New challenges when Downscaling Global to Urban CO_2 emission inventories

The potential of the Covenant of Mayors initiative

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BIPM Workshop
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Sèvres, France

Context

- **Urban areas account for about 80% of population and 70% of the total primary energy demand in the European Union** (IEA, 2010 and UNDP, 2012). Therefore, cities have a high potential to drive climate change mitigation and adaptation policies.

- **There is a need for comparable emission inventories at city level**, including small to large cities, to develop evidence-based policies accounting for the relation between emissions and institutional, socio-economic and demographic characteristics.

- **The voluntary-based Covenant of Mayors (CoM) initiative** launched in 2008 already allowed to collect **more than 3400 local CO_2 emission inventories** over Europe **for small to mega cities**.

Purpose

To present JRC current activities aiming at **assessing the potential of CoM for verifying/improving the precision and downscaling of EDGAR** (Emission Database for Global Atmospheric Research) **CO_2 emission inventories** from Global to Urban scales.

Outline

EDGAR : Emission Database for Global Atmospheric Research

- What is EDGAR?
- EDGAR emission inventory approach
- CO_2 emissions : Results from global to national scales

CoM : Covenant of Mayors initiative

- What is CoM?
- CoM CO_2 emission inventory approach
- Status of CoM initiative

The potential of CoM for the down-scaling of global inventories

- The «CoM Sample 2013»
- Comparison to Global gridded emssion at national scale
- Potential for down-scaling global to urban emission inventories

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EDGAR: Emission Database for Global Atmospheric Research

- **Joint project** of the European Commission Joint Research Centre (JRC) and the Netherlands Environmental Assessment Agency (PBL).
- **Addresses Policy and Science needs** (information, accountability) on anthropogenic emissions
- **Provides global anthropogenic gridded emission data**
  - 1970-2008(12) historical GHG and Air Pollution emissions EDGARv4.2(.3)
  - **2000-2010 EDGARv4.2FT2010 Greenhouse Gases emissions**
  - **2000-(year -1) for CO_2 under the EDGARv4.3FT(year-1) update**
  - 2005-2050 emission projections UNEP, EC (POLES)

EDGAR EMISSION DATABASE FOR GLOBAL ATMOSPHERIC RESEARCH

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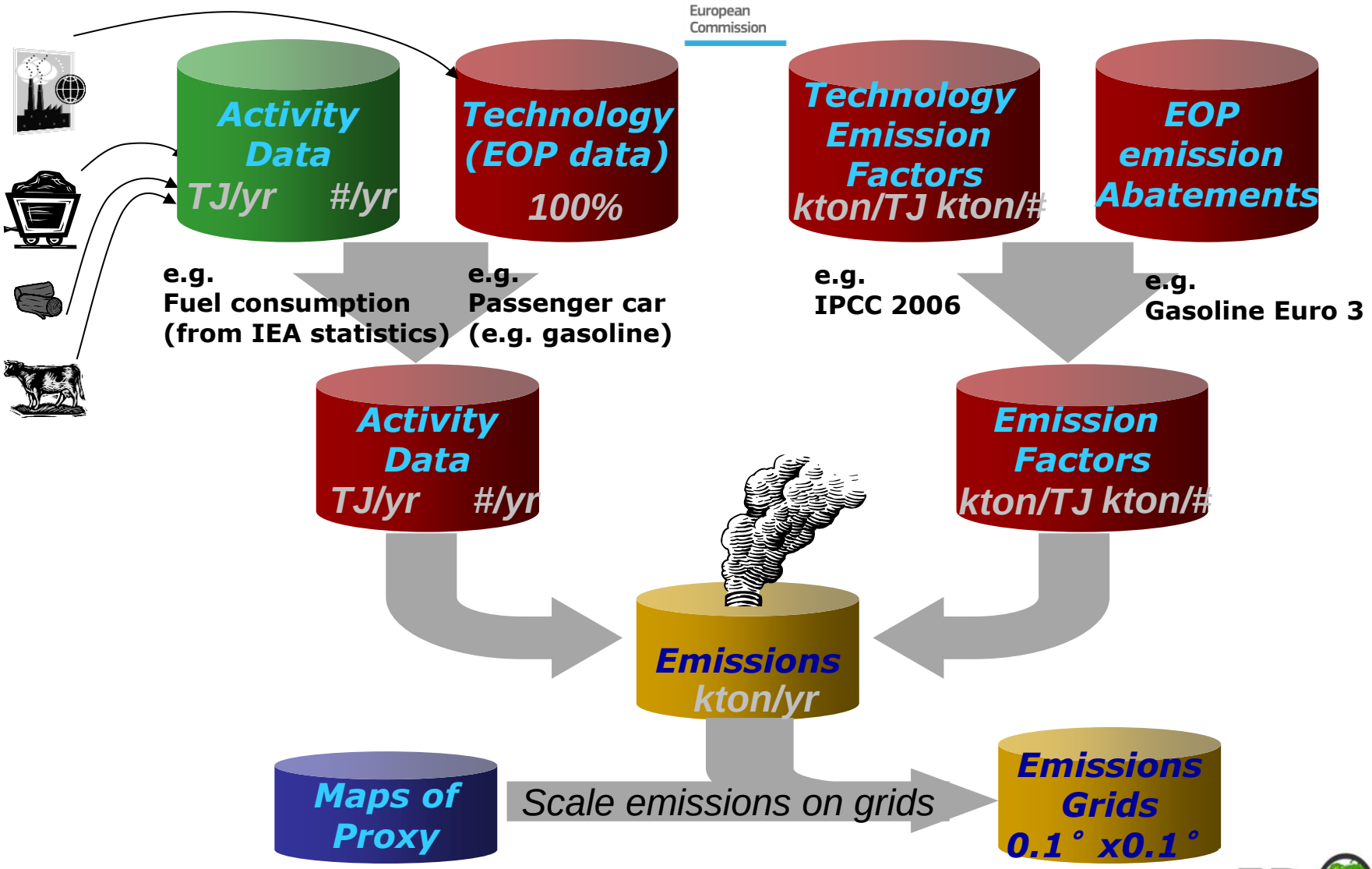

Examples of proxy: Urban/rural population density (based on CIESIN), road density maps , animals density, burnt areas, flight trajectories and cruise height, railways, sea fishing areas,..

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Activities

All human activities (all IPCC sources/sinks categories)

IPCC 1-2-3-4-6

IPCC 5:LULUCF: forest&peat fires, post-burn decay,forest land remaining forest land(forest growth, harvest, deforestation)

Chemical substances

GHG: CO_2, CH_4, N_2O, F-gases

Air pollutants: CO, NO_x, NH_3, SO_2, NMVOC

Aerosols: PM_{10} and $PM_{2.5}$, BC and OC forthcoming

Coverage and resolutions

Global coverage

Point sources and diffusive **proxy**: on 0.1° x 0.1° grid

Zoom for urban areas on 0.01° x 0.01° grid

Monthly distribution

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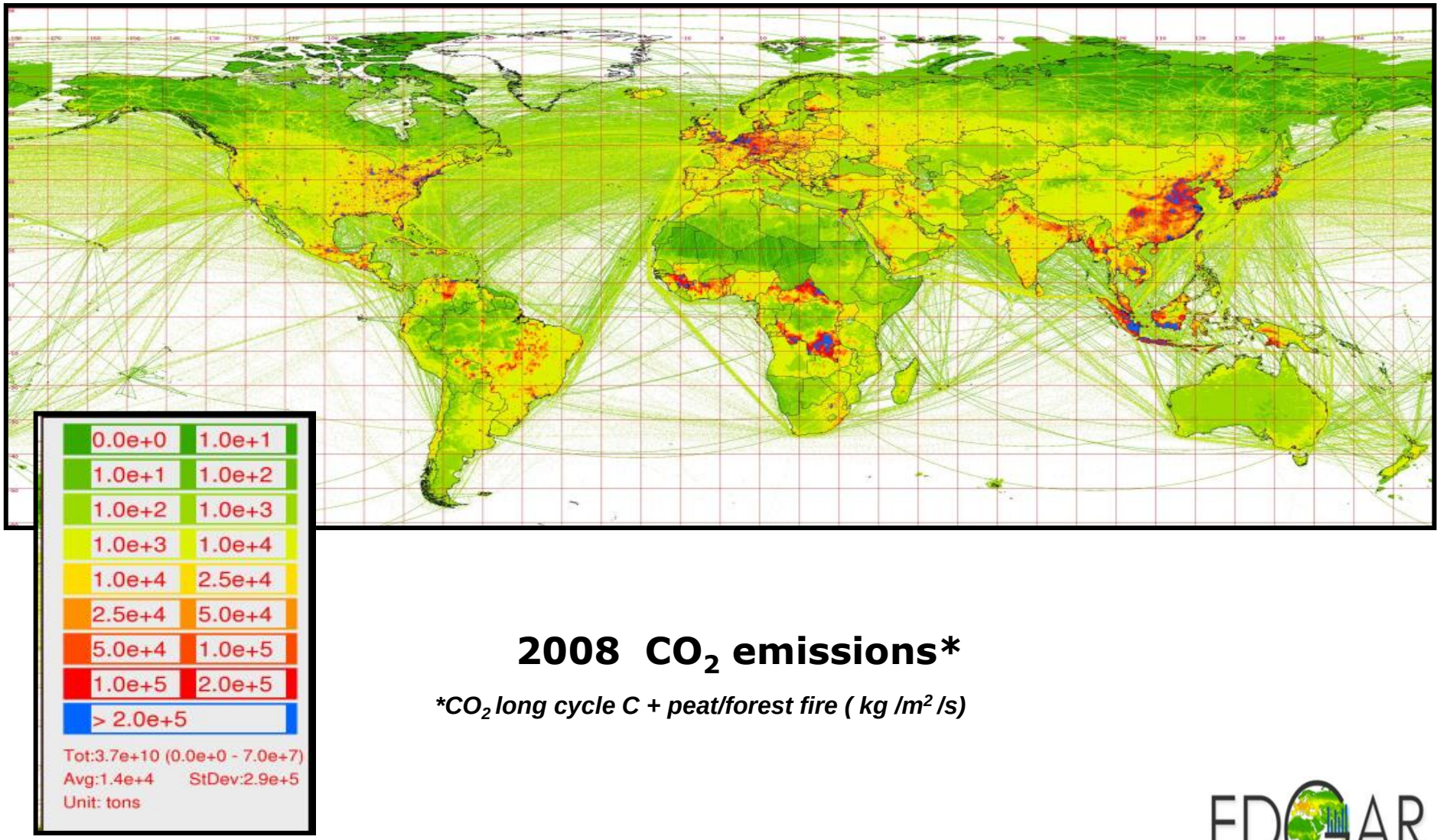

2008 CO_2 emissions*

**CO_2 long cycle C + peat/forest fire (kg /m^2 /s)*

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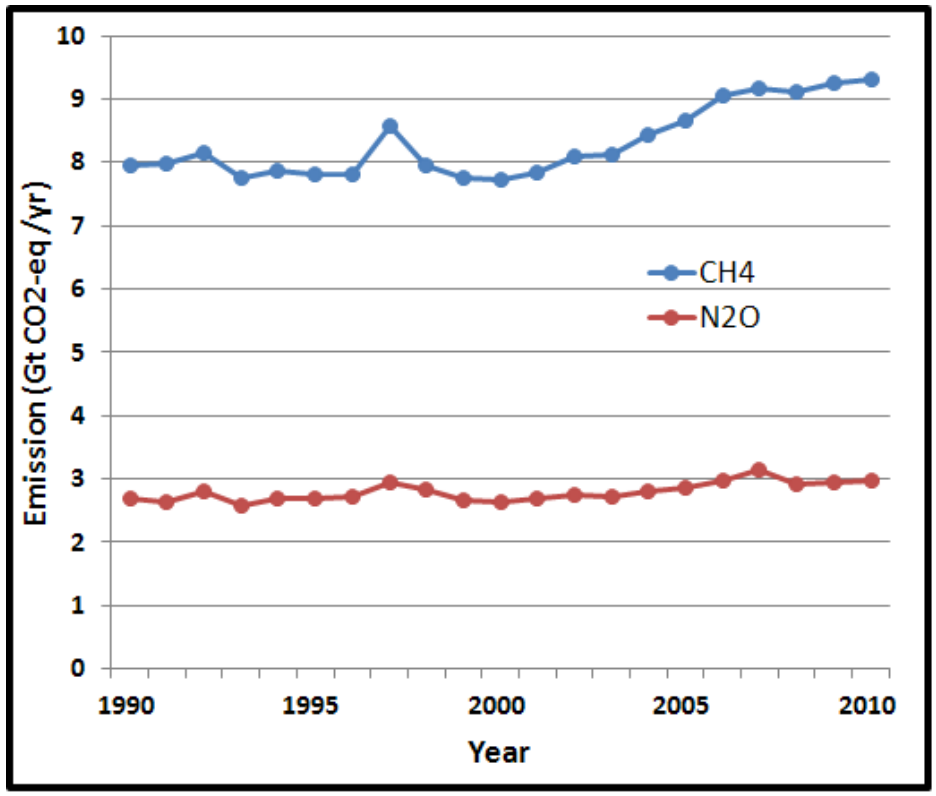
EDGAR EMISSION DATABASE FOR GLOBAL ATMOSPHERIC RESEARCH

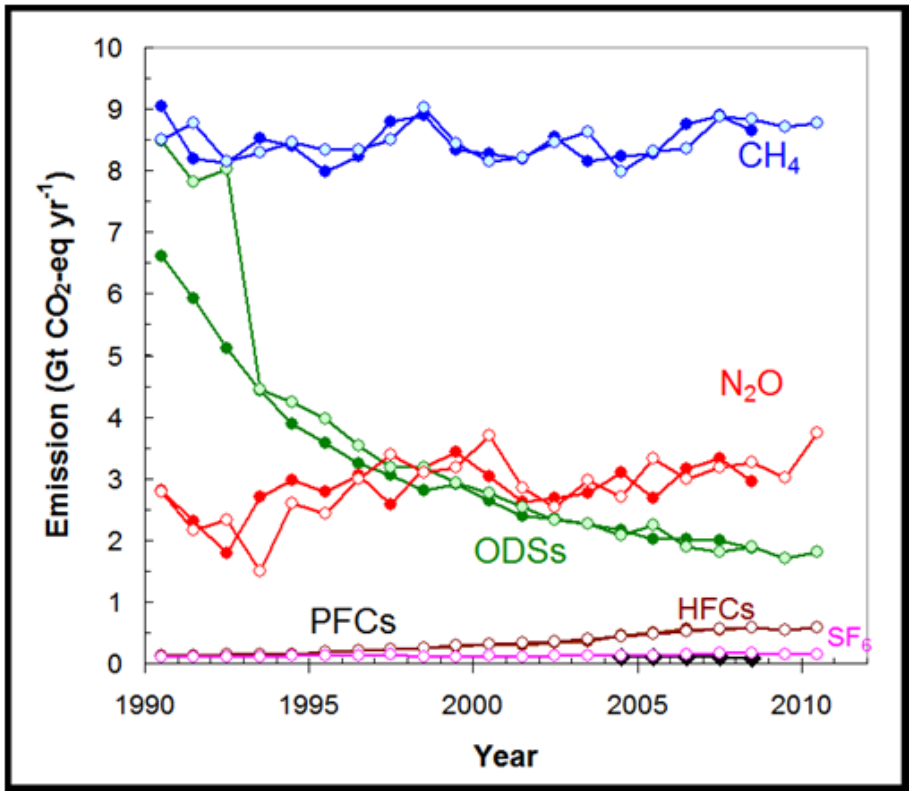
Global GHG: EDGARv4.2 versus NOAA satellite measurements

EDGARv4.2FT2010 bottom-up time series of global total



Olivier & Janssens-Maenhout (2012)

NOAA global background atmospheric observation



Montzka et al. (2011)

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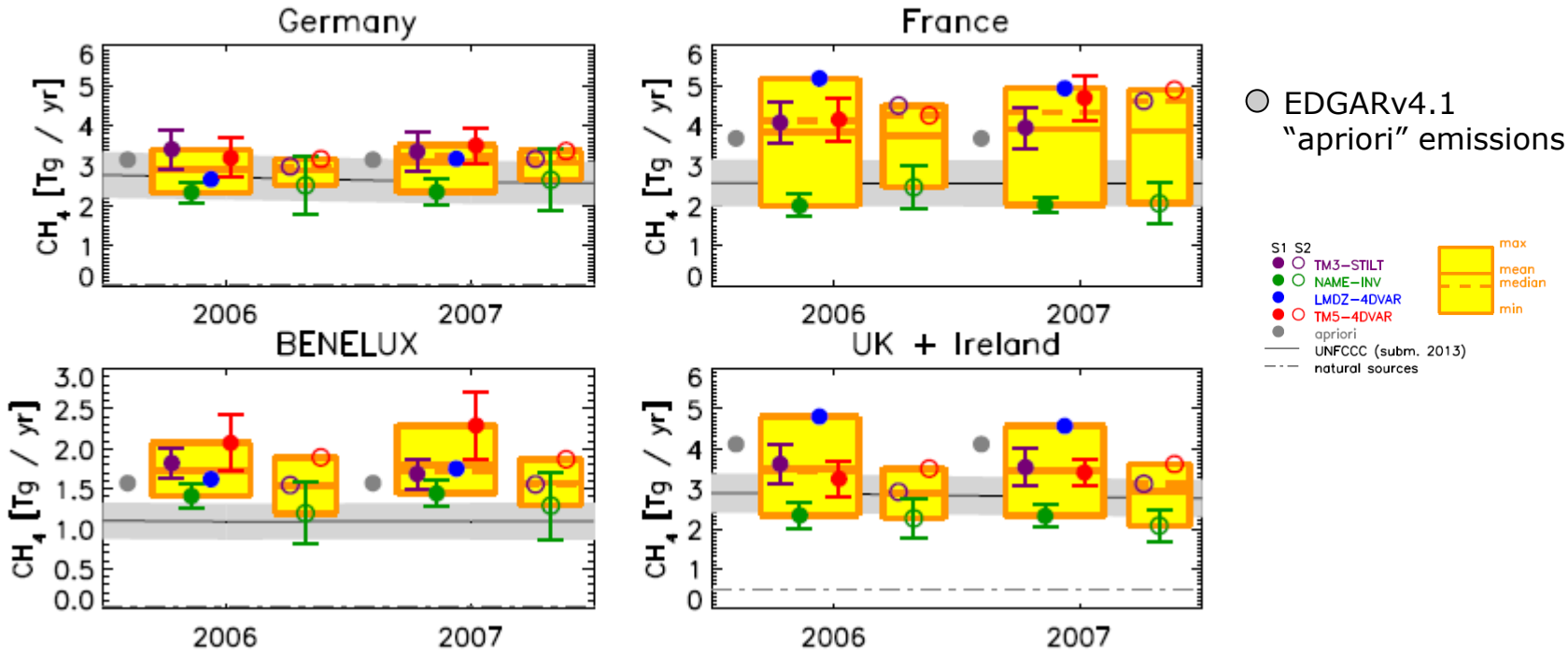
National CH_4 : EDGARv4.1 versus inverse modeling



Part of :

Figure 3. European CH_4 emissions by country and aggregated region. For each year, the left yellow box shows the results for inversion S1–CH_4, and the right yellow box for S2–CH_4. The grey-shaded area is the range of UNFCCC CH_4 emissions (based on reported uncertainties, as compiled in Table 6).

Bergamaschi *et al.*, 2015

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Uncertainties in national emission inventories

Low (L), low medium (LM), upper medium (UM) or high (H) uncertainty

	CO_2	CH_4	N_2O	VOC	CO	BC/OC	Good statistical infrastructure (1)	Poor statistical infrastructure (2)
Industry	LM	LM	LM	UM	LM	LM	L< 15%	L< 35%
Transport	LM	UM	UM	UM	UM	H	15% ≤ LM < 50%	35% ≤ LM < 70%
Residential	LM	UM	UM	UM	UM	H	50% ≤UM <100%	70% ≤UM <150%
Agriculture	UM	UM	UM	UM	UM	H	100% ≤ H	150% ≤ H

(Andres et al. 2012)

(1) the 24 OECD-1990 countries and India (using the British statistical accounting system according to Marland et al. 1999). (2) Other countries : a larger range in uncertainty is present

The sector-specific uncertainty of the activity and the quality and representativeness of the controlled emission factors have been taken into account to qualitatively indicate a low (L), low medium (LM), upper medium (UM) or high (H) uncertainty for the different sectors and substances.

- The Covenant of Mayors was launched in 2008 by the European Commission, with the support of the Committee of the Regions and the European Parliament.

- It implies a **voluntary based commitment** by the participating local authorities (towns, cities and regions) to go beyond the objectives of the EU policy, i.e, **to achieve at least 20% reduction of greenhouse emissions by 2020** (with reference to 1990, or more to a more recent year), through measures in energy efficiency and greener local energy production.

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Commitments taken by CoM signatories

Reduce by at least 20% the CO_2 emissions
occurring in their respective territories by 2020

- Elaborate a **Baseline Emission Inventory** (BEI)
- Prepare a **Sustainable Energy Action Plan** (SEAP)
- Implement their Action Plan and report periodically on progress, including a **Monitoring Emission Inventory** (MEI) every 4 years
- Involve citizens and other stakeholders
- Adapt city structures and allocate sufficient resources
- Encourage other cities to join

European Commission

Guiding principles to the CoM approach

- Scientifically sound and robust support
- **Compatibility with IPCC principles** to the extent possible
- **Adaptation** to the CoM requirements:
  - In line with the CoM core text
  - Allowing to prioritise the reduction measures
  - **Flexibility and Simplicity of use** : the BEI should not be a barrier for action and should suit very different situations
  - **Key target: energy efficiency and local renewable energy** in the non-ETS sectors (therefore excluding power stations, combustion plants as well as iron and steel, paper and cement industries, etc.)
  - **Provide a single CO_2 emission total from one base year**, which represents unambiguously the starting point for the signatory

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Flexibility and simplicity: Choice of the approach for emission estimations

- **Bottom-up emission inventory following IPCC guidelines***
  Based on the Carbon content of fuels.

- **LCA (Life Cycle Analysis) estimate of emissions:**
  Includes embodied emissions that occur upstream (e.g. emissions required to extract, transform, transport the fuel up to the city).

** CoM guidelines for emission factors are based on IPCC 2006 Guidelines (IPCC, 2006), CO_2-eq characterisation factors are based on the IPCC 4th Assessment Report (IPCC, 2007)*

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Flexibility and simplicity: which sectors should be included in BEI?

STRONGLY RECOMMENDED

- **Municipal buildings**, equipment/facilities
- **Tertiary** (commercial & non-municipal services)
- **Residential buildings**
- **Urban road transportation** (municipal fleet, public and private transport)

RECOMMENDED IF IN THE ACTION PLAN

- Industries not involved in the EU ETS
- Other road transportation (e.g. highways)
- Wastewater treatment, solid waste treatment

NOT RECOMMENDED

- Industries involved in the EU ETS
- Aviation
- Agriculture (enteric fermentation, fertilizer application, etc…)
- Land use, land use change, forestry

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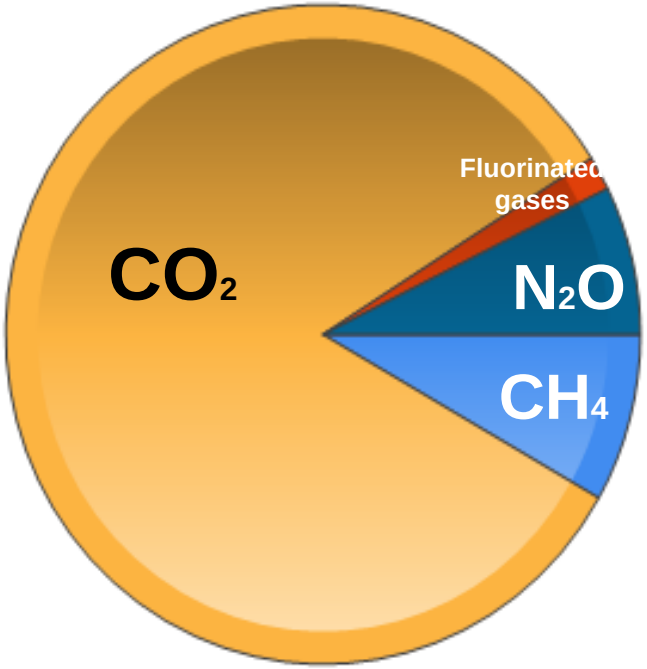
Flexibility and simplicity: Choice of greenhouse gases

Mandatory ($T CO_2$)

Combustion
&
Usage of fossil fuels



Recommended only if actions planned in these sectors ($T CO_2$-eq)

Agriculture (77%)
Industry (8%)

Agriculture (49%)
Waste (31%)
Fugitive emissions (15%)

Share of greenhouse gases - EU27- 2008 (EEA, 2009)

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How to calculate the emissions?

On line reporting

Energy Cons. = Activity data x Emission factor

Ex: MWh of natural gas consumed

Value in t CO2 / MWh

Table A x **Emission Factor**

Data relevant to the particular situation of the local authority need to be found

Most emission factors can be found in tables (Guidebook, IPCC)

= Table B (emissions)

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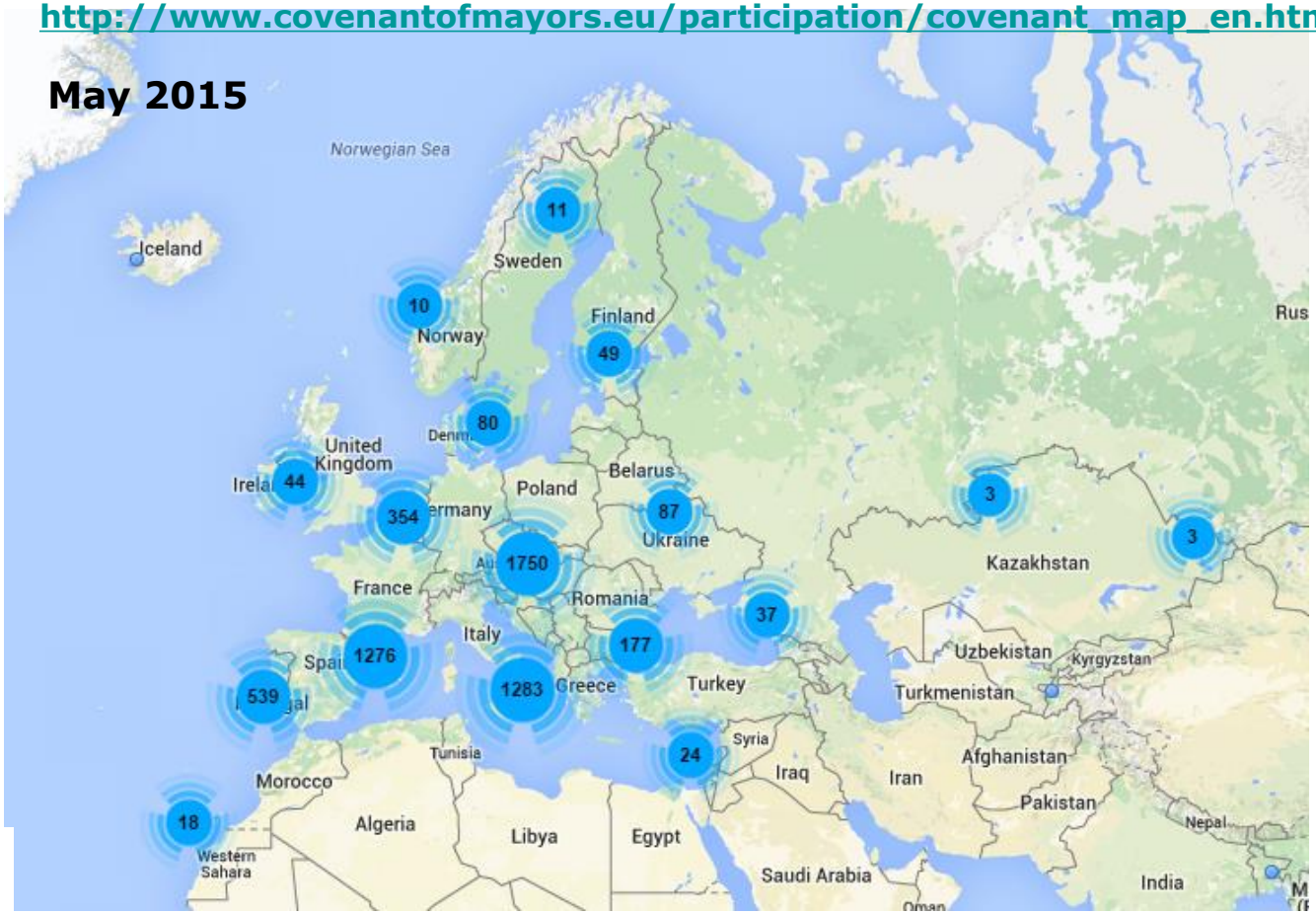
6320 CoM signatories

www.eumayors.eu

http://www.covenantofmayors.eu/participation/covenant_map_en.html



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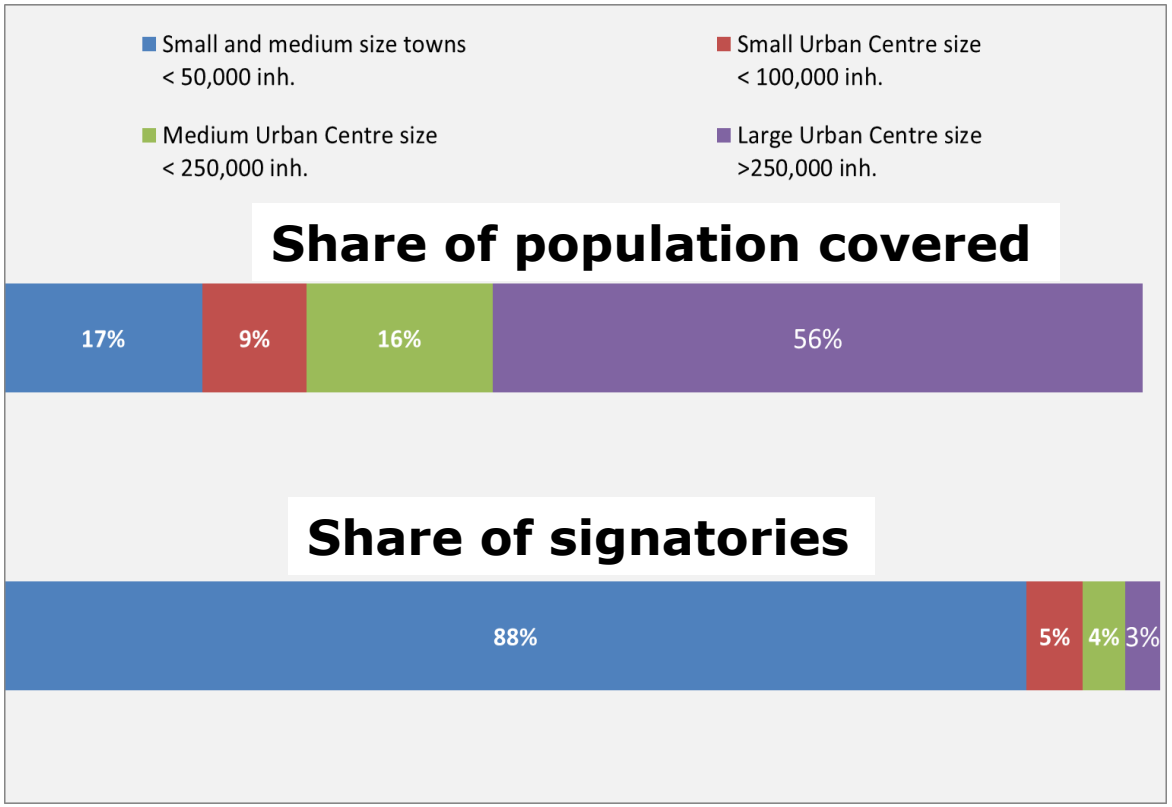
CoM Baseline Emission inventories (as of May 2014)

3421
Base Emission inventories



"Covenant of Mayors: Performance Indicators – 6 Year Assessment", Kona et al. 2015.

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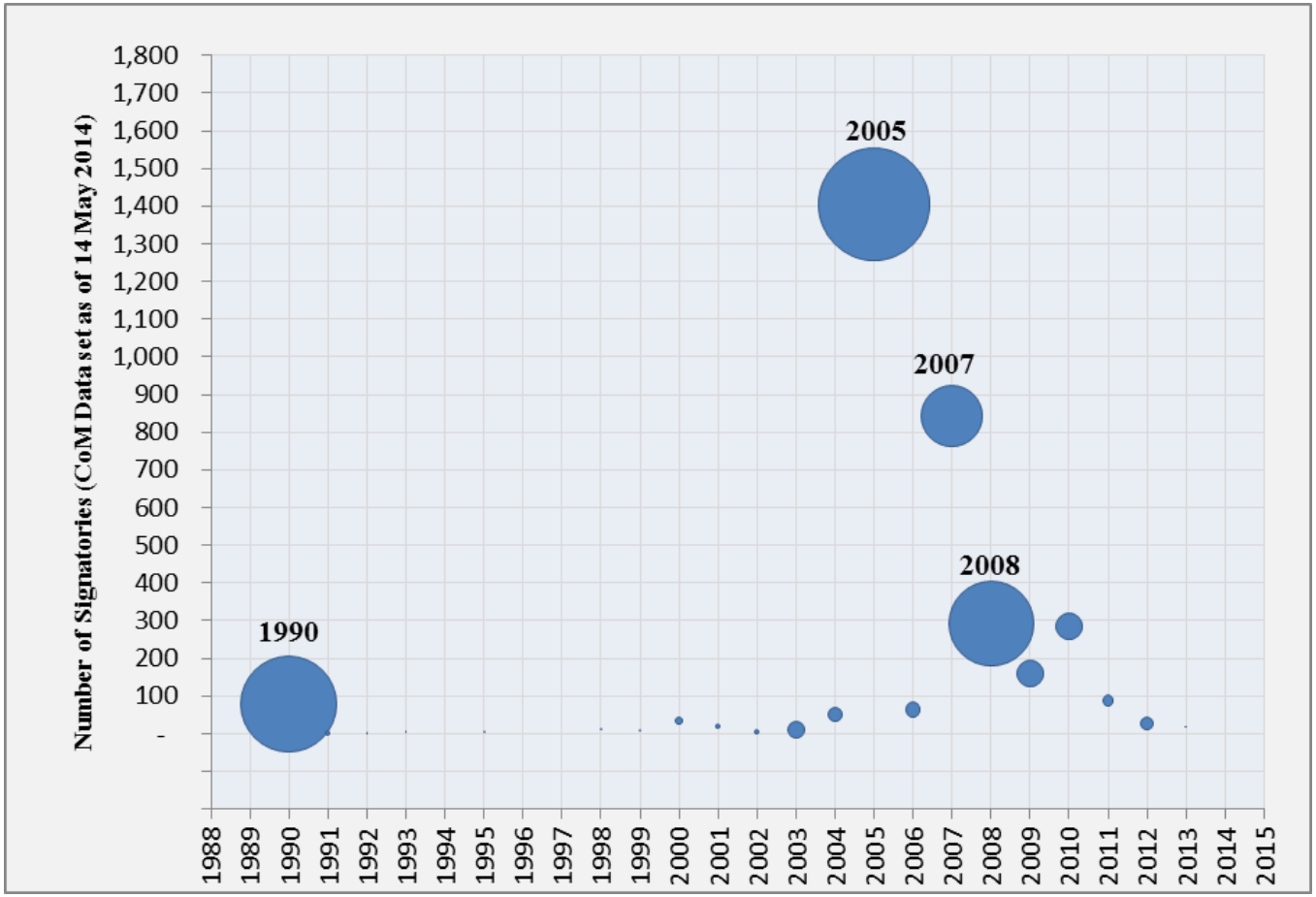
CoM BEI years



"Covenant of Mayors: Performance Indicators – 6 Year Assessment", Kona et al. 2015.

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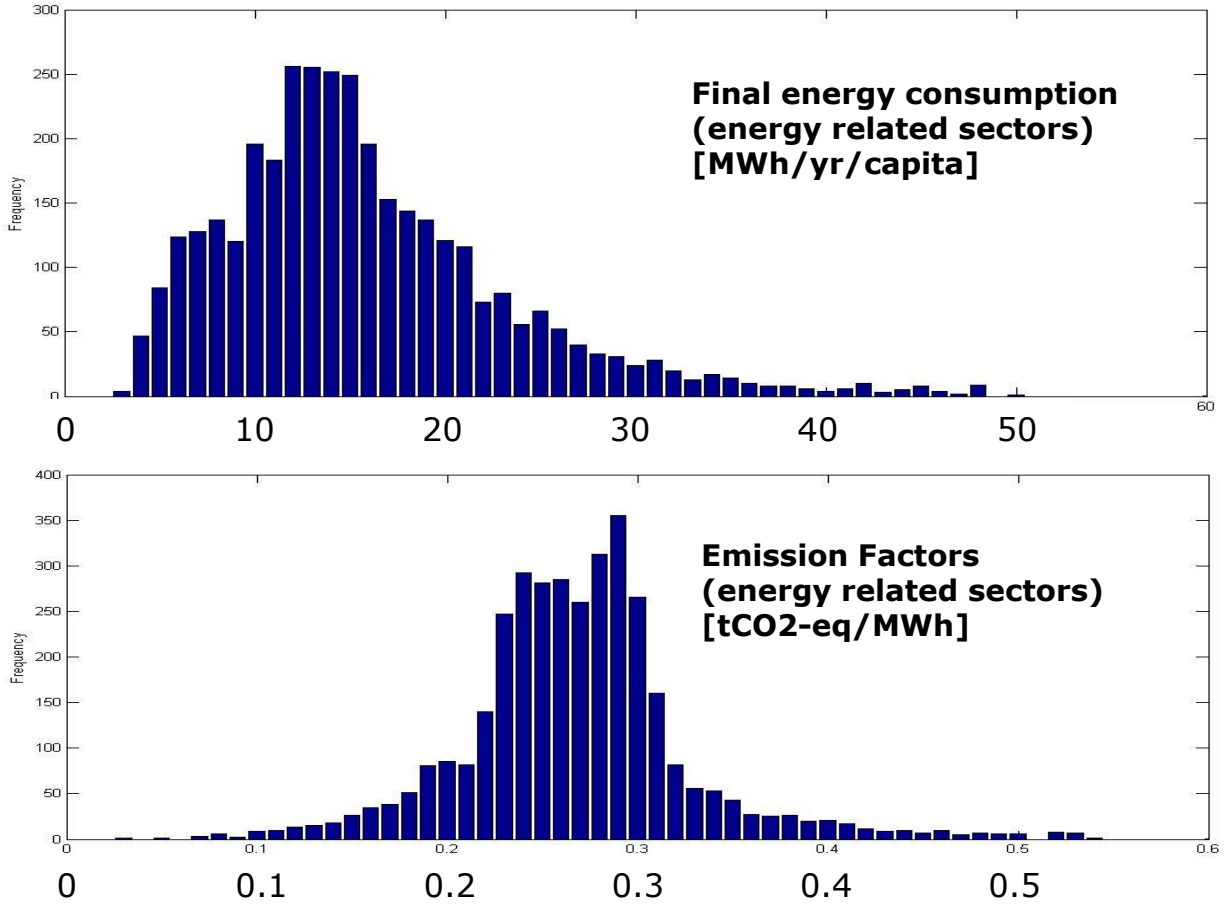
Frequency distributions of CoM BEI indicators

As of May 2014



"Covenant of Mayors: Performance Indicators – 6 Year Assessment", Kona et al. 2015.

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CoM 6–year assessment report

JRC report

Kona et al., 2015

CoM Sample 2013

Peer-reviewed publication, Submitted (ESSD)

Iancu et al., 2015

A harmonised dataset of greenhouse gas emissions inventories from cities under the EU Covenant of Mayors initiative.

A. Iancu[1], S. Martelli[1,3], A.K. Cerutti[1*], G. Janssens-Maenhout[1], G. Melica[2], S. Rivas-Calvete[2], A. Kona[2], P. Zancanella[2], P. Bertoldi[2]

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Abstract

The realization of national climate change commitments, as agreed through international negotiations, requires local action. However, data is still insufficient to make accurate statements about the scale of urban emissions (UNHABITAT, 2011). The need of comparable emission inventories at city level, including smaller cities, is widely recognized to develop evidence-based policies accounting for the relation between emissions and institutional, socio-economic and demographic characteristics at city level. This paper presents a collection of harmonized greenhouse gases (GHG) emission inventories (the "CoM sample 2013") at municipal level directly computed by the cities and towns that participate in the EU Covenant of Mayors initiative. This is the mainstream European movement of local and regional authorities who voluntarily commit to reduce GHG emissions by 20% or more by 2020. The "CoM sample 2013" (http://edgar.jrc.ec.europa.eu/com/data/index.php?SECURE=123, doi: 10.2904/EDGARcom2013) has been carefully checked to ensure its internal consistency and its congruity with respect to internationally accepted guide values for emission factors. Overall, it provides valuable data for the analysis of the heterogeneity of final energy consumption and greenhouse gas emissions of cities.

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The CoM data :

- **an unique bottom up inventory** of local greenhouse gas emissions for the EU and related emission reduction potentials, as estimated by local authorities.
- can be used to enhance the precision of existing emission inventories and explore the local diversity
- limitations in terms of consistency and completeness partly due to the voluntary based character of CoM

The "CoM sample 2013" (*Iancu et al.*, ESSD, 2015, submitted)

- **CoM 2013 data sample = 919 cities**
- **Carefully harmonized and checked** to ensure its internal consistency and its congruity with respect to guide values for emission factors.
- **Compared at national scale** with IEA Energy data and EDGAR emissions, **for the Building and Transport sectors**

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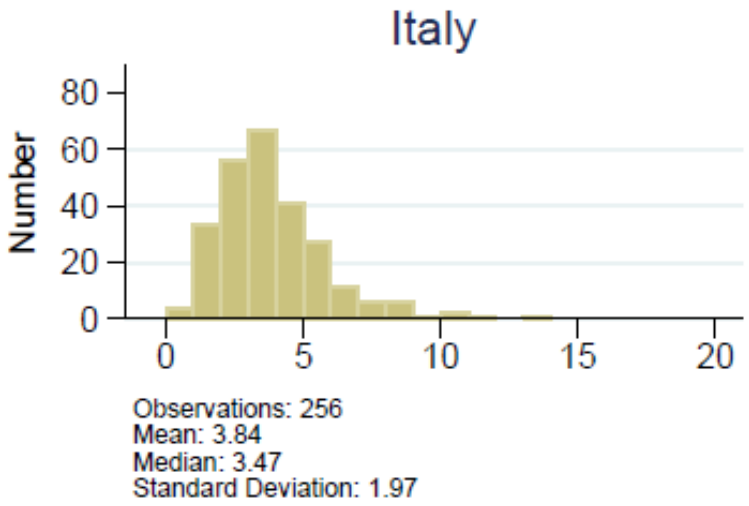
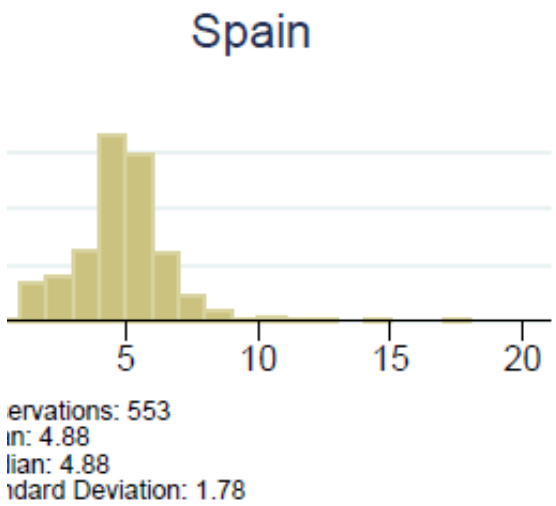
The "CoM sample 2013"

919 cities **40.8 M inhabitants** 97% of the cities used the IPCC approach





Spain and Italy account for 80% of the cities

CO_2 emissions per capita (tons/yr) – All sectors reported

Iancu et al., ESSD, 2015

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Comparison between CoM data sample and other databases at national level

	CoM sample	EDGAR database	IEA database	EUROSTAT database
Time series	One year inventory within the period between 1990-2012	1970-2010 Complete time series	1971-2012 Complete time series	1990-2012 Complete time series
Data collection	Mostly Bottom-up inventories (completed with national/regional averages when data at local level are not available)	Top-down, national averages // National data spatially allocated to a grid of 0.1°x0.1° using proxy data.	Top-down, national averages	Top-down, national averages
Geographical distribution	Administrative boundaries of the signatory	Worldwide coverage	Worldwide coverage	EU28 and other European countries[g]
Emission factors	IPCC default emission factors or Local Factors	EDGAR Emission factors which take into consideration also the mix of technologies, the end-of-pipe measures.[h]	Standard IPCC default emission factors	Country specific emission factors[i]

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Iancu et al., ESSD, 2015

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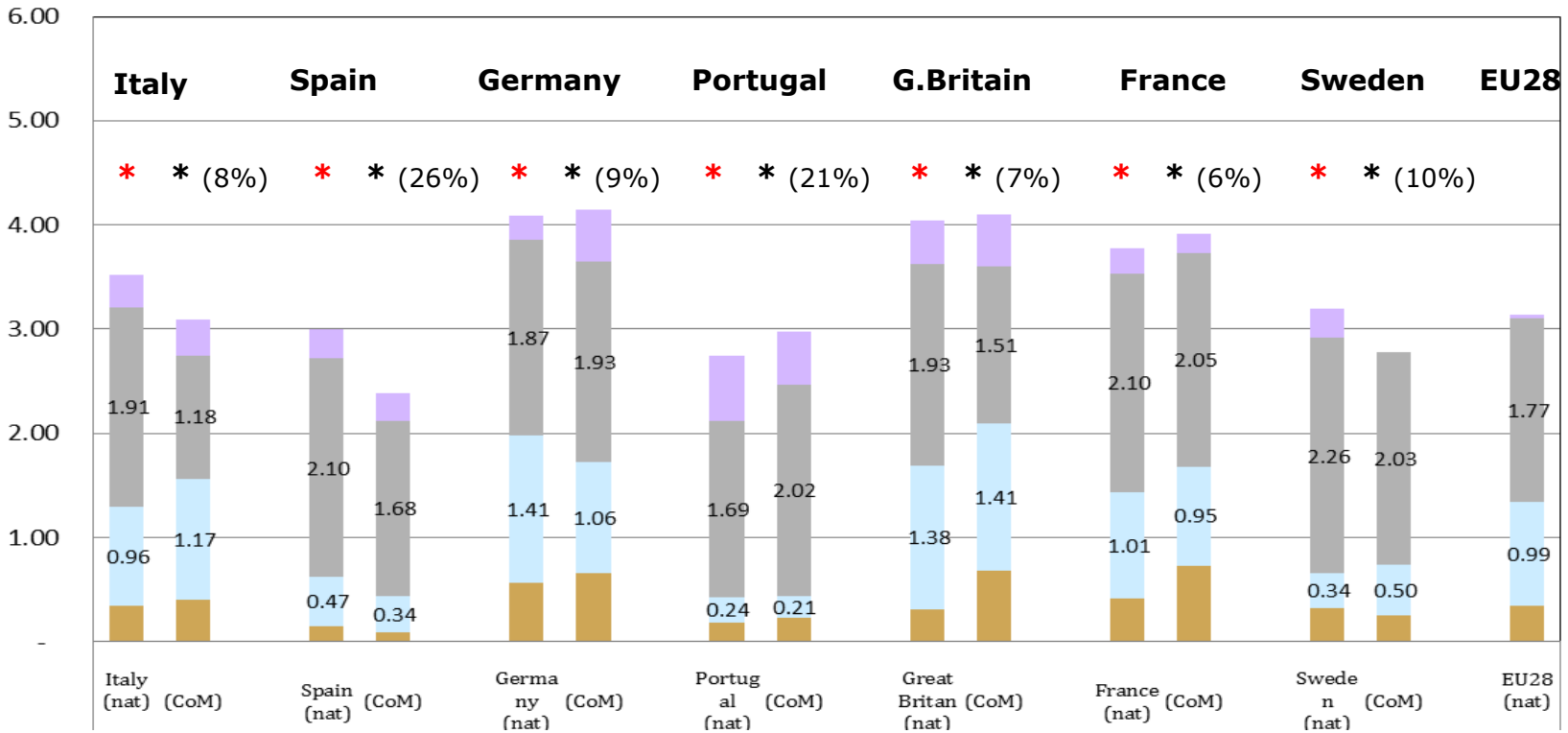
CO2 eq emissions (t. per year per capita)

Fossil fuels and Waste management

National average * [1] (EDGARv4.2) versus **CoM 2013 sample*** *(% of country pop.)*



Iancu et al., ESSD, 2015

[1] *weighted according to CoM reference years*

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"**A harmonised dataset of greenhouse gas emissions inventories from cities under the EU Covenant of Mayors initiative**" (*Iancu et al.*, ESSD, 2015, submitted)

- Overall, it provides valuable data for the analysis of the heterogeneity of final energy consumption and greenhouse gas emissions of cities.
- The dataset might be soon publicly available
- Should be regularly (yearly) updated ..

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What is the potential of CoM data ..

- to explore the local diversity e.g. in the residential and transport sectors **?**
- to assess relations between emissions per capita and demographic characteristics (city size, urban and rural density populations, degree of urbanization, ...) at sector level**?**
- to compare with existing/new emission inventories at sector level **?**
- to derive parametrisations to adapt the proxy data for the downscaling **?**

Illustrations of very preliminary analyses ..

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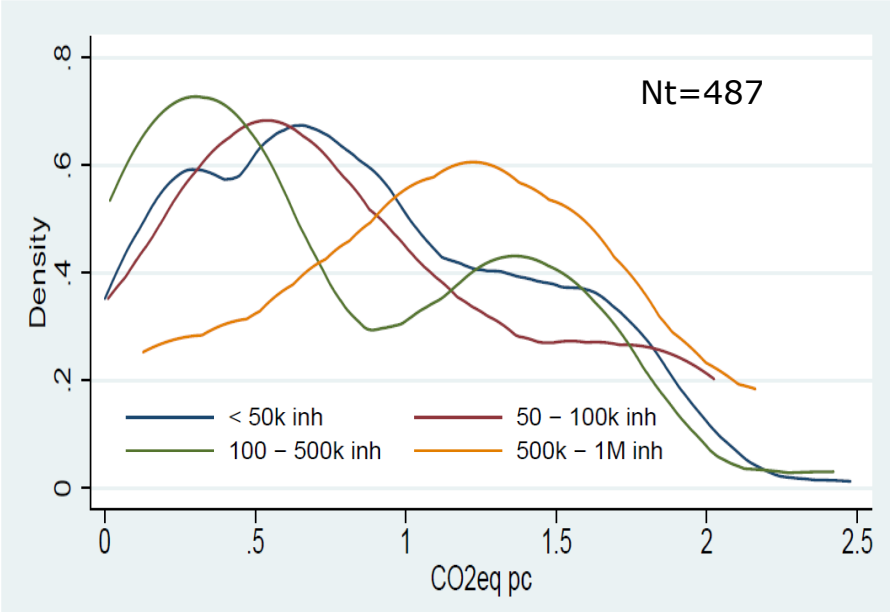
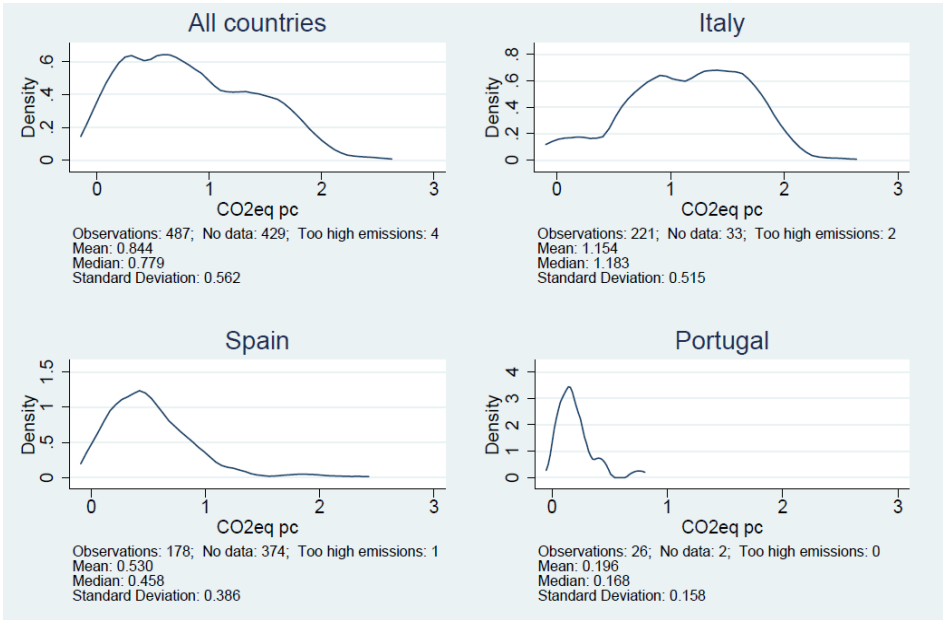
… as a function of the city size

CoM Sample 2013





CO_2 emissions (per capita per year) for the **Residential sector (fossil fuels)**

Courtesy of S. Martelli, EU, JRC

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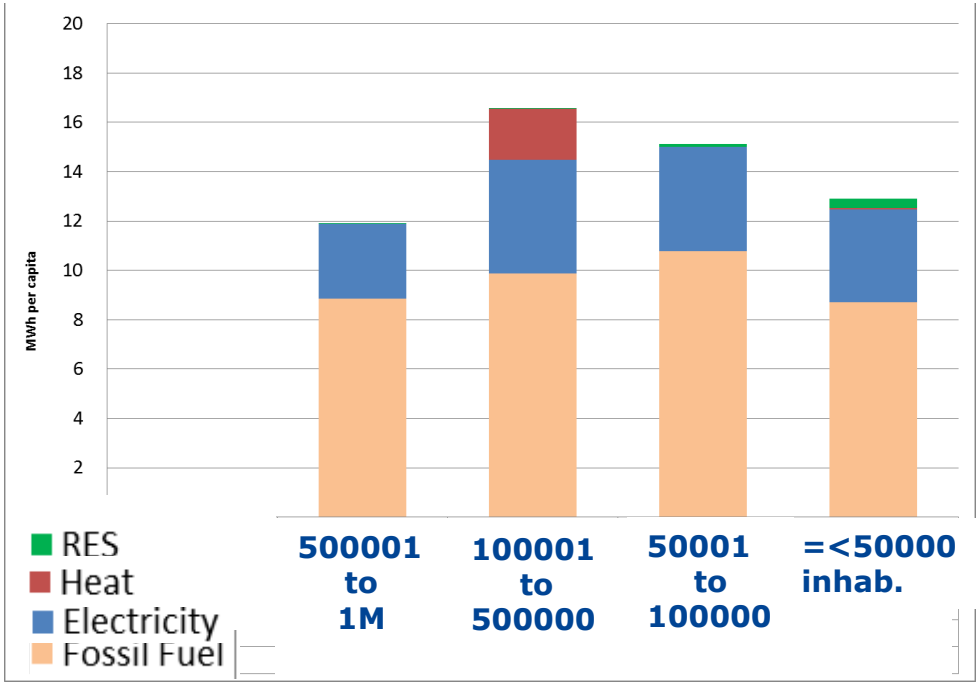
… as a function of the city size (and sectors)

CoM Sample 2013

Italy



Energy consumption (MWh per capita per year) for the **Building sector**

Courtesy of A. Iancu, EU, JRC

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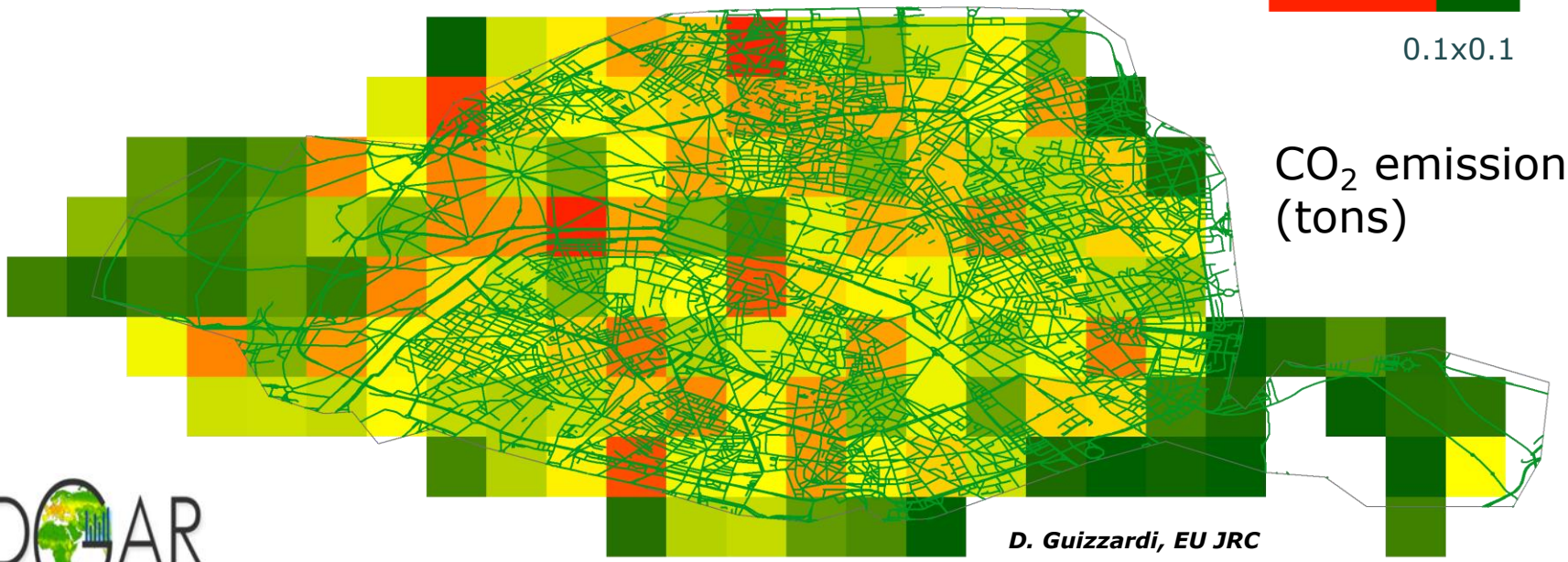
… to compare to existing/**new emission inventories**

2000-2012 EDGARv4.3

- CO_2 kept updated till year – 1
- Resolution: from 0.1x0.1 to 0.01x0.01°



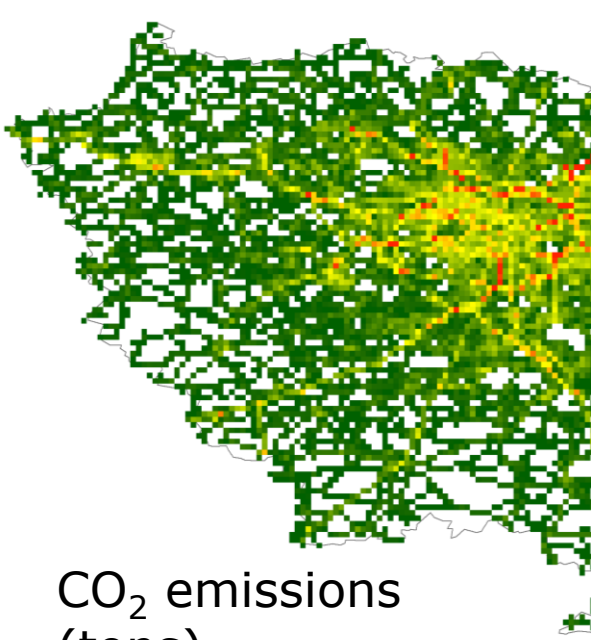
Paris : 2004 road transport CO_2 emissions

European Commission

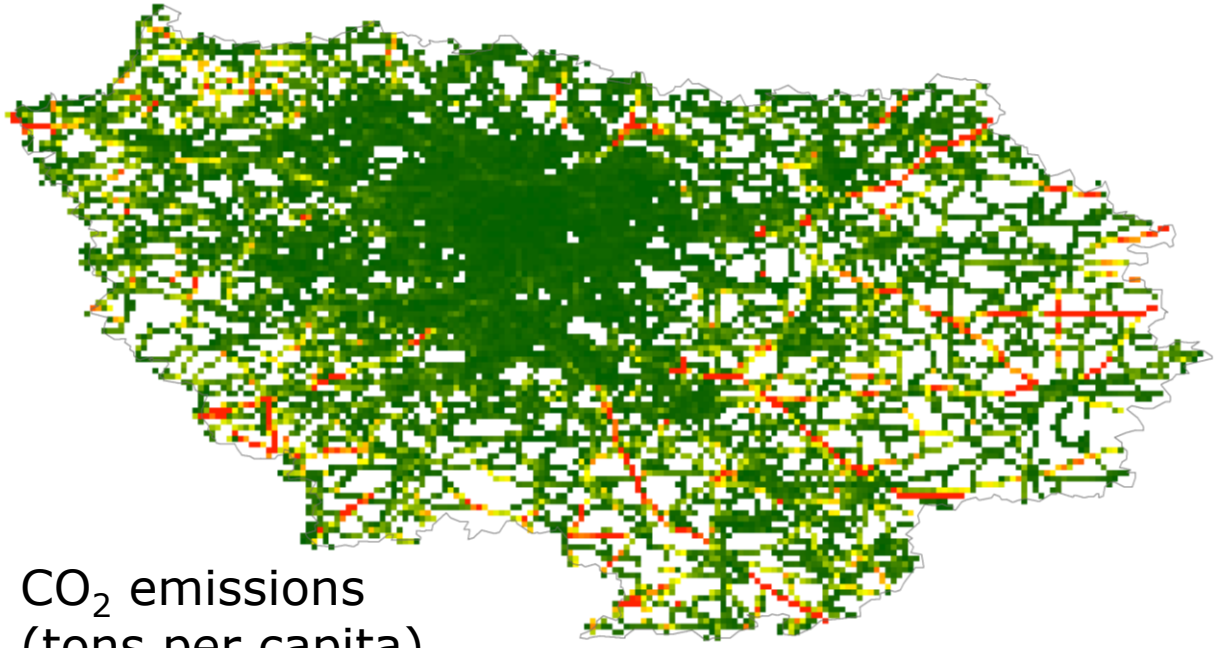
… to compare to existing/**new emission inventories**

2000-2012 EDGARv4.3

- CO_2 kept updated till year – 1
- Resolution: from 0.1x0.1 to **0.01x0.01°**



CO_2 emissions (tons)



CO_2 emissions (tons per capita)

Ile de France : 2010 road transport emissions

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… on the effect of urbanization

Comparison of downscaled global v4.3 inventories at urban scale and bottom-up city inventories

G. Janssens-Maenhout, M. Crippa, F. Dentener, S. Galmarini, D. Guizzardi, A. Iancu, B. Koffi, S. Martelli, M. Muntean

GEIA 2015 Conference, Beijing, November 2015

"Comparison of the CoM and EDGAR emission inventories for the buildings sector of some cities allows an assessment of the ***relation between emissions and demographic characteristics.***

In particular, this serves ***to test the hypothesis that*** *it costs more emissions to build up a city, but from a certain city size onwards, the* ***emissions increase only sub-linearly with the population density"***

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Limitations & Challenges

CoM data potential

- **Clear set of definition of sectors**, but which remain "diffusive" sectors
- **Weaknesses in the reporting** (quality & completeness)
- **Sample representativeness** (population covered, geo-coverage)
- **Consistency/ comparability with EDGAR**
  - Inventory approach, respect of sectors/sub-sectors definitions
  - Need for additional on-line information from CoM signatories (territory area, ..)

EDGARv4.3 downscaling

- Disaggregation in space and in sector leads to **higher uncertainties**
- **Need for more local data** as input (high spatial/ temporal resolution)

Thank you

The EDGAR and CoM teams of the Joint Research Centre

Institute for Environment and Sustainability

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