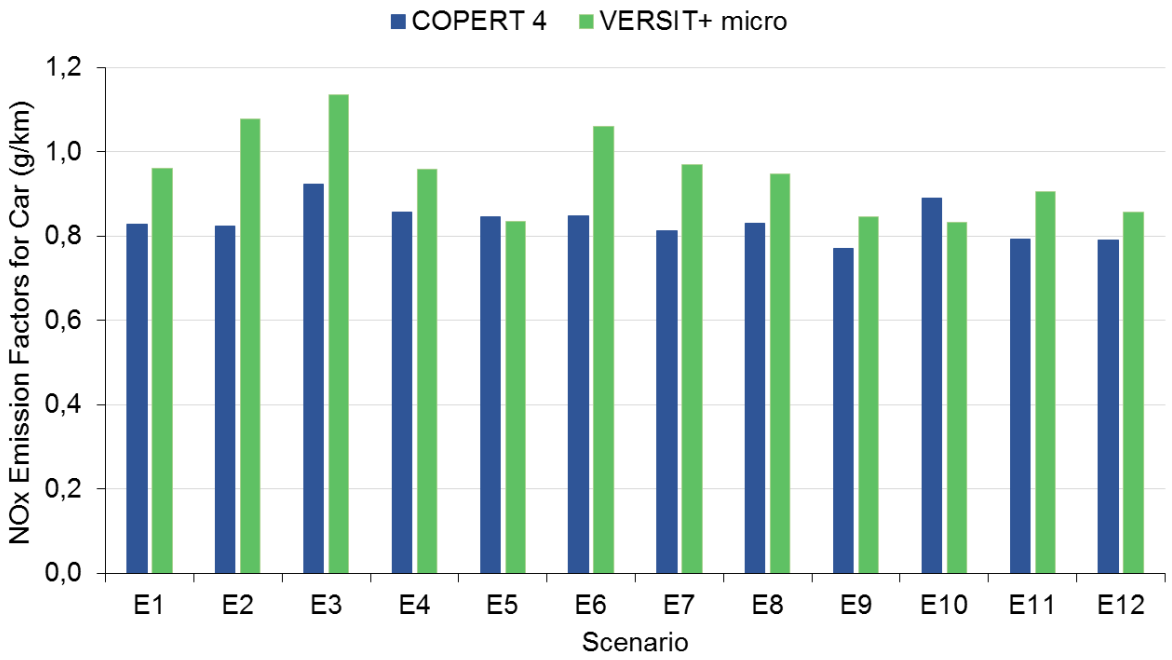
NO_x: 6444.00 g/h surface
3015.00 g/h tunnel
3.47 g/km surface
0.66 g/km tunnel

PM_{10}: 309.60 g/h surface
232.50 g/h tunnel
0.17 g/km surface
0.05 g/km tunnel



Comparison with COPERT 4

- Emission factors as a function of speed have been estimated



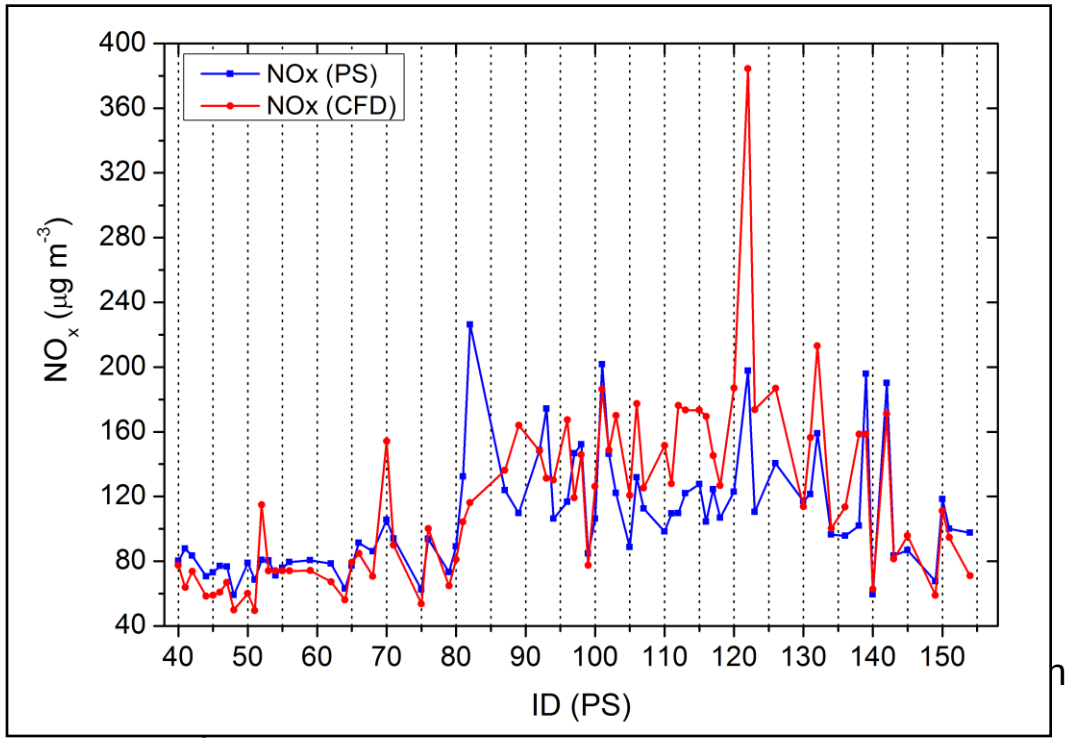
- Mean normalized bias error = 14% (taking COPERT as a reference)
- Deviations of VERSIT+ at scenario level range between -6% and 31%

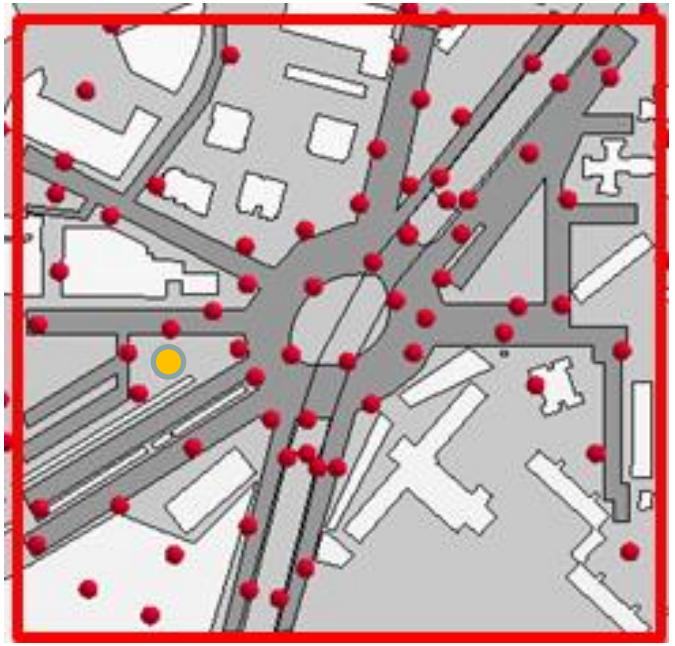
CFD modelling and comparison with passive samplers

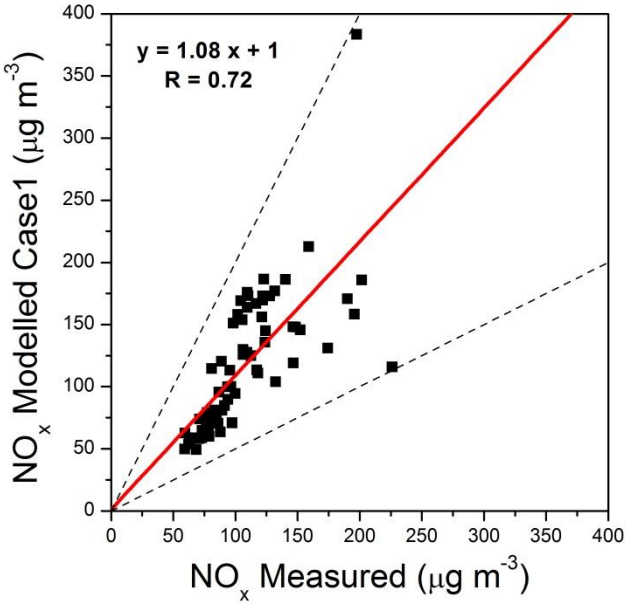
- Zoom 300 m x 300 m → 72 passive samplers
- Passive samplers: NO_2 averaged concentration over 444 h at 3 m. NO_2 is transformed into NO_x using the time average of the ratio at AQ station

$$[NO_x] = [NO_x] / [NO_2])_A$$

- NO_x averaged concentration over 444 h is modelled.



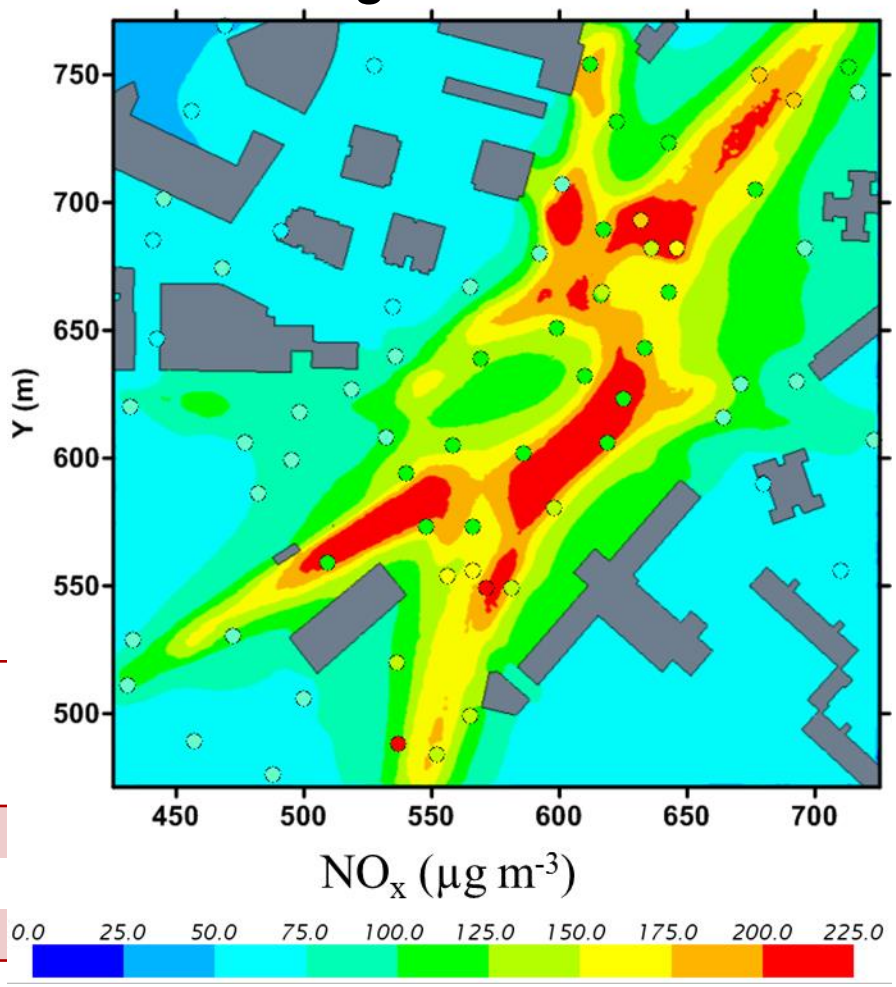




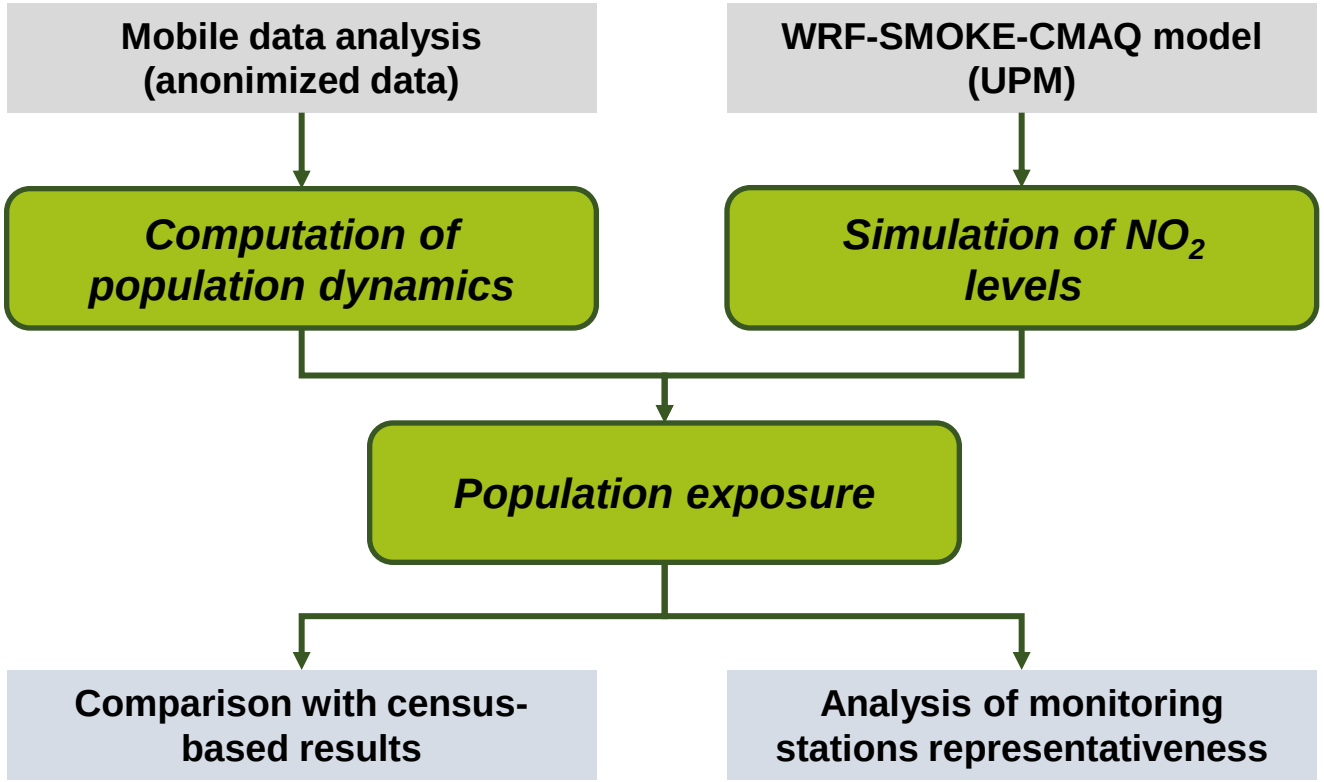
- Slight overestimation

	$C_{mod}/[u_*]$	Acceptance Criteria (Goricsan et al., 2011 and Chang et al., 2005)	
NMSE	0.11	<1.5	Good
FB	-0.09	-0.3 <0 <0.3	Good
R	0.72	0.5<R<0.8	Fair

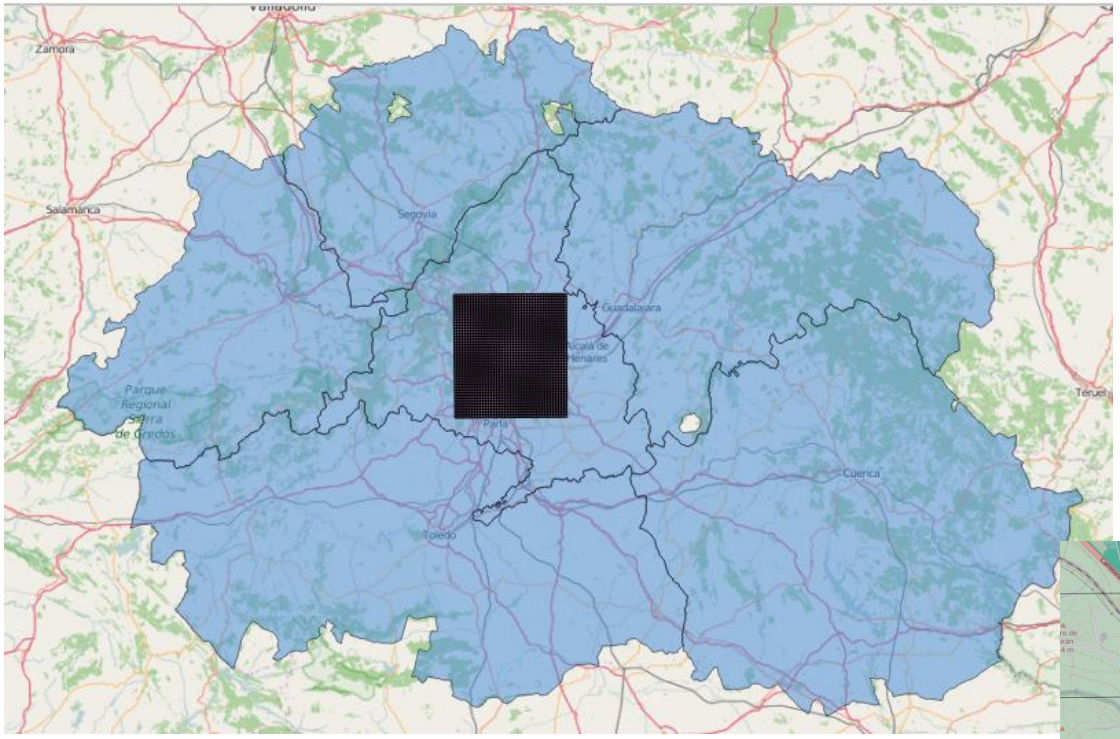
NOx average concentration at 3m

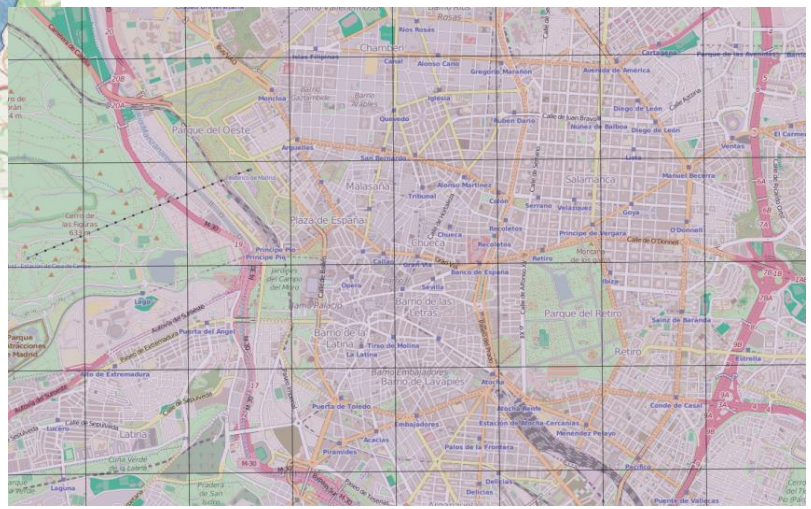


6.- Population exposure through mobile data

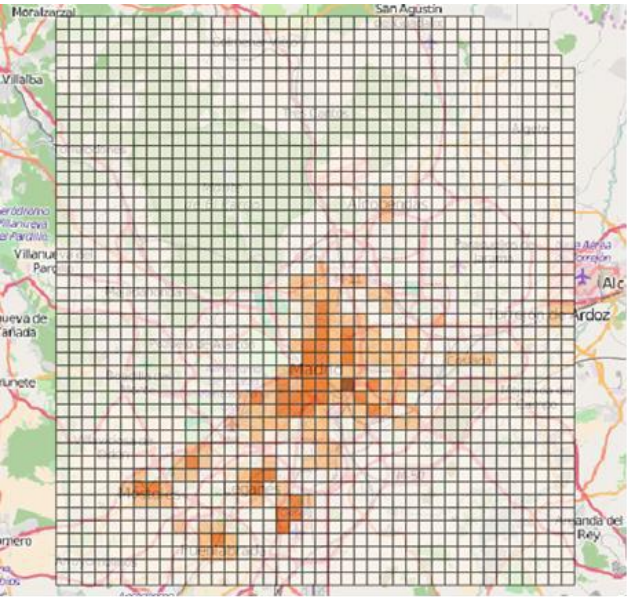


Area of the study

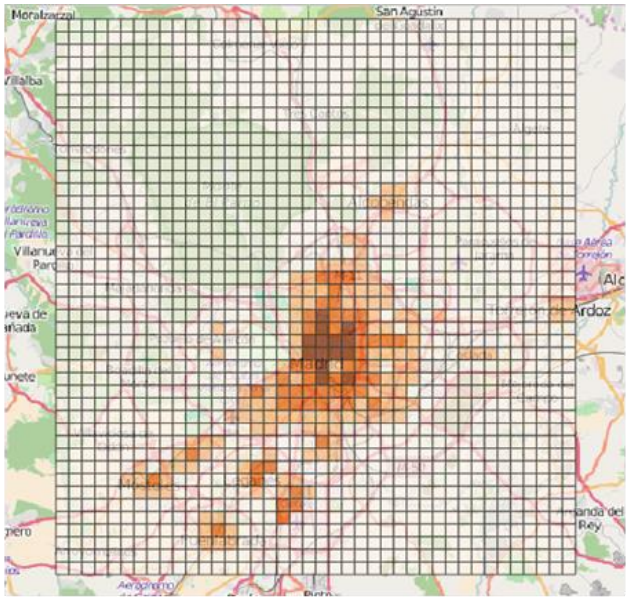




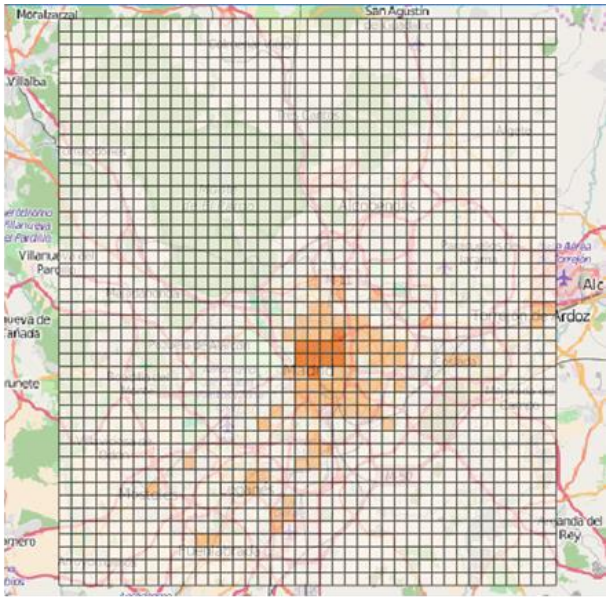
Exposure indicator at different periods of time



04:00

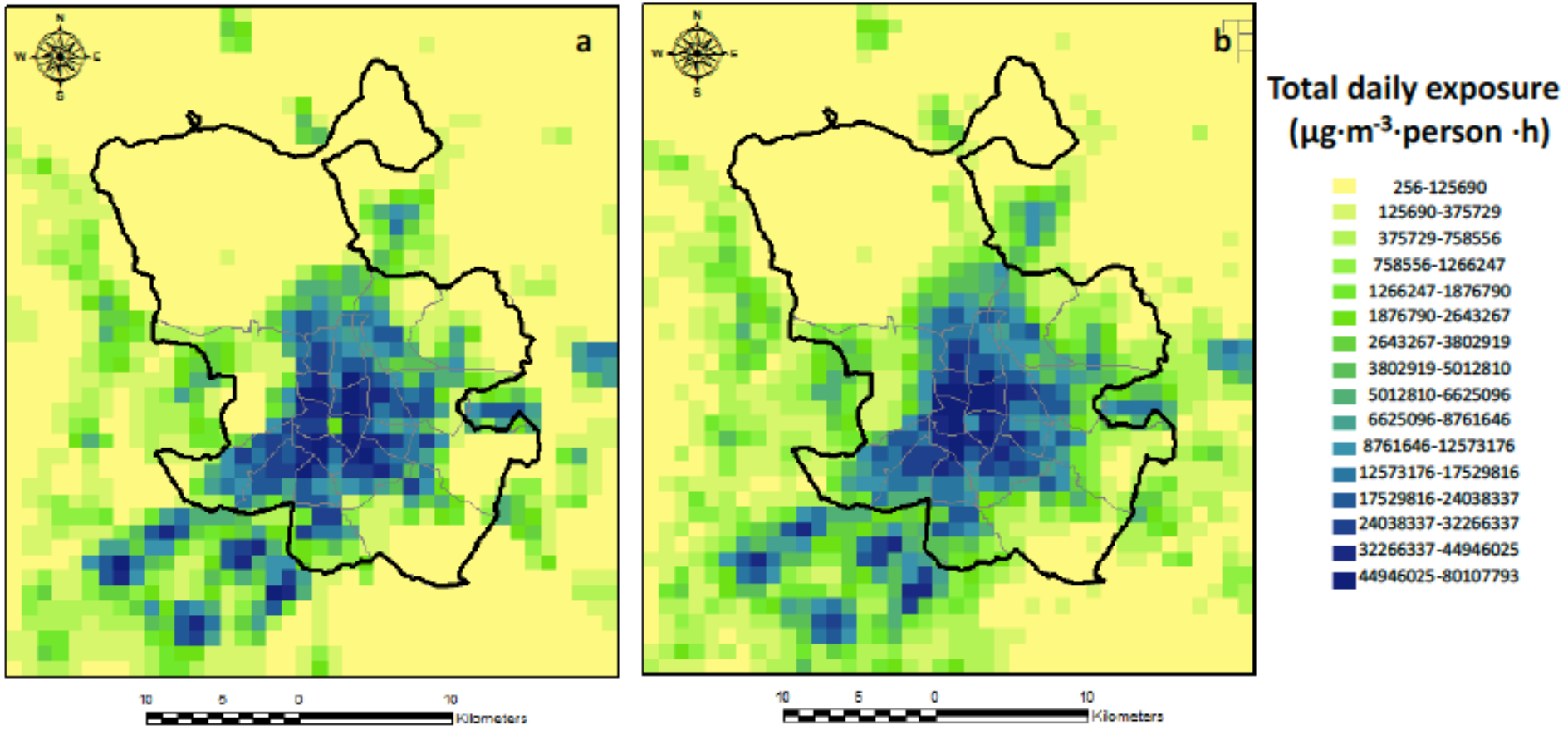


09:00

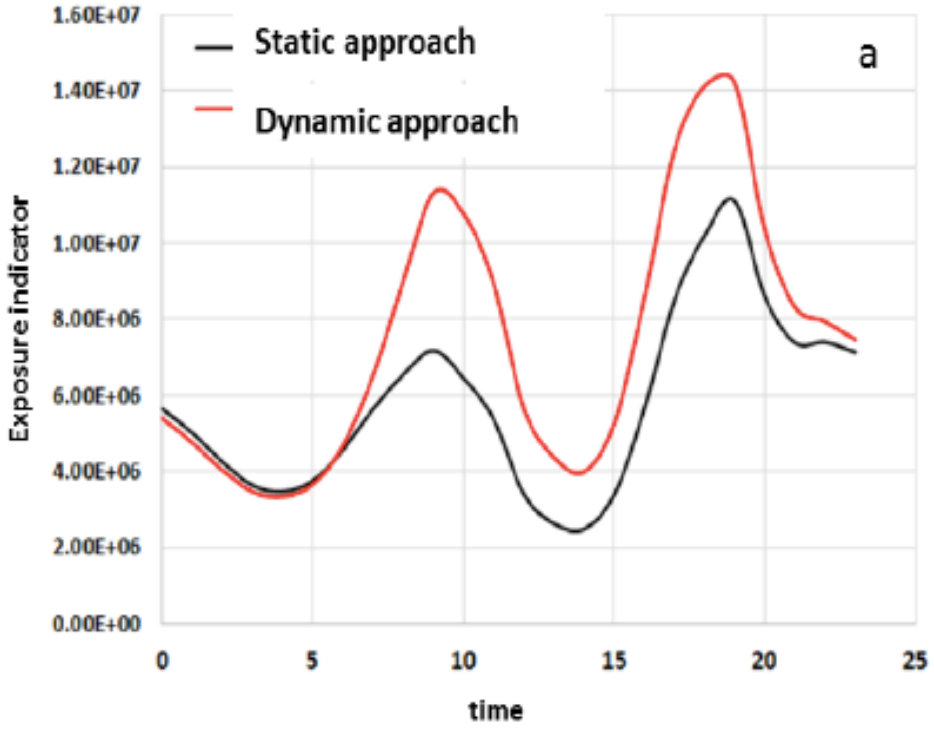


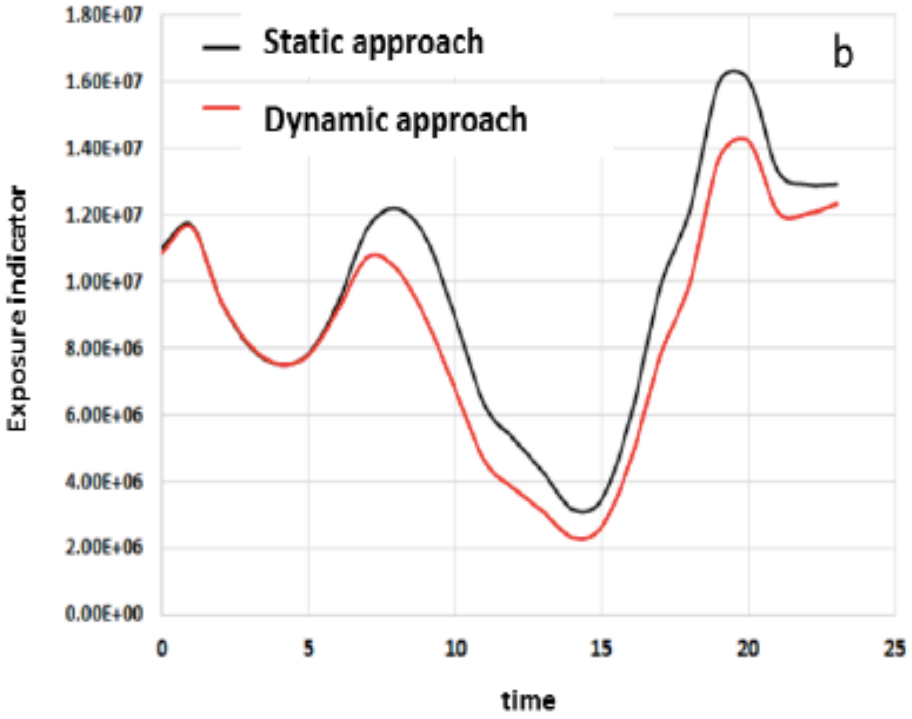
12:00

Total exposure throughout the day estimates: a) static census-based approach and b) dynamic CDRs-based approach



Exposure indicator evolution along the day for specific city areas: a) Chamartín District, and b) Carabanchel District



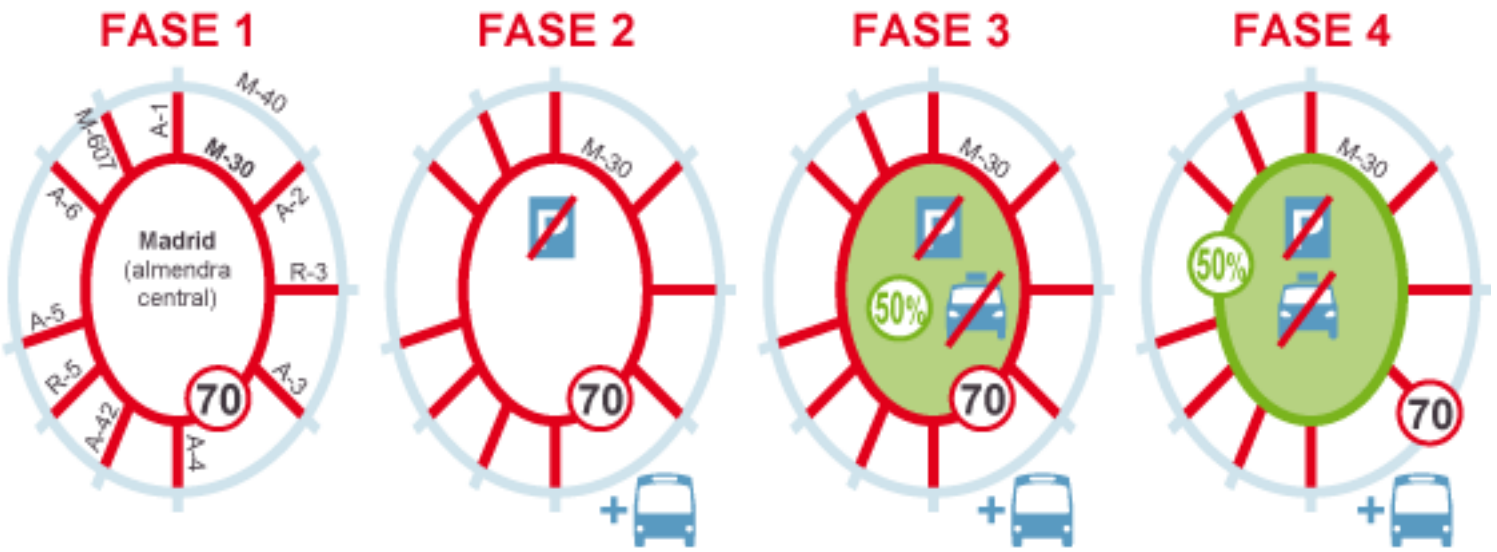


7.- Future Madrid AQ Plan

- **Road traffic (reduction on motorized traffic):**
  - Population mobility redistribution
  - Park and ride in the crown of the city
  - Increased cost of surface parking: use of public space and motorized mobility
  - Development / implementation of reserved platforms (BUS-HOV lanes)
  - Redistributing road space
  - Expansion of the cycling network
  - Promoting bicycle use
  - Encouraging modal exchange
  - Increased efficiency of Urban Freight (logistics platforms, improving loading and unloading bays, etc.)
  - Encourage mobility plans in companies
  - Control access to the city

- **Road traffic (reduction on motorized traffic):**
  - Speed reduction in access roads
  - Promotion of technologies with less emissions (based on the labeling of the DGT)
    - Private: incentives - priority access and parking
    - Taxi: limitation of sale and priority access
    - Heavy duty vehicles: access limitation
    - Buses: reduction of diesel buses and increase of electric vehicles
    - Other municipal fleet
  - Mobility restrictions for empty taxis
  - Restructuring the bus network
  - Street washing activities

8.- Protocol for high pollution episodes

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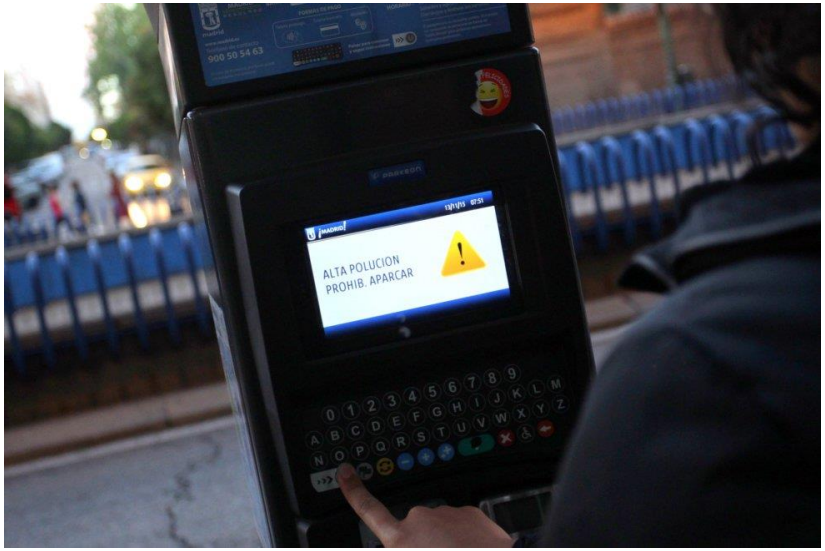
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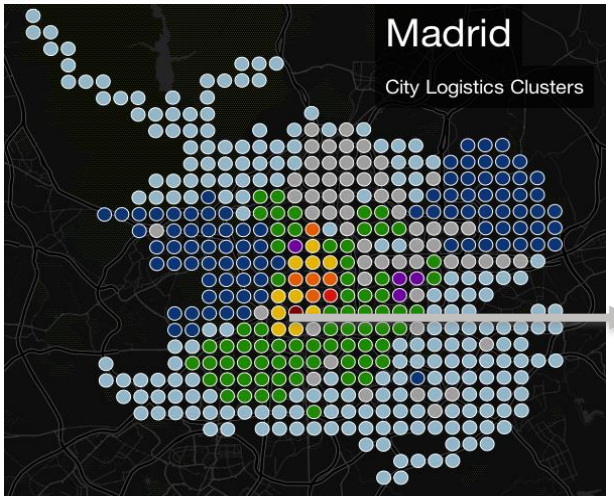
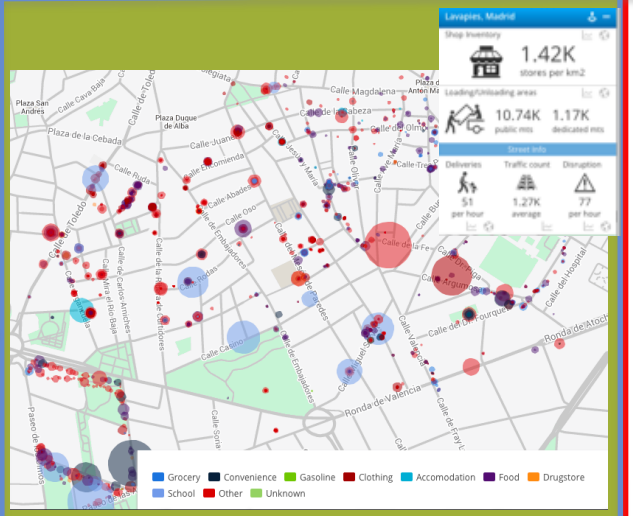
9.- Urban freight distribution

Data-driven methodology to guide city logistics decisions

e.g. parking, night-deliveries, vehicle restrictions, urban consolidation centers





Policy & incentives

Better cities for logistics

Practices & technology

Infrastructure

City-wide assessment:
- M: PCA & cluster analysis
- O: identify critical areas

Analysis of critical areas:
- M: km², high-res analysis
- O: quantify deliv. intensity

Policy recommendations:
- M: Different techniques
- O: Better Cities For Logistics

M: Methods - O: Outcome

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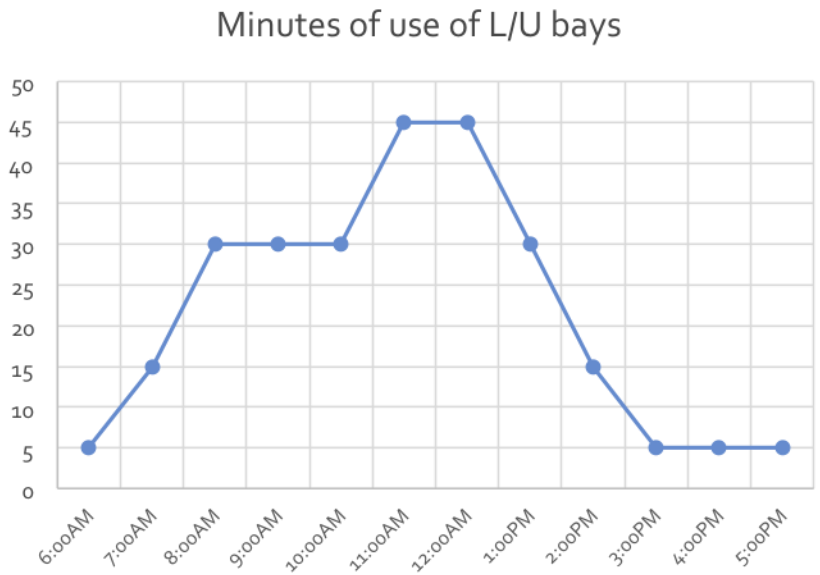
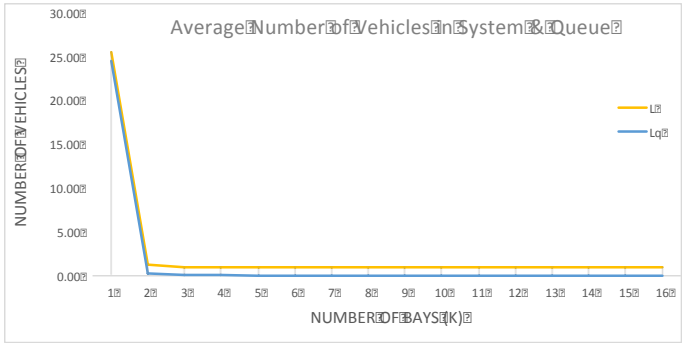
1 Plot the time of use of L/U bays



Based on our data collected, we can also estimate time of L/U parking based on:

- commercial vehicle type
- type of stores
- store sizes

2 Estimate the number of L/U bays



3 Optimal location of delivery bays

$$\min z = \sum_i \sum_j h_i \frac{d_{ij}}{v} y_{ij}$$

$$\sum_j y_{ij} = 1 \quad \forall i$$

$$y_{ij} - x_j \le 0 \quad \forall i, j$$

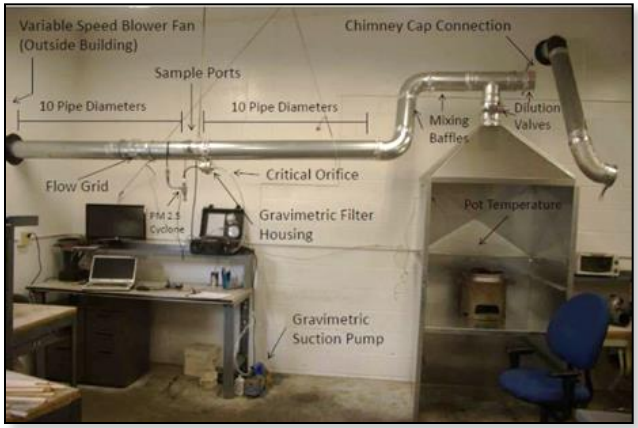
$$\sum_j x_j = P$$

$$y_{ij} = \{0,1\}$$

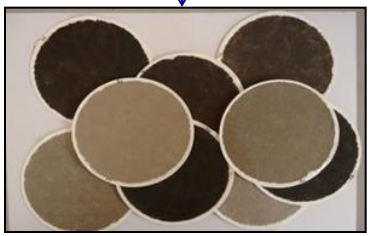
$$x_j = \{0,1\}$$

10.- Other work

Laboratory estimation of black carbon emissions from cookstoves



Standarized Water Boiling Test (WBT) conducted in a LEMS[4]



$PM_{2.5}$ emissions collected in quartz fiber filters

Stove type (Fuel type: Cordyla Pinnata)	 **3-Stones**	 **Ceramic**	 **Rocket**	 **Gasifier**
Fuel consumption to boil 5 L of water (MJ)	10454±563	9239±1192	9435±780	14966±390 (Boil+ simmer)
Fuel consumption to simmer 45 min (MJ)	11278±347	11235±1062	11408±867	
BC Emission Factor (EF) to boil (mg/MJ)	102±10	98±15	214±68	90±24 (Boil+ simmer)
BC EF to simmer (mg/MJ)	80±6	91±13	149±44	
Total BC emitted (g)	1998±200	1935±343	3752±1372	911±492

Comparison between GAINS and national emission inventory

TABLE 1 - SO_2 emissions: GAINS scenario vs national inventory

	2005			2010		
	Activity rate	Sectoral implied emission factor	SO_2 emissions	Activity rate	Sectoral implied emission factor	SO_2 emissions
Power generation	19% ↑	21% ↓	5% ↓	33% ↑	54% ↓	38% ↓
Industrial combustion	3% ↑	53% ↓	51% ↓	16% ↑	76% ↓	72% ↓

↑ means that GAINS > national inventory and ↓ means that GAINS < national inventory

Road transport	3% ↑	4% ↑	7% ↑	2% ↓	9% ↑	7% ↑
Power generation	19% ↑	32% ↓	19% ↓	33% ↑	38% ↓	17% ↓
Industrial combustion	3% ↑	10% ↓	7% ↓	16% ↑	42% ↓	32% ↓

TABLE 2 - NO_x emissions: GAINS scenario vs national inventory

	2005			2010		

TABLE 3 - $PM_{2.5}$ emissions: GAINS scenario vs national inventory						
	2005			2010		
	Activity rate	Sectoral implied emission factor	$PM_{2.5}$ emissions	Activity rate	Sectoral implied emission factor	$PM_{2.5}$ emissions
Non-industrial and non-mobile combustion	5% ↓	23% ↑	17% ↑	18% ↓	9% ↑	11% ↓
Road transport	3% ↑	13% ↑	16% ↑	2% ↓	28% ↑	26% ↑
Industrial combustion	3% ↑	55% ↓	54% ↓	13% ↑	65% ↓	59% ↓
Power generation	19% ↑	18% ↓	2% ↓	33% ↑	10% ↓	21% ↑

↑ means that GAINS > national inventory and ↓ means that GAINS < national inventory

- Significantly different sectoral emissions although similar national totals (not for $PM_{2.5}$)
- In 2010, GAINS scenario moved away from official national emissions, especially for some sectors and activities (eg. lime production)
- Potential problems for emission projections

Thank you for your attention!

www.tecnaire-cm.org

Study carried out within the TECNAIRE-CM (innovative technologies for the assessment and improvement of urban air quality) scientific programme funded by the Directorate General for Universities and Research of the Greater Madrid Region (S2013/MAE-2972).

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