Category		Title
GG		General guidance
		Inventory management, improvement and QA/QC
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1 Introduction

Maintaining good inventory management principles will ensure the efficient and timely delivery of high quality inventory data. To do this an inventory management system needs to be established and should include:

1. a **clear inventory process** so that key activities and resources can be focused towards delivery deadlines and delivery quality;
2. **institutional arrangements**: clearly defined roles and responsibilities for delivering the inventory to specified time and quality standards;
3. a **quality framework** to ensure that the data is fit for purpose.

An outline inventory management system is presented in Figure 1-1. This illustrates the importance of establishing roles and responsibilities for the delivery of the inventory as well as a QA/QC framework that ensures the quality of the inventory process and the inventory outputs.

This chapter provides guidance on how to ensure that this complicated process results in an inventory submission that is fully compliant with the reporting requirements of the Convention and its protocols (ECE/EB.AIR/80) ([1]).

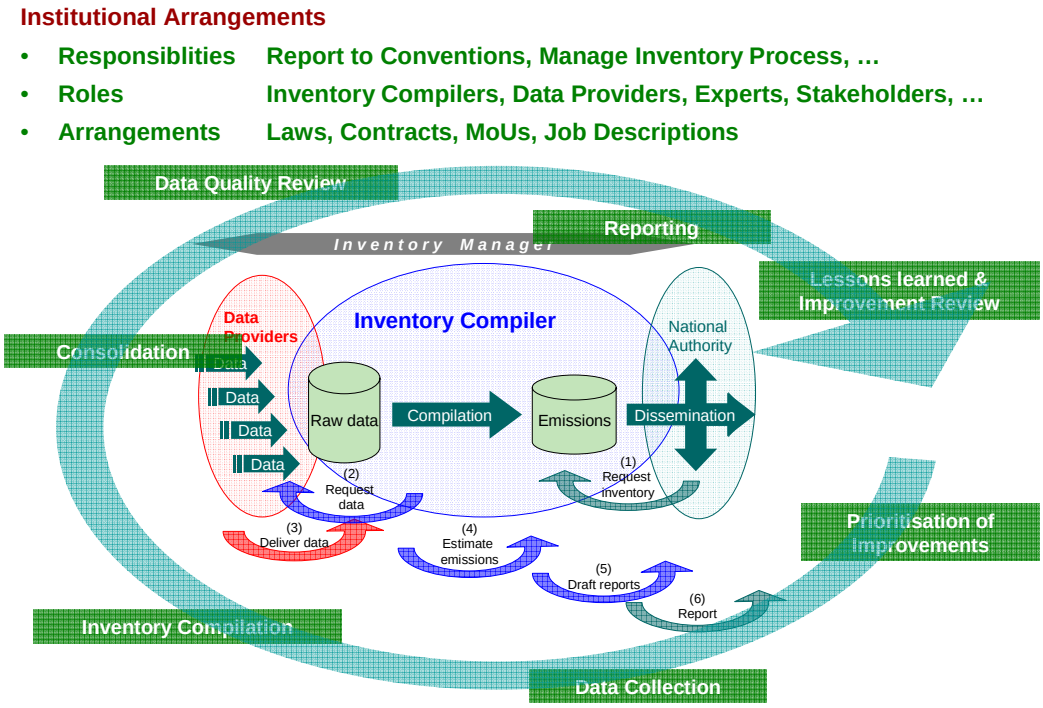

Figure 1-1 Aspects of Inventory Management

All of this is basically a management task. It is good practice to ensure that the overall process is managed by an explicitly appointed 'Inventory Manager', which can either be an individual or a formally established committee. The inventory manager is responsible for the inventory process:

([1]) The European Union, on behalf of the Member States, is a Party to the Convention and a signatory to various protocols. Various legal instruments within the EU require Member States to report the information it needs to the European Commission to report to the Long-Range Transboundary Air Pollution (LRTAP) Convention for the EU as a whole.

management of resources, data acquisition, internal and external deadlines, and inventory-related external consultant contracts, etc. The inventory manager and the inventory compiler have different functions, that may or may not be performed by the same institute or individual.

The inventory management guidance is designed to achieve practicality, acceptability, cost-effectiveness, incorporation of existing experience, and the potential for application on a world-wide basis. The inventory management system contributes to the objectives of good practice in inventory development, namely to improve transparency, consistency, comparability, completeness, and accuracy of national air pollutant inventories.

The process presented in Figure 1-1 is very similar to the one set up under the United Nations Framework Convention on Climate Change (UNFCCC) Convention, where the Intergovernmental Panel on Climate Change (IPCC) Guidelines and IPCC Good Practice Guidance are to be followed (UNFCCC 2006). This chapter therefore is largely based on the 'Quality Assurance/Quality Control and Verification' chapter of the 2006 IPCC Guidelines (IPCC 2006). This Guidebook further elaborates the QA/QC and verification approach as described in the IPCC 2006 Guidelines in that it more explicitly aims at inventory improvement, using the annual inventory cycle. It is good practice that the compilation of an inventory for the submission of year N builds explicitly on the experiences of earlier years' submissions.

NOTE 1:

Since air pollutant inventories cover a wider range of pollutants as compared to greenhouse gas inventories, managing the compilation of an air-pollutant emission inventory is more complicated. A concept like 'Global Warming Potential', enabling prioritisation across greenhouse gases is not available or even possible for the wide range of air pollutants.

NOTE 2:

Targets, set under the Long-Range Transboundary Air Pollution (LRTAP) Convention and its protocols and under the European Union National Emission Ceilings (EU NEC) Directive are expressed as absolute levels of emissions for individual pollutants, rather than reduction percentages of an aggregated indicator. Together with the fact that these targets are almost directly linked to effects as described by critical loads, the concept of 'inventory improvement' has a slightly different meaning as compared with the greenhouse gas emissions process. For this reason, this guidebook expands on the guidance as provided by IPCC 2006 Guidelines in further elaborating the inventory improvement process.

2 The inventory process

2.1 Main objectives and tasks

The main objective of the inventory process is to respond to the reporting obligation under the LRTAP Convention and its protocols. Since this obligation follows from the signature and ratification of an international agreement, the overall responsibility for this reporting lies with the national authorities.

The United Nations Economic Commission for Europe (UNECE) Reporting Guidelines (UNECE, 2009) clearly define a deadline and a set of quality criteria. It is good practice for the inventory to be transparent, consistent, comparable, complete and accurate.

Transparency means that Parties should provide clear documentation and report a level of disaggregation that sufficiently allows individuals or groups other than the designated emission expert or the compiler of the inventory to understand how the inventory was compiled and assure it meets good practice requirements. The transparency of emission reporting is fundamental to the effective use, review and continuous improvement of the inventory.

Consistency means that estimates for any different inventory years, pollutants ([2]) and source categories are made in such a way that differences in the results between years and source categories reflect real differences in emissions. Annual emissions, as far as possible, should be calculated using the same method, and data sources for all years, and resultant trends should reflect real fluctuations in emissions and not the changes resulting from methodological differences. Consistency also means that, as far as practicable and appropriate, the same data are reported under different international reporting obligations.

Comparability means that the national inventory is reported in such a way that allows it to be compared with national inventories of other Parties. This can be achieved by using accepted methodologies as elaborated in the Reporting Guidelines by using the reporting templates and through the use of the harmonized Nomenclature For Reporting (NFR), as specified in Annex IV of the Reporting Guidelines.

Completeness means that estimates are reported for all pollutants, all relevant source categories and all years and for the entire territorial areas of the Parties covered by the reporting requirements set forth in the provisions of the Convention and its protocols. Where numerical information on emissions under any source category is not provided, the appropriate notation key defined in Annex I of the Reporting Guidelines should be used when filling in the reporting template and their absence should be documented.

Accuracy means that emissions are neither systematically overestimated nor underestimated, as far as can be judged. This implies that Parties will endeavour to remove bias from the inventory estimates and minimize uncertainty.

2.2 The process

It is good practice that the inventory process is set up such that both the deadlines and the quality criteria of the Reporting Guidelines (UNECE, 2009) are met. The full inventory process is schematically given in Figure 2-1. The process comprises six distinctive steps, between three types of tasks:

([2]) The draft Reporting Guidelines use 'gases' instead of 'pollutants'. This probably is a copy from a similar definition in the UNFCCC Reporting Guidelines

- parties to the LRTAP Conventions, typically via their Ministry of Environment, have the final responsibility within the country for **complying with the obligations** under the Convention and its protocols as specified by the Reporting Guidelines (ECE/EB.AIR/2008/4);
- inventory compiler(s) and several institutions **prepare the obligatory submissions** following the requirements of the reporting obligations under the Convention and protocols (UNECE, 2009);
- data providers, such as the National Statistics Office, several ministries, facility operators, regulatory authorities, and research institutes **provide information** to inventory compilers.

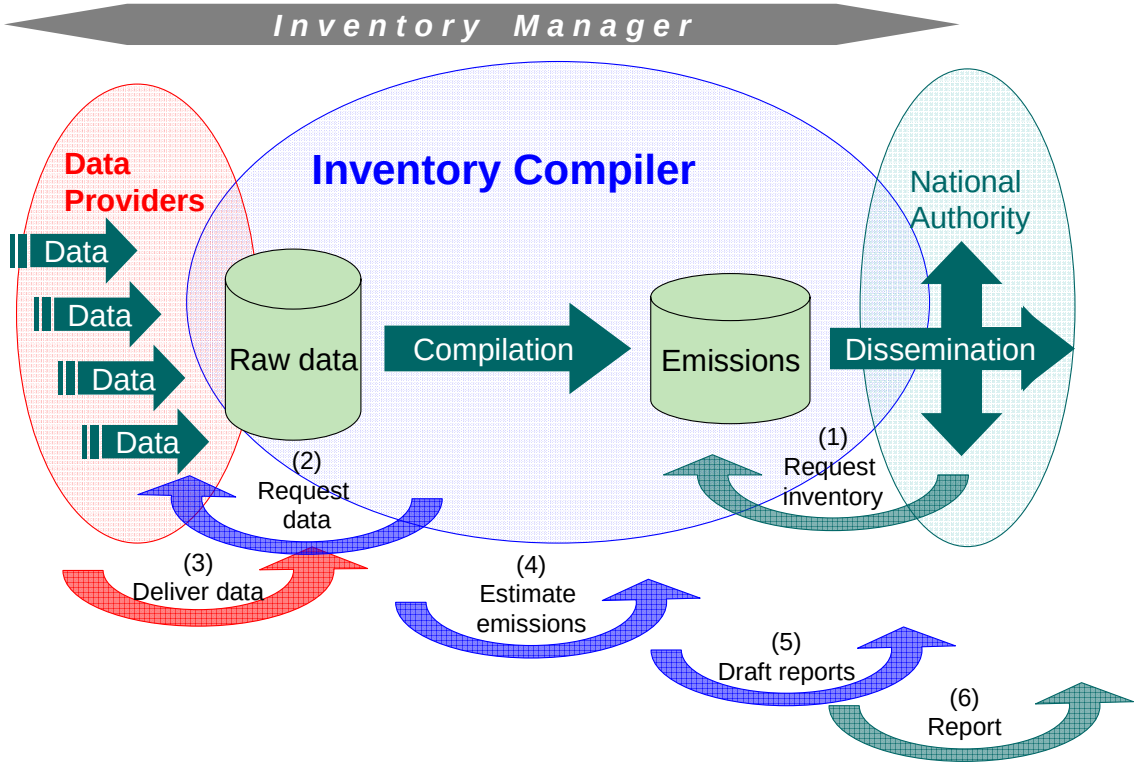

Figure 2-1 Schematic representation of the inventory process

These six successive steps are:

Step 1) a national authority must respond to a reporting obligation and requests a draft emission inventory and a draft inventory report. It is the responsibility of the inventory compiler to deliver these drafts within a predefined budget in time and resources;

Step 2) to perform this task the inventory compiler will need data and requests these from the data providers;

Step 3) the data providers deliver these data, serving as the raw data needed to estimate emissions, to the inventory system,;

Step 4) during inventory compilation, the inventory compiler will use the raw data to estimate emissions;

Step 5) the inventory compiler prepares draft reporting formats and accompanying inventory reports and delivers these to the national authority;

Step 6) the national authority endorses the draft inventory and report and submits these to the Convention.

2.3 Data flow

The Convention and its protocols ([3]) require annual reporting. This means that the full cycle of the inventory process as drawn up in Figure 2-1 is also an annual process and it is good practice to complete this full cycle within one year. The Reporting Guidelines (ECE/EB.AIR/2008/4) require annual inventories to be consistent over time.

Inventory compilation is a data-intensive process. These data include statistical data on activities in the country:

- energy statistics
- industrial production statistics and data on installed production technologies
- agriculture statistics
- transport statistics
- demographic data and census and questionnaire results
- other.

Many of these data are collected within each country for other reasons than for compiling emission inventories: they are needed for decision making in all policy fields and in many cases must be reported to international organisations.

It is good practice to use statistical data, reported in other national and international reporting obligations, also in the national inventory to ensure consistency amongst different national reports. The inventory process therefore needs a strong and continuous flow of data from national statistical offices, ministries and other institutes that collect such data for other reporting obligations and other national use.

2.4 Timeliness

An important issue in this dataflow can be to solve any deadline problems. In a number of source categories it might very well happen that the statistical data are compiled using a time schedule that does not lead to timely availability of the required data for the latest year in the inventory under preparation. Since the deadlines in the Reporting Guidelines are fixed, either one of the two possible solutions must be chosen:

- agree with the data provider to speed up the statistical data collection process, such that these data will be available on time for the emission estimation;
- agree with the data provider to use preliminary data and how to obtain these for the latest year in the inventory. This will often be the case for energy and other production statistics, that typically take more time to collect and publish than is available within the deadlines of the inventory submission.

([3]) And the NEC Directive for the EU Member States.

The first option will, in most cases, not be realistic, since statistical procedures within a country are generally well established and complicated. Use of the second option, however, will possibly lead to the updates of the activity data used, once the underlying statistics have been finalized. This does not need to be a problem, since all emission reporting obligations allow for 'recalculations' of emissions.

3 Institutional arrangements

3.1 Formalising the inventory tasks and co-operation

In a typical emission inventory process many institutes and stakeholders are involved. The deadlines are tight and complicated data flows are needed to meet the quality targets of the inventory. It is good practice to set up a system of formal agreements between the institutions involved, describing who does what when and what will happen if they do not.

Examples of such arrangements are:

- **laws** and other formal legislation, requesting (statistical) data to be delivered to the inventory compilers before a specific date;
- **contracts**: a contract is a legally-binding exchange of promises or agreement between parties that the law will enforce;
- **memorandums of understanding** (MoUs); an MoU is a legal document describing a bilateral or multilateral agreement between parties. It expresses a convergence of will between the parties, indicating an intended common line of action and may not imply a legal commitment. It is a more formal alternative to a gentlemen's agreement, but in some cases, depending on the exact wording, lacks the binding power of a contract;
- **a gentlemen's agreement** is an informal agreement between two or more parties. It may be written or oral. The essence of a gentleman's agreement is that it relies upon the honour of the parties for its fulfilment, rather than being in any way enforceable.

It is good practice to support the inventory compiler with this system of institutional arrangements in meeting the quality and timing requirements of the reporting obligation. It should ensure that all data needed are delivered on time.

NOTE:

It is good practice to identify a single, unambiguous organisation with this responsibility of a 'national authority'. A Party could choose to link this responsibility to the 'national entity' as defined within the Kyoto Protocol reporting provisions.

The inventory compiler will ensure that the following four aspects are in place and well functioning:

- a smooth and timely data flow from all data providers into the inventory compilation process (subsections 2.3 and 2.4 of the present chapter) that should be based on the institutional arrangements supporting the inventory process (Section 3 of the present chapter);
- an inventory quality framework, that ensures that the inventory is compiled meeting the quality criteria and deadlines as defined in the Reporting Guidelines (Section 4 of the present chapter);

- a documentation and archiving system that ensures the transparency of the process and allows for external review (Section 5 of the present chapter);
- an inventory improvement approach that uses the experiences from earlier inventories in improving the current and future ones (Section 6 of the present chapter).

3.2 Data delivery protocols

To ensure the timely availability and consistency of all data needed it is good practice to establish some form of formal arrangements between the inventory compiler and the respective data providers as part of or annex to the institutional arrangements discussed above. It is good practice that such a formal agreement (a 'data delivery protocol') clearly describes what data are needed when and in what format these data will be delivered. It is good practice that each agreement includes:

- a contact person or (e-mail) address for both the specific data provider and the inventory compiler;
- an agreed data format (text file, spreadsheet or database file or any other format);
- the contents in this format in terms of attributes or fields;
- a deadline;
- a procedure to accommodate any findings from the QA/QC procedures.

It is advisable to also include a brief description of what will happen if the data provider is not able to deliver the data as agreed in the data protocol. In such cases the inventory compiler will have no other choice than to approximate these data to develop at least a first preliminary estimate for the source category.

4 The inventory quality framework

4.1 General

Compiling an inventory is an annual process. It is good practice to set up a management process involving a management plan at the beginning of each cycle and an evaluation at the closure of the cycle, providing proposals for improvements (Figure 4-1). The evaluation of completed cycle feeds into the management plan of the next. Following the terminology of the IPCC 2006 Guidelines, this Guidebook will call the management plan the 'QA/QC plan'.

The QA/QC plan for the inventory establishes all procedural and technical issues to produce an inventory that complies with the requirements of the Convention for a specific year N. The QA/QC plan directs activities and attention to ensure the quality of the inventory while it is being compiled. It is essentially an internal annual plan, but it is good practice to make this plan publicly available, for instance via a web site.

The inventory manager ensures that all institutes keep to the procedures and agreements as laid down in the QA/QC plan.

It is good practice to close the inventory management cycle by the production of an 'inventory management report' (see subsection 4.6 below). The inventory management report evaluates the inventory process and provides proposals for updates of the QA/QC plan. Also, the inventory management report is essentially an internal annual report, which could also be made publicly

available together with the QA/QC plan. When the country decides to combine the QA/QC plan (for year N) and the inventory management report (for year N–1) in one document, both parts should be clearly separated in this document.

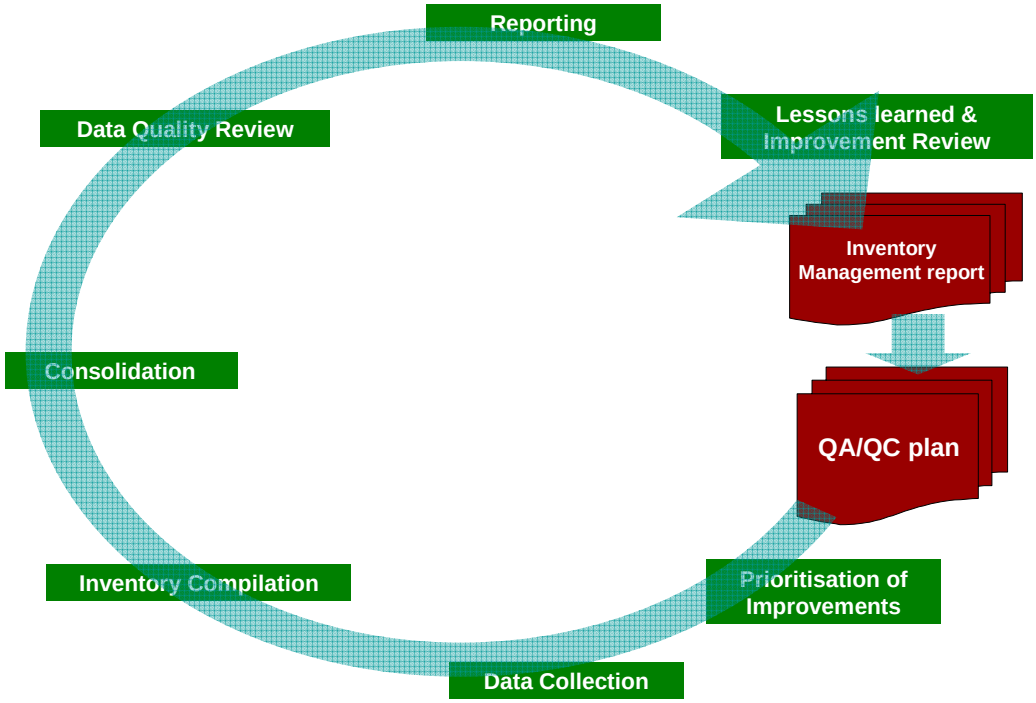

Figure 4-1 Inventory Management Cycle

Although this Guidebook takes a broader scope as compared to the similar chapter in the IPCC Guidelines, the guidance provided here and the vocabulary used are fully consistent with the IPCC 2006 Guidelines (IPCC 2006) and the IPCC Good Practice Guidance (IPCC 2000). The IPCC 2006 Guidelines provide additional details especially in the area of QA and QC, which is not repeated in this chapter. The reader is referred to the IPCC 2006 Guidelines chapter on 'Quality Assurance/Quality Control and Verification' (IPCC (2006, Volume 1, chapter 6).

4.2 What is QA/QC?

An important goal of this inventory guidance is to support the development of national air pollutant inventories that can be readily assessed in terms of quality. It is good practice to implement quality assurance/quality control (QA/QC) and verification procedures as an integral part in the inventory management approach to accomplish this goal.

The terms 'quality control', 'quality assurance', and 'verification' are often used in different ways. The following definitions of QC, QA, and verification will be used for the purposes of this guidance ([4]).

Quality Assurance (QA) is a planned system of review procedures conducted by personnel not directly involved in the inventory compilation/development process. Reviews, preferably by independent third parties, are performed upon a completed inventory following the implementation of QC procedures.

([4]) These definitions are copied from the IPCC 2006 Guidelines.

Reviews verify that measurable objectives (data quality objectives, see subsection 4.3 of the present chapter) were met, ensure that the inventory represents the best possible estimates of emissions given the current state of scientific knowledge and data availability, and support the effectiveness of the QC programme.

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

- provide routine and consistent checks to ensure data integrity, correctness, and completeness;
- identify and address errors and omissions;
- document and archive inventory material and record all QC activities.

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

Verification refers to the collection of activities and procedures conducted during the planning and development, or after completion of an inventory that can help to establish its reliability for the intended applications of the inventory. For the purposes of this guidance, verification refers specifically to those methods that are external to the inventory and apply independent data, including comparisons with inventory estimates made by other bodies or through alternative methods. Verification activities may be constituents of both QA and QC, depending on the methods used and the stage at which independent information is used.

The reader is referred to the IPCC 2006 Guidelines chapter on 'Quality Assurance/Quality Control and Verification' (IPCC 2006 Guidelines, Volume 1, chapter 6) for further information on techniques that could in general be applied for QA/QC of emission inventories.

From the definition above of 'verification' if follows that this activity is external to the inventory. It is best seen as part of the inventory improvement program (Section 6 of the present chapter).

4.3 QA/QC Plan

A QA/QC plan is an internal document to organise and implement all activities across all of the emissions inventory activities including:

- stakeholder engagement (stakeholders = e.g. suppliers of data, reviewers, recipients, other inventory compiling institutes)
- data collection
- data manipulation
- inventory compilation

- consolidating the inventory estimates (e.g. into a single national database)
- reporting.

The QA/QC plan (illustrated in Figure 4-2) is a fundamental element of an inventory management system. The plan needs to clearly identify all important activities used by the inventory compiler and ensure that the minimum data quality objectives required under any relevant reporting obligations are met. Figure 4-2 shows the different QA/QC checks against a typical time scale aimed at submitting an official inventory by mid-February of each year.

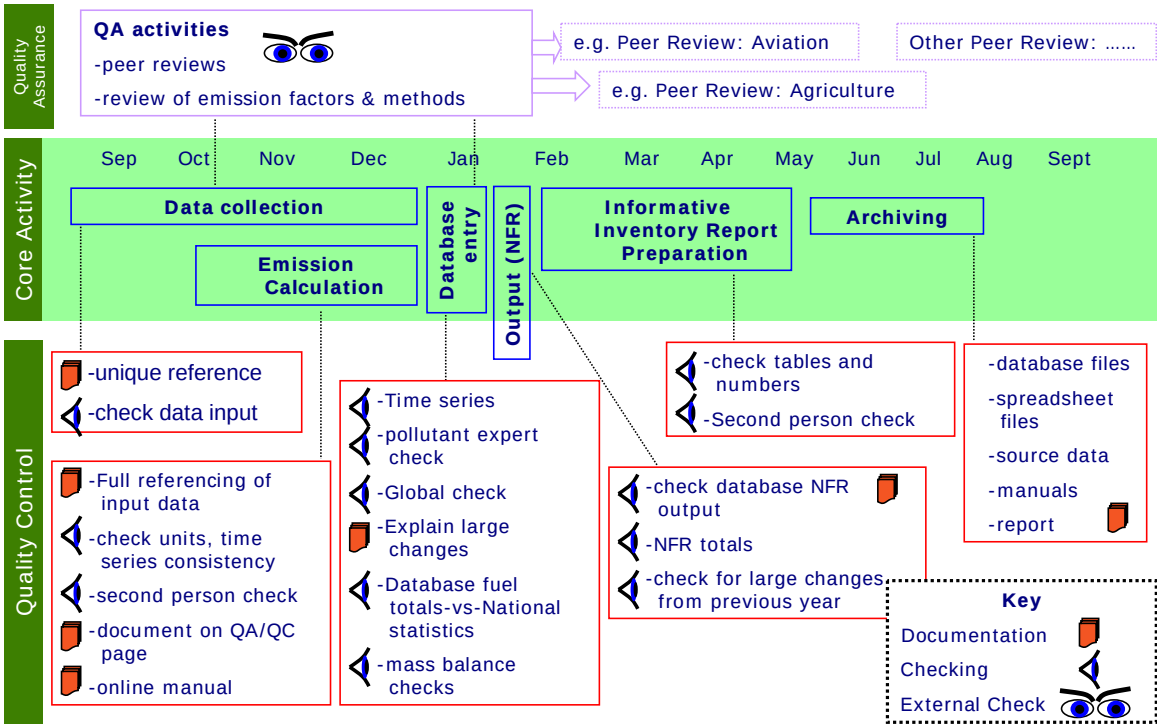

Figure 4-2 QA/QC plan process

The elements of inventory data quality objectives are identified in subsection 2.1 above. These elements set the scope of a system that will ensure that the required level of quality is established in the inventory system.

A key element of a QA/QC plan is a list of data quality objectives, against which an inventory can be measured in a review. Data quality objectives are concrete targets to be achieved in the inventory preparation and relate to the specific requirements of the reporting obligation or other national commitment to provide emissions inventory data. Table 1 below outlines the core elements of the data quality objectives.

Table 1 Data quality objectives

Element	Data quality objectives (general)
Transparency	• Ensuring sufficient documentation and referencing to be able to trace any inventory estimates back through the calculations to the source data, data providers and assumptions. • Maintaining a national inventory report that describes methods, data sources and significant trends, completeness, accuracy and uncertainty, and changes to the inventory, and appropriate source sector breakdown are used for reporting.(See

Table 1 Data quality objectives

Element	Data quality objectives (general)
	Annex 1); this report could serve as the 'Informative Inventory Report' or IIR mentioned in the Reporting Guidelines. • Addressing recommendations related to transparency provided by the inventory reviewers in the following inventory submission. • Maintaining full documentation on quality checks, checklists and electronic checking routines used during QC procedures.
Consistency	• Ensuring that methods are consistent with good practice as defined in this guidebook and that source data and assumptions are used consistently across the time series and pollutants in the inventory. • Eliminating any inconsistencies between the estimates reported under different instruments. • Ensuring consistency with independent inventory, statistical or measurement data.
Comparability	• Using agreed good practice methodologies and formats for estimating and reporting emissions. • Allocating emissions and reductions to source categories in accordance with the split given by the in Reporting Guidelines. • Implementing cross comparisons with other country inventories (indicator assessments and Implied Emission Factor comparisons.)
Completeness	• Addressing recommendations related to completeness provided by independent inventory reviews in the following inventory submission. • Providing all NFR tables including notation keys where appropriate and complete sectoral background data. • Providing information in the inventory documentation on the completeness and changes in completeness of the emissions inventory.
Accuracy	• Using of appropriate or better tiered methodology that is consistent with the guidebook and other guidelines. • Ensuring that quantitative uncertainty estimates are compiled and reported. • Ensuring that Tier 2 or higher tier methods are used for estimating emissions from key categories as far as is feasible.

The QA/QC plan will need to specify the target objectives against each of these elements and contain all QA/QC and verification actions that will be implemented along with identification of the institutional arrangements and responsibilities for implementing those activities.

It is good practice that the plan includes a scheduled time frame for the QA/QC activities that follows inventory preparation from its initial development through to final reporting in any year.

Once developed, the QA/QC plan can be referenced and used in subsequent inventory preparation, or modified as appropriate (notably, when changes in processes occur or on advice of independent reviewers).

In developing and implementing the QA/QC plan, it may be useful to refer to relevant standards and guidelines published by outside groups involved in inventory development. For example, the International Organization for Standardization (ISO) introduced specifications for quantification, monitoring, and reporting of greenhouse gas emissions and removals (ISO 14064) in organisations. It is good practice to define any specific details of a QA/QC and verification system in the QA/QC plan so that national circumstances can be taken into account.

As part of the QA/QC plan, it is good practice to accommodate procedural changes and a feedback of experience aimed at improving the quality of the inventory. Conclusions from previous reviews need to be used to improve the procedures. Such changes can also concern data quality objectives and the QA/QC plan itself. The annual review and revision of the QA/QC plan, as part of the annual inventory management report (subsection 4.6), is an important element to drive the continued inventory improvement.

4.4 QC procedures

In general, QC procedures include generic quality checks related to calculations, data processing, completeness, and documentation that are applicable to all inventory source categories. This section lists the QC checks a compiler should use routinely throughout the preparation of the inventory. It is good practice that these checks are applied irrespective of the type of data used to develop the inventory estimates. They are equally applicable to categories where default values or national data are used as the basis for the estimates. It is good practice to document the results of these QC activities and procedures as set out in Section 5 of the present chapter.

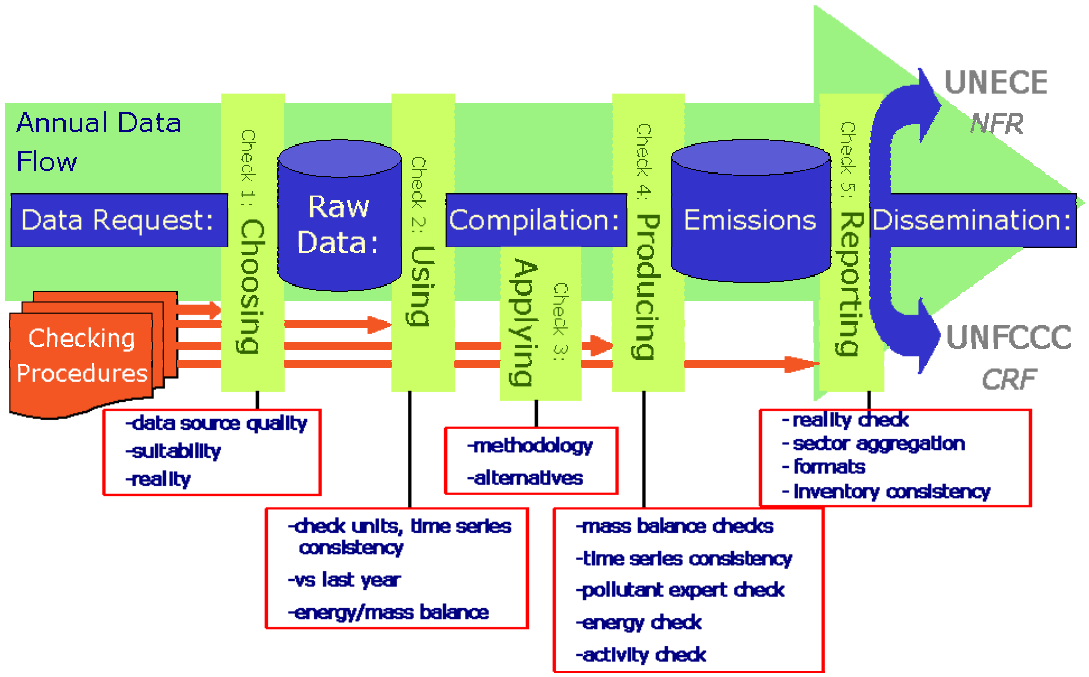

Figure 4-3 QC checks during the inventory process

It is good practice to discriminate between input data, the conversion algorithm of a calculation and the output. Not only does the output need to be recorded, but also the input, the conversion algorithm, and how this algorithm accesses the input. Such an approach allows for intrinsic documentation of the work, and for easy understanding of the calculation procedure. It is good practice to retain the documentation with the material archived in support of the completed inventory.

The QC checks therefore cover three areas:

- choosing data: what information and data is used to compile the inventory? Selection and import of data from data providers into a raw data set;

- using data: how is this information used to estimate the emissions? Compilation of the emissions inventory: conversions and calculations using the raw data to build the emissions database;
- reporting emissions: how are the emissions data included in the inventory formats and reports? Have any errors or mistakes made during this process?

It is a prerequisite that all calculations leading to emission estimates should be fully reproducible. Adequate documentation and archiving of the inventory compilation process is therefore crucial. Guidance on this is given in Section 5 below.

Obviously, it is good practice that any errors found during the QC checks are repaired.

4.4.1 Collecting input data

Emission estimate prepared by inventory compiler

In a typical emission inventorying process the inventory compiler searches for data on both activity rates, emission factors and other parameters for certain source categories and uses these in estimating the emissions. Quality controlling the input data collection process aims at ensuring that the data used in the inventory compilation are traceable and appropriate. It is good practice to perform the following QC checks:

- where do input data come from?
  - check whether the input data for the emission calculations are properly referenced,
  - check the availability of the referenced material,
  - confirm that bibliographical data references are properly cited;
- what input data are used?
  - check that assumptions and criteria for the selection of activity data, emission factors, and other estimation parameters are documented,
  - cross-check descriptions of input activity data, emission factors and other estimation parameters with information on categories and ensure that these are properly interpreted and used,
  - check that parameters and units are correctly recorded and that appropriate conversion factors are used,
  - check that units are properly labelled in calculation sheets,
  - check for consistency in data between categories:
    - ✓ identify parameters (e.g., activity data, constants) that are common to multiple categories, and
    - ✓ confirm that there is consistency in the values used for these parameters in the emission calculations,
  - Check time series consistency:
    - ✓ identify temporal inconsistency in time series input data for each category,
    - ✓ take into account the effects of mitigation.

Emission estimate prepared by other institutions

In some cases, estimates are prepared for the inventory compiler by outside consultants or agencies. In such cases the inventory compiler uses these emission estimates as inputs for the inventory. The inventory compiler should:

- ensure that the consultants/agencies are aware of the QC procedures listed in this chapter and that these procedures are performed and recorded;

NOTE:

In cases where the inventory relies upon official national statistics — as is often the case for activity data — QC procedures may already have been implemented on these national data. However, it is *good practice* for the inventory compiler to check that this is indeed the case.

- confirm that national statistical agencies have implemented equivalent QC procedures.

Because activity data may have been collected for other purposes using standards and data quality objectives different from the inventory, additional QC checks may be necessary.

Confidential data

The Reporting Guidelines allow for not reporting specific information, subject to its laws governing the confidentiality of commercial information, where such information could lead to the disclosure of confidential information. Where confidential information is used in an inventory, it is good practice to make reference to the provision that authorizes such practice. Note that this confidentiality is referring to the publication of the information only and not necessarily to the inventory compiler having access to it.

It is good practice that the inventory compiler checks the quality of confidential data either through direct access to the underlying information or by ensuring that these data have been independently audited and approved, as shown by an official audit report.

When direct access is not possible or an independent audit report is not available, it is good practice for the inventory compiler to consider not using these data.

4.4.2 Conversions and calculations

The objectives described above for quality controlling input data are similarly applicable to all calculation procedures used to prepare a national inventory. Checks of the calculation algorithm should safeguard against duplication of inputs, unit conversion errors, or similar calculation errors:

- check whether all source categories occurring in the country are covered and if specific source categories that do not occur are marked with the appropriate notation key (NO or not occurring);
- check for any double counting or duplicate input;
- check the use of units and all unit conversions needed;

NOTE:

Energy statistics are in many cases available in (equivalent) mass units (tons of oil equivalents) or volume units (m^3), whereas emission factors will be available on an energy basis (kg/TJ or similar). In these cases unit conversions are needed.

- check consistency of activity data used across pollutants within each source category.

NOTE:

Emissions from mobile sources might be calculated on the basis of fuel use or kilometres driven or even both. It is good practice to check whether the mileage data are consistent with fuel statistics.

Check that emissions are calculated correctly:

- reproduce a sample of emissions calculations;
- use a simple approximation method that gives similar results to the original and more complex calculation to ensure that there is no data input error or calculation error.

Check time series consistency:

- check for consistency in the algorithm/method used for calculations throughout the time series;
- check methodological and data changes resulting in recalculations.

4.4.3 Checking the output

When the emission calculations are completed, good practice requires executing a number of arithmetical checks.

Identify major methodological errors

Such checks can be independent 'back-of-the-envelope' calculations, which simplify the algorithms to arrive at an approximate method. If the original calculation and the simple approximate method disagree, it is good practice to examine both approaches to find the reason for discrepancy. Whenever a higher Tier method is applied, a 'quick and dirty' re-estimate using the Tier 1 method could serve as such a test, especially when the uncertainty information on both the Tier 1 emission factors and on the method applied is available.

The opposite, using a higher Tier to check a Tier 1 estimate is not very probable. If a higher Tier estimate is available, it is good practice to report the emissions, using the higher Tier.

Check time series consistency

If earlier inventories have been reported, it is good practice to compare the estimates of the latest inventory with these earlier versions. It is good practice to check any unexpected change in emission levels and, if it is real, explain it. Any unexplained change in emissions might reveal errors or mistakes, both in the current or in earlier inventories. If these errors or mistakes occur in the estimates for earlier years in the inventory, it is good practice to perform a recalculation.

Check comparability

One of the quality criteria of the Reporting Guidelines is comparability between parties to the Convention. A comparison of the inventory with published inventories of other countries might be helpful in checking the validity on the inventory. Obviously it is good practice to take into account differences between the countries in such comparisons. Possible quick and illustrative comparisons might be:

- compare emissions per capita;
- compare emissions per value added;
- compare emissions by fuel type and fuel consumption.

A number of international data sets for population, economic indicators and energy consumption are available, for instance from the International Energy Agency (IEA), Eurostat and the UN Statistics Division.

Obviously, it is good practice to repair any errors found during these QC checks.

4.5 QA procedures

Quality assurance comprises activities outside the actual inventory compilation. Good practice for QA procedures includes reviews and audits to assess the quality of the inventory, to determine the conformity of the procedures taken and to identify areas where improvements could be made. QA procedures may be taken at different levels (internal/external), and they are used in addition to the QC procedures. The inventory may be reviewed as a whole or in parts. The objective of QA implementation is to involve reviewers who can conduct an unbiased review of the inventory and who may have a different technical perspective. It is important to use QA reviewers who have not been involved in preparing the inventory. Preferably these reviewers would be independent experts from other agencies or national or international experts or groups not closely connected with the national inventory compilation, e.g. inventory experts of other countries.

It is good practice for inventory compilers to conduct a basic expert peer review of all categories before or as part of the endorsement by the national authority. This review will identify potential problems and make corrections where possible. It is good practice to give priority to key categories as well as to categories where significant changes in methods or data have been made. In smaller countries, where there may not be external expertise in all technical areas, it is good practice for the inventory compiler to consider contacting inventory compilers from other countries as part of an external review.

More specific information on QA procedures related to individual categories is provided in the category-specific QA/QC sections in Part B of this Guidebook.

4.5.1 Expert review

Expert peer review consists of a review of calculations and assumptions by experts in relevant technical fields. This procedure is generally accomplished by reviewing the documentation associated with the methods and results, but usually does not include rigorous certification of data or references such as might be undertaken in an audit. The objective of the expert peer review is to ensure that the inventory's results, assumptions and methods are reasonable as judged by those knowledgeable in the specific field. Also, where a country has formal stakeholder and public review mechanisms in place, these reviews can supplement expert peer reviews, although they should not replace them.

There are no standard tools or mechanisms for expert peer review of emission inventories, and its use should be considered on a case-by-case basis. If there is a high level of uncertainty associated with an estimate for a category, expert peer review may provide information to improve the estimate, or at least to better quantify the uncertainty. Effective peer reviews often involve identifying and contacting key independent organisations or research institutions to identify the most appropriate individuals to conduct the review. It is preferable for this expert input to be sought early in the inventory development process so that the experts can provide review of methods and data acquisition that could affect final calculations.

The results of expert peer review, and the response of the inventory compiler to those findings, may be important to general acceptance of the final inventory. It is good practice that all expert peer reviews are well documented, preferably in a report or checklist format that shows the findings and recommendations for improvement.

4.6 Inventory management report

At the end of the annual inventory process a brief internal management report may list all issues encountered during data flow, inventory compilation and reporting phases of the process. It is good practice that the report describes the lessons learned during the now almost finalized inventory cycle and provide proposals for improvements in the next and subsequent cycles. The annual review and revision of the QA/QC plan, as part of the annual inventory management report, is an important element to drive the continued inventory improvement.

The inventory management report is as essential for the inventory improvement as is the QA/QC plan (subsection 4.4 of the present chapter). It is good practice that the management report refers back to the current QA/QC plan, its implementation schedule, and discusses the responsibilities for its implementation.

In this summary, it is good practice that the inventory compiler focuses on the following activities:

- data and data flows:
  - any changes in the institutional arrangements governing the data flow from the data providers to the inventory compiler,
  - explain significant trends in the time series, particularly where trend checks point to substantial divergences. It is good practice to include any effect of recalculations or mitigation strategies in this discussion;
- quality assurance and quality control:
  - describe which activities were performed internally, and
  - what external reviews were conducted for each source/sink category and on the entire inventory?

    Records of QA/QC procedures provide especially important information to enable continuous improvement to inventory estimates (see subsection 4.6). It is good practice for records of QA/QC activities to include the checks/audits/reviews that were performed, when they were performed, who performed them, and corrections and modifications to the inventory resulting from the QA/QC activity. An example checklist to use for recording QC activities at both the general- and category-level is provided in Annex 6A.1 of Chapter 6 of the IPCC 2006 Guidelines;
- inventory improvement:
  - present the key findings, describing major issues regarding quality of input data, methods, processing, or estimates for each category, and
  - show how they were addressed or plan to be addressed in the future.

It is good practice to report a summary of all management issues, including the implemented QA/QC activities and key findings as a supplement to each country's annual national inventory.

5 Archiving, documentation and reporting

Figure 5-1 illustrates the documentation activities throughout the inventory process.

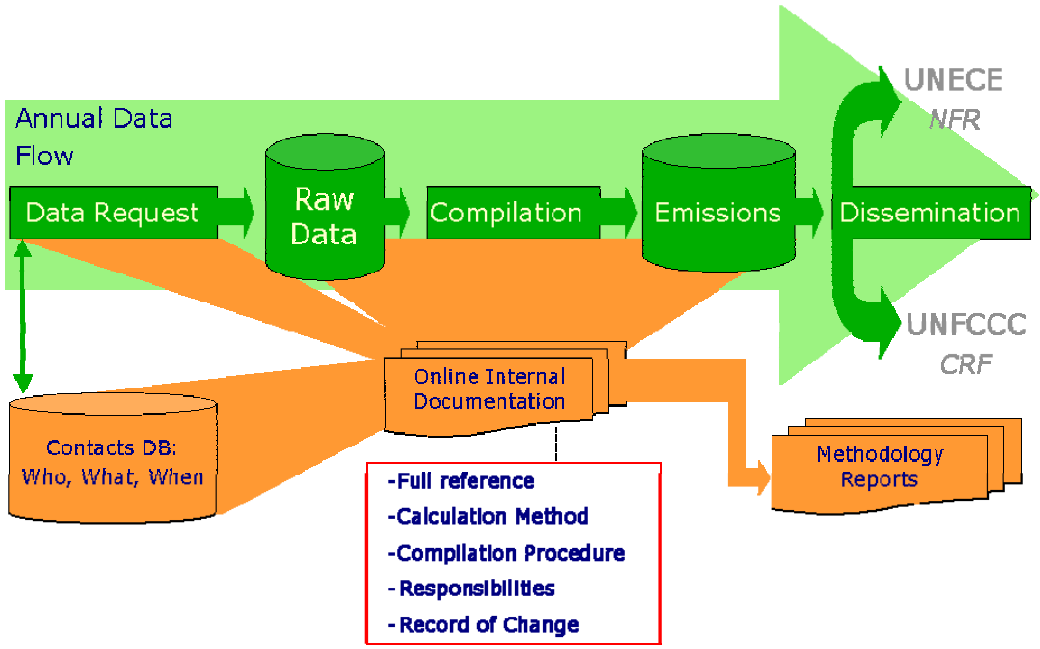

Figure 5-1 Documentation activities during the inventory process

It is good practice to document and archive all information relating to the planning, preparation, and management of inventory activities. This includes:

- institutional:
  - responsibilities, institutional arrangements, and procedures for the planning, preparation, and management of the inventory process (see Section 3 of the present chapter),
  - names and co-ordinates of responsible individuals within the co-operating institutions,
  - identification of individuals providing expert judgement for emission factors and/or uncertainty estimates and their qualifications to do so;
- methodological:
  - methods used, including those used to estimate uncertainty and those used for recalculations,
  - rationale for choice of methods,
  - assumptions and criteria for the selection of activity data and emission factors,
  - changes in data inputs or methods from previous inventories (recalculations);
- data:
  - emission factors and other estimation parameters used, including references to either
    - ✓ the table in this Guidebook where a default Tier 1 or Tier 2 emission factor is used, or
    - ✓ published papers or other documentation for other emission factors used in higher tier methods,

  - activity data or sufficient information to enable activity data to be traced to the referenced source,
  - information on the uncertainty associated with activity data and emission factors;
- technical:
  - details of electronic databases or software used in the production of the inventory, including versions, operating manuals, hardware requirements and any other information required to enable their later use,
  - worksheets and interim calculations for category estimates, and aggregated estimates and any re-calculations of previous estimates,
  - secure archiving of complete datasets, to include shared databases that are used in inventory development. This is particularly important for categories that rely on the multi-step development of emissions from a large set of primary data from outside sources;
- quality assurance and quality control:
  - QA/QC plans,
  - records of QA/QC procedures;
- final inventory report and any analysis of trends from previous years.

It is good practice for inventory compilers to maintain this documentation for every inventory produced and to provide it for review. It is good practice to maintain and archive this documentation in such a way that every inventory estimate can be fully documented and reproduced if necessary.

6 Inventory improvement

6.1 Using the QA/QC systems results

It is good practice to manage the improvement process through the QA/QC systems by keeping record of identified and completed improvements and the impact on the inventory estimates.

Annual improvement reviews should determine the priorities for improvement of the inventory. These reviews should consider the outcomes of the following activities:

- QA/QC and verification that may result in a reassessment of inventory or category uncertainty estimates (Chapter 5, Uncertainties in the General Guidance part of this Guidebook) and to subsequent improvements in the estimates of emissions. For example, the results of the QA/QC process may point to particular variables within the estimation methodology for a certain category that should be the focus of improvement efforts;
- an uncertainty analysis as described in Chapter 5, Uncertainties, in the General Guidance part of this Guidebook identifies the major sources of uncertainties in the inventory.

Any improvements must be appropriately addressed in the inventory including application to the full-time series and checking that the improvement has actually improved the inventory and is repeatable (e.g. data for future years will be available).

6.2 Verification

For the purposes of this guidance, verification activities include comparisons with emission or removal estimates prepared by other bodies and comparisons with estimates derived from fully independent assessments, e.g. atmospheric concentration measurements. Verification activities provide information for countries to improve their inventories and are part of the overall QA/QC and verification system. Correspondence between the national inventory and independent estimates increases the confidence and reliability of the inventory estimates by confirming the results. Significant differences may indicate weaknesses in either or both of the datasets. Without knowing which dataset is better, it may be worthwhile to re-evaluate the inventory. This section describes approaches that can be used to verify inventory estimates at both the source/sink category and inventory wide levels.

The considerations for selecting verification approaches include scale of interest, costs, desired level of accuracy and precision, complexity of design and implementation of the verification approaches, availability of data, and the required level of expertise needed for implementation.

An ideal condition for verification is the use of fully independent data as a basis for comparison. Measurements of atmospheric concentrations potentially provide such datasets, and methods of 'inverse modelling' allow using such data as a basis for emission inventory verification. The approach is particularly valuable as it is independent of standard estimation method drivers, such as sector activity data and implied emission factors. The scale of such models can be designed around local, regional, or global boundaries and can provide information on either level or trends in emissions. A recent report by Van Velthoven *et al.* (2004) provides an overview of methods and aspects that are available in this respect. Further discussion and elaboration on application of these techniques in green house gas emissions can be found in more comprehensive summaries on the use of these methods for inventory verification (Rypdal *et al.*, 2005; Bergamaschi *et al.*, 2004; Benkovitz, 2001; Benjey and Middleton, 2002).

Where verification techniques are used, it is good practice to reflect their results in the management report (see subsection 4.6 above) and incorporate recommendations for inventory improvement into the QA/QC plan. The limitations and uncertainties associated with the verification technique itself should be thoroughly investigated so that the results can be properly interpreted.

7 Glossary

Data provider	An institution or individual that holds data needed for the inventory preparation
Inventory report	A report describing the methods and assumptions used in the inventory
Inventory system	The ensemble of institutions and institutional arrangements set up to meet the requirements of the reporting obligation under the Convention
Management report	An internal report to the Inventory system, describing and evaluating the latest inventory compilation process; the report should propose improvements in the system, in the data flows and in the data
National authority	The national authority responsible for compliance with the reporting obligation under the Convention and its Protocols

QA/QC plan	A systematic write-up of the procedures and review processes for the upcoming inventory submission. The QA/QC plan explicitly addresses the inventory improvement activities in the upcoming compilation process
Quality assurance	(QA) is a planned system of review procedures conducted by personnel not directly involved in the inventory compilation/development process. Reviews, preferably by independent third parties, are performed upon a completed inventory following the implementation of QC procedures. Reviews verify that measurable objectives (data quality objectives) were met, ensure that the inventory represents the best possible estimates of emissions and removals given the current state of scientific knowledge and data availability, and support the effectiveness of the QC programme
Quality control	(QC) is a system of routine technical activities to assess and maintain the quality of the inventory as it is being compiled. It is performed by personnel compiling the inventory. The QC system is designed to: • provide routine and consistent checks to ensure data integrity, correctness, and completeness; • identify and address errors and omissions; • document and archive inventory material and record all QC activities. QC activities include general methods such as accuracy checks on data acquisition and calculations, and the use of approved standardised procedures for emission and removal calculations, measurements, estimating uncertainties, archiving information and reporting. QC activities also include technical reviews of categories, activity data, emission factors, other estimation parameters, and methods
Recalculation	A recalculation of an earlier inventory, following improved data or improved methods; recalculation of earlier inventory years is essential to ensure time series consistency when improved methods and data are used in the latest inventory year
Reporting guidelines	Reporting Guidelines (Guidelines for reporting emission data under the Convention on Long-Range Transboundary Air Pollution, ECE/EB.AIR/2008/4
Validation	Is the establishment of sound approach and foundation. In the context of emission inventories, validation involves checking to ensure that the inventory has been compiled correctly in line with reporting instructions and guidelines. It checks the internal consistency of the inventory. The legal use of validation is to give an official confirmation or approval of an act or product
Verification	Refers to the collection of activities and procedures conducted during the planning and development, or after completion of an inventory that can help to establish its reliability for the intended applications of the inventory. For the purposes of this guidance, verification refers specifically to those methods that are external to the inventory and apply independent data, including comparisons with inventory estimates made by other bodies or through alternative methods. Verification activities may be constituents of both QA and QC, depending on the methods used and the stage at which independent information is used

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ISO 14064-3: 2006 Greenhouse gases — Part 3: Specification with guidance for the validation and verification of greenhouse gas assertions.

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9 Point of enquiry

Enquiries concerning this chapter should be directed to the co-chairs of the Task Force on Emission Inventories and Projections (TFEIP). Please refer to the TFEIP website (www.tfeip-secretariat.org/) for the contact details of the current co-chairs.

Appendix A Elements to include in a transparent inventory report

Note that a template providing the recommended structure of an Informative Inventory Report (IIR) is provided as an annex to the EMEP Emission Reporting Guidelines (UNECE 2009).

Recommended element	Description
National inventory background	• Explanation of the inventory in a national context, including: o geographic scope (e.g. explanation of differences between totals presented in table IV1A); o national total for the entire territory; o national total for the entire territory (1997 Guidelines); o national total for the European Monitoring and Evaluation Programme (EMEP) grid domain. • Explanation of the reason for differences in reported national totals compared with other related national inventories. • Explanation of differences between activity data in the inventory and published national statistics.
Institutional arrangements	• A description of the institutional arrangement for inventory preparation, institutional responsibilities, stakeholders' responsibilities. • Information on archiving.
Inventory preparation process	• A brief description of the process of inventory preparation (e.g. data collection, data processing, data storage, data base systems and procedures).
General methods and data sources	• Brief general description of methodologies and data sources used, e.g. national statistics, regulated process information and country/default emission factors used.
Key categories descriptions	• Explanation of methods used to determine key categories. • List of key categories by pollutant.
QA/QC and verification methods	• Identification of quality assurance/quality control (QA/QC) and verification methods used to ensure quality and time-series consistency of the inventory.
General uncertainty evaluation	• Identification of methods used to assess uncertainty and the use of uncertainty analysis to prioritise inventory improvement.
Sources not estimated (NE)	• List of sources not estimated in the inventory. • A qualitative assessment of their importance, currently and in future. • Description of intentions to calculate these in future or an explanation of why there are no such plans.
Sources included elsewhere (IE)	• Identification of sources aggregated in Table IV1A and not assigned to a specific NFR. • Justification of the decision to aggregate them rather than report the data under specific NFR categories and intentions for future aggregation.
Explanation of key trends	• Explanation of significant changes in the time trend for key

	categories (i.e. dips and jumps) to enable a reviewer or data user to be confident that the changes result from changes in the activity/abatement/process of the source and not as a result of different methods or source data used for different years. • Identification of methodology or activity data based time series inconsistencies.
Main sector method descriptions	• Detail of key activity statistics and statistical balances (e.g. energy balances). • Identification of major changes in methodology for key categories. • Identification of the key methodology features and country specific emission factors used for the sector, e.g. basis of fuel-based estimates (either fuel-combusted or on fuel-sold basis) providing rational for the choice of statistics and method used. • Quantitative or qualitative assessment of uncertainties per NFR or sector group.
Recalculations	• Identify and justify recalculations (by sector, year and pollutant). • Highlight implications for the inventory totals and trends with reference to the new methods documented in Chapter 2, Key category analysis and methodological choice, • Identify new sources added to the inventory (reference new methods on the methodology chapter). • Overview of recalculations since the base year of each any target commitments (relevant for assessment of compliance with each commitment) (including a description of sources that were not included in the base year but have been added since or sources that were included in the base year and no longer is).
Planned improvements	• Identify any improvements and sector and pollutants affected.
Projections	• Description of methods and background data used for any reported projected emissions and activity data.
Annexes	• Annexes necessary to improve transparency • Annex 1: Key category analysis • Annex 2: Detailed methodological descriptions for individual source categories (where relevant) • Annex 3: Further elaboration of completeness use of IE and (potential) sources of air pollutant emissions excluded (where relevant) • Annex 4: National energy balance • Annex 5: Additional information to be considered part of the IIR submission (where relevant) or other useful information • Annex 6: Other annexes (any other relevant information - optional)