New challenges when Downscaling Global to Urban CO$_2$ emission inventories

The potential of the Covenant of Mayors initiative


BIPM Workshop
“Global to Urban Scale Carbon Measurements”
30 June - 1 July 2015
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 CO₂ 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) **CO₂ emission inventories** from Global to Urban scales.
Outline

EDGAR : Emission Database for Global Atmospheric Research

- What is EDGAR?
- EDGAR emission inventory approach
- CO₂ emissions : Results from global to national scales

CoM : Covenant of Mayors initiative

- What is CoM?
- CoM CO₂ 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 emission at national scale
- Potential for down-scaling global to urban emission inventories
**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 CO₂ under the EDGARv4.3FT(year-1) update
  - 2005-2050 emission projections UNEP, EC (POLES)
What is EDGAR?

Emissions inventory

Results

Activity Data
TJ/yr  #/yr

Technology (EOP data)
100%

Technology Emission Factors
kton/TJ kton/#

EOP emission Abatements

e.g. Fuel consumption (from IEA statistics)
e.g. Passenger car (e.g. gasoline)
e.g. IPCC 2006

e.g. Gasoline Euro 3

Activity Data
TJ/yr  #/yr

Emission Factors
kton/TJ kton/#

Emissions
kton/yr

Scale emissions on grids

Maps of Proxy

Emissions Grids
0.1° x 0.1°

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,..
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$_2$O, 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° × 0.1° grid
**Zoom for urban areas** on 0.01° × 0.01° grid
Monthly distribution

BIPM Workshop, 1st July 2015, Sèvres, France
What is EDGAR?

Emissions inventory

Results

2008 CO₂ emissions*

*CO₂ long cycle C + peat/forest fire (kg/m²/s)

BIPM Workshop, 1st July 2015, Sèvres, France
Global GHG: EDGARv4.2 versus NOAA satellite measurements

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

NOAA global background atmospheric observation

**Results**

**Emissions inventory**

**What is EDGAR?**

Olivier & Janssens-Maenhout (2012)

Montzka et al. (2011)
National CH$_4$ : EDGARv4.1 versus inverse modeling

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
## Uncertainties in national emission inventories

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

<table>
<thead>
<tr>
<th></th>
<th>CO₂</th>
<th>CH₄</th>
<th>N₂O</th>
<th>VOC</th>
<th>CO</th>
<th>BC/OC</th>
<th>Good statistical infrastructure (¹)</th>
<th>Poor statistical infrastructure (²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry</td>
<td>LM</td>
<td>LM</td>
<td>LM</td>
<td>UM</td>
<td>LM</td>
<td>LM</td>
<td>L &lt; 15%</td>
<td>L &lt; 35%</td>
</tr>
<tr>
<td>Transport</td>
<td>LM</td>
<td>UM</td>
<td>UM</td>
<td>UM</td>
<td>UM</td>
<td>H</td>
<td>15% ≤ LM &lt; 50%</td>
<td>35% ≤ LM &lt; 70%</td>
</tr>
<tr>
<td>Residential</td>
<td>LM</td>
<td>UM</td>
<td>UM</td>
<td>UM</td>
<td>UM</td>
<td>H</td>
<td>50% ≤ UM &lt; 100%</td>
<td>70% ≤ UM &lt; 150%</td>
</tr>
<tr>
<td>Agriculture</td>
<td>UM</td>
<td>UM</td>
<td>UM</td>
<td>UM</td>
<td>UM</td>
<td>H</td>
<td>100% ≤ H</td>
<td>150% ≤ H</td>
</tr>
</tbody>
</table>

(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.

BIPM Workshop, 1st July 2015, Sèvres, France
The Covenant of Mayors initiative

• 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.
Committed taken by CoM signatories

Reduce by at least 20% the CO₂ 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
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 CO₂ emission total from one base year**, which represents unambiguously the starting point for the signatory
**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), CO₂-eq characterisation factors are based on the IPCC 4th Assessment Report (IPCC, 2007)
**Flexibility and simplicity:**
which sectors should be included in BEI?

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

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

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

---

**BIPM Workshop,**
1st July 2015, Sèvres, France
Flexibility and simplicity: Choice of greenhouse gases

Mandatory (T CO₂)
Combustion & Usage of fossil fuels

Recommended only if actions planned in these sectors (T CO₂-eq)
Agriculture (77%)
Industry (8%)
Agriculture (49%)
Waste (31%)
Fugitive emissions (15%)

Share of greenhouse gases - EU27- 2008 (EEA, 2009)
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)
6320 CoM signatories

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

May 2015
3421 Base Emission inventories

CoM Baseline Emission inventories (as of May 2014)

- Small and medium size towns < 50,000 inh.
- Medium Urban Centre size < 250,000 inh.
- Small Urban Centre size < 100,000 inh.
- Large Urban Centre size > 250,000 inh.

**Share of population covered**
- 17%
- 9%
- 16%
- 56%

**Share of signatories**
- 88%
- 5%
- 4%
- 3%

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

CoM Emission Inventory

CoM Status

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

CoM Emission Inventory

CoM Status

Frequency distributions of CoM BEI indicators

As of May 2014

Final energy consumption (energy related sectors) [MWh/yr/capita]

Emission Factors (energy related sectors) [tCO2-eq/MWh]

"Covenant of Mayors: Performance Indicators – 6 Year Assessment", Kona et al. 2015.
CoM 6-year assessment report
JRC report
Kona et al., 2015

CoM Sample 2013
Peer-reviewed publication,
Submitted (ESSD)
Iancu et al., 2015

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/consdata/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.
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
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

CO₂ emissions per capita (tons/yr) – All sectors reported  

Iancu et al., ESSD, 2015

BIPM Workshop,  
1st July 2015, Sèvres, France
## Comparison between CoM data sample and other databases at national level

<table>
<thead>
<tr>
<th></th>
<th>CoM sample</th>
<th>EDGAR database</th>
<th>IEA database</th>
<th>EUROSTAT database</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Complete time series</td>
<td>Complete time series</td>
<td>Complete time series</td>
<td></td>
</tr>
</tbody>
</table>

| **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 |

| **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. | Standard IPCC default emission factors | Country specific emission factors |

---

*Iancu et al., ESSD, 2015*
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.)

<table>
<thead>
<tr>
<th>Country</th>
<th>CoM 2013 Sample</th>
<th>Comparison to EDGAR emissions</th>
<th>Ongoing developments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Italy</td>
<td>1.91 (CoM)</td>
<td>0.96 (nat)</td>
<td></td>
</tr>
<tr>
<td>Spain</td>
<td>1.18</td>
<td>1.17 (CoM)</td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>1.87 (CoM)</td>
<td>1.68 (nat)</td>
<td></td>
</tr>
<tr>
<td>Portugal</td>
<td>1.93</td>
<td>1.93 (CoM)</td>
<td></td>
</tr>
<tr>
<td>G.Britain</td>
<td>1.06</td>
<td>1.06 (CoM)</td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>2.10</td>
<td>2.10 (CoM)</td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td>2.05</td>
<td>2.05 (CoM)</td>
<td></td>
</tr>
<tr>
<td>EU28</td>
<td>1.77</td>
<td>1.77 (CoM)</td>
<td></td>
</tr>
</tbody>
</table>

*weighted according to CoM reference years

Iancu et al., ESSD, 2015
“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
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 ..
... as a function of the city size

CoM Sample 2013

CO₂ emissions (per capita per year) for the **Residential sector (fossil fuels)**

Courtesy of S. Martelli, EU, JRC
CoM Sample 2013

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

Courtesy of A. Iancu, EU, JRC

BIPM Workshop,
1st July 2015, Sèvres, France
... to compare to existing/new emission inventories

**2000-2012 EDGARv4.3**
- CO₂ kept updated till year – 1
- Resolution: from 0.1x0.1 to 0.01x0.01°

**Paris: 2004 road transport CO₂ emissions**

BIPM Workshop,
1st July 2015, Sèvres, France
... 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°**

Ile de France: 2010 road transport emissions

<table>
<thead>
<tr>
<th>CO$_2$ emissions (tons)</th>
<th>CO$_2$ emissions (tons per capita)</th>
</tr>
</thead>
</table>

D. Guizzardi, EU JRC
### 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”
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
G. Janssens-Maenhout, A. Iancu, S. Martelli, D. Guizzardi, B. Koffi

Institute for Energy and Transport
G. Melica, S. Rivas-Calvete, A. Kona, P. Zancanella, P. Bertoldi

Brigitte.koffi-lefeivre@jrc.ec.europa.eu