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Veolia Environnement

Study Report
Comparative Analysis of Local GHG Inventory Tools

Final report as of July 10th 2009
Study carried out from 1 October 2008 to 31 April 2009

Authors : Nikolas Bader, Dr. Raimund Bleischwitz

For further information please contact:

College of Europe - Nikolas Bader - nbader@coleurop.be (until the end of August 2009), nikolas.bader@coleurope.eu (as of September 2009)

Institut Veolia Environnement - Gaëll Mainguy - gaell.mainguy@institut.veolia.org

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Introduction

"We need many indicators because we have many different purposes—but there may be over-arching purposes that transcend nations and cultures, and therefore there may be overarching indicators."(Donella H. Meadows, 1998)

The importance of cities for mitigating climate change is undisputable: More than two thirds and three fourth of the world's energy was consumed in cities in 2006 and this share has been forecasted to further increase to 73% by 2030 (IEA/OECD 2008, p. 179). Accordingly, cities will have a major role to play in monitoring and reducing greenhouse gas (GHG) emissions and mitigating climate change. If Europe wants to succeed in reducing its CO2 emissions by 20% by 2020, cities will have to align their policies on that goal. Many cities are indeed willing to do so. The adoption of the Leipzig Charter on Sustainable European Cities (2007) and the launch of the Covenant of Mayors (2009) show that many cities are ready to pursue an ambitious climate policy – and may even push the EU to go ahead with its ambitious plans. Such actions may also have an impact on cities outside Europe.

Any action to reduce greenhouse gas (GHG) emissions at local level, however, requires that local governments have a good overview on the emission sources and the respective reduction potentials. Cities need appropriate tools to take a GHG emissions inventory. Recent developments are very promising: International city networks as well as national initiatives have developed such tools at local level - many of which are comprehensive if not sophisticated and display a great variety of different functions.

While there is a growing amount of material available on how to construct and implement mitigation and adaptation policies, there is no one resource that provides a "road map" to this information. Instead, the profusion of information on scientific expertise, tools and best practices form a complex, unstructured, and somehow disconcerting, corpus. Which accounting method should be used? What is the expected efficiency of a specific action? Can it be replicated in another urban context? As illustrated by the succes of the Covenant of Mayors (as of June 2009, 547 cities have joined in just a few months), most acors are seeking help and guidance to elaborate their climate plan and select suitable accounting methods.

In that view this study analysed different GHG inventory tools currently available. How do methodologies which underlie different GHG inventory tools differ? What are the critical variables explaining differences between inventories? Can different GHG inventory tools be compatible – and/or interoperable – and under which conditions?

This study addresses city representatives, policy makers at municipal and EU level, developers of GHG inventory tools and researchers or companies active in the field of local climate change mitigation. It highlights challenges and opportunities towards:

- aligning climate policy with local development
- sharpening the awareness of municipal stakeholders about the links between local activities and climate change
- the development of local timelines and action plans for meeting long term emission reduction targets in line with a post-Kyoto protocol or a 60% to 80% GHG reduction until 2050
- detailed carbon inventories indicating where actions should focus on, i.e. where biggest reduction potentials lie
- realizing cost reductions due to a refined understanding of local energy consumption
- a methodological framework on the basis of which cities can accurately report progress to a third party
- local benchmarks against a city's own historical emissions

The study is structured as follows:

- The first section discusses methodological challenges related to the formation of local GHG inventories. Rather than giving a comprehensive overview on methodological problems, this section mainly highlights some of the central methodological challenges posed by local GHG inventories. This overview indentifies critical variables and is all the more important that it clarifies concepts that are necessary for the understanding of the subsequent analysis.
- In section two, some of the most advanced GHG inventory tools are screened and assessed using a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis. Finally, the paper draws conclusions on the differences between these tools and gives some tentative research and policy recommendations.

1. Basic notions and methodological challenges of local climate footprint measurement

The concept of climate footprint is closely related to that of "carbon footprint". The latter can be defined as "a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product" (Wiedmann/Minx 2007, p. 4). Activities can hereby refer to those of businesses, populations, individuals or organisations. The definition given above limits the scope of carbon footprint measurement to CO2 emissions only. Yet, in the wider sense the term carbon footprint sometimes refers also to CO2 equivalents (Carbon Trust 2008, p. 2), i.e. the global warming potential of different GHG expressed in relation to that of CO2. For reasons of comprehensiveness the term "carbon footprint" will also refer to CO2 equivalents and will thus be used as a synonym for "climate footprint" in the following study.
For cities that are planning to develop an emissions inventory, the question whether they want to include many different GHG emissions or focus exclusively on CO2 is only one of many, often very technical questions, to answer. However, the many issues that the creation of a GHG inventory raises can be summarized in three general questions:

- **Whose** emissions are measured?
- **What** is measured?
- **How** are emissions measured?

The challenges and problems that are linked to these questions are manifold and will be highlighted in the following sections.

1.1 Whose emissions are measured?

The question whose emissions are measured relates to the boundaries of the measurement. Should only the activities of the public authority be measured? Should the emissions caused by all the activities of the city be measured? Should the inventory be carried out within the administrative boundaries of the city or should the emissions of the greater agglomeration be measured? Since there are no legal requirements city representatives have to weigh the pros and cons of different measurement boundaries and then decide in favour of the solution they deem best.

However, in some cases the best solution may not be practical or may be very difficult to implement. Data availability or the challenge posed by different administrative levels may force cities to refrain from pursuing certain options. The issue of the measurement boundaries is therefore closely linked to the one of data availability.

1.1.1 Data availability

The accuracy of an inventory depends to a large part on the data that feed into it. Ideally cities base their inventory on a comprehensive and reliable data set. This presupposes that the national or regional statistical agencies collect data on all GHG emission sources (material flows, emissions from agriculture, industry, power generation etc.) for the local level (villages, cities, regions etc.). Unfortunately, such comprehensive datasets are usually not available for cities or regions.
In the history of national accounting, environmental accounting is a relatively recent development. In the 1980s, Statistics Netherlands developed a "national accounting matrix including environmental accounts" (NAMEA). It combines a traditional national accounting matrix with environmental accounts in physical units. Thus it can highlight how the standard categories of national accounts (such as certain industries or household categories) impact on the environment. Since the mid 1990s Eurostat has been disseminating the practice of NAMEA accounting over the EU.

Air emissions are the most advanced environmental area in NAMEA. Today, all member states compile NAMEA air emissions data (Moll et al. 2009). The definition of industries is also harmonized in the EU in the form of so called NACE codes (nomenclature des activités économiques dans la Communauté Européenne). At national level EU member states thus show a relatively high degree of statistical harmonization (Eurostat 2004).

On global level the process of harmonization is less advanced. However, the United Nations Statistics Division disseminates the practice of environmental accounting and has published jointly with the European Commission, the International Monetary Found, the World Bank and the OECD a Handbook on Integrated Environmental and Economic Accounting (UN et al. 2003).
Whereas at national level the United Nations Framework Convention on Climate Change requires states to take inventory of their GHGs, the data availability on sub-national levels greatly varies among regions and cities. In Europe, the EU Commission has been supporting efforts to develop a "regional accounting matrix with environmental accounts" (RAMEA). As the name indicates, RAMEA is consistent with NAMEA. Its data stem from national and regional accounts. As regional GHG emissions data are often not

available they are disaggregated from national data (Bonazzi et al. 2009). So far (April 2009), RAMEA has only been used in the five regions that were also involved in its development as well as in Italy where RAMEA accounts for the year 2005 are available for all Italian Regions. A simplified accounting scheme is shown below.

		RAM			EA				
		Economic aggregates			Environmental Indicators				
NACE (COICOP)	Sectors	Output	Value Added	Final Consumpt	GHG (CO2 eq)	Acidification (H+ eq)	PM	NMVOC	CO
A, B	Agriculture, hunting and forestry, fishing	2,8	4,0	-	12,2	47,0	24,2	4,6	9,8
C	Mining and quarrying	0,1	0,1	-	0,1	0,1	0,2	0,2	0,0
D	Manufacturing activities	41,2	27,4	-	31,5	21,2	31,3	30,7	2,4
E	Electricity, gas and water supply	1,3	1,3	-	14,3	10,2	4,6	3,2	0,5
F	Construction	5,5	5,0	-	0,2	0,1	2,2	3,9	0,1
G, H	Wholesale and retail trade, hotels and restaurants	14,4	17,8	-	2,0	0,7	0,9	1,7	0,5
I	Transport, storage and communication	6,4	7,1	-	7,0	7,5	13,2	6,9	5,6
J-Q	Other services	28,2	37,1	-	6,2	1,9	2,1	1,3	2,1
07	Transport	-	-	3,4	12,3	9,1	13,3	34,1	70,3
04	Heating	-	-	2,1	14,1	2,1	8,0	1,9	8,0
-	Furnishings, h/hold equipment, house manteinance	-	-	94,6	0,1	0,0	-	11,4	0,7
	Total - Economic Activities	**100,0**	**100,0**	**-**	**73,5**	**88,8**	**78,7**	**52,6**	**21,0**
	Total - Households	**-**	**-**	**100,0**	**26,5**	**11,2**	**21,3**	**47,4**	**79,0**
	Total	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**

RAMEA simplified scheme (data in %), for further information see RAMEA construction manual and
http://www.arpa.emr.it/pubblicazioni/ramea/generale_1052.asp

Below the national level, the EU uses the so called NUTS classification (nomenclature des unités territoriales statistiques). According to population size, territories are grouped in NUTS I (3 to 7 million inhabitants), NUTS II (800.000 to 3 million) and NUTS III (150.00 to 800.000) levels. Below the NUTS level, the EU uses the LAU (local administrative unit) classification. Depending on their population size, cities may fall either within the NUTS or within the LAU classification. Usually, the boundaries are not entirely identical.

For the national level, data on 30 different air pollutants can be accessed via the Eurostat webpage. However, data on air emissions for smaller statistical territories such as LAUs are not always available. Depending on the services offered by the national statistical agencies data may be available or not. In general it seems that for small or medium sized cities data are often not available. According to the International Energy Agency (IEA) there is no international consensus on how to define a city. For the practical reason of data availability the IEA therefore adopts a relatively vague definition in its World Energy Outlook 2008 and refers to cities as "all urban areas, from 'mega-cities' to small-scale urban settlements" (IEA/OECD 2008, p. 181). In the context of this study cities will be defined as public, regional or local authorities below the level of national and/or central government, with a political power of representation derived from an election by an appropriately designated body as the case may be in the different national, regional or local administrative systems.

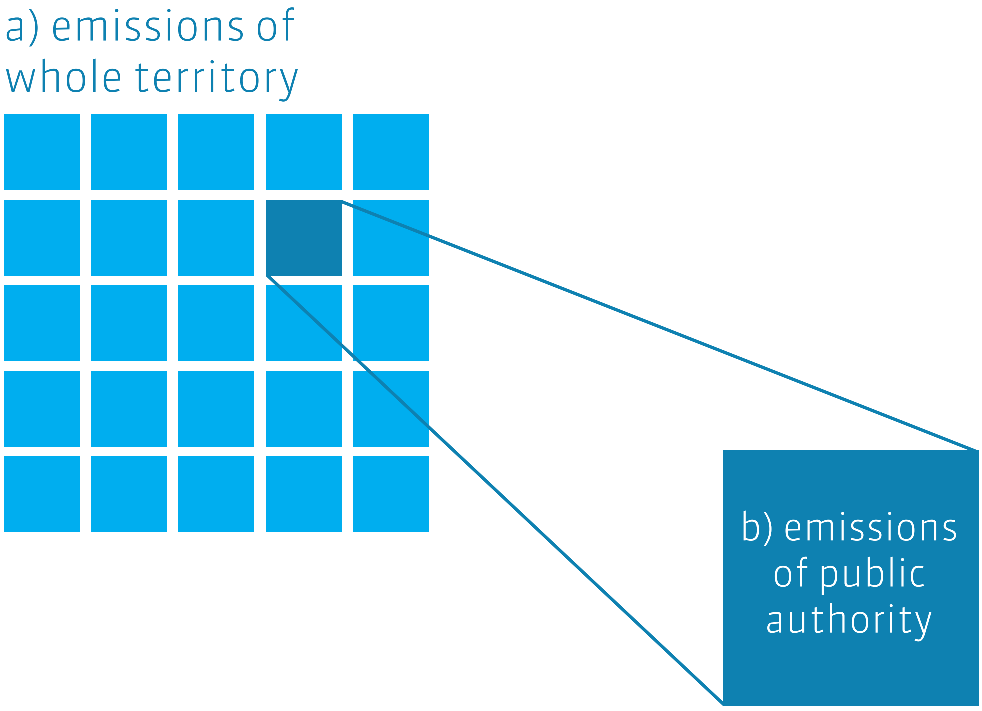
Many cities have started to collect their own emissions data. However, globally there is a clear lack of standard reporting methods (IEA/OECD 2008, p. 181). The EU project "Balance" has therefore recommended developing or selecting a harmonised methodology for the formation of carbon inventories in the framework of the European Energy Award (Balance 2007, p. 34). The International Council for Local Environmental Initiatives (ICLEI) has published an "International Local Government GHG Emissions Analysis Protocol" (ICLEI 2008). The impact that this recent initiative may have also beyond ICLEI members will need to be explored at a later stage.

1.1.2 Defining measurement boundaries

Closely linked to the question of data availability is the question of the scope of the inventory. Cities which plan to take inventory of GHG emissions have typically to decide whether to measure

a) all GHG emissions that fall within the geographic boundary of the territory, including emissions from the private sector and households
b) only GHG emissions that are directly linked to activities carried out by the public authority.

Emissions of the public authority as part of the overall emissions of the territory



Option a) will in many cases be more complicated an undertaking than option b). Yet, it allows taking inventory of the emissions of the territory as a whole. One might argue that e.g. emissions from private cars are not under the control of the local authority and should therefore not be measured. However, even though the local authority cannot prohibit the use of private cars it can nevertheless set incentives to use them in a more efficient manner or less often, to switch to other modes of transportation or set incentives for clean cars. The examples of congestion charges in London or Stockholm have shown that public measures can have an impact on the emissions caused by private transport. Thus there is a case for measuring all local GHG emissions.

Option b) will arguably be in many cases less difficult to implement than option a) given that local governments have relatively good access to the relevant emissions data and almost direct control over the emissions. The emissions of the public authority relate to operations, facilities or sources owned by the local authority or operations for which the city has the right to implement environmental, health or safety policies (operational control).

An emissions inventory can, of course, comprise the emissions from all sectors of the territory (option a) **and** the emissions caused by operations of the local government (option b). Ideally all emissions that fall within the geographical boundaries of the territory

Reporting standards for corporations

The emissions of the public authority can to a certain degree be compared to the emissions of a corporation. Consequently, the basic principles of reporting standards for corporations can be applied. The "Greenhouse Gas Protocol" developed by the World Resources Institute and the World Business Council for Sustainable Development is one of the most widely used reporting standards for corporate and project emissions. The "Local Government Operations Protocol" developed by ICLEI and environmental agencies in California e.g. is also based on the GHG Protocol. It deals with GHG emissions related to government operations and is in theory applicable to all U.S. local governments (California Air Resources Board et al. 2008). The International Organization for Standardization has recently also developed a standard for corporate emissions reporting that builds on many concepts of the GHG Protocol (ISO 14064) and complements its work on a product carbon footprint (ISO 14040; Buser/Lieback, 2008).

should be taken into account when compiling an inventory – including the emissions of the local authority as well as all other sectors (option a and b).

In general local GHG inventories are based on the **territory principle**. This means that the GHG are allocated to the territory where they were emitted. GHG that were emitted within the geographic boundaries of a city must therefore be included in the inventory of this city.

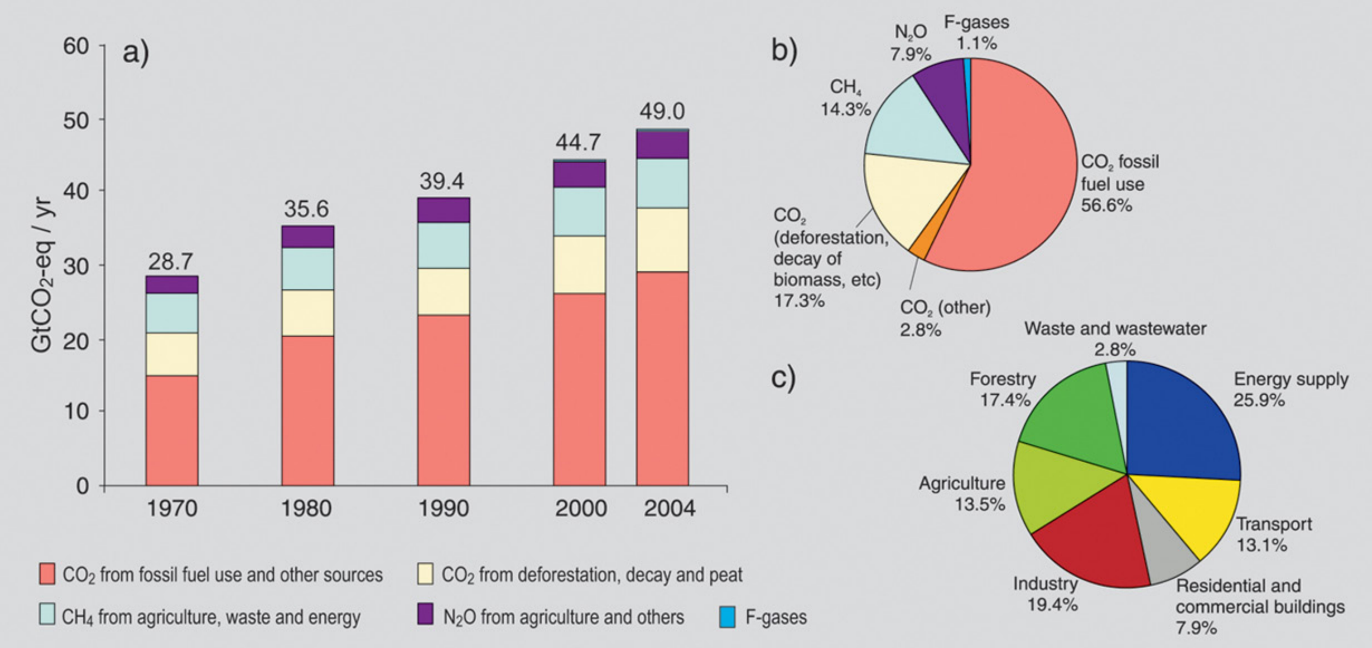
In some cases, however, also GHG that are emitted outside the territory are included in the inventory because the **activity principle** is applied. The activity principle requires that activities of a territory that lead to GHG emissions elsewhere must also be allocated to the territory. This can be illustrated at the example of a local government that purchases cars which were produced elsewhere. The emissions related to the production of these cars are caused by the activity of the city and are therefore incuded in the inventory. Ideally an inventory should comprise the emissions of as many territorial activities as possible. However, in practice this principle often applies only to specific sectors such as the transport sector or emissions of electricity produced outside the territory. A complete application of the activity principle would e.g. require that also emissions caused by the production of all goods that are purchased within the territory are included in the inventory.

1.2 What is measured?

Already small quantities of very potent GHGs such as nitrous oxide can have an important impact on the carbon footprint of communities. Thus, a GHG inventory should ideally cover as many GHGs and emission sources as possible.

1.2.1 Greenhouse gases

The IPCC defines greenhouse gases as "those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect" (IPCC, 2007b). A GHG inventory should focus on anthropogenic, i.e. manmade emissions. Water vapor for instance is the gas that has the greatest impact on the greenhouse effect. However, the atmospheric water vapor concentration is not substantially affected by human activities, thus water vapor is commonly not referred to as a major anthropogenic greenhouse gas.
Some greenhouse gases in the atmosphere are entirely manmade such as the halocarbons and other chlorine- and bromine-containing substances. The Montreal Protocol deals with these gases. The Kyoto Protocol refers to the following gases: CO2, N2O, CH4, sulphur hexafluoride (SF6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs). These six "Kyoto gases" are supposed to be the most important anthropogenic gases with regard to the greenhouse effect (see also table 2, b).



(a) Global annual emissions of anthropogenic GHGs from 1970 to 2004.5 (b) Share of different anthropogenic GHGs in total emissions in 2004 in terms of CO2-eq. (c) Share of different sectors in total anthropogenic GHG emissions in 2004 in terms of CO2-eq. (Forestry includes deforestation.), source: IPCC 2007a, p. 36.

In view of making the climate impact of different GHG comparable they are normally converted to CO2 equivalents. CO2 is thereby the reference gas against which other gases are measured and has a global warming potential of 1. The global warming potential represents how much a certain mass of a gas contributes to global warming compared to the same mass of CO2 over a given time period. It is based on the different times "gases remain in the atmosphere and their relative effectiveness in absorbing outgoing thermal infrared radiation" (IPCC, 2007b). For instance nitrous oxide is 310 times more potent than CO2. A ton of nitrous oxide can thus be converted to CO2 equivalents by simply multiplying it by 310 using the values of the second assessment report (100 year lifetime). The other values can be seen in the table below.

Ideally every inventory should display results in CO2 equivalents. In this respect it is of crucial importance that the sources and values on which the calculation of these equivalents is based are made transparent. This can be illustrated at the example of the time horizon used for the calculation of the global warming potential. Some gases remain only for short periods of time in the atmosphere whereas other gases can remain for thousands of years in the atmosphere. Thus, different time horizons lead to different global warming potentials. Methane for instance has on average a shorter lifetime in the atmosphere than CO2. If the calculation of the global warming potential of methane is based on the second assessment report and a time horizon of 20 years, methane has a global warming potential of 56 (= 56 times greater than CO2). A time horizon of 100 years yields a global warming potential of 21 and a time horizon of 500 years a global warming potential of 6,5 (IPCC, 2007c). Commonly a time horizon of 100 years is used.

In recent years, the IPCC has revised the global warming potential of GHGs every time new scientific results allowed a more precise calculation. The values for the global warming potential of gases are published in the assessment reports of the IPCC (see in particular the section of working group 1). Between 1990 and 2007, the IPCC published four assessment reports. The table below shows how the IPCC updated the global warming potential values in its different reports. Any GHG inventory should therefore be transparent

Gas	Lifetime (years)			GWP over 20 years			GWP over 100 years			GWP over 500 years		
	4th AR	3rd AR	2nd AR	4th AR	3rd AR	2nd AR	4th AR	3rd AR	2nd AR	4th AR	3rd AR	2nd AR
Carbon dioxide	Not given[1]			1	1	1	1	1	1	1	1	1
Methane	12	12	12	72	62	56	25	23	21	7,6	7	6,5
Nitrous oxide	114	114	120	289	275	280	298	296	310	153	156	170
Sulphur hexafluoride	3.200	3.200	3.200	16.300	15.100	16.300	22.800	22.200	23.900	32.600	32.400	34.900
HFC-23 (Hydrofluorocarbon)	270	260	264	12.000	9.400	9.100	14.800	12.000	11.700	12.200	10.000	9.800

with regard to the IPCC report underlying the calculation of CO2 equivalents.

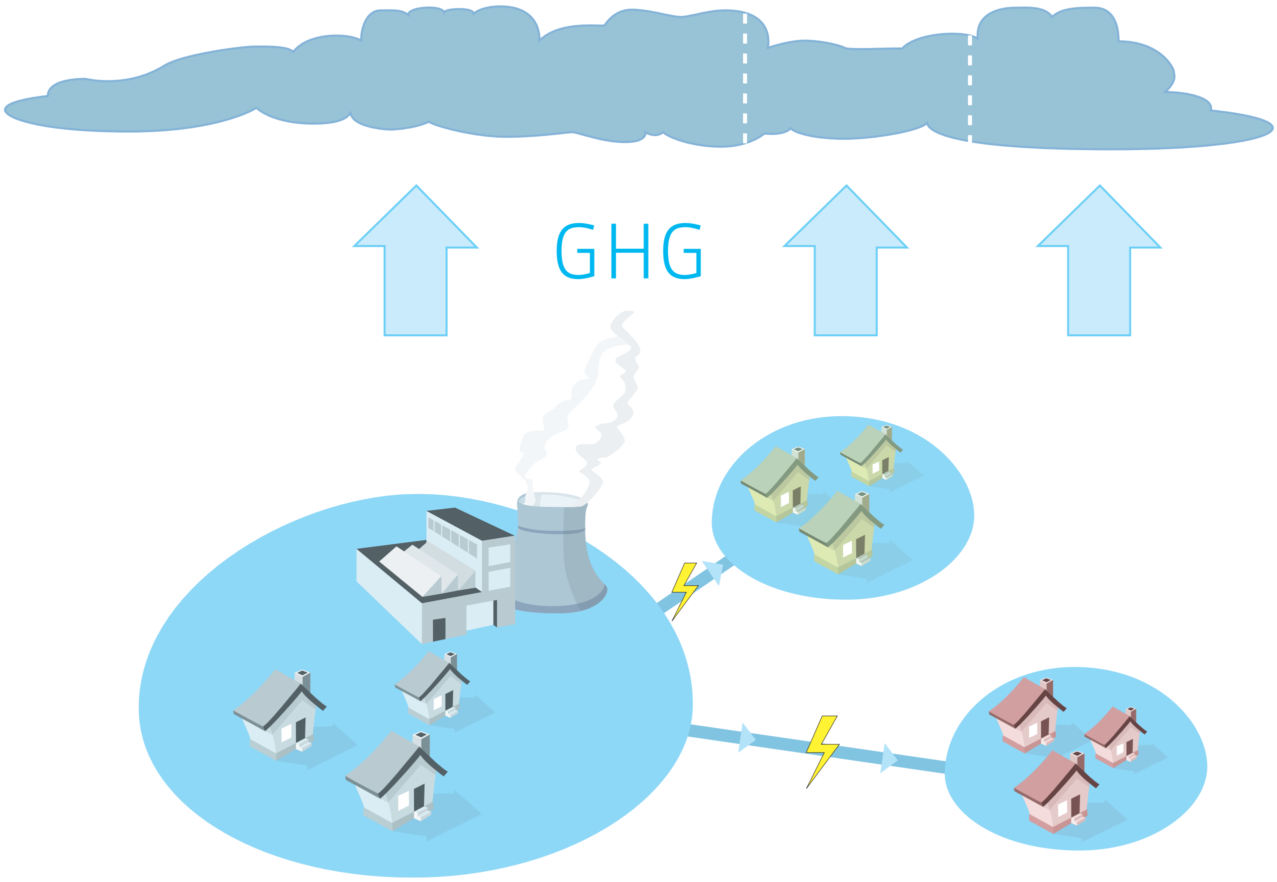
Global warming potential values and lifetimes of different gases in the fourth (2007), third (2001) and second (1995) IPCC assessment report, own compilation, mainly based on IPCC, 2007c [1]

1.2.2 Emission scopes

After deciding on the gases to be included in the inventory, the next step is usually to define emission categories. Emission categories, also called "scopes", delineate emission sources and thus make the measurement more transparent. They help to identify whether some emissions risk to be double counted in different territories and make some basic principles of the inventory clearer. One example for emission categories is shown below. The GHG Protocol Corporate Standard of the World Resources Institute and the World Business Council on Sustainable Development recommends to group emissions in three "scopes". These three scopes were designed for companies planning to take inventory of their GHG emissions (see figure). However, this classification can also be used for GHG emissions of local authorities. ICLEI has based its "International Local Government GHG Emissions Analysis Protocol" largely on the GHG Protocol.

1) Scope 1: Direct emissions, i.e. all GHG that are directly emitted on the territory, such as stationary combustion, mobile combustion, process and fugitive emissions
2) Scope 2: Indirect emissions which result as a consequence of activities of the territory such as emissions due to the generation of electricity, district heating, steam and cooling
3) Scope 3: All other indirect and embodied emissions such as landfill or compost emissions

1. The IPCC does not give a single absolute value for the lifetime of CO_2 in its fourth assessment report (in the second assessment report the value of 50-200 years is given, in the third assessment report 5-200 years). This is due to the fact that a single number might lead to misinterpretation. Different removal processes of CO_2 have different uptakes. About 50% of a CO_2 increase in the atmosphere is likely to be removed after 20 years, a further 30% is likely to be removed in several centuries and the remaining 20% are likely to stay for many thousands of years in the atmosphere, see also Moore, 2008.



The generation of electricity causes GHG emissions. These emissions can be allocated as direct emisssions to the territory where the power plant is located (point of generation). A certain share of these emissions may also be allocated as indirect emissions to the territories that import a certain share of this electricity (point of use).

These three scopes help to group emissions and to avoid double counting within the inventory of a territory. Yet, when several inventories are added together a problem of double counting arises. In fact, unlike companies that normally generate power exclusively for their own use, territories sometimes export electricity. This can be illustrated at the example of a power plant which is located on the territory of city A where it produces electricity. As industry and households in city A do not demand all the electricity produced by this plant a great share of the electricity is exported to city B. All the GHG emissions caused by the plant would be taken into account by city A as direct emissions (scope 1). City B would include the GHGs caused by the production of the purchased electricity as indirect emissions (scope 2) in its inventory. Thus, there would be a problem of double counting.

Whether double counting is or is not a problem depends on the purpose of the inventory. If the inventory is used for reporting purposes (such as reporting to an association of municipal authorities), the approach is commonly well defined by the relevant reporting guidelines. Some reporting guidelines are based on the conception that local inventories should be comparable with the national inventory for the United Nations Framework Convention on Climate Change (UNFCCC) and that the aggregation of all local GHG inventories of a country (i.e. all local inventories added together) should yield the same result as the national report to the UNFCCC. In this case double counting at local level should be avoided.

Other reporting guidelines may follow the approach that all emissions that can be quantified within a specific territory and which are due to the activities of the territory must be included in the inventory. In that respect the problem of double counting or the consistency with the UNFCCC does not matter given that the main aim is to form an inventory which is as comprehensive and detailed as possible. The choices behind different approaches are often normative, practical or a mix of both. In theory there are many different possibilities of forming an inventory (see info-box). If inventories are to be compared across cities it is, however, important that all inventories follow the same approach and the same methodology.

Approaches to emissions accounting

There are many different approaches to the formation of an inventory.

Energy end-use approaches aim to take account of the energy used by final energy consumers. They commonly do not take account of all emissions of the energy chain such as transport losses, refinery emissions or energy conversion losses. End use energy carriers are e.g. gasoline, electricity or heat. They have the advantage that data are relatively easily available. One of the most important drawbacks is that energy end use does not reflect all the emissions of the energy chain. No (grey) emissions are associated with electricity or heat.

Source approaches cover manifold emission sources in the energy chain. In principle all GHG emission sources within the territory are covered. The emissions are allocated to the site where they occur (energy plants with emissions; electricity and heat without grey emissions).

Life cycle assessment/analysis approaches (LCA). Unlike the two before mentioned approaches which normally do not take account of the emissions associated with the use of products LCA approaches aim to take account of the full environmental impact of products, including the GHG emissions and the material input associated with the production of goods. LCA approaches give a relatively accurate picture of the GHG emissions of a territory. However, the inclusion of LCA data in a local GHG inventory is relatively complex and time consuming.

In most cases inventories **combine different approaches** or cannot be clearly associated with one of these three approaches above.

1.2.3 Defining the sectors to be included in the inventory

In view of reducing GHG emissions it is of crucial importance to have a detailed overview of the emissions of different sectors. An inventory that gives only one absolute value for all the emissions of a territory is only of little help for the development of target-group oriented reduction plans. Any strategy to reduce GHG emissions will naturally aim at reducing emissions first in those sectors where reduction costs are relatively low and the reduction potential is relatively high. A break-down of emissions by sectors gives not only a more detailed picture of emission sources it also allows for developing ratios (e.g. GHG emissions per square metre in the buildings sector or emissions per passenger in the public transport sector) and comparing them with the relevant ratios of other territories (sectoral benchmarks) or previous inventories of the same territory (historical comparison).
The inventory should be linked to its purpose and help to form policy. Ideally the inventory should comprise the sectors which are likely to produce the greatest shares of local GHG emissions and have the lowest abatement costs. The importance of sectoral emissions differs from one territory to the other. In some (rather rural) territories the agricultural sector may be very important in terms of GHG emissions whereas in other (rather urban) areas the agricultural sector may be of only minor importance. It is therefore difficult to state in general which sectors should be included in the inventory. Based on their knowledge of the territory the persons who compile the inventory will best know which sectors are likely to be highly relevant. However, certain sectors such as the transport or the residential sector are likely to be relevant for every territory.

The IPCC 2006 guidelines group emissions into five main sectors:
- Energy
- Industrial processes and product use
- Agriculture, forestry and other land use
- Waste
- Other

These sectors were defined by the IPCC for national inventories. Yet, for local inventories these categories may be less useful. Local governments sometimes do not have an agricultural sector nor do they commonly have an energy sector as such. Local governments are more likely to consider sub sectors of the “energy sector” as policy fields such as the buildings/residential sector or the transport sector. The IPCC breaks the “energy sector” down in several sub sectors which in turn have also their own sub categories. Some of these sub sectors and sub categories (e.g. fuel combustion activities, manufacturing industries, transport, residential, commercial/

institutional etc.) may represent better the main emission sources and main policy fields of local governments than the five main sectors proposed by the IPCC for national inventories.
In some cases local governments report their emissions to a third party and use the sector definitions of the relevant reporting guidelines. In other cases the local authority may define sectors according to data availability and practicality. It is therefore questionable whether sector specific results of inventories that do not follow the same reporting principles can be compared.

1.3 How are GHG emissions measured?

A GHG inventory tool should provide guidance to local authorities on how to quantify emissions and make the compilation of the inventory a process as simple as possible. This refers to the quantification of emissions and the usability of the tool.

1.3.1 Quantifying emissions

GHG emissions can be quantified by either directly measuring them or by estimating them. Based on a review of the IPCC 2006 guidelines and guidelines from national government agencies, the World Resources Institute identifies four main quantification methods – the emission factor-based method, the mass balance method, the predictive emissions monitoring system (PEMS) and the continuing emissions monitoring system (CEMS) (World Resources Institute, 2002, p. 20-23).

Quantification methods

- Emission factor-based method: This method is often used to estimate the emissions of large entities, such as cities or countries but it can also be used for small entities. The “emission factor” is a coefficient which quantifies the emissions per activity. Site specific data on the exact quantity of GHG emissions are not needed. Instead, data samples are used that represent the amount of GHG emissions released when a certain activity is carried out under specific operation conditions. The factor-based approach can be written as follows: E = A * EF, where E represents the emissions, A represents the activity data (e.g. fuel consumption or production output) and EF represents the emission factor (expressed in e.g. tons of CO2). The precondition for using this method is of course that emission factors have been calculated for the activity to be measured. As operation conditions differ across countries/sites it may be necessary to calculate site-specific or local emission factors to improve the accuracy of the measurement.

- Mass balance method: The basic idea of this method is to follow the mass flow of an element such as carbon or oxygen through a process. This method can be used if the input/output streams as well as the chemical reactions of a process can well be identified (e.g. for stationary combustion technologies). Its general equation reads as follows: Input = Output + Emissions.

- Predictive emissions-monitoring system (PEMS): This method comprises elements of the direct measurement and the calculation based approach. It requires that for the unit in question a correlation test is made to determine the relationship between process parameters and the level of GHG emissions. The determined correlation serves as input for mathematical models which calculate the released emissions for a given process.

- Continuous emissions-monitoring system (CEMS): The CEMS approach is based on direct measurement of emissions. It allows obtaining very accurate and real-time data.

Depending on the purpose of the GHG measurement different methods may be used. For a voluntary programme which aims at gathering data on a wide range of gases and emission sources, the emission factor or mass balance method may be very suitable given the various sources. If emissions are to be measured in a regulatory framework and thus for mandatory purposes, the methods to be used may be already defined. Some protocols and programs define “tiers” to indicate different levels of accuracy. Normally, three tiers are given whereby the tier three method is the most accurate and the tier one method the least accurate. The IPCC recommends e.g. to use tier two or three methods to calculate the key emission sources of a country (IPCC, 2006).
The methods used may also differ according to the gas to be quantified and the emission source. However, if the main aim of the measurement is to compare emissions from the same type of technological unit in different entities, it may be advisable to use the same or at least very similar methods. If different methods lead to different degrees of accuracy the integrity of the whole pro-

gramme could be affected (World Resources Institute, 2002, p. 24).
Furthermore, the issue of quality control should also be taken into account when opting for one or the other method. If human resources devoted to quality control are limited, those methods which lead to relatively easily controllable results, such as the emission factor method (possibility to double-check!) should be given serious consideration. The cost of the four methods can also vary. The CEMS provides the most accurate data but is also the most expensive option. Emission factor methods are the least costly option and are relatively easy to implement (World Resources Institute, 2004, p. 25). They are therefore often used at local level.

Emission Factors

Many tools provide emission factors in view of rendering the compilation of the inventory easier. GHG emissions can thus be calculated by multiplying specific activity data (e.g. total gasoline consumption within the territory) by the corresponding emission factor. The IPCC provides default emission factors. The use of these **default emission factors** would represent a tier 1 approach, i.e. the least accurate emission estimation.

A more accurate tier 2 approach requires that default emission factors are replaced by **country specific emission factors** which take account of country specific data. For instance a country specific emission factor for fuel combustion would take account of the average carbon content of the fuel, fuel quality, carbon oxidation factors and the state of technology development.

A tier 3 approach would in addition take account of operation conditions, the age of the equipment used to burn the fuel, control technology, operating conditions, the fuel type used and combustion technology. Such an approach represents the most **accurate** emission quantification. However, for many local territories the use of a tier 3 approach might be too complex. For big plants data on plant-specific CO2 emissions are increasingly available.

It is good practice to use the most disaggregated, site and technology specific emission factors available. If a local authority has access to country and regional emission factors, then the regional emission factors should be preferred (IPCC, 2006).

1.3.2 Functions of the tool

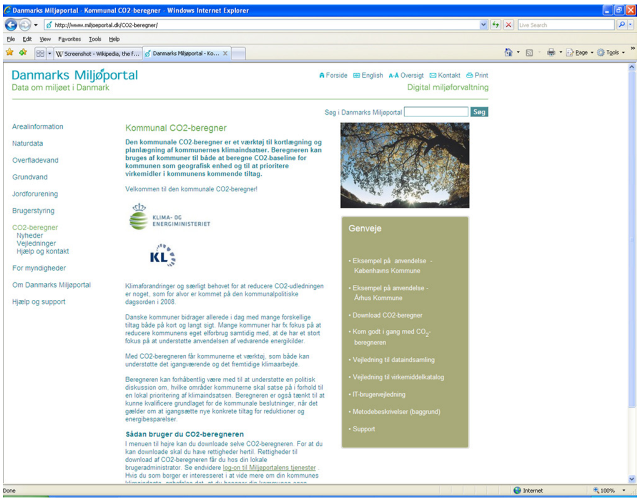
GHG emissions from cities in different countries or geographic settings are difficult to assess and to compare. Cities differ e.g. with regard to the energy system they are part of or their climate. The GHG emissions of the residential sector in northern European cities are typically to a relatively large part due to cold winters. In contrast, GHG emissions from the residential sector in warmer regions can be expected to lie at a lower level.

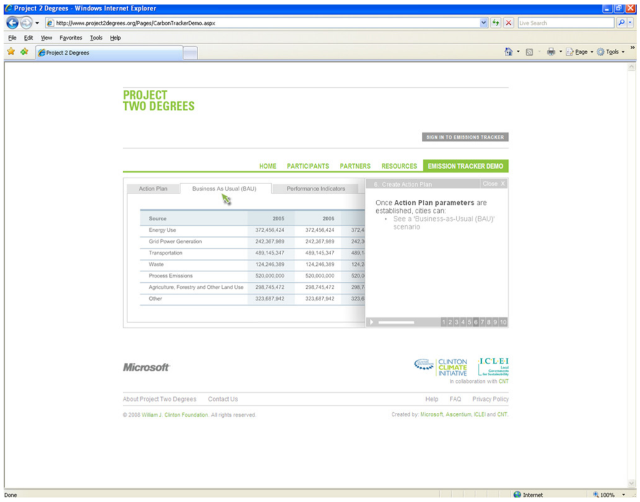
The energy mix of a country can also have great impact on its GHG emissions. In Poland electricity is mainly produced through coal combustion. The average indirect GHG emissions of a Polish city are therefore higher than those of a French city which purchases electricity deriving from nuclear power plants (ceteris paribus).

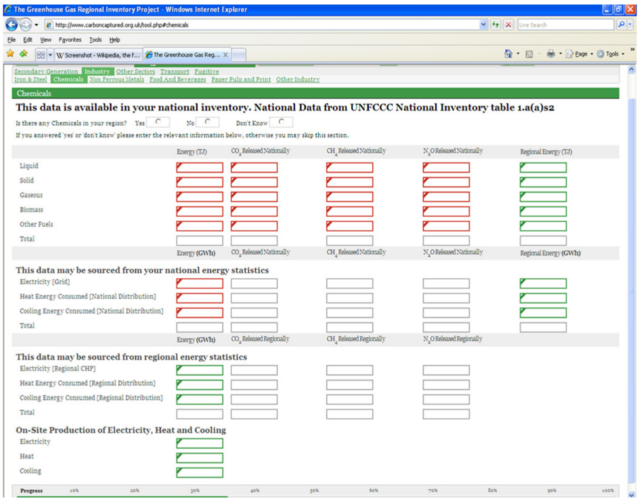
The industrial structure of the urban economy also impacts on the total quantity of GHG emissions measured. An urban economy based on services releases normally less GHGs than an economy of the same size that is based on energy intensive industries. Another example for different emission levels is the structure of the city itself. A city with a low population density and long distances to go may more heavily rely on cars and other carbon intensive forms of mobility than a densely populated city with short distances to go.

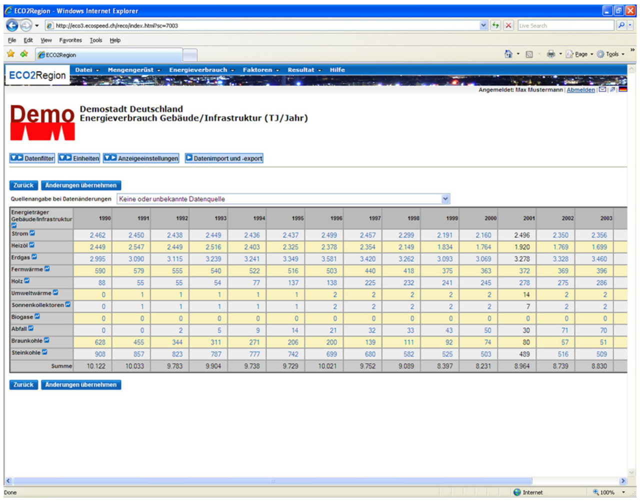
These factors should be taken into account when assessing or comparing the GHG emissions of different cities. Inventory tools may e.g. allow for selecting specific sectors which may be comparable with those of other cities and create ratios (provided of course that the methodology underlying the inventory of the other city is the same). The overall GHG emissions of a city with heavy industry cannot be compared with the overall emissions of a city based on services. However, the residential sector or the transport sector may well be comparable.

The purpose of local GHG inventories is to help cities and regions to reduce emissions. The condition sine qua non of any action plan is that the local government has a good overview on the overall emissions and the emissions per sector. This should be the basic functionality of every tool. Yet, some additional functionalities can be of great added value. Some tools can e.g. be used to analyse the impact of different measures. City officials may e.g. have the following question: How many tons of CO2 equivalents could we save if we improved the insulation of buildings? How many tons of CO2 could we save if, alternatively, we installed more modern gas heating systems in buildings? Some tools allow for comparing the effect of both options. Many other functionalities are of course also conceivable.









1.3.3 Usability of the tool

Whether or not a local authority is successful in compiling a GHG inventory depends to a large extent on the usability of the tool. As shown above, it is a rather technical and sometimes difficult undertaking to form an inventory. A user friendly user interface, well written guidance documents or trainings are therefore very important factors for the success of this undertaking.

The user interface of a tool can have the form of Excel sheets or be Windows like, the latter being presumably more user friendly, even more so if it can be accessed via the internet. The tool may furthermore offer a help desk. Some tool developers provide very detailed and well written guidance documents which explain the methodology, the calculation of emission factors and the compilation of the inventory. In some cases the developers of the tool offer also training courses for users.

Finally, the price of the tool can also have great influence on the decision of a local authority to compile an inventory. The price may include the software package for an unlimited timeframe or it may limit the use of the tool to a specified timeframe (e.g. licence for 1 year). Additional costs to be taken into account are the costs of trainings (if offered), other forms of support and the costs related to the working time of the official who uses the tool. The latter is likely to be the biggest cost factor in most cases. Thus the overall cost of compiling an inventory is to a large part linked to the duration of this process and the relevant working time needed.

1.4 Conclusions on main variables between local inventories and tools

The first section has highlighted several methodological challenges related to the formation of local GHG inventories. Already small methodological differences can greatly complicate the comparison of results obtained with different tools. In addition to methodological differences, tools may differ with regard to their usability.

The table below summarizes some differences related to accounting practices:

Variable	**Example of variation**
GHG measured	Only CO2 is measured ⇔ all GHG are measured
Global warming potential values	Global warming potential values derive from second IPCC assessment report ⇔ values derive from fourth IPCC assessment report
Boundaries	only operations controlled by the public authority are measured ⇔all GHG emitting activities of the city are measured
Scope of the measurement	measurement takes only direct emissions into account ⇔ measurement takes direct, indirect and life cycle emissions into account
Sector definitions	different definition of specific sectors such as the transport sector
Quantifying emissions	Default emission factors are used ⇔regional/local emission factors are used

In addition, software tools may differ with regard to their price and usability:

Variable	**Example of variation**
Price	software use for free ⇔ use of software is costly
User interface	Excel sheets ⇔ interface similar to Windows
Access	Accessible through the internet ⇔ not internet based
Language	available in English only ⇔ available in several languages
Guidance	guidance to use the tool is provided (courses) ⇔ no guidance provided or necessary
Scenarios/Forecasts/Measures	Software helps to compare and select measures to reduce climate footprint ⇔ no such functionality available
Transparency	the methodology underlying the inventory is transparent

These variables will guide the analysis of the different software tools in section two.

2. Analyzing GHG inventory tools

Following the conclusions of section 1, the subsequent chapters will analyse different tools for the formation of local GHG inventories. The analysis is structured in chronological order, with the tools that have been in use for the longest time being dealt with first. This analysis is based upon the methodological guidance documents of the tools, test versions of the tools and semi standardised interviews with developers of inventory tools and may need further feedback from users.

2.1 The "CO2 Grobbilanz" and the "EMSIG" tool (Klimabündnis Österreich, Energieagentur der Regionen)

The "EMSIG" (Emissions Simulation in Gemeinden) was developed in 2002 by the "Energieagentur der Regionen" (energy agency of the regions) in Austria. Since then the tool has been refined. In 2006 a simplified version of the tool, the so called "CO2 Grobbilanz" was developed jointly with the "Klimabündnis Österreich (Climate Alliance Austria) in view of meeting the needs of communities for a tool that is easy to use. The rationale for developing the CO2 Grobbilanz was to take account of the GHG emissions generated by cities and to learn more about the different reduction measures that could be taken in consequence. The CO2 Grobbilanz can be used in two modes, a standard mode and an expert mode which is more detailed. The standard mode of the CO2 Grobbilanz has been used in around 70 communities, the expert mode has been used in around 35 communities and the EMSIG tool has been used in 15 communities.

Whose emissions are measured?

The tools can in principle be applied to any entity provided that the basic data are available. The tools have been used by relatively small communities (around 1.000 inhabitants) as well as by larger communities. The emissions controlled by the public authority can be measured as well as the emissions of the whole territory. The tool is based on data and emission factors for Austria.

What is measured?

The CO2 Grobbilanz takes account of three gases: CO2, methane and nitrous oxide. The EMSIG tool takes account of all the six Kyoto gases as well as of other gases such as CFCs. Both tools, the CO2 Grobbilanz and the EMSIG tool, can display results in CO2 equivalents. Since 2004, the global warming potential has been calculated on the basis of the IPCC values of the third assessment report of 2001. The inventories carried out before 2004 are based on the second IPCC assessment report of 1995.

The tools are mainly based on the territory principle. This means that all the emissions caused by activities carried out in the territory are taken into account. If an activity uses electricity which was generated in another territory, then the (indirect) emissions caused by the generation of the electricity are included in the inventory. The CO2 Grobbilanz thus measures direct and indirect emissions. The EMSIG tool takes furthermore also account of life cycle emissions.

The territorial principle does not apply to the mobility of the inhabitants of the community. In this case the emissions caused by inhabitants of the community who travel outside the community territory are included in the inventory regardless of the place where they occur. In addition, all the transport emissions induced by local industry/business/agriculture/stockbreeding or forestry are taken into account. The freight transport by ship or plane, however, is neglected.

The CO2 Grobbilanz and the EMSIG tool measure the emissions of the following sectors: heat, electricity, mobility, waste and agriculture. They are to a large extent consistent with the IPCC guidelines. However, the CO2 Grobbilanz does not take account of industrial processes, solvent use and land use. The EMSIG tool covers these sectors as well as all the six Kyoto gases. In addition, the EMSIG tool also includes the life cycle emissions of the average basket of goods purchased by the inhabitants of the community and linked to the economic activity of the territory.

How is the inventory carried out?

The time needed to carry out the inventory depends largely on the degree of accuracy and completeness wished as well as on the mode that the user chooses. The standard mode of the CO2 Grobbilanz can relatively easily be used by an employee of the local authority. The latter has to respond to seven questions which allow producing a broad estimate of the emissions of the territory (e.g. "Quantify the wood area of your community? Is there a railway station on the community territory?" etc.). The expert mode yields a higher degree of accuracy and detail. Yet, it also necessitates precise data on the local pattern of energy consumption and use. The expert mode may require that the community first collects these data and carries out interviews in households. The communities using the expert mode need thus often the help of an expert.

The EMSIG tool is the most complex and most sophisticated tool offered by the "Energieagentur der Regionen". The use of the tool requires that the city cooperates with an expert.

The tools are pre-loaded with emission factors. They are based on GEMIS data, statistical data provided by the Austrian statistical services and data that were calculated by the tool developers.

The tools provide not only a GHG inventory but also propose several measures for reducing the carbon footprint of the community. If the community is e.g. located in a rural area and wishes to reduce the GHG emissions caused by agriculture, the measures to be proposed can be focused on agriculture.

The CO2 Grobbilanz is web based and has a relatively simple user interface. The EMSIG tool is based on Excel sheets. However, this tool is used by trained experts and not by community employees.

How much does it cost to compile an inventory?

The use of the CO2 Grobbilanz costs around €150. This is the amount of money needed to purchase data for the compilation of the inventory. The expert mode often requires the help of an external expert. The costs related to this expert advice normally amount to €3.000. An inventory carried out with the EMISG tool costs around €12.000. This includes all the services provided by the experts during the whole project phase.

The CO2 Grobbilanz can only be used by communities which are member of the Austrian Climate Alliance. The membership to this alliance requires that communities commit to a 50% emissions reduction target for 2010 (1987 being the base year). The use of the EMSIG tool is not linked to any specific commitment.

Strengths

The CO2 Grobbilanz is simple to use and allows also relatively small communities such as villages with only 1000 inhabitants to compile an inventory.

The tool meets the needs of larger communities for detailed inventories in the same way as the need for small communities for a relatively basic inventory. The EMSIG tool allows including life cycle emissions of purchased products.

Weaknesses

The standard mode of the tool is easy to use but of course also less accurate than the expert mode or the EMSIG tool. The latter yields a very comprehensive inventory but may be too expensive for many small and medium-sized communities with limited financial resources.

Opportunities

The CO2 Grobbilanz is one of the few tools that allow compiling a simple inventory for small communities. Even though the inventory is not very accurate it enables villages and small cities to have an overview on their GHG emissions.

Threats

The inventories are not completely consistent with international protocols. Comparisons with other inventories are therefore difficult and may hinder the diffusion of the tool provided that international comparisons become important in future.

2.2 The “ ECO2Region” tool (Ecospeed, Climate Alliance, European Energy Award)

The “ECO2Region” tool has its roots in Switzerland. In 2002, Swiss cities developed jointly with the company Ecospeed and the Swiss energy and environmental agency the first version of the ECO2Region tool. In the following years, the tool was adapted to the needs of German cities so that today three versions of the tool are in use (smart, pro, premium). In early 2009, the tool had been used by 113 German and 83 Swiss cities. Based on the German version an Italian version was developed. At the beginning of 2009 the Italian version of the tool was tested in 10 Italian cities.

The basic version of the tool is called “ECO2Regionsmart”. This version is used by the German and Italian member cities of the Climate Alliance as well as by some Swiss cities. “ECO2Regionpro“ is a more advanced version of the tool. It is mainly used by the Swiss cantons and some Swiss cities. “ECO2Regionpremium” is almost identical with “ECO2Regionpro” but offers furthermore a scenario development function.

Climate Alliance has around 1.400 members (cities, municipalities and districts) who have all committed to a CO2 emissions reduc-

tion of 10% every 5 years. By 2050 Climate Alliance members should reduce their emissions by 50% compared to 1990 levels. On the long term, Climate Alliance members aim at converging towards a level of 2,5 tons CO2 equivalent emissions per capita and year.
In view of documenting their respective efforts, Climate Alliance members are required to regularly draft a report. It is therefore of great importance for Climate Alliance to ensure that its members measure their emissions with the same or very similar tools so that inventories and emission reductions are comparable. The tool is furthermore used in the framework of the European Energy Award which has around 450 member communities.

Whose emissions are measured?

The tool can in principle be used by any city or region. The emissions of the public authority can be measured as well as the emissions of the whole territory. Emission factors are available for Germany, Switzerland and Italy.

What is measured?

The German and Italian members of Climate Alliance use ECO2Regionsmart. This tool measures CO2 only. However, it is planned to extend these Climate Alliance inventories in future also to other GHG.
The inventories compiled with ECO2Regionsmart cover the category "energy" of the IPCC. The transport sector as well as the energy consumption of the local economy (primary sector, secondary sector, tertiary sector), of households and of the public authority are therefore part of the inventory. The remaining IPCC categories (industrial processes, solvent use, agriculture, LULUCF and waste) are not part of the inventory.

Climate Alliance recommends its members creating inventories based on primary energy consumption and LCA of fossil fuel based energy. This means that all emissions related to the supply of final energy (fossil fuel extraction, transport etc.) are allocated to the point of use. Thus the emissions of the whole fossil energy chain are taken into account.
Electricity that is generated by power plants in the territory but exported outside the territory is not taken into account by ECO2Regionsmart. All (indirect) emissions related to the supply of electricity actually used in the territory are included in the inventory. Given that Climate Alliance recommends compiling inventories that allocate emissions to the point of use and take account of all emissions of the energy chain (including emissions that occur outside the territory) the inventories are not consistent with the IPCC guidelines.

However, the ECO2Region tool as such also allows to compile inventories that are consistent with the IPCC guidelines. The users (or user communities such as city associations) can decide on different principles according to which they want to compile the inventory. Inventories created with "**ECO2Regionpremium**" and "**ECO2Regionpro**" can largely be consistent with the IPCC guidelines. They cover all the main categories (energy, industrial processes, solvent use, agriculture, LULUCF and waste) and all the six GHGs of the Kyoto protocol. Users may also include additional pollutants such as PM10 in the inventory.

How are GHG measured?

The starting mode of all ECO2Region tools requires only two sets of data: the number of inhabitants of the territory and the number of employed persons working in the territory. Based on these data the software then automatically creates a first estimate of the emissions. This estimate is derived from the relevant average emissions for Germany, Switzerland and Italy.

The user of the tool then replaces bit by bit the national average emissions by more precise data, i.e. data which were actually measured in the territory. This allows the persons working with the tool to constantly compare the actual emissions of their territory with the national average. The difference between the estimate of the starting mode and the final inventory is normally relatively small and lies at around 5%.

The data for emission factors are derived from various sources and are updated every year. The life cycle inventory data for fossil fuels are derived from Ecoinvent and GEMIS. The availability of precise activity data differs from one country to the other. In Germany e.g. it is often difficult to obtain data on freight transport, trains or heating oil.

The tool allows for breaking the result down in different sectors, energy carriers or vehicle categories. The tool can also be used to estimate the impact of different measures such as replacing oil heating by natural gas. ECO2Regionpremium furthermore offers a specific scenario function with which scenarios for 2030 can be developed.

The ECO2Region software can be accessed through the web. It is a dynamic user interface and allows for downloading graphs or the whole inventory in different formats. It is also possible to establish different user profiles and user rights.

A “Community Platform” offers cities and regions the possibility to share their data with other local authorities. Users are free to decide about how to define a community. Thus a community may be a city network, cities of a specific region or county etc. Via the community platform members of a community can exchange information and data. All the datasets which can be displayed for an individual user can be compared with other users in the community and the community as a whole.
The tool is available in German, Italian and French; an English version is planned to be released in autumn 2009. Principally the tool can be used without further guidance. However, often users have no experience in GHG accounting and need support. Climate Alliance therefore proposes one day workshops that give an introduction into carbon accounting, the structure of the ECO2Regionsmart tool and its use. In addition, Climate Alliance offers telephone support. Ecospeed, the company which developed the ECO2Region tools, also offers one day trainings and telephone support.

How much does it cost?

Climate Alliance members pay €350 for a one year license of the ECO2Regionsmart tool. The price for local governments that are not member of Climate Alliance depends on the number of inhabitants. Thus, a community with up to 20.000 inhabitants is required to pay €500, a community with 20.000-100.000 inhabitants €800 and a community with more than 100.000 inhabitants €1.500. Local governments in Germany can apply for funding from the German ministry for environment which may cover 100% of the costs. The price for the “ECO2Regionpro“ tool varies between €800 and €1500 depending on the number of inhabitants of the territory. The ECO2Regionpremium” tool costs between €1500 and €4500.
The participation fee for the workshops amounts to €215 for Climate Alliance members and to €540 for participants that are not member of Climate Alliance.

Strengths

The start inventory provides already a first estimate taking account of the average national emissions as well as the number of inhabitants and employed persons. Thus, with every step that the local government takes towards the creation of an inventory (by overwriting the given data with the actual data measured in the territory) a comparison of the situation in the own community with the national average is made. The comparison already indicates in which sectors the community performs better/worse than the national average and where reduction potentials may lie.
Workshops and telephone support is offered to the users of the tool.

Weaknesses

The ECO2Regionsmart tool only takes account of CO2. The advanced versions, however, include all Kyoto gases.

Opportunities

Climate Alliance and the European Energy Award are associations with respectively around 1.400 and 450 members in different European countries. Thus, the ECO2Region tool can potentially be widely disseminated and may be used by a great number of local governments. So far it seems to be the by far most widely used tool in Europe.

ECO2Region is one of the rare tools that are available in different languages and adapted to different countries (Germany, Switzerland and Italy). The tool can be consistent with international standards.

The linkage with the CO2 reduction targets of Climate Alliance emphasizes that local governments should use the tool in view of better managing the long-term emissions reduction pathway. The tool is used in a greater framework which pushes for GHG emission reductions.

Threats

The inventory methodology chosen by Climate Alliance ensures comparability within Climate Alliance but is not comparable with other inventories on a larger scale.

2.3 GRIP – The Greenhouse Gas Regional Inventory Protocol (CURE, Manchester University, UK Environment Agency)

The development of the Greenhouse Gas Regional Inventory Protocol (GRIP) started in 2001. Since 2006/07 the tool has been applied by different European cities. It was initially funded by the Tyndall Centre and the UK Environment Agency since then METREX, the Network of European Metropolitan Regions and Areas which incorporated the use of GRIP in one of its projects (was part-financed by the European Union). Thus, the tool could be tested in four different METREX regions from North, West and South Europe and in varied climatic circumstances. In early 2009, 18 metropolitan areas (such as London, the province of Bologna, Stockholm or North

West England) had used the tool. It has also been used in Sacramento, California, is due to be used in Washington DC, and is uner negotiation to be applied in China and South America.

Whose emissions are measured?

The tool has been designed to take account of the GHG emissions of metropolitan areas, i.e. major urban areas and their areas of influence. It has been applied at the city and local scale. The inventory takes account of the emissions of the whole territory as well as electricity associated emissions from outside.

What is measured?

The methodology of the GRIP tool is to a large part based on the IPCC guidelines. The inventory therefore covers the six GHG of the Kyoto Protocol. Results are displayed both in terms of each gas and in terms of CO2 equivalents. In accordance with national reporting standards the global warming potential is calculated on the basis of the values of the second assessment report of 1995 (could easily be changed).

Following the IPCC guidelines GHG emissions are grouped in the main categories of energy, industrial processes, waste, agriculture, land use change.

The inventory can break the result down in the following sectors and sub-sectors (a break-down in sub-sub-sectors is partly possible):

- Energy use (all combustion of fuel except for grid power generation and transport; examples include fossil fuel use for heating, cooking, and manufacturing; includes also electricity consumption and fugitive emissions from fuels)
- Grid Power Generation (fuel used to generate electricity)
- Transportation (fuel used both on-road and off-road transport modes)
- Waste (solid waste and wastewater)
- Process Emissions (industrial processes that generate emissions other than those from combustion of fossil fuels; this sector includes processes such as cement manufacturing, ammonia production, and the electronics industry)
- Agriculture (farm animals, fertilizer application, rize cultivation etc.)

The inventory follows the IPCC guidelines with one exception: The GRIP tool takes account of emissions of electricity generation at the point of consumption whereas the IPCC recommends for national reports to take account of these emissions at the point of electricity generation.

How are GHG measured?

The GRIP tool provides different entry fields for different levels of data accuracy. Level 3, red, outputs have the highest level of uncertainty associated with them; level 2, orange, outputs sit in between and offer a medium level of certainty. The most accurate data, green, are those that are available for the area under examination. Essentially these levels map onto top-down and bottom-up inventory approaches. Level 1, green, approaches are bottom-up. Level 3, red, are top-down. Level 2, orange, are a combined top-down and bottom-up approach – or a more detailed top-down approach.

The philosophy behind the tool is to encourage learning. As a consequence regional/city actors using it are required to source all the data. This includes emissions outputs and associated activity – nationally. The tool is not pre-loaded with national emission factors. This data is sourced from the national UNFCCC reporting documents or on the Eurostat webpage. According to the developer this affords a greater opportunity for the users to understand the relative effects of different activity in their area – so they are better placed to communicate it.

The tool is web-based and has a relatively user friendly interface. A coloured bar e.g. tells the user how far through the inventory programme he/she has progressed. Trainings are offered in different European countries. An accompanying scenario tool can also be used to develop emission scenarios which may serve as a decision aid. Scenarios allow exploring the impact of differing energy demand, fuel mixes and gerneration technologies. Users can manipulate the scenario by making different energy choices such as fuel use in specific sectors, electricity sources etc. These energy choices can be complemented with specific socioeconomic futures regarding demographic development, economic growth or general behaviour. The scenarios thus combine numerical elements (how much energy and of what type) with socioeconomic aspects. The scenario approach is focused on learning.

How much does it cost?

The inventory tool is currently free to use (lifelong licence). However, the training on how to use it has to be paid for. The use of the scenario tool and of the planning tool is not free. However, if a group of cities in the framework of a common project compiles inventories the overall price for the services offered is reduced.

Strengths

The tool is relatively easy to use. In principle it can be used in different countries and is European wide applicable. It has furthermore been applied in the United States and is under negotiation to be applied in China.

Weaknesses

The GRIP inventory tool is not pre-loaded with national emission factors. The users must input these. According to the developer this encourages learning of the user.

The software is so far only available in English. The formation of a GHG inventory is a technical and difficult task. Following instructions in a foreign language while compiling the inventory may render the task more difficult for many non-native speakers. There are therefore plans in place to translate the tool into multiple languages and provide video tutorials.

Opportunities

The GRIP methodology is to a large part based on the IPCC guidelines for national inventories. In principle regional GRIP inventories could be compared with national inventories which are reported to the UNFCCC.

The GRIP tool has been used in different countries and has been diffused internationally by METREX, the organisation of Europe's metropolitan regions. The close ties with METREX can potentially disseminate the use of the GRIP tool also in future in Europe, with linkages in the USA, South America and China seeing further dissemination.

Threats

Users may prefer tools that are geared towards national or even regional needs (i.e. tools that are available in the language of the country and are pre-loaded with country specific emission factors). This may hinder the widespread use of GRIP.

2.4 The "Bilan Carbone" (ADEME)

The "Bilan Carbone® Collectivités - Territoires" builds on a GHG inventory tool which the French environmental agency "Agence de l'environnement et de la maîtrise de l'énergie" (ADEME) developed for companies. The first version of the tool was tested in 2005 in 15 municipal and territorial authorities. The results of this testing phase contributed to the improvement of the tool in view of its dissemination by ADEME (ADEME, 2006). The current tool – version 5.0 - has been available since January 2007.

Whose emissions are measured?

The tool can in principle be applied to any entity provided that the required data are available. The tool can be used for measuring emissions of the local authority (module "patrimoine & services") and/or for measuring the emissions of all GHG emitting activities of the territory (module "territoire").

The "Bilan Carbone" is mainly geared towards the needs of French cities. However, some of the French cities are located in overseas territories and thus in different climatic zones than the cities of mainland France. Specific emission factors have therefore been calculated for these territories (DOM-TOM). Furthermore, ADEME has launched a cooperation with the United Nations Development Programme (UNDP) in view of compiling carbon inventories in emerging and developing countries.

What is measured?

The "Bilan Carbone® Collectivités - Territoires" measures all the six Kyoto GHG. In addition, it also takes account of other directly emitted GHG such as chlorofluorocarbons (CFC) or the water vapour emitted by planes in the stratosphere. The tool can take inventory of principally any gas that has an impact on the global climate provided that sufficient scientific knowledge of its global warming potential exists. A limitation of the inventory to the Kyoto gases only is possible.

The tool takes account of manifold possible emissions sources. In fact, many inventories do not take account of international aircraft or maritime emissions because they cannot be assigned to a state or territory. As the "Bilan Carbone" is based on the principle that any emission that can be assigned to a specific activity must be taken into account, it also takes inventory of indirect emissions like those of international aircraft and maritime transport that are related to the activities of a local territory. The tool does not take inventory of GHG emissions from biomass since its developers assumed that it will mainly be used in the industrialized world where deforestation is balanced by afforestation. Furthermore, the tool (module "territoire") does not take account of materials that enter the territory due to the lack of data that correctly reflect this flux for a given territory.

The Bilan Carbone calculates with "carbon equivalents"; final results can, however, also be displayed in "CO2 equivalents". The values for the global warming potential of gases were initially derived from the third assessment report of 2001. Since the publication of the fourth assessment report in 2007 the values have been updated.

How are GHG measured?

The tool is pre-loaded with emissions factors for French cities and territorial authorities. However, for the French overseas territories (DOM-TOM) specific emissions factors partly apply. Given that these territories are located in different climatic zones than mainland France (higher average temperature), the energy consumption of their buildings sector differs. Thus specific emissions factors had to be calculated.

The tool can also be used for reporting emissions according to existing standards. Extractions can be made for the EU Emission Trading Directive as well as for the ISO 14064 guidelines for corporate emissions reporting. The results for the latter can be broken down into three scopes. The three ISO scopes are almost identical with those recommended by the GHG Protocol.
Once a GHG inventory has been created, the local authority can use the tool to investigate what combinations of emission reductions in different sectors yield a total reduction of X.

How much does it cost to compile an inventory?

The use of the tool is principally for free. Yet, cities are required to attend a two day training (cost of training: €1.250) after which they get access to the tool in its standard version. The version for cities and territories requires also that future users attend a second specialized training (€500) after which they receive the tool free of charge (ADEME, 2009b).
In addition, ADEME trains experts who may support cities and territories when they use the tool. Thus, there is a wide network of experts available in France which may be used by cities when they need external help for carrying out the inventory. The costs of such a service can amount to up to €30.000 for the compilation of an inventory representing the GHG emitting activities of a whole territory (ADEME, 2009a).

The idea behind the compulsory trainings is to explain the tool and the underlying philosophy to city officials. The "Bilan Carbone" does not only aim at creating an inventory but at activating cities and territories and to make them understand what measures are needed to reduce emissions. The trainings are therefore a cornerstone of the "Bilan Carbone". In addition, ADEME tries to be as transparent as possible and discloses all the information related to the calculations of emission factors and the methodology in general. Following the rationale of reaching out to the public and disseminating the use of the Bilan Carbone ADEME subsidises also the trainings of experts who may provide support for cities.

Strengths

The "Bilan Carbone" can be used for calculating almost all GHG emissions of a territory and allows for compiling detailed inventories. Detailed reports describe how the emission factors were calculated and give a thorough introduction to the methodology and use of the tool. One of the main strengths of the "Bilan Carbone" is therefore its transparency.
Another great strength of the "Bilan Carbone" are the manifold services that ADEME provides:

- Users of the tool must attend training seminars where experts give an introduction into the methodology, the use and limits of the tool.
- City officials can cooperate with external experts who have been trained by ADEME. The costs for these external experts, however, may be too high for some cities. Therefore ADEME provides funding which covers up to 50% of the costs of the external expertise whereby the total maximum amount of funding is of € 15.000 (ADEME, 2009c).
- To ensure that services provided by an external expert are of good quality and comprehensive, ADEME has published a performance requirements template. It details the different steps of GHG accounting and the services that the external expert should provide (ADEME, 2008).
- A rich documentation on the tool and its underlying methodology is provided.

Weaknesses

The price to pay for the "Bilan Carbone" and the compulsory trainings is relatively high compared with that of other tools.
The tool and its user interface are based on Excel. This allows for transparency (equations are clear) and quick adaptation of the tool to different requirements. Yet, a dynamic, windows like interface which furthermore can be used via internet is probably easier to handle for most users.

Opportunities

The "Bilan Carbone" incorporates not only the GHGs of the Kyoto Protocol but also many other gases that have an impact on global warming such as CFCs. The equations underlying the calculations are transparent in the Excel files. The tool can thus be quickly adapted to different requirements.

The use of the "Bilan Carbone" requires that the relevant local authority commits to GHG reductions. Thus, the tool goes beyond the simple functionality of "emissions measuring" and supports the local authority in its efforts to follow a more sustainable development path.

Threats

Some cities may be reluctant to try out the tool given that trainings or the involvement of external experts are a prerequisite of its use. For small municipalities the costs related to the formation of a carbon inventory with "Bilan Carbone" may be too high.

2.5 The CO2 Calculator (Danish National Environmental Research Institute, Local Government Denmark and COWI)

The municipal greenhouse gas calculator (CO2-Beregner) was developed in 2008 by the Danish National Environmental Research Institute (NERI) in cooperation with a private consultancy firm (COWI). The emission factors and the calculation algorithms of the tool were developed by NERI, while the computer programming was done by COWI.

The project of developing the calculator was initiated by the Ministry of Climate and Energy and the city association Local Government Denmark (LGD) in cooperation with NERI.

The main objective of the Danish project was to provide an opportunity for the municipalities to monitor the development of their GHG emissions, and to provide a tool that could be used for assessing the impact of local mitigation measures. Given that only few municipalities were expected to have much manpower or money to put into the compilation of a GHG inventory, a further goal was to ensure that the tool is easy to use and free of charge.

In early 2009 between 30 and 40 Danish municipalities had either already used the calculator or were in the process of doing so. Denmark has a total of 98 municipalities.

Whose emissions are measured?

The calculator is designed to be used by the municipality as a geographical entity. This however does not limit the ability of the programme to handle the municipality as a company. The calculator is geared towards the needs of Danish territories.

What is measured?

The gases covered in the first version of the calculator are CO2, CH4 and N2O. However, CH4 and N2O from combustion of fuels are not included. F-gases were not included in the first version of the calculator, due to the relative small share of overall GHG emissions in Denmark, and the fact that the use of F-gases derives from a large range of smaller sources making it difficult for municipalities to get suitable activity data.

Emissions are for the final totals calculated as CO2 equivalents. The global warming potential values underlying the calculation of CO2 equivalents are derived from the IPCC 2006 Guidelines corresponding to the values of the third IPCC Assessment Report. Generally the emission sources covered correspond to the IPCC Guidelines used for national greenhouse gas inventories. That means that indirect N2O emissions from agriculture are included as well as indirect CO2 emission from the use of solvents. Domestic aviation and national shipping are included in the calculator. Emissions from use of products (LCA emissions) have not been included.

The calculator provides break-downs for the following main sectors:

- Public electricity and heat (production of electricity and heat)
- Individual heating (households, industry, commercial/institutional)
- Transport and mobile sources (road transport, railways, aviation, navigation, non-road machines in industry, agriculture, forestry, fishing and households)
- Industrial processes (cement production, production of lime, use of limestone, refineries, production of bricks and tiles, processes within chemical industry and iron and steel industry)
- Use of solvents
- Agriculture (CH4 from enteric fermentation, CH4 and N2O from manure management, N2O from agricultural soils, indirect N2O from atmospheric deposition and leaching and run-off, emissions from sludge used as fertilizer, CO2 emission from the use of lime), it is also possible to account for utilization of biogas

- Land Use, Land Use Change and Forestry (LULUCF) (Deforestation, afforestation, reforestation, establishing of wetlands, parks, road trees, hedgerows, buffer zones and use of sphagnum)
- Waste (Solid waste disposal on land and waste water handling, waste incineration in Denmark is done with energy recovery and is therefore included under public electricity and heat)

The estimation methodologies are largely modeled after the Danish national system, which follows the IPCC Guidelines for reporting to the UNFCCC. However, due to the different challenges for municipalities compared to country inventories some adjustments to the methods were made.

How are GHG measured?

One of the main challenges in developing a local inventory following the methodology for a national inventory was the availability of data. Many datasets used in the national reporting cannot be disaggregated to the municipal level. Therefore part of the project was to ensure that the requested activity data could be acquired on municipal level.

The tool requires a wide variety of activity data, e.g. electricity consumption for different sectors, number of animals, kilometers driven by different vehicle types, agricultural areas of different crops, fuel consumption in industries etc. The final model has over 400 input fields. The data availability varies from municipality to municipality. In some communities it is e.g. relatively difficult to get data for the transport sector if the municipality does not have a developed transport model in place whereas for other communities it can be more difficult to gather fuel consumption data for industries.

The calculator is divided into several tiers for each subsector. Generally the simplest tier estimates emissions based on national level emissions. Thus it is possible to obtain a result even though the municipality cannot get all the activity data needed to complete a more detailed inventory. The calculator will be updated annually with the latest emission factors and other constants used in the calculations. Additionally it is planned to implement improvements based on input from municipalities using the calculator.
The user interface is windows like allowing easy navigation. The calculator supports a variety of output formats (pdf, xls, rtf, html etc.) so that the users can export their data and results. The data basis for the calculator is an xml file. The calculator can be downloaded from a webpage; updates are done automatically on the user's PC.

As an additional functionality the calculator can calculate the GHG reduction of 37 different reduction measures. These 37 mitigation initiatives are also described in detail in a guidance document. Further guidance documents cover the use of the software, data collection and the underlying methods and assumptions. In total 4 guidance documents are available. In addition several (so far well attended) courses have been offered to municipalities. The users of the calculator can get both technical support, and support regarding scientific aspects.

The time needed to compile an inventory is estimated at about 3 weeks if the municipality does the work itself. Consultants experienced in the field may compile the inventory faster. However, the compilation of the inventory usually stretches over several months due to the time needed to obtain the necessary data.

How much does it cost to compile an inventory?

The use of the tool is for free. The personnel cost linked to the compilation of the inventory must of course be taken into account by the municipal authority.

Strengths

The calculator offers a very detailed inventory provided that all data are available. Given that Denmark is a relatively small country even tier 1 methods based on default (national) emission factors are likely to be relatively accurate (compared with national default emission factors for big countries). A further strength of the tool is its great transparency: Four guidance documents are available which detail the methodology and the use of the tool. In addition, trainings are offered. The tool is for free. It furthermore offers a dynamic user interface and is accessible via internet.

Weaknesses

Relatively many data entries are needed. However, this is the precondition for every detailed inventory.

Opportunities

The inventory is modelled after the Danish national inventory and therefore in line with the IPCC guidelines for reporting to the UNFCC (with some adjustments). It follows therefore a worldwide recognized reporting standard which may in future also be used by other municipalities. It furthermore seems highly likely that the calculator will become very widely used in Denmark. In fact, already in 2009 (in the first year after its launch) around 40% of Danish municipalities had used the tool or were in the process of doing so.

Threats

In other European countries inventories do not always follow as accurately the IPCC standards as the Danish CO2 calculator. There is therefore the risk that results may not be comparable with local inventories of other countries. However, the fact that the calculator is based on the IPCC guidelines should in general rather be seen as an opportunity (see above).

2.6 Project 2 Degrees (Clinton Climate Initiative, ICLEI, Microsoft Corporation)

The Project 2° is collaboration between the Clinton Climate Inititative, ICLEI and the Microsoft Corporation. Together they have developed a tool to measure, compare and reduce GHG emissions of cities around the world. The use of the tool is therefore not confined to a specific country or world region. On the contrary, it has been developed with the aim of offering a service to cities "around the world".

The tool is based on the HEAT tool of ICLEI. In early 2009, it was tested by C40 cities, a group of the world's largest cities committed to reduce GHG emissions. Given that ICLEI is partner of the cooperation, the inventories developed with the tool are consistent, amongst others, with the ICLEI Protocol (International Local Government GHG Emissions Analysis Protocol).

Whose emissions are measured?

The tool allows taking account of the GHG emissions of the city government as well as GHG emissions that fall within the boundary of the territory. It is designed for parallel accounting of both inventories. The emissions of the city government are tracked the same way as corporate emissions. Inventories of the whole territory are structured in a different way (described below).

What is measured?

The tool of Project 2° takes account of the six GHGs of the Kyoto Protocol. The software converts final results in CO2 equivalents. The tool is relatively flexible with regard to the calculation of the underlying global warming potential. It provides values for the second, third and fourth assessment report. By default, the CO2 equivalents are calculated on the basis of the second assessment report given that these values are still widely used in many areas.

The following sectors should be covered by "community inventories", i.e. inventories that comprise all the emissions that fall within the boundaries of the territory (Project 2° 2008):

- Energy Use (all combustion of fuel except for grid power generation and transport; examples include fossil fuel use for heating, cooking, and manufacturing; includes also electricity consumption)
- Grid Power Generation (fuel used to generate electricity)
- Transportation (fuel used in both on-road and off-road transport modes)
- Waste (solid waste and wastewater)
- Process Emissions (industrial processes that generate emissions other than those from combustion of fossil fuels; this sector includes processes such as cement manufacturing, ammonia production, and the electronics industry)
- Agriculture, Forestry and Other Land Use (includes all emissions from land use changes)
- Other (use of GHGs in products, such as refrigerants and N2O as an anesthetic; fugitive emissions from fuels; any other emissions not categorized in the other sectors)

The emissions tracker was designed to be regime and protocol neutral. The data can be modified and structured for different purposes and accounting protocols such as ISO 14064, International Local Government GHG Emissions Analysis Protocol (ICLEI) or the GHG Protocol Standard (World Resources Institute). The algorithms used in the calculator as well as the definitions of emission sources are consistent with the 2006 IPCC guidelines (2006 IPCC Guidelines for National Greenhouse Gas Inventories).
The inventory must include all scope 1 and scope 2 emissions. All scope 3 emissions for which data are available should also be reported (e.g. emissions from air or marine transportation that originate within the community/territory).

How are GHG measured?

The calculator is pre-loaded with the IPCC default emission factors and some national emission factors taken from UNFCC national reporting documents. Users can change these emission factors if they dispose of more accurate data. The software allows also for entering GHG emission data directly and converting these quantities in CO2 equivalents.

Users can design their own inventory by choosing the categories or subcategories they are most interested in. They can e.g. opt for a very detailed inventory comprising many subcategories (e.g. every single building can have its own subcategory) or they can opt for an inventory which covers only the main categories and no subcategories.

The tool of Project 2° is available in English. It is planned that the emissions tracker will be translated in other languages, including French, Spanish, Russian, Japanese, Chinese and Portuguese. However, new language versions will only be released if sufficient demand exists.

The tool is web-based. It offers some additional functions that help authorities to create an action plan for the reduction of GHG emissions. This is done as follows: First, the software estimates future emissions under business as usual conditions. Second, the territory can set a reduction target, e.g. the goal of reducing GHG emissions by 30% by 2025 compared with the base year emission level. Third, on the basis of the inventory and the knowledge of the emissions level of different sectors, the territory plans reduction measures. In a 'Resources' section users can furthermore get access to information about best practices for emissions reductions and to expert advice.

In a users guidance manual as well as in a 'Help' section of the webpage users can find information and advice should they encounter problems.

How much does it cost?

The tool can be used free of charge by invited cities around the world. The use of the tool is subject to an invitation to ensure that only legitimate representatives of local authorities can have access to it. Cities and territories that would like to use the emissions tracker but have not been invited should contact the project administrators.

Strengths

The tool is based on an easy to use web-interface. The use is free of charge. The software furthermore supports local authorities with the creation of action plans and provides information on different reduction measures. The methodology underlying the inventory is made transparent and all the relevant information can be accessed through the project webpage. The tool is designed in a neutral way and allows for extractions for different standards and protocols.

Weaknesses

The software is so far only available in English. The formation of a GHG inventory is a technical and difficult task. Following instructions in a foreign language while compiling the inventory may render the task more difficult for many non-native speakers. However, the release of further versions in different languages is planned.

Opportunities

The use of the tool may be disseminated worldwide through the C40 cities. The emissions tracker of Project 2° is furthermore open to different protocols and reporting standards which makes international comparisons possible.

Threats

In countries where similar tools are available in the national language, the emissions tracker of Project 2° may not be widely used given that it is so far only available in English. Further language versions will only be released if there is strong demand for such a service. In countries where other tools are available the demand might remain relatively weak.

Conclusions

The study has highlighted the main methodological challenges of local GHG accounting and has developed a framework for the analysis of inventory tools and methodologies. The research undertaken has shown that many advanced tools already exist in different European countries and worldwide, sombe being more advanced/and or used than others.

Surprisingly many tool developers contacted during the compilation of this study were not aware of the work currently undertaken on this topic and sometimes did not know of the existence of other tools (on the assumption of their tools being one of the first of their kind). This may be explained by the fact that most of the tools were developed only in recent years and often in isolation to other similar initiatives. The time seems therefore right to draw the first conclusions on the state of the art and discuss possible future developments.

In general the methodologies underlying the different tools are relatively similar. However, results obtained with different tools are normally not comparable. The study has highlighted the main points where differences stem from.

This study was very much developer driven, so as to understand the underlying methodologies, their differences, the reasons why different results are obtained and explore how interoperability could be achieved. Indeed, in view of the work being undertaken by cities in Europe and other parts of the world, it appears that interoperability is desirable as it would enable cities ot better gauge their policies and actions and would improve the ability of cities to take effective action-oriented decisions.

In order to develop the analysis a step further, a user driven discussion on tools and methodologies, experiences, and results is certainly desirable. It would enable a better understanding of the differences and similarities between toools and would provide the requirements to ensure better comparability.

Towards a better understanding of the differences between tools and methodologies

The assessment undertaken has shown that there are 6 main criteria to take into account in order to compare the different methodologies and assess how different GHG inventory tools could be made interoperable:

1. **Gases to be measured**: Some inventories take account of CO2 only, others cover CO2, methane and nitrous oxide while other inventories cover all the six gases of the Kyoto Protocol or even several more.
2. **Emission sources**: The emission generating activities to be included in the inventory. For instance, some inventories take account of emissions from international air and maritime transport while others do not.
3. **Sector definitions**: sectors are defined as the aggregation of specific emission sources. The emissions of the transport sector could e.g. be defined as aviation emissions + emissions of cars + emissions of trucks + emissions of buses + emissions of railways etc. Sector specific emissions can only be compared if the sectors are defined in exactly the same way, i.e. cover the same emission sources.
4. **The scopes of the measurement**: It is not always clear which scopes inventories cover. Most of the tools take account of direct and indirect emissions. However, emission sources that fall into these categories can differ between tools. Few inventories take also account of life cycle emissions of purchased goods.
5. **The global warming potential values to be used:**The global warming potential values to be used: The values used for the calculation of the global warming potential of gases differ. Some inventories use values of the second, some of the third and others of the fourth assessment report. On the basis of these values CO2 equivalents are calculated.
6. **Tier methods to be used**: The accuracy of the different quantification methods is normally classified in three tiers, tier 1 methods being the least accurate methods. Local GHG inventories commonly quantify GHG emissions with emission factor based methods. The accuracy of the method depends on the emission factors used. Region specific emission factors are more accurate than country specific emission factors.

If inventories are to produce results that are broadly comparable, a common understanding of these points is needed. This does not imply that all tools must be exactly the same. On the contrary, the analysed tools are normally geared towards a specific need and are therefore excellent solutions in the country specific context.

However, the relative degree of urgency with which climate change needs to be tackled and the relative long lifetime of urban infrastructure means that cities need to take well informed, effective and action driven decisions quickly. The comparability or interoperability between tools would ensure a relative comparability of results and thus facilitate this process.

Interoperability could be achieved through three different ways:

1) enabling communication between existing tools
2) development of an international standard
3) adoption of a common tool

Firstly, after the identification of the main variables between tools, a protocol could be elaborated. This protocol should allow different tools to dialogue with others. Comparability would be ensured by "providing translation" between existing tools. This would not require that cities or city associations abandon their already established reporting guidelines.

Secondly, an international reporting standard could either be adopted or developed. An internationally accepted standard for municipal inventories does not seem to exist. Adopting an international standard would require existing standards to be screened and agreed between all the main actors. Some tools follow the IPCC guidelines and the relevant emission source and category/sector definitions to a large extent. A harmonisation towards the IPCC guidelines may therefore be a promising approach. Also the International Local Government GHG Emissions Analysis Protocol developed by ICLEI may be a useful reference since it has been developed for local authorities.

For an international standard to be developed current practices and methodologies first need to be discussed by the main actors. For instance it may be possible to define a rather simple reporting standard which covers only the most important GHG as well as a limited number of emission sources and sectors. The tools could offer extractions for this basic standard while allowing cities also to compile more sophisticated inventories (that cover more GHG, more emission sources and more sectors).

Finally, a common tool could be adopted or developed. A common tool would involve a common user interface, a common standard, common guidance documents and common administrators. Thus, it would require more harmonization than an international standard and would tend to replace existing tools.

These three alternatives differ substantially with regard to the implementation process and their goal but they are nonetheless not mutually exclusive: convergence of existing tools could result in a common tool and/or serve as a base to develop an international standard.

A prerequisite for any of these three methods is the involvement of the main actors, i.e. the users and developers of tools. There will never be a common tool, a common standard or communication between tools if the developers and users are not willing to support this process and are not involved in it.

Good practices
The study has shown that the requirements for national GHG inventories also apply to local GHG inventories: inventories should be transparent, consistent, comparable, complete and accurate (IPCC, 2006, see also Annex III). The study has also identified further good practices for the compilation of local GHG inventories:

- Trainings: compiling a GHG inventory is a very technical and difficult task. Trainings which give an introduction to the objectives, opportunities and limitations of GHG accounting as well as to the use of a specific tool can be of great help for users.
- Dynamic user interface: A dynamic user interface, web access and automatic internet updates can render the task to compile an inventory easier.
- Pre-loaded emission factors: Tools should be pre-loaded with default (country specific) emission factors in case more accurate local data are not available.
- Pre-filled tables: On the basis of the population and the number of employed persons of a territory the entry fields of the tool can be pre-filled. The user of the tool is thus confronted with the average national emissions corresponding to the population size and working population of the territory. Bit by bit the user can then replace these average national emissions data by the actual emissions data of the territory. With every step the user takes he/she can compare the local emissions with the national emissions level.
- Guidance documents: In some cases it was very difficult to find information on the methodology, the emission factors and functionalities of tools. These documents are, however, of great importance for any user and also for reasons of transparency and comparability.
- Embedding the inventory in a wider strategy/plan: The use of some tools is linked to the commitment to reduction goals. This ensures that the inventory is only the first of many steps towards a long term GHG reduction.
- Community platform: The webpage of a tool can provide a platform for an exchange and comparisons between users.

- Scenario development/forecasts: Some tools allow developing scenarios and/or comparing the reduction potential of different measures. This functionality can help local authorities to pass from the phase of inventory formation to the phase of implementation of reduction measures.
- Support for implementation of measures: Some tools provide access to information, discussion fora and useful addresses concerning the implementation of reduction measures.

A local GHG inventory must never be an end in itself. The overall aim must be to use it as a tool for emissions monitoring and as basis for short, medium and long term emission reductions. Given the enormous challenge s presented by climate change and the limited time available to mitigate its impacts, local governments need to seriously embark on long term emissions reduction pathways. In this perspective the use of inventory tools by local authorities must become common practice in European cities and regions.

A step further

The study has shown that the wealth of expertise, initiatives and work being undertaken on the issue of carbon inventories is significant. But more often than not, the work is undertaken in parallel and in isolation to one another. The philosophies, approaches, underlying methodologies, tools and strands of actions are therefore varied and not necessary like-minded, even if all are heading towards a common ovjective. The inventory never aims to be an end in intself but rather a tool for emission monitoring and a basis for developing carbon reduction strategies, implement action plans and guarantee GHG emission reductions.

It therefore appears necessary to bring all those actors together on a common platform, or forum of exchange, in order to associate expertise, optimise the effectiveness and interoperability of tools, test different approaches, develop common approaches when deemed suitable and foster the exchange of best practice. It would be an efficient way to associate experts and local governments, developers and users. The aim of such a common platform would be to facilitate the development and improvement of action-driven decision-making processes, thereby complementing the work currently undertaken by the European Commission in the context of the Covenant of Mayors.

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- Eco2Region (used by the Climate Alliance; in German only): **http://eco2.ecospeed.ch/reco/index.html**
- GRIP – Greenhouse Gas Regional Inventory Protocol (Tyndall Centre and UK Environmental Agency) **http://www.grip.org.uk**
- Bilan carbone (developed by ADEME; in French only): **www.ademe.fr/bilan-carbone**
- CO2 Calculator (Danish National Environmental Research Institute, Local Government Denmark and private company COWI; in Danish only) **http://www.miljoeportal.dk/CO2-beregner/**
- Project2Degrees (developed by ICLEI, Microsoft and the Clinton Climate Initiative): **http://www.project2degrees.org**

GHG inventories and environmental accounting:

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- IPCC **http://www.ipcc.ch**
- IPCC Emission Factor Database **http://www.ipcc-nggip.iges.or.jp/EFDB/main.php**
- EUROSTAT **http://epp.eurostat.ec.europa.eu/portal/page?_pageid=2873,63643317,2873_63643793&_dad=portal&_schema=PORTAL**
- RAMEA **http://www.arpa.emr.it/ramea/**
- International Organization for Standardization (ISO provides standards for corporate carbon footprint accounting and product carbon footprint accounting) **www.iso.org**
- Urban Audit (statistical data on European cities; however, only few data on GHG emissions): **http://www.urbanaudit.org**

Local authorities:

- ICLEI **http://www.iclei.org/**
- Climate Alliance **http://www.klimabuendnis.org/**
- Covenant of Mayors **http://www.eumayors.eu/**
- METREX **http://www.eurometrex.org/**
- C40 cities **http://www.c40cities.org/**

ANNEX

ANNEX I: Persons contacted

Name	Tool discussed	Organisation	Date
Dr. Horst Lunzer	CO2 Grobbilanz, EMSIG	Energieagentur der Regionen (Energy Agency of the Regions, Austria), Klimabündnis Österreich	24 February 2009 Telephone interview (45 minutes)
Sylvie Padilla	Bilan CarboneTM	Agence de l'Environnement et de la maîtrise de l'énergie (ADEME)	26 February 2009 Telephone interview (25 minutes)
Ole-Kenneth Nielsen	Municipal CO2 Calculator	National Environmental Research Institute Aarhus University Department of Policy Analysis	26 February 2009 Completed questionnaire
Miguel Morcillo	ECO2Region	Climate Alliance	16 March 2009 Telephone interview (50 minutes)
Dr. Sebastian Carney	GRIP	Tyndall Centre for Climate Change Research	22 April 2009 Telephone interview (10 minutes)
Christoph Hartmann	ECO2Region	Ecospeed	27 April 2009 Telephone interview (25 minutes)

ANNEX II: Overview tables

Table 1: GHG included in the inventory

	Carbon Dioxide	Methane	Nitrous oxide	Sulphur Hexafluoride	Hydrofluorocarbons	Perfluorocarbons	Other GHGs
CO2 Grobbilanz	X	X	X				
ECO2Region	X	(X)	(X)	(X)	(X)	(X)	
GRIP	X	X	X	X	X	X	
Bilan Carbone	X	X	X	X	X	X	X
CO2 Calculator	X	X	X				
Project 2 Degrees	X	X	X	X	X	X	

The values for the ECO2Region tool are in brackets because the number of GHG included in the inventory depends on the version of the tool which is used.

Table 2: Global warming potential values used

	Second Assessment Report (1995)	Third Assessment Report (2001)	Fourth Assessment Report (2007)
CO2 Grobbilanz		X	
ECO2Region	X		
GRIP	X		
Bilan Carbone			X
CO2 Calculator		X	
Project 2 Degrees	X	(X)	(X)

The values for the carbon tracker of Project 2 Degrees are in brackets because the tool is pre-loaded with data of all the three assessment reports. However, the default values are those of the second assessment report.

Table 3: Allocation of electricity emissions

	Point of use	Point of generation
CO2 Grobbilanz	X	
ECO2Region	(X)	X
GRIP	X	
Bilan Carbone	X	X
CO2 Calculator		X
Project 2 Degrees	X	X

ECO2Region allocates the emissions either to the point of generation or the point of use depending on the method chosen by the user. Climate Alliance decided to allocate the emissions to the point of use. Other inventories take account of electricity emissions both at the point of use and at the point of electricity generation.

Table 4: Consistency with international standards

	GHG Protocol	ISO	ICLEI	IPCC
CO2 Grobbilanz				(X) a
ECO2Region	(X) b	(X) b		(X) b
GRIP				(X) c
Bilan Carbone		X		
CO2 Calculator				X
Project 2 Degrees	X	X	X	(X) d

a) The CO2 Grobbilanz and the EMSIG tool allocate electricity to the point of use and not the point of generation. The CO2 Grobbilanz furthermore differs from the IPCC guidelines inasmuch as it does not take account of industrial processes, solvent use and land use sinks.
b) The inventories following the recommendations of the Climate Alliance are not consistent with the IPCC guidelines. However, the ECO2Region tool allows also for the compilation of inventories that are consistent with the IPCC guidelines. With regard to the GHG Protocol and the ISO standard, the ECO2Region tool allows for displaying results for scope 1 and 2.
c) GRIP inventories allocate electricity to the point of use and not the point of generation. Otherwise they are consistent with the IPCC guidelines.
d) Project 2 Degrees states that the inventory is consistent with the IPCC. However, it is not clear whether some adjustment for the local level (and if so in which fields) have been made.

Table 5: Languages

	English	German	French	Italian	Danish	Other
CO2 Grobbilanz		X				
ECO2Region	planned	X	X	X		
GRIP	X					
Bilan Carbone			X			
CO2 Calculator					X	
Project 2 Degrees	X		planned			planned

Ecospeed plans to release an English version of the ECO2Region tool in autumn 2009.
Project 2 Degrees plans to release additional language versions according to the demand of local authorities (French, Spanish, Russian, Japanese, Chinese and Portuguese).

ANNEX III: IPCC guidelines for national inventories

The 2006 IPCC guidelines for national GHG inventories state that national inventories should be transparent, consistent, comparable, complete and accurate (IPCC, 2006). This also applies to inventories of local authorities.

"Transparency: There is sufficient and clear documentation such that individuals or groups other than the inventory compilers can understand how the inventory was compiled and can assure themselves it meets the good practice requirements for national greenhouse gas emissions inventories […].

Completeness: Estimates are reported for all relevant categories of sources and sinks, and gases. Geographic areas within the scope of the national greenhouse gas inventory are recommended in these Guidelines. Where elements are missing their absence should be clearly documented together with a justification for exclusion […].

Consistency: Estimates for different inventory years, gases and categories are made in such a way that differences in the results between years and categories reflect real differences in emissions. Inventory annual trends, as far as possible, should be calculated using the same method and data sources in all years and should aim to reflect the real annual fluctuations in emissions or removals and not be subject to changes resulting from methodological differences […].

Comparability: The national greenhouse gas inventory is reported in a way that allows it to be compared with national greenhouse gas inventories for other countries. This comparability should be reflected in appropriate choice of key categories […], and in the use of the reporting guidance and tables and use of the classification and definition of categories of emissions and removals […].

Accuracy: The national greenhouse gas inventory contains neither over- nor under-estimates so far as can be judged. This means making all endeavours to remove bias from the inventory estimates […]."