Discrepancies on community-level GHG Emissions Inventories

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Abstract

Purpose - The purpose of this paper is to investigate the discrepancies among existing Greenhouse Gases Inventory methodologies, particularly those aimed to the measurements of city and neighbourhood level emissions. .

Design/methodology/approach - The paper uses literature review to access information about existing GHG inventory guidances applicable to neighbourhood-level policymaking. The guidances were compared in terms of emissions sources, level of reporting, GHG gases included and ease of use. Finally, a comparative analysis was made, focusing on the problems that arise when using scaled-down data, like Emissions Factors, to calculate indirect, transboundary emissions.

Findings - Existing GHG inventory guidances, tools and procedures favour scaled-down estimations and direct emission sources. However, policy makers cannot rely on scaled-down data from national GHG inventories to take action on a neighbourhood level. As the geographic coverage of a GHG inventory gets smaller, emission activities that occur within the defined boundaries are intrinsically interconnected with 'out-of-bound' areas. In this case, accounting for emissions taking place outside a neighbourhood is not an option, but a requirement.

Research limitations - This paper is essentially exploratory, and comparisons were made only to the most common guidances used by cities to estimate their GHG emissions. It does not cover any guidance that may be under development and thus not made publicly available.

Practical implications - The findings suggest that there is a need to enhance and expand existing guidances, particularly the '*Greenhouse Gas Protocol for Communities*', in order to use city level inventories to guide policymaking in the level of neighbourhoods.

Originality/value - This paper discuss existing guidances and methodologies for the inventory of GHG, in terms of its applicability to neighbourhood-level GHG inventory.

Keywords: greenhouse gases, neighbourhood, urban planning, policymaking

2. Research rationale and conceptual references

2.1 The anthropogenic origin of climate change

Extreme weather events, which have been reported with increasing frequency by several countries, are due to climate change resulting from *global warming*[i]. According to Hansen *et al.* (2010), IPCC (2013), GISTEMP (2015), and NOAA (2015), the land surface temperature increased by 0.74°C ± 0.18°C over the last hundred years, and the average global surface temperatures are the highest in the past five centuries. This is caused by an intensification of the *greenhouse effect*[ii], due to the increased concentration of certain gases in the atmosphere. According to the Assessment Reports from IPCC, it is expected an increase in the (re)occurrence of extreme weather events, such as heat waves and more severe droughts, more intense storms and flooding, rise in sea levels and changes in atmospheric photochemical reactivity.

"Global GHG emissions have grown since pre-industrial times, with an increase of 70% between 1970 and 2004 (high agreement, much evidence). With current climate change mitigation policies and related sustainable development practices, global GHG emissions will continue to grow over the next few decades (high agreement, much evidence)." (IPCC, 2007b). See also IPCC (2013).

From an economic perspective, extreme weather events have significant consequences and might, for example, give origin to outages throughout business supply chains and affect transport networks, ultimately paralyzing the operations of companies. As an example, the study from Marcovitch *et al.* (2011) presents an integrated methodology for systematic assessment of the economic impacts of climate change in Brazil. In this study, losses due to climate change in Brazil are estimated between 0.5% and 2.3% of Brazilian GDP expected for 2050. In addition, the work from Bienert (2014) explores the impact of extreme weather events on real estate property values, and introduces a valuation tool that can be used to calculate these losses.

However, those consequences are not limited to the business environment. The social impacts of extreme weather events and climate change are quite significant, affecting people who are in a condition of greater vulnerability. Populations around the world are already suffering from extreme weather events that directly affect their livelihoods, reducing crops, destroying homes and reducing food affordability.

Over the last decades, global GHG emissions have grown at an increasing rate and, although this growth has slowed down, the long-term trend of emissions is likely to continue. Nevertheless, while the Earth's climate has undergone natural changes throughout its history, the current trend has a markedly distinct aspect: its *anthropogenic* cause.

Anthropogenic GHG emissions happen in virtually all sectors of the economy, and the book from Goudie (2013) depicts several detailed examples of impacts that anthropogenic activities have had over time upon vegetation, animals, soils, water, landforms and atmosphere. These can be such as in agriculture, through the preparation of land and fertilizers use; livestock, through the processing of manure and the enteric fermentation of cattle; transportation, through the use of fossil fuels; waste management, by the means waste is handled and disposed; in forests, through deforestation and forest degradation; and industries, through the production processes of basic materials such as cement, aluminium, iron and steel.

About three decades ago, there was no consensus in the international scientific community about the reality of anthropogenic global warming. However, this situation has changed with the publication of the IPCC reports, and now there is enough agreement in the scientific community on this issue. The IPCC Assessment Reports presents statements that highlight this conviction, such as:

"The current warming trend is of particular significance because most of it is very likely human-induced and proceeding at a rate that is unprecedented in the past 1,300 years." (IPCC 2007a, p.5)

"Global warming is unequivocal and the dangers of inaction have become more serious. The main cause of the warming is, with very high degree of certainty, the emission of gases by human activities, especially the emission of carbon dioxide gases." (IPCC, 2013)

The scientific community has put considerable effort into studying the emissions of GHG from anthropogenic sources, and now it is considered a clear phenomenon[iii]. This is established not only by the references that support the work of the IPCC, but also by independent scientific studies such as Oreskes (2007), Ramaswamy *et al.* (2006), Doran *et al* (2009), Anderegg (2010), Santer *et al* (2012), Santer *et al.* (2013) and Cook *et al.* (2013), which confirmed that climate scientists accepted the anthropogenic causes of global warming as a matter of fact.

2.2 The role of the cities

GHG emissions have global implications, but populations feel their impacts on a smaller geographical scale, at the city level. Studies from Gurjar and Lelieveld (2005) and Gurjar *et al.* (2008) deal in detail with the effects of anthropogenic GHG emissions on cities climate. Also a comprehensive overview of the global impacts of (mega)cities on climate is available at WMO/IGAC (2013), underscoring the impact of cities on climate change. Although there are obvious variations within different stages of urbanization, climate changes occurring in major cities over the past century show similarities in terms of frequency and expected magnitude, in line with IPCC's projections.

Most GHG emissions that contribute to global climate change come from urban areas, although there is no evidence of a consensual percentage of this contribution, mostly due to compatibility issues with existing GHG emissions accounting procedures. Nevertheless, the works of Dhakal (2010) and Hoornweg et al. (2011) gives an extensive comparison on several large cities GHG emissions.

Those GHG emissions are a consequence of human activities developed in the process of urbanization, such as changes in land use, energy applied in construction, increased surface roughness and the release of pollutants. Understanding the dynamics of urban GHG emissions is, therefore, critical to develop mitigation strategies to limit further climate change. When analyzing the estimates made by the United Nations (UN, 2014), a trend of migration from rural to urban areas is evidenced: As of 2014, 52% of the global population lives in urban areas, and this percentage is likely to increase up to 66.4%, with an expectation that the global population reaches 9.55 billion until 2050. For each country, those figures differ in a great extent: in Brazil for instance, 84% of the population currently lives in urban areas, with a projected rate of 86.8% in 2020 and 91% by 2050. In Germany, the present level of urbanization is 74.3%, with an expected rate of 76.4% in 2020 and 83% by 2050.

This urbanization trend has manifold consequences as, *ceteris paribus*, a higher urbanization rate will most likely increase the amount of GHG emissions caused by transport, waste management, construction and other activities (Kojima *et al*, 2001 and Crutzen, 2004). In addition, the urban system can increasingly affect climate dynamics, e.g. the heat island effect. High urbanization rates also indicate that more people will be exposed to extreme weather events, and the quality of life can be negatively impacted, particularly when considering health problems due to high concentrations of air pollutants (Barton, 2009). Nevertheless, when the urbanization process occurs in a planned manner, it can actually reduce the per capita amount of emissions associated with economic activities, as investigated by Kojima *et al* (2001) and Kalnay *et al.* (2003).

2.3 Urban planning, policymaking and Urban GHG emissions

A growing body of scholars and practitioners of the field has studied the costs to society of urban GHG emissions. The work from Smit *et al.* (1999), presents a clear framework to define 'adaptation to climate change', and stresses how IPCC Assessment Reports should address adaptation and mitigation issues. Although adaptation measures help cities to deal with the effects of climate change, only mitigation actions can tackle the long-term influence of urban systems on climate dynamics (Hoornweg *et al.,* 2011). In this sense, local governments should follow a 'Local Agenda 21' perspective, thinking globally and acting locally, pursuing strategies for a low-emission urban development. The Local Agenda 21 is a process of democratic practices regarding sustainability issues. It implies that city officials must be open to share the political competencies of policymaking with civil society organizations.

Unplanned and politically oriented measures concerning the mitigation of urban GHG emissions, such as the untimely imposition of a more restrictive construction legislation, or the establishment of restriction zones for vehicle circulation, often have counterintuitive results. Urban GHG emissions present a complex dynamic and are inherently linked with other environmental, economic and social issues. Therefore, planning and coordination are key to establish municipal policies that harmonize the requirements and priorities of distinct sectors, and are aligned with national and regional climate policies.

City officials have various options for mitigation of GHG emissions, such as increase energy efficiency of buildings, replace fossil to renewable energy sources, replace carbon-intensive fossil fuel, enhance solid waste management, sewage and industrial effluents treatments and foster carbon sequestration measures. Due to heterogeneous urban structures resulting from geographical characteristics, climatic conditions, and different economic and political contexts, the circumstances for low-emission urban development strategies are different among cities. For example, the requirements of a German city affected by severe winter storms are considerably different to those of a city located in tropical region, like São Paulo. In that sense, the development of a GHG emissions inventory establishes a common base to identify best practice mitigation options and helps direct city efforts and financial resources.

3 GHG inventory frameworks

While estimates of GHG emissions at a country or even regional level are available from reliable sources, specific guidances that are compatible with neighborhood-level actions are rare (see Kennedy *et al.*, 2009 and Hoornweg et al., 2011). Existing guidances, tools and procedures emphasize scaled-down estimations, leaving unexplored opportunities to reach an efficient governance of urban GHG emissions at a neighborhood level. Dakhar (2010) discusses with more depth the so far unexplored opportunities for urban carbon mitigation. The establishment of a consistent protocol for quantifying GHG emissions attributable to each neighborhood area within a city would support mitigation policymaking and foster low-carbon oriented urban solutions.

Several international initiatives provide guidance for preparing GHG inventories at a national, regional or, more recently, city level. Kennedy *et al.* (2009) compares methods and approaches used by different cities, and Bader *et al* (2009) present a comparison of the tools used for structuring city-level GHG inventories. Lead initiatives in this direction include the IPCC *International Standard for Determining GHG Emissions for Cities*, the *International Local Government GHG Emissions Analysis Protocol* (ICLEI – Local Governments for Sustainability), the *Baseline Emissions Inventory* from the European Covenant of Mayors, and the recently launched *Global Protocol for Community-Scale GHG Emissions* (GPC).

3.1 IPCC - National Inventory Program

The initial approach promoted by the IPCC was that of establishing national GHG inventories for comparison among the nations (IPCC, 2006). IPCC started its National Inventory Program in 1991, and a Task Force for National Inventories of GHG was established in 1999. The program aimed the development of an internationally agreed methodology to estimate and report net emissions of greenhouse gases at a national level. Countries members of the IPCC were encouraged to apply the methodology, and all Parties under the United Nations Framework Convention on Climate Change UNFCCC should produce their national GHG inventories. This approach, and the subsequent initiatives to national data disaggregation at regional level, have been successful for the purposes that they were designed for, i.e., comparison and alignment of national and regional policies.

However, regardless of the fact that national GHG inventories are comparable, regional inventories are commonly not, mostly because different approaches in the treatment of emissions can be adopted. Therefore, the sum of net emissions from regional inventories is not necessarily equal to the total net emissions estimated in the national inventory. This is because in national inventories emissions offset from one state to another are irrelevant, as the national estimate is generated considering the whole territory. As for the state inventories, estimates can omit emission sources or have double counting.

To avoid problems when using the national guidelines at a city level, the IPCC developed in 2010 the International Standard for Determining Greenhouse Gas Emissions for Cities, a standard that specifies the application of the IPCC Manual at a city level. This was a collaborative effort of the World Bank, the UN-Habitat and UNEP, with several other institutions related to mitigation of GHG from cities. The standard builds on the IPCC National Inventory Guidelines, and but also on the initiatives from GHG Protocol and ICLEI-IEAP. Therefore, it has the same Kyoto gases coverage, emissions sectors and the 'scopes' approach, but offers more clear guidance on what emissions should be included as a scope 3 (indirect) emissions.

3.2 CoM - Baseline Emissions Inventory

The European Commission Covenant of Mayors developed the Baseline Emission Inventory (BEI) to quantify the amount of GHG emissions (reflected in CO2 equivalent) due to energy consumption within the territory of the respective covenant signatory, i.e. a city. The BEI provides knowledge on the nature of the emission sources, and represents a first step that signatories should take to conduct a Sustainable Energy Action Plan (SEAP). This Plan describes activities, periods, responsibilities and measures to achieve the CO2 reduction target by 2020. The BEI is prepared based on the IPCC national inventory methodology, but to calculate the CO2 equivalents users can apply either the IPCC default emissions factors or specific LCA emissions factors. The method focus mostly on energy and has a mixed approach, considering not only direct emissions, but also some indirect emissions from heating, cooling and electricity produced outside the geographical boundaries of the city. In terms of reporting, BEI depicts different categories and sectors, making the comparison with inventories based on other methods a challenging task. Another major difference is that the BEI oblige the accounting of just one of the six Kyoto Protocol GHG, the CO2. It argues that the other gases are of lower importance and may be optionally reported.

3.3 ICLEI - Local Governments for Sustainability

Founded in 1990 as the International Council for Local Environmental Initiatives, ICLEI now becomes known as the Local Governments for Sustainability. It is an international association committed to the sustainable development of cities, having for that several programs related to climate change and urban sustainable development, such as the Climate Mitigation Program, Climate Resilient Communities Program, and the Sustainability Program. Local government officials are encouraged to take steps to achieve GHG reduction targets, which encompass the development of a GHG inventory baseline. Guidance and tools are offered via the ICLEI Green Climate Cities initiative, to help city officials to establish this baseline.

The International Local Government GHG Emissions Analysis Protocol (IEAP) was developed in 2009 following IPCC guidelines. It covers the six Kyoto protocol gases and allows the use of distinct categories and sectors to report the emissions. A 'scopes' approach was adopted, and indirect emissions are accounted only for energy-related emissions, on 'scope 2'.

3.4 GPC - GHG Protocol for Cities

The Greenhouse Gas Protocol (GHG Protocol) is one of the most used references to quantify and manage corporate GHG emissions. Its conceptual "scopes" framework avoid double counting within the same inventory, and served as basis to the ISO 14064-1 standard. This scopes framework is applicable also to city-based GHG accounting and reporting guidances, like the IEAP and IPCC, and constitute the basis of the GPC Protocol.

The GHG Protocol founders started the 'Global Protocol for Community-Scale Greenhouse Gas Emissions (GPC) Project'. The GPC was developed from the knowledge and practical experience previously published by IPCC and ICLEI , and was made in accordance with the Memorandum of Understanding signed in 2011 between ICLEI, C40 Cities Climate Leadership Group, UNEP, UN-Habitat and World Resources Institute. The pilot version of GPC was made available in May 2012 and in May 2013, meetings were held for the establishment of the first version. In June 2013, the pilot version of the GPC was made available for comments. The latest version of the GPC was launched in December 2014 at the UN-COP20 in Lima, Peru. It is expected that, when finalized by the end of 2015, the GPC will harmonize the various methods cities use for tracking urban GHG emissions, replacing IEAP and IPCC guidances.

The GPC considered in its development, the best practices and lessons learned from 35 pilot cities. It is stated that the guidance can be applied not only for cities, but also to smaller geographically limited areas. Literally quoting, "although the GPC is primarily designed for cities, the accounting framework can also be used for boroughs or wards within a city, towns, districts, counties, prefectures, provinces, and states" (GPC, 2014). However, there is no indication of how it should be applied on a neighbourhood level, particularly in terms of obtaining local activity data and specific emissions factor. The future development of the Scope 3 of the guidance goes in this direction, making the use of GPC to neighbourhood inventory feasible.

The Table 01 depicts for comparison the main features of these GHG accounting and reporting initiatives. Although these initiatives include some transboundary (or indirect) emissions, the cities inventories differ either for the calculation methods, inclusion or exclusion of gases, criteria for defining geographical boundaries and a lack of clear definition for the emission sources, thus, a precise comparison among city inventories becomes an almost unfeasible task.

Based on IPCC2006, Gurjar et al. 2008, Kennedy et al. 2009, Hoornweg et al., 2011 Denier van der Gon, et al., 2011 and GPC, 2014

Name	Date	Author	Reporting Focus	Apply to Neighbourhood	Consistency with IPCC emission sources categories	Adoption of in-boundary /out-of-boundary framework	In-boundary emissions	Out-of-boundary emissions	Gases	Detailed guidance on calculation methodologies
IPCC Guidelines for National Greenhouse Gas Inventories	2006	IPCC	National governments	No	IPCC established the default emission factors categories	IPCC emission sources categories include all in-boundary emissions and international aviation and water-borne related out-of-boundary emissions.	Yes	Yes	6 gases	Yes
International Standard for Determining Greenhouse Gas Emissions for Cities	2010	UNEP, UN-Habitat, World Bank and IPCC	Cities worldwide	No	Yes	Yes	Yes	Limited, only upstream embedded GHG emissions	6 gases	No
International Local Government GHG Emissions Analysis Protocol	2009	ICLEI	Local government operations and cities	No	Most part, but Sub-category 'government' not consistent with IPCC categorization	Yes	Yes	Yes	6 gases	Yes
Baseline Emissions Inventory BEI	2010	The Covenant of Mayors Initiative	Cities in the European Union	No	Limited. Does not include industry energy, air transport, water-borne sources. Includes waste but not agriculture, forestry and industrial processes	Yes	Yes	No	CO2	No
Global Protocol for Community-Scale GHG Emissions GPC	2014	C40, ICLEI, WRI	Cities worldwide	Yes (scope 3, future development)	Yes	Yes	Yes	Yes	7 gases	No

4 Research Results

Existing GHG emissions inventories of cities present discrepancies and the resulting assessments (i.e. vulnerability, reduction targets, and benchmarks) may be quite different, invalidating comparisons. These discrepancies are in three extents: which gases to include, what emission sources to consider, and how to consider transboundary (indirect) emissions.

4.1 Kyoto Protocol greenhouse gases

The Kyoto Protocol regulates carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), sulphur hexafluoride (SF6), and nitrogen trifluoride (NF3), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs). It determines specific targets for reducing emissions of the main greenhouse gases, which should be included in a GHG inventory. Some of existing GHG emissions inventories concentrate on CO2, leaving other non- CO2gases out of the inventory. However, non-CO2 GHGs contribute with up to 40% to overall global warming (Rao et al, 2005), and inventories should not omit them. The Urban GHG project contemplates all Kyoto Protocol gases, using the most recent IPCC's Global Warming Potential factors to calculate CO2 equivalents.

4.2 Emission Factors and Activity Data

An emission factor is a coefficient that converts the activity data into an estimate of GHG emissions. EF are usually derived from a regression line through a set of measurements, and can be obtained from several sources, the most reliable source being the IPCC EFDB. According to US Environmental Protection Agency (EPA), *"an emission factor is a representative value that relates the quantity of a pollutant released to the atmosphere with an activity associated with the release of the pollutant."*

By its own nature, it is unfeasible to make direct measurements of all GHG emission sources existing within a city. Therefore, GHG inventories are reliant on estimation methods, such as:

- Emissions factors multiplied by activity data;
- Energy balance (how much of each type of energy was used in the city);
- Simulation model (requires specific activity data, and is more sophisticated); and
- Inverse modelling (using atmospheric measurements to refine further estimation methods).

The choice of the appropriate estimation method depends on local circumstances, including the availability of data, but the major existing guidances apply the emission factor estimation method, and are based on the product of activity data (AD) and emission factors (EF).

A lot of quality research has been conducted to improve the disaggregation of national data for use on smaller scales. Still, when the purpose is to identify activity data at a municipal level, the breakdown of nationwide data, when possible, incorporates high degrees of uncertainty, making those inventories unsuitable to support low-carbon development strategies for cities.

4.3 Transboundary emissions

Existing GHG inventories apply three levels of detail, or scopes. The selection of the scope can vary between guidances and emission sources, leading to comparability problems. A key problem when using existing city level emission inventories is that due to relatively smaller geographic coverage, in-boundary activities for a city can become transboundary activities for a neighbourhood. This means that scope two and scope three emissions may account for a larger percentage in an inventory and should not be neglected.

Existing GHG inventory guidances fail to cover the complexity inherent to indirect, transboundary emissions. The GHG emissions characteristics of each neighbourhood within the city, translated by the local activity data and specific emission factors, should be gathered and made visible by an accessible platform. This would help city officials to map neighbourhood specific needs and propose policies that would be most beneficial to the city as a whole.

4.4 The need for a neighbourhood scale framework

To this day, city policymaking processes concerning GHG emissions, when existent, are reliant on high-resolution data sets and guidances that do not fully account for transboundary emissions, such as transportation, waste management and energy & water generation and distribution.

However, policy makers cannot rely on scaled-down data from national-level GHG inventories, to decide and act locally, on a neighbourhood level. Urban policymaking is regarded on the level of neighbourhoods, i.e. Zoning Master Plans, as instruments to regulate and organize the urban development, divide the city into zones for which specific regulations are set, considering for this the neighbourhood boundary. The use of a neighbourhood scale has several advantages for policymaking and, when compared to larger scales, it shows faster results. The urban system has large amounts of GHG emissions flowing in and out of its administrative and physical limits, and this circumstance has important consequences, not only for policymaking, but also for an effective management of these emissions. An urban system perspective is needed to integrate all GHG emission sources and sinks, in and out of neighbourhood boundaries. Low-emission urban development strategies demand a full range of interdisciplinary, yet coherent information. As the geographic coverage of a GHG inventory gets smaller, emission activities that occur within the defined boundaries became more interconnected with ‘out-of-bound’ areas. In this case, accounting for emissions that occur outside a neighbourhood due to an inward demand is not an alternative, but a requirement.

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[i] The term *climate change* is used to refer to temporal climate variation in global or regional scale. These variations are associated with changes in temperature, cloudiness, precipitation, and other weather phenomena related to their respective historical averages. The term *global warming* was formally used for the first time in 1975 in the article by Broecker (1975). Later, the National Research Council published a study (NRC, 1979 and NRC, 2010) which disclosed the role of carbon dioxide in the atmosphere, being first introduced the term climate change by the scientific community. From this time, became popular the use of the term 'global warming', when it comes to increasing the global surface temperature of the planet, and the term 'climate change' when referring to the effects of global warming.

[ii] The greenhouse effect is a natural process that occurs when some of the infrared radiation emitted by the Earth surface is absorbed by certain gases that are present in the atmosphere. As a result, some of the heat that is not released into space is retained in the atmosphere. The occurrence of this process keeps the Earth at temperatures that allow for the maintenance of life.

[iii] A list of institutions corroborating the statement is available at http://climate.nasa.gov/scientific-consensus