

A Use-Based Analysis of Local-Scale GHG Inventories

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Abstract

As action against climate change is territorialized, moving from global to local efforts, the importance of emission inventories as a planning, reporting and tracking tool must also make the transition, adapting to the specific needs of local authorities. This paper attempts to better understand the requirements posed in developing local-level GHG inventory tools through a use-based approach based on the premise that the utility of GHG inventories that correspond solely to internal uses by local authorities is rapidly diminishing due to the necessity of linking mitigation effort across all levels of government.

An analysis of how local-scale GHG inventories are used at the local and national levels reveals a number of use-based trends. Local GHG inventories can be categorized along two principal axes that influence their structure. First, the division of inventories into two categories based on *internal or external uses* by the local authority influences the required framing concerning scope, reporting and verification. Second, the *perimeter* at which inventories are conducted influences a number of structural issues related to structure and methodology. Further, the design and development of inventories is linked to two key trade-offs to take into consideration: the first functioning across *scales* between *cost and accuracy* and the necessity to avoid second across *uses* between *action and comparability*.

The results of this analysis indicates that in addition to the technical issues of *perimeter* and *use*, normative political choices such as how the responsibility for emissions is attributed play a central role, often defining the *sectors* and the emission *scopes* to be taken into consideration. Given their influence on the structure of local scale emission inventories, it is clear that national governments and international authorities must develop a consensus on these elements.

In order to be considered as credible actors, local authorities must collectively be able to demonstrate that they are able to make, and reach, credible, transparent and measurable GHG emission reduction commitments. This indicates that inventories that are detailed, transparent and comparable are not only necessary, but essential.

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Table of Contents

Introduction	4
1.The Use and Scales of GHG Inventory Tools at the Local Level	5
1.1. Uses of Inventories	7
1.1.1. Internal Use	7
1.1.2. External Use	9
1.2. Perimeter of Inventories	10
2.Structural Elements of Greenhouse Gas Inventories: Theory and Definitions	11
2.1. <i>Whose emissions are being measured?</i>	12
2.2. <i>What is being included in the measuring?</i>	13
2.2.1. Basic Principles: Scopes and Sectors	13
2.2.2. GHG Emission Attribution and Responsibility	15
2.2.3. Concessions and Sub-Contractors	17
2.3. <i>How are emissions quantified?</i>	17
2.4. Verification of GHG Inventories	19
3.Impacts of Choices Concerning Use and Perimeter on Inventory Structure	19
3.1. Impacts of Uses on Structural Aspects of Inventories	20
3.2. Impacts of Perimeter on Structural Aspects of Inventories	25
3.3. What Lessons Can Be Drawn Regarding Inventory Structure?	27
3.3.1. Variables Structure GHG Inventories	28
3.3.2. The Role of Trade-Offs	28
3.4. Next Steps for National and Local Authorities.....	29
4.Towards a “Model” Inventory Framework for the Evaluation of Existing Methodological Approaches.....	30
4.1. Towards a “Model” Inventory Framework.....	30
4.2. Next Steps for Research.....	35
Bibliography:	36

Introduction

The anthropogenic greenhouse gas emissions that contribute to climate change are deeply rooted in many of the processes that are at the heart of economic and social development. While the saying “you can only manage what you can measure” may be overly reductive, it provides an important insight into efforts to reduce greenhouse gas emissions. Reducing emissions requires a detailed understanding of their sources that serves as a basis for actions to achieve development pathways less-intense in greenhouse gas emissions. For over two decades, greenhouse gas inventory tools have been used to assist private companies and national governments to both better understand their emissions profile as well as conform to UNFCCC and Kyoto Protocol reporting requirements.

Recently, action against climate change and the reduction of greenhouse gas emissions has gone through a process of what can be termed “territorialization”. On one hand, many national governments have made, in many cases, binding commitments to reduce GHG emissions, leading to the implementation of policies and mechanisms at the federal or national level. On the other hand, due to a lack of national engagement on the subject, many sub-national regional, state or “local”¹ authorities have taken action. In both cases, local-scale authorities are being recognized as relevant, if not essential, actors, especially in terms of diffuse emissions sources such as transport and buildings. As action against climate change is “territorialized,” moving from global to local efforts, the importance of emission inventories as a planning, reporting and tracking tool must also make the transition, acquiring the ability to function at reduced scales and adapting to the specific needs of local authorities.

This paper attempts to better understand the requirements posed in developing local-level GHG inventory tools through a use-based approach, taking into account three assumptions. First, *the implementation of local actions requires tools calibrated to local uses*. Second, *many existing GHG inventory tools were developed for use at the international / national scales or for private companies* and thus do not always correspond to local needs. Third, *the coordination of local climate policies with national efforts requires consistency between the two systems of measure*.

The paper will address two primary questions with the goal of identifying a path for the numerous efforts to produce local GHG inventory tools to adopt common principles and methodologies to ensure comparability and homogeneity across levels of government, location and time:

¹ “Local” is used, in this paper, in reference to sub-national levels of government, referring primarily to metropolitan areas in the USA or *collectivité territoriale* in France. These areas tend to be characterised by a high level of urbanisation. The following paper does not treat the question of the specificities of rural areas.

- What are the needs of local authorities in terms of greenhouse gas inventories as a tool to inform, implement and evaluate mitigation policies?
- How must GHG inventories be structured in order to respond to the identified needs of local authorities?

This paper explores these issues by taking a use-based approach, focusing on the potential tradeoffs between *cost and accuracy* on one hand and *timeliness of information to support action and comparability* on the other.

Section I explores the potential needs of local authorities in terms of greenhouse gas inventories and how they can be deployed across the territory. Section II presents a short review of the structural issues to take into consideration in the development of GHG inventories. Section III explores how needs influence the structural parameters of inventories and explore the lessons that can be taken from this analysis. The paper concludes with Section IV, describing a possible path forward in developing an open-architecture inventory structure adapted to local and national-level needs.

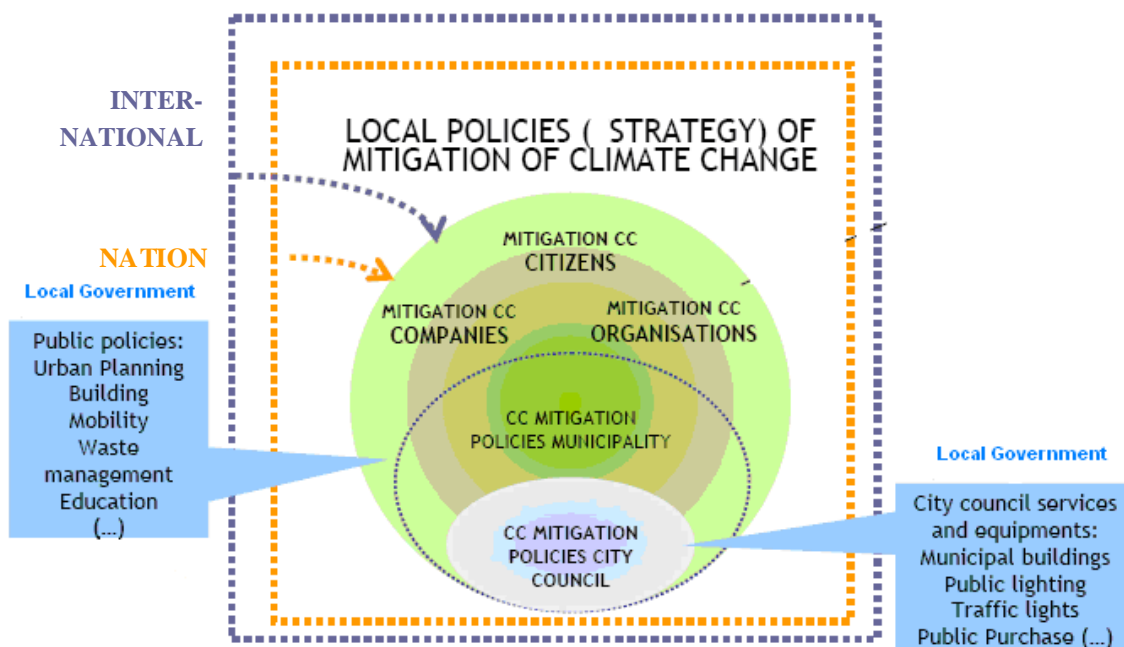
1. The Use and Scales of GHG Inventory Tools at the Local Level

A greenhouse gas inventory functions principally as an informational tool to provide a profile of the sources of anthropogenic greenhouse gas emissions through the identification and quantification of emissions. This information can be used in light of policies established internally by an entity or through policy frameworks established by external bodies. As seen in Figure 1, the range of actors and emission sources found at the local level are subject to mitigation policies originating from different levels of government (international, regional, national, local). The resulting policies and frameworks can include actions ranging from the reduction of operational emissions to the implementation of a system of domestic offset projects. Informational demands of each mitigation policy can influence the overall structure of the inventory required to set baselines, plan actions and track progress.

Given the complex combinations of policies influencing local scale actors, it is relatively surprising that the subject is only cursorily addressed in the literature on greenhouse gas inventories. The literature treating the subject of local/regional-level greenhouse gas inventories is limited primarily to a highly-technical grey literature, either presenting specific approaches or tentatively addressing the methodological difficulties in moving from national systems to the local level. Frequently, the literature focuses more on the politics and difficulty of assigning responsibility for greenhouse gas emissions (Dodman, 2009; Bastianoni *et al.*, 2004) or presents a technical methodology of how to conduct the inventory itself (Kennedy *et al.* 2009; Parashall *et al.*, 2009; Ramaswami *et al.*, 2008; Steinberger & Weisz *et al.*, 2009). While the work is essential in terms of the practical deployment of inventories, relatively little comprehensive analysis of the different inventory approaches and tools is available (Bader & Bleischwitz, 2009; Corfee-

Morlot et. al, 2009; Energie-Cités's 2003). As such, an analysis of the specific uses of inventories and the impact of this on their structure is not readily found in the existing literature. As such, the following section attempts to identify the range of uses and perimeter of deployment of GHG inventories.

Figure 1: Range of Policies Influencing Local-level Emission Sources



Source: Modified from Pon (2009)

An analysis reveals a number of used-based trends concerning the needs of local authorities vis-à-vis GHG inventories. Local GHG inventories can be categorized along two principal axes that influence their structure. First, the division of inventories into two categories based on *internal* and *external uses* influences a number of elements concerning scope, reporting and verification. Secondly, the *perimeter* at which inventories are conducted can vary depending on programs objectives. These divisions are detailed below.

Uses of Inventories

- **Internal Uses**
 - o *Baseline & Planning* – Identification and quantification of emission sources
 - o *Indicator of Progress* – Identification and quantification of changes in emissions totals over time
- **External Uses**
 - o *Voluntary* - Comparative (Policy Sharing), Communication, Non-binding commitments (ICLEI, EU Covenant of Mayors), Voluntary projects
 - o *Compulsory Programs* – Registries , External Cap-and-Trade Mechanisms, Project Mechanisms (CDM, JI - Domestic Offset Projects)

Perimeter of Inventories

- **Project** – includes emissions stemming from specific emission reduction projects
- **Entity** – includes the emissions of the local or regional government as a discrete public entity, thus those related only to their operations²
- **Territory** – includes the emissions from ensemble of activities and entities (both corporate and public) located or functioning within a given geographic area.

The following sections explore these two divisions of inventories related to their use and perimeter of deployment, focusing on local authorities. This section draws on an analysis of climate action plans of three major urban areas (Paris, London and New York – see Box 1), existing national reporting structures and the different internationally-established requirements for participation in existing and planned market based mechanisms.

1.1. Uses of Inventories

While there is a wide range of possible uses of GHG inventories, uses can be grouped principally by whether they correspond to *internal* uses by the local authority or to *external* uses, either by the entity itself or other actors or institutions. It should be noted that, in practice, emissions data is often used for a number of purposes and do not have a single use. Nevertheless, a number of trends can be identified.

1.1.1. Internal Use

Greenhouse gas emission inventories, when appropriately calibrated, can be powerful tools for local authorities in the (1) *planning of mitigation policies* and (2) serving as *indicators of progress* towards established emission reduction goals.

Baseline and Planning

Inventories established for the purpose of establishing an emissions baseline for a project, a city government or a territory are used principally for identifying opportunities for emissions reductions. These inventories function as a snapshot of current emissions disaggregated by a given set of criteria (usually corresponding to the IPCC sectors). This information can be used at the city level to identify cost-effective actions such as through comparison of the marginal cost of abatement across different sectors and between policy choices. As such, it is important that these inventories are comprehensive in order to fully understand the complete emission profile.

² This can equally include the emissions of subcontractors and concession operations under direct or financial control by the local authority entity. However, consensus must be reached concerning how responsibility for these emissions are attributed.

Indicators of Progress

Inventories developed for policy evaluation focus primarily on tracking the progress of policies that have been put into place, often through the use of a planning-focused inventory. A tracking-based inventory would collect emissions data from the sectors upon which the local authority has chosen to focus, attempting to evaluate progress towards mitigation goals and, if possible, relate this to specific policy measures. While it is normally difficult to establish direct links between many mitigation policies and total emission reductions, a tracking inventory can be used more generally in evaluating the effectiveness of emission reduction investments and actions.³

Box 1 : Internal Uses of GHG Inventories – Example of Built Environment

As described above, GHG inventories can serve to both aid in the process of planning GHG mitigation actions as well as an indicator of progress towards meeting mitigation goals and evaluating the effectiveness of different measures taken. Stemming from the analysis of the Climate Action Plans of Paris, New York City and London, a wide range of mitigation policies for implementation have been identified. Table 1 presents the range of actions planned to address emissions from existing buildings in the three cities.

Table 1 : Local-Level Policy Measures: Existing Built Environment

Built Environment - Existing Structures			
Policy Measure	Paris	NYC	London
Energy efficiency schemes within municipal buildings (such as schools)	X	X	X
Thermal renovation of public buildings	X		
Rehabilitation of social housing	X		
Marketing and behavioral change campaigns	X		X
Information provision and counseling	X		X
Social housing and fuel poor program			X
Professional skills training	X		X
Subsidized energy efficiency measures	X		X

Source: City of New York, 2007; Mairie de Paris, 2007; Greater London Authority, 2007.

Emission inventories are an important tool to help in choosing not only between economic sectors, but also between various policies themselves as they often allow an evaluation of their potential. While it is often difficult to identify the exact contribution of a single policy to overall emission reductions, inventories can provide GHG panel data when conducted across time, useful in the evaluation of policy effectiveness.

³ It is difficult to track the direct effects of many policy instruments to reduce GHG emissions as they are usually only one factor among many influencing GHG intensity of certain activities as well as the frequency that the activity is performed. While it is possible to accurately quantify the GHG reductions from, for example, the retrofitting of public buildings using physical data, it is more difficult to calculate the impact of improved financing options for renewable technology deployment over the entire territory.

1.1.2. External Use

External uses represent the second grouping of GHG inventory uses. Local-scale emission inventories can be used externally for *voluntary comparative* or *compulsory reporting* purposes regionally, nationally, or internationally. While serving different purposes, *voluntary* and *compulsory* applications share a number of methodological requirements: both require a high level of homogeneity in both how they are conducted (inclusion of scopes and sectors, quantification) as well as in the data reporting framework.

Voluntary Uses

The voluntary uses of GHG inventories typically occur through formal and informal networks between local authorities. These networks promote the comparison of GHG inventories across local areas as an important means of information sharing, creating opportunities for collaboration. Comparisons allow cities to assess their progress and to compare results and cost-effectiveness of emissions reductions at the sector level with other regions. Cities can also use these comparisons to informally rank themselves with other urban areas with similar characteristics, for example wealth, population, or average climate, etc., and to understand how and why major changes in emissions occur over time (Corfee-Morlot *et al.*, 2009). These can occur formally through initiatives such as the *Covenant of Mayors* and networks such as ICLEI's *Cities for Climate Protection* program, or through informal exchanges.

Compulsory Uses

Compulsory uses of greenhouse gas inventories are those where, either through voluntary “opting-in” or required participation, local authorities must follow specific prescriptive guidelines in establishing and maintaining information on GHG emissions. Two broad categories of compulsory uses exist: national-government programs and carbon-finance-based programs. In the first case, whether in the interest of territorializing national GHG reduction commitments or in using inventories as a basis for allocating performance-based subsidies, local-scale inventories are a key tool for relevant national agencies to track and assist sub-national mitigation progress. When implemented widely, they can potentially be used to understand how different national-level policies influence local GHG emissions, target promising mitigation actions for financing and track progress. In the second case, inventories, and more generally accurate data on baseline emissions and mitigation potential, are key elements for access to financing through carbon finance, such as the Kyoto Protocol's JI or CDM mechanisms, or through structured voluntary markets.

Box 2 : Market-Based Mechanisms and GHG Inventories

At the local level, market-based mechanisms hold substantial potential to play a role in the financing of greenhouse gas reductions. Emission inventories play a key role in these efforts as they serve as a means, once established, to gain access to carbon finance mechanisms.

Project-Based Mechanisms – CDM & JI

Through the project-based Kyoto Flexibility Mechanisms, emission inventories are key components of gaining access to funding for mitigation projects. As these types of project lead to the generation of emission offsets that can be used against the emissions cap, inventories are key in evaluating the emission reductions generated by the projects and ensuring that they do not infringe on the effectiveness of the emissions cap. Verification by an independent third-party is a necessary part of ensuring the accuracy and quality of GHG inventories used for project mechanisms.

Local Cap and Trade Inventories: The Case of Tokyo

While traditionally established nationally or regionally, a movement to local or urban-based cap-and-trade systems in major metropolitan areas may lead to locally established GHG emission inventories for cap-and-trade purposes. In 2009, the Tokyo Metropolitan Government announced its plans to implement a cap-and-trade GHG emissions system at the scale of the metropolitan area. Designed to target the GHG emissions of large-scale commercial properties, the largest and fastest-growing emissions sector in the metropolitan area of 13 million inhabitants, the system's goal is to reduce emission by 25% from 2000 emission levels by 2020. The system requires that the owners of large-scale and commercial properties submit information on past emission in order to establish a cap at 6% below the base year (2008). Trading will occur between covered owners. With a start date of April 1, 2010, it represents the first urban cap-and-trade program of its kind.

Source: Tokyo Metropolitan Government (2009) Presentation to Tokyo Workshop 2009 on Urban Cap & Trade Towards a Low Carbon Metropolis, 3/9/2009.

1.2. Perimeter of Inventories

As indicated above, GHG inventories are accounting tools used to better understand the emissions related to a grouping of different emission sources. In the context of local authorities, these inventories can function to regroup emission sources at different scales. An analysis of the Climate Action Plans of Paris, New York and London demonstrates a broad range of close to 100 different policy actions that can be taken by local authorities to reduce GHG emissions. These policies address both city operations as well as the emissions of the entire territory. From this analysis, it appears that local authorities have three principal options available in meeting emission reduction commitments: they can reduce emissions through the implementation of specific projects; they can reduce emissions from their own operations as an entity or owner; or reduce emissions through policies

targeting the entire territorial/ administrative region over which they have influence as a regulator, policy-making body, or information provider. In all three cases, inventories have an important role in this process.

An inventory conducted using the *perimeter of a project* is developed to include all of the emission sources related to the implementation of a specific mitigation project (such as the deployment of district heating projects or renewable energy technologies). These projects can range in size and in terms of the number of emission sources that fall within their operational boundaries.

An inventory at the *perimeter of an entity* serve to better understand the GHG emissions stemming from the local authority as a corporate entity, regrouping the emissions stemming from the provision of public services and operations.

Inventories using the *perimeter of a Territory* are used as a tool to analyze the emissions of an entire geographical or administrative region over which the local authority has direct, and depending on the juxtaposition between jurisdiction-geographic perimeters, indirect influence.

These different perimeters are in many ways hierarchically nested within one another as a wider perimeter tends to regroup the ensemble of the perimeters below it. For example, an inventory conducted using the perimeter of a territory groups together the ensemble of projects and entities located within the established boundaries. Moving from one perimeter to another can substantially influence a number of structural elements including the number of emission sources covered, the range of actors and institutions involved and how emissions data is estimated and quantified.

2. Structural Elements of Greenhouse Gas Inventories: Theory and Definitions

To understand how inventory use influences structure and form, this section aims first to describe the basic structural components, boundaries and framing elements of greenhouse gas inventories used at all levels of government. Variation of a range of factors can greatly influence the results of a given GHG inventory conducted at any level of detail. Differences in *perimeter*, *sectors* and *scopes*, including the basic question of what gases to include, can skew results and render homogeneity difficult, if not impossible. The following section builds on the analysis by Bader & Bleischwitz (2009) focusing on **whose** emissions and **what** is measured using which **quantification** approach (how).⁴

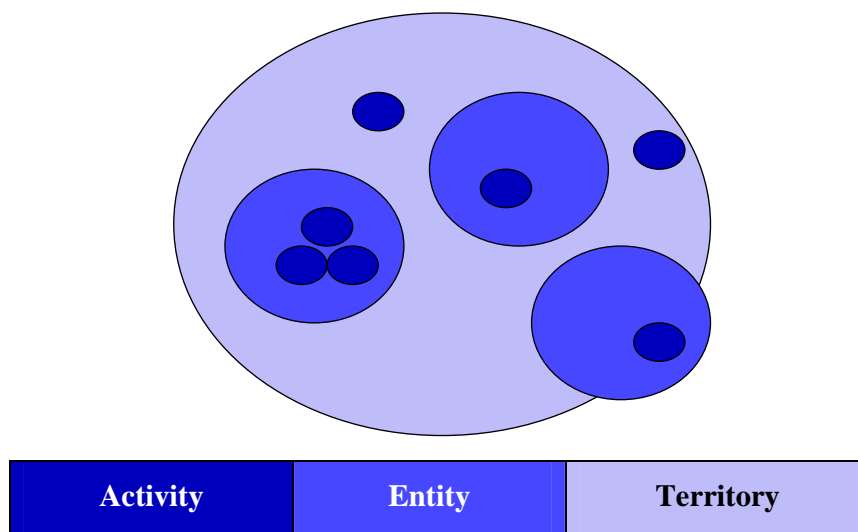
⁴ For a detailed description of the basic notions and methodological challenges of local climate footprint measurement, see Balder & Bleischwitz (2009).

2.1. Whose emissions are being measured?

The basic purpose of a greenhouse gas inventory is to quantify formally the emissions of GHGs resulting from an activity or the ensemble of economic and social activities. At the heart of this process is the measuring of emissions resulting from a single process, or source⁵, however in most cases inventories regroup a number of processes. Inventories take three possible forms in terms of levels of aggregation and coverage:

- **Activity** – regroups the emissions stemming from the various GHG-emitting processes related to the function of an economic or social activity to allow “project” level management;
- **Entity** – regroups the ensemble of activities attributed to the functioning and operations of a given entity (corporate or public);
- **Territory** – regroups the emissions from ensemble of activities and entities (both corporate and public) located or functioning within a given geographic area. Depending on the level of aggregation of inventory data, territory-based inventories can range in scale from a city block, a metropolitan area or the entire country.

Figure 2 – Overlap between GHG Emission Scales



The perimeter chosen for *whose* emissions to include in the above categories typically corresponds to pre-existing geographic, administrative or jurisdictional boundaries. The selection of whom and what gases to include in the inventory is often related, firstly, to exogenously-determined final use, and secondly, to data availability. The existing collection and aggregation of activity and emission data often does not correspond directly to the desired inventory perimeter.

⁵ Emission sources are typically classified as either “stationary” or “mobile” in reference to its relative mobility. For example, a power plant is considered to be a stationary source as it does not “move” and its emissions can be easily attributed to a single geographic location. Conversely, passenger vehicles are classified as mobile sources as they often cannot be easily attributed to a single geographic location. The difference between stationary and mobile sources introduces complications concerning data collection, quantification and assigning of responsibility of GHG emissions.

As each category represents a larger scale and a greater number of sources, the complexity of quantification typically increases due to increased data demands.

2.2. What is being included in the measuring?

2.2.1. Basic Principles: Scopes and Sectors

The decision of what to include in the inventory can vary greatly. The “what” of an inventory can refer to (1) the greenhouse gases included tracked in the inventory, often corresponding to the six principal gases included in the Kyoto Protocol.⁶ Or, (2) the sectors to include in inventories can vary, often following the framework established in the IPCC national Common Reporting Framework.⁷ The inclusion of emission sources and sectors can be based around accounting thresholds. The WRI/WBCSD⁸ outlines two methods of accounting thresholds: *de minimis* and materiality. *De minimis thresholds* define the quantity of emissions that can be excluded from an inventory where emission sources representing less than a given percentage of total emissions can be excluded from the inventory.⁹ However this approach is often rejected due to concerns of completeness. The second approach is based on *materiality thresholds* and is evaluated during inventory verification. This threshold, in the form of a percentage of total emissions, is used to determine if an omission or error will significantly skew inventory results. In both cases, the order of magnitude of emissions heavily depends on the size of entity in consideration such that both percentage and real-emission standards may need to be put into place. Further, both cases are complicated by the need for rough estimates of the sectors and sources not included in order to understand their potential weight vis-à-vis total emissions.

The larger issue of inventories is (3) that of what *emission scopes* to include. As developed by the World Resource Institute and the World Business Council on Sustainable Development’s *Greenhouse Gas Protocol* (WRI/WBCSD, 2004), there are three principal emission scopes: *Scope 1* includes the direct emissions from a project, entity or territory. *Scope 2* includes the direct and indirect emissions produced elsewhere linked to electricity, steam, heating and cooling used by the project, entity or territory in question. *Scope 3* corresponds to direct, indirect and up-stream and embodied emissions of goods and services either consumed in the project, by an entity or within a territory (carbon footprint approach). The choice of what is included in an inventory is linked to its exogenously-established purpose. If an inventory is designed to support management of only those emissions over which an entity has direct operational or financial control, a more limited approach

⁶ The Kyoto Protocol includes the following gases: CO₂, N₂O, CH₄, SF₆ (sulphur hexafluoride), HFCs (hydrofluorocarbons) and PFCs (perfluorocarbons).

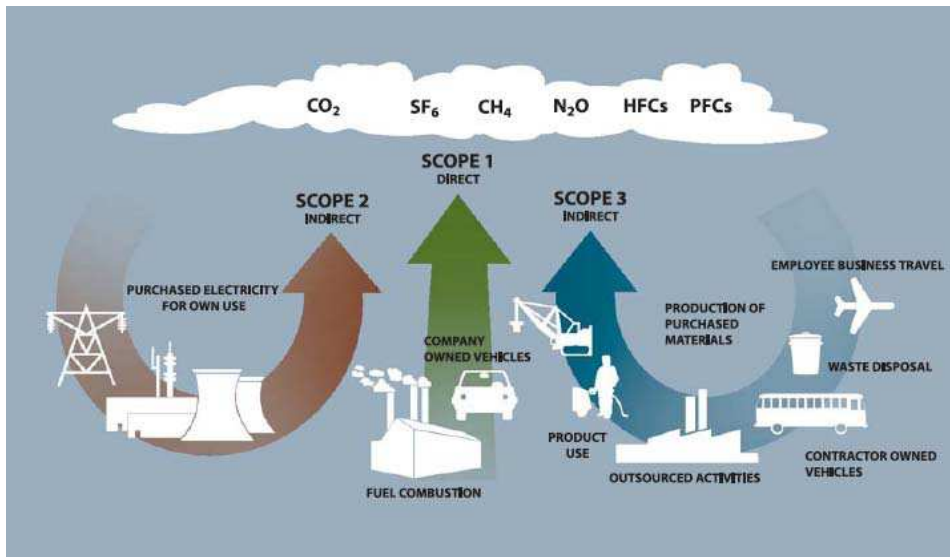
⁷ The IPCC 2006 guidelines include five principal sectors: Energy (including Transportation); Industrial processes and product use; Agriculture, forestry and other land use; Waste; and Other.

⁸ *Measuring to Manage: A guide to designing GHG accounting and reporting programs*, Chapter 4.

⁹ With the condition that the sum of all of these excluded sources is not greater than the *de minimis* threshold

will be taken (principally Scope 1 and Scope 2). However, if the goal is to understand and manage the carbon footprint, or the total GHG emission content (both direct and indirect) of all goods and services produced and consumed by a given person, entity or over an entire territory, a much broader definition of *what* to include will be adopted (mixture of all three scopes).

Figure 3 - Overview of Scopes and Emission Sources



Source: WRI/WBCSD (2004).

Box 3: IPCC Common Reporting Framework

The *IPCC Common Reporting Framework*, most recently updated in 2006, provides guidance for reporting complete, consistent and transparent national greenhouse gas inventories, regardless the method used to produce the data (IPCC, 2006). The guidelines and reporting framework establishes and resolves what is included, and what must not be included, in order to produce comparable information across applications by different countries. In addition to defining what gases should be included and how different anthropogenic emissions sources should be treated, the CMF presents a method of aggregating and reporting GHG estimates into five categories: Energy (including Transportation); Industrial processes and product use; Agriculture, forestry and other land use; Waste; and Other. Each category is then disaggregated into a number of sub-categories corresponding to specific sources, classified by type of activity.

Box 4: GHG Emissions Scopes - The Example of a Hypothetical City Hall

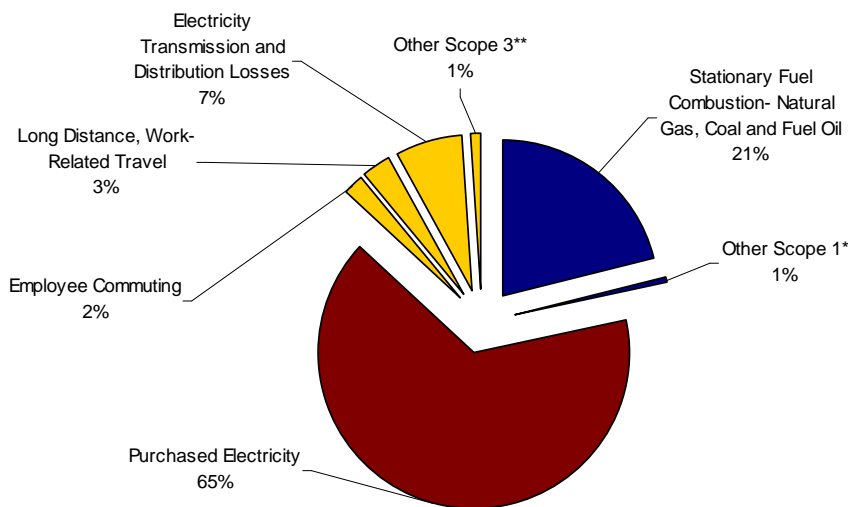
The example of a theoretical “City Hall” is used to better understand how emissions sources can be separated into emission scopes.

Scope 1 corresponds to all direct emissions under the direct control of the City Hall. This includes categories such as stationary, on-site, combustion of fuels in boilers and furnaces for heating, the combustion of fuels by the public vehicle fleet, along with process and fugitive emissions if applicable.

Scope 2 includes the direct and indirect emissions from purchased electricity or steam either from a public utility or from a private producer.

Scope 3 includes the indirect emissions from any other activities that are selected for inclusion in the inventory. This typically can include the upstream and downstream emissions embodied in different products and services consumed or provided, emissions related to the daily commuting of employees, work-related travel not using the official vehicle fleet as well as outsourced activities, waste disposal, etc.

Figure 4: City Hall Emissions by Scope



* Other Scope 1 emission-source categories: Agriculture, City Hall Fleet Vehicles and Fugitive Emissions from Refrigeration equipment.

** Other Scope 3 emission source categories: Solid waste and personal vehicle travel (official City Hall business).

2.2.2. GHG Emission Attribution and Responsibility

The inclusion of different Scopes in inventories is directly related to the attribution of responsibility for greenhouse gas emissions. The principal approaches for attributing responsibility can be divided into either production-based or consumption-based. Clearly assigning responsibility for GHG emissions is key in resolving a number of methodological issues such as double counting. However, it

is rooted in a number of complex normative issues, as it requires a judgment as to whether consumers or producers are primarily responsible for the emissions stemming from the goods and services. Often, a pragmatic “middle ground” can be found when the capacity to actors to mitigate is taken into consideration.

A *production-based* approach allocates the accounting (responsibility) of emissions to the place where they are produced. As such, only emissions generated on a given territory are attributed to the city in its inventory. In this case, the emissions related to production and transportation of imported goods and services (including electricity if imported) are not included and the goods and services produced, but exported to other regions, are included.¹⁰

This accounting method and attribution of responsibility can be considered valid as the economy of the given area is structured around the products producing GHG emissions. In some cases, urban areas have the ability to incentivize the production of goods and services using less GHG-intensive methods. Normatively, production-based methods have been blamed for diverting attention from high-consumption lifestyles as drivers of increased GHG emissions, and practically, focuses only on territorialized aspects of complex product production chains (Dodman 2009:195). As such, production-oriented urban areas are assigned the responsibility for the production of products consumed by service-based urban areas, which, using these methods, appear to have lower overall GHG emissions.

Conversely, a *consumption-based* approach of accounting and responsibility allocates emissions to their point of consumption. The scope of this accounting method is variable in application, ranging from a limited portion of upstream emissions to a full life-cycle analysis. As such, the emissions related to the production, transportation, and consumption of all goods imported into the territory are included, while those goods and services which are *produced for export* are not. In theory, this approach is valid as the production of the goods in the producer region is dependent upon the demand for the product, thus responsibility for the emissions are dependent on the consumers. By attributing these emissions to the consumers, paired with policies to integrate the GHG intensity of the product in to the total cost of consumption, demand-based methods can be used to reduce emissions. Nevertheless, the consumption-based approach has inherently a greater degree of uncertainty as a wider scope of processes and emission sources must be factored into the calculations (Dodman 2009:196) and policy action becomes more complex.

In practice, as established by the principally territory-based IPCC methodology developed for application by national government, a production-based approach dominates most sectors except for the use of consumption-based accounting for Scope 2 emissions (electricity, steam, heat and cooling). However, as in the end the attribution of emissions is a normative issue, it remains a political decision.

¹⁰ This approach is in many ways in accordance with the *Polluter Pays Principle* used in environmental law.

2.2.3. Concessions and Sub-Contractors

The attribution of responsibility of emissions stemming from the concession or “contracting out” of functions by entities (either private or governmental) equally poses a complex question. Determining the responsibility for emissions stemming from concession-granting or the outsourcing of services is increasingly important, particularly at the local level. For example, what percentage emissions should an entity be responsible for if they use a private vehicle service for work-related transport needs rather than maintaining their own fleet of vehicles?

Two principle approaches exist that are rarely, however, applied consistently in practice. Firstly, a financial-based approach considers the equity share of a given entity (e.g. publicly-owned energy production) where the percentage of responsibility for emissions corresponds to the percentage of equity share, thus, for example, 40% of emissions for a 40% equity stake. Inversely, if operational criteria are taken into consideration, entities are responsible only for those emissions over which they have direct control. Thus, the local authority would be responsible for 100% of the GHG emissions from a contracted service provider (e.g. transport services) over which they can require mitigation efforts (i.e. technology changes, etc.). However, if they do not have this direct control, they are responsible for 0% of emissions.

2.3. How are emissions quantified?

While a number of quantification methods exist, the most widespread is that of the *Emissions-factor-based* method. The *Emission factor-based method* uses average data samples concerning specific activities that are used to extrapolate total emissions.¹¹ The quantification of GHG emissions resulting from a given activity is characterized by the below function:

$$E_{g,a,t} = A_{a,t} \times F_{g,a}$$

Where:

E – Emissions of a given gas (g) resulting from a given activity (a) over time period (t)

A – Quantity of a given activity (a) over time period (t)

F – Emission factor (GHG intensity) per unit of activity (a)

Different means of quantifying A and F, based either on estimates, modeling or physical data, introduce varying degrees of uncertainty concerning the accuracy of results. It is important this uncertainty be communicated in the final results.

This formula can also be an interesting method of understanding how different mitigation actions attempt to reduce GHG emissions, focusing either on reducing

¹¹ Four principle approaches can be identified: the Emission factor-based method; the Mass-balance method; the Predictive emissions-monitoring system (PEMS); or the Continuous emissions-monitoring system (CEMS) (2009:12).

overall quantities of a given activity or on reducing the GHG intensity per unit of activity.¹² The accuracy of the emission factor approach is dependent on the calibration of the emission factor used: as explored below, accurate monitoring may require that *context-specific or Tier 3* emission factors¹³ be developed for activities - taking into consideration the specific context and technologies used. While not all emissions factors will need to be updated, Tier 3 emission factors may need to be calculated to ensure accuracy as the greenhouse gas intensity of activities may vary widely over time and across locations as well as be directly modified by policies.¹⁴

While changing the perimeter of emissions inventories, from given activity to entity for example, does not necessarily change the basic calculation used for quantifying emissions, it does, however, have important implications for the collection and aggregation of activity data used in calculations. As mentioned above, moving from one inventory “perimeter” to another increases the number of emission sources involved, whether grouped into projects, entities or territories. While bottom-up, highly-detailed and verified physical data is preferable for calculations as accuracy is concerned, this data is often not available concerning the different sources (fuel-specific consumption, passenger-km, etc.) and can rapidly increase costs as the number of sources increases. As such, it is often necessary to rely on a number of different solutions, including modeling and/or downscaling of top-down statistics. A similar observation can be made concerning different economic sectors as data availability can vary greatly. While often necessary, these approaches can introduce additional uncertainty into the final results as the margin of error increases. As such, the question of data quality demonstrates that a major difficulty in formulating inventories is finding a balance between accuracy and cost and the time necessary to produce the inventory.

¹² For the purposes of this paper, the IPCC terminology concerning emission factor tiers will be used. In this system, three tiers of emission factors exist: Tier 1 factors are taken directly from the IPCC and provide the least accurate estimations as they are often based on rough global averages. Tier 2 factors are established at the national level taking into account national specificities. Tier 3 factors are the most accurate as they take into consideration the actual conditions on the ground, including technologies employed and operating conditions (IPCC, 2006).

¹³ Tier 3 factors will need to be calculated principally for those emission factors represented aggregate characteristics of the entity in question. This corresponds principally to electricity (when it varies from national/regional averages) and the local vehicle fleet (given high levels non-fossil technology, hybrid, biofuels, etc., penetration).

¹⁴ For example, due to policies focusing on the deployment of renewable energy sources, the carbon-intensity of the local energy mix may vary from national and international averages.

Table 2 – Principal Data Sources by Inventory “Scale” Categories*

Project	Entity	Territory
<ul style="list-style-type: none"> • Physical Activity Data** 	<ul style="list-style-type: none"> • Physical Activity Data** • Model Outputs*** 	<ul style="list-style-type: none"> • Physical Activity Data** • Model Outputs*** • Down-Scaled Statistical Data****

* While all methods of calculating activity data can be used at any scale, this table attempts to indicate which are most common at each scale.

** Physical data may include: Electricity, fuel, energy consumption, passenger-km, production values, waste mass, cultivated area, size of herds, etc.

*** Model Outputs are the estimates of activity produced using modeling techniques calibrated to the territory. For example, transport/land-use models can be used to estimate passenger-km traveled at the scale of the entire territory. It is important, however, to establish the margin of error introduced by modeling techniques.

**** The Down-scaling of statistical data (National or International) can be used to estimate the portion of national activity for which the territory in question is responsible.

2.4. Verification of GHG Inventories

The verification of the measuring and reporting process is a key component in identifying both unintentional errors and intentional manipulation. Verification can be performed either internally by the entity conducting the inventory or by an external governmental or private entity. While verification is not necessary for all potential uses, as explained further below, it can catch both technical mistakes as well as deviations from proscribed methodologies. Verification becomes important when financing is involved, such as in the case of national to local financial transfers to support GHG mitigation policies. The critical necessity of verification is especially present in the case of market-based mechanisms where emission permits are given a financial value.

3. Impacts of Choices Concerning Use and Perimeter on Inventory Structure

The above section has identified the principal structural elements of GHG inventories. Nevertheless, a better understanding alone of these elements does not demonstrate why elements often vary between applications of the same, as well as different, inventory methodologies in practice. Unfortunately, the existing literature cannot respond to these issues as they are less related to the technical and methodological questions of how to prepare an inventory as to the issue of *why* an inventory is being conducted, including its ultimate purpose and desired use. This remains a point of contention often with deeply politicized roots. To better understand these issues, Section 3 will explore how the range of potential uses of GHG inventories identified in Section 1 impact inventory structure.

3.1. Impacts of Uses on Structural Aspects of Inventories

As noted above, the various uses can have implications for the structure of inventories. These different uses can imply a number of broad demands on inventory structure, primarily in terms of reporting and verification. These different structural demands summarized in Table 3 are expanded upon below.

Who

While the question of *Who* is principally dependent on the scale of the inventory (project, entity, territory) as described above, the introduction of external uses can potentially add a number of actors. In most cases, both *Voluntary* and *Compulsory Uses* introduce an external coordinator. Whether a government agency as in the case of many compulsory financial assistance programs or non-governmental organization such as ICLEI and many other voluntary uses, external coordinators are typically charged with the collection, aggregation and processing of reported inventory data.

What

As indicated above, the question of *what* is included in different GHG inventories is more related to the normative / political decisions concerning specific programs than individual uses of inventories themselves. As such, it is less important to discuss what scopes and sectors are included than to stress the issue of homogeneity. See Box 5 for a description of inventory uses, structure and homogeneity.

How

How emissions are quantified varies between the different uses. In the case of *Internal* uses, the quantification of emissions, including the data requirements and emissions factors, is closely linked to the issue of the scale of the inventory (project, entity, territory). This holds true for *External* uses, however, it is likely that *Voluntary* uses will have an accompanying recommended methodology for the calculation of activity data as comparative results are built on homogenous GHG accounting methodologies and approaches. Equally, *Compulsory* uses will require the use of approved quantification processes. However, it should be noted that in terms of quantification, there appears to be less of a need for local authorities to employ the same techniques. As reported in Kennedy *et al.* (2009), the use of different quantification methods (in this case the use of directly-measured physical data vs. modeled data) can result in comparable emission totals. However, it will be important for comparative purposes that variations to be noted in any reporting, especially if different emission factors, global warming potential values or other technical details are used.

Variance occurs when the issue of *frequency* of conducting inventories is taken into consideration. While the frequency is likely to be program-specific, a few trends can be discerned that correspond to different uses. In terms of *Internal* uses, it appears that it is more useful for inventories used for *Indicator of Progress* purposes to be conducted more often than those used for *Baseline & Planning* purposes. This is not only related to a need for comparable data across time to track policy progress, but can also stem from the ratio between the relative expensive of *Planning* inventories versus *Indicator* inventories (sectors included, etc.). Equally, *Indicator* inventories should be performed at a frequency that corresponds to the ability for policies to be modified and progress towards mitigation targets observed (often recommended as annually). *External* use inventories, particularly in the case of *Compulsory* uses will have a recommended or required frequency (again, often annually).

Reporting

An aspect in some ways as equally important as the quantification of emissions is the aggregation and reporting of this information. In general, reporting frameworks have adopted many of the basic elements of the IPCC-devised UNFCCC Common Reporting Framework. Nevertheless, different levels of aggregating and disaggregating data can influence the usefulness and policy-relevance of the produced data. As such, there is significant variance between *Internal* and *External* uses.

Inventories conducted for *Internal* uses, whether planning measures or tracking ex post, should adapt approaches to the aggregation and categorization of sectors that respond to specific policy sectors and actions to facilitate the tracking of progress, including: buildings; lighting and traffic signals; water delivery facilities; etc. This type of categorization presents inventory results in a form more conducive to adjusting locally-controlled policies. As a result, they may not precisely follow IPCC-established sectors as they are less useful for local-level use and action. Nevertheless, the association of these categories with the larger IPCC structure should be indicated. An example can be seen in Table 4 from the ICLEI IEAP.

Conversely, homogeneity and comparability are central to *External* use reporting frameworks (see Box 5). If cities are given the flexibility to construct inventories with different boundaries (*e.g.* in terms of reporting direct scopes and sectors), at a minimum for *Voluntary* uses, it will be necessary to report these in a disaggregated, modular manner such that comparable estimates can be constructed from elements with similar perimeters, scopes, sectors and methodologies. This framework will need to be consistent with the IPCC reporting framework, adopted internationally. As such, local inventories that have disaggregated emissions to meet internal needs should clearly indicate their relationship to this system. *Compulsory* uses will require a specific framework that is most likely highly adapted to the purposes of the program.

Table 3 : Structure of Local-Scale Greenhouse Gas Inventories By Use*

Use	Internal		External	
	Baseline & Planning	Indicator of Progress	Voluntary Uses	Compulsory Uses
Why				
Purpose	* Identify internal opportunities for emission reductions * Track and communicate on overall mitigation progress	* Track and communicate on policy progress on selected sectors	* Compare to similar urban areas (policy sharing) * Track & Communicate on progress	* Qualification and tracking for external (regional, national, international) funding programs * Partial Integration into external inventories
Who				
Scale	* Project * Entity * Territory			
Institutions Involved	* Perimeter-Dependent	* Perimeter-Dependent	* Perimeter-Dependent * Voluntary external coordinator	* Perimeter-Dependent * Official External coordinator
Actors Included	* Perimeter-Dependent			
What				
Scopes (WRI WBCSD)	Program-Dependent (Exogenous) However, International Norms Usually Demand: * Scope 1 Direct emissions * Scope 2 Indirect emissions (Electricity, heat, steam) * Scope 3 Other indirect emissions			
Sectors	Program-Dependent: <i>All applicable IPCC sectors can be included</i>			
How				
Activity Data	* Perimeter-Dependent		* Recommended Methodology	* Official Methodology
Recommended Frequency	* Program-dependent <i>However, recommended Multi-Annual</i>	* Program-dependent <i>However, recommended Annual</i>	* Program-Dependent	* Program-Dependent
Relative Data Requirements	* Program-dependent (Exogenous) * Partially Perimeter-Dependent			
Emission Factor	Tier 3 Local emission factors required for some sectors			
Attribution of responsibility	* Program-Dependent * Choice typically left to entity conducting the inventory			
Reporting & Verification				
Reporting	* Disaggregated to local need * Re-aggregated for IPCC categories		* Common Reporting Format (IPCC Compliant)	* Official Reporting Format (IPCC Compliant)
Verification	* Internal * Optional		* Voluntary * Internal or External	* Official external (third-party) verification

* Zones shaded in yellow are elements established principally exogenously, representing political or normative choice.

Table 4 : Example of Disaggregated Local Reporting Framework - ICLEI International Local Governments GHG Emissions Analysis Protocol

Macro Sector (IPCC)		Government Sector (ICLEI)
Energy	Stationary Combustion	Buildings and Facilities
		Street Lights and Traffic Signals Water/Sewer (energy only)
	Mobile Combustion	Vehicle Fleet
		Employee Commute
Fugitive emissions	Other	
Industrial Processes and Product Use		Other
Agriculture, Forestry and Other Land Use		Other
Waste	Solid Waste Disposal	Waste
	Biological Treatment of Solid Waste	
	Incineration and Open Burning of Waste	
	Wastewater Treatment and Discharge	

Source: ICLEI 2009.

Verification

The verification of GHG inventories is an important step in confirming its accuracy and validating its use as a tool for local authorities. Again, differences exist between uses. The verification of *Internal* use inventories, while a useful step, is not completely necessary as this document is to be used primarily as an internal planning and tracking tool. Verification, when applicable, can occur internally and does not necessarily require a third-party independent professional.¹⁵ In terms of *External* uses, the necessity of verification depends on how the reported data will be used for either *Voluntary* or *Compulsory* purposes will most likely influence how verification will occur. In the case of *Voluntary* uses, it remains optional, however recommended, as verification is an important step to ensure accuracy and comparability. In the case of *Compulsory* uses, it is necessary as often these programs involve the creation of financial resources (carbon credits) or the transfer of funds. As such, verification by either a national body or a third-party is necessary.

¹⁵ Nevertheless, the verification of inventories used internally can increase the credibility of actions taken by local authorities across levels of government.

Box 5: Inventory Use, Structure and Homogeneity

Homogeneity is key in assuring comparability of results between applications of greenhouse gas inventory methodologies across both time and between localities. As seen in Table 5, when inventories are used for *internal* planning and indicator purposes, homogenous application is necessary to ensure comparison over time in a single location. Equally, homogeneity is at the heart of *external* uses to foster comparability. When inventories are conducted periodically, homogeneity is necessary to create emission profiles that can be faithfully compared to track changes in profile and policy progress.

Table 5 – GHG Inventory Use and Required Homogeneity

Homogeneity across:	Internal		External	
	Planning	Indicator of Progress	Voluntary	Compulsory
Applications (Location)	NA	NA	Recommended	Mandatory
Time	Necessary	Necessary	Recommended*	Mandatory
* Voluntary reporting is principally based on snapshot comparisons between inventories, although time-series data may also be compared.				

A note should be made, however, that in some cases Emission Factors will need to be updated to accurately reflect changes in GHG intensity of activities. A clear differentiation must be made between the “updating” and the “recalculating” of emission factors. Updating emission factors uses current information on changes in regional or local GHG intensity of activities (energy mix, etc.) paired with the hypotheses established previously to adjust the factors to current conditions. Updating emission factors is a normal process of tracking policies that aim at reducing the GHG intensity of a given activity. Emission factors may need to be recalculated, using new hypotheses, to better reflect both historic and current conditions. This is particularly the case when local authorities implement policies focusing on improving vehicle fuel efficiency and increasing the portion of renewable energies. These policies focus on changing the GHG intensity of a given activity (electricity generation, heating and transport, etc.), rather than focusing on reducing overall activity itself.

3.2. Impacts of Perimeter on Structural Aspects of Inventories

As seen above with changes in use, adjustments in inventory perimeter can substantially influence a number of structural elements including the number of emission sources covered, the range of actors and institutions involved and how emission data is estimated and quantified. This information is described in detail below and summarized in Table 6. As further discussed in Section 3.3, while the definition of perimeter may influence what is included in terms of scopes and sectors, this is more related to the exogenous, normative choices concerning the attribution of responsibility of GHG emissions and the completeness of the inventory than to technical aspects.

Who

Moving from one perimeter to another progressively “casts the net wider,” regrouping a larger number of emission sources. This inherently means that a wider range of institutions and actors become involved in the process.

Inventories using a *project-level perimeter* have, in most cases, the most limited number of institutions and actors involved, as they tend to include only those directly involved in the project itself. This usually includes the participation of the local government itself and, more precisely, the relevant division directly implementing the project.

Entity-level perimeters involve the analysis of emissions from public operations, including those actors over which the entity has direct administrative or budgetary control, such as public buildings, services, concessionaries and subcontractors.

The perimeter of a *territory-scale* GHG inventory in this context is much larger than that of the entity-scale, including public operations, private companies and households. While some variation is inevitable, the perimeter typically includes all entities over which the local authority can exert direct or indirect influence, which may extend beyond officially defined jurisdictions.¹⁶ A region-based approach can be chosen as well, grouping together the emissions of multiple interconnected local jurisdictions.¹⁷

What

While the Scopes covered by an inventory is normally established exogenously as part of a specific program, a number of general trends concerning sectors can be seen due to range of functions normally covered by local authorities. Inventories performed for urbanized areas will most likely be dominated by energy-sub sectors

¹⁶ For example, in some cases local authorities can require the adoption of more stringent building codes, directly affecting the energy efficiency of new construction. Indirectly, they can develop informational campaigns to educate the public on various topics (energy efficiency, alternative transport options, etc.).

¹⁷ For an example of this approach, see the GRIP – *Greenhouse Gas Regional Inventory Project*

with the varying inclusion of the full range of sectors (industrial processes and land use, land-use change and forestry (LULUCF)) when appropriate (Bader & Bleischwitz (2009).

How

Perhaps the largest impact of changing inventory perimeter is the constraints placed on data due to the regrouping of an ever-larger range of emission sources. While the calculation of GHG emissions should ideally depend on physical data from each source, the resulting costs of this approach may outweigh benefits given budgetary and time constraints. As such, as noted in Section 1, different methodological approaches to the calculating of activity data are used as the number of individual sources increases.

As, theoretically¹⁸, *project-level perimeter* inventories regroup the smallest number of emission sources (depending on the project structure itself), they often require the lowest level of data. Emissions are principally calculated from direct physical data with little recourse to modeled or estimated data using updated Tier 3 emission factors calibrated to locally specific energy mixes and GHG intensities.

At the *Entity level*, the quantification of emissions can usually be conducted using principally operations activity data and updated tier 3 emission factors calculated specifically to reflect the GHG intensity of the local energy mix, technologies in use, and vehicle fleet. In general, physical data is relatively available with little need to rely on modeling or downscaled economic statistical data to estimate emissions.

The quantification of emissions at the *Territory level* can typically be conducted using activity data and updated Tier 3 emission factors reflecting the GHG intensity of the local energy mix and vehicle fleet. As it is likely that the aggregation of physical territorial data on energy use and other sectors may not correspond directly to the perimeter of the inventory, different methods of estimating emissions including modeling and economic input-output data can be used to fill gaps. In some cases, such as the transportation sector, modeling can be used to calculate activity data (traffic flows, kilometers traveled, and site categories, for example) used in emission factor-based calculations.

¹⁸ Different program constraints however can lead to the demand for highly detailed data and the recourse to modeled data.

Table 6 – Inventory Structure and Quantification by Perimeter*

Perimeter	Project (Activity)	Public Operations (Entity)	Territory
Why			
Aim	Quantify total emissions from a given mitigation project	Quantify total emissions of public operations	Quantify the total emissions of a given territory
Who			
Public Institutions Involved	* Local authority	* Local authority	* Local authority * Regional authorities (if applicable)
Actors Included	* Division involved in mitigation project * Affected private actors	* Public Employees * Private subcontractors	* Public Employees * Private subcontractors * All residents and businesses
What			
Sectors	* Program-dependent, but range included tends to increase as perimeter increase		
How			
Relative Data Requirements**	Low to moderate	Moderate to Intensive	Intensive
Emission Factors	Tier 3 Local emission factors required for some sectors - emission factors take on a more aggregate form as the perimeter of inventories increase.		
Activity Data	* Physical data	* Physical data * Limited modeled data	* Physical data * Modeled data * Downscaled data

* Zones shaded in yellow are elements established principally exogenously, representing political or normative choices

** "Relative data requirement" is estimated relative to the number of sources included in the perimeter of the inventory. Specific program requirements can, however, substantially increase this estimate.

3.3. What Lessons Can Be Drawn Regarding Inventory Structure?

GHG inventories are an important tool for local authorities in the planning, implementation, tracking and evaluation of GHG mitigation policies. They also represent an important means of linking local-scale action with regional, national and international mitigation efforts if basic requirements of homogeneity and comparability are met. As explored above, an analysis of the structure of greenhouse gas inventories in light of the needs of local authorities indicates that changes in inventory *use* and change in inventory *perimeter* have important implications for their design. However, while a number of characteristics can be strongly linked to scale and use, there are normative elements that are established exogenously that need to be taken into consideration.

3.3.1. Variables Structure GHG Inventories

As presented in Table 7, the variables influencing inventory structure can be divided between those that are normative and established exogenously, and the technical variables that depend on choices linked to the scale of deployment and internal/external use.

Table 7: Variables Influencing Inventory Structure

Normative (Exogenous) Variables	
<ul style="list-style-type: none"> • Attribution of Responsibility • Scopes Included • Sectors + Gases Included 	
Technical (Endogenous) Variables	
Internal / External Use	
<ul style="list-style-type: none"> • Institutions Involved • Frequency 	<ul style="list-style-type: none"> • Reporting • Verification
Perimeter of Deployment	
<ul style="list-style-type: none"> • Actors • Institutions 	<ul style="list-style-type: none"> • Data Requirements • Activity Data Quantification

Firstly, a number of normative, exogenously-determined, variables have a central role in the structuring of inventories. Decisions establishing how responsibility for emissions is attributed; the emission Scopes included; and the sectors and gases included are at the heart of the structure and base architecture. As such, it seems clear that further international agreement on these elements could represent significantly important steps towards harmonization of approaches and methods.

Secondly, the technical, endogenous, variables structuring an inventory are related to how the information will be used, internally, externally or both; and to the inventory’s perimeter of deployment. Changes in *internal versus external uses* can influence the frequency at which inventories are conducted, reporting frameworks as well as the need for verification. Uses can also impact the institutions involved through the addition of an external “coordinator,” either formal or informal, responsible for data collection and review. Changes in inventory *perimeter*, moving from the *Activity* or *Project* scale to that of the entire *Territory*, can lead to changes in the actors and institutions involved, shifts in data requirements as the number of sources increases, and shifts in the methods used to calculate activity data.

3.3.2. The Role of Trade-Offs

The above analysis begins to illustrate the role of trade-offs in the development of inventory tools. As with any policy tool, a careful weighing of the costs and benefits is necessary to ensure that it is both useful and efficient given budget and time constraints present at all levels of government. Additionally, however, the

structure of inventories in terms of *perimeter* and *use* introduce additional trade-offs.

The first trade-off takes the form of an arbitrage between *cost* and *accuracy* when moving across scales. Typically, as the number of emission sources, institutions and actors increases, so does the relative data requirements and thus, in most cases, the cost of data collection and treatment. Theoretically, directly measuring GHG emissions at their source would in most cases produce the most accurate data. However, this is typically the most expensive, time-consuming, method that is often not feasible. As such, a balance between the accuracy of emission estimates and the cost of data collection and processing must be carefully established.

There is equally the potential for a second trade-off to emerge between *action* and *comparability*, apparent in different demands resulting from internal and external uses. While these two uses are not incompatible, the need to produce inventories whose results allow for local-scale *action*, and thus responding to the needs of specific uses and policies, is often presented in opposition with a need for *comparability* in terms of the homogeneity of methodologies as to ensure the value of results for external, comparative, purposes. This tradeoff, however, can be avoided as the standards and protocols established to foster homogeneity must take into consideration the needs of all relevant authorities, both local and national. Care must be given to how comparability is achieved to ensure that emission reductions resulting from local efforts can be related to national and international efforts, thus fostering the credibility and recognition needed while at the same time providing the data necessary for local-scale action.

Finding a means to balance between *cost* and *accuracy* and avoiding the potential tradeoffs between *action* and *comparability* will be an important issue to take into consideration requiring a close analysis of how inventories are specifically used in the policy process at all scales.

3.4. Next Steps for National and Local Authorities

The above analysis points to a few actions vis-à-vis GHG inventories that will be necessary for both national and local authorities if local GHG mitigation action is to be measurable, reportable and verifiable.

In order to be considered as credible actors, local authorities must be able to demonstrate that they are can make, and reach, credible, transparent and measurable GHG emission reduction commitments. As such, it will be necessary for local authorities to demonstrate collectively that their combined efforts lead to real GHG reductions. This indicates that inventories that are detailed, transparent and comparable are necessary that can fulfill the requirements posed across scales of deployments as well as between internal and external uses. The utility of inventories that correspond solely to internal uses is rapidly diminishing due to the necessity of linking mitigation effort across all levels of government.

However, the onus cannot be placed solely on local authorities. Given the range of normative, exogenous, factors that influence the structure of local scale emission inventories, it is clear that national and international governments and organizations must develop a consensus on these elements. Clear messages from these actors on attribution of responsibility, Scopes, sectors and gases will do much in homogenizing methodological approaches and improving comparability across applications. Equally, given the cost and in many cases the non-immediate benefit to local authorities and communities of producing accurate, comparable inventories, national governments must provide the necessary incentives for local authorities to move in this direction.

A promising pathway is making access to carbon finance as well as to financial subsidies contingent on the production of comparable inventories that respond to both internal and external needs. Access to these types of programs typically requires the types of detailed and comparable inventories described above. Given the time required for the development and deployment of greenhouse gas inventory methodologies, this subject must quickly become a priority in discussions at all scales of government.

4. Towards a “Model” Inventory Framework for the Evaluation of Existing Methodological Approaches

As many local authorities have begun to conduct GHG inventories, it is important to understand whether existing inventories sufficiently fulfill the requirements placed on inventory tools for the range of uses. The above sections have laid out the structural issues to be taken into consideration in the development of greenhouse gas inventories and how these are impacted by changes in inventory *scale* and in *use*. The above analysis can be used to formulate a preliminary open-architecture structure to tie all of the potential uses together with a “core” and module-based structure, resulting in a “model inventory” for evaluating the existing methodological approaches.

4.1. Towards a “Model” Inventory Framework

However, before a “model” inventory framework can be established, a few normative assumptions must be made to frame the ensuing analysis.

Firstly, while no norms have been adopted unanimously, it is often the case that a *production-based approach* is taken in the attribution of responsibility of Scope 1 emissions to projects, entities, and territories combined with a consumption-based approach for the assigning of Scope 2 emissions. Further, Scope 3 emissions tend to be included as an optional element as it is not often possible for the entity in question to act directly upon those emissions.

Secondly, the IPCC sectors have been widely accepted as the basis for both guiding what to include and exclude in terms of emissions sectors as well as establishing an aggregated reporting framework.

Thirdly, it is assumed that the perimeter of GHG inventories, in terms of organizational and territorial boundaries, correspond to the local authority's ability to act and directly or indirectly in any significant manner, implement mitigation actions.

Finally, it is assumed that the objective all inventories is to be as comprehensive and accurate as possible in the face of cost efficiency.

Using the above normative assumptions, a number of insights can be drawn concerning the different elements drawn:

4.1.1. Perimeter:

The organizational or territorial perimeter chosen should minimally include all parts of local government under direct operation or financial control. When extended territorially, this should ideally include all entities over which the local authority can exert direct or strong influence¹⁹, which may extend beyond officially defined jurisdictions.

4.1.2. Attribution of Emissions:

While a consumption-based attribution approach may result in a distribution of responsibility for GHG emissions conform to the increasingly internationally-accepted “polluter pays” principle, this approach introduces a level of complexity when applied generally to all sectors. As such, production-based approaches should be used for most sectors, except for electricity and heat, following the recommendation of the WRI and IPCC to use a consumption-based system. Worldwide, there is a movement towards the adoption of cap-and-trade systems (European Union, the United States, Australia) that cover major electricity producers. In places where such systems are in place, assigning responsibility to local authorities and territories only for the portion of electricity emissions they use more closely matches the overall purpose of emission inventories: implementing policies to reduce GHG emissions. Larger cap-and-trade schemes as well as other policy instruments that are typically beyond the jurisdictional control of local authorities are often more suited to promote technology substitutions and the restructuring of production infrastructure towards low-emission pathways. While local inventories should report all emissions stemming from controlled and locally-sited power utilities, responsibility should only be assigned in Scope 1 for the portion of the power consumed either by city operations or by the territory, depending on the perimeter used.

¹⁹ This is particularly the case if mechanisms exist for cooperation between the surrounding communes.

Further, responsibility for transport-related emissions (city as public transport service provider, etc.), should be primarily assigned to municipal authority as, in general, few national policies directly address the demand-side component of these emissions and city officials are usually the most appropriate entities to address this aspect given their ability to foster the development of transportation alternatives.

4.1.3. Emission Sectors:

All applicable anthropogenic emission sectors as defined by the IPCC should be included so that the most accurate and complete emissions profile can be established within the limits of cost efficiency²⁰. In most cases, primary attention should be given to energy-related (including transportation), waste and industrial emission sectors as they will most likely constitute the largest portion of urban inventories.

4.1.4. Scopes:

It is essential for inventories established for the purposes of planning and tracking to include both Scope I and Scope II emissions, with Public Operation emissions serving as a core for territorial-wide totals. Responsibility for electricity emissions should be attributed at the site of consumption, following the rationale cited above. Scope III emissions should be included, when possible at reasonable cost, to understand the full range of emissions from the territory, including those that the local authority may not be able to influence. Care needs to be taken as overlap exists between Public Operations Scope III employee emissions and Territory-wide Scope I transport emissions. Further, an over representation of Scope III emissions over which actors have limited to no control could potentially be counterproductive, contributing to inaction, as it could appear that action could only influence a relatively small portion of emissions.

4.1.5. Methodologies:

Whenever possible, physical data should be used in combination with locally-updated (Tier III) emission factors for energy mixes, etc. It is critical that when emission-factor approaches are used in the quantification of emissions, Tier 3 type emission factors are calculated that accurately reflect fleet composition, fuel mix and electricity GHG intensities.²¹ While modeling may be necessary in some cases (such as estimating territory-wide transportation use and electricity consumption), it is essential for the homogenous methodologies to be applied across updates so

²⁰ As seen in the above sections, there is a constant trade-off between cost and accuracy of inventories.

²¹ This is necessary not only to establish accurate inventories in the first place, but also must be updated to reflect progress in the deployment of renewable energy technologies and changes in GHG intensity in terms of transport technology.

that comparable results are produced that can be used as indicators of progress towards emission goals. If methodologies are changed, in most cases all historic data sets and emission estimates will also need to be recalculated (often costly and time-consuming) to allow comparison across time periods. As indicated above, different methodologies, whether based on physical or modeled data can yield comparable results, which, depending on the purpose of the reporting system, may be sufficiently accurate. However, it is important that deviances from any established methodological norms be clearly indicated. This holds true for other technical details, such as emission factors and global warming potential values.

4.1.6. Homogeneity

Homogeneity in the establishment of the perimeter is necessary to ensure comparability, and when methods diverge, data from both less- and more-inclusive approaches should be reported in a way that at least portions of inventories can be useful for comparative/reporting purposes.

4.1.7. Aggregation and Reporting of Results:

Categories should be established that correspond to local-level policies and actions to facilitate tracking. Nevertheless, these categories should be placed within the larger IPCC-compliant sector divisions to facilitate comparison and integration with national inventories, as explored below. The reporting format is key to comparability, thus the IPCC Common Reporting Framework. Data should be reported in both aggregated and disaggregated forms (when methodologies have varied from norms) following the IPCC sectors and the WRI/WBCSD Scopes. Finally meta-data concerning the urban area, including information on geophysical, climatic, economic and social characteristics, should be included for comparative purposes.

4.1.8. Verification of Results:

Due the important relationship between *verification* and final use of inventory results, this element will most likely remain program-dependent. However, the above analysis indicates generally that for strictly internal purposes, a third-party or independent governmental body is desirable, not necessary (see above). Conversely, the value of these actors becomes clear in the case of *voluntary* and *compulsory* uses, and above all, when market-access is involved.

Table 8: “Model” Inventory Framework

Aim	Quantify the total emissions of activities, public operations and entire territory
Who	
Institutions Involved	<ul style="list-style-type: none"> * Local authority * Regional authorities * National coordinator
Actors Included	<ul style="list-style-type: none"> * Public Employees * Private subcontractors * All residents and businesses
What	
Gases	* 6 IPCC-recognized greenhouse gases
Perimeter	* Project * Entity * Territory
Scopes (WRI WBCSD)	<ul style="list-style-type: none"> * Scope 1 direct emissions * Scope 2 indirect emissions (electricity, steam, heat) * Optional Scope 3 other indirect emissions * Care taken to avoid overlap with Scope 3 Public operations and Scope 1 Territorial emissions (transportation)
IPCC Sectors	All applicable IPCC sectors can be included
How	
Frequency	Annual (flexible depending on use)
Emission Factor	<ul style="list-style-type: none"> * Tier 1 factors recognized internationally (IPCC) * Tier 2 factors for zones that vary greatly from international standards * Tier 3 Local emission factors required for locally-dependent characteristics (heat and electricity, vehicle fleet, etc.)
Activity Data	<ul style="list-style-type: none"> * Physical data * Modeled data * Limited Downscaled data
Attribution of responsibility	<ul style="list-style-type: none"> * Production approach for Scope 1 emissions * Consumption approach (Scope 2 + Transport)
Reporting	<ul style="list-style-type: none"> * Disaggregated to local need * Re-aggregated for IPCC categories
Verification	* Third-party involvement necessary to ensure quality and accuracy especially when financial transfers are involved.

4.2. Next Steps for Research

This research suggests the need for an analysis of the normative and technical aspects of existing inventory methodologies and their ability to respond to the demands of the various uses identified in this paper. In addition to the technical analysis of scales and uses on inventory structure is the need for a better understanding of the political economy of the development and implementation of an inventory architecture that caters to the issues identified above. In the discussion of local-level greenhouse gas inventories, limited capital, both in terms of technical competences as well as the available financial resources has been identified in the literature, principally leading to a call for national governments to assist in the process (Corfee-Morlot *et al.*, 2008).

If comparability and coherent national- and local-level GHG inventory frameworks is a goal, it appears that national or international guidance is needed concerning how the responsibility for emissions is attributed, influencing the emission scopes included, and the perimeter of inventories – both in terms of emissions sectors as well as the appropriate methods of determining administrative and geographic boundaries.

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