EUROPEAN UNION

European Regional Development Fund

Regional Initiative Project

Common Information to European Air

Integrated Urban Emission Inventories

Dissemination level	External
Component	3
Author(s)	Sylke Davison, Sef van den Elshout, Bart Wester
Co-author(s)	Chapter 4: Cécile Honoré Annex 8.1 Cécile Honoré Annex 8.2 Antonio Lazano Annex 8.3 Fabio Nussio Annex 8.4 Linton Corbet Annex 8.5 Michalina Bielawska Annex 8.6 Ziva Bobic
Status	Final Version
File Name	
Contact	Sylke.Davison@dcmr.nl, 0031-10-2468199 DCMR, PO Box 843, 3100AV Schiedam, the Netherlands
Project Start Date and Duration	October 2008, 36 months

European Union
European Regional Development Fund

Co-financed by the ERDF

INTERREG IVC
INNOVATION & ENVIRONMENT
REGIONS OF EUROPE SHARING SOLUTIONS

Made possible by the
INTERREG IVC Programme

Revision history

Date	Author	Version
16-02-2009	Sylke Davison	Draft
08-03-2009	Sef vd Elshout	Draft
12-5-2009	Sef vd Elshout	Draft
Nov 2009	Sylke Davison	Draft
28-02 2010	Sylke Davison	Draft
September 2010	Sylke Davison/Bart Wester	Draft
2011	Hermann Heich, Bart Wester, Sef van den Elshout Sylke Davison	Draft

TOC

Preface

The aim of CITEAIR II is “to jointly identify, test and transfer a set of good practices through the exchange of experiences and to improve the effectiveness of regional development policies in the area of air quality protection, sustainable transport and reduction of greenhouse gas emissions”. The project was co-funded by the INTERREG IVC programme, was launched in 2008 and lasts until 2011.

The green paper on Adapting to climate change in Europe – options for EU action (COM(2007) 354) recommends to provide support to practitioners on knowledge and mitigation measures and cost benefit analysis. In this context existing emission inventories for air pollution emissions could be used as a foundation for including CO_2 so they can be used to monitor both air quality and climate policy. This guidebook looks into combining CO_2 emission inventories (EI-s) with existing air pollutant EI-s. A review of existing EI-s and their methodology has been prepared and a proposal has been made on how best to integrate EI-s

In short: This guidebook elaborates guidelines on how to develop baseline information to formulate and monitor climate change and air quality programmes in a consistent way.

Chapters 1, 2 and 3: are a general introduction. If you are new to the subject of emission inventorying these chapter are a good introduction they will help you to get started. If you are already working with emission inventories and you are interested in how to deal with GHG sinks in your area, chapter 4 will give you general and specific information on how to deal with these sinks. Chapter 5 gives practical information on problems and solutions you will encounter when building an integrated emission inventory for your city. Within the project a tool (CollectER (a database in Microsoft Access) with extra applications developed in the project) was tested and further developed (to make the tool easier to use by cities) in this chapter the tool is described and there is a link to a handbook that describes the use of the tool. Chapter 6 give information on how you can use and what you can use the integrated emission inventory for. Chapters 5 and 6 can help you decide if an integrated emission inventory is what you really want and need for your city.

Executive Summary

In recent years it has been increasingly recognised that air pollution and climate change are linked in several ways, and that they could be beneficially addressed by integrated policy. The push for policy integration comes mainly from consideration of implementation costs. Policy integration means finding the mix of end-of-pipe, structural and behavioural measures that meet air pollution and climate change targets at the lowest cost. Climate change is a major environmental challenge, and both greenhouse gases and air pollutants originate largely from the same emission sources

Inventories of emission, providing for emission by sources and removals by sinks, are one of the vital components of the environmental decision-making process. Hence emission inventories must be as accurate as possible in order to provide a solid base for decision making. They must be complete, covering all emissions. Over the last decades a lot of different methods for building emission inventories have emerged. There is a lot of information and software available however it is a jumble of information and will take quite some time to sort through. Information on integrated emission inventories is available but still scarce. Emission inventorying is time consuming as well the compiling as the maintaining of the database. This document presents several examples used in the participating cities and presents lessons learned building an integrated EI for which a software demo on the CITEAIR webpage:[1].

There are numerous difficulties in compiling an emission inventory for a city. There are two general methodologies used to estimate regional emissions: Bottom-up and Top-down. Bottom-up methodologies for example estimate industrial emission that are based on activity data and emission factors (amount of emissions per unit activity). Generally these emission estimates must be given finer sectoral, spatial (usually gridded), temporal, and for some inventories species resolution. Temporal and spatial resolution are obtained via the using activity information or surrogate information, such as population, land use, traffic counts etc which already exists in or can directly be converted to gridded emissions. Top-down emissions are usually derived from national statistical information on total fuel use in various sectors of the economy. Regionalisation is achieved using the location of important individual sources, and surrogate information such as population densities.

In this guidebook we describe a methodology with all its pros and cons so that municipalities will be able to build their own integrated emission inventory. It is based on a software tool (CollectER) mainly used for top-down EI-s for national emission reporting obligations. The database was adapted to cater for local spatial information needed for air quality modelling.

Acknowledgements

Valuable contributions to this guidebook were made by;

Chapter 4: Cécile Honoré, Airparif

Annex 8.1 Cécile Honoré, Airparif

Annex 8.2 Antonio Lozano, EGMASA

Annex 8.3 Fabio Nussio, Agenzia mobilita Roma

Annex 8.4 Linton Corbet, CHMI

Annex 8.5 Michalina Bielawska, ARMAAG

Annex 8.6 Ziva Bobic, City of Maribor

Hermann Heich from Heich Consult for giving valuable comments and input on the guidebook.

We also thank Tinus Pulles (TNO) for getting us started in several ways and providing information on CollectER.

[1] IMACE, http://www.citeair.eu/.

Glossary

ACTION PLAN: See “Local Action Plan”

AIR4EU: Air Quality Assessment for Europe: from local to continental scale, EC-Project

ANALYSIS: See “Emissions Analysis”

ARTEMIS: Assessment and Reliability of Transport Emission Models and Inventory Systems, EC project

BAT: Best available techniques

BASELINE: A hypothetical scenario for what greenhouse gas emissions, removals or storage would have been in the absence of the greenhouse gas project or project activity.

BASE YEAR: The emissions level against which to measure change over time, comprised of the annual emissions by activities within the boundaries of the analysis for a selected year.

CEPMEIP: Co-ordinated European Programme on Particulate Matter Emission Inventories, Projections and Guidance

BIOFUEL: A fuel derived from a recent biological (as opposed to fossil) source (e.g. vegetable oil, wood, straw, etc).

BREF: Best Available Techniques Reference Document

CARBON DIOXIDE (CO2): The most common anthropogenic greenhouse gas, CO2 is released naturally by respiration and anthropogenically by the burning of fossil fuels. It is removed from the atmosphere by photosynthesis in green plants.

CLRTAP UN-ECE: Convention on Long Range Transboundary Air Pollutants

COGENERATION: The generation of two forms of energy, such as heat and electricity, from the same process with the purpose of utilizing or selling both simultaneously.

CollectER III: tool for emission experts to collect and report national emission inventory data to international obligations of UNFCCC and UNECE LRTAP(http://acm.eionet.europa.eu/country_tools/ae/CollectERIII.html)

COPERT: Computer Programme to calculate Emissions from Road Transport

CORINAIR: Core Inventory of Air Emissions, European emission inventory of the European Topic Centre on Air Emissions (ETC/AEM)

CORINE: Coordination of Information on the Environment, EU Programme

CRT: Continuously Regenerating Trap

C-stock: carbon stock

CTM: Chemistry Transport Model

DIRECT EMISSIONS: Emissions that are owned or controlled by the reporting organization.

DM: Dry matter

DMS: Dimethylsulfide

ECE cycle: Economic Commission of Europe, Urban Driving Cycle

EI: Emission Inventory

EMEP: Co-operative Programme for the Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe

EMISSION ANALYSIS: A comprehensive, quantitative assessment of greenhouse gas emissions. The analysis may include a base year emissions inventory and an emissions forecast for municipal operations and the community as a whole.

EPA: United States Environmental Protection Agency

EPER: European Pollutant Emission Register

EUDC: Extra Urban Driving Cycle

EUROTRAC EUREKA Project: on the Transport and Chemical Transformation of Environmentally Relevant Trace Constituents in the Troposphere over Europe; Second Phase

FORECAST YEAR: Any future year in which predictions are made about emission levels based on growth multipliers applied to the base year.

FUGITIVE EMISSIONS: The unintended emissions of greenhouse gases from the transmission, processing, or transportation of fossil fuels or other materials (e.g. coolant leaks in HVAC systems or natural gas line leaks).

GENEMIS: Generation and Evaluation of Emission Data, EUROTRAC-2 subproject

GIS: Geographic information system

GHG: Green house gases

HC: Hydrocarbons (sometimes referred to as "VOC")

HBEFA: Handbook Emission Factors for Road Transport

HDV: Heavy duty vehicles

IIASA: International Institute for Applied Systems Analysis

IER: Institute of Energy Economics and the Rational Use of Energy, University of Stuttgart

IMPRESAREO Improving the Spatial Resolution of Air Emission Inventories Using Earth Observation Data, WP 4000 .Evaluation, Validation and Refinement of Spatially Resolved NOx Inventories**.**

INDIRECT EMISSIONS: Emissions that occur because of a local government's actions, but are produced by sources owned or controlled by another entity. For example, the purchase of electricity that was generated by emission-producing fuel outside of the jurisdiction's boundaries.

INVENTORY: The quantification of all emissions within the jurisdiction's boundaries during a particular year.

IPCC: Intergovernmental Panel on Climate Change

LDV: Light duty vehicles

LOCAL ACTION PLAN includes the Emissions Analysis, Emissions Reduction Target, Emissions Reduction Strategy, and Emissions Reduction Implementation Strategy.

LOTOS: Long Term Ozone Simulation, Eulerian grid model of TNO

LPS: Large point sources reported to CORINAIR

LSD: Low sulphur diesel

LULUCF: land use, land use change and forestry

MARIN: Maritime Research Institute Netherlands http://www.marin.nl/web/show

MEET: Methodologies to Estimate Emissions from Transport, EC project

MERLIN: Multi-pollutant, Multi-Effect Assessment of European Air Pollution Control Strategies: an Integrated Approach, EC project

NAEI UK: National Atmospheric Emissions Inventory

NATAIR: Improving and Applying Methods for the Calculation of the Natural and Biogenic Emissions and Assessment of Impacts on Air Quality, EC project

NEDC: New European Driving Cycle

NFR UN-ECE: Nomenclature for Reporting

NGV: Natural Gas Vehicle

NUTS: Nomenclature of Units for Territorial Statistics

OSCAR: Optimised Expert System for Conducting Environmental Assessment of Urban Road Traffic, EC project

PARTICULATES: Characterisation of Exhaust Particulate Emissions from Road Vehicles, EC project

PC: Passenger Cars

Pg: Pentagrams (= 10^{15} g)

PROXY DATA: Data that is unrelated to energy use but that can be used to estimate energy usage. For example, annual electricity cost in a region can be used to create an estimate of actual electricity use in a jurisdiction's inventory of emissions from government operations.

PRTR: Pollutant Release and Transfer Register

RAINS: Regional Acidification Information and Simulation model

SATURN: Studying Atmospheric Pollution in Urban Areas, EUROTRAC-2 subproject

SCENES: European Transport Forecasting model

SCR: Selective catalytic reduction system

SCRT: Combination of SCR and CRT systems

SNAP: Selected Nomenclature for Air Pollution

SUTRA: Sustainable Urban Transportation for the City of Tomorrow, EC project

TFEIP: United Nations Economic Commission for Europe (UNECE) - Task Force on Emission Inventory and Projection

TNO: Institute of Environmental Sciences, Energy and Process Innovation

TREM: Transport Emission Model for Line Sources

TREMOD: German Transport Emission Estimation Model

TREMOVE: Combination of TRE (TRENEN) and MOVE (FOREMOVE)

TRENDS: Transport and Environment Database System

ULSD: Ultra-low-sulphur diesel

ULP: Unleaded petrol

UNFCCC: United nation framework convention on climate change

USGS: United States Geological Survey

VERIFICATION: A process through which a third party confirms that a greenhouse gas emissions analysis has met a recognized minimum quality standard and complied with the appropriate procedures and protocols for calculating and submitting the emissions information.

VOC: Volatile organic compounds

Definitions:

Source: Any process or activity that releases a GHG (such as CO2 and CH4) into the atmosphere. A carbon pool can be a source of carbon to the atmosphere if less carbon is flowing into it than is flowing out of it.

Sink: Any process, activity or mechanism that removes a GHG from the atmosphere. A given pool can be a sink for atmospheric carbon if during a given time interval more carbon flows into it than flows out of it.

Activity data: Data on the magnitude of human activity resulting in emissions/removals taking place during a given period of time (e.g. data on land area, round wood extraction, lime and fertilizer use).

Emission factor: A coefficient that relates the activity data to the amount of chemical compound that is the source of later emissions. Emission/removal factors are often based on a sample of measurement data averaged to develop a representative rate of emission or removal for a given activity level under a given set of operating conditions.

Greenhouse Effect - The effect of heat retention in the lower atmosphere as a result of absorption and re-radiation by clouds and various greenhouse gases of long-wave terrestrial radiation. Incoming, short-wave radiation, including visible light and heat, is absorbed by materials which then behave as black bodies re-radiating at longer wavelengths. Certain substances (e.g. carbon dioxide) absorb long-wave radiation, are heated by it, and then begin to radiate it, still as long-wave radiation, in all directions, some of it downwards. Despite its name, the actual heating in a real greenhouse is caused mainly by the physical obstruction of the glass, which prevents warm air from leaving and cooler air from entering.

Greenhouse Gases (GHG) – Gases which are transparent to solar (short-wave or light) radiation but opaque to long-wave (infrared or heat) radiation, thus preventing long-wave radiant energy from leaving Earth's atmosphere. They thereby reduce the amount of the Sun's reflected radiation that escapes back to space, with consequent warming of the lower atmosphere and the earth's surface (see Greenhouse Effect). For the purposes of this

Protocol, GHGs are the six gases controlled by the Kyoto Protocol: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydroflurocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF6).

Intergovernmental Panel on Climate Change (IPCC) – An organization established jointly by the United Nations Environment Programme and the World Meteorological Organization in 1988 to assess information in the scientific and technical literature related to all significant components of the issue of climate change, and providing technical analysis of the science of climate change as well as guidance on the quantification of greenhouse gas emissions.

Removal factor: Rate at which carbon is taken up from the atmosphere by terrestrial systems and sequestered in biomass and soil.

United Nations Framework Convention on Climate Change (UNFCCC) – An international environmental treaty adopted at the United Nations Conference on Environment and Development in Rio de Janeiro in 1992. The UNFCCC provides an overall framework for international efforts to mitigate climate change. The Kyoto Protocol is an update to the UNFCCC.

1 Introduction

1.1 Integration of air quality and climate protection efforts

Air pollution extends from local (urban pollution) to regional (dispersion, deposition and chemical transformation of the pollutants, acid rain, photochemical reactions) and global level (greenhouse effect and depletion of the stratospheric ozone layer). Many initiatives that aim to both clean the air and protect the climate are emerging. The higher temperatures forecasted by scientists will worsen the air quality in several ways. Ozone formation tends to increase with higher temperatures, strong sunlight, and a stable air mass. Recent research confirms that global climate change will likely trigger increases in smog and health problems even if the level of man-made smog-causing pollutants remains the same. Just as climate change exacerbates air pollution, air pollution also exacerbates climate change. Incomplete combustion of fossil fuels, biofuels, and biomass produces black carbon, also called soot or particulate matter. The impact of these air pollutants on global temperature is very complex [1,2]. Some climate scientists assert that their overall impact is to heat the atmosphere. Air pollution and climate change share causes and solutions. Reduction in fossil fuel consumption reduces both pollutants and GHG emissions. Many pollutants, specifically the various oxides of nitrogen (NO_x) produced during combustion originate from fossil fuel combustion, as does carbon dioxide (CO_2), the primary greenhouse gas. Volatile organic compounds (VOCs) are ozone precursors, and will under certain circumstances, produce methane. Reducing VOCs improves air quality and helps protect the climate. The United Nations Environment Programme (UNEP) has launched an Integrated Assessment of Black Carbon and Tropospheric (ground level) Ozone to evaluate their roles in air pollution and climate change.

Climate Change and Air pollution are intimately linked through emissions from common sources, primarily those related to the use of fossil fuels; nevertheless in both science and policy these topics were often treated separately. In continuing to address pollutant challenges, state and local officials have the opportunity to capture significant GHG emission reductions. The most effective path for achieving this goal is to ensure that, in obtaining emission reductions needed for pollutant attainment, the applied strategies are ones that also provide GHG reduction benefits, rather than measures that are ineffective or counterproductive from a GHG perspective. Electricity generation and road transport are two of the most significant sources of both air and climate pollutants. Other sources include shipping (NO_x PM and CO_2), agriculture (NH_3, nitrous oxide (N_2O) and methane (CH_4)), and biomass burning (PM, NO_x and N_2O). Strategies that cut standard air pollution sometimes cut GHG emissions as well but often miss them or even worsen the GHG emissions; strategies that reduce GHG emissions almost always improve air quality as well[2].

There are numerous synergies that can be achieved by combining climate and air pollution policies, but there are also trade-offs. Interrelations between air pollution and climate change can be subdivided into four categories:

- emissions of one pollutant may contribute to regional air pollution as well as to climate change;
- climate change and regional air pollution may have an effect on each other and on emissions;
- air pollutants and greenhouse gases may be emitted by the same source; and
- technical measures to reduce emissions of greenhouse gases may affect emissions of air pollutants and measures to reduce emissions of air pollutants may affect greenhouse gas emissions.

Some clean air technologies actually increase CO_2 by lowering plant efficiency, thus requiring more energy to be used. Some alternative fuels that are good for air quality either have no effect or increase GHG emissions. Traffic congestion management measures like signal synchronization often reduce emissions only temporarily. Emissions may actually increase in the long run because short-term traffic relief encourages people to drive more. Technical emission control measures aiming at the reduction of one type of emissions from a particular source may reduce or increase the emissions of other sub-

[2] A particularly nasty problem is the fact that reducing NO_x and SO_x emissions reduces the formation of secondary inorganic aerosol that is believed to cool the earth by reflecting incoming solar radiation.

stances. In the energy sector, efficiency improvements and increased usage of natural gas can address both problems (synergies), while desulphurisation of flue gases reduces sulphur emissions but can — to a limited extent — increase carbon dioxide emissions (trade-offs). In agriculture, some specific measures to abate ammonia emissions could enhance nitrous oxide and/or methane emissions, while other types of measures would reduce these. Energy scenarios that ignore the linkage between emissions of local and regional air pollutants and greenhouse gases ignore the constraints imposed by concerns about local and regional air pollution on the development of the energy system and thus tend to overestimate the potential growth of greenhouse gas emissions. Similarly, an integrated assessment across economic sectors is important to identify possible situations in which emission reductions in one sector or region of one type of pollutant would lead to increasing emissions in another sector or region.

Public health benefits of strategies that simultaneously reduce GHG emissions and local air pollution precursors. Many other organizations are analyzing the linkages between localized and global air quality issues, including The National Association of Clean Air Agencies (NACAA) (formerly STAPPA and ALAPCO) [3].

Implementing climate policies, e.g. in order to achieve the Kyoto Protocol targets, can significantly reduce the costs of meeting air quality targets. In the same way, meeting stringent air quality targets is at the same point likely to require measures beyond end-of-pipe technological solutions, and require broader structural changes (e.g. in the energy mix), consistent with climate goals.

Neither the Convention on Long Range Transboundary Air Pollution of the United Nations Economic Commission for Europe (UNECE CLRTAP) [4], nor the current climate negotiations under United Nations Framework Convention on Climate Change (UNFCCC)[5] address Air pollution and climate change policies in Europe for these issues on policy level. At the technical assessment level however, the opportunities are increasingly noted (Intergovernmental Panel on Climate Change — IPCC, UNECE Task Force on Integrated Assessment Modelling — TFIAM). If climate change considerations were to be taken into account when designing policies and measures to abate local and regional air pollution (and vice versa), the cost-benefit equation and thus the relative priorities of policy options could change considerably; there is as yet no agreed operational framework to evaluate the importance of climate change versus air pollution. It is important to take into account the linkages between climate change and air pollution both in cost-effectiveness analysis (how to reach adopted environmental quality goals in the cheapest manner) and cost-benefit analysis (what is the economically optimal level of abatement?).

Choice and design of policies and measures to address climate change can affect the spatial and temporal distribution of emissions and hence their effectiveness in terms of air pollution. This needs to be taken into account in integrated assessment studies. A combined analysis of air pollution and climate change requires bridging different temporal (from a 10 to a 100 year perspective) and spatial (from local/urban to global) scales. In Europe, the European Environmental Agency has issued a report that analyzes the linkages between climate protection and air quality [57]. In the US the National Association of Clean Air Agencies (NACAA) in 1999 issued a substantial education resource guide to help state and local officials identify and assess harmonized strategies and policies to reduce air pollution and address climate change simultaneously. Many communities use software to help organize and convert data into emissions and create reports. ICLEI [6] and NACAA developed and released new software, called Clean Air Climate Protection Software (CACPS) in 2003 to enable communities to inventory criterion air pollutants and GHG emissions.

More information on air-quality and climate change co-benefits in policymaking is referenced in chapter 7 of this guidebook [44] [45] [46] [50] [52] [53]

A joint strategy would aim to find the optimal mix of end-of-pipe, structural and behavioural measures that meet both air pollution and climate change targets, taking into account the dynamics in technological developments and atmospheric processes by which air pollutants can affect climate change and vice versa. Integrated assessment models can help find such an optimal mix of measures once policy targets are set.

Note:

The challenge in addressing air pollution and climate change over the coming decades will be to maximise synergistic policies at international, national, regional and local level, while striving to minimise conflict between policies and to manage any residual negative impacts.

1.2 General information on emission inventories

From a policy perspective, the most important linkages between climate change and air pollution exist at the level of emission sources. Air pollutants and greenhouse gases are often emitted by the same sources and hence changes in the activity levels of these sources affect both types of emissions. Air quality is determined by the concentrations of pollutants in the atmosphere, which are, in turn affected by the dispersion of pollutants from emission sources. An emission inventory is an accounting of the amount of pollutants discharged into the atmosphere. An emission inventory usually contains the total emissions for one or more specific greenhouse gases or air pollutants, originating from all source categories in a certain geographical area and within a specified time span, usually a specific year. Information on emissions of air pollutants has been used since the early 1970's to study causes and effects of air pollution problems [7]. Some of the oldest emission inventory programmes date from this time. The "emissieregistratie" [8] in the Netherlands was one of these early inventories. Understanding emissions is at the core of understanding environmental pollution. Emission inventories are also at the core of the international agreements on climate change. Especially the use of inventories to monitor progress towards the agreed emission targets is an important application both in the convention and under the Kyoto protocol. Emission inventories influence: Control Strategy Development, Cap and Trade Programs, Air Quality Forecasting, Field Studies, Risk Assessments, Economic Incentive Programs, Global Climate and International Transport (of pollutants, goods), Accountability and Assessment, Compliance Assurance.

An emission inventory is generally characterized by the following aspects:

Why: The types of activities that cause emissions,
What: The chemical or physical identity of the pollutants included,
Where: The geographic area covered,
When: The time period over which emissions are estimated,

Emission inventories are compiled for both scientific applications and for use in policy processes (see table 1).

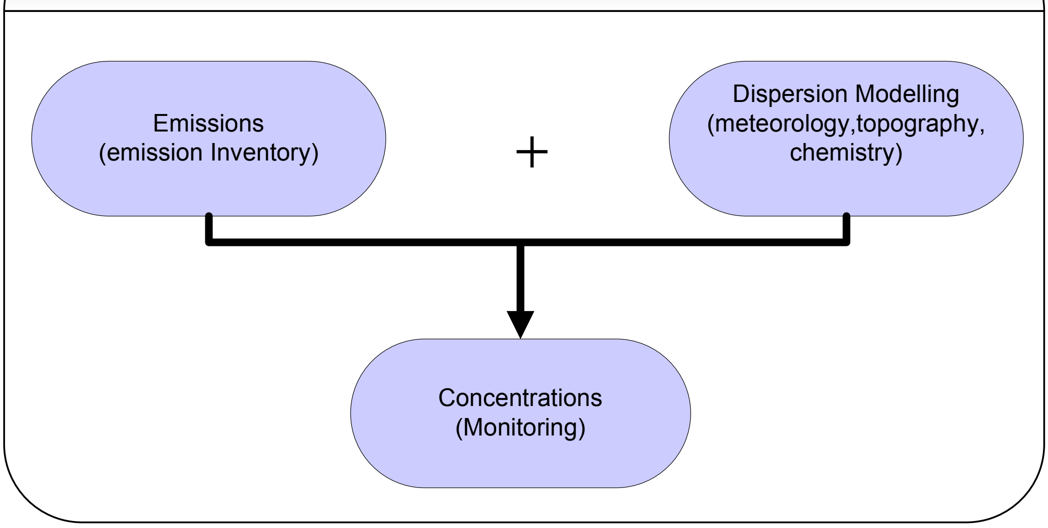
Policy use: Track progress towards emission reduction targets; annual reporting of national total emissions of greenhouse gases and air pollutants in response to obligations under international conventions and protocols; develop strategies and policies or; regular emission reporting by individual industrial facilities in response to legal obligations; this type of emission reporting is developed to support public participation in decision-making. The use of EI for regional/local purposes: For example for developing action plans as they are an obligation defined in the AQ directives

Scientific use: Inventories of natural and anthropogenic emissions are used by scientists as inputs to air quality and climate change models. Air quality models need input describing all air pollution sources in the studied area. This includes not only emissions but also geographic distribution, dispersion characteristics, etc. Air emission inventories provide this type of information.

Table 1 : Some examples of emission inventories for different uses

Use	Inventory examples
Policy use	National greenhouse gas inventories, submitted to the United nations Framework Convention on climate Change (UNFCCC) [5]
	National air pollution inventories submitted to the United Nations Economic Commission for Europe's Convention on Long Range Transboundary air Pollution (LRTAP) [4]
	Pollutant Release and Transfer Registers (PRTR) like the European Union EPER system (EPER) [9]
Scientific use	The GEIA emission databases GEIA [10]
	The EDGAR emission inventories (EDGAR) [11]
	The TNO Emission Assessment Model (TEAM) [12,13]

Figure 1 : Linkages between monitoring, modelling and emission inventories



In the absence of other air quality management tools, an emission inventory can provide an indication of pressures on the air environment and the maintenance of existing air quality. In conjunction with other tools, however, an emission inventory can be used to identify the sources of an air quality problem and can assist in the identification of management options to resolve the problem. This involves integration of the inventory data with other air quality tools such as monitoring data, meteorology, air quality targets and guidelines as well as other tools such as cost/effectiveness assessments.

Emission models and tools are needed to generate emission data as input for compliance monitoring and various other applications (figure 1). These models need to provide data with sufficient speed, in good quality, and with known uncertainties. In general these models apply methods that combine emission factors (EF) with activity data (A) to calculate emissions (E) in the following way:

$$\boxed{E = EF \times A}$$

EF: An emission factor can be defined as the average emission rate of a given pollutant for a given source, relative to the intensity of a specific activity.

Emission factors are used to derive estimates of air pollutant or greenhouse gas emissions based on for example the amount of fuel combusted, the number of animals in animal husbandry, on industrial production levels, distances travelled or similar activity data.

A: For each source the intensity of the activity needs to be estimated for all relevant locations and each of the years in the inventory.

However, even though this formula suggests a simple and straightforward approach, both the emission factors and the activity rates comprise a vast number of individual parameters which have an impact on the resulting emissions.

Benefits of developing an emission inventory: Accounting for emissions has helped many organizations gain better insights into the relationship between improving efficiency and reducing emissions. As a result, organizations have redesigned business operations and processes, implemented technological innovations, improved products and services, and ultimately saved money and sources. Identifying emissions sources to develop a GHG profile and management strategies may help local governments prepare for and respond to the potential impact of new regulations. Voluntarily reporting GHG emissions provides local governments with a pathway to recognize, publicize, and promote their environmental stewardship. Assembling an annual GHG emissions inventory can help inform management, constituents, employees, and the public about a local government's GHG emissions profile.

Benefits of developing an integrated urban emission inventory: CO_2 and air pollution have a common source: the combustion of fuels. So it is obvious that CO_2 and pollutant emissions are analysed in conjunction and that policy measures look at potential synergies and trade-offs. The green paper on Adapting to climate change in Europe – options for EU action (COM(2007) 354) recommends to provide support to practitioners on knowledge of both air quality and climate change action plans and provide local authorities with better information on how to deal with both challenges. An integrated emission inventory will enable cities to monitor both air quality and climate action plans. GHG and air quality policies have numerous synergies (e.g. improve energy efficiency, solar and wind power) but there are also trade-offs: the use of bio-fuels reduces CO_2 emissions but not necessarily the emissions of air pollutants and the carbon capture and storage technology actually increases NO_x emissions whilst storing CO_2. Integrated assessment of policy options is therefore essential. Having one integrated emission inventory will also save time. If changes occur, these changes will not have to be made in two different inventories. There will be more consistency between the two inventories then is now often the case.

Note:

An emission inventory is an assessment of the quantity of contaminants discharged to air and provides no indication of the impact of these contaminants on the environment.

2 Methodological issues on EI-s

2.1 Introduction

Emission inventories are developed using different types of information that describe source specific activities and emissions. For a good introduction on EI-s we refer to a document by Pulles and Heslinga [14].This document describes the general principles of emission inventorying. Point of departure of this document is the national reporting of emissions (e.g. to the EU). The emphasis is on getting the totals right. The document dwells briefly on practical issues. For EI-s used as a basis for detailed local modelling, practical issues are of utmost importance and in this guidebook we intend to identify and discuss the most important ones. Sturm and Winiwarter [15] provide information about methods for compiling an urban emission inventory in a harmonised way. The EUROTRAC-2 Subproject GENEMIS [16], as well as the EU project IMPRESAREO [17] are also useful references for guidance on urban emission inventory work. The IMPRESAREO project looked especially on using earth observations as a data source for improving urban emissions inventories. AIR4EU [18] addresses the needs for policy-orientated research on integrated air quality assessment by monitoring methods and modelling at different temporal and spatial scales for regulated pollutant components in Europe: PM10 (and PM2.5), NO_2, CO, SO_2, O_3 and benzene. The Emep/EEA Guidebook [19] contains the most influential set of emission estimation methods used in air pollution studies in Europe and elsewhere. It has been developed jointly over more than fifteen years by the UNECE Task Force on Emission Inventories and Projections (TFEIP), the European Environment Agency and its European Topic centres. The primary object of the guidebook is to support national experts in compiling emission inventories complying the requirements of specific legal obligations (LTRAP and its protocols and EU NEC Directive) The Revised 1996 IPCC Guidelines [20] contain three volumes, each of which provides assistance to the analyst in the preparation of national GHG inventory.

In the next few paragraphs methodological issues of building an air quality, a climate change and an integrated urban emission inventory are discussed.

2.2 Different ways to make EI-s

Different methodologies can be applied to establish an emission inventory. At the extreme ends one could devise them in top-down and bottom-up approaches.

Top-down approach:

A top-down inventory is characterised by a lack of detailed information about location and emissions from individual sources. When fuel consumption, production, vehicle and other activity statistics are available, a top-down inventory can be constructed, using the statistics and emission factors. So a top-down EI is based on statistical data collected over a larger region (a country, a NUTS region). If total emissions are a concern, e.g. EI-s to monitor emission ceilings or CO_2, this approach is often used. In a first phase, a top-down inventory can be produced with relatively little effort, to give an overview of the emissions, the most important sources and categories, etc. These inventories, however, lack local detail, as they use typical country-wide behavioural patterns which may not be reflected by an urban area to be considered specifically. Sometimes spatial information is added based on land use population densities, etc.

Bottom-up approach:

The bottom-up inventory is constructed from the more detailed knowledge of source types and locations, and their specific emissions or consumption data. A bottom-up EI is activity and location based. For each activity at all locations within an area (a city, a region) the emissions are determined. For monitoring emission policy the individual sources are aggregated for the area concerned. Bottom-up approaches provide a wealth of additional information compared to top-down approaches and can more easily be used to diagnose situations and formulate (local) policy. However, they are laborious to make and the chances of missing certain emissions are substantial. For detailed air quality modelling the individual emission sources are used.

Combined Approach:

Most CO_2 footprints are to a large extent top-down and most city air pollution EI-s are likely to be quite bottom-up. In an integrated air/climate EI, the two approaches need to be reconciled. This trade-off between top-down and bottom-up approaches is quite different for application to different scales. Exclusive use of bottom-up methods fails due to lack in available input data, while exclusive use of top-down methods will not lead to a desirable level of accuracy. So pure top-down or bottom-up approaches hardly exist and often a mixture is used. For example: often in a top-down emission database all individual sources above a certain threshold are described individually. In this way large point sources (energy production, oil refineries, steel mills, etc.) are monitored individually. Likewise, detailed bottom-up EI-s use top-down information for less important sources. Though the combination of bottom-up and top-down approaches or the construction of hybrid approaches makes sense, there is a strong risk of double counting, or forgetting emissions. Sturm and Winiwarter [15] recommend to use bottom-up approaches for traffic on the main road network, regular railway traffic on the rail network and scheduled traffic for ferry boats. A top-down approach might be used for traffic on the secondary road network (area sources), cold start emissions and evaporative losses, off road traffic, shunting activities in railway traffic, harbour activities, residential combustion, solvent uses etc.

2.3 City air quality and GHG emission inventories, what is the difference?

An EI for the modelling of air quality in a city is different from an EI for GHG. For air quality modelling one needs the spatial distribution of the emissions and the dispersion parameters of the sources. For GHG-s this is not needed. For AQ modelling in a city one generally needs data over a much larger area since air pollution is transported over long distances. This can be solved by nested models where a large scale model using for example a European EI is used to calculated general concentrations. The local EI can then be used to calculate the local contributions to be added to the large scale concentration field. In this case care should be taken that (large) sources are not included twice. EI-s for GHG generally stick to the boundaries of the area concerned, though sometimes emissions in other areas are added to a cities total as indirect or shadow emissions. (See section 2.8.)

In their most basic form EI-s contain the emissions in the area (and the associated spatial information and dispersion parameters in case of an EI for air quality modelling). For practical purposes this suffices and often not more information is available at local level. The details of how the emissions were calculated and what statistics they are based upon are often only available at a national le vel. For example local traffic emissions could be available without having the exact knowledge of the local fleet composition (age/type), the associated emission factors, distances driven, etc. Likewise the total emission of a plant could be known or obtained for a national database without the total fuel use of the plant, the total output of product and the emission factor being locally known.

However if an Integrated EI is to be made and to be used for policy monitoring or scenario analyses more information is needed. Ideally one compiles an inventory of all activities causing emissions, keeps track of the activity rates, the technology types and the emission factors associated with the technology type. If an EI based on activities is available, either for air quality modelling or for GHG, in principle it is not too complicated to establish an integrated IE. The only thing that is needed is to find the EF-s for the missing pollutants!

Assuming that an EI exists for NO_x based on the general concept:

$$E_{NOx} = \Sigma_i \, EF_{NOx,i} \; * \; A_i$$

Replacing $EF_{NOx,i}$ by $EF_{CO2,i}$ would instantly lead to a CO_2-footprint. Scenario analysis is conducted by varying activity rates (A) for changes in volume and EF-s for technological changes.

If a city has independently compiled EI-s for GHG and air pollutants it is interesting to compare the results when one is converted into the other. Ideally this should give identical results but due to a large range of assumptions needed to arrive to the simple equation above this is rarely the case. Doing this double check can be an indication of errors in one or both of the inventories. In chapter 6 some of these exercises are demonstrated.

2.4 Emission Sources

Emission inventories usually contain data on three categories of sources, namely point, area and line. This separation is important, for instance since these source categories are treated differently in dispersion models. The inventories should also contain geographical information so that emissions can be separated on area basis – e.g. region, country, province, urban air shed, city, neighbourhood, etc. According to the CORINAIR [21] Emission Inventory Handbook point, area and line sources are defined as followed:

Point sources : emission estimates are provided on an individual plant or emission outlet (usually large), usually in conjunction with data on location, capacity or throughput, operating conditions etc. Area sources: smaller or more diffuse sources of pollution are provided on an area basis either for administrative areas, such as counties, regions etc, or for regular grids (for example the EMEP 50x50 km grid, or far smaller grids for urban areas). Such sources are e.g. indoor heating (offices, domestic), small-scale fuel consumption for various activities/workshops etc., fuel consumption for road traffic which is not accounted for by the traffic count data which are usually available just for the main road network.

Line sources: in some inventories, vehicle emissions from road transport are provided for sections along the road system in a city or a country, based upon traffic data, and vehicle and technology type data. In country-wise inventories, also railway-tracks, rivers and sea-lanes could be considered as line sources.

The most recent emission source nomenclature for anthropogenic and natural activities is the SNAP 94 (Selected Nomenclature for Air Pollution) developed by the EEA. Together with the EMEP/CORINAIR "Atmospheric Emission Inventory Guidebook', a framework for estimating emissions can be defined.

Table 2 : Snap Code, Selected Nomenclature for sources of Air pollution

SNAP	Description
01	Combustion in energy and transformation industries
02	Non-industrial combustion plants
03	Combustion in manufacturing industry
04	Production processes
05	Extraction and distribution of fossil fuels and geothermal processes
06	Solvent and other produce use
07	Road transport
08	Other mobile sources and machinery
09	Waste treatment and disposal
10	Agriculture
11	Other sources and sinks

2.5 Access to emission data

Within Europe, a significant resource of publicly available officially-reported air emissions data is available. This information ranges from national emission inventory data reported by the European Union Member states, through to emissions reported by operators of industrial point source facilities. This includes emission inventories that are prepared on local and- regional level, e.g. for the development of action plans as they are defined in the air quality directives. This information can be used as input for the urban emission inventories. With emission reporting obligations towards the UNECE (Geneva Convention on Long- Range Transboundary Air Pollution)[4], the UNFCCC (United Nations Framework Convention on Climate Change) [5] or the EU (e.g. the NEC - National Emission Ceiling - Directive) [22], national emission data is mostly accessible via a country specific internet portal. Additional information concerning calculation methodologies, emission factors and uncertainties is often provided. Simple or more detailed methodologies and basic data for the calculation of most anthropogenic emissions can be found within the joined EMEP/CORINAIR Atmospheric Emission Inventory Handbook [21]. Several other national or international studies are currently available dealing with the availability and current state of knowledge regarding emission factors that can also be used for sectoral emission calculation [36]. Furthermore, information on specific emissions from industrial sources can be found within the Reference Documents on best available techniques (BREFs) (see http://eippcb.jrc.es) [23]. BREFs present results of an exchange of technical information organised in specific Technical Working Groups to determine and describe "best available techniques" in accordance with Council Directive 96/61/EC concerning integrated pollution prevention and control (IPPC Directive). The Organisation for Economic Co-operation and Development (OECD) publishes free-of-charge Emission Scenario Documents considering emissions from chemical industries within the framework of the Inter-Organisation Programme for the Sound Management of Chemicals (IOMC) (s. http://www.oecd.org/).

2.6 Uncertainties

An emission inventory is a model of the real world, designed to estimate the emissions of greenhouse gases and air pollutants, caused by economic and societal activities in a specific region and a specific year. We will never know if the estimate is the same value as the real emissions. It is unavoidable that the estimated emissions therefore are always uncertain. Following the definitions in the 2006 IPCC guidelines [27] two important concepts to understand uncertainties, and hence the quality of a reported inventory are;

Accuracy	Agreement between the true value and the average of repeated measured observations or estimates of a variable. An accurate measurement or prediction lacks bias or, equivalently, systematic error.
Precision	Agreement among repeated measurements of the same variable. Better precision means less random error. Precision is independent of accuracy.

Note:

The uncertainty in the assessment at the small local scale (i.e. Municipality) is far larger than the emission uncertainty at the national or regional level.

Uncertainties have a different impact in scientific and in policy applications of EI. Uncertainties are very important for scientific applications, an uncertainty analysis should always be part of any scientific study. The uncertainty analysis helps the scientist to explain their results. The policy community is not interested in uncertainties as such. In the need to know if targets have been met or not, they do not want an uncertainty on their yes or no. For improvement of the emission inventories uncertainty is interesting again.

The uncertainty of an emission inventory with respect to its elements is related to one of the following.

1) Uncertainty related to the choice of the indicators
2) Uncertainty related to the quantitative value of the indicators
3) Uncertainty related to the emission factors
4) Uncertainty related to the representativity of the emission factor for the sources it is applied to
5) Uncertainty related to a complex structure of emission estimate models
6) Uncertainty related to the temporal and spatial attribution of emissions .

All these points must be considered for each of the input parameters used for the inventory.

Information on quantifying uncertainties can be found in the report: the art of Emission Inventorying [14]. Some studies tried to assess the scientific uncertainties by comparing ambient air quality measurements with the expected concentrations, calculated by atmospheric dispersion and chemistry models in combination with emission inventories [24]. Chapter 6 of the IPCC Good Practice Guidance [31] provides relatively simple methods to quantify uncertainties. This approach had been incorporated in the EMEP/EEA guidebook [19].Another source is [54].

2.7 Practical problems in preparing EI-s for a city

Emission inventories are often made on a national scale in particularly in case of greenhouse gases. What could the benefits be to make an emission inventory at a lower scale. Table 4 gives a few strengths and weaknesses of making an emission inventory at a local scale.

Table 3 Local emission inventories versus a national/international emission inventory

Strengths	weaknesses
local emission inventories have a better precision at the local scale	Higher uncertainties
Better territory adherence	Congruence with higher scale EI-'s
Focus on key sources	Need for skill, time consuming
Better input for air quality modelling	Data that is not available at a local scale
Support for local policies	

The more the temporal and spatial scale decreases, the more the precision of the estimates at least for greenhouses gases decreases. Part of the local emission data is often not available at a local scale and needs to be estimated as a fraction of a national total.

<u>Boundary issues:</u>

A particularly difficult aspect of top-down approaches is the boundary problem and in CO_2 footprint this leads to two rather different approaches. Suppose we have a harbour where large amounts of fuel are sold. These fuel sales are registered by the statistics (tax) office. But how do we know where the fuel is used? For an EI, and especially one that is used for modelling the dispersion of emissions the location of use needs to be known. Bottom-up EI-s don't suffer from this problem but top-down EI-s need to account for the exportation of fuels sold or imported in the area. When it comes to CO_2 footprints the question arises how to deal with, for example, CO_2 produced in energy production, if this energy is exported? E.g. The CO_2 produced in making a quantity of petrol is it attributed to the location where the petrol is made, or where it is used? Similarly, if electricity is generated, is the CO_2 attributed to the power plant, or to the user of the electricity? They are not necessarily in the same area.

For Rotterdam's CO_2 footprint a "source approach" was used. This means that all emissions occurring within the Rotterdam territory are added to the Rotterdam footprint. The alternative is a "user approach". In this case the CO_2 emission is attributed to the final user of the product. The source approach is more straightforward to implement (and it is the most commonly used method) but in industrial areas and ports it often leads to higher CO_2 emissions. In case of Rotterdam the user and the source approach lead to 23, respectively 29 Mton CO_2 in 2005, implying that Rotterdam and the port-industrial area are exporting energy-content.

Double counting of emissions: This is a common problem in inventorying. It is generally caused by the use of different methodologies for the same emission sources (top-down and bottom-up approaches). The main reason for that is that in compiling the inventory at least two different kinds of activity data are being applied. Basically, statistical data used for economical statistics and data used for environmental statistics are being used together. A classic example of double counting are the different counting's used for kilometres for car use and the counting of fuel used. Both are used in emission inventories but never is there a fully accepted relation between the two of them. By comparing the emissions to the emissions calculated for the same entity by independent methodology one can find double counting. The issue of double counting greenhouse gases (GHG) is increasingly becoming a problem due to a lack of national guidance on GHG management. For example, consider a city conducting a community-wide GHG emissions inventory. If a power plant within city limits annually emits 1,000 metric tons of carbon dioxide equivalent (MTCDE) from its electricity production, these emissions are included in the city's inventory. Also, a large business is purchasing electricity generated from this same power plant, which the amount of electricity they purchase annually is equivalent to 10 MTCDE annually. In this scenario, 1 percent of GHG emissions from the power plant are being double counted. Both the business and the city are correctly accounting for their emissions, yet the power plant's emissions are still being double counted. What if the power plant itself conducted a GHG inventory? These emissions could then be triple counted.

Missing sources:

Emission inventories are based on a certain amount of assumptions, best guesses and expert judgements. Especially urban emission inventories, while assembling a considerable amount of detail and determined to be very accurate, may lack precisions due to the fact that emission factors may be applicable to averages and may not be so good for individual sources. This is why it is so important to compare results of an inventory to an independent approach [examples in 15].

Sources that are often missed are: small scale activities aside big industrial complexes or installations such as cleaning tanks, storages, emissions from buildings ,Illegal activities like cable burning in open air, burning buildings, cars containers, Agricultural/ nature emissions, stops and starts of industrial installations, incidental releases (spills, valves, flares), start-up and shut-down emission of industrial installations.

Several techniques exist to evaluate emissions data including "common sense" review of the data, source-receptor methods, bottom-up evaluations that begin with emissions activity rates and emission factors, and top-down evaluations that compare emissions estimates to ambient air quality data. Each evaluation method has strengths and limitations [25].

Displaying emission data graphically is also a useful means for quality assurance. A tile plot of gridded emissions is an effective tool for identifying misplaced sources and for assuring oneself that spatial patterns of emissions are consistent with the location of sources. Pie charts are useful for assessing whether distribution of emissions among source types or categories is plausible. Displays of time series enable to look at diurnal or weekly patterns in emissions to see whether these appear logical (e.g. comparisons for night vs. day or weekends vs. weekdays).

Another way to find out if sources have been missed is to compare models data with measurements, this is the best way to find gaps. A large amount of data on industrial processes that have to be submitted by the operating companies to regional or national administrative authorities might be used for emission modelling. These data often include activity rates such as production volume, fuel input etc., measured or calculated annual/monthly stack emissions and additional point source information but have a restricted availability due to data security concerns. If accessible, these data can be included as anonymous information, urban scale inventories in order to detect missing sources.

Data availability on urban scale is usually limited with regard to local/regional information on emission factors, activity rates and other parameters. Therefore, a significant lack of source-specific information usually exists for bottom-up analysis, especially for major sources such as road traffic or industry. Data has often to be used that was derived from other regions/technology stocks and national statistical distributions are often the only possibility to specify sources. As a result of possibly particular conditions, uncertainties of generated emission data on a high spatial resolution and a small-scale area can be much higher than on a regional scale and a coarser grid.

2.8 A particular issue, indirect or shadow emissions

Many cities have signed the Covenant of Mayors[3] . To show the success of a city in reducing its emissions a city might need something else than an emission inventory. For example energy used in city A. could be generated in a power plant in city B. Hence, the emissions of the people in city A. will be in the inventory of city B. For city A. to be able to monitor and show emission reduction progress it has to calculate and keep stock of its indirect or “shadow emissions”. Mixing emissions and shadow emissions in one inventory makes sense for local policy monitoring but the risk of double counting when regional emissions are aggregated is very real.

Indirect emissions are very important at a local scale. For air quality modelling only emissions that occur in the investigated area are considered. For GHG it is not so straightforward, It could be useful to consider the emissions due to the activities located in the territory and not consider the actual emissions. It could be very useful to consider these shadow emissions (these emissions are derived from actual consumption within the considered area but described as emissions from another area) local policies can do something about these emissions, hence they are very important for smaller municipalities and provinces. Estimating these emissions is relatively easy if you are deriving these emissions from for examples electric power consumption but a lot harder for other consumption that was produced elsewhere.

If shadow emissions are included in your EI, it is not an EI anymore but an emission balance.

The question is, is it better for your city to make an emission inventory or an emission balance (or carbon footprint) for greenhouse gases? This depends on the aim of your emission inventory. If you want to use your local emission inventory to set reduction policies it is a good idea to focus on activities (relative emissions) depending on policies that are locally manageable (including emissions from electric consumptions). A lot of local policies are focussed on household heating and urban traffic. Many emission reductions occur at a local scale, but they are controlled by higher policies: the renewal of the vehicle fleet by means of low CO_2 emission vehicles depends on regulations at the European level.

[3] The Covenant of Mayors is the mainstream European movement involving local and regional authorities, voluntarily committing to increasing energy efficiency and use of renewable energy sources on their territories. By their commitment, Covenant signatories aim to meet and exceed the European Union 20% CO_2 reduction objective by 2020.

3 EI-s and EI management

3.1 Quality of Emission Inventories

The quality of an emission inventory depends on its use. In policy applications, the inventory should comply with all what has been decided under the relevant convention. Both the UNFCCC [26] and LRTAP [4] conventions require an inventory to follow the quality criteria below.

Table 4 ; Criteria to be taken into account for UNFCCC and LRTAP

Criterion	Description
Transparent:	the assumptions and methodologies used for an inventory should be clearly explained to facilitate replication and assessment of the inventory by users of the reported information. The transparency of inventories is fundamental to the success of the process for the communication and consideration of information
Consistent:	an inventory should be internally consistent in all its elements with inventories of other years. An inventory is consistent if the same methodologies are used for the base and all subsequent years and if consistent data sets are used to estimate emissions. Under certain circumstances referred to in the chapter on time series consistency (Time Series Consistency chapter of the General Guidance part of this Guidebook), an inventory using different methodologies for different years can be considered to be consistent if it has been recalculated in a transparent manner, taking into account any good practices
Comparable:	estimates of emissions reported by Parties in inventories should be comparable among Parties. For this purpose, Parties should use the methodologies and formats agreed within the convention for estimating and reporting inventories
Complete:	an inventory covers all sources, as well as all pollutants, included in the Convention and Protocols , as well as other existing relevant source categories which are specific to individual Parties, and therefore may not be included in the Guidebook. Completeness also means full geographic coverage of sources and sinks of a Party.
Accurate:	a relative measure of the exactness of an emission estimate. Estimates should be accurate in the sense that they are systematically neither over or under true emissions, as far as can be judged, and that uncertainties are reduced as far as practicable. Appropriate methodologies conforming to guidance on good practices should be used to promote accuracy in inventories

A well constructed inventory should include enough documentation and other data to allow readers and users to understand the underlying assumptions and to assess its usability in an intended application.

It is good practice to implement quality assurance/quality control (QA/QC) and verification procedures as an integral part in the inventory management. IPCC [31] provides the following definitions:

Quality assurance (QA): is a planned system of review procedures conducted by personnel not directly involved in the inventory compilation/development process. Reviews, preferably by independent third parties, are performed upon a completed inventory following implementation of QC procedures. Reviews verify that measurable objectives were met, ensure that the inventory represents the best possible estimates of emissions given the current state of scientific knowledge and data availability, and support the effectiveness of QC programme.

Quality control(QC):is a system of routine technical activities to assess and maintain the quality of the inventory as it is being compiled. It is performed by personnel compiling the inventory. The QC system is designed to;

-provide routine and consistent checks to ensure data integrity, correctness and completeness.

-identify and address errors and omissions

- document and archive inventory material and record all QC activities.

QC activities include general methods such as accuracy checks on data acquisition and calculations, and the use of approved standardised procedures for emission and removal calculations, measurements, estimating uncertainties, archiving information and reporting. QC activities also include technical reviews of categories, activity data, emission factors, other estimation parameters and methods.

Quality assurance activities will always involve external expertise. In a number of cases compilers' can produce two independent estimates and compare the results between these. This might include an estimate based on a top-down approach, using national energy balance and national averaged emission factors and a bottom-up approach using detailed facility level data and energy consumption statistics.

3.2 Activity-based EI-s

Air emissions data are constructed from data on energy consumption. One of the most accurate methods for estimating air emissions is through an activity-based emissions inventory where emission estimates are based on activity levels versus for example fuel inventories.

Emission factors available from literature are applied to activity rates describing a specific emission source. It is evident that the appropriateness of an emission factor to a certain activity, as well as the precision of this emission factor can be very different from case to case. The same is true for applicability and magnitude of activity rates. Consequently, the quality of the resulting emission data depends on very subtle differences and variations of input choices

So for each source the intensity of the activity needs to be estimated for all relevant locations and each of the years in the inventory [14]. To do this several approaches are available:

Plant level data: The most detailed data that could serve as source for activity data are facility level or even plant level or installation level production data. However most facility level data sets, including EPER [8], contain emission only and no information on the underlying processes. The use of facility data in emission inventorying is a bottom-up approach.

National statistics: For those sources, where facility data are not available, activity data are preferably derived from national energy and production statistics. Both the IPCC Guidelines [27] and the EMEP/EEA Guidebook [21] provide source category specific information on how activity data can be derived from readily available statistics. This is a top-down approach.

International statistics: When national statistics are not available, several international statistical services can be used to find activity data for different sources. These include: UN statistical data [28], EUROSTAT [29], IEA [30].

Proxies: In some cases appropriate data cannot be found. In such cases application of a so-called proxy variable can help to derive at least rough estimates of the activity rate. A proxy variable is a variable that is not directly related to the data needed, but might have a good correlation with such data. Such proxy could be the population size or gross domestic product.

Thus, it is often necessary to aggregate or disaggregate parameters with the help of statistical data or other information. If for instance mileage data are only available for different vehicle categories and average urban, rural and highway road classes, more detailed emission factors have to be averaged using statistical distributions e.g. of slope, driving conditions, share of diesel and gasoline engines, EURO emission standards and vehicle capacity/ weight. Availability and level of detail of activity rates depend on national/regional conditions

Some examples:

- Residential heating emissions(snap 0202)

In Ile de France region residential heating emissions are calculated as follows:

Emission= Activity * EF

Emissions are residential boilers emissions calculated as grams of emissions per year

Activity is regional residential heating energy consumption data. It is available per residence types (house or apartment), per types of fuels (natural gas, coal..) and type of practices (heating, hot water and cooking…) per year.

EF are emissions factors usually expressed in grams per unit of energy (g/GJ) and per fuels

In this example, it is necessary to aggregate activity per residential types and type of practices because activity is more detailed than emissions factors.

- Activity-based emissions inventory for marine vessels
- Emissions are estimated as a function of vessel power demand (expressed in kW-hrs) multiplied by an emissions factor, where the emission is expressed in terms of grams per kilowatt hour (g/kW-hr). There are two equations used to estimate OGV emissions.

Equation 1 E = Energy * EF

Where:

E = Emissions from the engine(s) that are included in the "Energy" term discussed below, usually calculated as grams of emissions per unit of time (e.g. per year).

Energy = Energy demand in kW-hrs, calculated using Equation 2 below as the energy output of the engine (or engines) over the period of time covered by the estimate.

EF = Emission Factor, usually expressed in terms of g/kW-hr, discussed in more detail below.

The "Energy" term of the equation is where most of the location specific information is used.

Energy is calculated using Equation 2.

Equation 2 Energy = MCR * LF * A

Where:

MCR = Maximum continuous rated engine power, kW

LF = Load factor (no units)

A = Activity, hours

Eij = EFi * Ai * Fij (1)

where:

Eij = pollutant emission from source group i and (optional) component j

EFi = pollutant emission factor of source group i

Ai = annual, monthly, daily or hourly activity rate of source group i

Fij = (optional) factor (e.g. particle size factor, factor for chemical speciation of PM, VOC, NOx) for emission component j from source group i

- Bottom-up/top-down

The Saturn [32] project states: If the activity data is given on a statistical basis, a top-down methodology must be applied. This is normally the case for SNAP sectors 2 (heat demand), 6 (solvents), 10 (agriculture) and 11 (nature). As a prerequisite for applying the bottom-up approach instead of the top-down approach sufficient information has to be available on location, activity data and emission factors. An example could be the bottom-up approach of emissions from agricultural sources when detailed information on land use cover and location is known and specific meteorological data and emissions factors are available.

- Emissions in Seville

Air emissions are estimated through an activity-based emissions inventory.

Most activity sectors are treated by a bottom-up approach, for which the necessary information to estimate their emissions is received directly from plants, either by PRTR reporting or EI questionnaires (sent to plants every four years).

For example, the emissions released from the production of the bricks and tiles sector are estimated on a case-by-case basis, as a function of every plant's activity rates, such as bricks and tiles production, fuel consumption or raw materials consumed. Depending on pollutants, a suitable emission factor for each process within this activity is used. Thus, to estimate emissions from the bricks and tiles making industry, following equation are used:

$$E = A \times EF \times F$$

where:

E = emission from a bricks and tiles production plant, usually calculated as tons of emissions per year.

A = annual activity rate of bricks and tiles production plant; bricks and tiles production, fuel consumption or raw materials consumed (it depends on pollutant).

EF= pollutant emission factor for every specific process in bricks and tiles production. Generally it is used CORINAIR and EPA factors).

F = factor (e.g. particulate $PM_{10}/PM_{2,5}$ or chemical speciation of dioxins and furans).

There are cases where emissions cannot be calculated at a suitably small spatial scale, because of data availability. These sources (such as traffic, agriculture, domestic, forestry, etc.) are treated in an aggregated way. Their emissions need to be distributed across a spatial area (to municipality level) using a suitable statistic dataset according to activity sector. The general equation used to distribute emissions of this kind of sources is presented below:

$$E_i = E_t \times V_i \,/\, V_t$$

where:

E_i = emission attributed to a specific area (municipality or administrative boundary).

E_t = total aggregated emissions for a sector to be distributed at municipal level.

V_i = statistic data value of a specific area.

V_t = total statistic data value of all of specific areas within the whole area (to regional level).

3.3 Spatial emission data (for AQ modelling)

To model air quality in cities be it for compliance checking or for a scenario analysis, a spatially detailed EI is needed. Often temporal variations also need to be included for example to estimate the number hours the NO_2-concnetration exceeds 200 µg/m^3.

Ideally these inventories are made bottom-up though for some categories (e.g. residential heating) emissions are generated based on statistical data for administrative units and land use data

Point source data: must be assigned via their geographical co-ordinates (longitude, latitude and altitude). The data describing point source emissions can be divided into several groups. Some of the data describe the stacks through which the emissions are released into the atmosphere. Other data describes the technology installed to reduce the emissions, and yet other data describe the activity that generate the emission, in the form of emission, consumption or production data and operating schedule for a given process.

Area source data: are used when the activity data or the emission factor is a function of an area (e.g. emission in g/m^2 or activity in person/m^2)

Area source data may include emission data and energy consumption data distributed in administrative sub districts or in a grid. Population data is normally used for distribution of data which is related to human activities. Land use data is usually used to further allocate emissions spatially.

Example: Many small emitters (e.g. small stacks from residential combustion) can be treated as area sources. Surrogate factors should be identified for each area source category, used to spatially allocate the emissions. On EU scale, the spatial allocation of area source emissions to administrative units (NUTS 1, 2 or 3) can be done with the help of statistical data such as employees, land use or population [34]. Area sources on urban/local scale are usually distributed using land use data with high spatial resolution (e.g. 100 m x 100 m). In addition, data in further detail could be useful (e.g. data on fuel input or population per block/square of residential area). It has to be noted that for such applications a bottom up approach is necessary. A top-down approach (a disaggregation of statistical emission data) may not be sufficient.

Line source data: for the modelling of traffic induced emissions several input parameters must be defined.

- Road classes: Road classes are used to categorize road sections. A number of traffic parameters may be assigned default values according to the road class to which the individual road belongs. Typical road classification can be: major roads / transit roads, city centre streets, residential area streets, industrial area streets and secondary streets.
- Vehicle classes: Before importing data for traffic volumes, it is necessary to define the relevant vehicle classes. Such classes may be: passenger cars, buses, two-stroke engine motorcycles, trucks etc. The division is such that it is natural to assign emission factors to each vehicle class separately, as well as it is possible to obtain traffic counting of such vehicles on the various roads.
- Road link definition: The road network consists of several road sections which are called road links. These must be described with identification number, co-ordinates and name. In addition, physical description such as number of lanes, width in each direction, road class type, must be entered.
- Dynamic traffic data: For each road link or classes of road links, detailed information on the traffic flow must be collected. Examples of such data are: annual daily traffic, free flow speed, cold start ratio and vehicle class distribution. Most of the parameters above must be given for each lane and direction.

Example: Mobile sources_on the main road and rail network are treated as line sources. Ships are occasionally treated as line sources but also as series of point or small area sources. Traffic on major urban roads is often modelled based on traffic census data. Emissions from traffic on minor side roads are often allocated according to the road lengths per grid cell and treated as area source.

Data availability:

More detailed information can be found on in http://www.air4eu.nl/reports_products.htmlAIR4EU, Issue 1: data &data needs. [36]. On an urban scale data availability is usually limited with regard to local/regional information on emission factors, activity rates and other parameters. Therefore, a significant lack of source specific information usually exists for bottom-up analysis, especially for major sources such as road traffic or industry. Modelling point sources is often limited due to nondisclosure rules for industrial data. EPER data [8] provide the location of 8.082 major sources in the EU, Norway and Hungary that can be used if national/regional industrial data is not available. If single source information is not available for the calculation of effective emission heights, sector estimations might be used for the vertical allocation to model layers. A distribution of the effective emission height is given for SNAP source groups level1.

3.4 Combining activity and spatial data into one system

The first step of generating emission data is the calculation of sectoral emissions based on source specific basic data (activity rates, emission factors and source specifications). This leads to a sectoral source and emission inventory usually as an annual emission table for the whole area or already subdivided into different administrative units. (recommended approaches: [15]).

Table 5 : Parameters for the disaggregation to smaller administrative units

SOURCE CATEGORY	DISAGGREGATION PARAMETER
Industrial fuel use	industrial employment; industrial statistics: nominal production, energy consumption, fuel consumption, etc.
Industrial processes	industrial employment by branch; industrial statistics: nominal capacity of production, raw material consumption
capacity of production	raw material consumption
Domestic combustion	population or heating equipment and specific heat demand, domestic fuel consumption or sales
Regional road traffic	car registrations, population, fuel consumption or sales
Nature and agriculture statistics	total area or specific for forest uses of the administrative units

Satellite data may be used for improving disaggregation procedures in emission inventories. A suitable method for this purpose was developed in the frame of the EU funded project IMPRESAREO [17] Several test sites were chosen to optimise and to apply the spatial distribution of emissions following the approach developed within IMPRESAREO. The grid resolution used in these examples was consistently set to 1×1 km². The first applications referred to the cities of Stockholm and Linz (Austria), and were used to assess the weighting factors. These inventories were limited to just one pollutant (NOx). Multi-pollutant inventories were created for Belfast and London, as well as for the whole of England and Wales. The latter application proved that the method need not be restricted to urban areas. A final method evaluation, without further refinement, was performed for the Greater Athens Area and for the Milan province. For each of these areas, emission inventories are now available at different levels of detail, but at an identical spatial resolution.

The Generation of European Emission Data (GENEMIS) [16] project, a component of the European Experiment on Transport and Transportation of Environmentally Relevant Trace Constituents in the Troposphere over Europe (EUROTRAC) project, has developed values for European emissions at the appropriate temporal and spatial resolution for use in the EUROTRAC transport and transformation models [42]. Staring with annual values temporal resolution of ½ to one hour and daily and grid sizes of 80X80 and 60X60 are being achieved.

3.5 Practicalities on bottom-up and top-down approaches

The methodology used to define source strengths and activity data is crucial for the quality and applications of the emission inventory. A distinction between bottom-up and top-down methodology for stationary sources is not easy. It depends on the area under consideration, characteristics of emission sources etc. whether top-down or bottom-up approach can be made.

Provided the information is available, increasing the details in the inventory will improve the quality of the estimate. Getting more details is time consuming so the inventory compiler has to find a trade-off between more details and the accuracy of the inventory. To support this trade-off, inventory guidance for both greenhouse gasses and air pollutants, the so called Tiers, have been developed.

For relatively unimportant sources a so-called tier 1 (use a typical average technology) can be used For more important sources, the inventory guidance requires the use of technology stratified (Tier 2) or even process modelling (Tier 3) (table 6).

Table 6 : Definition of methodological Tiers EMEP/EEA Emissions Inventory Guidebook-2009

	Description
Tier 1	Is a method using readily available statistical data on the intensity of processes ('activity rates') and default emission factors. These emission factors assume a linear relation between the intensity of the process and the resulting emissions. The Tier 1 default emission factors also assume an average or typical process description. This method is the simplest method, has the highest level of uncertainty and should not be used to estimate emissions from key categories.
Tier 2	Is similar to Tier 1 but uses more specific emission factors developed on the basis of knowledge of the types and processes and specific process conditions that apply in the country of which the inventory is being developed. Tier 2 methods are more complex, will reduce the level of uncertainty and are considered adequate for estimating emissions of key categories.
Tier 3	Is defined as any methodology that is more detailed than Tier 2. This means that there could be a wide range of Tier 3 methodologies. At one end of the range, are methodologies similar to Tier 2 (i.e. activity data X emission factor) but with a greater disaggregation of activity data and emission factors. At the other end of the range are complex, dynamic models in which the processes leading to emission are described in great detail.

In the EMAP/EEA guidebook each technical chapter has a section on methodologies for emission estimation. This section contains a decision tree, which assists the compiler to choose the appropriate method for estimating air pollutant emission. Figure 2 is an example of the decision tree. With this an inventory compiler can select the appropriate methods and priorities for his work on the most important source categories. The guidebook states that a key category is one that is prioritised within the national inventory system because it is significantly important for one or a number of air pollutants in a country's national inventory of air pollutants in terms of the absolute level, the trend, or the uncertainty in emissions. For more information see the guidebook itself.

In many cases a bottom-up approach, starting from individual processes at individual plants, does not cover all facilities. Some facilities might fail to report and others might have emission below a threshold, set in the permit or other legislation. These emissions are usually about 10% of the total source category, these emission have to be estimated.

Problems that can be encountered in matching bottom-up and top-down approaches:

Wrongly downscaled emissions

In order not to miss emissions even bottom-up EI-s use national aggregates that are downscaled to local areas. For example, mobile equipment at construction sites uses fuel. But no one keeps track of what equipment was used where. A common approach is to allocate such emissions to large areas and distribute them for example according to population density. One approach used in the Netherlands is to distribute fuel used in small and medium enterprises according to the number of employees in a certain sector. In general this works well except for the port where it was observed that the fuel use of port equipment (often fully automated and unmanned!) was seriously underestimated due to this allocation principle. Likewise the emissions of small scale food processing (e.g. bakeries etc.) are arbitrary allocated to a 5 x 5 km spot in the city centre. In Rotterdam this had the unfortunate consequence that additional PM emissions for the whole of Rotterdam were located in the city centre next to an already busy road, where it caused a (calculated!) additional PM exceedence day.

Missing sources in Bottom-up EI-s:

For example not every car movement is counted, so traffic emissions based on actual traffic movements are always (a small) underestimation. Also the use of default emission factors for handling or storage (fugitive dust), VOC leakage can lead to both under and over estimates. Outdated EF (e.g. EF that have not been update in accordance with technology development) lead to overestimates. In the Port of Rotterdam area we had such a case in an area with a lot of transhipment. On the other hand. VOC leakages from storage are calculated with default formulas and recent research in Rotterdam (and elsewhere) seems to indicate that these widely accepted default formulas lead to considerable underestimations of VOC emissions.

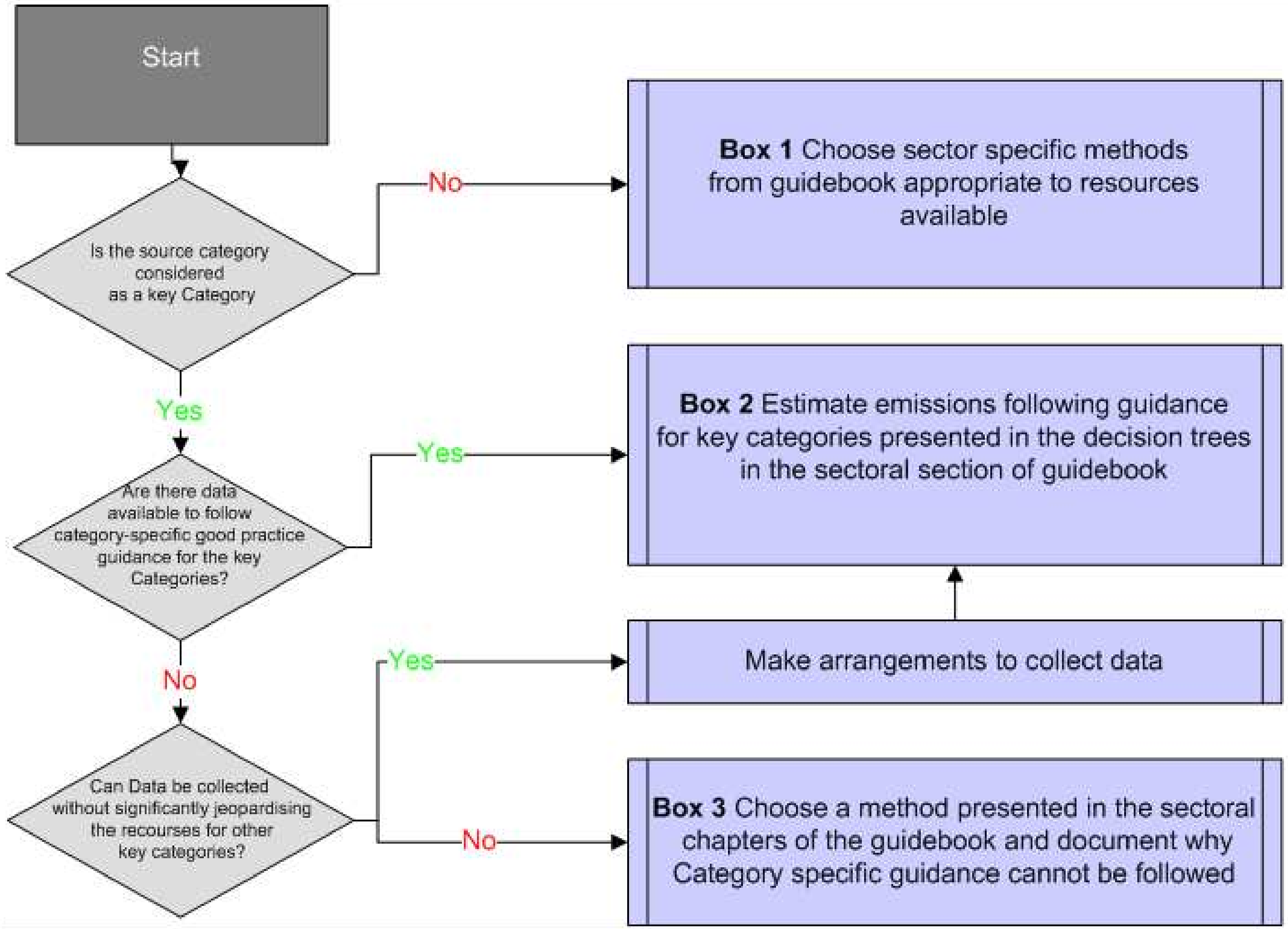
Returning to the North Sea shipping example: there appeared to be a large difference in emissions between a bottom-up approach using individual ship's data and the downscaling of North Sea aggregated data. Though this is awkward in the short run, confronting two approaches ultimately leads to better understanding of what is really happening.

The use of the registered vehicle fleet to calculate traffic emissions can lead to small overestimations. Not all vehicles registered are in use. Then, it is not a good solution to use them as an activity parameter for estimation nor as a spatial disaggregation parameter. Therefore, it would be recommended to use vehicle fleet in use instead of registered vehicle fleet for both estimation aggregated traffic emission and its distribution on smaller administrative areas (municipalities). However, this information is not usually available.

On the other hand, national EI estimates total traffic emissions taking into account slope of roads (considered in COPERT IV but not in COPERT III). To distribute these total emissions to local or municipality level, one approach used is to consider that the regional road network has the same structure than national road network, though this can obviously lead to serious over and underestimates.

Another factor which can lead to overestimates is a new phenomenon called *fuel tourism*. It happens when drivers from neighboring countries cross the border to fill up their vehicles with fuel cheaper. So, these emissions are counted in EI-s but really they are released out of the border. The same applies to marine fuel. If statistics based on fuel sales are used to estimate CO2 or air pollutant emissions in a given area, serious errors are made.

Figure 2: the EMAP/EEA guidebook; Decision tree to choose a good practice method



3.6 The general applicability/transferability of EF's

Emission factors are crucial for any emission inventory and the selection of appropriate emission factors for each technology applied in all activities in the inventory is a major task for the compiler. Data from source-specific emission tests or continuous emission monitors are usually preferred for estimating a source's emissions because those data provide the best representation of the tested source's emissions. However, test data from individual sources are not always available so emission factors are frequently the best or only method available for estimating emissions, in spite of their limitations.

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).

Sources where emission factors can be found;

Greenhouse gasses: IPCC Guidelines IPCC [20, 31,37,27], IPCC Emission Factor database [38]

Air Pollutants : EMEP/EEA Guidebook [21], US EPA Clearinghouse for Inventories & Emissions Factors [39], US EPA AP-42 [40].

These resources provide in most cases sufficient information for the inventory compiler to decide on which emission factors might be appropriate for application of the inventory under construction. Studies made in several European countries were synthesised in a set of algorithms published in EMEP/CORINAIR Emission Factor Handbook (EEA 2003) and which use is recommended by the European Environment Agency. For road transport, emission factors are provided by COPERT IV. The COPERT IV model (Computer Programme to calculate Emissions from Road Transport) follows a harmonised European approach and contains speed dependent emission factors per vehicle technology for hot, cold start and gasoline evaporation [55]. Additionally, other basic data is given such as monthly national temperatures, fuel quality, average speed and driving shares per country and road class. The model enables the user to calculate national total emissions for EU 15+ (with activity rates provided by the user). The user has to decide individually which emission factors are suitable for his scope. In addition, there are several other emission factor data sets having a local or national scope.

Other ways to get information are: in the case of large point sources actual continuous measurements are usually available; emission estimates may also be based on discontinuous measurements or on emission factors.. An important source is the Air4EU guidebook. Information can also be found on the following website: http://www.air.sk/tno/cepmeip/. The emission factors are based on data, collected within the CEPMEIP project. The Emission Database for Global Atmospheric Research EDGAR v4.0 (http://edgar.jrc.ec.europa.eu/overview.php) emissions are calculated for (section 1) direct greenhouse gases, (2) ozone precursor gases, (3) acidifying gases, (4) primary particles, primary aerosols, and (5) stratospheric ozone depleting substances. For each group an overview table presents the status of data available for download.

AP-42 emission Factors**:** The U.S. Environmental Protection Agency (EPA) has developed emission factors for inventory purposes. The factors are published in Compilation of Air Pollution Emission Factors, more commonly known as AP-42. Emission factors are developed for groups of facilities that have a common Standard Industrial Classification (SIC) or North American Industry Classification System (NAICS) group code. s.

EPA has also developed emission factors as part of rule development or for other purposes. The latest emission factors can be obtained on EPA's Factor Information Retrieval Data Set (FIRE).

Calculation of emission estimates from road transport. is fully incorporated in the computer programme COPERT III. The development of COPERT III was financed by the European Environment Agency,.

Urban and local road traffic emissions are usually calculated based on site-specific census data from automatic counting of small and large vehicles and/or manual counting of different vehicle classes. A detailed analysis of traffic flow, traffic volume and fleet composition is required for an accurate emission modelling. Two different calculation methodologies exists on urban and local scale:

– Emission calculation using emission factors and parameterised hourly or half-hourly traffic flow data; assignment of a typical average driving condition that present road class, slope and travel patterns as speed and flow.

–Emission calculation using emission functions and online traffic flow data from a traffic flow model; vehicle speed and acceleration are taken into account for single road segments; emission factors are based on engine emission maps taking into account speed and engine load; model calibration is often done with site-specific information on vehicle speed, composition etc.

Emission factors are usually assigned according to the road class, driving condition/speed, slope and other site-specific conditions like presence of traffic lights, crossroads or pedestrian crossings. In addition to hot emissions, excess cold start emissions have to be taken into account especially for urban traffic for the first 5 km driven after a cold engine start. Information on the average travel distance distribution per vehicle category and road class can be found in literature or derived from local traffic models. In addition, hourly or half hourly ambient temperature data are required for the calculation of cold start emissions, as cold start factors (e.g. g/start) depend on temperature.

There are however a couple of issues related to the representativity and coverage of these emission factors. The first issue relates to the sample size: Chassis dynamometer measurements are expensive and usually a small number of vehicles is used for the emission factor development in order to reduce the total cost of the study. Another, even more important issue, is whether the driving cycles utilized for testing are representative of realworld driving conditions. It may for example occur that while a driving cycle representing urban conditions is used for the production of an urban emission factor, real-world urban driving conditions are much more transient and therefore the emission factor underestimates the actual emission performance.

If significant point sources have to be included into an urban or local emission model, industrial emission data are often available from administrative authorities. The usage of emission factors from literature might not reflect local characteristics if the EF is not site specific enough and can lead to significant under- or overestimation of single source emissions.

For local area sources, emissions normally have to be calculated with a top down approach, using statistical parameters such as population data to derive urban and local activities based on national or regional information. Statistical data often exist on urban scale as well, e.g. for fuel consumption in households and industrial combustion. In some cases small-scale data e.g. the fuel consumption per block/square of residential area are available.

So on the basis of knowledge and type of process emission factors can be selected,

Points of attention are:

-currentness, is the emission factor dated?

-representativity for the type of process, isn't the process too different from the processes used to determine the emission factor?

-use of reduction measures, should the use of reduction measures be taken into account when determining the emission factor

Emission factors are changing over time. Newer knowledge on one hand, but also changing technologies; have influence on parameters and emission factors. While better emission factors apply to all years, technological improvement calls for a time-dependency of emission factors.

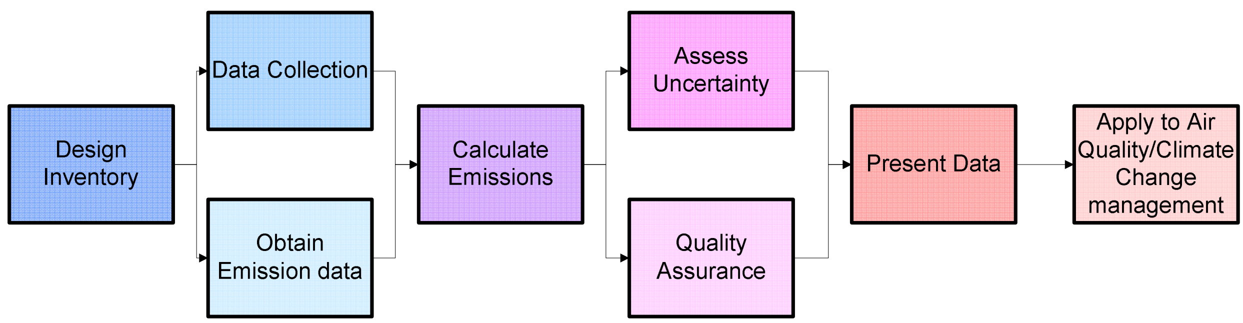
Summarizing: One size does not fit all. Emission inventories are "living databases" that require constantly updating and improving if new information/knowledge gets available. As a consequence, if calculation methodologies do change, emission time series should be recalculated to avoid incorrect emission trends.

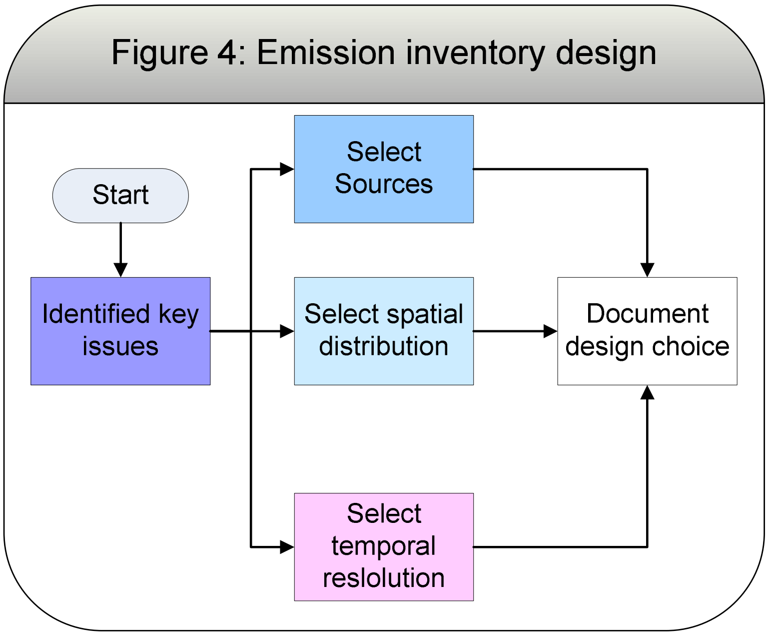
3.7 Step by step inventory compilation

Step 1 Emission inventory design

Defining the scope of the project in terms of time, resources, budget and goals and assessing the feasibility of the project. The time required to conduct an emission inventory will vary depending on the resources available, the size of the study area, and the proposed project outputs. The first major task in designing an emission inventory is the design phase. This comprises a number of subtasks identified below. It is important to specify the requirements and the data that have to be collected at an early stage, it might be very difficult to amend the emission inventory at a later stage once the methodology has been defined and data collection is in progress or even completed.

Figure 3: Managing an emission inventory





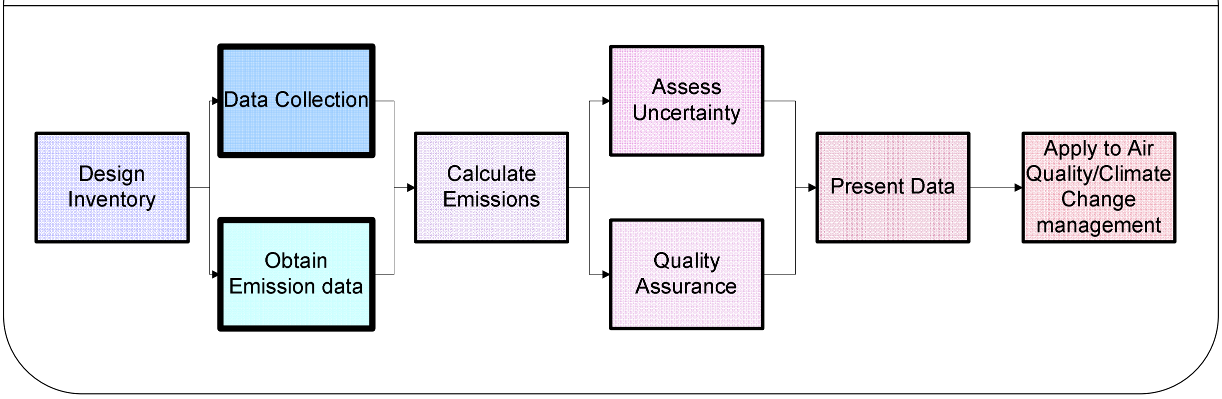
- Documentation: procedure: It is important to document all major decisions and key points for later use
- Identify key 'air quality issues': Identifying key issues in locations where problems exist has three main benefits:
- assessing the scope and objectives of an emission inventory
- identifying the sources that should be included
- indentifying contaminants to be included
- Identify sources to be included

  The key air quality issues may play a role in identifying the key sources to be included. Identifying the additional sources requires an assessment of which might make a reasonable contribution. Include a minimum of industry, home heating and motor vehicles
- Define the area to be covered: Selecting an appropriate boundary for an emission inventory will depend on the purpose of the inventory and its intended application.
- Spatial distribution: Once the boundary for the emission inventory is established, the need for further spatial distribution can be assessed. Selecting an appropriate spatial resolution for an inventory depends on a number of factors including size of the area, distribution of major sources, geography and meteorology and most importantly the intended use of the inventory.
- Temporal distribution; Data could be represented for a number of different timeframes including hourly, 24-hourly, monthly, seasonally and annually. Annual data are the minimum for combined air quality and GHG scenario analysis. For air quality compliance issues for some (e.g. traffic) or all sectors more temporal information might be needed., The variability in meteorological conditions that occur at different times of the day, and the subsequent effect on concentrations needs to be considered.

Step 2 Data collection & obtaining emission data

An important aspect of collecting data is ensuring adequate representation at the spatial resolution determined during the design of the inventory (see paragraph 3.4)

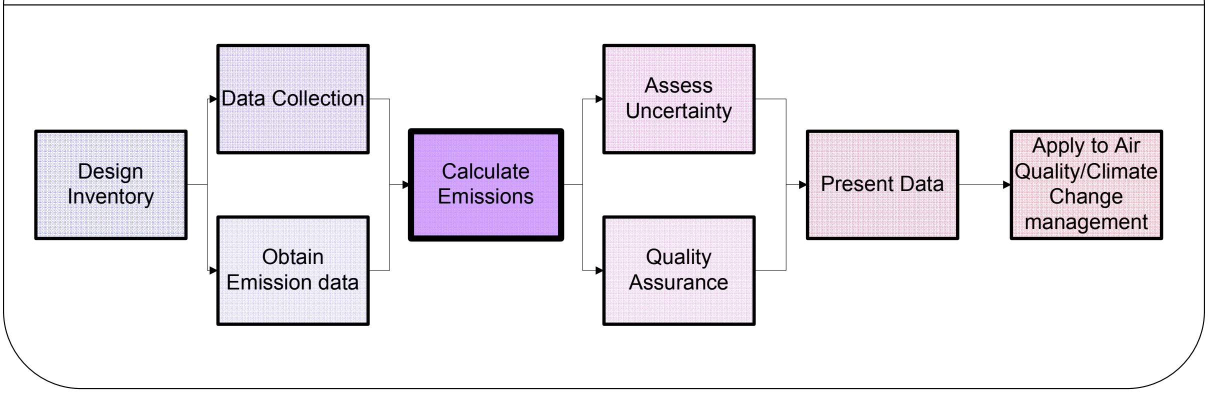
Figure 5: Managing an emission inventory step 2



Thus the first step in collecting activity data for industry is to examine the annual emission reports extract the data where possible and compose a list of industries that require the use of other methods to obtain activity data. The industrial sources to be included in the inventory are determined during source selection phase of the inventory design

Step 3 Calculating emissions

Figure 6: Managing an emission inventory Step 3

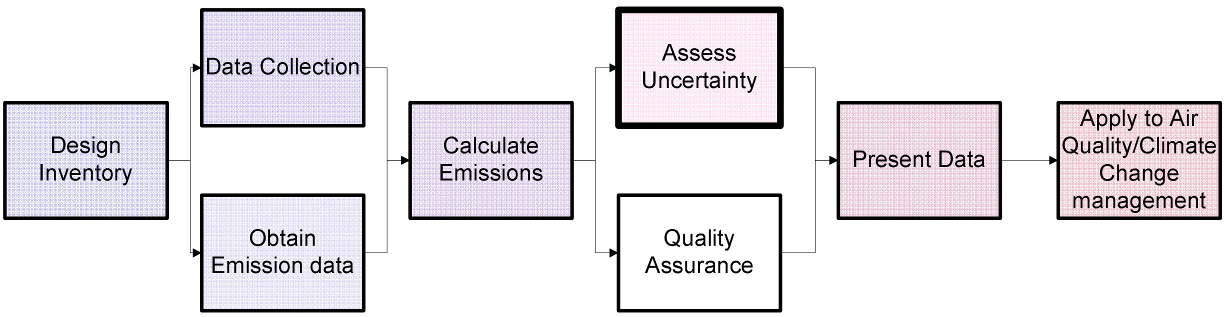


Calculating the emissions is in fact one of the easiest and least time-consuming components of the emission inventory, particularly if purpose designed software or existing calculation spreadsheets can be used. In de different case studies in the annexe the pros and cons of different software is discussed.

Step 4 Uncertainty assessment

Even the most well conducted emission inventories are subject to uncertainty.

Figure 7: Managing an emission inventory Step 4

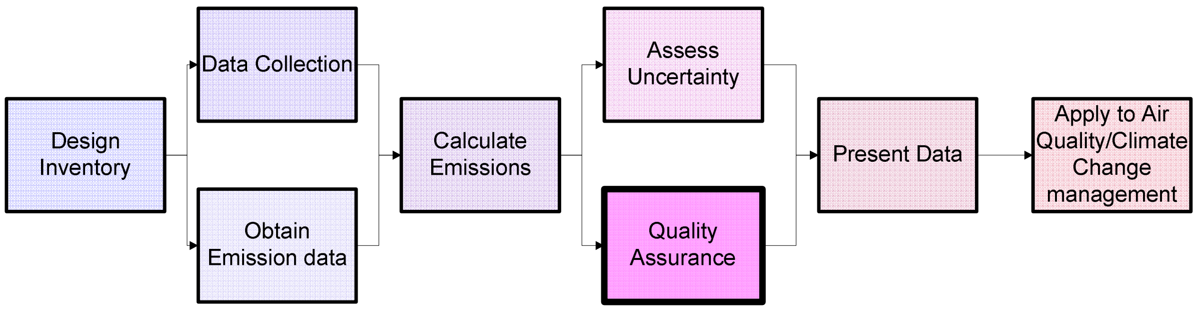


Errors are inevitable at the base level of data collection e.g., the activity data and emission factors. An emission inventory should contain a discussion detailing sources that have been excluded from the assessment because of lack of data and the potential significance of the exclusion, irrespective of the approach chosen for dealing with uncertainty.(for more information see paragraph 2.6)

Step 5 Quality assurance

The purpose of quality assurance is to provide an accurate and consistent emission inventory. Good quality assurance gives confidence in the inventory and any resulting regulatory provisions. Quality assurance is integrated into the process of preparing an emission inventory at all stages. In that sense, it includes the documentation of the process undertaken, the methods used and the assumptions made. (for more information see paragraph 3.1).

Figure 8: Managing an emission inventory Step 5



Validation of data is the use of any relevant information as a check that the data used is not inconsistent with other available data.

Step 6 Present data

Emission inventory outputs can be presented in a number of formats:

- fact sheets, web page
- summary report
- inventory report
- back-casting report
- technical appendices
- input for dispersion models

Methods used to communicate the results of an emission inventory to the public could include public presentations, the preparation of fact sheets, pamphlets or summary documents, inclusion of material on the internet and a media campaign.

Step 7 Apply to Air Quality/ climate change management

The final task in the emission inventory process is applying the results to air quality/climate management. One aspect of the application of an emission inventory to air quality management is the projection of the emission estimates into the future. Such projections are very useful to the management of air quality as they can provide indicators of potential problems and can assist in the assessment of the effectiveness of regulatory options.

4 Integration of GHG sinks into emission inventories

The land use, land use change and forestry (LULUCF) sector is a specific sector for an emission inventory. In fact, vegetation not only emits gases, but also captures greenhouse gases (GHG) (e.g. CO_2), by the process of photosynthesis gases are withdrawn from the atmosphere. The UNFCCC estimates that a seventh of the total atmospheric CO_2 passes into vegetation each year (in the order of 100 Pg CO_2-C per year) and in the absence of significant human disturbance, this large flux of CO_2 from the atmosphere to the terrestrial biosphere is thought to be balanced by the return respiration fluxes. To be complete, an emission inventory has to deal with this double flux, from and to the atmosphere, in order to give the best picture of the interactions of the LULUCF sector with this atmosphere. Moreover, as the vegetation can represent a "sink" of GHG when the flux of CO_2 captured is superior to the flux of CO_2 emitted, anthropogenic activities can have an impact on the GHG absorbed, e.g. by developing forest land. So it is understandable that measuring the emissions and the removals is very important for the countries which are involved in the Kyoto protocol, but also for regions or cities who want to evaluate their impact on the atmosphere.

The main methodologies concerning the integration of sinks of GHG are related with the Kyoto protocol and with the work done by the experts within the IPCC. The main references to build an GHG emission inventories for the LULUCF are provided by the IPCC, and especially described in their report "the Good Practice Guidance for Land Use, Land-Use Change and Forestry" (IPCC 2003 GPG http://www.ipcc-nggip.iges.or.jp/public/gp/english/), edited by the IPCC National Greenhouse Gas Inventories Programme in 2003; also in the "Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual" (IPCC 1996 GLhttp://www.ipccnggip.iges.or.jp/public/gl/invs1.htm), and finally in the "Handbook on GHG inventory in land-use change and forestry sector" published by the Consultative Group of Experts (CGE) on national communications from parties not included in annex I to the Convention from the United Nations Framework Convention on Climate Change (UNFCCC).

On one side, the CO_2 is captured from the atmosphere by the process of photosynthesis, which lead to a storage of carbon in the vegetal biomass. To summarize, the flux of CO_2 can be estimated by the increase of the organic matter. On the other side, GHG from the LULUCF sector are emitted to the atmosphere by several processes: the respiration of the vegetation, and the decay of organic matter in soils and litter. The amount of carbon dioxide emitted is linked to the size of the plant biomass, roots, and dead biomass. These different compartments represent the "pools of carbon" from where the carbon can be emitted, or to where the carbon can be stored. An emission inventory has to make the difference between the "pools of carbon".

The inventory should also take into account the difference due to the "level of activity" of the biomass, which refers to the intensity of respiration, decay and photosynthesis. This level is linked to the type of biomass (woodland, grassland, etc.), to the season (biomass in the tropical climate are more active than in temperate climate, more during summer than winter, etc), to the way that the biomass is managed (e.g. a managed woodland will differ from a non-managed one).

Moreover, when one considers the issue of CO_2 flux associated with land use today or in any base year, one must consider past land-use activities and their effects upon current fluxes of CO_2. As a matter of fact, carbon can be stored in the litter by decomposition of the organic matter for years, but can be released much more quickly by a change in land use.

The methodology described by the UNFCCC and the IPCC for inventory of the LULUCF sector rests upon two linked themes:

- Flux of CO2 to/from the atmosphere is assumed to be equal to the changes in C-stocks in existing biomass and soils. The changes in C-stocks can be estimated by establishing rates of change in land use and practices that bring about change in land use
- Estimating C-stocks in land-use categories: 1) that are not subjected to change, 2) that are changed

The main steps of those methodologies to assess GHG emissions and/or removals are :

- to create categories for each type of land use within the territory studied, because every land use has an specific evolution of their carbon stock. Then these categories must be subdivided according to their management way.
- For each type of land use, an appropriate methodology should be selected to assess the evolution of the area between now and a past-time reference period. This evaluation provided two kind of lands : those who remains into one land use, those who change from one land use to another.
- For lands that remain into one category, the methodologies provide equations to assess the GHG emissions or removals based on biomass evolution data like the average annual growth per hectare in biomass. (see the general equation for a example, and the following appendices for further details on the equations and the emission factors used)
- For lands that change from one land use to another, the methodologies provide equations on the release or the storage due to this specific change in the land use. Usually those equations can be adjust according to the moment when the land use change has occurred.

For lands that remains into one category, e.g. woodland remaining woodland a general equation can be drawn as followed:

hectare of land in a category	X	average annual growth per hectare of a carbon pool (tonnes dm/ha)

=

annual growth increment (1)

X

Removal factor per tonnes of dm (g eq CO_2/ tonnes dm)

=

Annual storage of carbon (2)

total of harvest and decay biomass by category	X	Rate of carbon in the harvest and emission factor from the decay

=

Annual carbon emitted (3)

(3) – (2) = Annual carbon change

The IPCC 2003 Good practices guideline provides advice and methodologies to facilitate the realisation of those steps. An abstract of those good practices can be found in the following sections. For example, they recommend to conduct a key source/sink category analysis to identify the key land categories and subcategories, the key non-CO_2 gases, and finally the key carbon pools. Finally an evaluation of the uncertainty should be conducted, as well as quality assurance/quality control procedures.

Finally, some convention are commonly taken when one conduct the realisation of an emission inventory for the LULUCF sector. Usually, the units of CO_2 emissions/removals and emissions of non-CO2 gases are reported in gigagrams (Gg). To convert tonnes C to Gg CO_2, one should multiply the value by 44/12 and 10^{-3}, and to convert unit from kg N2O-N to Gg N_2O, multiply the value by 44/28 and 10^{-6}.

For the purpose of reporting, which is consistent with the IPCC Guidelines, the signs for removal (uptake) are always (-) and for emissions (+). When compiling emissions and sinks estimated from land use, land-use change, and forestry with other elements of national greenhouse gas inventories, consistent signs (+/-) must be followed. In final reporting tables, emissions (decrease in the carbon stock, non-CO2 emissions) are always positive (+) and removals (increase in the carbon stock) negative (-).

4.1 Main steps from the IPCC 1996 guideline and the 2003 good practice guidance

The handbook published by the CGE highlights the main steps from the IPCC 1996 GL and from the IPCC 2003 good practice guidance:

Table 7: The main steps from the IPCC 1996 GL and from the IPCC 2003 good practice guidance

IPCC 1996 Guidelines	IPCC 2003 good practice guidance
Step 1: IPCC 1996GL does not provide a key category analysis approach.	**Step 1 :** Account for all land use categories and subcategories, all carbon pools and non-CO2 gases, depending on the key source/sink category analysis
Step 2: Select the land use categories (forest/plantations), vegetation types subjected to conversion (forest and grassland), land use/management systems (for soil carbon inventory)	**Step 2 :** Select the nationally adopted land-use classification system (categories and subcategories) for the inventory estimation. Each land category is further subdivided into a. land remaining in the same category (e.g. forest land remaining forest land) b. other land category converted to this land category (e.g. grassland converted to forest land) **Step 3 :** Select the land classification system most relevant to the country
	Step 4 : Conduct key source/sink category analysis to identify the key a. land categories and subcategories b. non-CO2 gases c. carbon pools
	Step 5 : Select the appropriate tier level for the key land categories and subcategories, non-CO2 gases and carbon pools, based on key category analysis and the resources available for the inventory process
Step 3: Assemble required activity data, depending on the tier selected, from local, regional, national and global databases, including the EFDB	**Step 6 :** Assemble the required activity data, depending on the tier selected, from regional, national and global database

Step 4: Collect emission/removal factors, depending on the tier level selected, from local, regional, national and global databases, including EFDB	**Step 7 :** Collect emission/removal factors, depending on the tier selected, from regional, national and global databases, forest inventories, national GHG inventory studies, field experiments and surveys, and use of EFDB
	Step 8 : Select the method of estimation (equations), based on the tier level selected, quantify the emissions and removals for each land-use category, carbon pool and non-CO2 gas. Adopt the default worksheet provided in GPG2003
Step 5: Estimate the uncertainty involved	**Step 9 :** Estimate uncertainty
	Step 10 : Adopt quality assurance/quality control (QA/QC) procedures and report the results
Step 6: Report GHG emissions and removals	**Step 11 :** Report GHG emissions and removals using the reporting tables
Step 7: Report all the procedures, equations and sources of data adopted for GHG inventory estimation.	**Step 12 :** Document and archive all information used to produce the inventory, including all activity data, emission factors, sources of data, methods used and QA/QC procedures adopted for different land categories and management systems, carbon pools and non-CO2 gases.

4.2 Definitions used in the IPCC 2003 methodology

The IPCC methodology uses some concepts that need to be defined before starting the description of the methodology. For instance, the categories of lands needed to be clearly defined to only count once an area and to avoid omission. On the same principle, the pool of carbon needs to be identified.

4.2.1 Top-level land categories

To identify the land, categories need to be made according to their use. The top-level land categories for greenhouse gas (GHG) inventory reporting made by the IPCC are:

Forest land

This category includes all land with **woody vegetation consistent** with thresholds[4] used to define forest land in the national GHG inventory, sub-divided into **managed** and **unmanaged**, and also by ecosystem type as specified in the IPCC Guidelines. It also includes systems with vegetation that currently fall below, but are expected to exceed, the threshold of the forest land category.

[4] These thresholds can be based on the definition provide during the Marrakech accords. According to these accords, “forest” is a minimum area of land of 0.05 – 1.0 hectares with tree crown cover (or equivalent stocking level) of more than 10 – 30 per cent with trees with the potential to reach a minimum height of 2 – 5 metres at maturity in situ.

Cropland

This category includes **arable and tillage land**, and **agro-forestry systems** where vegetation falls below the thresholds used for the forest land category, consistent with the selection of national definitions.

Grassland

This category includes **rangelands and pasture land** that is not considered as cropland. It also includes systems with vegetation that fall below the threshold used in the forest land category and are not expected to exceed, without human intervention, the threshold used in the forest land category. The category also includes all grassland from **wild lands to recreational areas as well as agricultural and silvi-pastural systems**, subdivided into managed and unmanaged consistent with national definitions.

Wetlands

This category includes **land that is covered or saturated by water** for all or part of the year (e.g. peatland) and that does not fall into the forest land, cropland, grassland or settlements categories. The category can be subdivided into managed and unmanaged according to national definitions. It includes reservoirs as a managed sub-division and natural rivers and lakes as unmanaged sub-divisions.

Settlements

This category includes **all developed land**, including **transportation infrastructure** and human settlements of any size, unless they are already included under other categories. This should be consistent with the selection of national definitions.

Other lands

This category includes **bare soil, rock, ice, and all unmanaged land areas** that do not fall into any of the other five categories. It allows the total of identified land areas to match the national area, where data are available.

When applying these categories, lands should be classified under only one category to prevent double counting. Thresholds have to be clear enough to avoid ambiguous classification.

It may happen that a regional or national data base provides a land classification system based on different criteria, with categories that do not match with the one described above. In that case, the IPCC guideline recommends to "combine or disaggregate" the existing land classes of this system of land-use classification in order to use the IPCC categories and to report on the procedure adopted. It is also good practice to specify national definitions for all categories used in the inventory and report any threshold or parameter values used in the definitions. Where national land classification systems are being changed or developed for the first time, it is good practice to ensure their compatibility with land-use classes above".

The broad categories listed above provide the framework for the further sub-division by activity, management regime, climatic zone and ecosystem type as necessary to meet the needs of the methods for assessing carbon stock changes and greenhouse gas emissions and removals.

4.2.2 Terrestrial pool of carbon

In the IPCC guideline, the methodology is firstly organised following the land-use categories, and secondly following the "pools of carbon". It describes the various parts of an terrestrial ecosystem where carbon can be stocked or released.

The following table, based on the IPCC guideline give a generic representation of these pools:

Table 8: the various parts of an terrestrial ecosystem where carbon can be stocked or released

Pool		Description
Living biomass	Above-ground biomass	All living biomass above the soil including stem, stump, branches, bark, seeds, and foliage.
	Below-ground biomass	All living biomass of live roots. Fine roots of less than 2 mm diameter are often excluded because these often cannot be distinguished empirically from soil organic matter or litter
Dead Organic Matter	Dead wood	Includes all non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps larger than or equal to 10 cm in diameter or any other diameter used by the country
	Litter	Includes all non living biomass with a diameter chosen by the country (for example 10 cm) lying dead, in various states or decomposition above the mineral or organic soil. This includes the litter, fumic and humic layers. Live fine roots (of less than the suggested diameter limit for below-ground biomass are included in litter where they cannot be distinguished from it empirically
Soils	Soil organic	Includes organic carbon in mineral and organic soil (including peat) to a specified depth chosen by the country and applied consistently through the time series. Live fine roots (of less than the suggested diameter limit for below-ground biomass) are included with soil organic matter where they cannot be distinguished from it empirically

4.3 General methods from the IPCC 2003 methodology:

4.3.1 Representing land area, three methods

Information about land area is needed to estimate carbon stocks and emissions and removals of greenhouse gases associated with Land Use, Land-Use Change and Forestry (LULUCF) activities. The good practices provided by the IPCC on the selection of suitable methods for identifying and representing land areas as consistently as possible in inventory calculations are described below. Three different approaches can be identified, and used according to the data available:

Approach 1: Basic Land use data

Approach 1 uses basic land use data set, usually prepared for other purpose than emission inventories, like forestry or agricultural statistic. Frequently, several datasets will be combined to cover all land classifications and regions of a country. The absence of a unified data system can lead to double counting or omission, since the agencies involved may use different definitions of specific land use for assembling their databases.

To avoid omission and double counting, it is good practice to:

- Harmonise definitions between the existing independent databases and also with the broad land-use categories above to minimise gaps and overlaps. For example, if woodland on farms were included both in forestry and agricultural datasets, overlaps might occur. In order to harmonise data, the woodland should be counted only once for greenhouse gas inventory purposes, taking into account the forest definitions adopted nationally. It is consistent with good practice to establish the relationship between definitions in use with the aim of eliminating double counting and omissions. This should be done throughout the dataset to maintain time series consistency

- Ensure that the land-use categories used can identify all relevant activities. For example, if a country needs to track a land-use activity such as forest management, then the classification system should be able to distinguish managed from forest areas.
- Ensure that data acquisition methods are reliable, well documented methodologically, timely, at an appropriate scale and from reputable sources. Reliability can be achieved by using surveys that can be related to the harmonised definitions. Grounds surveys can be cross-checked where independent data sources are available and will be needed for checking accuracy of cross-checking.
- Ensure the consistent of application of category definitions between time periods. For example, countries should check whether the definition of forest has changed over time in terms of canopy cover and other thresholds to ensure consistency throughout the time series and report on action taken.
- Assess whether the sum of the areas in the land classification databases is consistent with the total territorial area, given the level of data uncertainty. If coverage is complete, then the net sum of all the changes between two time periods should be zero to within the uncertainties involved. In cases where coverage is incomplete, the difference between the area covered and the territorial area should, in general, be stable or vary slowly with time, again to within the uncertainties expected in the data. If the balancing term varies rapidly, or (in the case of complete coverage) sums are not equal, it is good practice to investigate, explain, and make any corrections necessary. These checks on the total area should take into account the expected uncertainties in the annual or periodic surveys or censuses involved. Information on expected uncertainties should be obtained from the agencies responsible for the surveys. Usually there will be remaining differences between the sum of areas accounted for by the available data and the national area. It is good practice to keep track of these differences and to provide an explanation for the likely causes. Carbon stock changes and emissions and removals of greenhouse gases implied by variation through time of these differences may be due to land-use change and may therefore need to be accounted for in the GHG inventory.

Approach 2: Survey of land use and land-use change

Approach 2 not only provides information on the assessment of each category of lands and its evolution, but also on the change of land categories, e.g. previous use of one land that changed of category, or changes from and to a category.

Tracking land-use changes in this explicit manner will normally require estimation of initial and final land-use categories, as well as of total area of unchanged land by category. The final result of this approach can be presented as a non-spatially explicit land-use change matrix.

The matrix form is a compact format for representing the areas that have come under different transitions between all possible land-use categories. Existing land-use databases may have sufficient detail for this approach, or it may be necessary to obtain data through sampling. The input data may or may not have originally been spatially explicit (i.e., mapped or otherwise geographically referenced).

Although Approach 2 is more data intensive than Approach 1, it can account for all land-use transitions. This means that emission and removal factors or parameters for rate of change of carbon can be chosen to reflect differences in the rate of changes in carbon in the opposing directions of transitions between any two categories, and differences in initial carbon stocks associated with different land uses can be taken into account. For example, the rate of soil organic carbon loss will commonly be much higher through ploughing than the rate ofre-accumulation if cultivation is subsequently abandoned, and initial carbon stocks may be lower for transitions from cropland than from pasture.

Good practice points described for Approach 1 also apply to Approach 2, although at a greater level of detail, since the pattern of land-use change is available, not just the net change into or out of each land category or subcategory.

Approach 3: Geographically explicit land use data

Approach 3 requires spatially explicit observations of land use and land-use change. The data may be obtained either by sampling of geographically located points, a complete tally (wall-to-wall mapping), or a combination of the two. Approach 3 is comprehensive and relatively simple conceptually but data intensive to implement. The target area is subdivided into spatial units such as grid cells or polygons appropriate to the scale of land-use variation and the unit size required for sampling or complete enumeration. The spatial units must be used consistently over time or bias will be introduced into the sampling. Observations may be from remote sensing, site visits, oral interviews, or questionnaires. Sampling units may be points, or areas from 0.1 ha to a square kilometre or more, depending on the sample design. Units can be sampled statistically on a sparser interval than would be used for the complete coverage, chosen at regular or irregular intervals, and can be concentrated in areas where land-use change is expected. Recorded data could be of land use at a point or within a sampling unit on each occasion but could also include land-use change data within a sampling unit between the sampling years.

For effective implementation of Approach 3, the sampling needs to be sufficient to allow spatial interpolation and thus production of a map of land use. Sampling methods and associated uncertainties are discussed in the sampling section of Chapter 5 (Section 5.3). All LULUCF activities in each spatial unit or collection of the units are then tracked over time (periodically but not necessarily annually) and recorded individually, usually within a GIS.

The use of one or more approaches in a country will depend on, amongst other factors, spatial variability, the size and accessibility of remote areas, the history of biogeographical data collection, the availability of remote sensing staff and resources (outsourced, if necessary) and the availability of spatially explicit carbon data and/or models. Most countries will have some existing land-use data and a decision tree is provided to assist in using this data in ways that meet the guidance in this Chapter. There are three key decisions to be taken: is spatially explicit data required for Kyoto Protocol reporting, do the data cover the whole country and do they provide an adequate time series.

4.4 Fundamental basis

The fundamental basis for the methodology rests upon two linked themes: i) **the flux of CO2 to or from the atmosphere is assumed to be equal to changes in carbon stocks in existing biomass and soils**, and ii) **changes in carbon stocks can be estimated by first establishing rates of change in land use and the practice used to bring about the change** (e.g., burning, clear-cutting, selective cut, etc.).

Second, simple assumptions or data are applied about their impact on carbon stocks and the biological response to a given land use. The first order approach described above is the foundation for the basic methodologies presented in this chapter for calculating changes in carbon pools. **This approach can be generalised and applied to all carbon pools** (i.e., aboveground biomass, belowground biomass, dead wood, litter, and soils), subdivided as necessary to capture differences between ecosystems, climatic zones and management practice. The first equation below illustrates the general approach for estimating carbon stock change based on rates of carbon losses and gains by area of land use. In most first order approximations, the “activity data” are in terms of area of land use or land use change. The generic guidance is to multiply the activity data by a carbon stock coefficient or “emission factor” to provide the source/or sink estimates. Guidance is provided for all relevant carbon pools and changes of land use from one type to another. The full range of possible changes in land use from one type to another is covered systematically and default transition periods are provided.

ANNUAL CARBON STOCK CHANGE IN A GIVEN POOL AS A FUNCTION OF GAINS AND LOSSES
$\Delta C = \sum_{ijk} [A_{ijk} \bullet (C_I - C_L)_{ijk}]$

ΔC = carbon stock change in the pool, tonnes C yr^{-1}

A = area of land, ha

ijk = corresponds to climate type i, forest type j, management practice k, etc…

C_I = rate of gain of carbon, tonnes $C.ha^{-1}.yr^{-1}$

C_L = rate of loss of carbon , tonnes $C.ha^{-1}.yr^{-1}$

An alternative approach is proposed in the IPCC Guidelines where carbon stocks are measured at two points in time to assess carbon stock changes. The equation below illustrates the generic approach for estimating carbon stock change in this way. This latter approach is considered as an option in some instances.

ANNUAL CARBON STOCK CHANGE IN A GIVEN POOL
$\Delta C = \sum_{ijk} (C_{t_2} - C_{t_1}) / (t_2 - t_1)_{ijk}$

Where:

C_{t1} = carbon stock in the pool at time t1, tonnes C

C_{t2} = carbon stock in the pool at time t2, tonnes C

For both methods, it is necessary to define the past situation to which the actual situation is compared with. The time period recommended by the IPCC guideline is 20 years.

4.5 Three methodological tiers

To assess the evolution of each carbon stock, three levels of methodology can be drawn according to the data used. This tiers correspond to a progression from the use of simple equations with default data to country-specific data[5] in more complex national systems.

The Tier 1 approach employs the **basic method provided in the IPCC Guidelines** (Workbook) and **the default emission factors provided in the IPCC Guidelines** (Workbook and Reference Manual) with updates in this chapter of the report. For some land uses and pools that were only mentioned in the IPCC Guidelines (i.e., the default was an assumed zero emissions or removals), updates are included in this report if new scientific information is available. Tier 1 methodologies usually use activity data that are spatially coarse, such as nationally or globally available estimates of deforestation rates, agricultural production statistics, and global land cover maps.

Tier 2 can use the same methodological approach as Tier 1 but applies **emission factors and**

activity data which are defined by the country for the most important land uses/activities. Tier 2 can also apply stock change methodologies based on country-specific data. Country-defined emission factors/activity data are more appropriate for the climatic regions and land use systems in that country.

[5] Country-specific data may require subdivision to capture different ecosystems and site qualities, climatic zones and management practice within a single land category

Higher resolution activity data are typically used in Tier 2 to correspond with country-defined coefficients for specific regions and specialised land-use categories.

At Tier 3, higher order methods are used including models and inventory measurement systems tailored to **address national circumstances**, repeated over time, and driven by high-resolution activity data and disaggregated at sub-national to fine grid scales. These higher order methods provide estimates of greater certainty than lower tiers and have a closer link between biomass and soil dynamics. Such systems may be GIS-based combinations of age, class/production data systems with connections to soil modules, integrating several types of monitoring. Pieces of land where a land-use change occurs can be tracked over time. In most cases these systems have a climate dependency, and thus provide source estimates with inter-annual variability. Models should undergo quality checks, audits, and validations.

Tiers implicitly progress from least to greatest levels of certainty in estimates as a function of methodological complexity, regional specificity of model parameters, and spatial resolution and extent of activity data.

4.6 Priority Categories

In estimating the effects of landuse and land-use changes on the emissions of GHGs, it is reasonable to stage the calculation methods so that the most important components can be addressed first. Complexities and subtleties of the relationship of forestry and landuse change to fluxes of CO2 and other gases can be incorporated in a consistent manner into subsequent calculations as knowledge advances and data improve. The methodology presented in this chapter focuses initially on a simple, practical and fair procedure for determining the biomass-derived CO2 flux directly attributed to forest management and land-use change activities. This procedure must also account for the influence of inherited “emissions” or past land-use changes upon the contemporary CO2 flux, as well as trace gas emissions from biomass burning where this occurs in conjunction with landuse change.

The basic calculations focus primarily on the land-use changes (causing changes in land cover) and land-use activities (forestry) that result in the largest, potential flux of CO2 to the atmosphere or have the largest potential for sequestering carbon.

Two categories of land-use change are considered:

- forest and grassland conversion to agricultural lands
- abandonment of managed lands

On a global scale, the most important land-use changes that result in CO2 emissions and removals are:

- changes in forest and other woody biomass stocks - the most important effects of human interactions with existing forests are considered in a single broad category, which includes commercial management, harvest of industrial roundwood (logs) and fuelwood, production and use of wood commodities, and establishment and operation of forest plantations as well as planting of trees in urban, village and other non-forest locations;
- forest and grassland conversion - the conversion of forests and grasslands to pasture, cropland, or other managed uses can significantly change carbon stored in vegetation and soil;
- abandonment of croplands, pastures, plantation forests, or other managed lands which regrow into their prior natural grassland or forest conditions.
- changes in soil carbon.

The method also addresses the immediate release of non-CO2 trace gases (CH4, CO, N2O and NOx) from the open burning of biomass from forest clearing.

4.7 Conclusion

It is important to note that the methodologies available in the literature to assess the emission and removal from the LULUCF sector are mainly provided for a national level. The reason for this is simple, they were design for building emission inventory in the Kyoto protocol context. The transposition to a smaller scale, for instance a region or a city, need to be study in details. There should not be at first glance any major issues. The transfer to the Ile-de-France Region will be an example of it.

5 Implementation of an integrated EI in a CITEAIR city

The city of Rotterdam is situated in the middle of the so-called Rijnmond region (the port of Rotterdam region). The region consists of an urban area containing several municipalities and totalling approximately 1.2 million inhabitants. It is also home to one of the world largest port areas with intensive shipping and industrial activities.

For the Rotterdam Rijnmond area separate EI-s are available for CO2 and air pollutants (mainly NO_x, PM and SOx). The CO2 data are confined to the city and the port and are not spatially referenced. The air pollutants are spatially refrenced and cover a slightly larger area ("Rijnmond"). Though both EI-s are somehow based on activity data, this information is not included and the regionally available systems. There was a need for one, activity based, integrated EI.

5.1 Points of departure of the Emission Inventory for Rotterdam

For the Rotterdam area several data sources are available to build up an IEI. Most of the data come from the national emission inventory. The national inventory contains information on all sources including estimates for smaller sources based on proxy statistics as described in previous chapters. For air quality modelling purposes the data is spatially disaggregated.

The Netherlands Environmental Assessment Agency (PBL) uses this information in combination with estimates of technology development and economic scenarios to forecast future emissions (2020, 2030). The data available at regional level are in general emission totals (no separate data on activities, on EF and their evolution in time).

5.1.1 System

For the integrated EI to be developed a software system is used (CollectER, see next section) that stores (in fact, needs) separate input of activity rates, technology levels and EF-s associated with the technologies. Transforming our data into the format used in CollectEr achieves the goal of building an integrated EI. However CollectER does not have tables for the dispersion information needed to be able to model air quality. Hence some tables needed to be added. The final transformation of CollectER into an integrated EI is available as IMACE (http://www.citeair.eu/). IMACE is in use in Rotterdam since end 2010.

5.1.2 Data availability

Stationary sources

All stationary sources with substantial emissions report to the national EI and to EPRTR. DCMR, the regional EPA yearly receives and evaluates these emission data. The level of detail of the data ranges from emissions per individual installations to plant level emissions. Also information on energy use is included in this dataset. Production/output data is not generally available. For many smaller companies that don't have to report individually estimates are made by the national EI and PBL. The region obtains these data as area sources. The regional EPA has information over smaller companies that don't report individually. Integrating this information in the regional EI potentially improves it (improving spatial detail) but poses the risk of double counting. However, adding bottom-up information also revealed that several emission categories were seriously underestimated (mobile equipment) in our area.

Other collective stationary sources such as heating are obtained from the national database. They are available as area sources.

Mobile emission sources – Road Traffic

The so-called RVMK (regional traffic model) produced by the traffic department of Rotterdam contains detailed information on traffic composition (passenger cars, vans, heavy duty, busses, two-wheelers),intensities, average speed and the occurrence of congestion in the area. The traffic dataset is produced with the use of a periodically calibrated and updated OD-traffic model. It is a GIS dataset, with over 10 000 road segments. In addition to the traffic characteristics the dataset contains information for air quality modelling such as, road width, number of lanes, distance to nearest building, type of street (type of canyon, or open road), etc. RVMK contains a forecast of future traffic intensities.

Information on fleet age, % diesel, cold starts, etc. is not available. The Netherlands uses fleet average emission factors based on real world driving cycles. These EF-s are annually updated and forecasts for future years are available. Though this is readily available and frequently updated EF-data is a major advantage, the drawback is that it is very hard to model/monitor the penetration of new technology such as Euro VI emission standards, since fleet composition in Euro classes is not part of the existing database. In the database this is resolved by calculating new EF outside of the database and including the result as a new technology with a new EF.

Mobile emission sources – Shipping

The marine shipping database, produced by MARIN institute, contains detailed data on marine shipping movements. Ships emit so-called transponder signals that transmit gps coordinates, speeds, and a ship ID allowing to back trace the size and type of ship, its engines, type of fuel used, etc. The information is structured by type and size of vessels and allows for localizing emissions on a resolution of up to 100x100m. We currently store the data as 500x500m area sources. In addition to the emissions the data also contains dispersion information per ship type, such as average emission height, heat capacity, etc.

The PBL national emission records also include road traffic and shipping emissions, though on a lower resolution (typically 1000 x 1000 m).

Note that the mobile sources are available in an activity based format, the stationary sources are generally not available in an activity based format, though for the largest sources that report their emissions individually, the information is available though not yet used in the EI. In this project a start was made to change this.

5.2 The Database for the Emission Inventory

The database system that constitutes the emission inventory is based on the Collecter III system for several reasons:

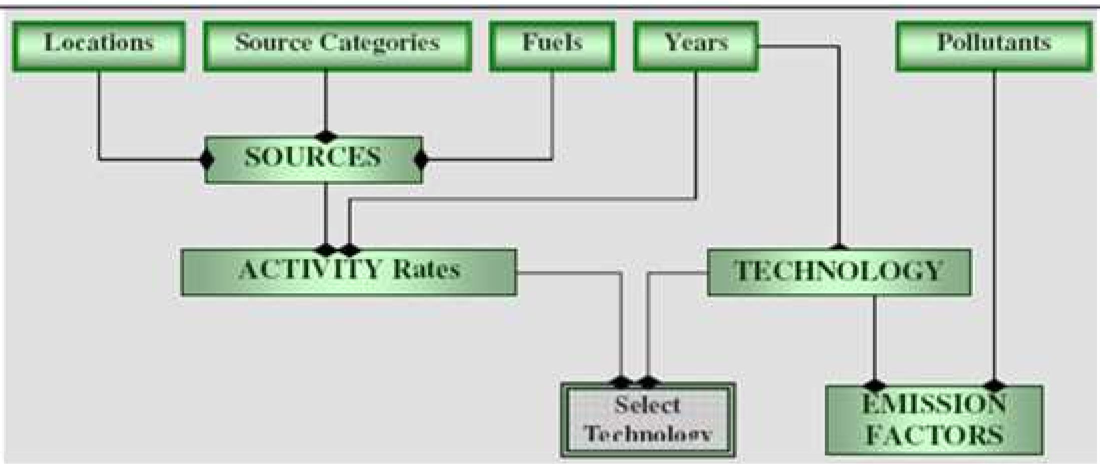
- CollectER III is a freely available emission inventory application developed by European Environment Agency (EEA) and its European Topic Centre on Air and Climate Change (ETCACC). They have been developing the data base since 1998. The tools are dedicated to support European countries in compiling annual air emission inventory submissions to international obligations.
- The MS Access based database of CollectER has been in use for some time now and is essentially free of bugs. Also a practical manual has been provided. Since it's main use has been to compile annual air emission inventory submissions for international obligations in several European countries, it's structure relates well to the EMEP/EEA emission inventory guidebook. Additional advantage of using CollectER is the fact that the MS Access database can be extended with additional tables and queries so as to provide for geographical information (This has resulted in the IMACE system).
- The application allows for compiling inventories over multiple years, includes extended tables for pollutants, fuels and source definitions (SNAP, NFR) and is in use in several European Union countries.
- Collecter builds on the concept that emissions can be derived from the combination of activities and related emission factors.

$$E_{ij}= EF_{ij} * Ar_i$$

Where E_{ij} is the emission of a pollutant j from a source with technology i and activity rate i.

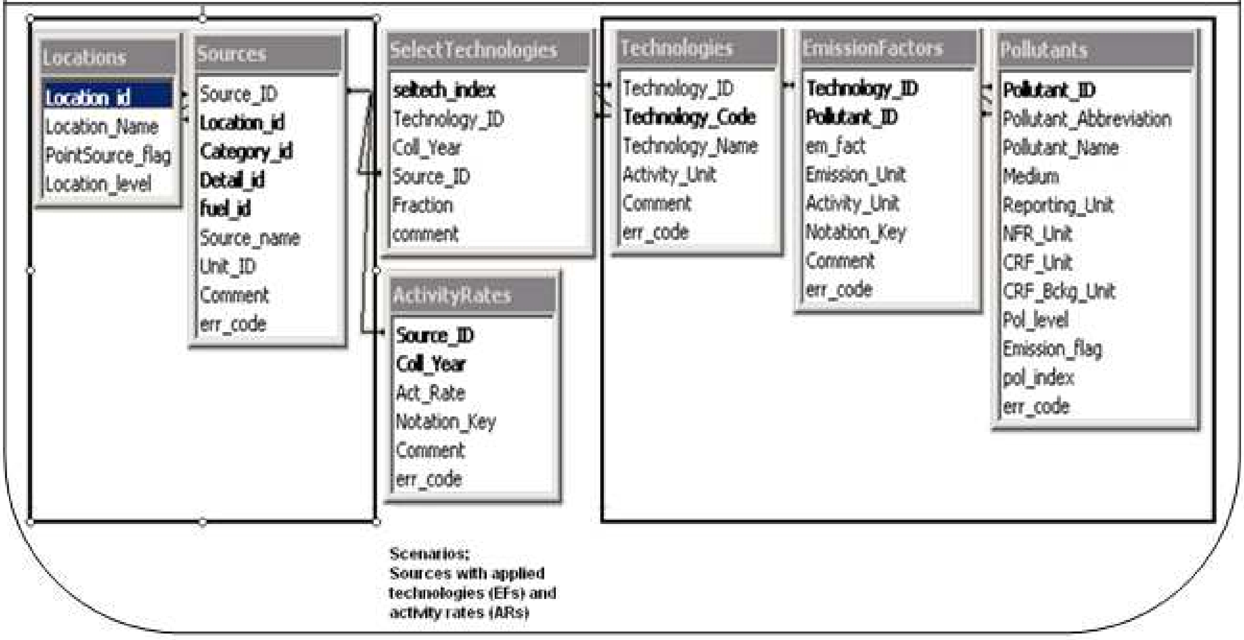
The emission factors depend on the type of technology used per emission source; activities per source are related to specific technologies. The structure of CollectER forces you to think logically and describe your emissions in a correct way. CollectER can in a sense be described as an integrated emissions database, since assigning specific technologies and related activity rates to emission sources will generate emissions of all pollutants for which emission factors are available in its data-base..

Figure 9: Structure of CollectER



A drawback is that CollectER has been used for compiling national emission inventories, so geograph-ical information of the source locations is not available. For our purposes it is necessary to include this information to ensure that the resulting inventory can be used for air quality modelling.

Figure 10: Database tables structure of CollectER



5.3 Adapting of the functionality of the database

5.3.1 Adding air quality modelling information

The most important change to the CollectER system is the need to add additional tables that supply information on the coordinates of the emissions sources and the relevant dispersion parameters. The exact information that is needed depends on the end user of the data, ie. the air quality model for which the data are used. Typically, this means data on source height & diameter, effective source height and or heat capacity, diurnal variation of the emitter and, in the case of non gaseous pollutants (such as PM_{10}), particle size distribution data.

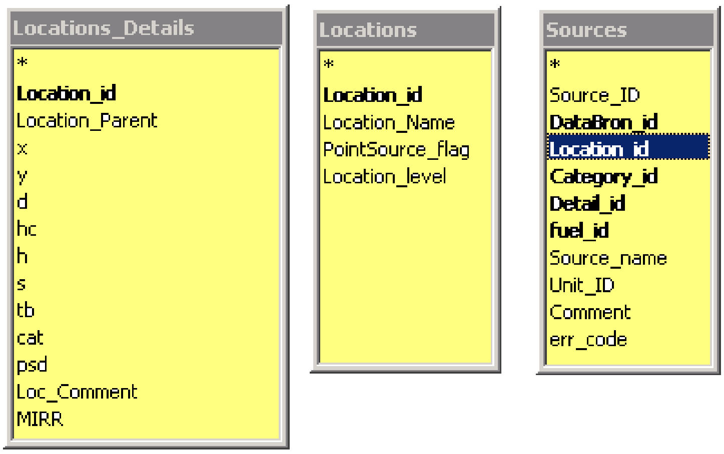
Most of these data is constant in time and doesn't depend on the technology level though some might (e.g. heat capacity, particle size distribution).

For the extension of the core database care was taken not to alter the original structure of the database. This means, that the original CollectER database is maintained and its data can still be used for compiling annual air emission inventory submissions.

In the core database a table (locations_details) was added to include the details of the emission sources and was connected to the locations table of the original database. In the new table all geographic information (as well as air quality input data) can be stored.

The field "location_parent" was added to this table, so that sources can be described on different levels of geographical resolution. For example, in the database several levels of locations where distinguished, the highest level being the province in which the city area is situated. Subsequent levels were the subregions, municipalities, 1x1 km grid elements, down to companies and finally individual emission sources (within companies). This allows the user to compile emission totals per sector *and per area* without having to export the tables to a GIS-system. The nesting assures that emission totals can be given at different desirable geographical levels.

Figure 11: Table addition for spatial detail



The choice of the levels that should be included into the database basically depends on two factors: On the one hand, the specific needs of the client-user are taken into account. Therefore specific regions (such as municipalities) are defined and lower levels are defined up to the desired resolution.

On the other hand, the level of resolution of the input data determines the resolution of the sublevels. For example, national EI data for the Rotterdam area are generally provided at a 1x1 km grid level, Marine shipping data are available at 100x 100m and 500x500m grid level. Hence all three sublevels (plus various administrative boundaries) are present within the database.

5.3.2 'Adapting' the existing data

As mentioned in the introduction to this chapter a large part of the available data are emissions only and separated activities and EF are not (yet) available.

For Rotterdam the base of the database is the GCN source data. In addition the emission records are categorized by type of activity in a Dutch national system that somewhat resembles the SNAP categorization as used in the CollectER database but it is not possible to fully translate the Dutch coding to the SNAP codes due to conceptual differences. Instead of using the SNAP coding we have therefore resorted to the use of our own national coding system. National codes have been linked to SNAP codes, but caution is in place, since the national codes can not be translated into SNAP codes on a 1 by 1 basis. If the database tool is applied somewhere else where SNAP codes are in use this can be used of course.

The data represent emissions (in g/s) from sources ranging from identified point sources with specific coordinates to collective emission sources located on 1x1 km (and sometimes on 5 x 5 km) grid cells. The challenge for our integrated database is to eventually translate emissions into activity derived emissions, with the use of technology specific emission factors (EFs) related to activity rates (ARs).

CollectER allows emissions to be inserted directly into the database, even though they are not directly linked to known technologies and emissions factors. This means that from the start results can be given, while progress is being made on obtaining the technology based EFs. We keep track of these records by marking them as having so-called implied EFs and virtual activity rates(e.g. the EF is equal to the total emission and the activity rate is 1). When knowledge on sources advances the correct data can be used to replace the temporary virtual activity rates. Great care should of course be taken if a CO2 foot print is derived from a NO_x EI. If the NO_x-EF for a certain source is an 'implied EF' this should be done for CO2 as well. Else serious errors are made.

5.4 Improving the inventory

As mentioned in the previous paragraph, inventory data should be provided in terms of activity rates and technology related EFs, so that a truly integrated inventory takes shape by defining EFs of specific components (pollutants and GHGs). Thus, simply giving the AR of a source will generate emissions for all components.

This process of improving the inventory requires a periodic iteration of inputting, comparing and replacing the available data with newly acquired data that does supply ARs and EFs. So eventually, the database will not only be filled with the original emissions (with unit activity rates and an implied EF), but also with source data based on ARs and EFs. At that point the databasetool can be used to easily generate emissions for pollutants not yet in the database and for scenario analysis.

For us it is crucial to keep the main structure of the inventory intact. No data should be deleted from the database, since comparing newly added data to the existing inventory is necessary and, as it turns out, provides much insight in the emission inventory as a whole. This also applies to the yearly update that is in principle available (in the Netherlands). So, it becomes evident that keeping track of the data sources and their documentation is essential. After some time emission sources will be described by more than one set of data and for scenario's it is essential that a selection can be made of which data sources with which specific references (source of information, date of the information, year for which the data is valid, etc.) to use.

In our experience, the iteration process of improving the database is tedious and time consuming. Prioritizing which data should be improved first is therefore necessary. In the case of the Rotterdam priority was given to describing traffic data. The case provides valuable information of practical problems we encountered and solutions we found.

5.4.1 Traffic data – integrated emissions

The national source data contain (top-down) traffic emissions. These emissions (NO_x and PM_{10}) are given for 1 x1 km grid cells for several categories of traffic and roads. In the RVMK regional (bottom-up) data contains all major roads within the area; traffic composition (light, middle and heavy weight cars) and intensities (amount of vehicles passing) are given per road segment. The traffic intensities can be considered as ARs, whereas the different categories of traffic can be seen as specific “technologies” for which derived EFs can be applied. By including both in the dataset we can discover if both approaches yield the same results.

Data from the RVMK was linked to the database in the following way:

- A traffic database was created with all road segments categorized in 1x1 km grid cells (where necessary, road segments were split).
- For all road segments per 1 x 1 grid cell ARs were described in terms of vehicle kilometres driven. ARs we're distinguished for all vehicle-road combinations, for which specific EFs are available. Thus a table was created in which ARs per traffic type per grid cell were given.

For the EFs the official Dutch set of EFs for the air quality modelling of traffic was used. This set provides EFs for several years (including forecasts for future years) for a comparable set of vehicle– road combinations.

For all vehicle-road combinations a specific “technology” was defined (such as: light vehicle on urban main road or heavy vehicle on motorway with speed limit of 80 km/hr, etc) and related EFs where inputted into the database. Approximately 19000 records were uploaded into the database and 36 different technologies were defined for each year for a 5 year period, with corresponding EFs for PM_{10}, NO_2, and CO_2 and others.

The official Dutch set of EFs does not include emission factors for CO_2. These have been derived with the use of data from the Central Bureau of Statistics (CBS). CBS data include fleet average g/km emissions for CO_2 and other main pollutants, with some distinction made for vehicle-road combinations. EFs for CO_2 were not available for the combinations described in the database. In order to arrive to these EFs, it was assumed that the ratio CO_2/NO_x can be taken to be constant for a specific vehicle type –road type combination. A check with overall yearly traffic emission data (also from CBS) showed that CO_2/NO_x ratios that are comparable to the ratios arrived at with g/km emission data.

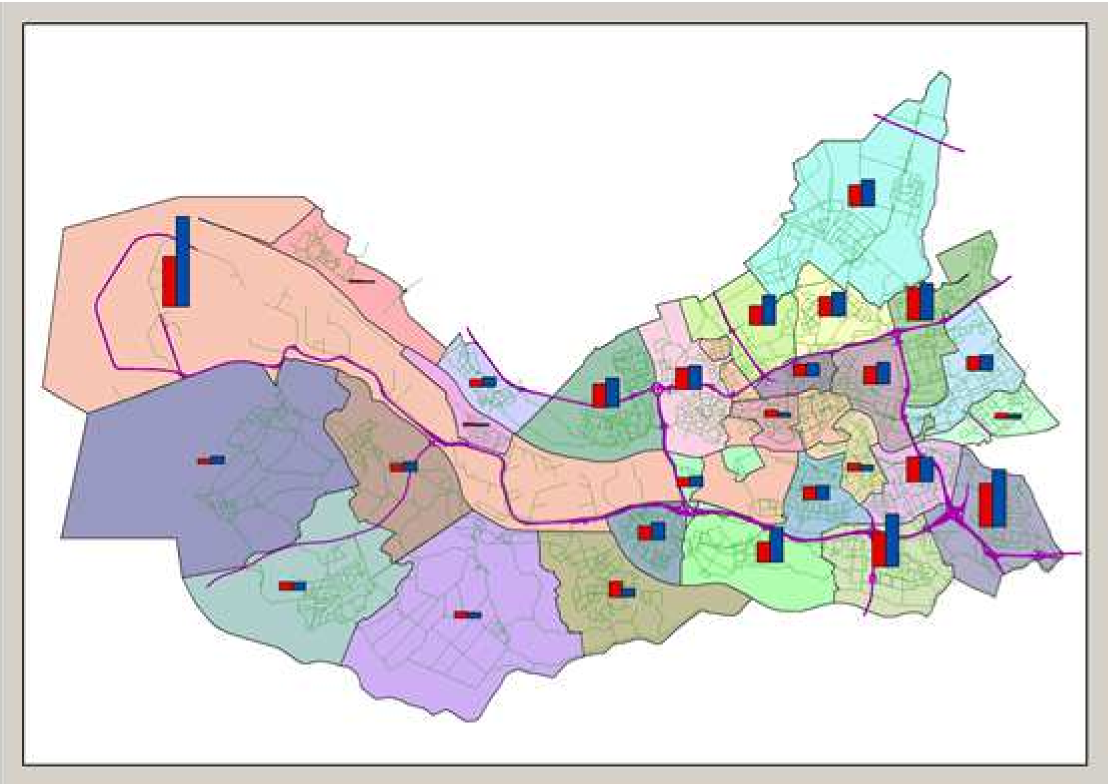
CO_2/NO_x ratios were determined for the CBS set and, using the available EFs for NO_x in the database set, EFs for CO_2 were then calculated for the corresponding year.

Now that all technology, EFs and other data are available in the database, the traffic sources can be included into the sources table and the corresponding ARs were uploaded into the ARs table. The emissions of the pollutants could be given on a 1 x 1 km grid level resolution and thereby a comparison could be made between these emissions and the GCN source emissions.

5.4.2 Traffic, reconciling the Top-Down with the Bottom-Up approach

A direct comparison of the emissions derived in two different ways is represented in the figure underneath. The NO_x emissions for 2009 are presented per administrative region for the Rotterdam area, in blue the emissions derived bottom-up form the traffic data, and in red the top-down national source data.

Figure 5: Top-down (red) and bottom-up (blue) approach for NOx emissions for 2009 (obtained from the EI and plotted on a map).



Overall NO_x emission from the traffic database (bottom-up) are significantly higher (approx. 20%), whereas PM_{10} emissions are in very good agreement ($\Delta \approx 3\%$). CO_2 traffic emissions are in good agreement with the CO_2 footprint that was separately made for the Rotterdam Climate Initiative. Many factors may contribute to these differences and an analysis of the possible causes is needed and helpful to gain more insight in the assumptions made.

One of the reasons why differences occur are boundary problems. Emissions from the top-down data are cut off to within the boundaries of the region of interest. Some of the emissions near the boundaries may not be allocated to the region. This effect tends to diminish at higher resolutions. Since the resolution of the top down data is at best at a 1 x 1 km grid level, differences may still arise.

Differences also appear to occur there where there are more motorways. This is the case for PM_{10}, but especially for NO_x emissions. Possibly, the spatial allocation of the national traffic emissions needs refinement. Differences may also be due to wrongly allocated activity rates or uncertainties in EFs, but since the top-down database only gives data as (g/s) emissions, the underlying information is not available. Differences between local emissions with top down emission data will not disappear. Reconciling these differences is important, since in the end the overall emissions need to be in good agreement and independent from the approach used. Above all, the objective for the inventory is:

- To present a correct figures of overall emissions in (sub)regions;
- To present an accurate geographical distribution of the emissions

One would expect that the top-down traffic emissions are higher than the bottom-up emissions. After all, the RVMK regional traffic model does not include every single small street, whereas the top-down data, if they were correctly down-scaled would include all emissions. We had envisaged to correct for the differences by incorporating them as an additional area source for the region.

The advantage is that the spatial detail of the majority of the emission sources is preserved and scenario's based on the data will reflect this. It will therefore give the best possible input for Air Quality modelling. On the other hand, the total emissions, though not entirely allocated with the same high spatial detail, are still correctly represented in the inventory. Since the opposite appears to be the case (bottom-up emissions are higher) no correction layer was made. Of course a correction layer could be made to decrease the emissions derived with the bottom-up method to reconcile them with the national perspective on our region. However, since it is believed that bottom-up emissions are more accurate, this was not done.

It is important that the correction data be separately labelled and added to the database. In that way, the data is recognizable and can, if so desired, be incorporated into scenario's. Also, separate labelling is crucial to maintaining and securing a continuing improvement of the inventory throughout subsequent cycles. The registered gaps are an indicator of how well both approaches are in agreement with each other.

5.4.3 Top-down and bottom-up, the case of container terminals

In the summer of 2010 an effort was made to fill in the information gap concerning container terminals. Several of these facilities are present in the Rotterdam port area and reported emissions in the national source data appeared not to be consistent with the local information.

This is an example where something goes wrong with national top-down data that was spatially disaggregated. In the case of mobile sources (not being road traffic) emission data are estimated with the use of overall national fuel consumption and they are spatially allocated assuming a relation with the amount of employed workers on a site. Though this seems a reasonable approach (by lack of anything better) it works out wrongly in case of container terminals. In Rotterdam these facilities use a large number of unmanned mobile carriers, so the relation with employment doesn't hold. In a preliminary analysis (among others from permit and inspection data) an inventory of unmanned equipment was made and high volumes of fuel consumption were found. On the other hand, emissions related to the facilities were apparently not accounting for the presence of mobile sources. Apparently, mobile sources are, at least in the case of container terminals, not correctly allocated.

It was decided to deviate from the national EI and collect specific data on fuel consumption and characteristics (power, type of motor, age) of mobile sources at different sites. Also, production rate data (yearly throughput of containers ie TEU's) were collected. Finally, it was decided to determine, as a first estimate, emissions, based on the fuel consumption and an overall emission factor for the whole population of container terminals. The calculated emissions were spatially allocated in the area of the considered container terminals.

Results show a marked difference (hundred times more) with the national source data.

In future, an effort will be made to derive EFs for the TEU throughput activity rate. Different EFs will be arrived at, since emissions depend on the composition of the mobile sources and the logistical structure of container terminals. The advantage of deriving ARs related EFs (instead of the more straightforward approach of relating EFs to fuel consumption) is the possibility to apply them across the container terminals in and outside the region (in the future the national EI wants to improve their handling of these emissions based on our findings) and to relate emissions to changes in production, and to make forecasts. This effort implies that benchmarking of container terminal emission rates is possible.

5.4.4 Benefits and limitations

This case highlights some of the benefits and limitations of setting up the emission inventory:

Benefits:

- The database information data can be used for Air quality modelling (care was taken, that the output from the database can be fed directly into the AQ model), giving detailed AQ information;
- Local knowledge is made available through the inventory, providing fresh insights in the situation;
- Emissions forecasts based on industrial activity can be made;
- Benchmarking across a sector of industry is possible;
- Scenarios can be made with varying EFs, that reflect technology driven improvements (such as modernizing the mobile sources and the logistical techniques);
- A better spatial allocation of mobile sources emissions may result in improved performance of the national emissions inventory.

Limitations and problems:

- The work is laborious and time consuming;
- Thorough (technical) knowledge is needed of the local situation. This knowledge will not always be available to the people involved with the development and maintenance of the inventory.
- Relevant in-company information (such as production and consumption figures) may be hard to get, since companies can be reluctant to share this. This is especially the case for data needed to derive ARs;
- Data availability and accuracy can be a problem (historical records);
- The data requires periodic evaluation and updating, meaning new time consuming work;

In light of the above it is recommended to:

- Prioritize the subjects/targets when refining the emission inventory;
- Secure a broad basis of agreement for the subjects/targets to tackle, so that a concerted effort can be arranged amongst partners and necessary means (time, personnel, finance) can be made available;
- Create awareness inside and outside the region, that the data can be valuable beyond city limits;
- When necessary, secure the cooperation of industry as a data supplier as much as possible;
- Make sure that the targeted expansion /refinement of the inventory is realistic;
- Consider maintenance and periodic updating/evaluation of the data when selecting the targeted expansion /refinement.

5.5 Further considerations

In the previous sections experiences in compiling an integrated EI were presented and some recommendations are made for the developer of an integrated emission inventory for a number of specific situations. In addition there are some extra considerations and recommendations.

Our experience is that the amount and diversity of data that is handled for the inventory can grow out of control rapidly. The CollectER application (and interface) will not be the most appropriate when a large amount of individual sources have to be handled. In fact, special care will be needed to efficiently (and above all, correctly) transfer new data to the inventory. This will require special data attachment queries. These are available in the IMACE database that was developed.

It is crucial to keep a clear record of the sources from which the datasets originate. This is especially the case for different data sources, that provide data on the same emission sources, since double counting emissions in compound scenario's may occur.

Tables were therefore included in the database tool, that allow the identification of data sources. annual emission reports Scenario's can and should be built in a way that checks for double counting of emission sources.

With respect to these distinct data sources, it is recommended to link them through coupled databases. In our case, separate databases have been linked to the main database, thereby maintaining integrity and transparency of the original data. It also facilitates maintenance on the inventory and updating data to the directory.

If GHG shadow emissions make up a large portion of the CO_2 balance of a city/region, an integrated emission inventory may be less useful, since those will not be accounted for within the inventory. This will generally be the case for areas without own power plants. In that case, a user approach, with per capita energy consumption figures, will be important to calculate shadow CO_2 emissions.

Even when an integrated emission inventory is not needed, making steps towards it can be useful. Such an inventory offers the possibility to compare top-down and bottom-up emissions for your region.

Comparison shows if the regionalisation of the emissions is correct and if national EFs are appropriate and applicable to the regional situation.

6 AQ and CO_2 combined indicators

If both CO_2 and air pollutants are stored on an activity basis in the same database it is possible to derive energy or environmental efficiency indicators. CO_2 or air pollutant 'efficiency' indicators are parameters such as the ratio of NOx/CO_2, CO_2 or NOx /km driven, CO_2 or NOx/MWe produced, etc. These indicators could serve two purposes:

- They indicate the energetic or environmental efficiency of a process and can therefore be used to compare cities or processes in cities (e.g. power generation, traffic)
- They monitor the same process over time to see if emission reductions or efficiency gains have occurred.

If the indicators are sensitive enough they can also be used to assess the climate impact of air pollution measures and vice versa). They can be used as a very first preliminary estimate of missing emissions: e.g. if an air pollution EI exists, a CO_2 footprint can be estimated if reliable data on ratio's are known.

6.1 CO_2 and air pollutant performance indicators

Comparing cities, sectors and verifying how emissions evolve over time are demonstrated.

The table below shows that the performance of the <u>different sectors</u> in the same area is different. This is not surprising. Assuming that CO_2 is an indicator for energy use (though it will also depend on the fuels used) a higher CO_2/NO_x ratio might indicate a cleaner process (less NO_x emitted per unit of energy used). This kind of comparison could be done between cities or regions where it makes more sense than comparing one sector to the other where processes and fuels can be very different.

Emissions of CO_2 (Mton) and NO_x (kton) in a 2007 study in the Rotterdam area

	Energy & industry			Road traffic			Shipping		
	CO_2	NO_x	CO_2/NO_x	CO_2	NO_x	CO_2/NO_x	CO_2	NO_x	CO_2/NO_x
1990	20.9	40.8	512	0.9	18.0	50	0.5	11.5	43
2005	25.3	23.1	1094	1.9	9.0	211	0.8	17.5	46
2025	42.1	26.4	1593	1.6	1.6	935	0.9	20.1	45*)

*) When this ratio was calculated marine shipping was still a little regulated sector. By now IMO has announced several measures that will reduce both SOx and NOx between now and 2025.

To compare cities we use data from the Eurotrac-2 project as presented by Sturm. Sturm compares aggregated results per sector for various cities and regions. He characterises, a.o., cities by the share of the industry sector in the total emissions (his fig 3.12). We calculated on the basis of his figure 3.11, different CO_2/NO_x ratio's for the industrial sector. Using his results we estimate similar CO_2/NO_x ratio's for the Milan and Lisbon areas (100-200) and a much higher ratio for the Linz area (700). This shows that the industries in the Milan and Lisbon areas at the time were quite different from those in the Lintz area (different processes, different fuel use and/or different levels of pollution control) in the amount of NO_x they produced per unit of energy consumed.

If we look at the evolution over time in the table above (partly historically, partly forecasted and hence making assumptions on how technology evolves) it is interesting to see that the energy & industry sector is making steady progress in reducing NO_x emissions despite the growth of the sector (rising CO_2 emissions). Industry & energy is a regulated sector so this progress can be anticipated.

Traffic is an even more regulated sector due to the environmental problems it causes in urban areas. Though one sees a growth in traffic as shown by increasing CO_2 emissions (note that real traffic growth might be even higher due to increased energy efficiency of cars) the NO_x emissions drop rapidly resulting in a spectacular increase of the CO_2/NO_x ratio.

Maritime shipping, a sector that was hardly regulated for a long time (note that his has changed recently) increased in volume (and is forecasted to do so) and hence in NO_x emissions. At the time of the study the CO_2/NO_x ratio was virtually constant over the time (note the similar starting points of traffic and shipping in 1990, and their respective evolutions).

6.2 Quick wins - Linking CO2 to pollutants

An integrated EI is a tool to better understand the impact one policy field has on the other. This point has been made several times in this document. Compiling detailed inventories is however not easy and in this section we explore the possibility to get a first estimate of the EI for one pollutant based on an existing EI for another pollutant. In short, if you have an EI for NO_x, can you estimate CO_2, or vice versa? Obviously this quick-and-dirty method is not sufficient if a detailed analysis of how various policies in one domain affect the emissions in another is needed.

To achieve a quick win it is recommended to prioritize by selecting those activities that represent the bulk of the CO_2 and NO_x emissions. A logical choice is to start with traffic and large (industrial) NO_x sources.

6.2.1 CO2/NOx ratio indicator

Linking pollutant emission inventories to CO_2 emissions can take place by using a CO_2/NO_x ratio. Arguments for using the CO_2/NO_x ratio are:

- In terms of overall emissions, combustion related NO_x emissions make up a large fraction;

- Among the NO_x emissions sources, industrial NO_x emissions are closely related to combustion activities.
- Much data is available on emission factors for combustion processes and in general combustion processes are relatively well understood.

Through an iterative process one can use this approach to reach increasingly higher detail levels. In a first order approach, one can estimate a generic CO_2/NO_x ratio for all activities e.g. of one SNAP code. The ratio can thus be used as a first estimate of CO_2 emissions from these sources. In the first order approach, NO_x and CO_2 emission factors can be obtained in the EMEP (http://www.eea.europa.eu/publications/EMEPCORINAIR5) and the EFDB (http://www.ipcc-nggip.iges.or.jp/EFDB/main.php) databases respectively. Based on this a ratio is calculated.

In a second order approach, more detailed information should be obtained on individual emission sources. When sufficient regional data is available for the considered sources, further differentiation can take place of the CO_2/NO_x indicator. This implies that from these sources the applied technologies can be discerned and thereby more sector or activity specific ratios can be deduced. This differentiation leads to better estimates of the CO_2 emissions involved. Available knowledge on fuel-type use and installed pollution control techniques (such as described in BAT/IPPC) should be assessed to differentiate the obtained CO_2/NO_x indicators into subcategories.

In some cases it makes sense to take CO_2 as the basis from which to determine other pollutants. At least in the case of the energy sector CO_2 emission rates are strongly related to productivity (energy output) and a more or less fixed relationship exists between emission and energy production. Pollution control technologies will result in a large variation of emission rates of pollutants such as NO_x and particulate matter, whereas CO_2 emissions will vary less. Which component to choose depends primarily on availability and reliability of data, so in some cases CO_2 may be the prevalent, whereas in other cases NO_x is.

6.2.2 Checks and caveats

Even if separately compiled EI-s exist it can be useful to calculated one EI from the other and vice-versa using the quick-and-dirty method. The comparison might give insight in missing or erroneous information. E.g. when parting from a regional CO_2 footprint one can check if this results in a good estimate for NO_x emissions, overall and for specific (SNAP) sectors. This gives insight in the (in)consistencies within the inventory and areas to be targeted for further analysis.

It is important to stress that, if the use of certain technologies and pollution control techniques are assessed correctly in the inventory, the resulting overall emission will give a reasonable estimate. Otherwise, the use of CO_2/ NO_x ratios may lead to large errors.

The use of the EFDB and EMEP databases is suggested as a starting point. However, it is clear that both databases are symptomatic for the separation of Air quality and Climate change policies; the one database lacks the data the other contains and combining the available emission factors of both database is not an easy task and a first order approach based on the EFDB and EMEP databases may not yield realistic results.

When using the inventory for local CO_2 policy planning, these errors may be a problem for benchmarking one city or region to another and production sectors within the region. On the other hand, when applying the data for the assessing and monitoring of reduction plans, those errors will generally be of minor importance.The case is quite different for AQ modelling purposes; Erroneous NO_x emissions (derived from CO_2 emissions) may have to large errors in air quality modelling, where contributions from low NO_x sources may have a considerable impact on the local air quality. It is therefore safer to estimate CO_2 from NO_x emissons than the other way around.

A case can be made to use other pollutants in order to verify if ratios are reliable or not. In that case care should be taken that the available data are true measurements or independently derived. Company data on emitted pollutants are frequently derived from fixed factorizations over other emittents. This on the one hand shows, that integral factorizations of emissions are actually common practice, on the other hand the derived data can not be used for verification. Evidently, this point of caution is equally applicable to the use of CO_2 and NO_x emission data.

6.2.3 Examples

The case of the energy sector in the Rotterdam port area

For the Rotterdam port area NO_x emissions of the energy sector (SNAP Source Category – 1.A.1) are used in this example. In a first order approach data from the EFDB and the EMEP/EEA database were extracted.

EMEP/EEA	**NOx (kg/TJ)**	**EFDB**	**CO2 (kg/TJ)**	**CO2/Nox Ratio**
Other liquids	180	Other/unspecified	70,800	393
Hard coal/brown coal	335	Lignite/Brown Coal/Anthracite/other sub bituminous *(average)*	98,467	294
Natural gas	89	Natural Gas	56,100	630

The observed CO_2/NO_x ratios were applied to the energy sector emissions sources, for which a NO_x emission was available, resulting in a first order estimate (see table below). Using knowledge of the installations and emission factors from BAT documents we get a more detailed (2^{nd} order) estimate.

	Real emissions	Estimated Emission (1^{st} order)	Estimated Emission (2^{nd} order)
NOx emission (ktons/year)	5.7	5.7	5.7
CO2 emission (ktons/year)	10700	2600	12600

It is clear that the default emissions (not taking into account NO_x reduction measures installed) lead to a serious underestimation of the total CO_2 emissions. The second order estimate is considerably better. An alternative 2^{nd} order approach is to use the average CO_2/NO_x ratio (in our case 1859) emissions of an energy sector that resembles the one under consideration. In this example we use a national average ratio and apply it to the regional energy sector. This gave a very good match.

	Estimated emission
NOx emission (ktons/year)	5.7
CO2 emission (ktons/year)	10600

Note: Emission factors may be derived by combining the data from the EMEP and the EFDB databases. However, special caution is needed, since emission factors may not take into account any pollution control technologies. By omitting pollution control technologies lower than expected CO_2/NO_x ratios will be found (since NO_x emissions will in reality be much lower).

As an example EMEP and EFDB factors for public electricity and heat production give 310 - 360 kg/TJ NO_x emission and 101000 kg/TJ CO_2 emission for coal burning facilities, resulting in a ratio of around 300. Actual data for coal burning energy plants where $DeNO_x$ techniques have been implemented are around 2200. This reflects a typical NO_x removal rate of approx. 85%.

The difference in the figures form the first and second order approach highlights the fact that NOx controlling measures have been implemented on a broad scale in the energy sector. This shows the importance of applying correct emission factors, that reflect the state of the energy sector under consideration. Once you dig deeper the EMEP/EEA database contains more detailed information for applying the correct factors.

Note that the example above using sector average emissions results in very good total emissions for the sector in the area. Obviously it leads to over and underestimates on plant level. For CO_2 where the total emissions are needed and no site specific information is required, this is not a problem. On the other hand, if NO_x emissions are estimated from an existing CO_2 footprint this produces local over and underestimates of the NO_x emissions so, if they are fed into a dispersion model, wrongly calculated concentration fields. E.g. even if the total emissions are correct the spatial distribution of the calculated concentrations is not correct. If, in addition to this the over and underestimates are unevenly distributed over high and low stacks, the resulting NO_2 concentration field can be seriously mistaken.

As an example, the generic approach for non-coal sources yielded an average CO_2/NO_x ratio of 1430. From this figure a NO_x emission of one of the combustion plants was derived. The actual reported NO_x emission of this plant was substantially (90%) higher than calculated.

	NOx emission (Ton/yr)
Derived emission from non-coal generic CO_2/NO_x ratio	237
Actual emission	450
Underestimate of this particular plant	213

This examples shows that care must be taken to derive NO_x from CO_2. And if this is the only way to get to a NO_x EI, differentiating for CO_2/NO_x factors according to the used technologies is essential.

Traffic

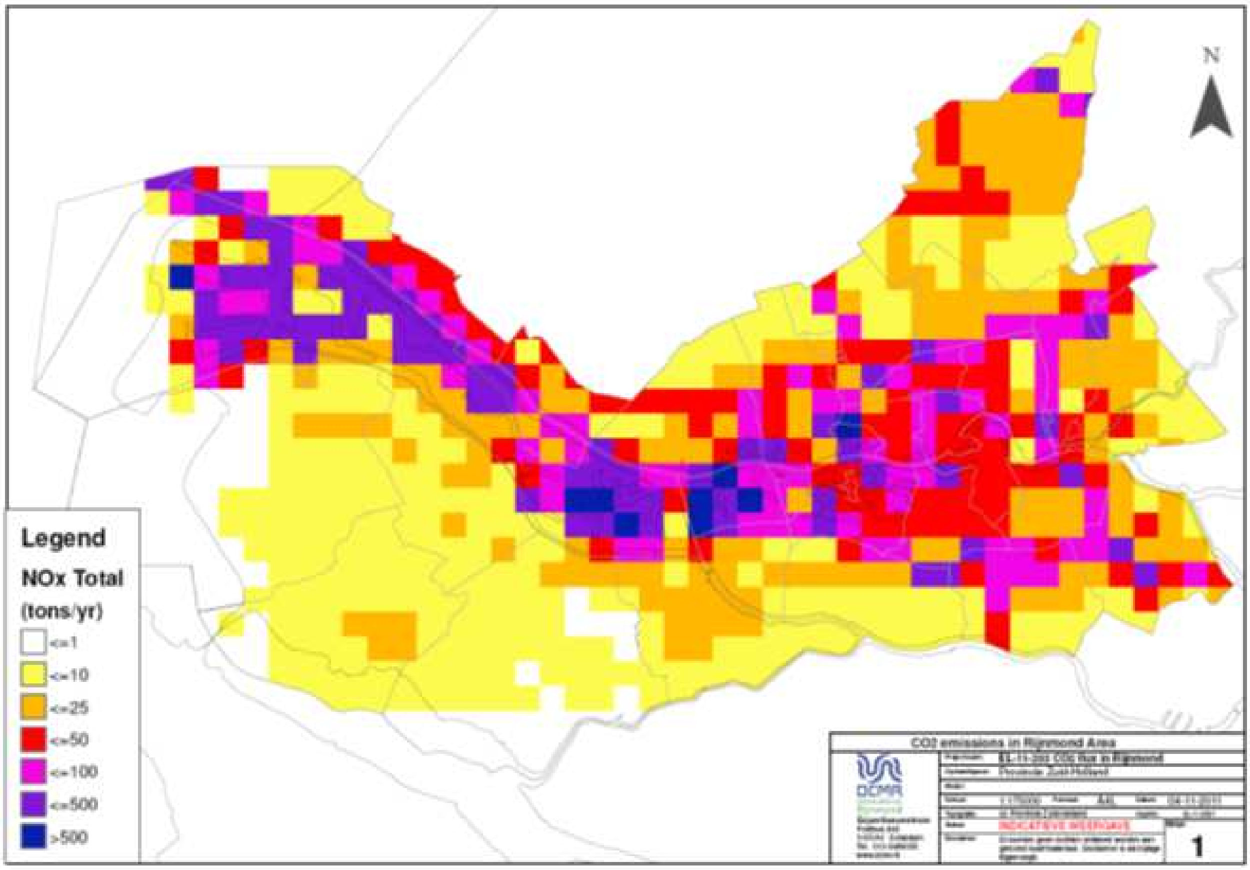
For a general CO_2/NO_x ratio data on traffic from the Dutch national bureau of statistics (CBS) was used. Applying it to the bottom-up NO_x total emissions a figure of 1975 kton CO_2 was calculated. This figure can be used as a first order approach for the traffic CO_2 emission in the region.

In a second order approach, distinct CO_2/NO_x ratios should be determined for the different vehicle and road types. National data were combined: on the one hand vehicle type and road type emission factors, on the other hand total yearly emissions for different vehicle types. Resulting CO_2/NOx ratios were applied and resulted in a higher emission of 2269 kton (+15%).

Interpreting this result turns out to be difficult; it is not clear if the NO_x or the CO_2 data are erroneous. The calculation seemed to imply a much higher emission from small cars, whereas bus emissions appeared to be much lower. This simple check shows that further work is needed to account for the discrepancies.

Results from the CO2 and NOx inventory for Rijnmond

The result of the work above is visualized in maps for the Rijnmond area with spatially distributed NO_x and CO_2 emissions. For different sectors (energy, industry, agriculture, traffic, shipping) a CO_2 inventory was derived from the NO_x inventory, applying sector specific CO_2/NO_x ratios. Total emissions and road traffic emissions have here been mapped separately. Main industrial activities as well as shipping and road traffic arteries can be discerned. Also, when studying the data, the varying performance of the different sectors, resulting in varying CO_2/NO_x ratios is revealed in the overall map. Though showing similar patterns, they are clearly different. For example, in the NO_x map, marine shipping contributions are clearly visible, whereas they can not be clearly discerned in the CO_2 map.



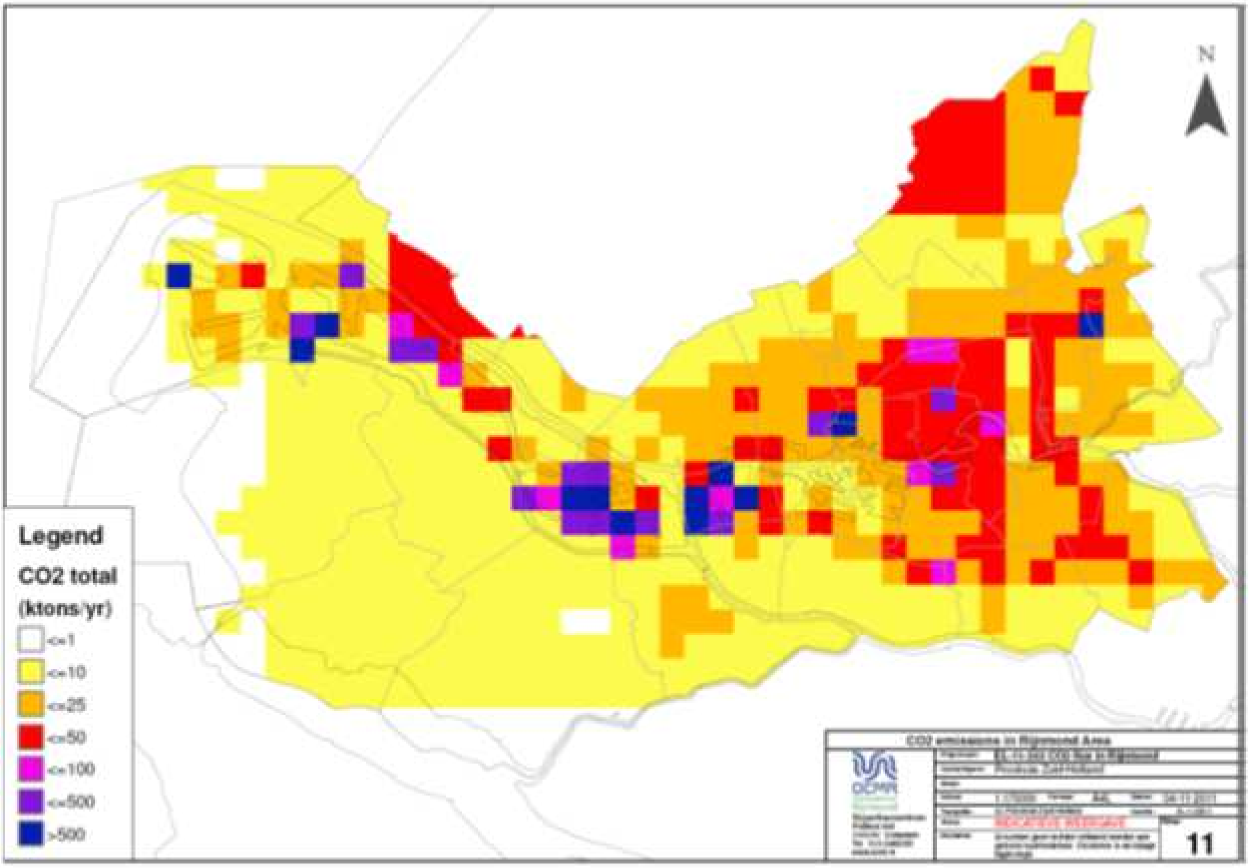


Figure 6 – Total NOx and CO2 (ktons/yr) emissions (tons/yr) in Rijnmond area

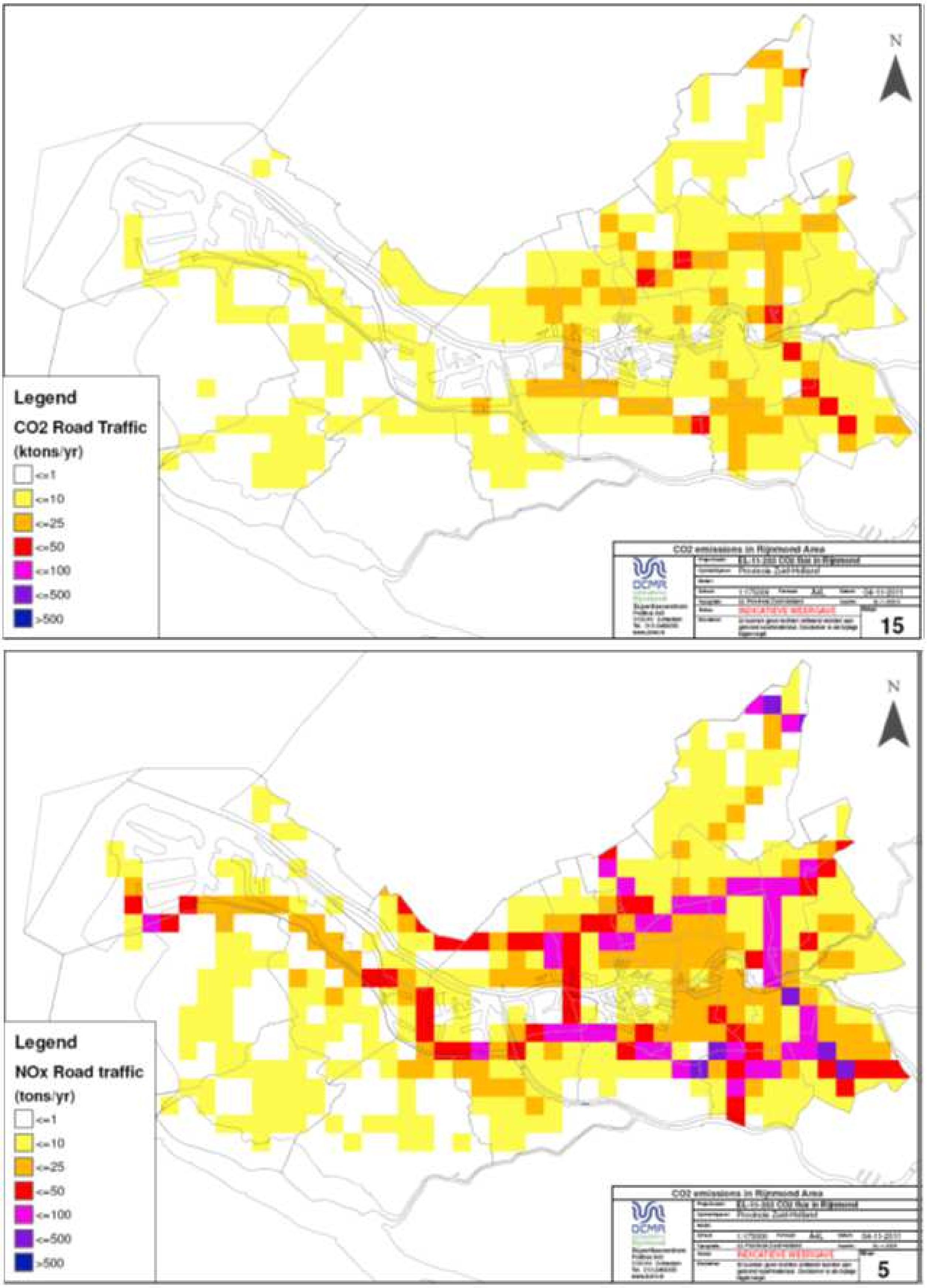


Figure 7 – Road traffic NO_x (tons/yr) and CO_2 (ktons/yr) emissions in Rijnmond area

7 Literature

1 **IPCC** (2001) Climate change 2001: The scientific Basis; Contribution of Working Group I to the third assessment report of the Intergovernmental Panel on Climate Change in J.T. Houghton, Y. Ding, D.J.Griggs, M.Noguer, P.J. van der Linden and D.Xiaosu (Eds.), Cambridge University Press, UK.: http://www.ipcc.ch/publications_and_data/publications_and_data_reports.htm#2

2 **IPCC** (2007), Climate Change: The physical science basis. Contribution of Working Group I to the fourth asassment report of the Intergovernmental Panel on Climate Change in Solomon, S., D.Qin, M.Manning, Z.Chen, M.Marquis, K.B. Averyt, M. Tignor and H.L. Miller (Eds.) Cambridge University Press, UK and NY, USA: http://www.ipcc.ch/ipccreports/ar4-wg1.htm

3 **NACAA** The National Association of Clean Air Agencies (formerly STAPPA and ALAPCO) http://www.4cleanair.org/

4 **LRTAP** (1979) UNECE Convention on Long Range Transboundary Air Pollution. http://www.uneco.org/env/ltrap/welcome.html; National data submitted under this convention can be found at http://webdab.emep.int/

5 **UNFCCC** (2003), All submissions of greenhouse Gas Emission inventories and National inventory Report scan be found at UNFCCC's website

6 **ICLEI**: Local Governments for sustainability: http://www.iclei.org/

7 Wachters, L.H.J (1973), emissieregistratie van luchtverontreinigingen met behulp van het door TÜV-Rheinland e.V. ontwikkelde registratiesysteem, TNO-rapport 73-01259

8 http://www.emissieregistratie.nl/ERPUBLIEK/bumper.en.aspx

9 European Commission, European Pollutant Emission Register **EPER**, http://www.eper.ec.europa.eu/

10 **GEIA** web site http://www.geiacenter.org/

11 **EDGAR** web site http://arch.rivm.nl/env/int/coredata/edgar/

12 **Pulles**, T,M. van het Bolscher, R. Brand ad A Visschedijk (2007) Asessment of global emissions from fuel combustion in the final decades of the 20th century, TNO Report 2007-A-R0132/B; http://www.tno.nl/content.cfm?context=markten&content=publicatie&laag1=186&laag2=1&item_id+215

13 **Pulles**, T.M. van het Bolscher, R.Bronad and A Visshedijk (2007) Asessment of global emissions from fuel combustion in the final decades of the 20th century, TNO Report 2007-A-R0132/B

14 **Pulles**, T. and Heslinga, D The Art of Emission Inventorying, 2010 TNO-rapport

15 **Sturm**, P. and Winiwarter Harmonized method for the compilation of urban emission inventories for urban air modelling. Sturm P.J., P. Blank, T. Böhler, M. Lopes,C. Mensink, M. Volta, W. Winiwarter, Harmonised method for the compilation of urban emission inventories for urban air modelling. In: P.M. Borrell and P. Borrell (eds.), Proceedings of the EUROTRAC Symposium '98 Vol. 2, pp. 708-709. WITPress, Southampton, 1999.

16 The EUROTRAC-2 Subproject **GENEMIS**: http://www.ier.uni-stuttgart.de/forschung/projektwebsites/genemis/

17 **IMPRESAREO** - Improving the Spatial Resolution of Air Emission Inventories Using Earth Observation Data, WP 4000 .Evaluation, Validation and Refinement of Spatially Resolved NOx Inventories. WW4/1200/001/1.3, Seibersdorf Research Report, OEFZS.S-0080, Seibersdorf.

18 **AIR4EU** (2004-2006) has provided recommendations on Air Quality assessment by monitoring and modelling for regulated pollutants in Europe http://www.air4eu.nl/

19 **TFEIP** (2009), EMEP/EEA Emission Inventory Guidebook-2009, http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009

20 **IPCC** 1996), Revissed 1996 IPCC Guidelines for national greenhouse gas inventories, http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.html

21 **EMEP/CORINAIR** Emission Inventory Guidebook 2007/2009. UNECE-Convention on long-range transboundary air pollution & European Environment Agency (EEA). http://www.eea.europa.eu/publications/EMEPCORINAIR5

22 National Emission Ceiling Directive (**NEC**) : http://www.esig.org/mediaroom/487/52/national-emission-ceiling-directive-nec/?cntnt01template=display_recents&cntnt01currentpage=1&cntnt01orderby=Date+DESC

23 Reference Documents on best available techniques (**BREFs**) (see http://eippcb.jrc.es)

24 **Van Aardenne**,JA,PJH Builstjes, L Hordijk, C Kroeze, MPJ Pulles (2002), using wind-direction-dependent differences between model calculations and field measurements as indicator for the inaccuracy of emission inventories, Atmospheric environment Volume 36, Issue 7 Pages 1195-1204 (http://www.sciencedirect.com/science/article/B6VH3-44GM9HM-3/2/a8ae1bc19cb4ff25abb3692aef2545)

25 **Carlos Borrego** and Ana Isabel Miranda CESAM, Department of Environment and Planning, University of Aveiro, 3810-193 Aveiro, Portugal Using Air Quality Modelling to Improve Air Emission Inventories, Alexandra Monteiro,

26 **UNFCCC** (2004), Guidelines for the preparation of national communications by parties included in Annex I to the Convention, Part I: UNFCCC reporting guidelines on annual inventories (following incorporation of the provisions of decision 13/CP. 9)

27 **IPCC (2006),** 2006 IPCC Guidelines for National Greenhouse Gas Inventories, http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

28 **UN Statistics,** UN data a World of Information, http:// data.un.org/

29 **EUROSTAT,** European Data Portal, http://epp.eurostat.ec.europa.eu

30 **International Energy Agency,** IEA online data service, http:// dataiea.org/ieastore/default.asp

31 **IPCC 2000**, Quantifying Uncertainties In Practice, chapter 6 in http://www.ipcc-nggip.iges.or.jp/public/gp/english/ , http://www.ipcc-nggip.iges.or.jp/public/gp/english/6_Uncertainty.pdf

32 **SARURN** The main objective of SATURN was to substantially improve our ability of establishing source-receptor relationships at the urban scale. Ensuring the validity of such relationships may also facilitate : Final report: Studying atmospheric pollution in urban areas (Nicolas Moussiopoulos) http://aix.meng.auth.gr/saturn/

33 Taghavi M., Cautenet S. and Arteta J. (2005), Impact of a highly detailed emission inventory on modeling accuracy, *Atmos Res*, **74**, 65-88.

34 **EUROSTAT** Region database, see http://epp.eurostat.ec.europa.eu

35 **Corine Land Cover** (CLC) is referring to a European programme establishing a computerised inventory on land cover of the 27 EC member states and other European countries, at an original scale of 1: 100 000, using 44 classes of the 3-level Corine nomenclature. http://etc-lusi.eionet.europa.eu/CLC2000/classes

36 **AIR4EU** http://www.air4eu.nl/, Issue 1: data &data needs

37 **IPCC** (2003), Good Practice Guidance for Land Use, Land-Use change and Forestry, http://www.ipcc-nggip.or.jp/public/gpglulucf.html

38 **IPCC** National Greenhouse Gas Inventories Program, Emissions Factor Database http://www.ipcc-nggip.iges.or.jp/EFDB/main.php

39 **US EPA** Environmental Protection Agency, Clearinghouse for Inventories & Emission Factors, http://www.epa.gov/ttn/chief/

40 **US EPA** AP 42, Fifth Edition. Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources. Documento de la US-EPA, donde se recogen los factores de emisión recomendados para el cálculo de las emisiones según el sector de actividad. http://www.epa.gov/ttn/chief/ap42/index.html

41 **Lenschow**, P, Abraham, HJ, Kutzner, K, Lutz, M, Preu?, JD and Reichenbächer W, 2001. *Some ideas about the sources of PM*10. Atmospheric Environment 35, S23-S33.

42 **Hahn, J.** EUROTRAC Data Handbook, pp67, EUROTRAC International Scientific Secretariat. Garmisch-Partenkirchen, Germany, 1996.

43 **Roe, S.M** et al. Development of a multipollutant Emission inventory for the state of IOWA.

44 **Nemet, G.F** et al. Implications of incorperating air-quality co-benifits into climate change policymaking.2010 stacks.iop.org/ERL/5/014007

45 **Wagner, F.** Co-benifits:linking air pollution and climate change

46 **Chiu et al,** Air quality and Greenhouse Gas Co-Benefits of Integrated Strategies in China, Sinosphere, 6(1): 40-47 March 2003

47 **Ministry for the environment Manatu mo te taiao New Zealand :** Quantification of Air Quality Co-Benefits from Climate Change Mitigation measures

48 **Bader, N,** et al Comparative Analysis of local GHG Inventory tools, july 2009

49 http://www.institut.veolia.org/ive/ressources/documents/2/491,final-report-Comparative-Analysis-of.pdf

50 **Pignatelli,T** et al The use of bio-mass : synergies and trade offs between Climate Change and Air Pollution, in Italy.

51 **Mensink Clemens:** Validation of urban emission inventories Vito Environmentalmonitoring and Assessment 65: 31-39, 2000 Kluwer.

52 **Mayerhofer,P et al**; Regional air pollution and Climate Change in Europe: an integrated assessment (AIR-CLIM), Water, Air and Soil Pollution 130: 1151-1156,2001 Kluwer

53 **Air Pollution & Climate Change two sides of the same coin**? Swedish environmental protection agency ISBN 978-91-620-1278-6

54 **Olivier et al:** Uncertainty in the Netherlands greenhouse gas emission inventory, estimation of the level and trend uncertainty using the IPCC Tier 1 approach.Netherlands Environmental Assessment Agency

55 **Ntziachristos, L., Samaras**, Z. 2000. Speed-dependent representative emission factors for catalyst passenger cars and influencing parameters. Atmospheric Environment, 34, 4611–4619.

56 **Orthofer, R et al;** Management and visualization of spacially resolved Emission Inventories and Emission Scenatios.

57 **EEA :**Air pollution and climate change policies in Europe: exploring linkages and the added value of an integrated approach," European Environment Agency, http://reports.eea.eu.int/technical_report_2004_5/en/tab_content_RLR

For a good introduction on EI-s we refer:

- **Pulles, T. and Heslinga**, D The Art of Emission Inventorying, 2010 TNO-rapport

IPCC (2006), 2006 IPCC Guidelines for National Greenhouse Gas Inventories, http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

- **TFEIP (2009)**, EMEP/EEA Emission Inventory Guidebook-2009, http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009

Estimation methodologies and emission factors:

- EMEP/CORINAIR Emission Inventory Guidebook 2007. UNECE-Convention on long-range transboundary air pollution & European Environment Agency (EEA). http://www.eea.europa.eu/publications/EMEPCORINAIR5/

- **AP 42**, Fifth Edition. Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources. Documento de la US-EPA, donde se recogen los factores de emisión recomendados para el cálculo de las emisiones según el sector de actividad. http://www.epa.gov/ttn/chief/ap42/index.html

- **The Factor Information Retrieval (FIRE) Data System** version 6.25 (EPA). Database management system containing EPA's recommended emission estimation factors for criteria and hazardous air pollutants obtained from the Compilation Of Air Pollutant Emission Factors (AP 42). http://cfpub.epa.gov/oarweb/index.cfm?action=fire.main

- **Uncontrolled Emission Fa**ctor Listing for Criteria Air Pollutants (EPA) http://www.epa.gov/ttn/chief/eiip/techreport/volume02/ii14_july2001.pdf

Revised 1996 **IPCC Guidelines** for National Greenhouse Gas Inventories. http://www.ipcc-nggip.iges.or.jp/public/gl/invs5.html

- **Greenhouse Gas Inventory Guidebook** (IPCC Guidelines for National Greenhouse Gas Inventories). http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

- **The Emission Factors Database. UK** National Atmospheric Emissions Inventory (NAEI). http://www.naei.org.uk/emissions/index.php

Sector-specific pollution inventory reporting guidance. UK Environment Agency. http://www.environment-agency.gov.uk/business/topics/pollution/32290.aspx

- **Best Available Techniques Reference Documents (BREF).** Integrated Pollution Prevention and Control (IPPC). http://www.prtr-es.es/fondo-documental/documentos-de-mejores-tecnicas-disponibles,15498,10,2007.html

- Expert Group on Techno-Economic Issues (EGTEI) Background documents. Centre Interprofessionnel Technique d'Etudes de la Pollution Atmosphérique (CITEPA). http://www.citepa.org/forums/egtei/egtei_index.htm#egteiwork

The Co-ordinated European Programme on Particulate Matter Emission Inventories, Projections and Guidance (**CEPMEIP**) Database. http://www.air.sk/tno/cepmeip/

- Air pollutant emission estimation methods for E-PRTR reporting by refineries. Conservation of Clean Air and Water in Europe (CONCAWE). http://www.concawe.org/Content/Default.asp?PageID=31 (Reports: Air Quality).

- Air pollutant emission estimation methods for PRTR-Spain reporting by refineries, prepared by Spanish Petroleum products Operators Association (AOP). http://www.prtr-es.es/data/images/Documento-de-refinerias.pdf

-The National Greenhouse Accounts (NGA) Factors. The Department of Climate Change of the Australian Government. http://www.climatechange.gov.au/publications/greenhouse-acctg/national-greenhouse-factors.aspx

- Pregger et al. Emissions & Data Needs. 2007. AIR4EU. WP 6 – Synthesis. Milestone Report 6.4

- **EMEP Emission Inventory Data Base**: http://webdab.emep.int/

- **The EUROTRAC Subproject GENEMIS** on "Generation and evaluation of emissions data": http://www.ier.uni-stuttgart.de/public/de/organisation/abt/tfu/projekte/genemis/

- **US EPA Office of Air Quality Planning & Standards maintains a comprehensive web site** where all material on available emission factors and emission estimation methods in the USA can be viewed and, in many cases, downloaded: http://www.epa.gov/ttn/chief/

- Compilation of Air Pollution Emission Factors Ap-42. Fifth Edition, Volume I: Stationary Point and Area Sources: http://www.epa.gov/ttn/chief/Ap42.htm

- Volume II: Mobile Sources (AP-42), pending 5th Edition (last updated 06 April 1998): http://www.epa.gov/oms/ap42.htm

- **Factor Information Retrieval (FIRE)** Data System: http://www.epa.gov/ttn/chief/fire.html

- **Ntziachristos, L.; Samaras**, Z. COPERT III, Computer Program to Calculate Emission from

Road Transport, Methodology and Emission Factors (version 2.1), European Environment Agency,

November 2000.

- **European Integrated Pollution Prevention and Control Bureau** Technological Background of emissions http://eippcb.jrc.es/pages/FActivities.htm

- **Australian National Pollutant Inventory** Useful site with many emission factors for various processes www.npi.gov.au

- **EPA Clearinghouse emission factors** Default methodologies in USA http://www.epa.gov/ttn/chief/efpac/index.html

- Locating & Estimating (L&E) Documents Emissions of hazardous substances methodology http://www.epa.gov/ttn/chief/le/

- **COPERT III** Estimating tool emissions of road traffic Default methodology road traffic emissions Europe http://vergina.eng.auth.gr/mech/lat/copert/copert.htm

-□□**Sector-specific guidance,** covers such industries as aluminum, iron and steel, cement, etc.

www.epa.gov/stateply/resources/sector-specific.html

- Ntziachristos, L. "Road vehicle tyre & brake wear, & road surface wear. Activities 070700 - 070800", *Emission Inventory Guidebook* , Aristotle University Thessaloniki / Lab of Applied Thermodynamics, Thessaloniki, Greece, Version. 1.0, August 2003, http://www.aeat.co.uk/netcen/airqual/TFEI/reports.htm

Activity data:

- PRTR reporting and Sector-specific Guidance supporting for reporting of relates to the Andalusian Pollutant Release and Transfer Register, developed by PRTR-Andalusia: http://www.cma.juntaandalcia.es/medioambiente/site/web/menuitem.998f18db9970c524a3dcdb7a5510e1ca/?vgntoid=3121d52388136110VgnVCM1000000624e50aRCRD&vgnextchannel=3259b19c7acf2010VgnVCM1000001625e50aRCRD&lr=lang_es

- Environmental integrated authorizations (Autorizaciones Ambientales Integradas, AAI) of companies and facilities located in Andalusia. Environmental prevention and control tools formulated with the law 7/2007 of 9 July, Integrated Environmental Quality Management. http://www.cma.junta-andalucia.es/medioambiente/servtc1/AAIo/?lr=lang_es

- National Emission Inventory. Spanish Ministry of Environment (MARM) http://www.mma.es/portal/secciones/calidad_contaminacion/atmosfera/emisiones/inventario.htm

- Casella Stanger (2002) *Emission Factor Toolkit.* Available: http://www.bv-modelling.co.uk/

Spatial emission data:

- Triacchini, G et al Preparation of a spatial emission inventory as input for modelling;

Improving the spatial resolution of air emission inventories using earth observation data, Winiwarter, W, er al,

- Winiwarter W., S. Ekstrand, D. Johansson.IMPRESAREO - Improving the Spatial. Resolution of Air Emission Inventories Using Earth Observation Data, WP 4000 . Evaluation, Validation and Refinement of Spatially Re-solved NOx Inventories, Seibersdorf Research Report, OEFZS.S- 0080, Seibersdorf, 2000. http://www.tfeip secrtariat.org/guidebook/GuidebookPDF4WebSite/AGeneralGuidance.html#Topic2

- G. Smiatek Land cover and topography mapping The use of emission data as input for air quality assessment requires a spatial, temporal and substance resolution. The comparison of modelled and monitored concentrations might lead to a validation and improvement of emission inventories

- **Urban emission inventories** (see the EU Project IMPRESAREO): Improving the Spatial Resolution of Air Emissions Inventories Using Earth Observation Data: http://www.aeat.co.uk/IMPRESAREO/

- **Alexander Monteiro et al** Using Air Quality modelling to improve air emission inventories.

- **Gois, V & Maciel, H** A detailed urban road traffic emissions inventory model using aerial photography and GPS surveys

- Gois, V et all Using Aerial photographic data for inventory of air emissions from road traffic sources : case study in the city of Lison, , 2005,

- The Nature Conservancy Carbon Calculator *www.nature.org/initiatives/climatechange/calculator*

Statistical data:

- **Andalusian Statistical Institute**. Andalusian Administration for Economic Affairs and Finance www.iea.junta-andalucia.es/index.html

- Andalusian Energy Agency (AAE). www.agenciaandaluzadelaenergia.es/agenciadelaenergia/nav/com/portada.jsp

- Institute for Diversification and Saving of Energy (IDEA). www.idae.es/

- Spanish Ministry of Industry, Tourism and Trade (MITYC). www.mityc.es

- Spanish Airports and Air Navigation (AENA). www.aena.es

- Spanish Ports. www.puertos.es

Information on emission inventories:

- ARTEMIS International engagements as well as impact studies require accurate and agreed methods for as-sessing pollutant emissions from the road transport. This ARTEMIS project - with 40 European research laborato-ries and a budget of about 9 M€ was initiated for the setting-up and improvement of the European inventorying tools for application at different spatial and temporal scales and which should enable objectives comparisons and evaluations.

The ARTEMIS tools were designed for three main applications: (i) classical emission inventories (at regional or national scale, per month or year), (ii) scenario calculation for assessing the impacts of alternative measures (time series over years), (iii) inputs for air quality models for assessing local and temporal impacts on the environment. The model was then designed to enable calculation at an aggregated level and at a street level. The daily calcula-tion can be done on a hourly basis or aggregated over a year, for the 1980-2030 period. André, M. (2004). The ARTEMIS European driving cycles for measuring car pollutant emissions. Sc. of the Tot. Envir., n°334-335, p. 73-84, 2004.

-Clean Air and Climate Protection Software (CACP) CACP 2009 is a one-stop emissions management tool that calculates and tracks emissions and reductions of greenhouse gases (carbon dioxide, methane, nitrous oxide) and criteria air pollutants (NOx, SOx, carbon monoxide, volatile organic compounds, PM10, PM 2.5) associated with electricity, fuel use, and waste disposal. ACP 2009 was created to support emissions inventorying and climate action planning based on the principles and methods of the Local Government Operations Protocol (LGOP). This tool can help you do the following: *Create emissions inventories for the community as a whole or for the government's internal operations.

*Quantify the effect of existing and proposed emissions reduction measures.

*Predict future emissions levels.

*Set reduction targets and track progress towards meeting those goals http://www.icleiusa.org/cacp

-**The UN Framework Convention on Climate Change**. The UNFCCC sets an overall framework for intergovernmental efforts to tackle the challenge posed by climate change. It recognizes that the climate system is a shared resource whose stability can be affected by industrial and other emissions of carbon dioxide and other anthropogenic greenhouse gases. The Convention entered into force on 21 March 1994 and enjoys near universal membership, with 191 countries having ratified.

Under the Convention, governments:

• gather and share information on greenhouse gas emissions, national policies and best practices;

• launch national strategies for addressing greenhouse gas emissions and adapting to expected

impacts, including the provision of financial and technological support to developing countries;

• cooperate in preparing for adaptation to the impacts of climate change.

- **INEMAR** Lombardy region (Italy) emission inventory: methodologies and results Stafano Caserini et al. A detailed Emission Inventory for air quality planning at local scale: the Lombardy (Italy) experience; Caserini er al;

- **Sturm** Air Pollutant Emissions in Cities Graz University of Technology, Institute for Internal Combustion Engines and Thermodynamics, A-8010 Graz, Austria

- **Rainer Friedrich et al**; Urban Air pollution- European aspects, Chapter 6: Emission inventories (Kluwer Academic Publishers, Dordrecht, 1998

- Reducing Greenhouse Gases and Air Pollution: A Menu of Harmonized Options," October 1999, STAPPA/ALAPCO, http://www.4cleanair.org/comments/execsum.PDF

- Within **UNECE's EMEP** programme a Task Force on Emission Inventories is maintaining the Atmospheric Emission Inventory Guidebook (Ref 5): http://www.aeat.co.k/netcen/airqual/TFEI/unece.htm

- **EMEP/CORINAIR** Emission Inventory Guidebook (3rd edition): http://reports.eea.eu.int/technical_report_2001_3/en

- **EPER** (European Pollutant Emission Register): http://europa.eu.int/comm/environment/ippc/eper/

- **European Topic Centre on Air Emissions** supports member states in making tools available for determining, collecting and reporting air emission data: http:/www.aeat.co.uk/netcen/airqual/TFEI/unece.htm

- **Intergovernmental Panel on Climate Change (IPCC)**, has produced guidelines for the establishment of emission inventories of greenhouse gases within its National Greenhouse Gas Inventory Programme (NGGIP): http://www.ipcc-nggip.iges.or.jp/

- **TANKS 4.07 fro Windows** ®: http://www.epa.gov/ttn/chief/tanks.html

- **The National atmospheric emissions Inventory of the United Kingdom** calculated general emission factors: http://www.aeat.co.uk/netcen/airual/emissions

- **The Australian emission estimation technique manuals**: http://environment.gov.au/epg/npi/eet_manuals.html

- The **OECD** maintains a comprehensive web site where material related to emission inventories can be viewed and documents can be downloaded: http://www.oecd.org/env/

- The **OECD Database** on Use and Release of Industrial Chemicals' comprises three modules which contain the following information sources: emission scenario documents, sources of Information on Uses and Releases of Specific Chemicals and sources of Information on Uses and Releases of Chemicals on Specific Use/Industry Categories: http://appli1.oecd.org/ehs/urchem.nst/

SARURN The main objective of SATURN was to substantially improve our ability of establishing source-receptor relationships at the urban scale. Ensuring the validity of such relationships may also facilitate : Final report: Studying atmospheric pollution in urban areas (Nicolas Moussiopoulos)

- **Denier van der Gon, H.A.C., M. Schaap, A.J.H. Visschedijk and P.J.H. Builtjes**, The gap between

observed and inventoried anthropogenic black carbon and fine aerosol in Europe, PM Emission

Inventories, Scientific Workshop, Lago Maggiore, Italy, 18 October 2004.

- **Peter Coenen** New developments in the emission Inventory of the Netherlands, TNO The Netherlands Organization for Applied Scientific Research

- **Peter Builtjes** Air4EU: report: Review of methods for assessing Air Quality at the regional/continental scale, 2005

- **Ntziachristos, L & Samaras**, Z 2000: Copoert III Computer emission to calcultate emissions from road transport. Methodology and emission factors Published by European Environment Agency (EEA) Copenhagen

- **Baugues,K** Everything That an emission factors, Emission Inventories could be. KERAMIDA Environmental, Inc.

- **EUROTRAC LOOP** http://loop.web.psi.ch/

- **CEPMEIP** (2002), Co-ordinated European Programme on Particulate Matter Emission Inventories, Projections and Guidance, Database presented on the Internet: http://www.air.sk/tno/cepmeip/.

- **NAEI** (2003), UK National Atmospheric Emissions Inventory, National Environmental

Technology Centre.http://www.naei.org.uk/emissions/index.php

-**UK National Atmospheric Emissions Inventory Default methodology** in UK http://www.naei.org.uk/emissions/index.php Expert Group on Techno- Economic Issues

http://www.citepa.org/forums/egtei/egt ei_index.htm#egteiwork

- **An overview of the methods** available to facilities to estimate their releases to air, water, and

Land http://www.unitar.org/cwm/publications/prtr.htm

- **OECD Clearing-house of guidancemanuals**/documents of release estimation techniques for the

- principal pollutant release and transfer registries http://www.oecd.org/env/prtr/rc ARIC (1999) *Emissions Inventory Update for Merseyside, 1998.* ARIC, Manchester Metropolitan University.

- ARIC (2002) *Atmospheric Emissions at Liverpool Airport 2001 - Update for Merseyside Emissions Inventory.* ARIC, Manchester Metropolitan University.

- Blair, J. (2003) *Compilation of an Emissions Inventory for Merseyside.* CERC, Cambridge.

Buckingham, C., Clewley, L., Hutchinson, D., Sadler, L., Shah, S. (1997) *Atmospheric Emissions Inventories for Four Urban Areas: Merseyside, Bristol, Southampton/ Portsmouth, Swansea/Port Talbot.* London Research Centre, London.

Tools or Modules

- **Greenhouse Gas Protocol** Tools www.ghgprotocol.org/calculation-tools/all-tools

- **Design principles guidance** includes overall guidance on defining inventory boundaries, identifying greenhouse gas (GHG) emission sources, and defining and adjusting a base year. *www.epa.gov/stateply/resources/design-principles.html*

- Option modules guidance includes optional emissions sources in which businesses or organizations have some control such as employee commutes. Emissions reductions from offset investments and renewable energy purchases can also be calculated for goal-tracking

purposes. *www.epa.gov/stateply/resources/optional-module.html*

- **NRC Environmental Benefits Calculator** *www.nrc-recycle.org/theconversionator/shell.html* The National Recycling Coalition's Environmental Benefits Calculator helps determine the GHG and energy benefits of current waste disposal practices. Users enter data on the amount of various waste materials they landfill, recycle, and incinerate, and the tool calculates how that waste disposal scenario compares with one in which all waste is landfilled. The tool reports the benefits in terms of GHGs and other air emissions, energy use, quantity of oil and gas consumed, waterborne wastes, and other metrics. Results are also displayed according to economic sector and life-cycle stage, and automaticallygenerated charts and graphs provide an illustrated view of the results. This versatile tool can be used by businesses, universities, and government agencies and may be useful in demonstrating the benefits of recycling programs.

8 Annex

8.1 What exists in the cities (in terms of EI-s)

A review amongst city partners led to the identification of good practices.

Results from the review are:

- Maribor, Paris, Prague, Rome, Rotterdam, Gdansk and Seville all have EI-s for pollutants.
- Except for Maribor (only traffic and energy) all cities cover all sources for air pollution.
- Seville and Paris have further developed EI-s and aim to improve their EI-s and integrate greenhouse gases (GHG).
- In general, the EI use bottom-up approaches to calculate pollutant emissions produced by industrial point sources, and traffic.
- Only Rotterdam and Paris use the EI for scenario studies
- Not all cities use an activity based EI where the actual emission is calculated by multiplying an activity with its emission factor (EF).
- The cities use different sources for their EF.
- All cities use different software to manage their EI. A common system could facilitate exchange.
- Paris, Rotterdam and Rome have GHG-EI-s acting as examples of how to make/manage CO2/GHG footprints.
- EI for pollutants usually use bottom-up approaches. EI for CO2 often use top-down approaches, this makes integration difficult whereas basically the same source information is needed.

Paris:

Air pollution in Paris is mainly related to traffic emissions. The traffic data collection is performed in quasi real time by the system developed under the framework of then HEAVEN European project. “Real time” traffic data are collected by the system and used as input to a traffic model in order to provide traffic information on the whole road network, that is about 35000 portions (or 10 650 km) of road throughout Paris and the Ile-de-France Region. This information is updated every hour. “Real time” traffic emissions are then calculated using the CORPERT III methodology and a detailed description of the fleet composition, specific of the Ile de France area.

Rotterdam:

In Rotterdam and the Rijnmond area, point sources such as industrial stacks and refineries are important emitters but contribute little to air quality due to their emission height. Large plants have to report to national and regional authorities, so information is available in detail. Small industries also have to report, but in order to avoid expensive accurate monitoring some plants report the maximum emission that is in their operation license. So emissions could be overestimated. Activity data for traffic emissions is derived from counts (by loops in highways and some innercity roads) and traffic flow models with origin/destination matrices for inner-urban driving. Emission factors are taken from the Dutch national data set. The amount of congestion on certain road links is not accurately recorded in the traffic emission databases and PM emissions linked to resuspension are still uncertain. As Rijnmond contains one of the largest ports in the world, emissions from ships are another important source. Exact figures, especially for PM, remain highly uncertain. Likewise, emissions from transshipment, from storage of coal and ore (PM), from leaking (VOCs) and from the container terminals (NO_x) are hard to quantify.

Rotterdam has developed a CO_2 footprint. The footprint was calculated using a ‘Source approach’. This means that all emissions occurring within the Rotterdam territory are added to the Rotterdam footprint. More information on the emission inventories in Rotterdam and the development of an integrated emission inventory can be found in can be found in Chapter 5)

Seville (Andalusia):

The EI collects the information about air pollution emissions at the region level, in the autonomous community of Andalusia. It covers all SNAP activities, both industrial and non-industrial point sources and area sources, and estimates annual emission for all major air pollutants produced by these different source categories, as well as greenhouse gas emissions. The basic air pollution source in Andalusia is constituted, in addition to certain industrial activities, the ever more congested urban concentrations and metropolitan areas (despite in Andalusia they have a medium sized under the European cities). This inventory includes all those activities whose emissions have some relevance. It covers releases of pollutant from vehicle traffic, industries and residential uses. In general, the AEI uses bottom-up methods to calculate pollutant emissions produced by industrial and non-industrial (waste treatment plants) point sources. It is possible as the industrial facilities quantify and report their annual emissions besides their fuel and raw materials consumptions or production and other information, to Pollutant Release and Transfer Register (PRTR). For area sources (such us traffic, domestic, agriculture, forestry, etc.), top-down methods are usually used. We receive the preliminary data from the Spanish Ministry of Environment (MARM) (total regional emissions for the official annual national EI) and statistical data and publications from official bodies and certain consulted entities. More information on the emission inventory in Seville can be found in The Seville case study described in annex 8.2

Prague:

Point sources in the emission inventory of Prague are represented by measured emissions for the largest stacks corresponding to the Czech classification REZZO 1 and calculated emissions for smaller point sources corresponding to REZZO 2 (the calculations are based on fuel consumption and CORINAIR emission factors). Combustion characteristics are described by stack height and diameter, flue gas temperature, flow rate and velocity. Source specific information for that is provided by the plant operators and validated by the Czech National Environmental Inspectorate. Temporal variation of emissions from large combustion sources is accounted for by annual profiles. In addition to that, some sources have weekly/ daily shift or irregular profiles, highest temporal resolution is on a daily basis. Similar to Oslo, traffic as classified in REZZO 3 is modelled as line source for major roads and area source for minor roads. Emission factors for traffic are taken from the Czech data base MEFA and are depending on the catalytic type, speed, slope and year. They are, however, considered to be too low. A cross-check with COPERT III emission factors has not been undertaken. Non-exhaust PM emissions from suspension are not included in the modelling. Area sources include small combustion and are allocated using land use data and population depending on ambient temperature and season.

Maribor:

We did greenhouse gas emission inventory for Maribor for the sector Energy (CRF sector 1) using the IPPC methodology and the traffic emission inventory with COPERT methodology. For GHG EI we used mainly top down approach. We calculated emissions from the national reports data on fuel consumption for the Maribor area. We also used data on energy products sold in Maribor, produced by MOM (Municipality of Maribor) from fuel dealers. For air emissions from industrial plants we used the state register which was provided by Ministry of Environment and Spatial Planning. Emissions were calculated using emission factors from national report or the IPPC guidelines. We prepared methodology for calculation of fugitive emissions including methane emissions from the transport, distribution and use of natural gas. For the calculation of transport emissions we used the program COPERT IV. The base year for EI preparation was 2006. Data about vehicle fleet were collected by the Ministry of the Interior. Data on the mileage, mileage share, average speeds in specific driving modes, the average trip length (Ltrip) and PSF values were taken from the Slovenia's National Inventory Report. Fuel consumption was calculated from the reports drawn up by companies selling fuel in the area of Municipality of Maribor. Fuel characteristics were taken from Slovene national legislation relating quality of liquid fuels. Minimum and maximum monthly temperatures for Maribor were taken from Environmental Agency of the Republic of Slovenia. Beta values calculated according to the COPERT IV methodology were used. All other required input data were default COPERT IV data. The Maribor case study is described in annex 8.6

Note:
At first glance, you might see only contrasts, not commonalities, between places for example like Paris and Maribor. But the local governments that help to maintain and enhance the respective ways of life in these communities share a strong commitment to: climate protection, clean energy solutions and sustainability. Their goal is to reduce GHG emissions, minimize local air pollution prevent global warming and protect public health

8.2 The Paris EI management

8.2.1 Example 1 for SNAP 0201, non industrial combustion plants.

Activities concerned:

Activity	N°SNAP
Non industrial combustion plants	0201
Commercial et institutional plants	020101
Combustion plants > = 300 MW (boilers)	020102
Combustion plants > = 50 MW and < 300 MW (boilers)	020103
Combustion plants < 50 MW (boilers)	020104
Stationary gas turbines	020105
Stationary engines	020106

NB : Emissions are calculated for the level 2 of SNAP because the available emission factors and energy consumptions don't make any differences in the power or the kind of boiler.

Pollutants

Numerous combustion pollutants have to be considered : SO2, NOx, CO, GHGs (CO2, CH4, N2O), PM (TSP, PM10, PM2.5), NH3, heavy metals (As, Pb, Ni, Cd, Hg, Cr, Cu, Se, Zn), PAH (Bap, BbF, BkF, IndPy), and others in lower quantities : PCDD-F, PCB, HCB.

Methodology

1. The way to calculate the emissions is always the same, per activity :

   Energy consumption * emission factor

2. Emission factors (sheets EF, EF_1 and EF_2 in the Excel document) for all the activities involved have to be calculated or found in a database (e.g. CITEPA, EMEP, ASPA). They depend on the fuel and the pollutant.

   For this particular emission inventory, a study has been done to compare the emission factors available, in order to find the one who matches the local conditions.

3. Energy consumptions depend on the kind of building and the type of energy used. They usually can be found in databases (e.g. provided by CEREN in France).

   For this particular study, energy consumptions are provided at a regional scale and per kind of building according to its activity (office, shop…). Data were provided for 2002, so we had to update them, adding the *weather severity indicator* (sum of degree day) corresponding to 2005.

   N.B: In this particular case, some industrials provided us with information about their emissions. Those emissions can be incorporated directly in the inventory, but a special care must be given to avoid a double counting of the emissions: one time directly, the other through the energy consumption (which should be subtracted in the total energy consumption)

Data bases used :

To find energy consumptions data :

- CEREN : Données de consommation énergétique par combustible et type d'établissements année 2002
- ARENE : Tableau de bord de l'énergie en Ile-de-France synthèse 2006 http://www.areneidf.org/energies/pdf/tableau-bord-energie.pdf
- Fiche ASPA

To find emission factors :

- Facteurs d'émissions : OMINEA, février 2008, Organisation et Méthodes des inventaires nationaux des Emissions Atmosphériques en France, Rapport d'inventaire national, 5ème édition, CITEPA
- Facteurs d'émissions : EMEP/CORINAIR Emission inventory guidebook – 2007, B112 http://reports.eea.europa.eu/EMEPCORINAIR5/en/B112vs3.1.pdf
- Facteurs d'émissions : EMEP/CORINAIR Emission inventory guidebook – 2007, B216 http://reports.eea.europa.eu/EMEPCORINAIR5/en/B216v2.pdf

8.2.2 Example 2 for SNAP 07, road transport.

Activities concerned

N°SNAP	SNAP/CORINAIR Activity	Reporting Detail
07	Road transport	
0701	Passenger cars	Road Transportation, Passenger Cars
0702	Light-duty vehicles < 3.5 t	Road Transportation, Light duty vehicles
0703	Heavy-duty vehicles > 3.5 t	Road Transportation, Heavy duty vehicles
0704	Buses and coaches	
0705	Mopeds and Motorcycles < 50 cm3 Motorcycles > 50 cm3	Road Transportation, Mopeds and motorcycles
0706	Gasoline evaporation from vehicles	Gasoline Evaporation from vehicles
0707	Automobile tyre and brake wear	Automobile tyre and brake wear
0708	Automobile road abrasion	Automobile road abrasion

in Airparif's reports about emissions from road transport, sectors 0704 and 0705 are aggregated (in 0705),and the emissions from buses and coaches are separated from those of heavy trucks (and attributed to 0704).

Pollutants

Numerous pollutants have to be considered : NOx, NMVOCs, particles, CO, CO2, SO2, PAH, NH3, N2O, heavy metals, PCDD-F…

Sector description

Emissions from road transport are of three types:

- Emissions related to fuel combustion: there are hot emissions and emissions occurring when the engine is cold, that cause a over emission; pollutants are those mentioned above;

Emissions related to fuel evaporation; they generate NMVOCs;
Emissions related to the technical wear of brakes and tires, and roads; they generate particles.

Methodology

The methodology used to calculate emissions is based on the Copert methodology, which is part of the EMEP / CORINAIR methodology. It is developed under the auspices of the UNECE and the Task Force on Emissions Inventories , for a uniform reporting of national emissions to the European Union.

Since 29 November 2006, Copert 4 replaces older versions of Copert. The most recent update of Copert occurred in December 2008 (version 6.0). For a full description of Copert 4, see http://lat.eng.auth.gr/copert/ .

The Copert methodology provides a database of emission factors for large classes of vehicles including:

- Personal cars (PC)
- Light duty vehicles (LDV)
- Heavy duty vehicles (HDV)
- Buses and coaches (PT)
- Two-wheelers (2W).

Emission factors are given up to technological standards. In Copert 4, the emission factors of about 220 different types of vehicles are completed.

Classically, emissions are calculated for each type of vehicle in multiplying an "activity" (related to road transport) with an emission factor:

Emission_i = Activity_i * EF_i

Index i is related to a specific type and standard of vehicle (e.g. Gasoline personal car, EURO III standard).

In the case of road transport, the approach for calculating emissions for a given area / period of time is “bottom up”. This is because the emission factors depend on “environmental” factors:

- Vehicle speed
- Ambient temperature (for over emissions and evaporations).\

The activity indicator is the mileage travelled. At Airparif, it comes out of a traffic model (AEL Davis) that was set up in the context of the HEAVEN project. This traffic model works in near real time and provides for each hour of the day an estimate of traffic fluxes for a 40,000 road network in Ile-de-France (about 10000km). For each segment of the network, three parameters are provided:

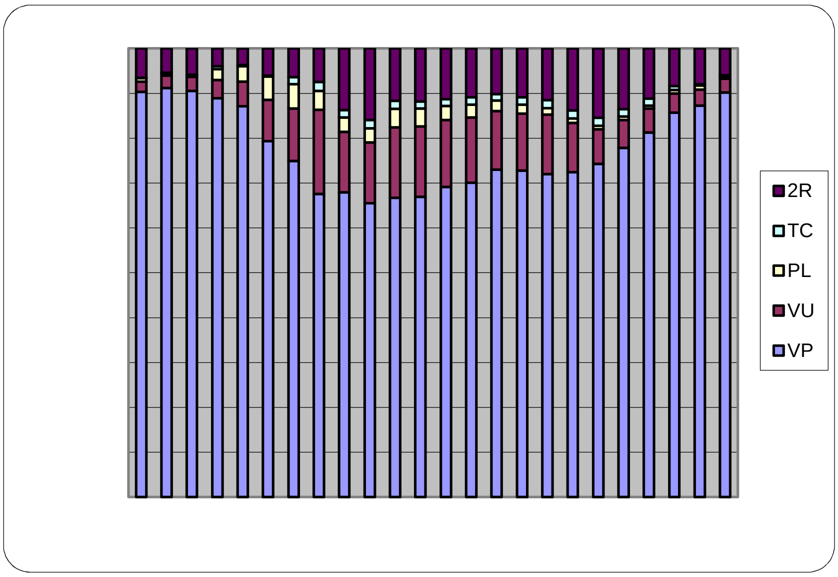
- The vehicle flow
- The average speed
- The share of vehicles operating in cold.

For a comprehensive description of the HEAVEN system, cf. the data sheet given in reference literature.

The relationship between traffic model outputs - traffic data for an average vehicle - and the Copert emission factors - given for each class of vehicles (PC, LDV, HDV, PT, 2W) at the level of technology standards - is done thanks to the knowledge of the fleet and fleet technology:

- The fleet characterizes the splitting of the total vehicle flux in large classes; it varies depending on time of day, type of day and route (urban, road or highway).
- The fleet technology characterizes the splitting of a large class in technology standards.

The figure below shows as an example the evolution of the fleet on urban roads for a week day (hours listed on the abscissa). (2R = 2W; TC = PT; PL = HDV; VU = LDV; VP = PC).



Data bases used

Type of data	Source	Cost	Remarks
Emission factors	Copert	-	Version 4
Trafic	AEL Davis		
Road network	DREIF	-	HEAVEN convention
Counting loops	City of Paris	-	HEAVEN convention
	National network, DRE / DIRIF data	-	HEAVEN convention
Fleet data	City of Paris	-	HEAVEN convention
Fleet technology data	CITEPA	-	Data updated annually based on national registration data
Meteorology	Météo-France		Temperature AR-PEGE data

Organization chart

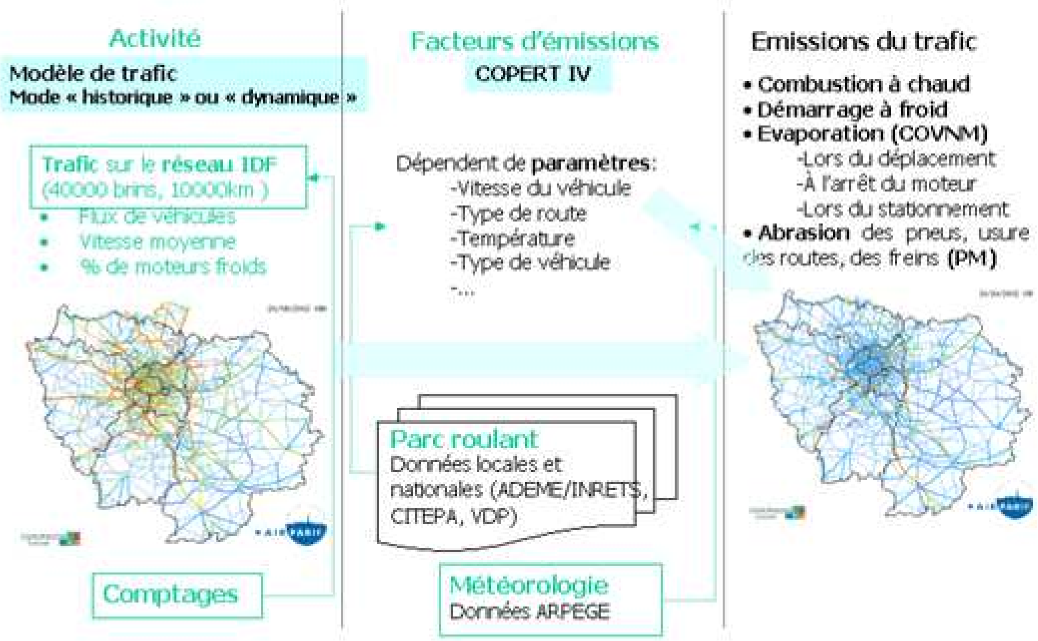


Figure 1 Organigram describing the methodology for calculating emissions from road transport.

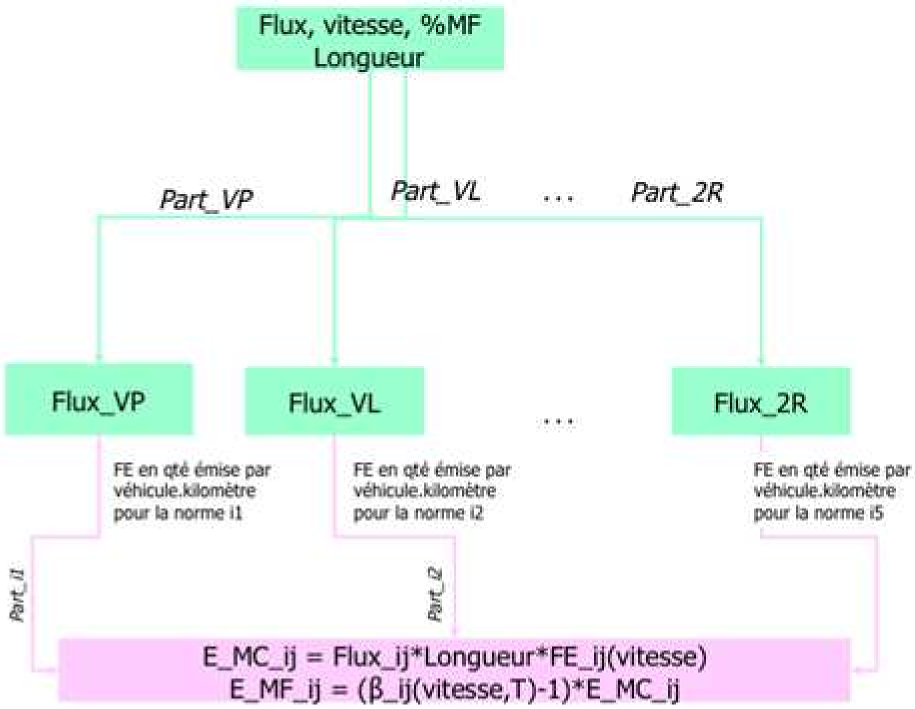


Figure 2 Organigram describing the methodology for calculating road transport emissions from combustion of fuel.

8.3 Seville (Andalusia) EI management

8.3.1 Introduction

The Emission Inventory aim is getting an exhaustive knowledge about origin, amount and temporal evolution of pollutant emission to air in Andalusia. It provides essential information to know the state of the environment, to design environmental policies and programs and to evaluate progress achieved through them or to develop environmental social and economic studies and research, among other purposes.

Since the basic air pollution source in Andalusia is constituted, in addition to certain industrial activities, the ever more congested urban concentrations and metropolitan areas (despite in Andalusia they have a medium sized under the European cities), this inventory covers releases of pollutant from vehicle traffic, industries and residential uses. Therefore, in order to releases, that this is a very complete inventory can be guaranteed, seeing that it includes all those activities whose emissions have some relevance, and not only the industrial ones.

The Emission Inventory's studied area is the Autonomous Community of Andalusia as a whole, and the temporal scope considered is annual.

The methodology used for preparing the inventory is characterized for a high degree of consensus achieved with other work groups, such as PRTR (Pollutant Release and Transfer Registers) in Andalusia, which replaced EPER (European Pollutant Emission Register) since 2007, the Spanish

Ministry of the Environment (MARM) for preparing The National Emission Inventories and Climate Change working group for monitoring greenhouse gas emissions and for implementing the Kyoto Protocol in Andalusia.

8.3.2 Pollutants

The Air Emission Inventory in Andalusia estimates emission for all major air pollutants produced by different source categories, as well as greenhouse gas emissions. This list includes moreover the pollutants The Spanish Ministry of Environment (MARM) considered for preparing The National Emission

Inventories, the pollutants selected in PRTR activities sublists, specified in Annex II of Regulation (EC) Nº 166/2006. In that list, the pollutants are grouped in following four blocks:

Acidifying pollutants, greenhouse gases and ozone precursors:

Methane (CH_4), Carbon monoxide (CO), Carbon dioxide (CO_2), Non-methane volatile organic compounds (COVNM), Hydro-fluorocarbons (HFCs), Hydrochlorofluorocarbons (HCFCs), Nitrous oxide (N_2O), Ammonia (NH_3), Nitrogen oxides (NOx) ($NO+NO_2$, expressed as total mass of NO_2), Perfluorocarbons (PFCs), Sulphur hexafluoride (SF_6) and Sulphur oxides (SOx) (SO_2 +SO_3, expressed as total mass of SO_2).

Heavy metals and particulate matter:

Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Mercury (Hg), Nickel (Ni), Lead (Pb), Selenium (Se), Zinc (Zn), Tallium (Tl), Antimony (Sb), Cobalt (Co), Manganese (Mn), Vanadium (V), Total particulate matter (PM), particulate matter < 10 µm (PM_{10}) and particulate matter < 2,5 µm ($PM_{2,5}$).

Organics pollutants:

Benzene, Polycyclic aromatic hydrocarbons[6] (PAH), Hexachlorobenzene (HCB), Hexachlorocyclohexane (HCH), 1,2-Dichloroethane (DCE), Dichloromethane (DCM), Dioxins and furans[7] (PCDD/F), Pentachlorophenol (PCP), Tetrachloroethylene (PER), Trichlorobenzene (TCB), 1,1,1-Trichloroethane (TCE), Tetrachloromethane (TCM), Trichloroethylene (TRI), Trichloromethane, Xylenes[8], Di-(2-ethylhexyl)phthalate (DEHP), Polychlorinated biphenyls (PCB), Ethyl benzene, Phenol and Toluene.

<u>Other pollutants of chemical nature:</u>

Hydrogen cyanide (HCN), Chlorine and inorganic compounds (Cl) y Fluorine and inorganic compounds (F).

8.3.3 Emission sources

In The Air Emission Inventory in Andalusia, the classification of emission sources takes place attending to the activity sector and the treatment they receive to estimate their emissions. This treatment is a function of activity (source) nature, its significance and availability of dates to estimate its emissions. So, the emission sources can be considered like punctual or area sources. The most outstanding activity sectors in Andalusia, attending to socioeconomics criterions, receive a punctual treatment. Because of their significance for the inventory they should be treated on an individualistic way. So the necessary information is received directly from the plants or facilities (either by reporting to PRTR or by questionnaires that the inventory sends plants every four years). On the contrary, the area sources, because of their reduced individual significance or the way to present their base information, needs to be treated in aggregated form. The pollutant sources specified in Air Emission Inventory in Andalusia fit the following classification:

- Point sources
    a. Industrial plants
        i. Generation of electrical energy
        ii. Petrochemical industry
        iii. Chemical industry
        iv. Paper industry
        v. Cement, lime and gypsum
        vi. Non-metal industry
        vii. Oil industry
        viii. Food industry, except oil
        ix. Metal industry
        x. Other industrial activities
    b. Non-industrial plants
        i. Solid waste treatment
        ii. Liquid waste treatment
- Area sources
    c. Mobile area sources
        i. Road traffic
        ii. Agricultural and forest machinery
        iii. Rail traffic

---

[6] Polycyclic aromatic hydrocarbons, total groups and substances:

- <u>PAH (borneff)</u>; Indeno(1,2,3-cd)pyrene, Fluoranthene, Benzo(g,h,i)perileno, Benzo(b)fluoranthene, Benzo(a)pyrene and Benzo(k)fluoranthene.
- <u>PAH (protocolo)</u>; Indeno(1,2,3-cd)pyrene, Benzo(b)fluoranthene, Benzo(a)pyrene y Benzo(k)fluoranthene.
- <u>PAH (total)</u>; Naphthalene, Benzo(g,h,i)perylene, Acenaphthene, Benzo(a)anthracene, Acenaphthylene, Chrysene, Fluorene, Benzopyrene, Fluoranthene, Benzo(b)fluoranthene, Phenanthrene, Benzo(k)fluoranthene, Anthracene, Dibenzo(a,h)anthracene, Indeno(1,2,3-cd)pyrene y Pyrene.

[7] Dioxins and furans, total group and substances: TCDD, PeCDD, HxCDD, HpCDD, OCDD, PCDD, TCDF, PeCDF, HxCDF, HpCDF, OCDF y PCDF.

[8] Ortho-xylene, meta-xylene and para-xylene

   iv. Air traffic
   v. Maritime traffic
   vi. Other mobile sources and machinery
d. Stationary area sources
   i. Residential sector
   ii. Commercial and institutional sector
   iii. Extraction and treatment of minerals
   iv. Road paving with asphalt
   v. Asphalt roofing materials
   vi. Fuel distribution
   vii. Petrol distribution.
   viii. Dry cleaning
   ix. Solvent use, except dry cleaning
   x. Use of refrigerants and propellants
   xi. Chemical products manufacturing or processing
   xii. Agriculture
   xiii. Livestock farming
   xiv. Biogenic emissions
   xv. Forest fires
   xvi. Waste incineration
   xvii. Cremation

8.3.4 Inventory phases

Development of Inventory consists of following phases:

- Information collection and methodology review.
- Calculation/estimation of emissions.

8.3.5 Preparation of database.

- Dissemination and exploitation of the results of inventory.

8.3.5.1 Information collection

For estimating emissions of area sources, the preliminary data derive from the Spanish Ministry of Environment (MARM) (total regional emissions) and statistical data or publications from official bodies or certain consulted entities such us Andulusian Statistical Institute (IEA) from Economy and Finance Department of Andalusian regional government (Junta de Andalucía), Spanish Airports and Air Navigation (AENA) and Port Authorities attached to the Spanish Ministry of Public Works, Andalusian Energy Agency (AAE) from Innovation, Science and Enterprise Department of Andalusian regional government, Institute for Diversification and Energy Savings (IDAE) attached to the Spanish Ministry of Industry, Tourism and Trade (MITYC), etc. In the information gathering process to estimate point sources emissions, one or more following ways can be used:

- Emission Inventory questionnaires. They are sent to companies every 4 years.
- PRTR Reporting. The industrial facilities quantify and report their annual emissions besides their fuel and raw materials consumptions or production among other information.
- Monitoring data. Data provided by network for the monitoring and control of air pollution (Red de Vigilancia y Control de Emisiones de la Contaminación Atmosférica) from environment department (Consejería de Medio Ambiente, CMA) of Andalusian regional government.
- Inspection reports of mobile emission measure unit (Unidad Móvil de medida de Emisiones, UME) from environment department of Andalusian regional government.

- Measures reports of co-worker entities of Environment Department of Andalusian Regional Government (Entidades Colaboradoras de la CMA, ECCMAs). Reports provided by provincial delegations of that Department.

8.3.5.2 Methodology review

Annually, the Inventory studies all air emission processes of each activity sector and, in individual way, several pollutants emitted by every one.

The emission quantification of certain activities is carried out applying emission factors recommended by several information sources, attending to:

- Raw materials consumed
- Fuels used
- Production

In each new inventory edition, an exhaustive bibliographic research to selection the most appropriate emission factors or to update those selected in previous edition takes place. The main sources consulted are:

- Guidance supporting for reporting of relates, developed by EPER-Andalusia group.
- National Emission Inventory, prepared by the Spanish Ministry of Environment (MARM).
- Methodological Guidance for Emission Inventory Development.
- Atmospheric Emission Inventory Guidebook (EMEP/CORINAIR).
- Compilation of Air Pollutant Emission Factors (AP 42-EPA).
- Factor Information Retrieval (FIRE) version 6.25 (EPA). This data system is a database management system containing EPA's recommended emission factors for criteria and hazardous air pollutants.
- Greenhouse Gas Inventory Guidebook (IPCC Guidelines for National Greenhouse Gas Inventories).

8.3.5.3 Estimation of emissions

The emission calculation methods depend on the considered activity nature and the available base information, and they are driven to obtain the most complete and precise emission result for every activity.

To calculate pollutant emissions produced by industrial and non-industrial (waste treatment plants) point sources, named microscale or bottom-up methodologies are used, which estimate emissions produced by each source using individual data. These methods can be classified such as:

- Emission measure-based methods:
  - Measures in continuous; Monitoring.
  - Periodic measures; Self-monitoring, UME and ECCMA.
- Balance of matter-based methods; SO_2 and CO_2, for combustion processes without contact.
- Emission factors-based methods: the main guidebooks used are Atmospheric Emission Inventory Guidebook (EMEP/CORINAIR) and Compilation of Air Pollutant Emission Factors (AP 42-EPA).
- Computer models-based methods:
  - TANKS: to calculate volatile compounds emissions from storage tanks.
  - COPERT III: to calculate emissions from road traffic.

On the other hand, for area sources, generally macroscale or top-down methodologies are used, which estimate emissions produced on de basis of statistic data by area or per capita.

8.3.5.4 Database management

The inventory information management is made through a database designed to allow its annual update in every new edition of the inventory and to include therein all data estimated for both study year and previous years, in several previous editions.

Basically, the inventory database contains the following information:

<u>For industrial and non-industrial plants:</u>

- Administrative data of the company and the installation.
- Activity variables: fuel and raw materials consumptions and production.
- Physical characteristics of the stacks.
- Emissions by stack, estimated for every edition of the inventory (since Inventory 2003) and the ones recalculated for Air Quality Improvement Plans affected areas, using updated methodology.

<u>For area sources:</u>

- Emissions at municipality level, estimated for every edition of the inventory (since Inventory 2003) and the ones recalculated f using updated methodology.

To import the estimated emissions into the Inventory database, we have two own programs; one for point sources and the other one for area sources. The load of information concerning activity variables is carried out making use of an Excel macro created to import such data into the Inventory database. These software and computer application imply an important advance on data migration process into the database, now that the typical mistakes relating to manual data entry have been eliminated and at the same time they imply an important time saving.

The inventory database allows to present the data in aggregated and non-aggregated forms, so that releases can be searched for and identified by:

- Installation, both to stack level and to plant level.
- Activity sector, main or secondary.
- Type of source, point sources (industrial plants or non-industrial plants) and area sources (mobile and stationary).
- SNAP activity.
- Municipality, province or the whole of Autonomous Community of Andalusia.
- Inventory year.
- Pollutant.

Also it's possible to cross several criteria previously listed.

8.3.6 Quality control and assurance

In accordance with Methodological Guidance for Emission Inventory Development, it is essential to implement procedures that ensure and control the final result's quality. The criteria specified in Guidebook have been adapted to the Andalusian Emission Inventory methodology.

It's important to point out that a good procedure of quality control and assurance will cause only results as good as the estimation methodology lets it.

Certain methodologies are inherently more precise than other ones, because they are based on well-defined and well-known procedures and/or en specific data of the source at issue.

As previously specified, the Inventory uses the calculation methods driven to obtain the most complete and precise emission result for every activity, being the priority order as follow:

- Emission measures in continuous (monitoring).
- Emission measures from self-monitoring.
- Periodic emission measures from UME.
- Periodic emission measures from ECCMAs.
- Emission factors.

In general, the methods used for the attainment of quality aims of data used for preparing the inventory are:

- Checking data of most outstanding sources attending to magnitude of air emissions, in accordance with the results of the previous edition inventory.
- Veracity checks. To detect significant mistakes made in calculation of emission phase, both if data comes from installation and from calculation procedure.

- Parity checks. Made by technical experts, in random way and for several sources when data can seem mistaken.
- Repetition of particular calculations. To detect computing mistakes, specific calculations are repeated in random way.
- Computerized checks. We use a set of spreadsheets to do the necessary calculations to apply emission factors, avoiding typical mistakes of calculation procedure.

8.3.7 Inventory applications

The main applications of Air Emission Inventory in Andalusia are the followings.

The AEI in Andalusia provides essential emission data and information of use for air quality dispersion modelling. One hand, it has geo-referenced plants and their stacks, and the other hand, for area sources, the air pollution emissions are allotted in the middle of towns.

Essential to evaluate progress achieved through projects both global level and related to phenomena such as climate change response, or through local environmental programs, in Andalusia emerged as various Air Quality Improvement Plans promoted by environment department of Andalusian regional government.

The Inventory data also can be used in thematic maps through the new SIG tools, giving a spatial view of emissions from both industrial plants and other emission sources such as traffic, agricultural and livestock activities, etc.

8.4 Case study Rome

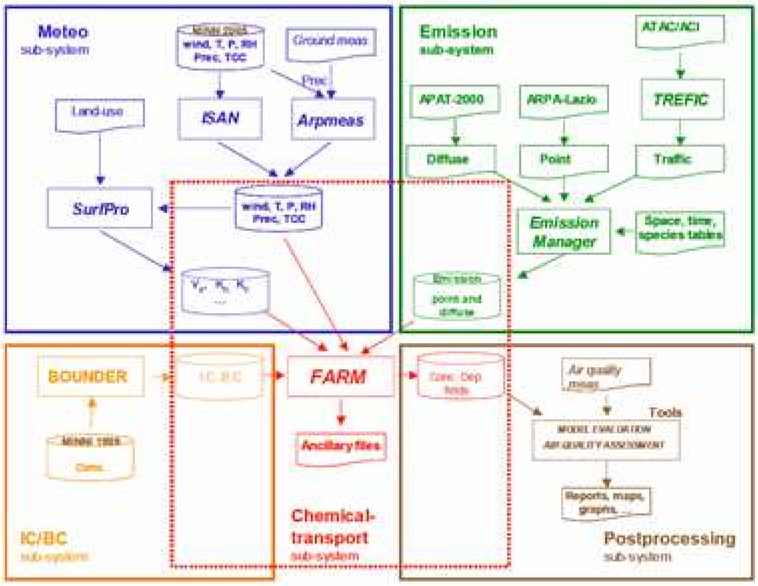
Air quality management and Emission Inventories – The Case of Rome

The current norm in Italy assigns the Regions the task to evaluate air quality through a classification of the territory in zones with a various criticality level.

The evaluation is carried out through an **integrated system** in which the emission inventories is a fundamental part.

In order to comply with these requirements, Arpa Lazio has a model system supporting the so called **air quality integrated evaluation on the regional territory**, to be more precise: to verify respect of the legal limits of the whole regional territory through the definition of concentration maps of various pollutants. Such a system allows to analyze severe pollutant episodes, to assess pollution levels and to estimate different emission scenarios associated with air quality improvement actions.

This model (see Picture 1) has been used to carry out simulations on the regional territory, to support the annual air quality evaluation as well as to study different emission scenarios.



Picture 1 – air quality evaluation model system

The model system needs the definition of an **emission input** as well as a **meteorological** one (useful to calculate air pollutant dispersion).

The set up of the emission database has entailed the definition of emission inventories, (built on the national inventory, Apat 2000), where all emission sources are split in:

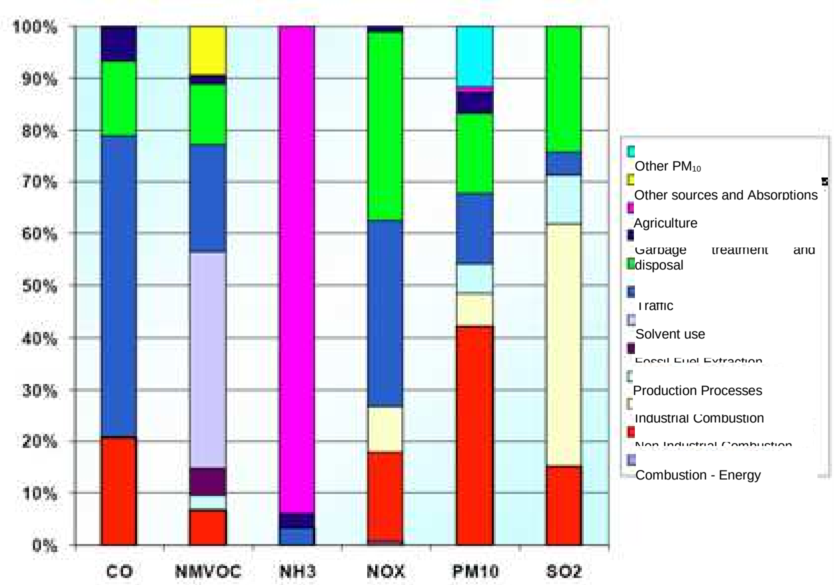
1. localized
2. diffuse.

The first (**localized**) include all those sources useful and possible to consider individually, localizable through geographical coordinates and chimneystack emission parameters, and defined by total emissions higher than 90/100 t/per year (or powers higher than 40/50 thermic MW for combustion process – on smaller areas limits decrease).

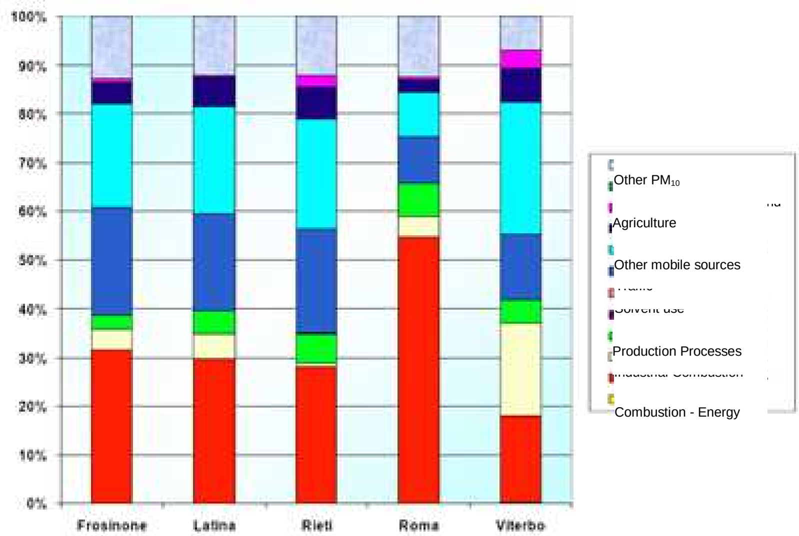
The **diffuse** sources are all those not included in the category just defined which calculus needs the use of statistic parameters. Included in these categories are: point sources emissions, which don't exceed the emission threshold above defined, natural emissions (for example resulting from forests), or those linked to diffuse traffic flows.

	CO	NMVOC	NH3	NOX	PM10	SO2
1) Combustion - Energy¶	24	1	-	232	2	-
2)Non Industrial Combustion¶	33.757	5.345	0	7.385	4.709	1.163
3)Industrial Combustion¶	439	119	2	3.757	695	3.552
4)Production Processes¶	6	2.235	-	-	636	734
5) Extraction and Distribution of Fossil Fuel, Geothermal science¶	-	4.095	-	-	5	-
6) Solvent use¶	-	33.290	-	-	1	-
7) Traffic¶	94.842	16.504	544	15.123	1.505	325
8) Other mobile sources¶	22.333	9.130	2	13.959	1.669	1.740
9) Garbage treatment and disposal¶	10.734	1.075	434	458	447	-
10)Agriculture¶	343	131	15.225	12	113	-
11)Other sources and Absorptions¶	-	7.596	-	-	-	-
Other PM10¶	-	-	-	-	1.305	-
TOTAL¶	162.478	79.521	16.207	40.926	11.087	7.514

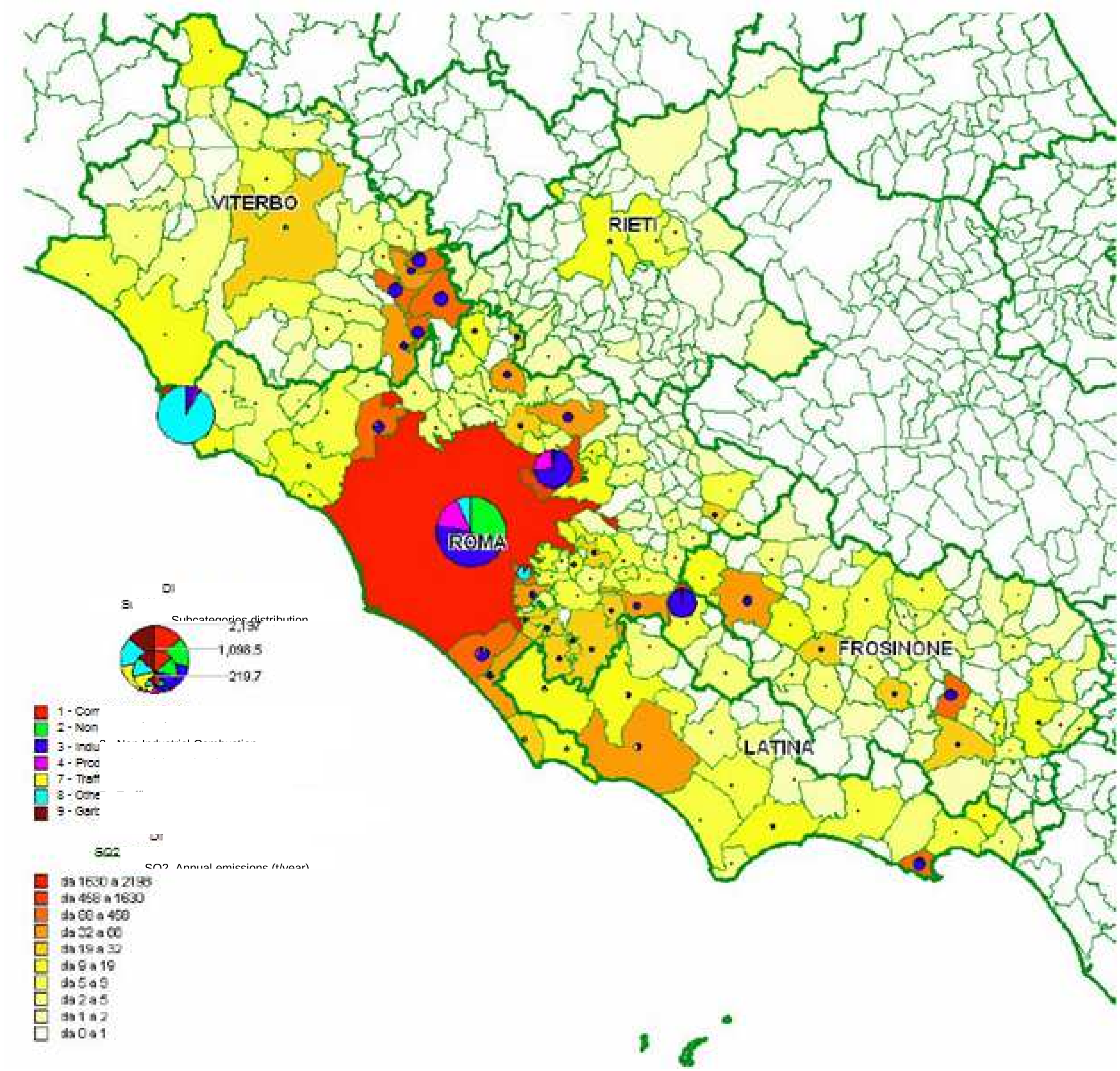
Picture 2 – Diffuse Emission inside the Lazio Region (t/year).



Picture 3 – Macrosectors' Contribution to total Emissions inside the Lazio Region.



Picture 4 – Macrosectors' Contribution to total Emissions inside the Lazio Region. Province aggregation.



Picture 5 - SO2 Diffuse Emissions of the Lazio Region. (without considering Rome municipality traffic flows contribution).

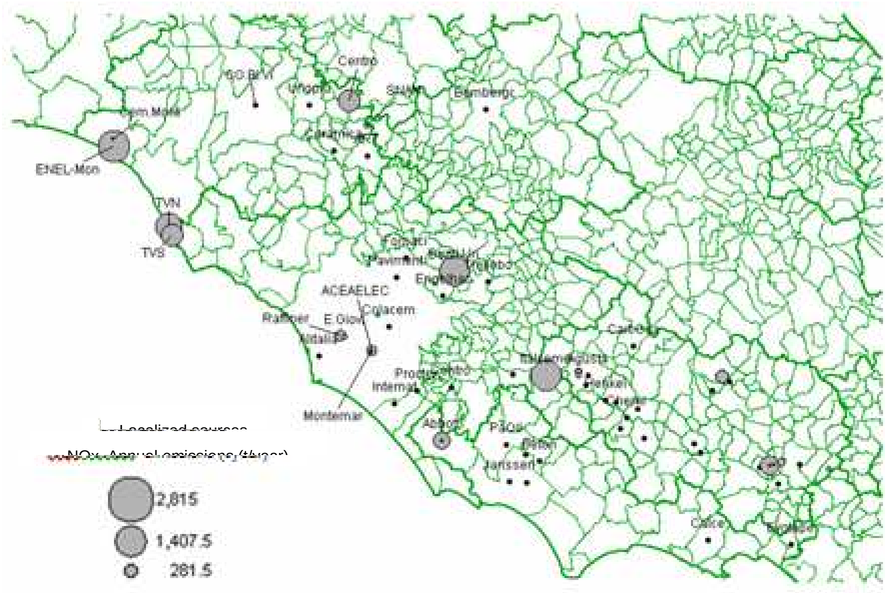
Emission arisen from localized sources have been obtained in the census carried out by Arpa Lazio.

The majority of the information on localized sources have been gathered from the annual data sheets of the industrial plants chemical analysis, which usually contain, for each chimneystack, some of the following aspects:

– height of the emission point (m)
– emission point's diameter (m)
– chimneystack fume's velocity (m/s)
– chimneystack fume's temperature (°C)
– total number of emission hrs/year
– chimneystack capacity (Nm3/h)
– pollutant concentration for each polluting agent (mg/Nm3)
– pollutant mass flow emitted (g/h)
– Chimneystack activity.

In total 75 localized sources have been branched, on the provincial level, according to the following scheme:

- Frosinone, 26 plants
- Latina, 9 plants
- Rieti, 1 plant
- Rome, 19 plants
- Viterbo, 20 plants.



The set up of the emission input, finally, also needs the evaluation of the traffic component. Traffic, especially in the Rome metropolitan area, is the biggest emission source, it therefore needs a proper treatment.

The detailed traffic data at our disposal concerning the city of Rome allows the adoption of the following methodology for the treatment of different traffic components (urban, suburban) during the time period under consideration:

- highway traffic emission calculation has been carried out using the Trefic code, based on the average traffic flows reported by AISCAT
- suburban traffic emissions have been obtained from the national inventory and updated from 2005 and 2010, as done for the other emissions
- urban traffic emissions have been treated using two different data sources:
  - for the city of Rome the road graph given by ATAC has been used, for the geographical part, and for the traffic flows database reconstructed with modelling assignment, as input for a detailed calculation of associated emissions, through the use of the Trefic Code
  - For the other towns (within the Lazio Region) national inventory values were used, (after subtraction of the contribution of the Municipality of Rome).

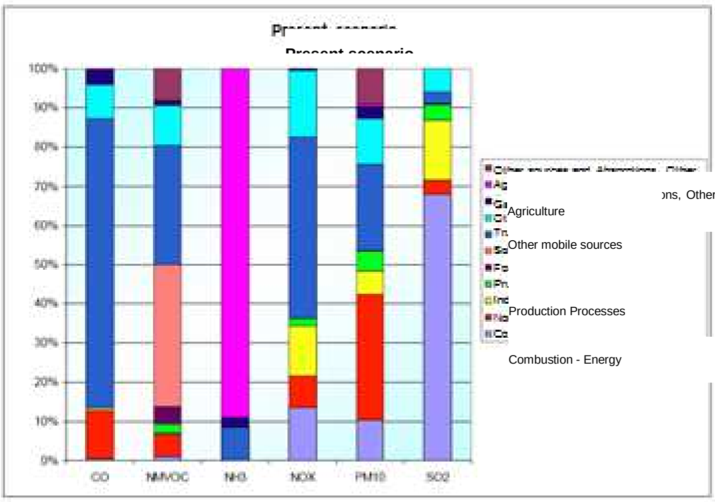
The traffic emission calculation, for what concerns highways and urban roads of Rome, has been carried out using Trefic code, implementing the European methodology Copert III for the estimation of emission factors of vehicles (Ntziachristos e Samaras, 2000).

For the pollutant PM10 TREFIC adopts more updated emission factors, including combustion terms (both gasoline and diesel engines), tyre, brakes and road surface abrasion formulated in the project RAINS-Europe (IIASA, 2004)

The following is the emission distribution, on the regional level, of each pollutant for every macro sector (2005) both in terms of absolute value (see table below) and percentage terms (in the figure below).

MACROSETTORI	CO	NMVOC	NH_3	NO_X	PM_{10}	SO_2
Combustion - Energy	996	1000	0	12423	1542	21166
Non Industrial Combustion	33757	5345	0	7385	4709	1163
Industrial Combustion	1684	120	2	11582	894	4727
Production Processes	57	2283	0	1714	729	1286
Extraction and Distribution of Fossil Fuel	0	4095	0	0	5	0
Solvent use	7	34167	1	19	28	48
Traffic	203821	28607	1448	42627	3273	897
Other mobile sources	23609	9460	2	15361	1727	1853
Garbage treatment and disposal	10739	1075	434	469	448	9
Agriculture	343	131	15225	12	113	0
Other sources and Absorptions, other PM	0	7596	0	0	1305	0
TOTAL	275013	93879	17112	91592	14773	31149

Picture 6 – Total Emission (Absolute value), regional scale.



Picture 7 - Total Emission (Percentage value), regional scale.

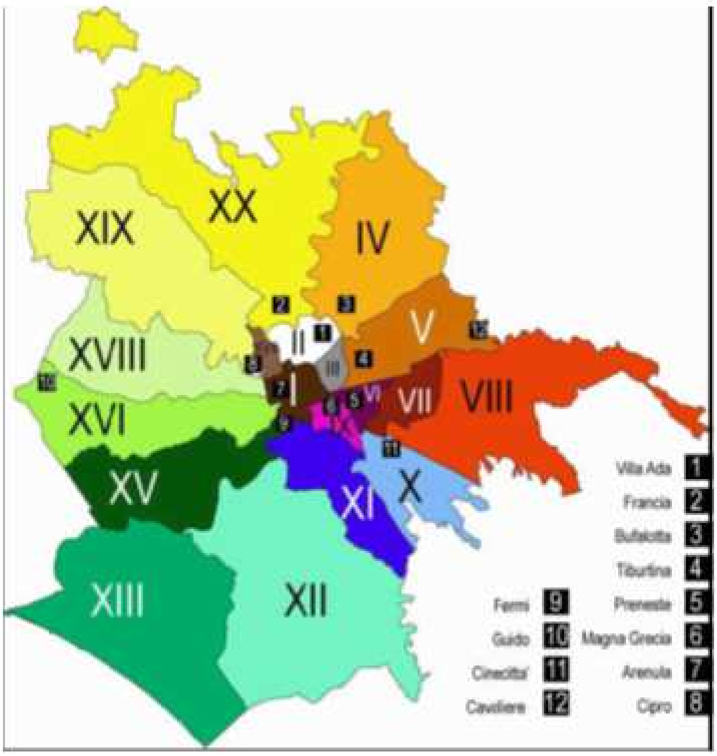
Air quality evaluation

Air quality in the Lazio region is continuously checked by an observatory network covering the whole regional territory and consists of 5 provincial sub networks plus the observatory sub network of Rome. These monitoring networks are currently owned and managed (using their own provincial technical structures) by Arpa Lazio. Below its current structure is presented.

Monitoring network structure

In the following figures is shown the current dislocation of monitoring stations on the whole regional territory and on the Rome municipality.

Picture 8 – Dislocation of the air quality monitoring stations outside the Rome municipality



Picture 9 – Dislocation of the air quality monitoring stations inside the Rome municipality

8.5 Case study Prague

Prague's emission inventories

The City of Prague compiles an emission inventory for air quality pollutants and an inventory for GHGs. The major sources of data for these inventories is the Czech Republic's national emission inventory system which provides AQ emission information and data about fuel use in Prague.

Air quality emissions

Prague's inventory for air quality emissions is based on the national air quality emission inventory for the Czech Republic referred to as the Air Pollution and Sources Register (the corresponding Czech acronym is REZZO). It is administered by the CHMI. The major difference between the national inventory and Prague's inventory is that Prague's is used for city-wide air quality modelling and therefore has temporal and spatial characteristics suitable for such an application. This means that emissions from mobile sources can be calculated in more detail for Prague's inventory.

Calculation of emissions for the national inventory generally follows the methodology for emissions calculation that is set out in the EMP/EEA (formerly CORINAIR) air pollutant emission inventory guidebook.

When modelling air quality in Prague more detailed emissions that those in the national inventory are required. The current MEFA (06) emission estimation methodology developed by Vysoka Skola Chemicko-Technologicka in Prague is used in such circumstances to calculate emissions from transport (mobile sources). This is done as part of the ATEM project every 2 years to enable air quality dispersion studies to be conducted.

GHG emissions

The Czech Republic is a signatory to the Kyoto Protocol and therefore manages a national inventory system in accordance with the Protocol. Under direction of the Ministry of the Environment the CHMI is authorised to coordinate the system so that all inventory collection, calculation and reporting requirements of the Protocol are met. The national GHG inventory includes emissions of CO_2, CH_4, N_2O, hydroflourocarbons (HFCs), perflourocarbons (PFCs) and sulfur hexaflouride (SF_6).

GHG emissions for Prague are calculated separately from traditional air quality pollutants. Calculations for GHG emissions are performed yearly for the Czech Republic and are maintained in the National inventory System of greenhouse gas emissions, administered by the CHMI. The City of Prague publishes, in its environmental yearbook, a summary of its GHG emissions which are calculated from data about fuel use reported and summarized for the whole City of Prague under the AQ inventory in the REZZO system. The City of Prague's GHG emission inventory is discussed in this case study. Prague's inventory holds emissions in tonnes of CO_2-equivalent and they are published in Prague's Environment Yearbook and primarily used for year-to-year comparison.

Emission sources

Air Quality

Point sources in the emission inventory of the Czech Republic (and therefore Prague) are represented by measured emissions (where possible) for large sources (corresponding to the Czech classification REZZO 1) and calculated emissions for smaller sources (REZZO 2 classification). The calculations for REZZO 2 sources are based on fuel consumption and EMP/EEA (formerly CORINAIR) emission factors. Combustion source characteristics are described by stack height and diameter, flue gas temperature, flow rate and velocity. Source specific information on these sources is provided by plant operators and validated by the Czech National Environmental Inspectorate. Temporal variation of emissions from large combustion sources is accounted for by annual profiles. Sources which have weekly, daily, or irregular shifts in emission profiles are described with a higher temporal resolution and the highest temporal resolution is daily.

Emissions from small sources such as home heating systems (REZZO 3 sources) are not calculated individually. For the inventory they are calculated over an area using land use and population data and ambient temperature and season.

Mobile sources (traffic) are classified as REZZO 4 sources however these sources have their emissions calculated within the ATEM project rather than being extracted from the REZZO system. This is largely due to the requirement that the inventory can be used for air quality modelling. Mobile source emissions are modelled using line sources for major roads and area sources for minor roads. At this point it should be noted that inventories that are used for modelling can vary substantially with regard to source type and description as the type of model often dictates how sources are described. The ATEM model (a steady-state Gaussian dispersion model) is used for AQ studies in Prague and therefore the inventory suits the model's input data requirements.

Facilities relating to the REZZO 1 classification generally release their emissions from point sources. They include:

- Large power plants (fuel combustion);
- Large heating plants (fuel combustion);
- Waste incineration facilities;
- Cement production facilities;
- Bitumen production facilities; and
- Other large industrial facilities.

REZZO 2 sources typically include:

- Sources similar to REZZO 1, but smaller. For example mid-sized electricity and heat generation plants and industrial facilities.

REZZO 3 sources typically include:

- Combustion of coal, gas or wood for domestic heating;
- Rural emission locations (for example ammonia);
- Solvent or VOC emission locations.

REZZO 4 sources relate to:

- Fuel combustion from mobile (or related) sources. This typically means vehicles.

Greenhouse gases

Sources of GHGs for Prague's inventory relate to fuel combustion and are therefore not individually identified for the inventory. Total natural gas and solid and liquid fuel combustion is used for emission calculation rather than a source by source calculation approach. In addition, external emission sources are partly included in Prague's inventory and reported under separate category. A source by source approach is possible, but is much more time consuming. Mobile source emissions are considered in the inventory due to fuel combustion and are also not specifically identified individually or spatially.

Data collection

The emission inventory is updated annually. Emissions from REZZO 1 and 2 sources are provided by plant operators.

REZZO 3 emissions are calculated by the CHMI using census data in addition to fuel usage statistics updated in cooperation with regional fuel and energy suppliers.

Prague's emissions from REZZO 4 sources are calculated as part of a contract with Transport Research Centre. Sufficient information on transport in Prague is collected to enable calculation of PM_{10}, SO_2, NO_X, CO, total hydrocarbons, VOC and benzene emissions.

A number of institutes, organisations and offices work together to provide the data for GHG emission calculations used for the national GHG inventory and therefore also for Prague's inventory. Once the National Inventory System is populated with GHG emission information, Prague's inventory is compiled by the CHMI.

Emission estimation methods

The AQ emission estimation methods for Prague's inventory are summarised by source type (REZZO classification) as follows:

REZZO 1 Large sources – Measurements and/or the EMEP/EEA air pollutant emission inventory guidebook's methods are used. These sources are typically point sources.

REZZO 2 Medium sources – – Measurements and/or the EMEP/EEA air pollutant emission inventory guidebook's methods are used. These sources are typically point sources.

REZZO 3 Small sources – The EMEP/EEA air pollutant emission inventory guidebook's methods are used. Emissions are calculated over an area using land use and population data and ambient temperature and season. These emissions are spatially averaged.

REZZO 4 Mobile sources – The MEFA methodology is used. Emission factors for traffic are taken from the Czech data-base MEFA. Only combustion-based emissions are calculated, Non-exhaust particulate matter emissions from re-suspension are not included in the emission inventory. The MEFA method considers:

- Vehicle type (car, bus, LDV, HDV), fleet composition information;
- Engine type (EURO rating);
- Fuel;
- Roadway inclination;
- Speed;
- Catalytic conversion;
- Year.

At the most detailed level REZZO 4 emissions are calculated for road lengths and at intersections, tunnels and stationary source areas (e.g. bus stations, car parks pump and refuelling stations).

GHG emission calculation

Fuel combustion is the most significant source of GHG emissions for Prague and therefore it is reported in Prague's environmental yearbook. This generation area includes energy production, heat generation and transport sources. As such this section will focus on fuel combustion.

The GHG emission calculation methods for Prague are based on knowledge of the carbon content of fuels and, as such, are in general agreement with internationally recommended methods. Sources of fuel combustion within Prague's geographical boundary are included in the inventory. Energy production is cross-checked against energy consumption statistics to verify whether all of Prague's energy is generated within its boundary. Typically, emissions related to energy produced outside Prague, but consumed within Prague, are also included in the inventory and reported under specific category to account for the total amount of energy used by Prague. These emissions are calculated using energy production and usage statistics.

Transport GHG emissions are calculated by the Transport Research Centre and are based on vehicle usage statistics in addition to fuel usage statistics. Transport GHG emissions for the national inventory are calculated for each region in the republic. As Prague forms a region in itself, no further calculations or boundary adjustments are required.

Summary of Prague's Inventories

Prague's GHG emission inventory is partly different to its AQ inventory and this is largely due to the ways in which they are used. Both inventories are used to track annual changes in totals of key species (increases and decreases) yet the AQ inventory is also used for dispersion modelling. As such it has more spatial and temporal detail.

8.6 Emission inventory Gdansk

Emission inventory is dived into three main categories: point, area and line emission. Nowadays we have got available emission data for 2008 and 2009 in resolution 250X 250 m in the city and 1x1 km outside the city. Below are described three types of emission in detail.

- **Emission Point**

Emission point include technical parameters such as : the height and diameter of the emitter and the velocity and temperature of the exhaust outlet. The source of obtaining data for industrial emissions are the questionnaires, integrated permits, licenses and decisions on the release of gases and dust into the air but also the application of installation.

Pollutants available:

SO2, NO2, CO, PM10, PM2,5, benzene , volatile organic compounds, cadmium, nickel , benzo(a)pyrene, mercury, lead , benzene.

Below example of map point emission of PM10 in the Agglomeration of Gdańsk:

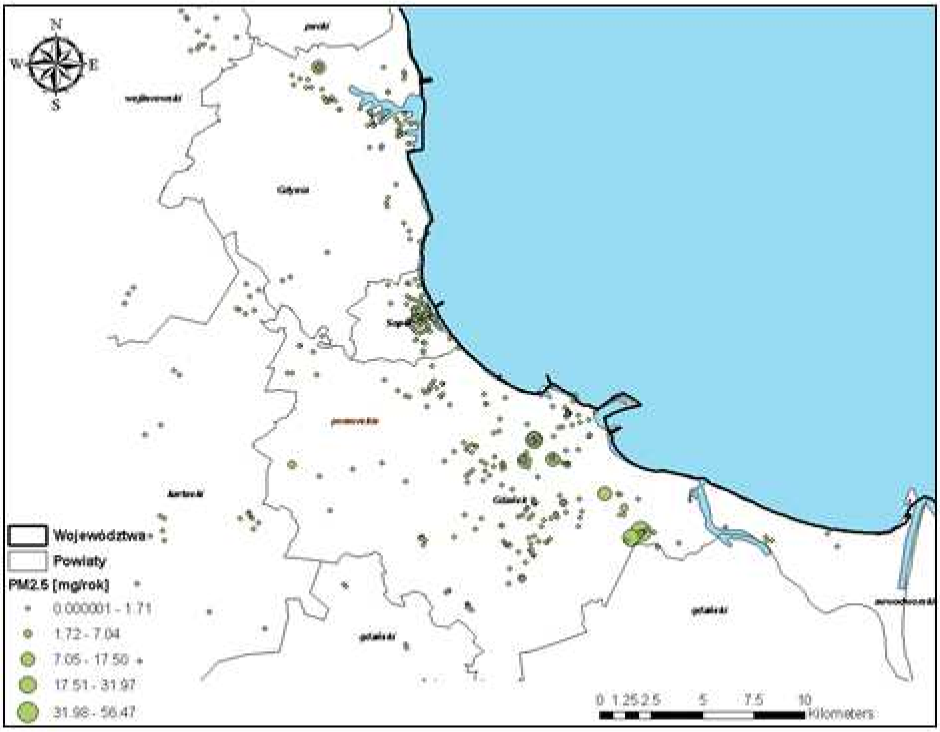


Fig. Point emission of PM10 in the Agglomeration of Gdańsk

- **Surface Emission**

a) Surface Emissions from industry

Emission inventory contains estimates of emissions from industry , mainly ports and shipyards in Gdansk and Gdynia. Distinguished the following types of industrial emissions:
- fugitive emissions from shipyards and heaps
- cargo handling in ports in the ports of Gdansk and Gdynia
- emissions from fuel combustion in ships

b) Surface Emissions from heating

Creating a database of surface emissions was dived into two stages. The first stage was associated with collecting the necessary information and fixing the base of activity in the form of various types of surface heating fuel is mainly based on layers of maps and statistical information. In larger towns to designate additional activities were used: local heat supply plans, study of spatial panning and / or the number of people registered in the streets.

Based on the heated surface of the medium and the emission factors provided by the National Emission Centre was possible to determine the emission of pollutants for each city/town.

The second stage was the designation of the cadastre of emissions and the total emission of the surface in the districts. Cadastral surface emissions for the years 2008 - 2009 were prepared for the two mesh sizes - for urban cadastre 250m mesh and out of cities 1km mesh.

Pollutants available:

SO2, NO2, CO, PM10, PM2,5, benzene , volatile organic compounds, cadmium, nickel , benzo(a)pyrene, mercury, lead , benzene.

Below example map of surface emission of PM10 in the Agglomeration of Gdańsk:

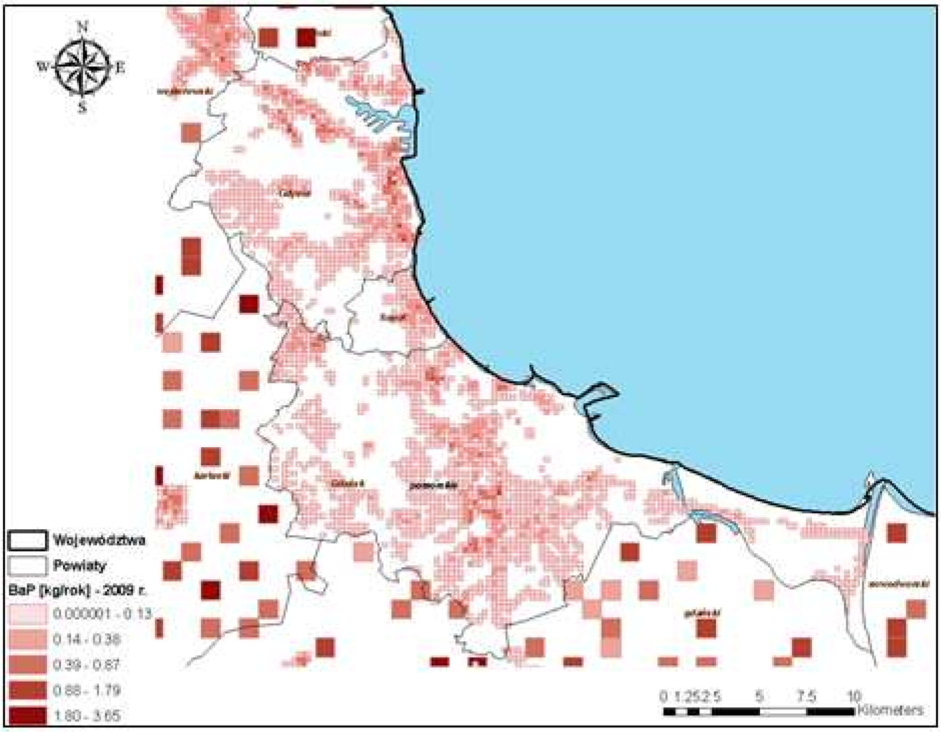


Fig. Surface emission of PM10 from heating in the Agglomeration of Gdańsk

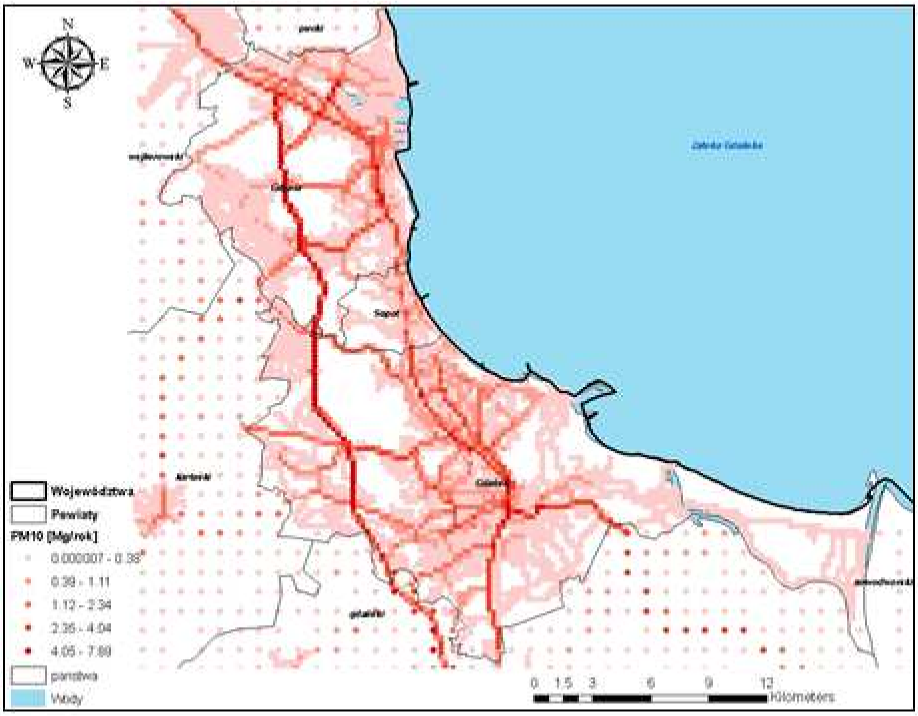
3) Line emission

To determine emission of road was used information about the intensity and structure of traffic. Source of data was: measurements and several sets of emission factors.The first set of emission factors was derived from fuel combustion in the engine developed by prof. Z. Chłopka. These indicators are approved by the National Emission Centre. After adding information about the speed of the various types of vehicles we receive emissions. Distinguished the following speeds:

Type of vehicle	Speed In the city [m/s]	Speerdoutsider the city [m/s]
Passengers cars	70	35
Vans	60	30
Lorry	45	30
Lorry with trailer	45	30
Buses	50	25
Motorcycles	70	50

The other set of factors are used for estimations of PM10. Methods for estimating dust was based on study: WRAP Fugitive Dust Handbook (EPA,2004).

Below example map of line emission of PM10 in the Agglomeration of Gdańsk:



8.7 Maribor EI management

Emission Inventories - Maribor

We did greenhouse gas emission inventory for Maribor for the sector Energy (CRF sector 1) using the IPPC methodology and the traffic emission inventory with COPERT methodology.

Example 1: GHG EI

Activities concerned:

- 1.A: Fuel Combustion
- 1.B: Fugitive Emissions

Activity
1.A.1 - Energy
1.A.2 - Manufacturing Industries and Construction
1.A.4 - Fuel combustion in public buildings (1.A.4.a) and residential buildings (1.A.4.b)

Pollutants

GHGs (CO2, CH4, N2O),

Methodology

4. The way to calculate the emissions is always the same, per activity:

   $$\boxed{\text{Emissions = Activity data * Emission factor}}$$

5. Emission factors for all the activities involved have to be found in a database IPCC or Slovenia's National Inventory Report.
6. For this study energy consumptions are provided at a regional and local scale. Data were provided for the period 1995 to 2006.

Data bases used

Energy emissions data:

Ministry of the Environment and Spatial Planning - In accordance with the law, we have a register of industrial plants, which are required to report to the country on air emissions.

http://www.arso.gov.si/zrak/emisije%20snovi%20v%20zrak/emisije%20iz%20naprav/

Statistical Office of the Republic of Slovenia - Data for calculating emissions from combustion of fuels by sector.

Municipality of Maribor - Data on energy products sold in Maribor.

Emission factors

Slovenia's National Inventory Report 2008

IPPC guidelines

Example 2: Traffic emissions

For the calculation of transport emissions we used the program COPERT IV. The year 2006 was the base year for EI preparation.

Activities concerned

N°SNAP	SNAP/CORINAIR Activity	Reporting Detail
07	Road transport	
0701	Passenger cars	Road Transportation, Passenger Cars
0702	Light-duty vehicles < 3.5 t	Road Transportation, Light duty vehicles
0703	Heavy-duty vehicles > 3.5 t	Road Transportation, Heavy duty vehicles
0704	Buses and coaches	
0705	Mopeds and Motorcycles < 50 cm3 Motorcycles > 50 cm3	Road Transportation, Mopeds and motorcycles
0706	Gasoline evaporation from vehicles	Gasoline Evaporation from vehicles

Pollutants

NOx, NMVOCs, PM10, PM2,5, CO, CO2, SO2, PAH, NH3, N2O, heavy metals, …

Methodology

The methodology used to calculate emissions is the COPERT IV methodology, which is part of the EMEP/CORINAIR methodology.

The COPERT methodology provides a database of emission factors for large classes of vehicles including:

- Personal cars (PC)
- Light duty vehicles (LDV)
- Heavy duty vehicles (HDV)
- Buses and coaches (PT)
- Two-wheelers (2W).

Emissions are calculated for each type of vehicle:

$$\boxed{\text{Emissions} = \text{Activity\_i} * \text{emission factor\_i}}$$

Where i is specific type and standard of vehicle.

Data about vehicle fleet were collected by the Ministry of the Interior. Data were divided to the vehicle classes as required by the methodology. Data on the mileage, mileage share, average speeds in specific driving modes, the average trip length (Ltrip) and PSF values were taken from the Slovenia's national inventory report. Fuel consumption was calculated from the reports drawn up by companies selling fuel in the area of MOM. Fuel characteristics were taken from Slovene national legislation relating quality of liquid fuels. Minimum and maximum monthly temperatures for Maribor were taken from Environmental Agency of the Republic of Slovenia. Beta values calculated according to the COPERT IV methodology were used. All other required input data were default COPERT IV data. Emission factors for calculating emissions were default emissions factors offered by COPERT IV.

Data bases used

Type of data	Source
Emission factors	COPERT IV
Road network	Municipality of Maribor
Fleet data	Ministry of the Interior
Mileage, mileage share, average speeds in specific driving modes, the average trip length (Ltrip) and PSF values	Slovenia's National Inventory Report
Fuel consumption	Municipality of Maribor
Fuel characteristics	Slovene national legislation relating quality of liquid fuels
Minimum and maximum monthly temperatures for Maribor	Environmental Agency of the Republic of Slovenia

8.8 EMIKAT ARC

Emission inventories require the management, documentation and interrelation of large amounts of heterogeneous data in a user-controlled logic. emikat.at is a system that supports those who compile emission inventories and use them. emikat.at consists of a data administration server and a user interface residing on the users' PC's (client). The server database administers all data specifically for different clients and different versions. Access is limited to authorized clients and their users. Through the user interface, users have the possibility to add, edit and delete data as wells as to define alternate scenarios and to calculate model results. emikat.at derives emissions for the smallest administrative units, the „census units". In each census unit, emissions are calculated according to the specific properties of emission sources, organized according to business sectors (NACE-system), emission source categories (SNAP-system), as well as input materials and fuel types, and transformation processes. Emissions from line sources (road traffic) are directly associated to the major roads of a census unit. Emissions can also be calculated on the basis of a 100x100 m raster grid; in that case, land use within a census unit is considered for the spatial allocation of emissions. Results that have a defined spatial reference (such as census units, communities, counties, raster cells) can also be visualized as maps.

Emission inventories are based on a survey of emission-generating activities and activity-relevant emission factors in a given spatial domain. The usual temporal domain is one reference year. Usually only few emission generating activities can be directly assessed: examples for that would be the fuel consumption of individually known large power stations and industrial plants. For most other air pollution sources (such as motor vehicles and residential heating) it is necessary to establish data models to calculate the contribution of the respective source groups by using surrogate data. For instance, emissions from motor vehicles may be estimated by using information about the overall number of vehicles in use and their fuel system (gasoline, diesel), their technical features and typical emission control systems, plus the driving characteristics (mileage, driving modes on different road types) etc.

Activity-specific emission factors (such as the amount of air pollutant released by a unit of activity, e.g. grams of CO per km driven) are combined with emission-generating activities to calculate the emission of pollutants. This sounds simple but is a complex process. Often it is necessary to use different calculation methods in order to get reliable results and to reduce uncertainties. Thus – while the results of emission inventories consist of relatively simple data tables – the production of emission inventories require complex data models. The complexity is even more pronounced when it comes to the establishment of emission scenarios. Scenarios reflect assumptions about „what if" certain emission-generating activities are being changed. Such scenarios are useful for the establishment of air pollution management plans. It is most important that all underlying assumptions of scenarios – emission generating activities, emission factors, or calculation models – are fully documented, otherwise it would not be possible to analyze resulting emission changes to the changes of input data.

emikat.at is a data system for managing emission-relevant data (i.e. emission-generating activities, emission factors, supporting information). All data and data changes are documented in the form of specific versions. Details of the system have been published recently [56]. emikat.at allows to

- import, store and document base emission-relevant data and data linkage models
- calculate emissions according to different models
- summarize results according to user-defined requirements
- visualize results as maps.

emikat.at was established in close cooperation with the City of Vienna Environmental Administration, which has defined the use cases and user requirements.

emikat.at consists of a central data server and an end-user application client. The data server is used for centralized data management and backup; it is based on Oracle 9i. The purpose of the client is to allow the users – depending on their access rights – to upload, download data, to change data sets, to establish or change calculation models, and to summarize and retrieve results. The client is a Java application. Whenever the client is started it that checks the user rights and privileges and provides access to the server. If an updated version of the client is available on the server, the client is updated automatically.

The emikat.at allows to organize, document and to logically interconnect large and heterogeneous data sets in a user-definable documented logic. All data changes and calculations are documented. Thus it is possible to relate all results to input data and calculation models.

High spatial resolution. The spatial resolution of the system depends on the requirements of the users. For the requirements of the City of Vienna, the spatial resolution refers to the census units of the Austrian Statistical Service which comprise units of about 1000 inhabitants. In Vienna with an overall area of about 41 500 ha, there are about 1 400 census units with a size between about 1 ha and 2 000 ha. To account for heterogeneous emission densities in the larger census districts in the outskirts of the city, the system includes an ex-post spatial disaggregation in a 100 x 100 m raster grid. This grid system allows to allocate „uniform emission sums“ within a census district into their emission-relevant raster cells based on the respective land use: e.g. emission from industry would be allocated only to raster cells that relate to industrial land-use, emissions from domestic sources only to those raster cells that relate to residential areas, etc. Different types of emissions The system handles three different types of emission sources: point sources, line sources, and area sources. Point sources relate to known locations. They are spatially defined through their respective long/lat coordinates that are automatically derived from their addresses. Emissions can be easily related to the relevant census district or to the relevant 100 m raster cell. Line sources relate to activities along roads. In Vienna, about 1 000 km of roads have been defined as lines. Line emissions are spatially allocated to the census districts in which they occur. Line emissions are important for emissions from motor vehicle exhaust and for particles emissions caused by motor vehicles movement. Emissions from line sources are allocated to the respective census districts according to the relative length of a line in a census district and to the respective 100 m raster cells. Area sources relate to sources whose locations are not specifically known. This comprises the majority of sources, including motor vehicle traffic on secondary roads, residential heating, and small industry. Area emissions are typically calculated using surrogate statistical information, either for each census district, or for the overall area. In the latter case emissions are spatially disaggregated to emission-relevant areas using land-use distribution function. For instance, emissions caused by utilizing nitrogen fertilizers in agriculture may be calculated from overall usage statistics for the total of Vienna, but the spatially disaggregated to relevant census districts using land use data. Within the census districts, emissions are allocated to the raster cells according to the respective land use (e.g. agricultural, residential, industrial, traffic, etc.). Variable temporal resolution as an international standard, temporal resolution of emission inventories is usually one year. The user can define a certain reference year and the system will look through the data base for all data that refers to this reference year or – in case such information is missing – for data in a year before. This is useful as in many cases data for emission-relevant activities are not available in all years, so that the emission calculation for a given year necessarily reflects an emission calculation that relates to “all information available until a reference year“. Within a base year, the emikat.at system can be used to estimate short-time temporal emissions intervals through applying temporal allocation models. Short-time emissions can be calculated for months, weeks, days, or even hours.

emikat.at is a tool that allows the management of data that is relevant to estimate air pollutant emissions. Of particular usefulness is the option that all data are stored in different versions and all changes to the data sets are documented. This feature allows to establish emission scenarios, which could relate to different reference years, or different „what if“ assumptions. The possibility of displaying results as maps is a powerful tool to visualize results and to identify spatial hot sports of emissions. Introduction The Emission Inventory aim is getting an exhaustive knowledge about origin, amount and temporal evolution of pollutant emission to air in Andalusia. It provides essential information to know the state of the environment, to design environmental policies and programs and to evaluate progress achieved through them or to develop environmental social and economic studies and research, among other purposes. Since the basic air pollution source in Andalusia is constituted, in addition to certain industrial activities, the ever more congested urban concentrations and metropolitan areas (despite in Andalusia they have a medium sized under the European cities), this inventory covers releases of pollutant from vehicle traffic, industries and residential uses. Therefore, in order to releases, that this is a very complete inventory can be guaranteed, seeing that it includes all those activities whose emissions have some relevance, and not only the industrial ones. The Emission Inventory’s studied area is the Autonomous Community of Andalusia as a whole, and the temporal scope considered is annual. The methodology used for preparing the inventory is characterized for a high degree of consensus achieved with other work groups, such as PRTR (Pollutant Release and Transfer Registers) in Andalusia, which replaced EPER (European Pollutant Emission Register) since 2007, the Spanish Ministry of the Environment (MARM) for preparing The National Emission Inventories and Climate Change working group for monitoring greenhouse gas emissions and for implementing the Kyoto Protocol in Andalusia.

8.9 Emission inventories in the Lombardia region

Probably the most intensely investigated area in terms of emissions is the Milan province, Italy.

The Lombardia Region is located in northern Italy and includes several cities (examples: Milano, Bergamo, Brescia, Varese, Como) as well as rural areas in the Po Valley. The domain is densely inhabited and includes highly industrialised and intensive agricultural areas. This area is regularly affected by high ozone levels, due also to frequent air stagnation conditions, especially during summer months.

PM10 and PM 2.5 levels are very high. Air quality standards are frequently exceeded with more tthan 70 days (daily concentrations higher than 50 µg/m³) These facts require a careful design of emission abatement strategies, taking into account photochemical regimes, emissions and meteorological conditions. Therefore, a reliable Lombardia area emission inventory is a must. A number of inventories are available for the area, which are derived from different institutions. Winiwarter [15] already made a case study of comparing the different emission inventories. He compares the more top-down inventories with the more bottom-up inventories. Some of the Milan province inventories are shown in table 1.

Table 1: Some emission inventories available for the province of Milan, Italy

Institution	Project	Extension and spatial resolution	Spatial resolution
JRC	Auto-Oil	Lombardy region	unknown
University Brescia	SATURN	100X100 km^2	2km
Regione Lombardia	LOOP	141 X 162 km^2	3 km
ENEL_CRAM Milano	GENEMIS	Lombardy region	4km
University Stuttgart		141 X 162 km^2	3km
ARC Seibersdorf	IMPRESAREO	Milano Province	1km
INEMAR	Regional Air Quality Plan (PRQA) of the Lombardy Region	Lombardy region	

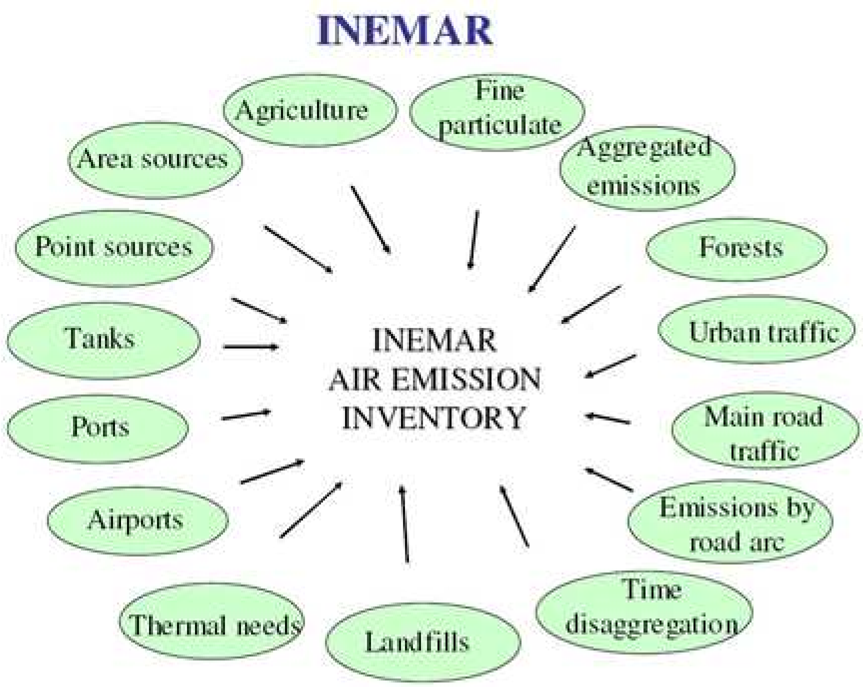
Loop basically compiled the inventory from individual data to a total (bottom-up inventory), GENEMIS applied national and provincial data and redistributed it according to surrogate statistics such as population data (top-down) A more detailed description of the inventories has been given by Winiwarter er al (1999)[X] and by Maffeis er al. (1999) [X] or Schwartz er al (1999) respectively.

Within the framework of the Regional Air Quality Plan (PRQA) of the Lombardy Region (Italy) a database named INEMAR (AiR EMission INventory) was developed for the estimation and management of the atmospheric emissions. The INEMAR system considers emissions of about 250 sources (point, area, biogenic, road transport) about 249 SNAP activities are described, the database contain information on 11 different pollutants (SO_2, NO_x.COV,CH_4, CO, CO_2, N_2O, NH_3, PM $_{2.5}$, PM_{10} and PTS), about 33 fuel types are incorporated and the database covers 1546 municipalities. INEMAR organizes all information needed for their estimation: activity indicators, emission factors, other statistical data necessary on spatial and temporal distribution of emissions. As the first Italian experience of an emission inventory source code made by a regional authority, INEMAR is a multi-user database that contains all the data for the emission estimates, the procedures that carry out the algorithms utilized for these estimates and the values of calculated emissions.

INEMAR's strength is the high resolution (municipality level) of all the emission results, great flexibility (database in 3rd normal form), and the client-server framework suitable for provincial inventories. The database is accessible by any PC user connected by the regional ISDN network or by Internet, in order to visualize or modify the data in the archive, or for local processing of the data. Output can be also visualized, in client-server mode, with maps, graphs and tables by means of a specific module of Nebula LTK, a GISoriented package previously developed by the Lombardy Region. The use of INEMAR by other Italian Region (i.e. Piedmont Region) and by the provincial offices of ARPA is ongoing.

Figure 1

Note:
Data is available on the INEMAR web page: http://www.ambiente.regione.lombardia.it Detailed information can be requested for pollutants, a municipality, an activity and fuel type.



The inventory is compiled mainly via a bottom-up approach. A detailed road network , local data on fuel use and local data on industrial activities is used. Activity data are inserted at a provincial level (11 in Lombardy) and then disaggregated to the municipal level through proxy data. For some activities (solvent used in some sectors) only regional or national data are available.

INEMAR is now uses in 8 Italien regions (Lambardia, Piedmonte, Emilia Romagna, Friuli Venezi Giulia, Veneto, Trentino-Alto Adige, Marche and Puglia).

The classification used for the inventory of Lombardy Region 2003 is the one defined within the framework of CORINAIR project in its last version named SNAP 97 (Selected Nomenclature for sources of Air Pollution - year 1997). The code that identifies each activity consists in two numbers, representing respectively the group, the sub-group and the activity to which emission estimates is referred.

Characterized groups are the following 11: Combustion in energy and transformation industry; Non-industrial combustion plants; Combustion in manufacturing industry; Production processes; Extraction and distribution of fossil fuels; Solvent and other product use; Road Transport; Other mobile sources and machinery; Waste treatment and disposal; Agriculture; Other sources and sinks.

The proposed classification, created in order to carry out inventories at national, regional and county level, includes all activities which are considered relevant for atmospheric emissions. This is in any way an updateable nomenclature, as it is always possible to insert new items that take into account significant emissions for activities which are specific for some areas. SNAP 97 nomenclature was used in the carried out emission inventory. The new added activities, considered significant for this inventory, are written in italic. In fact it was necessary to add new activities to the basic nomenclature in order to make the best of the huge bulk of data available by means of the census, and to avoid the aggregation of information that is more useful in a disaggregated form for the Regional Plan of Air Quality. Among these new activities there are coffee toasting, fodder production, inactive waste landfills and motors used in waste landfills. A very common problem is the apportionment of an emission datum evaluated at an aggregated territorial level, such as a region or a nation, to a portion of territory contained in it, e.g. a county or a municipality. This operation of disaggregation is carried out basing on some indicators, also called "surrogated variables " or "proxy variables", considered able to represent the weigh distribution of the different emission on the territory. In order to go from a "total" value of a given emission to a "local" one, is then possible to use this formula:

$\mathbf{E_l = E_t * V_l / V_t}$ (2)

where:
$\mathbf{E_l}$ = local emission;
$\mathbf{E_t}$ = total emission;
$\mathbf{V_l}$ = local value of the surrogated variable;
$\mathbf{V_t}$ = total value of the surrogated variable.

Examples of surrogated variables are number of inhabitants, fuel consumption, industrial production, or the employees in a given sector whose emission is to be evaluated. The choice of the surrogated variable is a very sensitive element, and must also take into account the available information about emission factors. This approach was used also in the inventory and in the INEMAR database: the disaggregation of county emissions at municipal for each activity was carried out using some proxy variables. Example In order to explain the application of this methodology si riporta come esempio the calculation of N_2O emission from the use of fertilizers on ploughed lands (activity SNAP 10.1.2) in the municipality of Dovera (CR):

A_{CR} = indicator = use of fertilizers in the Province of Cremona = 13,183 t/year; FE_{N2O} = N_20 emission factor = 20 g/kg of fertilizer. N_20 emission from the use of fertilizer in the Province of Cremona is then:

$E_{CR,N2O} = A_{CR} * FE_{N2O}$ = 13,183 * 20 = 263,660 g/y = 263 kg/y

The surrogated variable used per la disaggregation is the area of ploughed land (hectares): Total area of ploughed land in the Province of Cremona = 162,896.68 ha Area of ploughed land in the municipality of Dovera = 1,059.02 ha Using (2) N_2O emission in the municipality of Dovera is:

$E_{Dovera,N2O} = E_{CR,N2O} * Sup_{Dovera} / Sup_{CR}$ = 263 * 1,059 / 162,897 = 1.71 kg/y

In order to consider temporal variation of emissions, the simpler approach uses temporal emission profiles that consist in a series of coefficients (24 for hourly emission, 7 for daily variation in a week, 12 for monthly modulation) which, properly multiplied for the total annual emission, allow to achieve the hourly, daily or monthly one. A substantially analogous approach is used for the detailed description of the temporal activity of a source, of yearly duration factors (d/y) or daily working factors (h/d). Coefficients that constitute the temporal profile are often presented as normalized, on the medium value or on the emission maximum value. If temporal modulation coefficients are normalized on the medium value, the relative emission at a given hour "h", day "d" and month "m" can be obtained from annual emission basing on the following formula:

$\mathbf{Emission_t = Q / (24 * 7 * 12) * p_h * p_d * p_m}$ (3)

where:
$\mathbf{Emission_t}$= emission at the time t (hour: o; day: g; month: m);
$\mathbf{Q}$= annual emission;
$\mathbf{p_h}$= hourly coefficient at the time t;
$\mathbf{p_d}$= daily coefficient at the time t;
$\mathbf{p_m}$= monthly coefficient at the time t.

Temporal modulation coefficients seldom derive from statistical elaborations carried out using experimental data; monitoring systems for the main pollutants are installed only for a very limited number of major plants such as waste incinerators or power plants, allowing to define an experimental trend of the emissions. For all other not controlled sources, a statistical simulation approach is needed, and requires the use of weight variables, also named indicators, basing on which it is possible define coefficients used for the disaggregation. Examples of indicators are working hours or traffic flows, and they are specific indicators of the source class (civil, industry, traffic). Example An example in order to clarify the application of this methodology is the calculation of nitrogen oxides hourly emission from the public power plant of Ostiglia (MN), SNAP activity 1.1.1 Combustion plants > 300 MW (boilers), annual emission and temporal profile being known:

NO_x annual emission = 10,130 t/y;
p_h = hourly coefficient (13-14) = 1.1 (4.7 %) ;
p_d = daily coefficient (Wednesday) = 1.12 (16 %);
p_m = monthly coefficient (January) = 0.85 (7.1 %).
NO_x emissions from 13 to 14 of a Wednesday of January are achieved applying the formula (3):
Ejan,wed,13-14 = 10130 / (24*7*12)*1.1*1.12*0.85 = 5.3 t/hour
while emissions from 3 to 4 of a Sunday of July (ph = 0.8, pd = 0.62, pm = 0.92) is equal to:
Ejul,sun,3-4 = 10131/(24*7*12)*0.8*0.62*0.92 = 2.2 t/hour

An emission inventory is characterized by three different typologies of emissions: area, point and linear sources. Emissions from sources distributed on the territory are considered area emissions. For this typology of emissions a direct measurement is not feasible, it is therefore necessary to estimate them from statistical data and specific emission factors. To achieve this activity national and international experiences have been analyzed, by means of a search for literature information and involvement in expert panels in emission inventory groups. The work has been realized following methodologies adopted in both national (ENEA-ANPA) and international framework (Corinair). For instance, the Corinair - SNAP 97 classification has been adopted for activities, as described in methodology.

Definition, data collection and processing

Several contacts have been set up for data collection regarding quantities produced, energy consumed, number of employees in every type of manufacturing industry existing on the Lombard territory. In the beginning this work required a survey for information existing in Regione Lombardia, mainly held by the Statistical Office and Data Base. For other data (quarries, agriculture, waste) research has been made both in ARPA Lombardia sectors and with a partnership with Punti Energia for a common definition of fuel consumptions. ISTAT web site furnished other data, in particular the number of employees per ISTAT category from its ASIA archive and national productions of some industrial sectors for the year 2003. Finally several trade associations have been contacted to obtain data needed for the inventory both in terms of productions and consumptions. As regards data acquired, with the exception of the Regional Statistical Office whose data are available at a municipality level, in some events data have been furnished at a county level, in other at regional or national level. Only for some big industrial sources (i.e. refineries) point data have been instead acquired. Institutions and associations contacted have been more than 60: the municipality level has been obtained only from institutions whereas trade associations has often provided national data. An emission factor represents an emission referred to a unit of activity of the source, expressed for instance as a quantity of pollutant emitted per product unit, or as a quantity of pollutant emitted per fuel unit consumed, etc. The choice of the emission factors signifies a particularly critical aspect and it presents troubles of reliability. Emission factors has to be chosen following the characteristics of the plant, obtaining data from literature and adapting them to the particular actual situation. Data are generally available by type of process, combustion and abatement techniques; it derive from measurement campaigns on representative sources: if not expressed data are intended to be prior to the abatement system. If specified, emission factors could be referred to emissions at the stack, that is already inclusive of the effects of the abatement systems. For some combustions (i.e. fuel oil, coal, etc.) it is possible to obtain the emission factors of some pollutants (SO_2, heavy metals) from the chemical composition of the fuel. In the evaluation of emission from a category of sources (for instance a complete industrial sector) the emission factor can be derived as a geometric mean of factors related to different types of technology, giving weigh to the technologies through coefficients which represent the "penetration" of that technology in the sector. In other words the emission can be estimated by a formula as the following:

$$\mathbf{Q = A * \Sigma_i(FE_i * P_i)}$$

where:
Q = emission flow of the pollutant (i.e. g/hour);
A = activity indicator (i.e. kg of product/hour);
$\mathbf{FE_i}$ = emission factor for technology i (i.e. g/kg of product);
$\mathbf{P_i}$ = penetration of technology i in the sector (-).

In this manner it is possible to distinguish the economic component (A) that derives from the general development of the sector, from the technical term (FE) and from the "compartmental" term (P), that derives from the plant typology of the sector. This formula can be utilized also to project emissions trends in a sector owing to the adoption of different technologies. Among the most complete references for emission factors are the Environmental Protection Agency reports, and in Europe the emission factors collected and proposed by the Corinair project, illustrated in three successive versions of its Guidebook, which present the best characteristics of completeness and reliability. These reports are more and more available as databases, freely available on CD-ROM or from the Internet sites of EPA or European Environmental Agency. Different uncertainties are connected with the use of emission factors. Besides what explained above, the causes could be the following ones: factors processing tests referred to a little period of time and thus not representative of long term emissions, for the entire life of the plant; emission data obtained from a few number of plants, statistically not representative; the definition of a "medium" emission factor for a certain category of sources does not take into account of the actual penetration of the different technologies inside the sector; the actual efficiency of the measurement systems is minor of that foreseen, declared by the builder in "ideal" conditions; non consideration of the control efficiency, quality of maintenance, characteristics and age of plants; possibilities of accidental emissions not comprised in emission factors. At last, even though it seems necessary to stress that these are estimates, which could be more or less precise but not equivalent to measured data, on the other hand it should be taken into account that the acceptability of the simplification adopted depends on the use of the results. In the framework of this emission inventory, being necessary to arrange reliable emission factors, data from the sources described above have been collected and compared, besides the emission factors supplied by APAT Atmospheric emission estimates are typically subject to uncertainties, due to several causes distributed all along the data processing. The term "uncertainty" refers to a lack of knowledge in statistics, or else to the not accuracy or imprecision in estimates. The uncertainty connected to an emission data varies considerably as the type of pollutant, the activity and the level of spatial disaggregation. For instance emission data of an energy power unit, obtained from the point sources survey, are surely more reliable than those estimated for a plant through medium emission factors. In the same way the municipality data of an area source has a bigger uncertainty than the county level data from whom it derives. Emission estimates from industrial sources and, in most cases, from non-combustion sources are often less reliable than emission estimates from combustion; both the choice and quantification of indicators used for evaluation and its emission factors are affected by a great range of uncertainty due to the heterogeneity of processes existing in the industrial sector. As other example, the estimation of volatile organic compounds emissions (VOC), that it is always critical, becomes problematic for evaporative losses (solvent evaporation, vehicles losses, tank losses, even during refueling or loading); more uncertainties are also in the estimation of emission produced by agricultural activities and from biological activity of natural cycle of plants. The possibility of "accidental" emissions (known also "off-normal" emissions) due to probabilistic events as mistakes, transitory, process overloads, it is usually not taken into account in estimations done for emission inventories, that in general refer to annual average emissions related to normal working conditions, and not to accidental situations. After all these considerations, it is therefore important in an emission inventory to manage a summarizing picture of all emissions. The methodology usually employed for evaluation of emission data is for "successive approximations": collection criteria of databases (indicators, emission factors) of emission inventory are revised and improved, on the basis of available resources and results obtained in the first steps. It cannot be missed that precision required to an emission inventory depends on the uses its data are expected to. Surely local inventories, specific for a limited territory (for instance a municipality) can be more reliable than the estimate from the regional inventory, that for its nature can not consider all local specificities. Also for local inventories, the regional inventory is however a useful basis, to provide a first estimate that can address efforts to further studies.

8.10 Development of the Merseyside Atmospheric Emission Inventory

In 1997 the former London Research Centre (LRC) prepared a series of atmospheric emissions inventories for the Department of the Environment, Transport and the Regions (now DEFRA). An inventory report for the Merseyside region included the local authorities of Liverpool, Wirral, Sefton, St Helens, and Knowsley, together with the Cheshire districts of Halton and Ellesmere Port and Neston. The purpose of these inventories was to identify and quantify significant sources of emissions to the atmosphere across the respective study areas (Buckingham et al., 1997). During 1999 the Merseyside emissions inventory database was maintained, improved and updated by ARIC for a base year of 1998 covering Merseyside and Halton only (ARIC, 1999).

In July 2000 the Merseyside Air Quality Management Group (MAQMG) commissioned Cambridge Environmental Research Consultants Limited (CERC) to construct an atmospheric emissions inventory utilising the CERC Emissions Inventory Toolkit (EMIT).

An updated emissions inventory was compiled in 2006 for a base year of 2004. The Merseyside A mospheric Emissions Inventory (MAEI) 2004 involved revision, assessment, improvement and expansion of the previous emissions inventory. The work was carried out by an appointed officer who reported into the MAQMG throughout the update process. This inventory has now been updated to a base year of 2006 as described in the following sections. The MAEI work and associated air quality projects are currently funded by the Merseyside Local Transport Plan Partnership.

Pollutants estimated in the MAEI 2006

Emission estimates are contained in the MAEI 2006 for all pollutants of concern for Local Air Quality Management**1**, and for all pollutants considered in the UK National Air Quality Strategy (NAQS) with the exception of ozone (DETR, 2000a): Benzene, 1,3-butadiene, Carbon monoxide (CO), Lead, Mercury, Non-methane volatile organic compounds (VOC), Oxides of nitrogen (NOX), i.e., NO and NO2, Particulate matter less than 10 micrometers aerodynamic diameter (PM10), Sulphur dioxide (SO2) (assuming all emissions reported as sulphur oxides

(SOX) are emitted as SO2).

Greenhouse gas pollutants are also contained in the MAEI 2006:Carbon dioxide (CO2), Hydro-fluoro carbons (HFC), Methane (CH4), Nitrous oxide (N2O), Per-fluoro carbons (PFC), Sulphur hexafluoride (SF6).

Spatial scope of the MAEI 2006

The geographical area covered by the MAEI 2006 includes the five Merseyside local authorities; Liverpool City Council, Knowsley Metropolitan Borough Council (MBC), Sefton MBC, St Helens Council and Wirral MBC (see Figure 1). The total area of the Merseyside districts is 643 km2 however the coverage of the MAEI 2006 as defined by 1 km2 grids results in a slightly larger study area. Surrounding emission sources also have the potential to affect Merseyside and therefore neighbouring local authorities have been included in the inventory coverage area for consideration of some sources. This total covers a rectangular area of 4,221 km2 grids which corresponds to the farthest outlying sources in the north, south, east and west.

Total emissions of each pollutant on a 1 km by 1 km grid cell basis across the study area were calculated. This enables the spatial distribution of pollutants to be shown and potential pollution hotspots identified. While details about emission variation within each 1 km2 grid cell are lost in calculating total emissions, the data within each 1 km2 grid cell are available in Airviro for detailed localised studies when required.

Point emission source category - This includes stationary emission sources identified individually due to the quantity or nature of their atmospheric emissions. The point emission source category is divided into three sub-categories:

Part A Processes: Large industrial processes regulated by the Environment Agency

Part B Processes: Smaller industrial processes regulated by the local authorities

Boilers: Large boiler plants greater than 2MW

Line emission source category - This includes emission sources along a defined line. It includes mobile emission sources in the following sub-categories:

Road transport: Road vehicles operated on all major roads (and some minor roads where traffic data are available) in the Merseyside region Rail transport: Passenger and freight diesel trains operated on the Merseyside rail network.

Area emission source category - This includes emission sources that may be treated in an aggregated fashion, since it is not necessary or may not be feasible to locate the emissions any more specifically. This category also includes sources that emit pollutants directly to the atmosphere and not through a well-defined stack or vent, in the form of fugitive emissions. The area emission source category is divided into the following sub-categories:

- Bus stations: Large bus stations with significant through flow of buses per day Tunnel vents: - Ventilation shafts for the road tunnels passing under the River Mersey
- Petrol stations: Petrol stations releasing fugitive emissions from their forecourt
- Airport: Aircraft and airport activities with significant ground level impact at Liverpool John Lennon Airport. Note: Aircraft emissions input as a series of points across the relevant area with varying heights to represent the landing take-off cycle.
- Rail stations: Large rail stations with significant through flow of diesel trains per day, namely Liverpool Lime Street and Southport Stations.

Grid emission source category - This includes emission sources whose individual emissions do not qualify them as point or line sources (individually they emit smaller quantities of pollutants), however; significant emissions can arise from a cumulative impact. It also includes emission sources for which detailed source data are not yet available for more accurate spatial allocation of emissions, namely shipping. The grid emission source category is divided into six sub-categories:

- Minor roads: Emissions from roads for which no detailed traffic flow data are available

  Cold starts, hot soaks and diurnal evaporation: Road vehicle emissions at journey start and journey end, plus further evaporative emissions.

- Domestic heating: Domestic emissions arising from gas use and solid fuel heating
- Industrial and commercial heating: Industrial and commercial emissions arising from gas use (solid fuel burning emissions assumed to be encompassed within Pollution Inventory report ing)
- Domestic electricity use: Point-of-use CO2 emissions for domestic electricity consumption - Industrial and commercial electricity use Point-of-use CO2 emissions for industrial & comer cial electricity consumption
- House and garden machinery: Emissions from use of domestic house and garden machinery - Agriculture Agricultural machinery and solid fuel use emissions
- Shipping port: Emissions from shipping movements and activity in the Liverpool port area.

Detailed emission estimation methodologies

The emissions estimation methodologies employed in the MAEI 2006 are based principally on emission factors and activity data estimated or measured in the base year. Emission factors are applied to activity data relating to a source in order to estimate emissions as follows:

Activity rate x Emission factor = Emission rate

Emission factors used in preparing the MAEI 2006 were predominantly derived from the National Atmospheric Emissions Inventory online data warehouse and from the Design Manual for Roads & Bridges.

Major road traffic emissions for each of the Merseyside local authorities were derived using annual average daily traffic flow (AADTF) data for 2006 in conjunction with vehicle related emission factors. Flow data were taken from the following sources in order of priority i.e. uplifted flow data were only used if there were no data available from the other sources: Department for Transport (DfT) count point data for 2006 Mott MacDonald MIS sourced data for districts' automatic traffic count site network for 2006 MAEI 2004 or Mott MacDonald MIS sourced data uplifted to 2006 using the central NRTF (DETR, 1997) annual growth rate of 1.69 % for total traffic between 2001 and 2006.

Minor roads traffic: With no detailed traffic flow data available for minor roads, emissions from this source were estimated using DfT Regional Transport Statistics (DfT, 2007a) figures indicating the total distance travelled on the whole road network for each local authority in 2006, and assuming that 44.44 % of vehicle kilometres travelled were on minor roads. This percentage was based on the minor road proportion of total distance travelled on Merseyside roads in 2006 (DfT, 2007a). This information was used to calculate estimated minor road vehicle kilometres travelled per 1km2 in each local authority.

Industrial processes: Emissions data for prescribed pollutants from Part A registered industrial processes in Merseyside in 2006 were obtained from the Environment Agency's Pollution Inventory database. The Pollution Inventory collects information on releases of pollutants and transfers of waste off-site from businesses regulated by the Environment Agency in England and Wales.

For more information on the methods used for the emissions mentioned above and for emissions on Cold starts, hot soaks & diurnal evaporation, Mersey tunnel vents, Bus stations, Rail stations, Rail traffic, Ships - Liverpool port activity and the data sources see: **Merseyside Atmospheric Emissions Inventory 2006**

8.11 Comparison of several tools to build a GHG EI

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. 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. 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.

Veolia environment has already done a comparative analysis of local GHG inventory tools for cities [49]. 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?

Questions that they asked in their analysis were:

Do GHG inventory tools differ? *Answer yes*

If so, does it matter*? Answer, yes*

Is it possible to get comparable results? *Answer, yes to some extent*

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.

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.

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 consum ers. They commonly do not take account of all emissions of the energy chain such as trans port 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 ap proaches 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. How ever, the inclusion of LCA data in a local GHG inventory is relatively complex and time con suming.

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

The tools they analyzed were:

- CO2 Grobbilanz/EMSIG (Climate Alliance Austria, Energy Agency of the Regions
- ECO2Region (Climate alliance, Ecospeed)
- GRIP (Tyndall Centre UK Environment Agency
- Bilan Carbone(ADEME)
- CO2 Calculator (Danish National Environmental Research Institute, Local Government Denmark, COWI)
- Project 2 degrees (ICLEI, Clinton Climate Initiative, Microsoft)

The research results are summarized in table 1.

Table 1 Bader et al, 2009

Variable	Example of variation
GHG measurements	Only CO_2 is measured ↔ all GHG measured
Global worming potentials	Global warming potential values derived from the second IPCC assessment report ↔ all GHG emitting activities of the city are measured
Boundaries	Only operations controlled by the public authority are measured ↔ all GHG emitting activities of the city are measured
Scope of the measurements	Measurement takes only direct emissions into account ↔measurements 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.
Price	Software use for free ↔use of software is costly

The strengths, weaknesses and opportunities of these different tools can be found in the Study Report: Comparative Analysis of Local GHG Inventory Tools [49].

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.

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.

ICLEI has developed this International Local Government Greenhouse Gas (GHG) Emissions Analysis Protocol (http://www.iclei.org/index.php?id=ghgprotocol) to provide an easily implemented set of guidelines to assist local governments in quantifying the greenhouse gas emissions from both their internal operations and from the whole communities within their geopolitical boundaries. By developing common conventions and a standardized approach, ICLEI seeks to make it easier for local governments to achieve tangible reductions in greenhouse gas emissions. The standardized approach described in this Protocol facilitates comparisons between local governments and the aggregation and reporting of results being achieved by the action of diverse communities.

The purpose of the Local Government GHG Emissions Analysis Protocol is to:
-Promote understanding of a local government's and community's impact on climate change and awareness of changes that can be made to reduce that impact;
-Enable practitioners to develop complete and accurate emissions analyses to the extent possible and appropriate at the community level;
-Support comparison of different communities in a consistent, detailed, policy-relevant way;
-Enable measurement towards climate goals;
-Provide easily understandable metrics for a wide audience;
-Enable other networks and entities to define custom reporting requirements within the context of the Local Government GHG Emissions Analysis Protocol; and
-Function in tandem with existing or potential regulatory requirements and emissions certification opportunities.

The development and implementation of this *Local Government GHG Emissions Analysis Protocol* follows principles consistent with those used in the finance sector, to ensure accurate accounting and reporting. These principles have previously been adapted by the WRI/WBCSD GHG Protocol Initiative to apply to the accounting and reporting of greenhouse gas emissions and are followed in this Protocol.
Relevance: The greenhouse gas inventory shall appropriately reflect the greenhouse gas emissions of the local government or the community within the local government area and should be organized to reflect the areas over which local governments exert control and hold responsibility in order to serve the decision-making needs of users.
Completeness: All greenhouse gas emission sources and activities within the chosen inventory boundary shall be accounted for. Any specific exclusion should be disclosed.
Consistency: Consistent methodologies to allow for meaningful comparisons of emissions over time shall be used. Any changes to the data, inventory boundary, methods, or any

relevant factors in the time series, shall be disclosed.
Transparency: All relevant issues shall be addressed in a factual and coherent manner to provide a clear audit trail, should auditing be required. Any relevant assumptions shall be disclosed and include appropriate references to the accounting calculation methodologies and data sources used, which may include this Protocol and any relevant Supplements.
Accuracy: The quantification of greenhouse gas emissions should not be systematically over or under the actual emissions. Accuracy should be sufficient to enable users to make decisions with reasonable assurance as to the integrity of the reported information.

Analyzing community-scale emissions presents a number of challenges. Local governments are typically responsible for the governance of sub-national regions and are not able to use the same information sources used by national governments when compiling national inventories for the purpose of reporting under the UNFCCC.

Records of the flow of energy and materials are typically most accurate at the national level, due to national governments having governance over imports and exports. Reducing the spatial area of the analysis from national to sub-national results in a lower level of accuracy in records of material and energy flows. As the spatial area of analysis is reduced to city or municipality, the accuracy of an analysis may be further reduced due to the difficulty of tracking the movement of materials and energy across jurisdictional boundaries. The need to analyze greenhouse gas emissions at a local community level means that a combination of national and local area information is likely to be required in order to model emissions.

A complete emissions inventory includes careful tracking of location and degree of control over the emissions (scopes) as well as the reliability of, and methodological complexity of, the data sources (tiers).

The two boundaries that are applicable to local government are:
Organizational Boundary – consisting of functions directly under local government control, consistent with private sector reporting. In cases where certain functions are shared, a proportional share approach may be needed;
Geopolitical Boundary – consisting of the physical area or region over which a local government has jurisdictional authority.

A complete local government greenhouse gas emissions inventory should separately account for emissions associated with the operations of the government and all activities that occur in the geopolitical area.

In developing an emissions inventory, all emission sources should be considered in accordance with the principles of relevance, completeness and consistency. Although this should be interpreted within the context of each local government, this section provides guidance regarding an acceptable approach to inventory compilation.

The emissions inventory includes all important sources of greenhouse gas emissions occurring within the jurisdiction's geopolitical and organizational boundaries. Differentiating between emission scopes helps to avoid the possibility of double counting emissions and misrepresenting emissions when reporting but allows all policy relevant information to be captured. Three classifications are used to categorize emissions sources, differing slightly when applied in the context of government operations and community-scale inventories.

Depending on the level of detail required or wanted in a GHG inventory, a business or organization can include three levels or scopes consisting of direct and indirect sources of emissions See Figure 1.

Scope 1 emissions – Direct emission sources owned or operated by the local government.
Scope 2 emissions – Indirect emission sources limited to electricity, district heating, steam and cooling consumption.
Scope 3 emissions – All other indirect and embodied emissions over which the local government exerts significant control or influence.

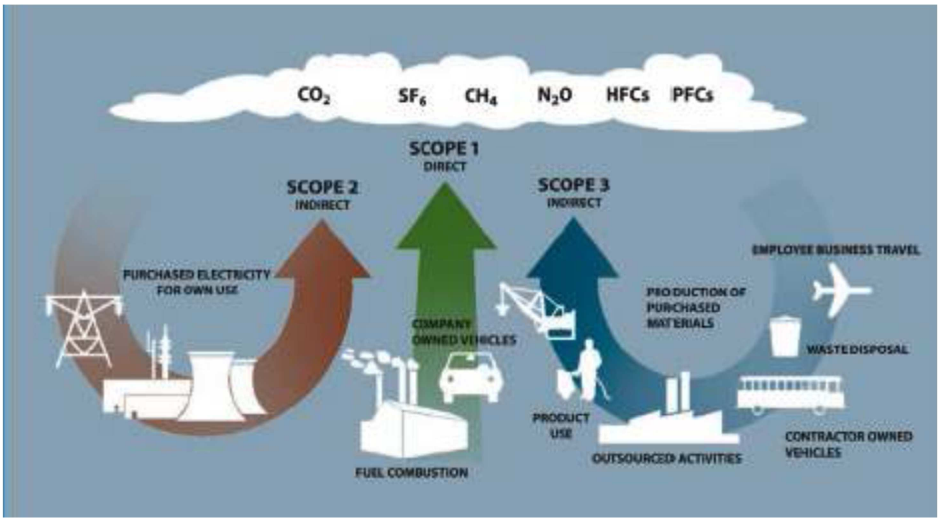


Figure 1 : Source: http://www.yale.edu/sustainability/images/emissions.jpg

A tier represents a level of methodological complexity. Three tiers are described for categorizing both emissions factors and activity data. Tier 1 is the basic method, frequently utilizing IPCC-recommended country-level defaults, while tiers 2 and 3 are each more demanding in terms of complexity and data requirements. Although tiers 2 and 3 are considered to be more accurate, there is a trade-off between the effort involved in obtaining

the information and the benefit of having it. Local governments analyzing greenhouse gas emissions from their municipalities should use the highest practicable tier.

Development of a Multipollutant Emission Inventory for the State of Iowa

Stephen M. Roe er al.

Many states, including Iowa have begun to develop Greenhouse Gas (GHG) inventories and forecasts to inform state and local-level climate change planning processes. In most cases, these GHG inventories have been developed using methods and structure that is consistent with EPA's national GHG inventory. Currently, EPA's national GHG inventory is developed separately from the NEI (Air Quality emission inventory). It hampers policy analysis in both the climate change and ambient air quality arenas. Analysts need to be able to assess the impacts to GHG emissions levels from CAP/HAP (aur quality action plans) control programs and vice versa.

The objective of the pilot project is to develop a combined statewide emissions inventory covering criteria air pollutants (CAPs), toxic air pollutants (TAPs), and greenhouse gases (GHGs) at the county level. Detailed documentation of the procedures used to integrate the inventory data on a sector by sector basis will be developed for future use by Iowa, other states, and the EPA. Among the integration procedures/issues are: new source classification codes for GHG sources that do not have a direct analog in the CAP/TAP inventory structure; state to county-level allocation of GHG emissions for the nonpoint sectors; accounting for both emissions and sinks (including negative emissions) within the existing NIF data structure. The final report for the project presents results in the form of summary tables and graphs of GHG/CAP/TAP emissions, as well as lessons learned from the integration process. A single system to house the necessary activity data, emissions data, control data, projection data, and other ancillary data would reduce the overall level of effort needed for inventory development and maintenance. Another important benefit is that a combined system would assure that a common basis for emissions activity, growth, and control is being used to estimate policy impacts for ambient air quality and climate change programs. Finally, many municipalities and counties have also begun to develop and maintain GHG and sometimes other air pollutant inventories as part of their climate change mitigation programs. Potentially, some of the inventory work conducted at the loca area (metropolitan statistical area, township, county) could be integrated with future state submittals to EPA offering more accurate bottom-up emission estimates. The purpose of this project is to generate an integrated multi-pollutant (GHG, CAP, HAP) inventory of air emissions for Iowa. The inventory developed will retain data at the county-level generally and specific facility locations for point sources, consistent with the NEI. The methods used are described in the article [43]

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/

8.12 EEA national emission reporting tool

Emission inventories require the management, documentation and interrelation of large amounts of heterogeneous data in a user-controlled logic.

Data sources/data availability
Data basis per sector

Energy sector
Industry
Road transport
Railways
Shipping
Other sectors
waste

Describe the system of CollectER ().
CollectER is an emission inventory tool. Issue to study/resolve are:
- how useful is this national reporting tool on a city level, is it not too heavy?
- If you have a nice integrate emissions database you still have to add spatial information if you want to use it for AQ modelling. How easy is it to import, export data to this emission management tool?

CollectER

CollectER is a database devised by the European Energy Agency, that integrates both greenhouse gases and aerosols. It calculates emissions by multiplying an activity rate (usually production rate) with an emission factor, and the percentage of a certain category (industry, households, etc.) that has a specific emission factor).

Collecter calculates emissions via:

$$E_{pollutant}(t) = \sum_{activities}\left(\sum_{technologies}\left(AR_{activity}(t) \times P_{activity,technology}(t) \times EF_{technology,pollutant}\right)\right)$$

$$with \quad \forall activities, \forall\, t: \quad \sum_{technologies} P_{activity,technology}(t) = 100\%$$

The most recent version of CollectER can be downloaded for free from http://air-climate.eionet.europa.eu/country_tools/ae/CollectER_III.html.

At it's base lies Microsoft Access, a database program that is standard in Microsoft Office.

The limits of CollectER are thus the same as those for Microsoft Access:

database size	2 Gb
objects in database	32.768
table size	2Gb- size system requirements
fields in a table	255
number of open tables	2048
recordset size	1Gb
tables per query	32

If you want to enter more data, there is need for a different program (e.g. Matlab, Oracle). The trouble with those programs is that they are often expensive, and relatively difficult to operate.

Data entering and output

Entering data directly into CollectER is relatively easy: you are guided through the process; an error occurs when you enter invalid or incomplete data. A teaching guide with example is/ will become available.

A quick overview of what you need to enter, and in which order:
-choose a country from the predefined list
-the year(s) over which you want to know the emissions
-locations (different levels, e.g. country-province-city)
-category (CRF category, predefined list)
-detail (SNAP, predefined list)
-fuel (predefined list, also select unit)
-activity rate (in correct unit)
-new technology (technology code and –name to your liking, unit from predefined list)
-emission factor (pollutant from predefined list, emission factor as determined)
-fraction (0.01 to 1)

Click ‘emissions’ tab to get output table (still in CollectER). To work with your data outside CollectER, one can output the data in NFR or CRF document. However, the easiest way is to copy-paste the data into Excel (or make a query between Excel and Access).

The disadvantage of this approach is that you can enter only one source at a time, and you need to complete the whole process before entering a new source.

Directly entering data via Access is also possible, than you can enter multiple sources at one time. However, you have to have quite some knowledge of both Excel and Access.

An overview of the tables where you have to enter/choose information:

-**Years**: *Coll_Year* (speaks for itself)
-**Location**: *location_id* (can be set to autonummering), *location_name* (whatever you like), *PointSource_Flag* (yes or no), *location_level* (0 being the highest, e.g. country, see above)
-**Sources**: *Source_ID* (can be set to autonummering), *Location_ID* (has been set in ‘Location’ table, must match), *Category_ID*, *Detail_ID*, and *fuel_id* (are predefined, see above, pick the right one from the list), *Source_Name* (whatever you like), *unit* (pick from the list), *comment* (if you want) *error_code* (should be 0)
-**ActivityRates**: *Source_ID* (must match *Source_ID* in ‘Sources’), *Coll_Year* (as in ‘Years’), *Act_Rate* (Activity Rate in chosen units), *Notation_Key* (choose ‘none’), *comment, err_code*
-**Technologies**: *Technology_ID* (can be set to autonummering), *Technology_Code* (whatever you like), *Technology_Name* (whatever you like), *Activity_Unit* (pick from the list), *Comment, err_code*
-**EmissionFactors**: *Technology_ID* (as in ‘ActivityRates’), *Pollutant_ID* (pick from the list), *em_fact* (emission factor), *Emission_Unit* (unit for emission factor, e.g. kg per ton, per capita, per vehicle), *Activity_Unit* (as in ‘Technologies’), *Notation_Key, Comment, err_code*
-**SelectTechnologies**: *seltech_ID* (autonummering), *Technology_ID* (as in ‘Technologies’), *Coll_Year* (as in ‘Years’), *Source_ID* (as in ‘Sources’), *Fraction* (0.01-1), *comment*

Adding extra data in Access

Adding extra data to the CollectER database is possible, but this must be done in Access. The newly added data is not visible within the CollectER shell, but can only be viewed in Access or Excel. New data can be added to existing table within the CollectER database (e.g. if you want to add a specific pollutant). Adding an extra table directly into Access is also possible, for example x and y data, to show emission on a map, or extra data that are needed for model input (stack height etc.). However, if the data need to be edited or changed very often (in the case of model input, new versions etc.) it might be easier to enter data in Excel and than make a query to Access (in Excel it is easier to adjust multiple data at once).

Both procedures do no change the outcome in the Access query, or in the CollectER shell.

In Access **import-<excel table>** (the table must have one unique field (e.g. "Technology_Code")) that can be matched to a field in a table in Access.

In the Access 'query-field' one can add an extra query, or add the table with the x-y data to the "CalculateEmissions"query. However, it is better to create an extra query, so that in case things go wrong with your new query, the original query with emissions is not lost.

Easiest way to create a new query is to chose **new** from the query tab. Choose **design**, and in the Access toolbar choose **SQL**. Now copy paste the SQL-code from the "CalculateEmissions" query (right-click on "CalculateEmissions", choose **design**, than choose **SQL**) and add and remove new tables to your liking. However, keep checking that all data is OK (that is, the same as in your "CalculateEmissions"query).

Keep in mind that in case you change the name of your Excel file, you need to update your query, of Access can't find the file anymore.

A disadvantage of looking at the final data in Excel is that the pollutant_ID is changed to a specific code. This means that you would have to know this by heart, or keep a list with the codes. However, if you work this way a lot, you will learn quite quickly which code is which pollutant.

Emission Factors

To collect the right emission factors can be difficult: There might not be an emission factor for the fuel-type and technology-type combination you need. Rapid development on new (environmentally friendly) production methods and new (bio)fuels, make it difficult to keep emission factors up to date. When an emission factor is available, it might not be in the right units, and conversion is often difficult. For some countries, emission factors are determined by the government. If you are a regional authority you might no better suitable emission factors, but you might be forced to use the national ones.

Some information on/ tables with emission factors can be found here: First of all, there is the EMEP/EEA air pollutant emission inventory guidebook (latest version 2009):

http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009. This guidebook gives some emission factors, and standards on how to calculate them. The IPCC is setting up a database for emission factors. It is not complete yet, but it contains some useful data: http://www.ipcc-nggip.iges.or.jp/EFDB/find_ef_s1.php. The U.S. Environmental Agency also has information on emission factors: http://www.epa.gov/ttn/chief/ap42/. Another useful source might be the website of the National Atmospheric Emissions Inventory in the UK: http://www.naei.org.uk/index.php..

In the case that no emission factors are available, measured emissions can be added directly into collectER. In this case the emission must be entered as the ActivityRate, the fuel type must be set to 'measured emission (DE in the list)', and the emission factor must be set to one. However, this is not desired: The idea of collectER is that emissions don't have to be adjusted all the time. For future versions of collectER this is supposed to be easier.

Ideally there is one emission factor per activity (unique combination of location, category ID, detail ID, fuel_ID and technology code). It is possible to specify a certain percentage within a single activity. This is best viewed in an example:

Say you have three powerplants that produce between 50 and 300 MW electricity, and use coal as a fuel. However, all three are of different age, and have therefore different emission factors. It is then possible to set one source, e.g. powerplants. Within this source you set one technology for 'powerplant_old' one for 'poweplant_medium', and one for 'powerplant_new'. Now you can enter different EFs for the different technologies. For every technology you can enter a different factor between 0 and 1 for the percentage they play in the total electricity production. (Of course the three number must add up to one).

Used data

Data used for testing collectER are from factories in the Rijnmond area that are obliged to publish their annual emissions. They come from the report 'Inventarisatie en vergelijking jaaremissies' (inventarisation and comparison of annual emissions) that was published by the DCMR in september 2008. The other part of the data are the emissions of consumers in 2006, calculated by the 'design agency for the environment'. These were used to compose the GCN, an annually published map that shows concentrations from all sources for different aerosols over the whole country.

The data are emissions per pollutant per company per year. By adding them up per year the total amount of emission per company per year (=activity rate per company per year) was calculated. The calculated percentage of each pollutant per company per year was entered as an emission factor.

For CO_2, the percentage was about 99 % of the total emission, but for other compounds (NMVOC, NO_x, SO_2, NH_3, TSP, carcinogenics), this differed per company.

In Excel a table was composed containing x and y data for the different companies, along with the column “technology_code”. Adding this table to Access was done by choosing **import** in the Access table field. After that it was related to the “Technologies” table. In the “query” field a new query was added, in which the SQL data from the “CalculateEmissions” query where pasted, which were then altered somewhat to include the x and y data.

This new query was exported to Excel, and the Excel table was added to ArcGIS. In ArcGIS it is possible to display emissions per year, per pollutant, or per company. (It is possible to directly import Access tables to ArcGIS, but for now this seemed more convenient).

However, when using x and y data, every different x and y is displayed in your query, even if they have the same source (or technology_code in this case). This means that you can end up with a lot of rows in your query, when you only need one (if emission is the same for every point).

A problem might be to calculate the emissions of traffic and other mobile sources.

Problems/difficulties

- You have to have quite a lot of specific information about your sources (information on products produced, fuel type, etc.). Collecting all this information might be quite a lot of work.
- The CollectER shell is much more rigid than the Access table. Entering data in CollectER must be done in a certain order, or your data do not get saved. Changing certain values can be more difficult in CollectER than in Access.
- Finding the right emission factor is a challenge, see above.
- A problem might be to enter activities or emissions from traffic and other mobile sources.