Statistics Norway
Department of Economic Statistics

Ketil Flugsrud, William Irving and Kristin Rypdal

Documents

Methodological Choice in Inventory Preparation. Suggestions for Good Practice Guidance

Statistics Norway

Statistisk sentralbyrå

Background

The agreements on Kyoto protocol and the United Nation Framework Convention on Climate Change (UNFCCC) to limit emissions of greenhouse gases (GHG) demand high quality emission inventory data. It is recognised that emission data for several of the GHG are highly uncertain compared to the emission target set in the Kyoto protocol. These uncertainties cannot be eliminated in the short term. This makes it necessary both to assess these uncertainties and to develope a set of good practice rules to manage these uncertainties. The IPCC/OECD has during 1998 and 1999 arranged several workshops to make suggestions for good practice guidance for inventory preparation, both for specific source sectors and in general.

This paper has been prepared by the authors[1] for discussion during the IPCC expert meeting on Cross-Sectorial Methodologies for Uncertainty Estimation and Inventory Quality in Culham United Kingdom October 5-7 1999. The goal of this paper is to address some cross cutting issues in inventory preparation, especially rules for recalculations and a proposal for a standard methodology to identify key sources to be prioritised. The recommendations made here form the basis for the recommendations from the meeting for further review and possible approval in the future.

The authors are grateful to Roberto Acosta, Niclas Höhne, Dina Kruger, Thomas Martinsen, Jim Penman and Audun Rosland for extensive comments on the first draft versions of this paper. Part of this work has been funded by the Norwegian Pollution Control Authority.

Summary

This paper considers some key cross cutting issues for choice of methodologies for GHG emission inventory preparation; how to define the key sources in the inventory, choice of methods and resource prioritisation for key and other sources, and how to deal with changes in methodologies, recalculations and the introduction of abatement.

Countries will from time to time have good reasons to change their methodologies and earlier submitted estimates of GHG emissions. It has been agreed by the UNFCCC Subsidiary Body of Science and Technology Advice (SBSTA) that such recalculations are allowed in the reporting. However, the purpose of all recalculations should be the *improvement of accuracy* and/or *completeness*. Recalculations always have to ensure consistency of the time-series. The inventories of an entire time-series, including the base year and all subsequent years for which inventories have been reported, should be estimated using the same methodologies, and the underlying activity data and emission factors should be obtained and used in a consistent manner. It is proposed that it is good practice to change methods when the method used is not according to good practice or does not sufficiently reflect the available national knowledge and data. It is also proposed that good practice is, whenever methodologies have been changed, to document the reason for changing the methodology and demonstrate that it is actually an improvement.

Reasons to change the methodology are changes in available data and methods, changes in good practice recommendations, increased importance of a source, changes in national conditions or changes in inventory resources. Criteria are also suggested for when a change in methodology is really an improvement. The criteria include accuracy, completeness, documentation, time series consistency and good practice guidance.

---

[1] Ketil Flugsrud and Kristin Rypdal (lead author) from Statistics Norway and William Irving from United States Environmental Protection Agency.

When methodologies are changed it is frequently difficult to maintain a consistent time series. Recalculations of the entire time series are required. Recalculations are also necessary when errors have been detected. This problem will increase as the protocol base year (often 1990) is becoming more distant in time. When it is impossible to use the same technique for every inventory year, options for splicing methodologies are extrapolations and interpolations, use of surrogate data, overlap of methodologies and use of constant estimates. Generally, it is difficult to splice methodologies when there have been large changes in emission factors or abatement.

The effect of abatement measures can be difficult to account for properly in the inventory. This is especially true for measures influencing the emission factors. In order to account for abatement, it is usually necessary to implement more rigorous (higher Tier) methodologies and perform surveys to show actual changes in activity rates. For key sources, whenever national emission factors are used these should be updated regularly to ensure consistency.

Due to limited resources, it is usually not cost effective to use the most accurate and resource demanding methodologies for all sources of the inventory. A *key source* is defined as one with high priority for obtaining better data within the national inventory system, because its estimate has significant influence on either the absolute level or the trend of the GHG emissions in a country. This will be sources contributing significantly to the total emission level and sources whose emission level is changing rapidly, but also other considerations can make a source key. In particular, sources with high estimate uncertainty may be considered key, even if the contribution to total emission is low. The reason is that much can be gained in reduced total uncertainty by improving these estimates.

The sensitivity analysis technique is useful for identifying and ranking the key sources with respect to level and trend. If the uncertainties of the sources are known, also each source's contribution to total uncertainty can be compiled. The paper gives practical guidance on how to identify the key sources by using a sensitivity analysis. Approaches at various levels of sophistication are suggested:

Tier 1a: Sources contributing over a certain threshold to total emissions
Tier 1b: Sources contributing over a certain threshold to total emissions or total trend or total uncertainty.

Tier 2a: A simple analytical sensitivity analysis
Tier 2b: A sensitivity analysis based on simulation methods

Taking the uncertainty into account is useful, as an improvement in the methodology for the more uncertain sources will be most effective for reducing the total inventory uncertainty. In this way these types of analyses may be a dynamical tool for inventory improvements.

The conclusion is that a limited number of sources are key in each country. Sources that are not identified as key according to the sensitivity analysis could be defined as key by individual considerations, e.g. due to abatement, expectation of future growth or other special considerations.

Also emissions from sources not identified as key shall according to good practice be estimated and reported. For these sources countries may choose among the good practice recommended methods. However, countries should be aware that resources spent on sources not considered key could conflict resources spent on the key. For the key sources the source specific good practice recommendations give guidance, that is frequently to implement a rigorous and data intensive method. It is only when the necessary data or other resources are absolutely unavailable that the countries should consider using a simpler method. The conclusion that data are absolutely unavailable implies that all possibilities of data collection have been tried. Countries are encouraged to collaborate closely with statistical offices, the industry and sector experts to collect data.

Contents

1. Introduction

Several IPCC/OECD experts meetings have during 1999 established guidance on good practice in emission inventory preparation for each source category of the 1996 Revised IPCC guidelines for greenhouse gas inventories (IPCC 1996). Good practice guidance has been provided on methodological choice for estimation and implementation, as well as reporting and documentation and quality assurance/quality control. Good practice recommendations have been provided for all levels (tiers) of the Revised Guideline methodologies, to allow for differing national circumstances. It has also been noted that the methods have different levels of accuracy, transparency and completeness, or in some cases, will lead to different conclusions. Frequently, but not always, the most accurate estimation methods are also the most resource intensive.

It is unlikely that most countries will be able to use the most detailed and accurate methods for all sources of the inventory, due to resource constraints. Consequently, the inventory agency will have to prioritise its resources. Most of the resources should be spent on the most important emissions sources with respect to the overall inventory quality and applications. Thus, this paper will address

- how to identify the important or key sources in an inventory, and
- how to determine which sources should be prioritised in terms of resource allocation

In addition, because inventory methods, data and resource availability are expected to improve within countries over time the paper will consider issues related to change in methodologies and inventory recalculations. In order to enable accurate assessment of emission trends, it is important that consistent methodologies are used over time, and thus where methods are improved the inventory for all years often need to be recalculated. Such recalculations can sometimes be difficult due to limited historical data or very resource demanding methodologies. Thus, this paper will address

- criteria for when changes in methodologies are appropriate or encouraged
- techniques to ensure consistent time series when methodologies are changed
- rules for how to account for changes in emissions due to the introduction of various abatement measures

2. Changes in methodologies and estimates

The Revised 1996 guidelines give options for choice of emission estimation methods, and use of national methods may also be according to good practice. Choice of methods is a dynamic process, taking into account key sources (see chapter 4), available methods and data, recommendations, and resources. Countries will therefore from time to time have good reasons to change their methodologies and earlier submitted estimates. It has been suggested by SBSTA[2] that such change in methods and subsequent recalculations are allowed in the reporting. However, the purpose of all recalculations should be the *improvement of accuracy* and/or *completeness* of the inventory. Countries should report and properly document justifications for these changes.

Recalculations of earlier submitted estimates are discussed in 3.1. The focus of this paragraph is the process of changing the methodology according to good practice.

[2] Subsidiary Body for Scientific and Technological Advice of the United Nation Framework Convention of Climate Change (UNFCCC).

2.1. When could and should methodologies be changed?

There are two aspects of changing the methodology. On one hand good practice is to demonstrate that the changed methodology is an improvement as required by SBSTA. On the other hand good practice is also to change methodology whenever a significant improvement is possible to achieve. In some cases bias might be introduced because the country is better off not changing the methodology. That implies that good practice rules are needed both for when the methodology *could* be changed as well as when it *should* be changed (2.1). The rules will be partly overlapping. Another set of rules is directed towards demonstrating *improvement of accuracy* and/or *completeness* (2.2).

We propose that methodologies or estimates *could or should be changed* if:

- **Available data have changed** (less or more or just different). Since the introduction of the first *IPCC Guidelines*, greenhouse gas inventories have been steadily improving. Inventory experts regularly accumulate new data sources, conduct surveys, initiate sampling programs, and working with the private sector to gather new information. More often, however, this new data leads to the improvement of the existing method rather than the adoption of an entirely new methodology. For example, if new data permits further disaggregation of a livestock enteric fermentation model, so that it now accounts more homogenous categories, this does not constitute a methodological change. This new data could, however, create a problem of time series inconsistency if new data are not available for previous years. If new data makes it possible to implement a more rigorous and accurate methodology according to good practice recommendations, then the methodology *should* be changed. For example, if a country that currently uses the most simple method (Tier 1) default emission factors is able to develop country-specific emission factors for livestock enteric fermentation, then the more advanced Tier 2 method should be implemented if this is a key source. Methods may also need to be changed if data collection is reduced or changed. This is not a desirable situation and it is good practice to try every attempt to avoid this situation.
- **National conditions have changed.** This implies that the assumptions originally made no longer are valid. Examples are assumptions about technologies in use or agricultural practises. Normally this implies that the method *should* be changed.
- **IPCC Guidelines have been revised**. Possible future revisions may lead to recommendations of new methods. Here new methods may be suggested, but the current methods may also remain recommended. This may imply that methods *could* be changed or *should* be changed, as *all* methodologies should be according to the guidelines.
- **The current methodology is not according to good practice for that particular source**. This requires change of methodology, as *all* methodologies should be according to good practice.
- **New methodologies have become available**. In the future, availability of new technology at affordable cost could improve the menu of methods for certain sources. For example, remote sensing technology may make it possible to estimate emissions from natural gas pipelines more accurately than by using simple production-based emission factors. In most of these cases, this implies that the method *should* be changed. In other cases, however, new methods may serve to verify emission factors rather than replace them.
- **A source formerly not considered key originally is now considered key**. A source considered to be not key in the base year may become important at a future point in the time series. For example, many countries are only beginning to substitute HFCs and PFCs for ozone depleting substances being phased out under the Montreal Protocol. This source may not be considered key for a 1990 base year, depending on the criteria used, but could become key after the year 2000. In this case, the most rigorous method should be used. If the trend is taken to account during the assessment of key sources, emission projections could be able to identify those sources with increasing or decreasing trends (see Section 4). Data necessary for the most rigorous methods should be collected for these sources, making the eventual adoption of the most rigorous method and its application over the whole time series possible. Normally this implies that the method *should* be changed.
- **Use of (significant) mitigation options not captured by original method**. In many cases only the higher (more sophisticated) tiers provide the possibility for taking into account mitigation

options. If mitigation is introduced, the country should consider whether this is reflected in the current methodology and should if necessary change their methodology.

- **Inventory resources have increased.** More resources will make it possible to spend more resources on each source and in that way improve the methodologies used. Also the country could have a long term plan to improve one or more sources every year by initiating studies.

Note that the list above is not complete, there may be additional reasons for changing methodologies.

2.2. How to document changes in methodologies and estimates?

Countries are by SBSTA encouraged to demonstrate that a change in methodology is an improvement. Good practice is whenever methodologies have been changed to document the reason for the change. It can be difficult to prove in a transparent manner that a change in methodology is actually an improvement. The change of methodology has been an improvement when all or most of the proposed criteria below are satisfied. Good practice is to document that these criteria are satisfied. It is strict to say that all the proposed criteria should be satisfied, but most of them should in order to conclude that a change is really an improvement.

- Accuracy is equal or higher (the uncertainty has not increased)
- Completeness is equal or better
- The new methodology is consistent with the 1996 Revised Guidelines or later revisions
- The new methodology is according to good practice guidance for that particular source
- The new methodology reflects national conditions better or equal
- The origin of all data and algorithms used in the new method is properly documented (new estimate is transparent)
- The entire time series can be recalculated and such a recalculations are performed according to good practice

3. How should time series consistency be ensured?

Whatever the reason for change in methodologies it may frequently be difficult to obtain a consistent time series. SBSTA has agreed that when methodologies have been changed or new sources have been included, new estimates shall be reported for the base year and all subsequent years, up to the year in which the recalculations are made. Furthermore: "Recalculations have to ensure consistency of the time-series. The inventories of an entire time-series, including the base year and all subsequent years for which inventories have been reported, should be estimated using the same methodologies, and the underlying activity data and emission factors should be obtained and used in a consistent manner. Where the methodology or manner in which underlying activity data and emission factors are gathered has changed, Parties[3] should recalculate inventories for the base and subsequent years".

The mandate of using the same method for all years will in some cases be impossible or extremely difficult. The reason may be that data for the estimation are lacking for all inventory years or that the methodology is too resource demanding to perform for every year. This problem will increase as the protocol base year (1990) is becoming more distant in time. An alternative for using the same data sources and methodologies every year is various techniques for splicing methodologies. Some possible good practice options for splicing methodologies are suggested in section 3.2.

[3] IPCC documents usually refer to Countries rather than Parties, but Party is used in this paper where the citation is directly linked to text in a SBSTA document.

3.1. Recalculations

Recalculations imply that a formerly reported estimate from a source category (one or all pollutants) is replaced by an estimate based on other methods and/or data. Recalculations may influence both the level and trend estimates.

Recalculations are always according to good practice if methodologies have been changed (see section 2), new sources have been included or errors have been detected and corrected. *Correction of errors* may be at several levels, emission factors, activity data and algorithms. Correction of data and recalculations of recent years may also occur as statistical data often are delayed so that the first emission estimates reported will have to be based on *preliminary data.*

When methods have been changed good practice will usually be to *recalculate the entire time series* based on a consistent set of input data. Recalculations are, however, not always necessary as a new method might give the same results as the former. This will have to be demonstrated. Good practice is to recalculate the entire time series, but special emphasis should be put on the base year (usually 1990).

Care should be taken when recalculations are made for sources where mitigation is introduced gradually (or other conditions are gradually changing). In these cases it has to be thoroughly checked whether recalculations are necessary for all years. See also section 3.3.

Suggested checklist for good practice recalculations:

- Are there any changes in the inventory from last reporting due to corrections of errors, inclusion of new sources, use of new data sources or changes in methodologies (see section 2 for a guidance on when changes in methodologies are appropriate or good practice)?
- Are the changes valid for all years? Recalculations shall not necessarily be performed for all years. Examples are sources not occurring every year, errors that not have been made every year or technologies not used all years.
- Have the estimates been recalculated for all years the changes are valid?
- Are all input data consistent between years? If not consider good practice for splicing methodologies (3.2).
- Can the estimate be made for every year? If not consider good practice for splicing methodologies (3.2).

Good practice is to report for which sources recalculations have been performed and the reasons (changes in methodologies or other reasons).

3.2. Splicing of methodologies

Recalculations are according to good practice as long as methods have been improved or errors corrected. However, in practice recalculations may be difficult as data are not available for the entire time series or the method is too resource demanding to perform for every year. Several techniques may be used to overcome this problem. It should, however, be stressed that the most accurate option is always to use the same method and a consistent set of data every inventory year. The option of splicing of methodologies implies that consistency of time series is approximated without using the same methodology or data for every year.

Typically, but not necessarily, the complete method and best data are available for recent years and not for the early part of time series. The examples reflect this, but the principles are applicable also for other cases. The methodologies below are not ranked, they may all be good practice depending on data and circumstances. However, when splicing is necessary care should be taken to choose the best option for this particular case and the choice should be properly explained and documented. No clear distinction is made between splicing due to discontinuity of input data and other problems using the same method for every year.

For a key source, the use of the same methodology throughout the entire time series should be strived as far as possible. For sources not considered key, splicing is a good option if the methodology is resource demand to perform or data are missing. For a key source, when method and data sources have been changed, and is impossible to use for every year, splicing of methodologies is according to good practice. For a key source, however, it will be according to good practice to check out several of the splicing methods suggested above for consistency.

For reporting countries should demonstrate that the time-series is consistent, and this is particularly important when the splicing options have been used. A simple graphical plot of emissions vs time and one or more relevant activity data is a quick way to detect inconsistencies. Such plots together with a comparison of the output of various splicing options and a discussion of the final choice is according to good practice for demonstrating that the time-series are actually consistent.

In general, few of the splicing methodologies are valid when technical conditions are changing throughout the time series e.g. as abatement is introduced. These can only be captured by using a complete methodology or have to be corrected for ad hoc.

Note that the splicing options are not only valid for recalculations, but also for ensuring consistent time series in general.

Overlap
Whenever the methodology is changed good practice is always to compare the output from the new and old method, both the level and trend. If the new methodology cannot be used for all years, an option is to use the overlap deviation to assess the time-series. If the first year with estimate from the new methodology is m, the new emission estimate for this year is y_m, and the original estimate x_m, then a revised emission estimate for the base year may be expressed as

$$x_0^* = x_0 \cdot y_m / x_m$$

This simple method follows from the following three requirements to the revised estimates:

1. Estimates with the new methodology are assumed to be most correct in all years of overlap between methods.
2. There should be no break in the time series between the revised original estimates and the new methodology, *i.e*, the combined time series is consistent.
3. The revised time series should be a simple scaling of the estimates from the original method. This is equivalent to assuming that the new methodology would give the same trend for the period as the original method (as yearly percent changes).

The third requirement may be inappropriate for some sources. For example, the difference between the new and original estimates might be assumed to be constant. In this case, the revised estimate for the base year should be estimated as

$$x_0^{**} = x_0 + (y_m - x_m)$$

If there is more than one year of overlap between the new and the original methodologies, the first two requirements leads to the conclusion that only the first year of overlap should be used for recalculation. If we relax the second requirement and accept a break in the time series, we can reformulate the first expression, replacing the simple ratio y_m/x_m with an average over the overlap period (n is the last year with estimates from both methodologies):

$$x_0^{***} = x_0 \cdot \left(\sum_{i=m}^{n} y_i \bigg/ \sum_{i=m}^{n} x_i \right)$$

It seems to be a conflict between the wishes on one hand to get a consistent time series without breaks, and on the other hand to use all information from the overlap of the methodologies (a break in time series is not according to good practice). However, if the trend is the same in both methodologies, *i.e.*, they differ only in level, then both methods for recalculating x_o will give the same result. If the difference in trend between the methodologies can be ascribed to random errors, then using only one year as the basis for rescaling may lead to bias, and the last expression using the average ratio should be used. If the trends are very different, then it may be more appropriate to use one of the extrapolation techniques described below.

Extrapolations and interpolations

If the methodology is too resource demanding to perform every year, suggested good practice is to perform a complete calculation for some years and interpolate for the years in between. A full estimate for the base year and Kyoto target years should be given priority. The interpolation could be arithmetic, but preferable simple corrections for variations in activity level should be made.

If an estimate for the base year not is feasible it may be extrapolated from the estimate most close in time using rate of change of activity and possibly other corrections. See "surrogate extrapolations" below for an equivalent description.

Surrogate extrapolations

When data are missing to estimate the emissions in the base year, surrogate extrapolations may be a useful technique. Data her can be activity data or measurements. The reason of missing data may be a changed data collection systems that has led to a non consistent time series, new data collection that does not include the inventory base year or former data collection that has been stopped. The extrapolation technique may also be used when the methodology is too resource demand to perform every year.

The technique relies on the possibility to find a statistical source that explains the time variations of the emission source in the best way. This is not necessarily the activity data actually used for the estimation (as this could be missing).

$y_0 = y_i * s_0 / s_i$

Where y is the emission estimate and s is the surrogate statistical parameter.

Care should be taken to find the best statistical parameter and it is recommended to try various options and compare the results. It is also possible to weight several of the options.

Two examples:

The emissions from aircraft are according to good practice estimated based on domestic fuel use for aviation. If this data is not available in 1990, but only for 1998, the emissions in 1998 may be extrapolated to 1990 using statistics on the number of passenger kilometres flown.

If emissions of a pollutant from an industrial process were measured in 1998 and not in 1990, production data may be used to extrapolate the 1990 emissions.

The extrapolation technique is based on the assumption that there have not been any technical changes. For the examples above, changes on fuel efficiency of aircraft or number of passengers per seat, or for the production example, abatement options would lead to wrong estimates.

Constant estimates
The same estimate may be used for all years of the inventory if the source is not considered key. Care should be taken to assess whether it is likely that this source will remain not key also in the future. If it is expected to grow much, the constant estimate technique is not according to good practice.

Two examples:
Emissions of CO_2 from liming of soils accounts for 0.01% of total national GHG in 1990. The estimate is based on a resource demanding data collection. The liming of soils is very stable and according to the agricultural authorities will remain stable. Use of the constant estimate technique is in this case according to good practice.

Emissions of HFCs accounted for 0.01% of national GHG is 1990. Use of HFCs are phased in to substitute ozone depleting substances. Consequently the emissions are expected to grow in the future. Use of the constant estimate technique is in this case *not* according to good practice.

For a key source the constant estimate technique is normally not according to good practice. That means that the constant estimate technique is only according to good practice when other techniques cannot be used and the source is not considered key.

3.3. Abatement measures

Abatement measures are directed towards various points of the emission generating chain. The effect of abatement measures can be difficult to account properly for in the inventory. This is especially true for measures influencing the emission factors. The reason is that it can be difficult to consistently measure the effect of technology changes on emission factors. That means that bias is easily introduced when an emission factor is changing over time. The bias may be an underestimation or an overestimation of the rate of change of the particular source. The effect on this on the entire inventory is discussed in part 4, trend errors.

Below we have grouped various types of abatement measures with a description on how to take the measure into account in the inventory. As a general rule, in order to account for abatement a more rigorous methodology (higher Tier) is needed to be implemented, as explained in the sections on determining key sources and choice of methods for these. Abated sources will frequently be identified as key sources according to the trend criteria.

Changes in activity rate
This is a measure relevant for all sources. It may simply be a reduction in production rate or technological using less input for a given production rate. Changes in activity rate will in most cases be reflected in statistical data and are directly taken into account in the inventory. For some sources good practice methods to estimate activity rates have been suggested. A general rule is that if the effect of abatement measures changing the activity rate cannot be measured directly they cannot be taken into account in the inventory. Surveys or register data are needed in order to show the trends in changing activity rates. Exceptions are in cases where source specific good practice guidance have special advises.

One example: If the amount of waste landfilled in a country is unknown, the amount may be estimated from factors giving waste generation per capita. These factors can, however, according to good practice *not* be reduced to account for changes in the waste generation pattern in the country. For this survey data need to be collected.

Changes in activity data may also include changes in behaviour and practices. This needs to be thoroughly documented in order to be taken into account in the inventory. Such documentation will be surveys or register data or indirect sources according to the source specific guidance on good practice.

Recovery
Recovery is used as an abatement measure for emissions of methane, HFC and SF_6 for particular source categories. These may be point sources or equipment. The use of this option is explained in the good practice guidance documents for each source. Frequently will the amount recovered of a gas be easy to measure directly, examples are landfills and HFC collection from refrigerators. For most cases it will be impossible to estimate the amount recovered if not known directly. Exceptions are in cases where an accurate good practice methodology is available for that particular source category.

Recovered gas may be incinerated or recycled. Care should be taken not to double count recycled gas.

Changes in emission factors due to changes in technology
This includes various options where there are changes in technology, installation of abatement or other influencing the emission factor (other than recovery). This type of abatement may be relevant for all sources.

Changes in emission factors should be introduced when there are clear reports on the use of new technology. Clear reports are well-documented reports from plants, importers and other relevant bodies.

Many of the good practice methodologies in the Revised IPCC Guidelines are directly technology based. The source specific good practice documents give guidance on how to apply emission factors. For most sources good practice may be to use well document national emission factors. However, it may be a problem when new technologies are introduced to maintain consistency in the time series. It is consequently important to update national emission factors regularly in order to keep track of the changes over time. How often need to be judged in each case from available resources, resource demand and the expected rate of change.

One example: In the base year no abatement was in use, but was being introduced later on. Measurements have only been performed for the abated emissions in 1997. In this case care should be taken not to introduce bias toward a too high reduction in emissions.

Note that abatement techniques may effect also other pollutants than they principally aim at, this may also lead to an increase in the emissions of some pollutants. Good practice is to take into account all these indirect effects.

4. Determining key sources

Each country should determine which of its national emission sources are important for their inventory conclusions, so that it can prioritise its resources and develope the best possible overall inventory estimates. Which sources these are will vary among countries. Some sources are likely to be identified in all countries (for example CO_2 from road traffic) while other sources e.g. specific production processes and rice cultivation may be absent or small in some countries and very important in others. As different sources have variable uncertainty, the contribution to total inventory uncertainty will also vary among sources. In the dynamic process of improving the inventory is it consequently essential to be able to identify the sources where choice of methodology is critical for the inventory applications. This chapter outlines criteria for determining which sources are to be considered key and describes how to apply them to national inventories.

4.1. Criteria for identifying key sources

Which sources are key will depend on the *inventory applications*. An accurate GHG emission inventory shall give as correct figures as possible for the level and trend of the emissions. In the following discussion a source is any combination of an IPCC source and pollutant.

For compliance assessments the trend is essential, while a correct level is important for scientific assessments, evaluation of the most cost-effective abatement measures and for several other applications. A key source is here defined according to the main applications of inventory data:

A key source is one with high priority for obtaining better data within the national inventory system because its estimate has significant influence on either the absolute level or the trend of the GHG emissions in a country

Thus, sources that contribute significantly to the total emissions and sources with rapid changing emission level should generally be considered key. Other considerations can also make a source key, such as:

- sources with a high estimated uncertainty, even if the contribution to total emission is low
- sources where national emission factors used are far lower than the information given in the 1996 Revised IPCC guidelines implies
- sources being abated when the simple IPCC methodologies not are detailed enough to detect mitigation options, and
- sources where future growth or decrease is expected

4.2. Description of methods for identifying key sources

Technical criteria
Several technical methods may be used to identify important sources.

The simplest method (Tier 1a) is simply based *on a source contribution to total emission*. The threshold is defined at a level where 90 % of total uncertainty in level and trend, respectively, are accounted for in most inventories. This will identify all key sources, but also some that are not key. It will, however, not give any insight into why these sources are important nor to special national inventory features.

The more accurate method (Tier 1b) gives more insight into the inventory. A key source with respect to level determination is defined as a source contributing over a certain threshold to total emissions or total uncertainty. Similarly, a key source with respect to effects of source level to total trend is a source which trend offset (source trend - total trend) weighted by the fraction of total emissions is higher than a certain threshold. The thresholds are defined at a level where 90 % of total uncertainty in level and trend, respectively, are accounted for in most inventories.

The thresholds suggested for the Tier 1a and 1b analysis are based on analysis of data for some countries.

The applications of the Tier 2a and Tier 2b sensitivity analysis techniques may give further insight into the inventory as they may take into account special features of the national inventory and are more flexible.

The methods described above are based on a set of model type errors. These are

- Errors in levels of individual sources influencing the total level estimate
- Errors in levels of individual sources influencing the total trend estimate
- Errors in trends of individual sources influencing the total trend estimate

See appendix A3 for a further explanation of these types of errors.

Other criteria
In addition to the level and trend criteria identified above, also other criteria should be considered for identifying key sources. These will be more dependent on national circumstances and specific inventory applications. Other criteria are:

- the need to take into account special circumstances and abatement measures
- to demonstrate or prove that emissions from a source are lower than information in the Revised 1996 Guidelines and activity level should imply
- the expectation of future growth
- other special considerations and applications

These other criteria cannot be directly evaluated (for example using the sensitivity analysis), but requires a manual evaluation.

4.2.1. Technical criteria: Overview of methods

A sensitivity analysis may be defined as *the computation of the effect of changes in input values or assumptions on the output* (Morgan and Henrion 1998). More specific, the purpose of a sensitivity analysis for an inventory compiler is to identify which individual parts of the inventory that might influence their conclusions on total GHG level and trends.

The conclusions that can be drawn from a sensitivity analysis are very limited if they cannot be related to uncertainties. A high sensitivity for a change in input parameter/emission estimate is more serious if this input parameter/source is uncertain. Sensitivities should consequently if possible be related to uncertainties, either nationally derived or default uncertainties. When interpreting the results the elasticity and uncertainty importance should be regarded as complimentary information. The elasticities give the main contributors to output and conclusions, while the uncertainty importances give the sources contributing most to total uncertainty (where most is gained by reducing the uncertainty).

One example: CO_2 emissions from energy production will in most countries contribute to a large fraction of total national emissions and in this respect be a key source. However, the uncertainty in emission factors and activity data is usually low even using a Tier 1 estimation methodology. That means that the contribution to total uncertainty is low and little is normally gained by improving the methodology with respect to reducing the total inventory uncertainty. In most inventories N_2O from agriculture will constitute a smaller fraction of total emissions, but will contribute much to the total inventory uncertainty. Much would be gained by reducing the uncertainty in this source.

These types of information may be used in the dynamical process of reducing the uncertainty of the entire national inventory.

If a country finds that performing a full sensitivity analysis is too resource demanding, this paper has suggested two sets of simpler methods based on fixed criteria (Tier 1), one very simple (Tier 1a) and one that is more accurate (Tier 1b).

The Tier 2a sensitivity analysis approach is to check the sensitivity of each input source on the output. The Tier 2b sensitivity analysis approach allows considering each input parameter (emission factor and activity data) separately as well as joint effects by using a stochastic simulation approach.

The options for approaches, rough resource demands and their advantages and drawbacks are illustrated in Table 1.

Table 1. Different approaches for identifying key sources.

	Method	**Resource demand**	**Advantage**	**Drawback**
Tier 1				
Tier 1a	Simple short cut criteria	Less than one hour	Demands few resources	Does not give any insight on how to improve the inventory. Cannot consider contribution to uncertainties.
Tier 1b	Accurate short cut criteria	Less than a day	Rather quick to use, suited for standard reporting and gives some insight to potential for inventory improvements	May loose special inventory features. Cannot be combined with an uncertainty analysis.
Tier 2				
Tier 2a	Sensitivity analysis	A few days	The easiest way to get insight into special national inventory features.	Less suited for standard reporting. Cannot be combined with an uncertainty analysis.
Tier 2b	Sensitivity analysis	More than a week	May be combined with an uncertainty analysis. Can be used for a detailed analysis. Can take into account joint effects of more than one input parameter.	Less suited for standard reporting Resource demanding

Technical methods to perform sensitivity analysis are sketched in Appendix A1. The basic level of analysis is the IPCC aggregated standard reporting format (table 7A). However, countries are encouraged to modify the level to reflect the methodologies being used. If the analysis is performed at a more disaggregated format care should be taken to check that data based on the same assumptions and methods not are too disaggregated or that appropriate correlations are accounted for. The sensitivities of input parameters should be related to the total emissions weighted with the GWP values. Sensitivities in trends should be scaled as reflected in the formulas in 4.2.2.

4.2.2. Tier 1 sensitivity analysis

The suggested limits given below for identifying key sources are based on the assumptions and data explained in appendix A4. The limits are based on an analysis of reported data and uncertainties. The suggested limits will for most countries cover 90 % of the uncertainty in level and trend.

There are two set of Tier 1 methods suggested to identify important sources.

Tier 1a

This method is simply to identify the sources that contribute over a certain threshold to total emissions. The suggested threshold will cover 90% of the uncertainty in most inventories.

An key source is a source that accounts for *more than 0.2 % of total emissions*.

This will cover all types of errors (level, level-trend and trend-trend), but will also identify sources that are not really key. While this criterion will identify all the key sources, it does not give any insight into *why* they are key. Furthermore, the uncertainty importance cannot be analysed. The uncertainty importance is useful for selecting the appropriate inventory improvements. The Tier 1a method may consequently be suited for reporting, but not a tool for inventory improvements.

If the threshold is made less strict, e.g. 0.5% of total emissions, the sources important for trend determination will not be identified for most countries. The threshold could also be made more strict. A threshold of e.g. 0.1% will in most countries identify more sources as important and cover more than 90 % of total uncertainty. However, it seems that little is gained with respect to contribution to total uncertainty by this strict criteria. These points are illustrated in table 2 and figure 1 and 2.

Table 2. Contribution to total emissions in some countries

Country	**0.1% of total**	**0.2% of total**	**0.5% of total**	**1% of total**
United States 35 sources	21 sources	14 sources	10 sources	7 sources
Australia 23 sources	17 sources	14 sources	9 sources	6 sources
Ukraine 22 sources	17 sources	15 sources	11 sources	7 sources
Philippines (18 sources no high GWPs)	15 sources	14 sources	12 sources	11 sources

Source: UNFCCC

Tier 1b
The criteria in the following sections for identifying key sources take level, trend, and uncertainty into account. That means that the identification of key sources will be more specific than for Tier 1a, and that it will give more insight into how the inventory may be improved. Tier 1b also takes uncertainty into account. If the uncertainty is low, the criteria may be relaxed, as little will be gained in overall inventory uncertainty by reducing these uncertainties.

There are three criteria. The source is a key source if *at least one of them is fulfilled.*

a) Sources whose level has significant effects on the total emission and its uncertainty

- *A key source with respect to effects of level to total level is a source whose emission is more than 0.5 % of the total emission of GHG.*
- *If the quality is known to be high ($2 \cdot \sigma$ less than 20%), only sources with emission of more than 2.5 % of the total emission are considered as key.*

b) Sources whose level has significant effects on the total trend and its uncertainty

- *A key source with respect to effects of level to total trend is a source for which standardised trend offset weighted by the fraction of total emission,* $[(1 + (t_i - T))^{20/n} - 1] \cdot e_{i0}/E_0$, *is more than 0.5%-points.*
- *If the quality is known to be high ($2 \cdot \sigma$ less than 20%), only sources with values above 2.5%-points are considered as key.*

c) Sources whose trend has significant effects on the total trend and its uncertainty

- *A key source with respect to effects of trend errors to total trend is a source for which the end year emission as a fraction of base-year total emission,* $(1 + t_i)^{20/n} \cdot e_{i0} / E_0$, *is more than 1%.*
- *If the quality is known to be high ($2 \cdot \sigma$ less than 20%), only sources with values above 5% are considered as key.*

Note: In the last criterion, one should in principle use the additional uncertainty σ_1 of the end year level. However, no data on this uncertainty were available. The general uncertainty σ was therefore used as a surrogate, and the limit at 20% was set accordingly.

List of variables:

E_0	= total emission in the base year
e_{i0}	= emission from source *i* in the base year
T	= total trend = $(E_1 - E_0) / E_0$, where E_1 is total emission in the end year
t_i	= trend of source *i* = $(e_{i1} - e_{i0}) / e_{i0}$, where e_{i1} is source emission in the end year
n	= period between base and end years used in the analysis, in years
σ	= uncertainty (standard deviation) of source emission

4.2.3. Analytical approach: Tier 2 Sensitivity analysis

Two main techniques for sensitivity analysis may be defined: one based a simple algorithm (Tier 2a) and one based on stochastic simulations (Tier 2b). These two approaches are expected to give essentially the same results. The advantage of the simple approach is that it is quick to apply and does not require special software. The advantage of the stochastic simulation technique is that it can be combined with an uncertainty analysis and that it may consider joint effects of more than one source.

Using the Tier 2 sensitivity approach there are no fixed criteria on when the source is key. Sources may be added up until a certain amount of uncertainty is accounted for. 90% is suggested as a general rule. The Tier 1 methods described above are special cases that simply use threshold values for one or more of the elasticities to define the key sources.

Tier 2a sensitivity analysis uses the elasticities of total level and trend with respect to source level and trend, which are described in Appendix A1. The sources may be ranked by their elasticities. Sources may then be defined as key until, say, 90 % of the total elasticity is obtained. Tier 2a also includes the possibility to include uncertainty importance elasticities if estimates of source uncertainty can be obtained. Again, the sources may be ranked by their uncertainty importance elasticities to identify and rank which sources contribute most to the total uncertainty.

The *Tier 2b* approach will differ from Tier 2a in that all individual parts of the inventory may be directly included (emission factors and activity rates separately), it allows to see the joint effect of all input parameters and it may incorporate uncertainties, function shapes and dependencies between parameters into the analysis.

Several methods exist to perform such analysis. The methods will require information on the uncertainty of each input parameter and the distribution density (in analytical or empirical form). See background paper no. 1 for this workshop for a more detailed description of the various approaches.

4.2.4. The criteria and level of analysis

The following considerations are important for all types of analysis, both the simpler and the more sophisticated.

Level of aggregation

The output of a sensitivity analysis (and the criteria) is very dependent on what aggregation level it is performed on.

It is suggested that the *basic level* of the analysis should be to identify the key sources at the level of *IPCC standard summary table*. It may, however, be a concern that this summary table not necessarily is balanced, that it is more detailed for some sources than others (depending on the national source mix). Further levels may also be investigated (that is at a *more disaggregated* level than the IPCC standard summary table), but at that level the conclusion will easily be that few sources are really key. This could partly be a correct conclusion, but may also mask the fact that the same methods (and also assumptions and emission factors) are frequently used for several of the disaggregated source categories.

The recommendation is that the analysis is performed at the level of IPCC standard summary table. The Tier 2b sensitivity analysis could be performed at a more detailed level. The level should be carefully chosen from national circumstances and level of methodologies chosen. For example if the Tier 2 approach is used to estimate methane emissions from cattle, while Tier 1 for other animals, cattle and other animals should be distinguished in the analysis. Care should also be taken to introduce sufficient dependencies (correlations) between emission factors and activity data wherever appropriate. For example are frequently the same emission factors used for several sources, the same activity data are used for more than one source or some activity data is determined as a residual. If this is not accounted for the conclusions of the analysis will be wrong.

GWPs

The GWP values should be fixed in the analysis as they are fixed in the Kyoto protocol.

Time horizon and standardisation of trend

The sensitivity on trend will depend much on the *time horizon*. There are two reasons for this. An inventory covering several years will be more sensitive to input errors than when a shorter period of time is considered. That means that if a sensitivity analysis is performed on a data set covering only a few years, or a data set very different from the data set in the compliance period this will not be useful for assessing the key sources. This can be accounted for by scaling the data set for a shorter historical time period. The other reason is that the source mix will change over time due to abatement and economic growth. Consequently, the most accurate result would be obtained if the analysis were performed on a data set that is as close to the future 2008-2012 data as possible, that will today be the projections[4]. However, projected data are of variable quality and may be unsuited for such an analysis. This implies that historical data usually are preferable and must be scaled.

The trend terms, $t_i - T$ and $1 + t_i$, depend highly on the period between the base year and the end year in the analysis. In order to standardise the accurate short cut criteria the trend terms are transformed to a 20 year interval corresponding to the period 1990-2010. If the period between the base and end years of the analysis is n years, the standardised trend terms are given as follows:

- Trend offset: $t_i - T$ Standardised value: $(1 + (t_i - T))^{20\ n} - 1$
- Overall trend $1 + t_i$ Standardised value: $(1 + t_i)^{20\ n}$

4.3. Example on how to identify a key source

As an example of how the identification of important sources can be performed, we present some analyses of the inventory data reported by the United Kingdom. The reported emissions are shown in appendix A5 (also uncertainties used).

The results from the Tier 1a analysis is shown in table 3. Out of 35 non-zero emission estimates, 21 are included as important with the suggested limit of 0.2 % of total emission. These 21 sources account for more than 99 % of total emissions. The table also includes data on cumulative uncertainty from a sensitivity analysis which show that these 21 sources account for more than 97 % of all the uncertainties in this inventory.

Table 3. Key sources* in the GHG inventory of the United Kingdom identified by the Tier 1a sensitivity method. 1996.

Fraction of emission:	Number of key	Cumulative fraction of			
		Emission	Uncertainties in effects of		
Limit for inclusion	sources		Level to level	Level to trend	Trend to trend
2 %	9	92.1 %	88.2 %	49.1 %	72.8 %
1 %	11	94.4 %	89.6 %	49.4 %	73.9 %
0.5 %	15	97.4 %	92.1 %	56.9 %	75.1 %
0.2 %	**21**	**99.3 %**	**98.5 %**	**97.3 %**	**98.4 %**
0.1 %	24	99.6 %	99.2 %	98.0 %	98.8 %
0.05 %	28	99.9 %	99.8 %	98.4 %	99.4 %
>0	35	100.0 %	100.0 %	100.0 %	100.0 %

Note: The uncertainties are taken from a simple analysis. HFC, PFC and SF_6 were not analysed

For comparison, the results with other limits are also shown. Since most of the emission and uncertainty is included with the 0.2 % limit, lowering the limit has little effect. However, when the limit is increased, the proportion of the trend uncertainties drops rapidly. The reason is that N_2O emissions from transport, with 0.4 % of total emissions, is lost with the higher limits. This source is highly uncertain and rapidly increasing. Thus, it has a major contribution to the uncertainties of the total trend.

In fact, for the UK 1996 inventory, a limit of 0.4 % would have been sufficient to include 16 sources that account for more than 90 % of all uncertainties. The 0.2 % limit was chosen on the basis of the inventories analysed in appendix A4.

[4] When using projections for this analysis, *the projected data are used as if they were historical.* That means that it is assumed that the uncertainties of the data are as in the base year or another historical year.

The results from the Tier 1b analysis are shown in table 4. By these criteria, 13 sources are included as important. As this analysis is more specific, fewer sources are identified as important. This is a more correct conclusion than can be drawn from the Tier 1a analysis. All 13 sources were, however, also identified in the Tier 1a analysis with the 0.2 % threshold.

Table 4. Key sources* in the GHG inventory of the United Kingdom by the Tier 1b sensitivity method. 1990-1996. Shaded when indentified.

		Effects of source level to total level			Effects of source level to total trend		Effects of source trend to total trend	
Comp./ Source	Source un-certainty	Elasticity: Fraction of total emission	Un-certainty import-ance elasticity	Trend (unstan-dardised)	Elasticity: Weighted trend offset (abs. value)	Un-certainty import-ance elasticity	Elasticity: Weighted overall trend (abs. value)	Un-certainty import-ance elasticity
	$2\sigma_i$	$U_E(e_i,E)$	$U_{GE}(e_i,E)$	t_i	$U_E(e_{i0},T)$	$U_{GE}(e_{i0},T)$	$U_E(e_{i1},T)$	$U_{GE}(e_{i1},T)$
		$=e_i / E$	$=U_E(e_i,E) \cdot 2\sigma$	$= (e_{i1}-e_{i0}) / e_{i0}$	$= e_{i0} / E_0 \cdot (t_i - T)$	$=U_E(e_{i0},T) \cdot 2\sigma$	$= e_{i0} / E_0 \cdot (1 + t_i)$	$=U_E(e_{i1},T) \cdot 2\sigma / 5$
Limits for inclusion:								
- high quality sources ($2\sigma_i / e_i < 20\%$)		2.5 %			2.5 %		5 %	
- other sources		0.5 %			0.5 %		1 %	
CO_2 1A1 Energy industries	6 %	27.4 %	1.6 %	-13.5 %	7.0 %	0.4 %	18.4 %	0.2 %
CO_2 1A2 Manufacturing and construction	6 %	12.6 %	0.8 %	-3.0 %	1.1 %	0.1 %	11.0 %	0.1 %
CO_2 1A3 Transport	6 %	16.7 %	1.0 %	5.2 %	6.2 %	0.4 %	17.7 %	0.2 %
CO_2 1A4 Other sectors	6 %	17.5 %	1.0 %	13.6 %	11.7 %	0.7 %	22.2 %	0.3 %
CO_2 5B Forest and grassland conversion	50 %	3.4 %	1.7 %	-6.7 %	0.1 %	0.1 %	2.7 %	0.3 %
CO_2 5E Other	50 %	0.5 %	0.3 %	0.0 %	0.1 %	0.0 %	0.5 %	0.0 %
CH_4 1B1 Solid fuels	50 %	1.0 %	0.5 %	-58.7 %	2.0 %	1.0 %	0.1 %	0.0 %
CH_4 1B2 Oil and natural gas	28 %	1.3 %	0.4 %	-7.8 %	0.1 %	0.0 %	1.0 %	0.1 %
CH4 4A Enteric Fermentation	20 %	2.7 %	0.5 %	-1.4 %	0.4 %	0.1 %	2.5 %	0.1 %
CH_4 6A Solid waste disposal on land	39 %	4.9 %	1.9 %	-9.0 %	0.5 %	0.2 %	3.7 %	0.3 %
N_2O 1A3 Transport	170 %	0.4 %	0.7 %	142.9 %	3.3 %	5.7 %	3.2 %	1.1 %
N_2O 2B Chemical industry	250 %	3.0 %	7.5 %	-26.2 %	2.0 %	5.1 %	1.4 %	0.7 %
N_2O 4D Agricultural soils	300 %	4.0 %	11.9 %	-5.3 %	0.1 %	0.2 %	3.3 %	2.0 %
Sum all sources		100.0 %	31.7 %	-5.8 %	37.0 %	14.5 %	91.2 %	5.7 %
Sum all important sources		92.6 %	29.3 %		34.2 %	13.8 %	85.3 %	5.3 %
Contribution from important sources		92.6 %	92.4 %		92.5 %	95.1 %	93.5 %	92.4 %
Sum important sources for this criterion		92.2 %	28.5 %		32.7 %	13.4 %	84.7 %	5.2 %
Contribution from important sources		92.2 %	90.0 %		88.5 %	92.4 %	92.9 %	91.3 %

*HFC, PFC and SF_6 were not analysed

For each source and criterion, the table shows the criterion value (elasticity: left column in each box) and the uncertainty importance elasticity (right column in each box). The latter value equals the criterion value times the uncertainty. The trend for the 6 year period is also included. Note that the uncertainty is given as two standard deviations, and that the trend uncertainty used for the effects of trend errors was set to 20% of the level uncertainty. The hatched cells show values above the criteria limits, identifying the important sources.

The table shows that sources accounting for 90 % of uncertainty were identified for all three criteria. Most of the sources were identified using only the first criterion: source emission as fraction of total emission. The only additional source that was identified by the other criteria was N_2O from transport. However, the table shows that this source is increasing rapidly, and it accounts for major parts of the uncertainty importance elasticity of the total trend. On current trends, the 2010 emission will equal 3 % of the 1990 total. This demonstrates the importance of including trend terms for identification of important sources.

The table also shows which sources contribute most to total uncertainty. For example nitrous oxide from agriculture contributes to about 1/3 of total uncertainty in level. Nitrous oxide from road transport and chemical industry contribute to more then 2/3 of the trend uncertainty. These three sources are also those where individual trend uncertainties potentially influence the conclusions.

The sources identified by the statistical procedure are the *minimum* number of important sources. Further sources could be added to the list as important. This will, however, require more detailed knowledge of the particular inventory according to the following checklist:

- Are there sources where special circumstances, e.g. abatement measures will require a more detailed methodology?
- Are there any sources that are far less important than the information in the Revised 1996 Guidelines and activity level should imply?
- Are there any sources that are expected to grow in the future (this is in principle covered by the trend criteria if projected data are used)?
- Are any of the sources far bigger in intermediate years than in the years used in the analysis?
- Does any of the sources require special consideration due to their inclusion in flexible implementation mechanism?
- Are there other considerations to make any of the sources important?

4.4. Reporting issues of choice of key sources

Each key source should be labelled as such, so those sources that are not labelled key are assumed to be less key. For each key source, there should be an identification of all criteria by which it was deemed to be key (e.g., level, trend, uncertainty etc.) and the methodology (Tier) used for the identification.

For quantitative criteria, there should be documentation of the analysis performed and the results should be listed in a table similar to Table 1 in this paper for the UK inventory. This table should include:

- Source information (base year estimate, most recent year estimate, uncertainty, source trend)
- Total inventory information (base year estimate, most recent year estimate, uncertainty, inventory trend)
- Sensitivity results

    Sources contributing by more than 0.2 % to total emissions (as the simplest)
    and preferably also:
    Elasticity of total level with respect to source emission level
    Elasticity of total trend with respect to source emission level.

Elasticity of total trend with respect to source trend.
Uncertainty importance elasticity of total emission with respect to source emission level.
Uncertainty importance elasticity of total trend with respect to source emission level.
Uncertainty importance elasticity of total trend with respect to source trend.

For qualitative criteria such as the potential for source reductions, documentation should include qualitative information on the source describing the reason for being key or not key.

It should be emphasised that estimates should be made and reported for all sources (also those that are not considered key). It should be demonstrated using a good practice approach that a source is not considered key. Otherwise this source should be reported NE (not estimated).

5. Prioritisation of methods: Source-level evaluation

An inventory compiler has limited resources and for obtaining a high quality inventory it is important to first prioritise the resources on the parts that are most essential to the inventory output, the key sources as described in chapter 4.

The source specific good practice documents form basis for the choice of methods for each source. According to these documents and methodological decision trees, simpler methods are often appropriate for sources not considered key. Further practical guidance will be given in the following.

5.1. Starting point: key sources and other sources

The analysis in this section takes as a starting point the results in chapter 4 in determining which sources are to be considered key, for the purposes of methodological choice. For those *sources that are not considered key*, good practice is to implement a suitable methodology given national data and resource constraints. In other words, for a source that is *not* considered key good practice may be to implement a sophisticated data-intensive method, *or* to produce a well-documented estimate using a Tier 1 or default methodology, in both cases provided that the good practice recommendations for each source are followed. From the standpoint of resource availability, preparing basic estimates does usually not require a large amount of resources. However, the country should be aware that doing a data intensive method for a not key source could take resources away from doing a data intensive method for a key source.

5.2. Choosing the good practice method for key sources

For each key source, it is proposed that countries should use the method recommended for key[5] sources as shown in the source specific decision tree. This method will frequently be the most rigorous method and the highest tier considered feasible by the IPCC experts in the Good Practice guidance material for each source. For some sources, the highest tier that is considered feasible will not be the most technically advanced method. For example, the most rigorous method recommended by good practice for open-pit coal mines is to use country or basin-specific emission factors, because continuous emission monitoring of open-pit mines, while technically possible, would require an unreasonably large amount of resources. While there are likely to be exceptions to the rule, generally the most rigorous method will involve more data and more resources than less rigorous methods. There are also examples where little is gained by using more advanced methods (e.g. aircraft and shipping), and where countries need to weight the gain against the labour.

[5] These are frequently named "important" sources in the decision trees and documents.

Consequently, as a general rule countries should make every effort to devote the necessary human resources to implement the good practice recommended methodology for key sources. *It is only when the necessary data or other resources are absolutely unavailable that the countries should consider using less rigorous methods*. Data may be available for some years, though unavailable for several years. Prior to concluding that data is absolutely unavailable, countries should identify the reasons why it is unavailable and consider possible solutions. Some of the most common reasons for data unavailability are described below, along with possible responses:

1. *The data have never been collected in the past:*

   Example 1: Some data sets are not useful for any application other than estimating greenhouse gas emissions (e.g., the size and capacity of the bank of electrical equipment using SF_6 gas), and thus may not have been collected previously. In other cases, a country has wanted to collect the data for other purposes, but has been unable to do so because of resources constraints (e.g., synthetic and organic fertilizer applied to soils). The first step is to assess the feasibility of collecting the data needed for the most rigorous method. If obtaining the data will divert an inappropriately large amount of resources away from other key sources, then collecting data is not feasible. The institution responsible for inventory management should seek collaboration to facilitate relevant data collection. Statistical offices may for example frequently more cheaply provide possibilities for data collection by redesign or additions to already existing surveys. Statistical offices frequently also has a juridical basis for the data collection. For some type of data collection full surveys of all units are needed, in other cases sample surveys are sufficient. Already existing data can also form a basis for assessing the needed activity data. Sector experts should be contacted for expert estimates. It should be noted that experts during the good practice sector workshops took resource availability into account in recommending the most rigorous methodology, and a developed country not undergoing economic transition, is expected to spend the required resources collecting data needed for their protocol reporting requirements.

   Example 2: Many rigorous methodologies require periodic surveys in order to establish a foundation for estimates in future years rather than annual surveys. Extrapolating survey data through the use of available drivers produces estimates for non-survey years. Examples of this include a detailed survey of natural gas facilities to determine activity data and emission factors for different pieces of equipment, or the development of disaggregated methane emission factors for livestock enteric fermentation. Since this data should be used over a period of possibly five years, the feasibility assessment should view the cost as borne over the whole period, rather than just the year in which the data were collected.

   Example 3: In some situations, it may be feasible to estimate, extrapolate, or use proxy data when actual data are unavailable. For example, the experts at the IPCC waste workshop recommended the Tier 2 method for estimating methane emissions from solid waste disposal sites. This method requires historical waste disposal rates for up to 25-40 years, but countries may have waste disposal date for only a portion of this period. It is possible to correlate current waste disposal rates with GDP or GDP/capita, and fill in the missing data for historical years. This technique should be used only in situations where it does not seriously compromise the methodology or lead to bias. Simply "guessing" or inventing data is not good practice, and will likely lead to an estimate that is less desirable than that produced by using a less rigorous method.

2. *The data have been collected by the private sector but are considered confidential:*

   Example 4: Particularly for industrial process emissions, private sector firms may have declined to divulge data that could lead to the disclosure of confidential business information. Private firms are concerned about the information that can be gleaned from emission estimates, rather than the emission estimates themselves. For example, the estimate of emissions of HFC23 from a competitor's HCFC-22 production plant does not in itself reveal confidential business information. Rather, the concern is that production data might be revealed. In this case, a third party should be allowed to have access to confidential data in order to estimate of emissions using the most rigorous method (in this case the HCFC-22 plant specific measurement method). Countries should seek close collaboration with the industry. As reporting is required, the industry will often also have the interest in reporting the correct data and not a guess or estimation. Furthermore, data may be confidential soon after the period they refer to. However, as the data gets historical industry might not have objections in publishing. It is important to document properly where confidentiality is a problem. The inventory compiler may also collect confidential information, but only report it in an aggregated form so that confidential information (e.g. production data in individual companies) cannot be revealed.

3. *The data are available but not in a usable format:*

   Example 5: Customs officials may keep accurate data on imports of aerosol products that are essential for calculating emissions from substitutes for ozone depleting substances (ODS substitutes). Typically, this data will not discern between aerosol products containing HFCs and products containing CFCs or other chemicals, and thus can not be used to estimate HFC emissions. It may be possible to make arrangement with customs officials to record additional information.

   Example 6: If another government agency or department collects data, it may be possible to make arrangements to modify the way data are collected or reported. For example, the agency that tests automobiles for emissions of NO_x, CO, and lead emissions may also be sampling but not reporting N_2O emission rates. It should be possible to arrange for the reporting and the necessary QA/QC of these data without expending a large amount of resources.

If after assessing the possibility of obtaining data for the most rigorous method and data proves to *absolutely unavailable*, a country decides that a less rigorous method is the only option available, then this decision should be documented and reported. Documentation should include an assessment of the feasibility of obtaining the data, and how this assessment led to the decision not to choose the most rigorous method. The documentation should also include an indication of the potential to obtain the data in future years and adopt a more rigorous methodology.

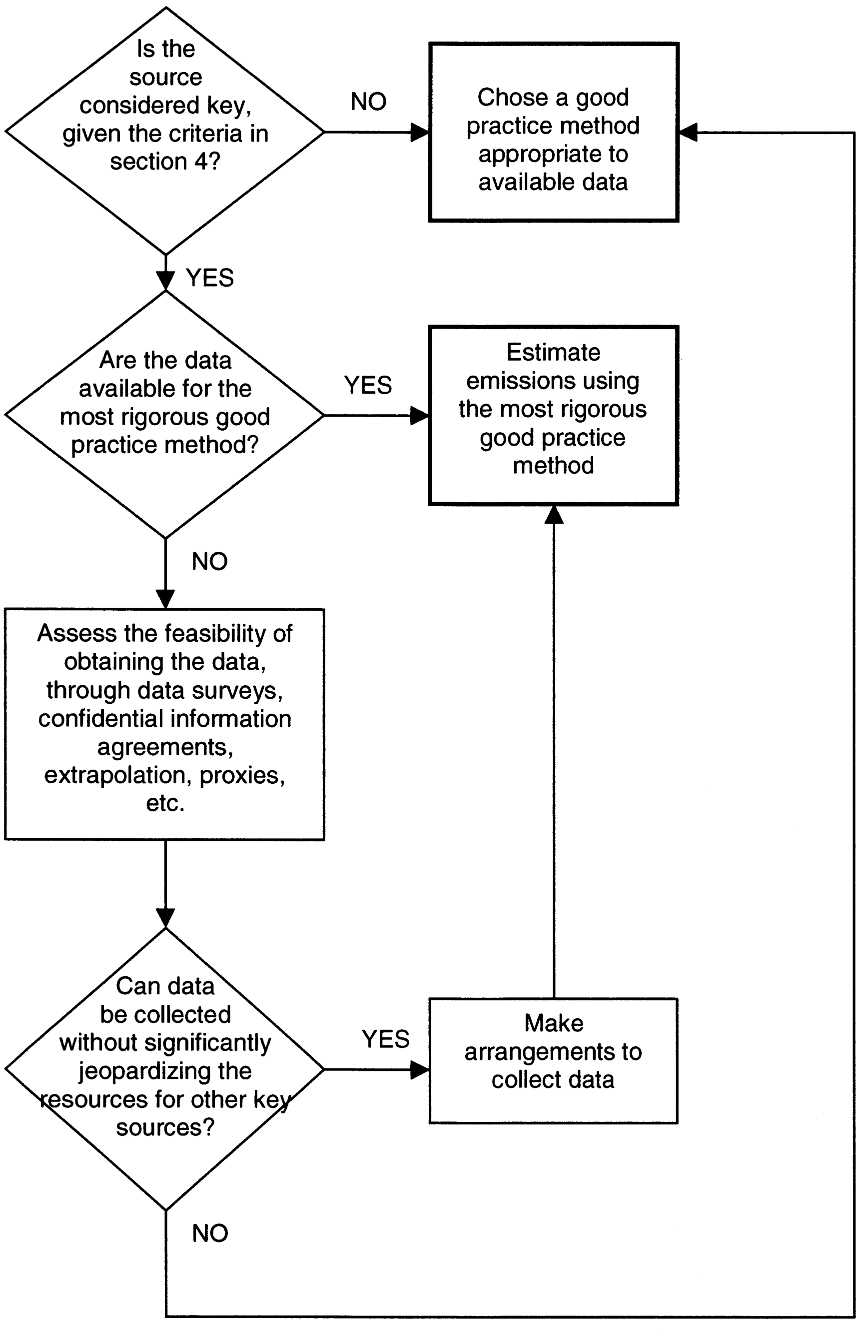
5.3. Analytical process for prioritising among key sources

The inventory agency should estimate the total resources required to implement the good practice methods for all key sources, and also the total resources needed to implement alternative methods. If the total resources required for implementing the good practice methods in all cases is less than or equal to the available resources, then there is no reason to prioritize. If available resources fall short, however, than new criteria are needed to guide the allocation of resources. The same criteria used to determine key sources could be used to prioritize among them:

- Level: Resources could be allocated to the largest sources first, and then to successively smaller sources until they are exhausted.
- Trend: Resources could be allocated to those sources with the greatest impact on the trend, as determined by elasticity with respect to source emission level, or source emission trend.
- Uncertainty: Resources could be allocated to the sources with the largest uncertainties as determined through quantitative analyses or default values.
- Some sources such as CO_2 from energy will be key in each country and could automatically require the necessary resources. Beyond CO_2, however, there may not be other sources in this category.

These criteria could be used in combination with an assessment of the relative potential gains available for each source by using the most rigorous methodology. In some cases, such as emissions from aviation the most rigorous and data intensive method may not lead to a significantly more accurate final estimate. While it may not be possible to quantify these potential gains in accuracy, it should be possible to estimate the relative impact of these changes (e.g. which improvements are likely to be the most significant), and then compare these results with the various elasticities calculated according to section 4. For example, if the natural gas sector is a significant source, there are large potential gains in accuracy in moving from a Tier 1 method to a detailed Tier 3 method. Implementing the Tier 3 method requires an expensive survey of natural gas infrastructure, but this may produce more benefit to the overall inventory than improving the estimate for CO_2 emissions from energy combustion.

It is also important to remember that other considerations than increased accuracy may be gained by changing methodology (see section 2.3).


Is the source considered key, given the criteria in section 4?
NO
Chose a good practice method appropriate to available data
YES
Are the data available for the most rigorous good practice method?
YES
Estimate emissions using the most rigorous good practice method
NO
Assess the feasibility of obtaining the data, through data surveys, confidential information agreements, extrapolation, proxies, etc.
Can data be collected without significantly jeopardizing the resources for other key sources?
YES
Make arrangements to collect data
NO

References

Granger Morgan and Max Henrion (1990): Uncertainty: A Guide to dealing with uncertainty in quantitative risk and policy analysis. Cambridge University Press 1990. 1998 reprint. ISBN 0-521-36542-2/0-521-42744-4.

FCCC/SBSTA/1999/6/add.1: National communications from Parties included in annex I to the convention. Guidelines for the preparation of national communications.

IPCC (1996): *IPCC Guidelines for National Greenhouse Gas Inventories.* Volume 1, 2, and 3. Intergovernmental Panel on Climate Change, London.

Rypdal (1999): Evaluation of uncertainty in the Norwegian emission inventory. Report 99:01. Norwegian Pollution Control Authority.

Appendices

A1. Description of techniques for sensitivity analysis

Two main techniques for sensitivity analysis may be defined: one based a simple algorithm (Tier 2a) and one based on stochastic simulations (Tier 2b).

These two approaches are expected to give essentially the same results. The advantage of the simple approach is that it is quick to apply and does not require special software. The advantage of the simulation technique is that it can be combined with an uncertainty analysis and that it may consider joint effects of more than one source.

In the following the terms "sensitivity" and "elasticity" will be used (see glossary). Both are a measure of responsiveness of one variable to another. Absolute sensitivity is an absolute measure, which cannot be compared for different sources, while the relative sensitivity or elasticity is a dimensionless measure, comparable for different sources.

A.1.1. General theory

The simple theory below on sensitivity measures and elasticities is mostly taken from Morgan and Henrion (1998).

We will here consider a simplified case where the total emissions (E) are a function of two uncertain input estimates (e_1 and e_2).

$E = f(e_1, e_2)$

E.g, the input parameters may be estimates of source emissions, $E = e_1 + e_2$, or they may be an emission factor and an activity measeure, $E = e_1 \cdot e_2$. The input estimates given in the inventory as the best estimates are e_1^0 and e_2^0, and the best estimate of total emission is E^0.

The absolute *sensitivity* is defined as the rate of change of the output (E) with respect to variations in the input, evaluated at the best estimate, that is

$$U_S(e_i, E) = \left[\frac{\partial E}{\partial e_i}\right]_{E^0}$$

The sensitivities are not directly comparable between various emission sources. The normalised sensitivity (or *elasticity*) is defined as the ratio of the relative change in E induced by a unit relative change in *e*. This expression should be used for comparing the sensitivity of various parameters since it is dimensionless. It is defined as:

$$U_E(e_i, E) = \left[\frac{\partial E}{\partial e_i}\right]_{E^0} \times \frac{e_i^0}{E^0}$$

Furthermore, the degree of uncertainty may be taken into account directly. According to the Gaussian approximation the *uncertainty importance* is

$$U_G(e_i,E) = \left[\frac{\partial E}{\partial e_i}\right]_{E^0} \times \sigma_{e_i}$$

Where

σ_e is the standard deviation of the input parameters.

This may also be modified into a uncertainty importance elasticy, that is

$$U_{GE}(e_i,E) = U_E(e_i,E) \times \frac{\sigma_{ei}}{e_i^0} = \left[\left[\frac{\partial E}{\partial e_i}\right]_{E^0} \times \frac{e_i^0}{E^0}\right] \times \frac{\sigma_{ei}}{e_i^0} = \left[\frac{\partial E}{\partial e_i}\right]_{E^0} \times \sigma_{ei} / E^0$$

Note that the Gaussian approach is a local approach and is not valid for large uncertainties and non-normal distributions. In these cases the analysis will be more accurate based on other approaches. Also note that the elasticities above allows a comparison and ranking between all variables of the same class, say, emission factors[6] or activity data, but not an inter comparison between classes.

The sensitivity analysis may be performed at several of the levels above. The elasticities tell us what input parameters contributes most to the total output and may be directly used to identify key sources. The uncertainty importance, on the other hand, tells us what input parameters contribute most to the overall inventory uncertainty. For inventory applications the uncertainty importance will be a useful parameter to rank the most important sources with respect to their contribution to total uncertainty, that is what parts of the inventory should be improved (if possible) to reduce the overall uncertainty.

A.1.2. Tier 2a

The simple approach is to look at contributions to total emission uncertainty at the level of source emissions, using source elasticities and, if possible, source uncertainties. We consider three cases: Effects of source level variation to total level and to total trend, and effects of source trend variation to total trend.

The elasticities are given as[7]:

$U_E(e_{io},E_0) = e_{i0} / E_0$	*Elasticity of total emission with respect to source emission level.* This equals the source emission as a fraction of the total emission.
$U_E(e_{io},T) = e_{i0} / E_0 \cdot (t_i - T)$	*Elasticity of relative trend of total emissions with respect to source emission level.* This equals the difference between source trend and total trend (the trend offset) weighted by the source fraction.
$U_E(e_{i1},T) = e_{i0} / E_0 \cdot (1 + t_i)$	*Elasticity of total trend with respect to source trend.* This equals the end year source emission ($e_{i1} = e_{i0} \cdot (1 + t_i)$) as a fraction of the base year total, and may also be viewed as the overall source trend $(1 + t_i)$ weighted by the source fraction.

[6] Emission factors given in the same unit, e.g. GWPs/activity rate.

[7] The elasticities are derived in appendix A2. Note that the elasticities of trend are given relative to base year emission and not to the trend itself. This means that the elasticities are given as percentage *points* and not as percentages.

The variables included in the formulae are:

- E_0 = total emission in the base year
- e_{i0} = emission from source *i* in the base year
- T = total trend = $(E_1 - E_0) / E_0$, where E_1 is total emission in the end year
- t_i = trend of source *i* = $(e_{i1} - e_{i0}) / e_{i0}$, where e_{i1} is source emission in the end year

If the uncertainties of the source estimates are known (as relative standard deviations σ_i/e_i), we may in addition compute the *uncertainty importance elasticities*. These may be viewed as the contributions to the uncertainty in total emission and trend from each source (given the simplification that all source emissions are independent)[8].

The uncertainty importance elasticities are given as:

$U_{GE}(e_{io},E_0) = e_{i0} / E_0 \cdot (\sigma_{i0}/e_{i0})$ respect	*Uncertainty importance elasticity of total emission with to source emission level.*
$U_{GE}(e_{io},T) = e_{i0} / E_0 \cdot (t_i - T) \cdot (\sigma_{i0}/e_{i0})$	*Uncertainty importance elasticity of total trend with respect to source emission level.*
$U_{GE}(e_{i1},T) = e_{i0} / E_0 \cdot (1 + t_i) \cdot (\sigma_{i1}/e_{i1})$	*Uncertainty importance elasticity of total trend with respect to source trend.*

where the additional variables are:

- σ_{i0}/e_{i0} = relative uncertainty of source *i*, assumed to be valid throughout the period
- σ_{i1}/e_{i1} = additional relative uncertainty of source *i* in the end year, or *source trend uncertainty*

A.1.3. Tier 2b

The Tier 2b approach will differ from Tier 2a in that all individual parts of the inventory may be directly included (emission factors and activity rates separately), it allows to see the joint effect of all input parameters and it may incorporate uncertainties, function shapes and dependencies between parameters into the analysis.

Several methods exist to perform such analysis. The methods will require information on the uncertainty of each input parameter and the distribution density (in analytical or empirical form). See background paper no. 1 for a more detailed description of the various approaches.

In a *nominal range sensitivity analysis*, the output may be evaluated for extreme values of the input values, that could for example be extreme uncertainties. This may be done for one and one parameter, or assuming that more than one or all have extreme values. The latter case is, however, unlikely. This may also well be done using the Tier 2a approach. In the Tier 2b we may also using stochastic simulation to model the probability of joint changes in input values. This is the main advantage of a Tier 2b sensitivity analysis.

---

[8] This assumption is not valid if the same emission factor is used for more than one source, this has to be treated in Tier 2.

A2. Derivation of elasticities for Tier 2a sensitivity analysis.

In order to derive the elasticities of emission level and trend, we will start with the following definitions:

Emission level in base year: $E_0 = \sum_{i=1}^{n} e_{i0}$

Total emission trend: $T = \frac{E_1 - E_0}{E_0} = \frac{\sum e_{i1} - \sum e_{i0}}{\sum e_{i0}} = \frac{\sum(e_{i1} - e_{i0})}{\sum e_{i0}} = \frac{\sum(e_{i0} \cdot t_i)}{\sum e_{i0}}$

where

e_{i0}	= emission from source *i* in the base year
e_{i1}	= emission from source *i* in the end year
E_1	= total emission in the end year
t_i	= trend of source *i*, defined as $t_i = (e_{i1} - e_{i0}) / e_{i0}$

These expressions defines E_0 and T as functions of the source emissions and trends e_{i0} and t_i. We may then use the definition of sensitivity as partial derivatives to derive the following formulae. Note that a change i e_{i0} is assumed to affect both base year and end year emissions, *i.e.*, a change in level, whereas a change in e_{i1} is assumed to affect the end year emission only, *i.e.*, a change in trend.

Sensitivity of emission level with respect to source emission level: $U_S(e_{io},E_0) = 1$
Sensitivity of total trend with respect to source emission level: $U_S(e_{io},T) = (t_s - T) / E_o$
Sensitivity of total trend with respect to source trend: $U_S(e_{i1},T) = 1 / E_o$

In order to compare sources, we want to normalise these sensitivities into elasticities. However, the parameter T is already defined as a rate. We find it more informative to consider absolute changes in the trend, *i.e.* changes in *percentage points*, rather than using relative changes in the trend. With this modification we get the following elasticities:

Elasticity of emission level with respect to source emission level:
$U_E(e_{io},E_0) = U_S(e_{io},E_0) * e_{i0} / E_0 = e_{i0} / E_0$

Elasticity of total trend with respect to source emission level:
$U_E(e_{io},T) = U_S(e_{io},T) * e_{i0} = e_{i0} / E_0 \cdot (t_i - T)$

Elasticity of total trend with respect to source trend:
$U_E(e_{i1},T) = U_S(e_{i1},T) * e_{i1} = e_{i1} / E_0 = e_{i0} / E_0 \cdot (1 + t_i)$

Note that the sensitivity is a local approach and is not valid for large deviations in non-linear functions. $E_0(e_{i0})$ and $T(e_{i1})$ are both linear, but $T(e_{i0})$ is non-linear. For a large change in e_{i0}, *viz.* $e_{i0}^* = e_{i0} \cdot (1+\mu)$, the change in T is $T^* - T = e_{i0}\, \mu\, (t_i - T) / (E_0 - e_{i0}\, \mu)$ (Rypdal 1999).

Another measure of the elasticity of total trend with respect to source trend is also possible. We may use t_i as an input variable for derivation instead of e_{i1}. In this case, both input and output variables are rates, and we may use the sensitivity directly as an elasticity for which both input and output are measured in percentage points. We then have:
$U_E(t_i,T) = U_S(t_i,T) = e_{i0} / E_0$

That is, an increase in one percentage point in the trend of source i leads to a change of a fraction e_{i0} / E_0 of a percentage point in the total trend. Of course, e_{i1} still enters the calculations, since t_i is defined in terms of e_{i1} or vice versa. $U_E(t_i,T)$ may replace $U_E(e_{i1},T)$ if it offers greater clarity.

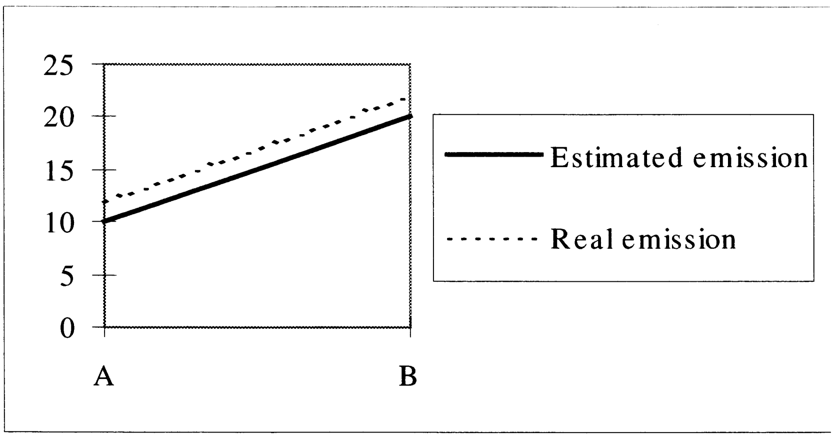
A3. Model type of errors

In an emission inventory the trend is given by the difference between two observations, A and B. The real emission might deviate from A and B, but it is often assumed that if A is underestimated B will also be underestimated and vice versa. This type of error is here called *level error.* The reason for such a systematic error is an error in an emission factor which source contribution is not changing or that one or more sources are not included in the inventory.

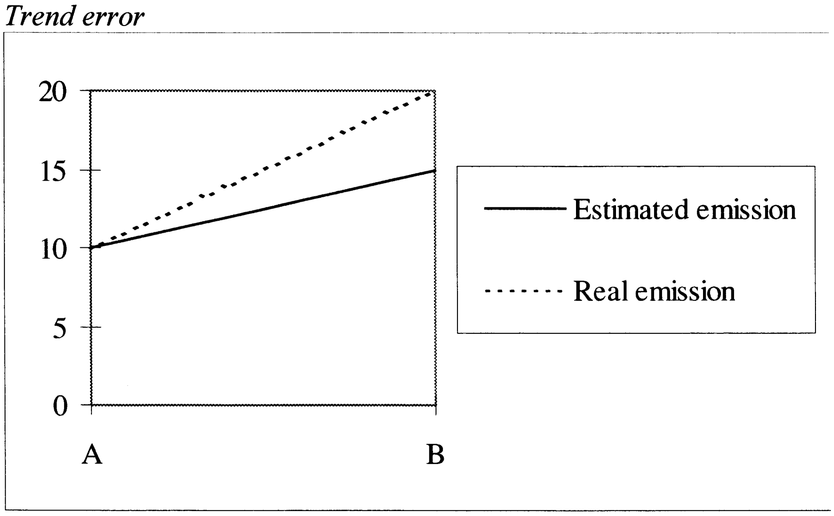
It is also possible in the inventory that the trend of one or more sources is wrong, this is here called a *trend error*. This implies that the percentage error in level is different in the end year compared to the base year. The reason for such a case is systematic errors in the trend estimates, e.g. that an emission factor is kept constant when in reality it is changing, introduction of new technologies with a more uncertain emission factor or change in estimation methodology without the possibility of updating of base year. This will also be the effect of *new* unknown sources.

In reality, most errors will be a combination of these two types of model errors.

Level error



Trend error



A4. Analysis of limits to be used in the criteria for key sources

The criteria limits given in section 4 were derived from an analysis of emission data reported to the UNFCCC from Norway, Sweden, and New Zealand. The study is described in this section, which analyses the distribution of contributions to elasticity and uncertainty importance elasticity among sources. The aim was to decide how a given fraction of the total elasticity can be accounted for with as few sources as possible.

The following inventory data were used (data are given in appendix A3):

- Source level of summary table 7a. (The term *source* is used below in a wide sense to include any combination of component * source category.)
- Components: CO_2, CH_4, and N_2O.
- Years: 1990 and 1996.

The uncertainty, measured as two standard deviations, was assigned to sources based on the reported quality classes as follows: High: 5%, medium: 25%, low: 75%. The implications of this choice will be discussed below. Whether sources have been fully or partly reported was not taken into consideration.

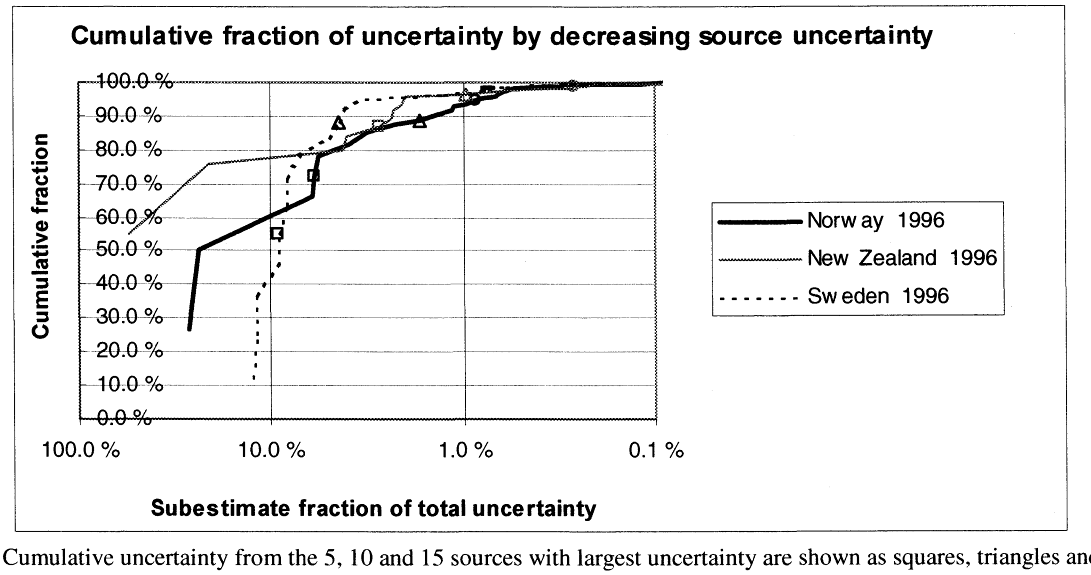
The numbers of non-zero sub-estimates range from 20 to 36.

The elasticity and uncertainty importance elasticity was calculated for each source. Sources were then ranked by both elasticities. The figures show the cumulative uncertainty importance elasticity by decreasing source elasticities. In this way one can easily see the proportion of the total uncertainty importance elasticity that is covered by sources above a given elasticity limit.

A4.1. Effects of source emission level to total emission

The the cumulative uncertainty importance elasticity of total emission level is shown in figures A4.1 and A4.2. In figure A4.1, the sources are ranked by their uncertainty [importance elasticity]. In the Norwegian data, 90 % of the uncertainty was obtained with approximately 10 sources, using 1.5% of total uncertainty as a cut-off value. The data for Sweden and New Zealand is even more concentrated.

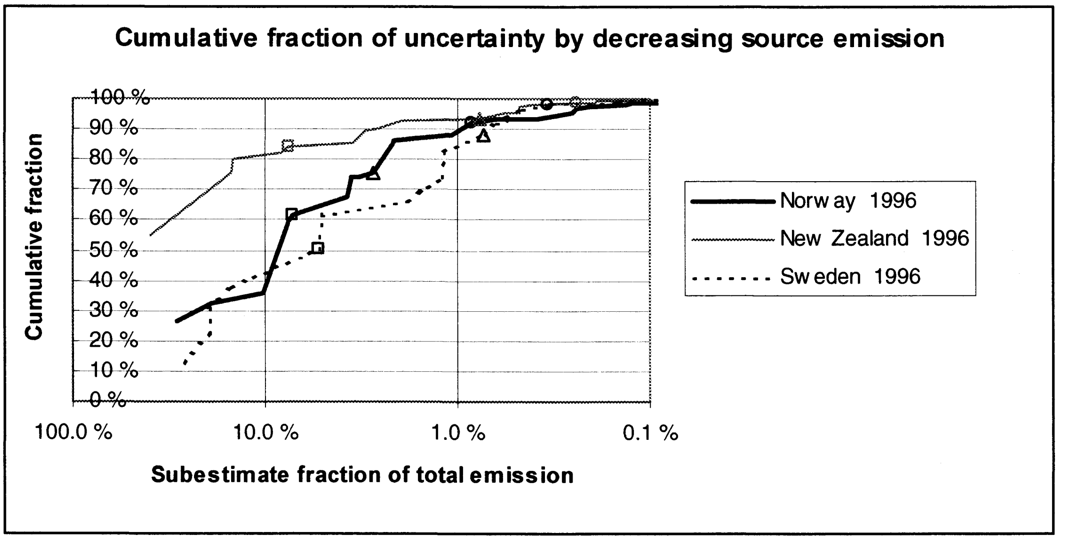
Figure A4.1.



Cumulative uncertainty from the 5, 10 and 15 sources with largest uncertainty are shown as squares, triangles and circles, respectively.

Ranking the sources by uncertainty is only feasible when the uncertainties are reasonably well known. If the uncertainty of the sources is unknown, the fraction of total emission may be used as a proxy. In figure A4.2, the sources are ranked by this criterion. As expected, we need more sources in order to account for a given level of total uncertainty importance elasticity when information on source uncertainty is not used. In the Norwegian data, 90 % of the uncertainty was obtained with approximately 15 sources, using 0.8% of the total emission as a cut-off value These sources accounted for more than 97 % of the total emission.

Figure A4.2.



Cumulative uncertainty from the 5, 10 and 15 sources with largest emission are shown as squares, triangles and circles, respectively.

Conclusion

A practical rule might be as follows, allowing for the fact that the uncertainty is usually known for at least some sources:

- *A key source is a source whose emission is more than 0.5 % of the total emission of GHG.*
- *If the quality is known to be high (2 · σ less than 20%), only sources with emission of more than 2.5 % of the total emission are considered as key.*

Based on this rule, key sources will cover at least 90 % of the uncertainty importance elasticity in all analysed inventories.

If we relax the desired level of uncertainty to 80%, the limits for key sources may be increased to 2 % in general and 5 % for high quality sources.

It should be noted that these limits depend strongly on the level of aggregation. With higher levels of aggregation, higher limits for key sources should be used.

The assigned levels of uncertainty does not have a large impact on the conclusions. In general, the major sources are better known, whereas small sources have large relative uncertainties. If we assume a higher relative uncertainty for high quality sources, then a higher proportion of the total uncertainty will be covered with a given limit for key sources. However, the effect is small, and the conclusions on limits for key sources seem reasonably robust.

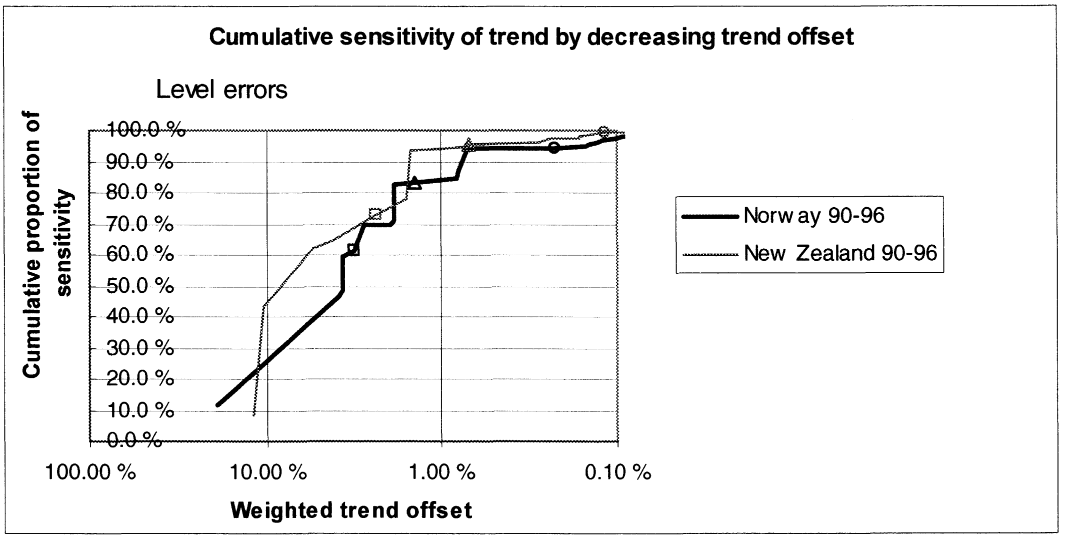
The total uncertainty importance elasticity was calculated by simple addition of the contributions from each source. In principle, this is only valid if the sources are independent. Although this may not be the case for all sources, it seems reasonable that the sources with major contributions to the uncertainty, such as CH_4 from landfills and N_2O from agriculture, are independent.

A4.2. Effects of source emission level to total trend

Whereas the level uncertainties are more or less evenly distributed over a number of magnitudes, the trend offsets t_i are usually of the same magnitude. Sources with a trend similar to the overall trend will have low offsets and low sensitivity, but only rarely will the trends be so close that the rank of trend sensitivity is much lower than the rank of level sensitivity. Hence, we would expect the trend sensitivity to show the same pattern as the level sensitivity.

Very large sources will frequently have trends close to the overall trend, hence level uncertainty in such sources will often contribute little to the uncertainty in trend.

Figure A4.3.



Cumulative uncertainty from the 5, 10 and 15 sources with largest emission are shown as squares, triangles and circles, respectively.

The analysis of trend sensitivity is shown in fig. A4.3. Again, 90 % of the uncertainty is reached with a limit of key sources at about 0.5 % of total emission.

The reasoning that t_i matters little is strongly dependent on the chosen limit for key sources. In the data for Norway, a limit of 0.5% of total emission will give 16 key sources. If we instead of e_{s0}/E_0 use $(t_i - T)\ e_{s0} / E_0$ as a ranking criterion, the 15 most key will be the same, and only the 16th is different. However, if the limit for key sources is restricted, the pattern changes. With a high limit of 5% of total emissions we get only 5 key sources. When trend offset is included in the criterion, only 2 of these sources are included. The proportion of trend uncertainty covered by 5 sources is much higher with trend offset included in the criterion.

Conclusion

Since the criterion including trend offset seems to be more robust with respect to the limit level, the following rule is suggested:

- *A key source with respect to effects of level to trend is a source for which trend offset times fraction of total emission,* $(t_i - T)\ e_{i0} / E_0$, *is more than 0.25%.*
- *If the quality is known to be high (2 · σ less than 20%), only sources with values above 1.25% are considered as key.*

Based on this rule, key sources will cover at least 90 % of the trend uncertainty in all analysed inventories. If we relax the desired level of uncertainty to 80%, the limits for key sources may be increased to 0.5%.

The trend terms, $t_i - T$ depends highly on the period between the base year and the end year in the analysis. The criteria given above are based on the 6 year period in the analysed inventories. In order to make the criteria applicable to any inventory period, the trend offset should be transformed to a standard period using the formula

$$((t_i - T)^* = (1 + (t_i - T))^{p \ n} - 1$$

where n is the period between the inventories in the analysis and p is the standard period.

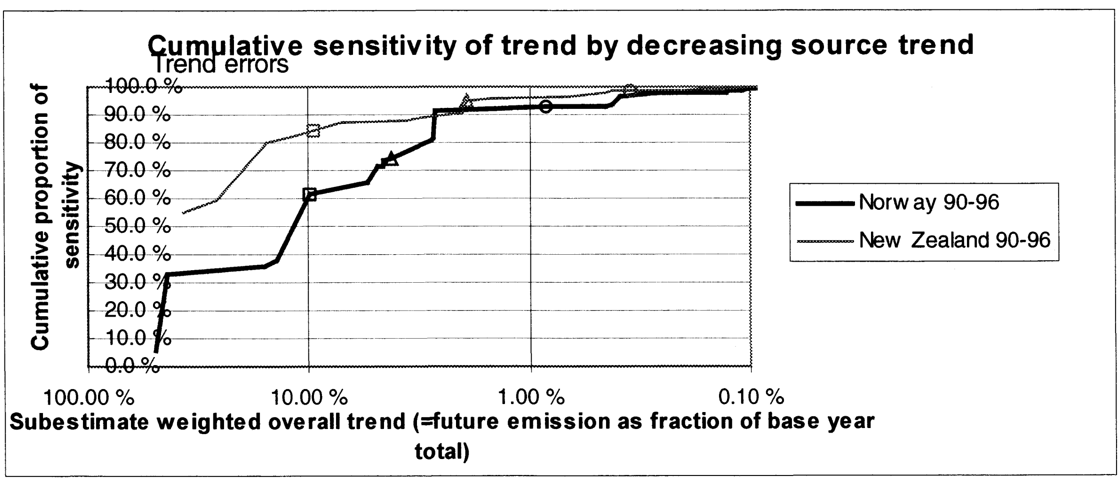
Any fixed period might be used, but 1 year (giving *p.a.* trend rates) and 20 years (corresponding to the period covered in the Kyoto protocol) seem most useful. A long standard period will give relatively more importance to sources with very deviating trends. As noted in section 4, the analysis should preferably use end years as close to the future 2008-2012 data as possible. This would also allow the sensitivities of level errors to be compared to the effects of trend errors as discussed below. Suggested limits are 0.5% / 2.5% and 1% / 5%.

A4.3. Effects of source trend to total trend

We have no information from the reported inventories on the additional uncertainties in trend, σ_{i1}/e_{i1} . We expect them to be lower than the general uncertainties in level. As surrogate values for the analysis we have set $\sigma_{i1}/e_{i1} = \sigma_{i0}/e_{i0} / 5$. Since the elasticity $U_E(e_{i1},T)$ is roughly equal to the level elasticity $U_E(e_{io},E_0)$, the results are similar to the analysis of level errors. Only for a few sources is the trend term $1 + t_i$ of such an order that the ranking of sources is changed.

The trend term $1 + t_i$ cannot be standardised to *p.a.* terms in a meaningful way. If we use *p.a.* values, the term will approach 1 for all sources, and the analysis will be even closer to the level sensitivity. An alternative method is to standardise the trend terms to a 20-year period, corresponding to the period between the base year and final year in the Kyoto protocol. The standardised value is defined as $(1 + t_i)^{20 \ n}$, where n is the period between the inventories in the analysis. In practice, this means that the trends in the period of analysis is projected to the whole 20-year period. If projections of future emissions are available, the trends from these projections could replace standardised values based on historical data.

Figure A4.4.



Cumulative uncertainty from the 5, 10 and 15 sources with largest emission are shown as squares, triangles and circles, respectively.

Conclusion

The following rule is suggested:

- *A key source with respect to effects of trend errors to total trend is a source for which the end year emission as a fraction of base-year total emission,* $e_{i0} / E_0 (1 + t_i)^{20/n}$, *is more than 1%.*
- *If the quality is known to be high (2 · σ less than 20%), only sources with values above 5% are considered as key.* (Note: The quality level refers of 20% refers to the level uncertainty σ_{i0}/e_{i0}, since the additional uncertainty in the end year, σ_{i1}/e_{i1}, is usually poorly known.)

Based on this rule, key sources will cover at least 90 % of the trend uncertainty in all analysed inventories. If we relax the desired level of uncertainty to 80%, the limits for key sources may be increased to 2 %.

If the level criterion is made wider also the sources covered by the two trend criteria are captured. However, this means that also not key sources will be identified.

The simplest criterion may be given as:

- *A key source is a source that accounts for more than 0.2 % of total national emissions.*

A5. Inventory data used in the analysis of elasticities. Source: official reports to the UNFCCC.

Norway
1990

Source and sink categories	CO_2	CH_4	N_2O	Quality, cat CO_2	Quality, cat CH_4	Quality, cat N_2O
	Emissions (Gg)					
Total national emissions and removals[1]	**35203**	**317.1**	**17.5**			
1 Energy	**28303**	**33,1**	**1.0**			
A Fuel combustion (sectoral approach)	**26403**	**13.2**	**1.0**			
1 Energy industries	7396	2.2	0.1	H	L	L
2 Manufacturing and construction	3043	0.4	0.1	H	L	L
3 Transport	13533	3.7	0.7	H-M	L	L
4 Other sectors	2431	6.8	0.1	M	L	L
5 Other						
B Fugitive emissions from fuels	**1900**	**20.0**	**0.0**			
1 Solid fuels	12	4.2		L-M	L-M	
2 Oil and natural gas	1 889	15.7	0.0	H	M	L
3 Geothermal						
2 Industrial processes	**6718**	**1.0**	**6.7**			
A Mineral products	653			H		
B Chemical industry	1096	1.0	6.7	H	M	H
C Metal production	4769			H		
D Other production						
E Production of halocarbons and SF_6						
F Use of halocarbons and SF_6						
G Other	200			H		
3 Solvent and other product use	**144**			M-L		
4 Agriculture	**0**	**100.8**	**9.5**			
A Enteric Fermentation		86.1			M	
B Manure management		14.7			M	
C Rice cultivation						
D Agricultural soils			3.6			L
E Prescribed burning of savannas						
F Field burning of agricultural residues						
G Other			5.9			
5 Land-use change and forestry[1]	**0**	**0.0**	**0.0**			
A Changes in forest and woody biomass						
B Forest and grassland conversion						
C Abandonment of managed lands						
D CO_2 emissions and removals from soil						
E Other						
6 Waste	**37**	**182.1**	**0.4**			
A Solid waste disposal on land	37	181.7		L	M-L	
B Wastewater Handling		0.4	0.4		L	L
C Human sewage						
D Other						
7 Other						

Norway
1996

Source and sink categories	CO_2	CH_4	N_2O	Quality, cat CO_2	Quality, cat CH_4	Quality, cat N_2O
	Emissions (Gg)					
Total national emissions and removals[1]	**41431**	**350.2**	**16.3**			
1 Energy	**33504**	**47,5**	**1.8**			
A Fuel combustion (sectoral approach)	**31570**	**14.5**	**1.8**			
1 Energy industries	10404	3.2	0.1	H	L	L
2 Manufacturing and construction	3847	0.5	0.1	H	L	L
3 Transport	15296	3.4	1.5	H-M	L	L
4 Other sectors	2023	7.4	0.1	M	L	L
5 Other						
B Fugitive emissions from fuels	**1933**	**33.0**	**0.0**			
1 Solid fuels	15	5.4		L-M	L-M	
2 Oil and natural gas	1919	27.6	0.0	H	M	L
3 Geothermal						
2 Industrial processes	**7750**	**1.0**	**4.8**			
A Mineral products	935			H		
B Chemical industry	1148	1.0	4.8	H	M	H
C Metal production	5463			H		
D Other production						
E Production of halocarbons and SF_6						
F Use of halocarbons and SF_6						
G Other	204			H		
3 Solvent and other product use	**137**			M-L		
4 Agriculture	**0**	**108.1**	**9.3**			
A Enteric Fermentation		92.2			M	
B Manure management		15.9			M	
C Rice cultivation						
D Agricultural soils			3.7			L
E Prescribed burning of savannas						
F Field burning of agricultural residues						
G Other			5.6			
5 Land-use change and forestry[1]	**0**	**0.0**	**0.0**			
A Changes in forest and woody biomass						
B Forest and grassland conversion						
C Abandonment of managed lands						
D CO_2 emissions and removals from soil						
E Other						
6 Waste	**40**	**193.6**	**0.4**			
A Solid waste disposal on land	40	193.2		L	M-L	
B Wastewater Handling		0.4	0.4		L	L
C Human sewage						
D Other						
7 Other						

New Zealand
1990

Source and sink categories	CO_2	CH_4	N_2O	Quality, cat CO_2	Quality, cat CH_4	Quality, cat N_2O
	Emissions (Gg)					
Total national emissions and removals[1]	**26115**	**1 672.8**	**37.1**			
1 Energy	**22855**	**35.4**	**0,6**			
A Fuel combustion (sectoral approach)	**22240**	**10.6**	**0.6**			
1 Energy industries	6040	0.3	0.0	H	M	M
2 Manufacturing and construction	4710	0.4	0.1	H	M	M
3 Transport	8645	7.1	0.4	H	M	M
4 Other sectors	2733	2.7	0.1	H	M	M
5 Other	113	0.1	0.0	H	M	M
B Fugitive emissions from fuels	**615**	**24.8**				
1 Solid fuels		11.9			L	
2 Oil and natural gas	258	10.4		M	M	
3 Geothermal	357	2.5				
2 Industrial processes	**2386**	**0.1**				
A Mineral products	448			H		
B Chemical industry	152	0.1		H	L	
C Metal production	1786			H		
D Other production						
E Production of halocarbons and SF_6						
F Use of halocarbons and SF_6						
G Other						
3 Solvent and other product use						
4 Agriculture		**1492.2**	**36.3**			
A Enteric Fermentation		1474.4			M	
B Manure management		17.8	0.1		L	M
C Rice cultivation						
D Agricultural soils			36.1			M
E Prescribed burning of savannas						
F Field burning of agricultural residues		0.1	0.0		M	M
G Other						
5 Land-use change and forestry[1]	**874**	**3.8**	**0.0**			
A Changes in forest and woody biomass				M		
B Forest and grassland conversion	874	3.8	0.0	M	M	M
C Abandonment of managed lands						
D CO_2 emissions and removals from soil						
E Other						
6 Waste		**141.2**	**0.2**			
A Solid waste disposal on land		137.0			M	
B Wastewater Handling		4.2			M	
C Human sewage			0.2			M
D Other						
7 Other						

New Zealand

1996

Source and sink categories	CO_2	CH_4	N_2O	Quality, cat CO_2	CH_4	N_2O
	Emissions (Gg)					
Total national emissions and removals[1]	**30498**	**1592.8**	**37.5**			
1 Energy	**26267**	**42.1**	**0.7**			
A Fuel combustion (sectoral approach)	**25594**	**10.8**	**0.7**			
1 Energy industries	6271	0.2	0.0	H	M	M
2 Manufacturing and construction	5646	0.5	0.1	H	M	M
3 Transport	10972	7.0	0.5	H	M	M
4 Other sectors	2624	2.9	0.1	H	M	M
5 Other	81	0.1	0.0	H	M	M
B Fugitive emissions from fuels	**672**	**31.3**				
1 Solid fuels		20.1			L	
2 Oil and natural gas	311	8.6		M	M	
3 Geothermal	362	2.6				
2 Industrial processes	**2742**	**0.1**				
A Mineral products	581			H		
B Chemical industry	167	0.1		H	L	
C Metal production	1994			H		
D Other production						
E Production of halocarbons and SF_6						
F Use of halocarbons and SF_6						
G Other						
3 Solvent and other product use						
4 Agriculture		**1430.9**	**36.5**			
A Enteric Fermentation		1413.7			M	
B Manure management		17.1	0.1		L	M
C Rice cultivation						
D Agricultural soils			36.4			M
E Prescribed burning of savannas						
F Field burning of agricultural residues		0.1	0.0		M	M
G Other						
5 Land-use change and forestry[1]	**1489**	**5.7**	**0.0**			
A Changes in forest and woody biomass				M		
B Forest and grassland conversion	1489	5.7	0.0	M	M	M
C Abandonment of managed lands						
D CO_2 emissions and removals from soil						
E Other						
6 Waste		**114.0**	**0.2**			
A Solid waste disposal on land		109.7			M	
B Wastewater Handling		4.3			M	
C Human sewage			0.2			M
D Other						
7 Other						

Sweden
1996

Source and sink categories	CO_2	CH_4	N_2O	Quality, cat CO_2	CH_4	N_2O
	Emissions (Gg)					
Total National Emissions and Removals	**63350**	**297.2**	**10.1**			
1 All Energy (Fuel Combustion + Fugitive)	**59390**	**37.8**	**7.1**			
A Fuel Combustion	**59390**	**37.8**	**7.1**			
1 Energy & Transformation Industries	14295	2.3	1.5	H	M	L
2 Industry	14400	5.4	2.8	H	M	L
3 Transport	19573	19.0	1.7	H	M	L
4 Small Combustion	11015	11.2	1.1	H	M	L
5 Other	107			M		
6 Traditional Biomass Burnt for Energy						
B Fugitive Emissions from Fuels						
1 Solid Fuels						
2 Oil and Natural Gas				L		
2 Industrial Processes	**3711**		**2.8**	M		L
3 Solvent and Other Product Use	**249**			M		
4 Agriculture		**198.4**	**0.2**			
A Enteric Fermentation		179.1			M	L
B Manure Management		19.3			H	
C Rice Cultivation					M	
D Agricultural Soils			0.2			L
E Prescribed Burning of Savannas						
F Field Burning of Agricultural Residues						
G Other						
5 Land Use Change & Forestry						
A Changes in Forest and Other Woody Biomass Stocks						
B Forest and Grassland Conversion						
C Abandonment of Managed Lands						
D Other						
6 Waste		**61.0**				
A Solid Waste Disposal on Land		61.0			M	
B Wastewater Treatment						
C Waste Incineration						
D Other Waste						
7 Other						

United Kingdom
1990

Source and sink categories	CO_2	CH_4	N_2O	Quality, num CO_2	CH_4	N_2O
	Emissions (Gg)					
Total national emissions and removals[1]	**614825**	**4438.0**	**215.0**			
1 Energy	**568589**	**1 24.8**	**15.5**			
A Fuel combustion (sectoral approach)	**558774**	**105.3**	**15.5**			
1 Energy industries	230775	7.5	6.3	6 %	50 %	150 %
2 Manufacturing and construction	94627	13.1	3.1	6 %	50 %	150 %
3 Transport	115901	31.5	4.2	6 %	50 %	170 %
4 Other sectors	112207	53.0	1.7	6 %	50 %	150 %
5 Other	5264	0.2	0.2	6 %	50 %	150 %
B Fugitive emissions from fuels	**9815**	**1319.5**				
1 Solid fuels	907	818.6		50 %	50 %	
2 Oil and natural gas	8908	500.9		5 %	28 %	
3 Geothermal						
2 Industrial processes	**13916**	**0.8**	**95.2**			
A Mineral products	8132			5 %		
B Chemical industry	1365		95.2	5 %		250 %
C Metal production	4420	0.8	0.0	5 %	???	
D Other production						
E Production of halocarbons and SF_6						
F Use of halocarbons and SF_6						
G Other						
3 Solvent and other product use						
4 Agriculture		**1089.6**	**103.9**			
A Enteric Fermentation		953.0			20 %	
B Manure management		124.0	5.2		30 %	300 %
C Rice cultivation						
D Agricultural soils			98.4			300 %
E Prescribed burning of savannas						
F Field burning of agricultural residues		13.0	0.3		???	???
G Other						
5 Land-use change and forestry[1]	**31660**					
A Changes in forest and woody biomass						
B Forest and grassland conversion	26563			50 %		
C Abandonment of managed lands						
D CO_2 emissions and removals from soil	1430			50 %		
E Other	3667			50 %		
6 Waste	**660**	**1 923.0**	**0.4**			
A Solid waste disposal on land	0	1890.0			39 %	
B Wastewater Handling	0	33.0			50 %	
C Waste incineration	660	0.0	0.4	25 %		???
D Other						
7 Other						

United Kingdom
1996

Source and sink categories	CO_2	CH_4	N_2O	Quality, num CO_2	CH_4	N_2O
	Emissions (Gg)					
Total national emissions and removals[1]	**593422**	**3712.0**	**189.0**			
1 Energy	**551369**	**893.5**	**20.5**			
A Fuel combustion (sectoral approach)	**543880**	**93.5**	**20.5**			
1 Energy industries	199698	17.0	6.1	6 %	50 %	150 %
2 Manufacturing and construction	91742	13.2	2.6	6 %	50 %	150 %
3 Transport	121882	24.2	10.2	6 %	50 %	170 %
4 Other sectors	127481	39.0	1.6	6 %	50 %	150 %
5 Other	3077	0.2	0.1	6 %	50 %	150 %
B Fugitive emissions from fuels	**7488**	**800.0**				
1 Solid fuels	50	338.4		50 %	50 %	
2 Oil and natural gas	7438	461.6		5 %	28 %	
3 Geothermal						
2 Industrial processes	**11703**	**0.7**	**70.3**			
A Mineral products	7036			5 %		
B Chemical industry	862		70.3	5 %		250 %
C Metal production	3805	0.7	0.0	5 %	???	
D Other production						
E Production of halocarbons and SF_6						
F Use of halocarbons and SF_6						
G Other						
3 Solvent and other product use						
4 Agriculture		**1063.6**	**98.3**			
A Enteric Fermentation		939.9			20 %	
B Manure management		123.7	5.1		30 %	300 %
C Rice cultivation						
D Agricultural soils			93.2			300 %
E Prescribed burning of savannas						
F Field burning of agricultural residues		0.0	0.0			
G Other						
5 Land-use change and forestry[1]	**29971**					
A Changes in forest and woody biomass						
B Forest and grassland conversion	24789			50 %		
C Abandonment of managed lands						
D CO_2 emissions and removals from soil	1515			50 %		
E Other	3667			50 %		
6 Waste	**378**	**1754.0**	**0.2**			
A Solid waste disposal on land	0	1720.0			39 %	
B Wastewater Handling	0	34.0			50 %	
C Waste incineration	378	0.0	0.2	25 %		???
D Other						
7 Other						

Recent publications in the series Documents

98/3: S. Holtskog: Residential Consumption of Bioenergy in China. A Literature Study

98/4 B.K. Wold: Supply Response in a Gender-Perspective, The Case of Structural Adjustments in Zambia. Tecnical Appendices

98/5 J. Epland: Towards a register-based income statistics. The construction of the Norwegian Income Register

98/6 R. Chodhury: The Selection Model of Saudi Arabia. Revised Version 1998

98/7 A.B. Dahle, J. Thomasen and H.K. Østereng (eds.): The Mirror Statistics Exercise between the Nordic Countries 1995

98/8 H. Berby: A Demonstration Data Base for Business Register Management. A data base covering Statistical Units according to the Regulation of the European Union and Units of Administrative Registers

98/9 R. Kjeldstad: Single Parents in the Norwegian Labour Market. A changing Scene?

98/10 H. Brüngger and S. Longva: International Principles Governing Official Statistics at the National Level: are they Relevant for the Statistical Work of International Organisations as well?

98/11 H.V. Sæbø and S. Longva: Guidelines for Statistical Metadata on the Internet

98/12 M. Rønsen: Fertility and Public Policies - Evidence from Norway and Finland

98/13 A. Bråten and T. L. Andersen: The Consumer Price Index of Mozambique. An analysis of current methodology – proposals for a new one. A short-term mission 16 April - 7 May 1998

98/14 S. Holtskog: Energy Use and Emmissions to Air in China: A Comparative Literature Study

98/15 J.K. Dagsvik: Probabilistic Models for Qualitative Choice Behavior: An introduction

98/16 H.M. Edvardsen: Norwegian Regional Accounts 1993: Results and methods

98/17 S. Glomsrød: Integrated Environmental-Economic Model of China: A paper for initial discussion

98/18 H.V. Sæbø and L. Rogstad: Dissemination of Statistics on Maps

98/19 N. Keilman and P.D. Quang: Predictive Intervals for Age-Specific Fertility

98/20 K.A. Brekke (Coauthor on appendix: Jon Gjerde): Hicksian Income from Stochastic Resource Rents

98/21 K.A.Brekke and Jon Gjerde: Optimal Environmental Preservation with Stochastic Environmental Benefits and Irreversible Extraction

99/1 E. Holmøy, B. Strøm and T. Åvitsland: Empirical characteristics of a static version of the MSG-6 model

99/2 K. Rypdal and B. Tornsjø: Testing the NOSE Manual for Industrial Discharges to Water in Norway

99/3 K. Rypdal: Nomenclature for Solvent Production and Use

99/4 K. Rypdal and B. Tornsjø: Construction of Environmental Pressure Information System (EPIS) for the Norwegian Offshore Oil and Gas Production

99/5 M. Søberg: Experimental Economics and the US Tradable SO_2 Permit Scheme: A Discussion of Parallelism

99/6 J. Epland: Longitudinal non-response: Evidence from the Norwegian Income Panel

99/7 W. Yixuan and W. Taoyuan: The Energy Account in China: A Technical Documentation

99/8 T.L. Andersen and R. Johannessen: The Consumer Price Index of Mozambique: A short term mission 29 November – 19 December 1998

99/9 L-C. Zhang: SMAREST: A Survey of SMall ARea ESTimation

99/10 L-C. Zhang: Some Norwegian Experience with Small Area Estimation

99/11 H. Snorrason, O. Ljones and B.K. Wold: Mid-Term Review: Twinning Arrangement 1997-2000, Palestinian Central Bureau of Statistics and Statistics Norway, April 1999

99/12 K.-G. Lindquist: The Importance of Disaggregation in Economic Modelling

99/13 Y. Li: An Analysis of the Demand for Selected Durables in China

99/14 T.I. Tysse and K. Vaage: Unemployment of Older Norwegian Workers: A Competing Risk Analysis

99/15 L. Solheim and D. Roll-Hansen: Photocopying in Higher Education

99/16 F. Brunvoll, E.H. Davila, V. Palm, S. Ribacke, K. Rypdal og L. Tangden: Inventory of Climate Change Indicators for the Nordic Countries. 93s.

99/17 P. Schøning, M.V. Dysterud og E. Engelien: Computerised delimitation of urban settlements: A method based on the use of administrative registers and digital maps. 17s.

Documents

PORTO BETALT VED INNLEVERINGA P.P. NORGE/NOREG

Tillatelse nr. 159 000/502

B

Returadresse:
Statistisk sentralbyrå
N-2225 Kongsvinger

Statistics Norway
P.O.B. 8131 Dep.
N-0033 Oslo

Tel: +47-22 86 45 00
Fax: +47-22 86 49 73

ISSN 0805-9411

Statistisk sentralbyrå
Statistics Norway