A comparison between the Dutch Emission Registry and an inventory created using the revised EMEP/EEA Guidebook

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ABSTRACT

This study compares an inventory using default methods from the revised EMEP/EEA Guidebook (formerly known as EMEP/CORINAIR Guidebook) to one using a complex inventory system as applied in the Netherlands for the year 2005. The recent revision process of the Guidebook has facilitated this comparison, since both the Guidebook and the countries' submissions to LRTAP now use the same source definitions. Guidebook emission factors have been combined with relevant activity statistics and compared directly to the emissions resulting from the complex inventory system of the Netherlands. The results of this comparison in general show that emissions calculated by using the Guidebook are higher than in the Dutch Emission Inventory, which is to be expected because of the relatively high level of abatement applied in the Netherlands compared to the international average. Keeping this in mind, for the major pollutants such as NO_x and NMVOC the comparison shows reasonably good agreement. For the less known pollutants such as persistent organic pollutants (POPs) and heavy metals the two estimates are much less similar. The comparison also shows some 'missing sources': sources that are significant in one inventory but negligible or absent in the other. Sources may indeed be missing, but also country specific activities may cause the differences, since the Guidebook represents only the average situation. We conclude that the comparison enhances credibility of country specific inventories and may help to unravel specific gaps that still exist between emission-based air quality modelling and measurements.

INTRODUCTION

Countries that ratified the Convention of Long Range Transboundary Air Pollutants (LRTAP) agreed to annually report national emissions of air pollutants. Following the provisions of the LRTAP Reporting Guidelines[1], the EMEP/EEA Guidebook provides all technical guidance for compiling these emission inventories. The Guidebook's major restructuring in 2007 and 2008, organised the guidance along the NFR source categories (NFR: Nomenclature for Reporting; see also Reporting Guidelines[1]) to simplify the inventorying process, linking it directly to the format of the national emission reports.

This study compares the results of the complex Dutch Emission Inventory system to the emissions as calculated using the revised EMEP/EEA Guidebook combined with relatively easy-to-find statistics for the year 2005. The goal of this research is to explore the quality of the Dutch Emissions Inventory and the Guidebook by analysing the resulting emission estimates. The following questions are formulated:

- Are there any sources in the Dutch Emission Inventory or in the Guidebook that are missing?
- Can major differences between the two emission inventories be explained?
- Is it possible to improve the Dutch Emission Inventory by using the Guidebook?

However, this study cannot be seen of as a way to verify the Dutch emission registry nor the Guidebook, since both emission inventories have a relatively high degree of uncertainty. The comparison will highlight some interesting similarities as well as differences between both inventories.

EMEP/EEA Guidebook

The EMEP/EEA Guidebook 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 (EEA) and its European Topic Centres.

The primary objective of the Guidebook is to support national experts in compiling emission inventories complying with the requirements of specific legal obligations (LRTAP and its protocols and EU NEC Directive[2]). In addition the Guidebook should support continuous improvement and reflect key new scientific and methodological insights and to support knowledge based and effective policy making. For this the Guidebook also needs to provide science and methods needed for emission inventorying so that countries that have the resources can produce the highest quality inventory. This is needed in order to ensure that the scientific quality of the inventories that feed into various types of models and policy assessment, including establishment of emission ceilings and compliance checking of emission targets, remains of the highest standard.

The Guidebook has been developed over a long period (more than fifteen years) to obtain a comprehensive set of emission estimation methods. Until 2006, this great effort has mainly been achieved through work undertaken by TFEIP experts at a voluntary basis. Some parts of the Guidebook have been regularly updated but there were gaps in the available information (both source coverage and emission factors), while other information (emission factors and technology descriptions) needed updating. Furthermore, emission estimation method descriptions were inconsistent between chapters. The Guidebook as it stood by end of 2006 fell short when reviewing countries' submissions in response to international reporting obligations. So, much of the Guidebook material was old and possibly outdated and incomplete. Finally, the Guidebook was difficult to update. Therefore, DG Environment has commissioned a consortium lead by TNO do perform a major revision and update.

The Guidebook revision process started in December 2006 and has resulted in:

- A Guidebook that has been split into two parts: one part describes the general issues that are not source specific and provides background information (General Guidance) and another part with technical source specific chapters, each with their specific emission estimation methodologies.
- A Guidebook that is now organised along the NFR source definitions in order to ensure consistency with the countries' reporting requirements.
- A clear guidance on how to split combustion and process emissions in the industry for reporting purposes.
- More consistency across chapters: each of the technical chapters is now structured in the same way, with separate sections on:
    - Description of the process, different technologies, emissions and abatement measures.
    - Available methodologies for estimating emissions, including guidance on choosing the appropriate methodology in a specific situation.
    - Information on source specific issues regarding data quality.

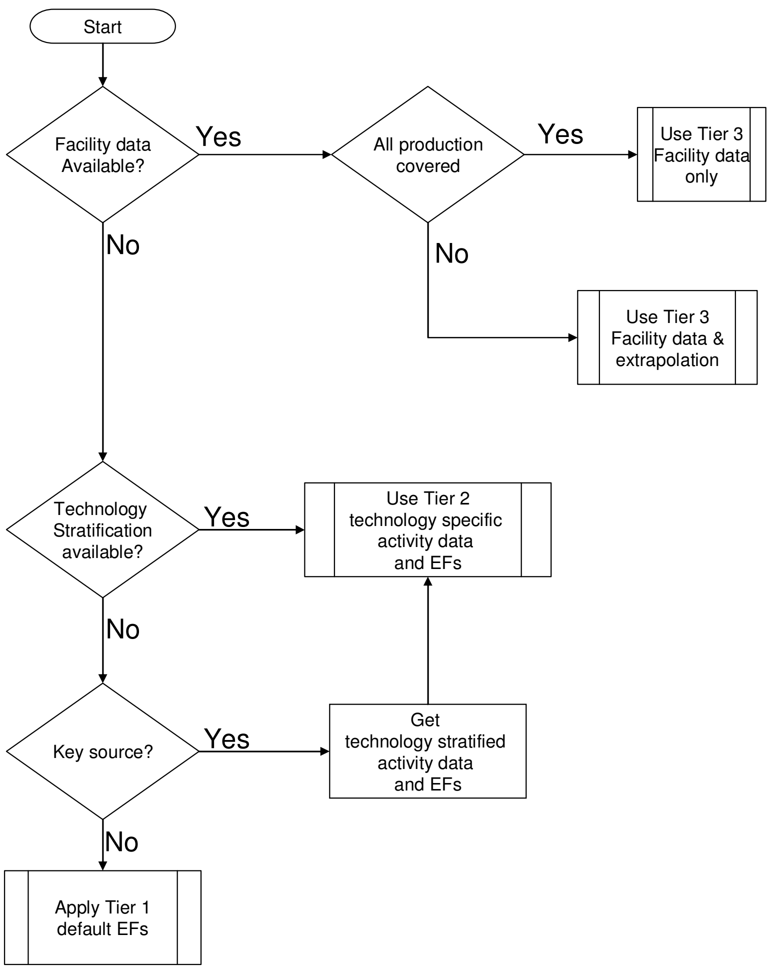
The revision process took place in close cooperation with the UNECE Task Force on Emission Inventories and Projections (TFEIP), its Expert Panels and other experts, including industrial representatives.

As mentioned earlier, each technical chapter has a section on methodologies for emission estimation. This section contains a decision tree, which assists the Guidebook user to choose the appropriate method for estimating air pollutant emissions. An example of this decision tree is given in Figure 1 for the case of cement production. Similar to the IPCC 2006 Guidelines[3], three classes of methods for estimating emissions can be distinguished:

- Tier 1 method: the simplest method, a default emission factor per pollutant that has to be multiplied with the activity rate for this source category.
- Tier 2 method: compared to the Tier 1 method now different technologies/practices within the source category are distinguished, for each an activity rate is multiplied by a typical emission factor.
- Tier 3 method: anything beyond a Tier 2 method, including emission modelling and the use of facility level emission data.

After the revision, the structure and outline of the Guidebook follows the IPCC 2006 Guidelines[3], both in the General Guidance and the Technical Guidance. The revised Guidebook has been brought in line with the "Good Practice" as originally developed by IPCC for reporting under the UNFCCC Convention. Also the introduction of the "Tier" concept exactly follows the IPCC 2006 Guidelines working procedures, by introducing decision trees and methodological tiers.

Figure 1. Example of a decision tree in the revised Guidebook, to choose the appropriate method to estimate air pollutant emissions.



METHODS

Dutch Emission Registry

The Dutch Emission Registry (hereafter referred to as ER) is a joint effort of PBL (Netherlands Environmental Assessment Agency), CBS (Statistics Netherlands), TNO (Netherlands Institute for Applied Scientific Research), SenterNovem, RWS-WD (Water Service, part of the Directorate-General for Public Works and Water Management) and Alterra. Every institute participates in one or more Task Forces, which calculate the emissions for different source categories (industry/energy, transport, agriculture and product use). Emissions to water are calculated by a separate water Task Force. The registration of emissions in the Netherlands started in 1974 with an emission assessment of individual companies. Eventually this has lead to a yearly inventory of the emissions of almost all sources.

Nowadays, many pollutants are covered and the figures derived from the ER are used to submit national emission reports of greenhouse gases under the Kyoto Protocol and the UNFCCC Convention (Netherlands National Inventory Report[4]) and of air pollutants under the Convention on Long-Range Transboundary Air Pollution (Netherlands Informative Inventory Report[5]).

Air Pollutant Emission Inventory using the Guidebook

Using the revised Guidebook as a starting point, an emission inventory has been compiled for the Netherlands for the year 2005 by combining the available emission factors from the Guidebook with information on activities. Relevant activity statistics have been derived from various sources. For the energy related source categories (NFR main category 1), data from the IEA Energy Statistics[6] have been collected. Agricultural statistics (number of animals, crop area, and fertilizer use) have been collected from the UN Food and Agricultural Organisation Statistics (FAOSTAT)[7]. Table 1 provides a complete overview of the sources for the non-energy activity data that have been used in this study. A number of NFR source categories are not listed in this table; these have not been taken into account in this study. This can happen for three reasons:

- The activity is not undertaken in the Netherlands (activity = 0);
- The activity is likely to be undertaken in the Netherlands in 2005, but activity statistics are unavailable or could not be found.
- No methodology for estimating emissions available in the Guidebook. There are activities that are known to be a source of emissions, but no emission factors are available. Generally however, these activities represent only a small contribution to the total emissions of any pollutant.

Table 1. Overview of the NFR source categories, the applied methodologies (Tiers) and the activity statistics

NFR Code	NFR Name	Method	Reference for activity data / Remarks
1	Energy; incl. all subsectors	Tier 1, 2	IEA Energy Statistics[6], Tier method based on available level of detail in IEA
2.A.1	Cement production	Tier 1	Estimation based on facility data
2.A.4	Soda ash production and use	Tier 1	USGS[8]
2.A.7.d	Other mineral products	Tier 1	IIASA GAINS model[9]
2.B.1	Ammonia production	Tier 1	Estimation based on facility data
2.B.2	Nitric acid production	Tier 1	Estimation based on facility data
2.B.5.a	Other chemical industry	Tier 2	FAOSTAT[7], USGS[8] and estimations based on facility data
2.C.1	Iron and steel production	Tier 2	World Steel Association[10]
2.C.3	Aluminium production	Tier 2	USGS[8]
2.C.5.b	Lead production	Tier 1	USGS[8]
2.C.5.d	Zinc production	Tier 1	USGS[8]
2.C.5.e	Other metal production	Tier 1	USGS[8]
2.D.1	Pulp and paper	Tier 1	VNP[11]

NFR Code	NFR Name	Method	Reference for activity data / Remarks
2.D.2	Food and drink	Tier 2	Various statistics, including FAOSTAT[7]
3.A.1	Decorative coating application	Tier 2	VVVF[12], assumed 2005 = 2004
3.A.2	Industrial coating application	Tier 2	VVVF[12], assumed 2005 = 2004
3.A.3	Other coating application	Tier 1	VVVF[12], assumed 2005 = 2004
3.B.2	Dry cleaning	Tier 2	Expert estimate
3.D.2	Domestic solvent use including fungicides	Tier 1	Population figures from CBS[13]
4.B.01.a	Dairy cattle	Tier 1	CBS[13]
4.B.01.b	Non-dairy cattle	Tier 1	CBS[13]
4.B.03	Sheep	Tier 1	CBS[13]
4.B.06	Horses	Tier 1	CBS[13]
4.B.08	Swine	Tier 1	CBS[13]
4.B.09.a	Laying hens	Tier 1	CBS[13]
4.B.09.b	Broilers	Tier 1	CBS[13]
4.B.09.c	Turkeys	Tier 1	CBS[13]
4.B.09.d	Other poultry	Tier 1	CBS[13]
4.B.13	Other	Tier 1	CBS[13]
4.D.1	Agricultural soils	Tier 1, 2*	CBS[13], IFA[14], RIVM data. Average temperature from KNMI.
6.A	Solid waste disposal on land	Tier 1	National Inventory Report 2008[4]
6.B	Waste-water handling	Tier 2	CBS[13]
6.C.a	Clinical waste incineration	Tier 1	Working group Waste Registration[15]
6.C.b	Industrial waste incineration	Tier 2	Working group Waste Registration[15]
6.C.c	Municipal waste incineration	Tier 1	Working group Waste Registration[15]
6.C.d	Cremation	Tier 1	LVC[16]
6.D	Other waste	Tier 2	CBS[13], Working group Waste Registration[15], Trimbos Institute[17]

* Tier 1 for NMVOC and PM, Tier 2 for NH_3.

The emissions calculated using the Guidebook can be expressed as:

Equation (1) $$E_{pollutant,source} = \sum_{technologies} EF_{technology,pollutant} \times AR_{technology,source}$$

where

$E_{pollutant,source}$	=	Emission for a chosen source and pollutant.
$EF_{technology,pollutant}$	=	Standard emission factor for a chosen technology to perform the activity for the relevant source, and for the relevant pollutant (available from the Guidebook).
$AR_{technology,source}$	=	Activity rate for the relevant source using the relevant technology (see Table 1).

The above equation basically describes the Tier 2 approach, where different technologies to perform a certain activity are identified. The Tier 1 approach can be regarded as a special case of the equation above, where there is only one technology applied. In Tier 1, this technology represents the average or typical technology used to perform the activity.

RESULTS

This study uses the Dutch inventory for the year 2005 as it has been submitted to UNECE under the LRTAP Convention in February 2008. These emissions are estimated for every NFR source category. These emissions can be compared directly to the emissions calculated using the Guidebook.

To analyse the results and make the comparison, the NFR source categories have been aggregated in a number of aggregated sectors, as shown in Table 2.

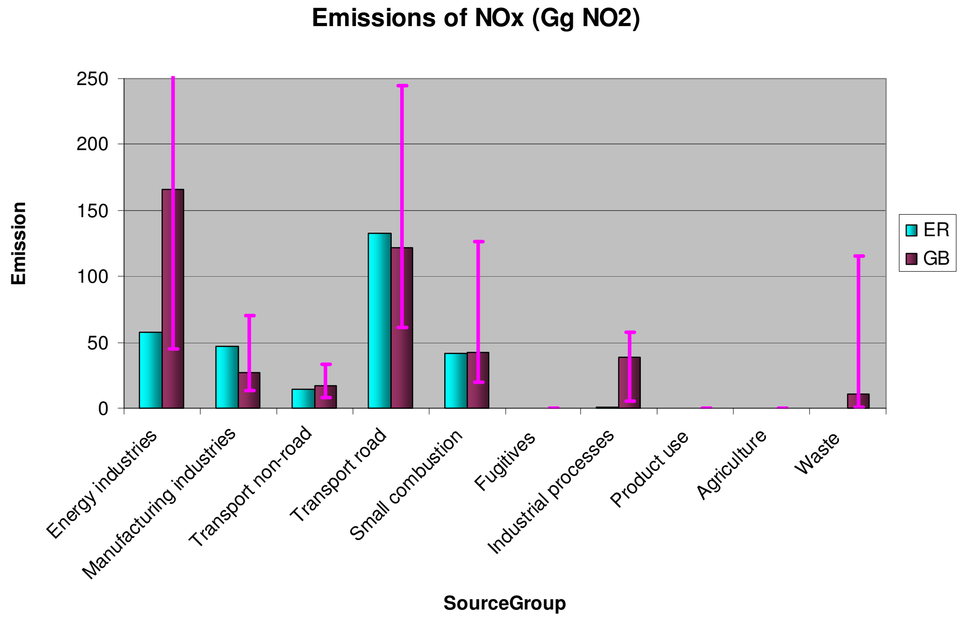
Table 2. Aggregated source categories for which the comparison has been made

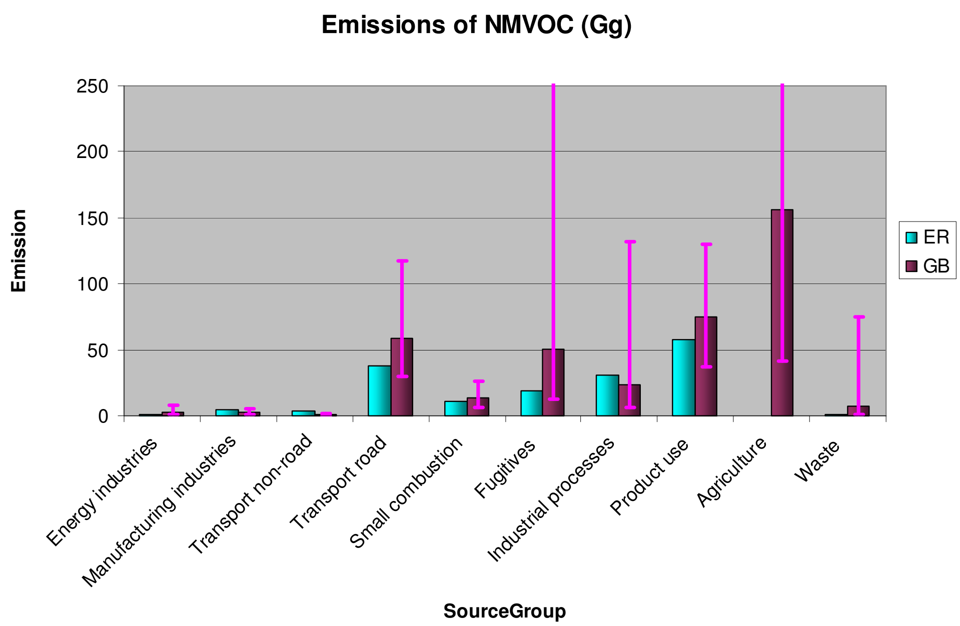
Aggregated NFR code	Aggregated source name	Detail
1.A.1	Energy industries	Power plants and refineries
1.A.2	Manufacturing industries	All combustion-related emissions in the industry
1.A.3 (without 1.A.3.b)	Non-road transport	Excluding emissions from international aviation and international shipping
1.A.3.b	Road transport	Includes emissions from exhaust, but also gasoline evaporation and tire, brake and road wear
1.A.4 & 1.A.5	Small combustion	Other combustion emissions, mainly residential/commercial heating
1.B	Fugitives	Fugitive emissions from the treatment and distribution of fuels, e.g. non-combustion emissions in refineries
2	Industrial processes	All non-combustion related emissions in the industry
3	Product use	
4	Agriculture	
6	Waste	
7	Other	Any sources that are not accounted for by another sector (the Guidebook does not contain a methodology for this "catch-all" sector)

The comparison between the Dutch Emission Registry and the Guidebook-based inventory has been performed for 4 selected pollutants, which will be discussed in the following section. To get more feeling for the uncertainties involved, we have taken into account the 95% confidence intervals from the Guidebook emission factors. The lower and upper limit for the emissions are calculated as being the activity data multiplied by the lower and upper limit for the emission factor, respectively. For the activity data as well as for the emission data from the Dutch Emission Registry no uncertainty estimates are available.

Figure 2 shows the results of the comparison for NO_x and NMVOC, two of the major and well-known pollutants.

Figure 2. Comparison between the Dutch Emission Registry (ER) and the inventory compiled using the Guidebook (GB) for the Netherlands for the year 2005, for the pollutants NO_x and NMVOC. The magenta error bars represent the range in the emission from the 95% confidence interval of the emission factor as provided by the Guidebook.





NO_x

Emissions from energy industries calculated using the Guidebook are significantly higher than in the Dutch Emission Registry. This is observed for almost all pollutants and is likely to be due to the level of abatement installed in the Netherlands, which is believed to be more advanced than the European average. The application of a more detailed method to estimate the emissions from this source category (Tier 2 or Tier 3) can contribute to confirm this assumption.

For industrial emissions, it is shown that the emission in the Dutch Emission Registry is higher than the Guidebook in the Manufacturing Industry, while in the sector Industrial processes the

Guidebook emission is higher. This difference is caused by an allocation problem, since the Dutch Emission Registry does not separate the process and combustion emissions for NO_x and reports all emissions in Manufacturing Industries, assuming being only combustion emissions. The Guidebook on the other hand distinguishes combustion processes and non-combustion processes and allocates emissions accordingly, wherever possible. In many cases however, industrial processes consist of both combustion and non-combustion processes and it is difficult to distinguish combustion and non-combustion (process) emissions.

For road and non-road transport, as well as small combustion sources (heating etc.) the difference between the NO_x emissions is relatively small. There is a contribution from the waste sector in the Guidebook, but also here an allocation problem may exist, since waste incineration emissions (the most important source of NO_x emissions in the Guidebook inventory) are to be reported under Energy Industries if the energy from waste burning is recovered. This information is not used in the Guidebook inventory.

NMVOC

The largest source of emissions in the Guidebook, accounting for ~ 40% of the total NMVOC emissions, is agriculture. The Dutch Emission Registry does not report any NMVOC emissions from agriculture, except for a relatively small amount in the category 4.G "Other agriculture", where NMVOC emissions from agricultural crops are reported. A more detailed look shows that the significant NMVOC emissions calculated using the Guidebook originate from manure management (NFR source category 4.B). Table 3 shows the activities, emission factors and emissions for this sector. Emission factors for NMVOC emissions from manure management in the Guidebook are based on a study by Hobbs et al.[18].

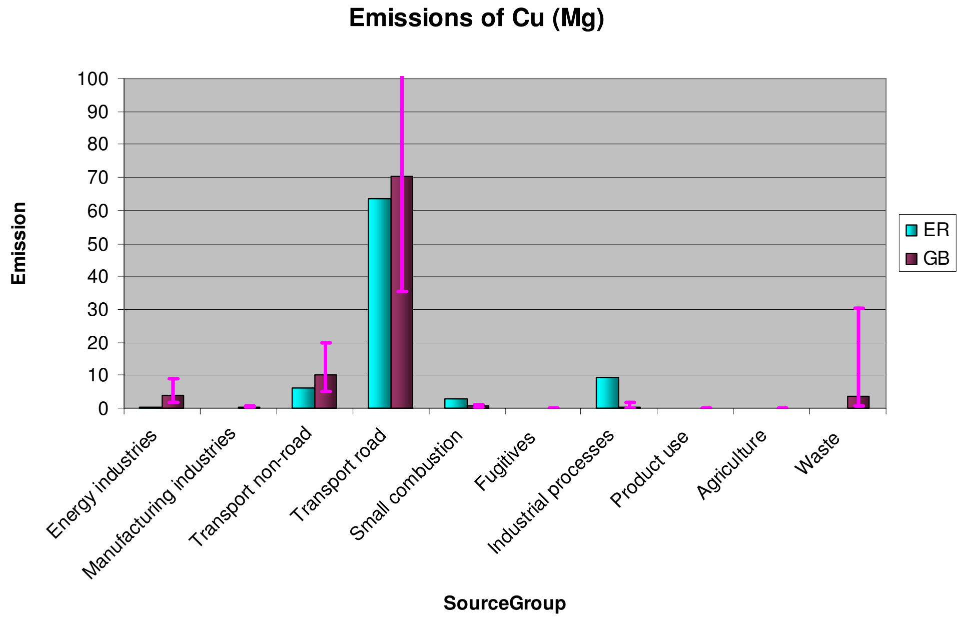
For most other sectors, the emissions show relatively good agreement. For most sectors the emission calculated using the Guidebook is higher than the emission from the Dutch Emission Registry, but this is expected a relatively high level of abatement to reduce emissions is installed in the Netherlands, compared to the European average.

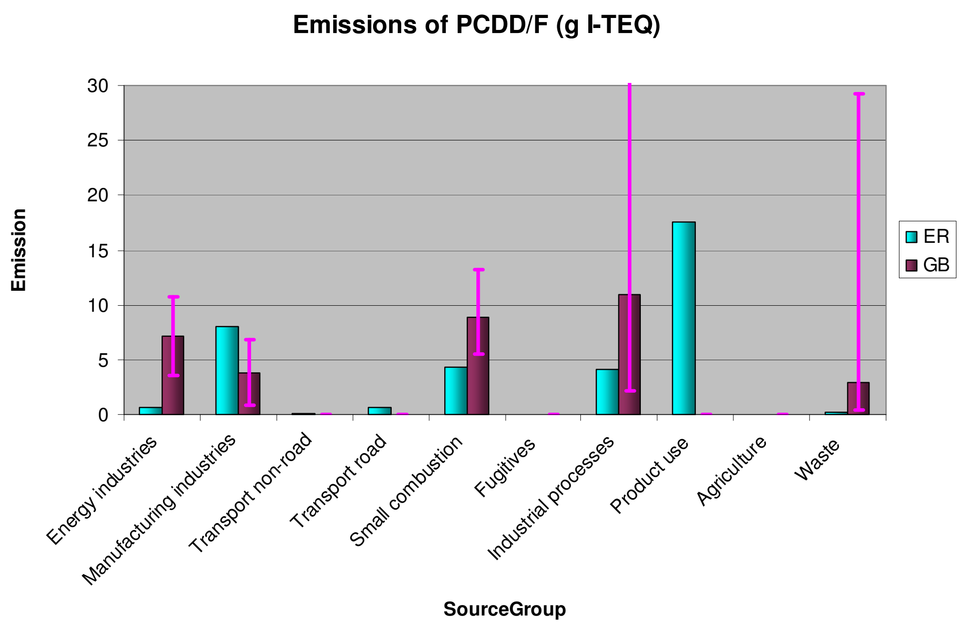
Table 3. Emissions of NMVOC from manure management (NFR source category 4.B)

NFR	**NFR Name**	**Number of animals**	**EF [kg/animal/year] for NMVOC**	**Emission [ton] of NMVOC**
4.B.01.a	Dairy cattle	1,433,202	13.6	19,492
4.B.01.b	Non-dairy cattle	2,365,602	7.4	17,505
4.B.03	Sheep and goats	1,654,755	0.2	331
4.B.06	Horses, mules and asses	133,321	-	0
4.B.08	Fattening pigs	5,528,016	3.9	21,559
	Sows	5,783,542	13.3	76,921
4.B.09.a	Laying hens	42,629,710	0.3	12,789
4.B.09.b	Broilers	50,284,466	0.1	5,028
4.B.09.c	Turkeys	1,245,420	0.9	1,121
4.B.09.d	Other poultry	1,305,487	0.9	1,175
Sum				**155,922**

To illustrate the comparison for less well-known pollutants, Figure 3 shows the comparison between the Dutch Emission Registry and the inventory using the Guidebook for copper and for dioxins and furans.

Figure 3. Comparison between the Dutch Emission Registry (ER) and the inventory compiled using the Guidebook (GB) for the Netherlands for the year 2005, for the pollutants Cu and PCDD/F. The magenta error bars represent the range in the emission from the 95% confidence interval of the emission factor as provided by the Guidebook.





Copper

For Cu emissions, the figure shows good agreement between the two estimates for the major sources. The largest contributor to Cu emissions in the Netherlands is road transport (in particular brake and tyre wear [19]), in both the Dutch emission inventory and the emissions calculated using the Guidebook this source is responsible for more than 75% of the total national Cu emissions.

The category "Industrial processes" is represented in the Dutch Emission Registry, while negligible in the Guidebook. The main source of Cu emissions in this source category within the Dutch Emission Registry is fire works, while for this source there is no emission estimation methodology in the Guidebook.

The category "Transport non-road" in the Dutch Emission Registry contains emissions from abrasion of contact wires and pantographs on trains. The main source of Cu emission in the Guidebook inventory however is the combustion of fuel in domestic navigation.

Emissions from small combustion are higher according to the Dutch Emission Registry. This is caused by differences in activity data. According to the Dutch Emission Registry, waste is used in residential burning, which causes the largest copper emissions in this sector. This is not included in the IEA Energy Statistics, on which the Guidebook inventory is based.

Small contributions of Cu are reported from Energy industries and Waste in the Guidebook. These sources are not covered by the ER, likely because of the strict measures taken in the Netherlands to prevent hazardous emissions from power plants and waste incineration plants. These additional measures (on top of the average European measures to reduce these emissions) are not accounted for in the Guidebook.

Dioxins and furans

First it must be noted that in this analysis the best available measures to reduce PCDD/F emission from waste incineration, as available from the Guidebook, have been applied. The original calculation, not taking into account any additional reduction measures, resulted in a total emission from waste in the Guidebook of over 36 kg I-TEQ. The additional add-on measures have reduced these by more than a factor 10,000.

The best available abatement measures are thought to represent the situation in the Netherlands well, since the country has put a lot of effort in reducing PCDD/F emissions in the past decade.

The general eye-catchers, as mentioned before, are also seen in this figure:

- For energy industries, the emission calculated using the Guidebook is much higher than the emission reported in the ER, even when emission factors with maximum abatement are used to estimate the emissions with the Guidebook.
- In Manufacturing Industries, the emission from the ER is higher. However, as for other pollutants this may be explained as being an allocation problem because in the Industrial Processes the Guidebook emissions are higher.

This figure also shows a few interesting specific issues:

- The largest source of emissions in the ER is product use. The emissions from this source are from category 3.D (Other use of solvents) and are related to PCP pressure treated wood, applied in private households. This source is not included in the Guidebook, while in the Netherlands it is considered to be the largest source of dioxin emissions.
- Despite the fact that the best available abatement measures have been applied in the waste sector, emissions calculated using the Guidebook are still well above the reported emissions in the ER.

CONCLUSIONS

This paper presents a relatively simple and straightforward comparison of the complex national inventory system of a country – in this case The Netherlands – to the emission estimation methods as they are available in the "international standard" concerning emission estimation methods, the EMEP/EEA Emission Inventory Guidebook. The main conclusions from the comparison are:

- Differences in major sectors:
    - The emission estimates in the Dutch Emission Registry (ER) are generally lower than those using the Guidebook for the main pollutants (NOx, SOx, NMVOC, NH3, CO, PM). This difference can be caused by the high level of abatement technologies applied in the Netherlands, compared to the global average.
    - For the less well-known pollutants (such as Heavy Metals and POPs) both estimates are relatively close.

- For industrial sources (1.A.2 Combustion in Manufacturing Industries and 2 Industrial Processes) the Dutch Emission Registry applies an allocation method to discriminate between combustion and process emissions from industry as suggested by the Guidebook.
- The emission estimates for the Energy Industries sector are higher when calculated using the Guidebook than reported in the ER. The ratio of the two estimates varies generally between a factor 2 and 8, with a factor 33 as peak ratio for Zn. The difference might be due to specific measures taken in the Netherlands to reduce emissions from power plants, while the methods from the Guidebook assume an "average" situation.

- The Dutch ER includes two sources that are not estimated by the Guidebook's methods:
  - Cu emissions from abrasion of contact wires and pantographs on trains (transport sector);
  - Cu emissions from the use of fire works, allocated to industrial processes. In the ER this is a significant source of Cu emissions, while it is not covered at all by the Guidebook.

  The Guidebook could be extended to include methods for these sources in the appropriate sections.
- The Guidebook provides methods for emissions not included in the Dutch ER:
  - There is currently a discussion among scientists about the NMVOC emissions from Agriculture. The Guidebook emission factors are based on a study by Hobbs et al.[18], leading to a very large contribution of this sector to the total NMVOC emissions. This issue needs further scientific information and development. The Dutch inventory system has not applied this method, since scientific discussions have not been completed yet.

This relatively simple comparison can be seen as a useful tool to improve emission inventories and identify areas where improvements in the guidance are necessary. However, the simple Guidebook methods as applied in this study cannot directly be used for emission reporting, since we did not apply Tier 2 technology specific emission factors in some of the major sources (combustion) as prescribed by the Guidebook's decision trees. In a follow-up of this study we plan to apply proper Tier 2 method for major combustion sources. We expect the two estimates to come much closer by doing so.

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KEYWORDS

Emission inventory
EMEP/EEA Guidebook
Dutch Emission Registry
Emission factor