Category	Title
General guidance	Inventory management, improvement and quality assurance/quality control
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Lead authors
Justin Goodwin, Chris Dore, Katrina Young

Contributing authors (including to earlier versions of this chapter)
John van Aardenne, Lee Tooly

Contents

1 Overview

There is now a well-established demand for regular (usually annual) inventory update, reporting and improvement. This inventory data is used nationally and internationally to support decision making on environmental protection. It is considered good practice that countries improve the quality (transparency, accuracy, completeness, comparability and consistency (TACCC)) of national inventories on a continuous basis. It is generally accepted that inventories are useful to users if they are updated on a regular basis. There should be improvement over time to provide increasingly useful information on national trends (including influencing factors) and transparent reporting. Establishing sustainable national inventory arrangements will help to continuously improve and regularly update national inventories. To facilitate this, it is important to consider the development of sustainable inventory management systems including:

Institutional arrangements:

- clearly defined roles and responsibilities for delivering the inventory to specified time and quality standards;
- A clear, standardised inventory process so that key activities and resources can be focused towards delivery deadlines and delivery quality;

A **quality framework** to ensure that the data is fit for purpose.

This chapter provides guidance on inventory management, improvement and QA/QC that can be used to help ensure that the inventory systems are able to be fully compliant with countries' reporting commitments under the LRTAP Convention and its protocols (ECE.EB.AIR/125). To ensure continued alignment with best practice in compiling GHG emissions inventories, a substantial amount of the content has been drawn from the latest version of the guidance on GHG emission inventories from the IPCC, the most recent updates being reported as the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2019).

Guidance provided in this section should not be considered prescriptive. It suggests possible approaches and examples of national inventory arrangements demonstrated to be useful when developing sustainable inventory systems that will improve quality[1], timeliness, and use of resources.

National inventory systems could benefit from being developed in cooperation or integration with other environmental and sustainability statistical data collection services and reporting activities (see Box 1).

[1] Transparency, accuracy, completeness, consistency and comparability.

Box 1

Linkages of inventory activities with other data collection and reporting

The following linkages can be beneficial and could be managed as a wider programme under air pollutant inventory arrangements.

National Statistical Systems provide a wide range of data that can be relevant for the inventory compilation. These statistical systems collect data on a regular basis and establish standards for data quality. Inventory compilation is a specialised national data collection activity that requires the collection of additional data that are not typically in national statistics (e.g. emission factors). Inventories should use national statistics where possible. Countries may integrate their national inventory arrangements, to varying degrees, with their national statistical systems.

Subnational inventory compilation and facility-reporting (e.g. cities, states, provinces, territories, and facility emission registries) can bring benefit to and gain from engagement with more structured and coordinated national inventory arrangements. This benefit can result from interest in and contribution to combined efforts to gather/collate/use geographically resolved data such as for regulated sites (including large industrial installations, waste disposal and recycling/treatment sites), and diffuse traffic and transport, agriculture and forestry and forest products. Use of common guidelines, approaches and assumptions and pooled resources/expertise between national and subnational estimation activities will also help to improve the efficiency and credibility of inventory estimates and decision-making processes associated with them.

National air pollutant and GHG inventories can be compiled in tandem. This cooperation or integration can improve quality across inventories, as a large proportion of the activity data (energy, agriculture, transport statistics) are the same for both. It may also improve linkages (through consistent use of data) between climate mitigation and air pollution reporting (e.g. to the UNFCCC and UNECE) and tracking the impact of air pollution and GHG measures to help decision makers understand the co-benefits and potential conflicts. Countries that apply this integrated or cooperative approach may pool resources and management systems for both GHGs and air pollutant inventories and operate more efficiently.

Other environmental and sustainability data gathering processes are undertaken in many countries. These processes involve the collection, reporting of environmental, and sustainability data, including air pollutant emissions and removals, (e.g., in support of indicators for the UN's Sustainable Development Goals and national statistical environmental economic accounts). These initiatives often have a direct links to air pollutant inventory compilation activities in either using data from the air pollutant inventory or providing inputs to its datasets.

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 Institutional arrangements

This section introduces the concept of institutional arrangements. There is a wide diversity in approaches used by countries to monitor, report, verify, and respond to review of its inventory estimates on a regular basis. A sustainable process for compilation and continuous improvement is an important aspect of institutional arrangements. Recognising this, this section presents some common concepts and provides some examples of approaches that could be used when setting up or strengthening sustainable inventory arrangements. Guidance provided in this section should not be considered prescriptive.

Institutional arrangements include the interactions between organisations that are involved with the inventory inputs, compilation processes, and outputs. This could include environment, energy, transport, agricultural, and statistical ministries and/or agencies, academic/research institutions, private organisations and career experts and consultants.

Countries may also consider the need for new or modified laws or directives establishing requirements for data collection, archiving, reporting, and quality management to formalize institutional arrangements for national inventory compilation in the context of existing national statistical data collection systems.

2.1 Inventory objectives

A useful concept to help define the inventory activities and outputs are a country's inventory objectives which should include other decision-making needs for the inventory data. The identification of objectives will help define the scope of data and expertise, specific roles and responsibilities, and timeframes (e.g. schedule and updating frequency) for the inventory compilation, reporting, and review processes. Identifying and assessing objectives also helps the institutions involved in the compilation understand how/if objectives interact/conflict/mesh with good practice.

An illustrative example of a simplified format that could be used to characterise objectives is presented in **Error! Reference source not found.**. Such a summary table could complement more detailed descriptions when presenting inventory arrangements. An illustrative example summary constructed around the United Kingdom's inventory objectives is presented in

.

Table 2-1 An illustrative example structure for capturing and sharing information on the objectives of the national air pollutant inventory

Objective[1]	Pollutant[2]	Sectors & categories[3]	Geographical resolution	Temporal resolution of estimates[4]	Time series span [5]	Reporting frequency[6]	Reporting formats[7]

1. List the objectives that the national air pollutant inventory supports.
2. Add gases included e.g. SO_2, NOx, NMVOC, NH_3, $PM_{2.5}$, BC.
3. Add sectors included Energy, IPPU, Agriculture, Waste, other sectors.
4. The temporal resolution is usually annual (e.g. 2010, 2011, 2012). Some inventories have different durations spanning several years or sub-yearly (e.g. monthly data).
5. Indicate the start and end date of the time series.
6. How frequently is the data updated?
7. Highlight any specific reporting formats (e.g. table structures, schemas, variables needed for specific reporting).

Table 2-2 Illustrative table constructed around UK air pollutant emissions inventory objectives

Objective	Gases	Sectors & categories	Geographical resolution	Temporal resolution of estimates	Timeseries span	Reporting frequency	Reporting formats[a]
UN/ECE Convention on Long-Range Transboundary Air Pollution (CLRTAP)	SO_2, NOx, NMVOC, NH3, $PM_{2.5}$ PM_{10}, TSP, BC, CO Pb, Cd, Hg As, Cr, Cu, Ni, Se, Zn PCDD/F, PAH's, HCB, PCB	Energy IPPU Agriculture Waste Other	UK totals (as defined in the Gothenburg Protocol)	Annual estimates	Yearly values from 1990 until two years prior to current calendar year	Annual	NFR and IIR [f]
			UK within EMEP Grid		Data for single year (two years prior to current calendar year)	Every 4 years	GNFR, EMEP Grid
			UK, point sources				GNFR, Points
EU Directive on the reduction of national emissions of certain atmospheric pollutants (EU2016/2284)			UK totals (as defined in the Directive)		Yearly values from 1990 until two years prior to current calendar year	Annual	NFR and IIR [f]
			UK within EMEP Grid		Data for single year (two years prior to current calendar year)	Every 4 years	GNFR, EMEP Grid
			UK, point sources				GNFR, Points
European Pollutant Release and Transfer Register (E-PRTR)	Those listed above, and others		Regulated installations in the UK		Data for two years prior to current calendar year	Annual	E-PRTR

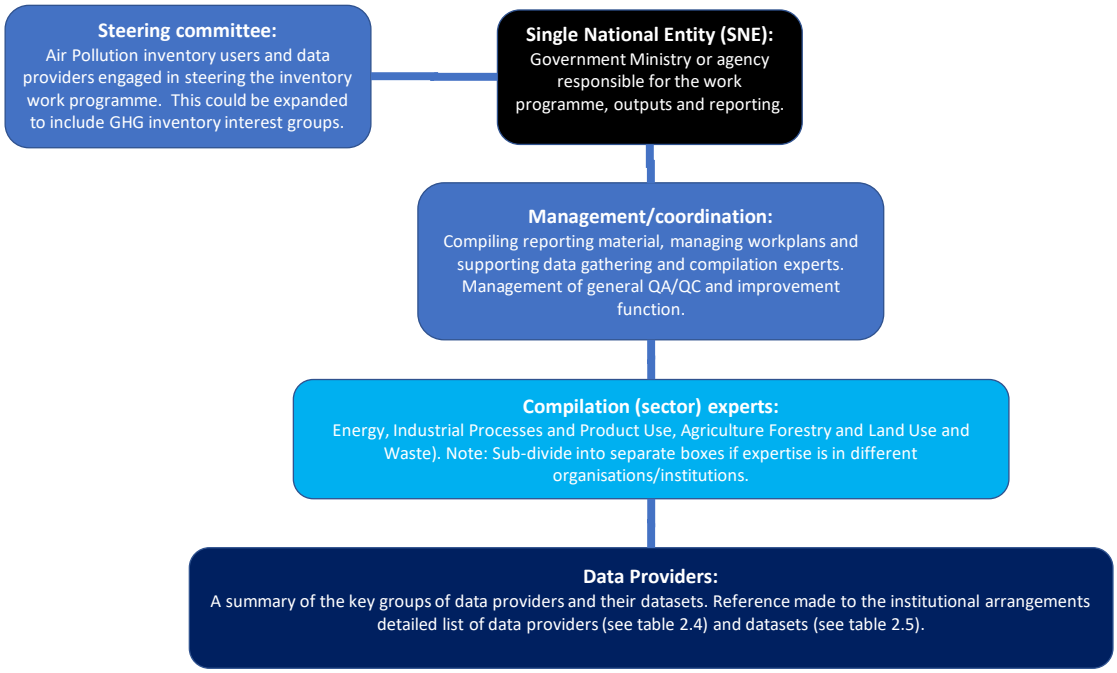
[a] NFR = Nomenclature for Reporting, IIR = Informative Inventory Report, GNFR = Geographical NFR.

2.2 Structuring of institutional arrangements

Clarifying the structure of institutional arrangements can help formalise and communicate the functional roles of organisations in the national inventory compilation process. An illustrative structure provides an overview of the roles and responsibilities whether institutional arrangements are part of a larger statistical data gathering operation or a stand-alone and dedicated inventory activity. An informative structure diagram could also include organisation names. An illustrative example structure with optional components is presented in **Error! Reference source not found.**2.1**Error! Reference source not found.Error! Reference source not found.**.

An overview of the roles and responsibilities within institutional arrangements is elaborated in section 2.1.3.

Figure 2-1 Illustrative example of Air Pollutant inventory institutional arrangements structuring[2]



There are numerous approaches other than use of a Steering committee that can bring outside input into the inventory process, such as through a public review period for the inventory.

2.3 Roles and responsibilities

There are many actors and stakeholders involved with and/or interested in inventory inputs, processes, and outputs. Common actors and stakeholder types are presented in **Error! Reference source not found.**. In some countries, a single individual/structure may serve in more than one actor role. Understanding the interests, contributions and involvement of these actors and stakeholders can help to establish a long-term and well-functioning national inventory system.

[2] The term "Steering Committee" has been used as a generic term to represent a group of interested stakeholders that have influence over the inputs to and development of the inventory.

Table 2-3 List of common actors and stakeholder types with their general roles and capabilities

Actor and Stakeholder Type	Examples of Typical Roles	Necessary Capabilities
Single National Entity (SNE) /National Focal Point (NFP) (see 2.1.4)	Acquisition and allocation of resources. Development of long-term strategy for inventory support to national decision makers, action on air pollution and reporting. Arranging contracts and agreements with collaborating entities that contribute data, research studies, estimate emissions or provide expert reviews, etc. Responsible for submission of inventory.	Technical and administrative expertise, as well as formal government authority. Understanding of reporting requirements and *good practice* concepts. Capacity to coordinate and lead the process. Authority to engage other government departments and non-government organisations.
A group or management structure that contributes to steering the inventory development and who is interested in its outputs and key messages on trends (e.g. Steering committee, see 2.1.5)	Provide input to the planning, coordination, management and technical facilitation of inputs and outputs in the process, advisors to the National Focal Point. Advice on choice of methods with regard to data availability and decision-making needs.	Sectoral, dataset and/or government policy involvement, knowledge, and authority over data collection, research and national strategies. Involved with policy and decision making and negotiations (e.g. on target setting and mitigation implementation) that uses national inventory data
Inventory manager/coordinator (see 2.1.6)	Management of contracts and delivery of workplans. Coordination with all actors and stakeholders. Management of experts. Management of data supply and data supply agreements. Identification of resources necessary to improve data flows. Coordination of reviews and responses to independent review/analysis and tracking of recommendations. Technical reporting of inventory data and formal submission of reports.	Project management & team management. QA/QC (see section 5.3). Technical knowledge of the reporting requirements, review processes and methodologies. Technical awareness of tools, processes, and IT systems for gathering and reviewing data.
Compilation (sector) experts and researchers (see 2.1.7) • Energy • IPPU • Agriculture • Waste • Other	Overall development of methods, data sources, data gathering, compilation and document management. Identify and propose ways to resolve cross cutting issues. Undertake research, data collection, calculations, drafting, quality control, archiving, and documentation. Coordinate with other sector experts. Specialist in a sector, category or group of categories. Identification of potential improvements to estimates.	Technical knowledge of the reporting requirements and methodologies. Technical skills to carry out the work required for the inventory calculation (data analysis, QA/QC, calculations, documentation). Familiarity with national statistics. Specific national sectoral or sub-sectoral knowledge of practices and technologies employed, data sources, trade associations, networks, policies and key assumptions.
Data providers (see 2.1.8)	Timely delivery of input data in appropriate format. Management of data acquisition, processing and reporting systems, QA/QC requirements.	Technical skills/knowledge of, legal authority to improve and enhance data collection. Understanding of the datasets provided.

	Communication with SNE, the Inventory Agency and sector experts, as needed.	
Other contributors and users	General interest in the work with provision of expertise, independent review, research or use of the data for other purposes.	Any
Policy analyst	Inventory data users that inform policies and feed into climate action analysis.	Any

Each actor/stakeholder contributing to the national inventory may need some form of terms of reference (ToR) to facilitate their engagement. Such a ToR can specify functional roles and responsibilities (e.g., inventory compilation, expert input, tool development and use, and/or data collection and storage) and the schedule for conducting this work. Existing terms of reference for duties such as environmental data gathering, or industrial reporting may also be revised to address inventory responsibilities.

The process of engaging actors and stakeholders is likely to vary between different countries and between sectors within countries. The development and maintenance of lists of actors and stakeholders, their roles, responsibilities and interests are quite common. **Error! Reference source not found.** provides examples of metadata for listing actors and stakeholders involved in the inventory process.

Table 2-4 Examples of metadata for tracking inventory stakeholders

1.Name	2.Organisation	3.Contact	4.Mandate	5.Engagement Activities	6.Sector	7.Role

1. **Name**: stakeholders name.
2. **Organisation**: organisation affiliation.
3. **Contact**: contact details.
4. **Mandate**: mandate/terms of reference to contribute to the inventory (if any).
5. **Engagement activities** (Activities that the stakeholder has been regularly involved with e.g. training, workshops, regular meetings attended, data provision etc.).
6. **Sector**: sectors/categories involved with (any particular sector or category involvement).
7. **Role**: type of involvement (e.g. as a data provider, data user, compilation expert, coordinators, data gathering, QA/QC, review, steering committee meetings, training, sectoral workshops, compilation and reporting activities, consultations, and reviews.

2.4 The Single National Entity

The term "single national entity" (SNE) is often used to refer to the lead organisation with the responsibility for reporting official national air pollutant estimates. It is often aligned with the national focal point or international point of contact on air pollutant reporting. A similar role may exist for GHG inventory reporting in the same or different organisation. The role of SNE is usually taken on by a government ministry with mandate to manage the country's inventory reporting and response to air pollution or may be with a national statistical or environmental agency. A key role within the SNE is that of overseeing the inventory activities. A designated focal point coordinates the activities needed to ensure that outputs are prepared of sufficient quality to meet the country's commitments. The role of SNE is sometimes delegated by a government ministry, via mandates/terms of reference, to an air pollution, environmental, or statistical agency with the technical capacity to prepare national reports. The SNE could be the Inventory Agency with a mandate to report the AP and/or GHG inventory data to the ministry or on behalf of the ministry internationally.

2.5 National inventory technical Steering Committee or working group

Countries may find it useful to establish a working group or committee of interested actors and stakeholders to participate in national processes for approving inventory developments and estimates.

This group or committee can consist of actors and stakeholders representing users of (e.g. policy makers) and data providers to the national inventory (e.g. research agencies, national statistical organisations, environment agencies, academic institutions, industrial trade associations, and consultancies). It can provide a forum for the SNE to coordinate and communicate on inventory activities and to secure data provision and independent analysis.

This group of stakeholders can be also convened in support of prioritisation and implementation of inventory improvements.

2.6 Inventory manager/coordinator

Types of institutions that could serve as inventory manager/coordinator include:

- **A government ministry.** Inventory management and coordination can be implemented by a government ministry that also serves as the SNE, in which case it should have the appropriate coordination and technical capacity.
- **A national institution/agency**. Inventory management and coordination can be delegated to a competent institution (e.g. statistical, meteorological, or environmental). Such an institution is typically focused on providing technical support and analysis to government officials for decision making and reporting. It will often have expertise on certain sectors and access to some of the datasets needed for the compilation and will then outsource other data gathering and compilation for other sectors (e.g. Agriculture, Industrial emissions/reporting agencies or institutions).
- **A private company, university or other non-government organisation**. The inventory management and coordination can be contractually delegated to an organisation outside of government, such as a university, research institute, or a consultancy/private company. This organisation may be selected for its technical competency and capacity to coordinate the activities and expertise for the compilation and reporting of the inventory. Contracts can be typically set-up with well-defined deliverables and quality objectives[3] and commitments to engage the organisation preferably over a suitable period (e.g. 4 to 6 years) to promote the sustained development and maintenance of the inventory. Provisions could be in place for the full transfer of data, documents, calculation and reporting tools and knowledge of the national inventory from the contracted organisation to the SNE or new contracting organisation at the end of the contract period.

Whether the inventory is managed within the national government or by external organisations, provisions could be in place for the transfer of data, documents, calculation and reporting tools and knowledge of the national air pollutant inventory to a new inventory manager/coordinator (from SNE to a new contracting organisation in case of private company), including consideration of adequate training investment. These provisions can help ensure national retention of institutional knowledge and capability to ensure that the inventory can continue to be delivered and achieve quality standards in the future.

2.7 Compilation experts

A national inventory system can benefit from a committed team of inventory compilation experts. These experts understand the requirements for inventory quality (as defined in Chapter 1.6 of the 2006 IPCC Guidelines), EEA/EMEP methods, national emission/removal related sectoral processes/practices, and national datasets. It is advantageous for experts to have a good understanding of international reporting and review processes, which can be developed through participation in international or regional peer review activities.

[3] Linked to the quality principles (TCCCA referred to in Volume 1).

As an example, roles and responsibilities for core compilation functions of the emissions inventory team are also outlined in a comprehensive templates prepared by the US EPA in the Greenhouse Gas Inventory Toolkit (EPA 2016). These are not the only examples, but they provide a useful starting point for specifying terms of reference.

2.8 Data providers

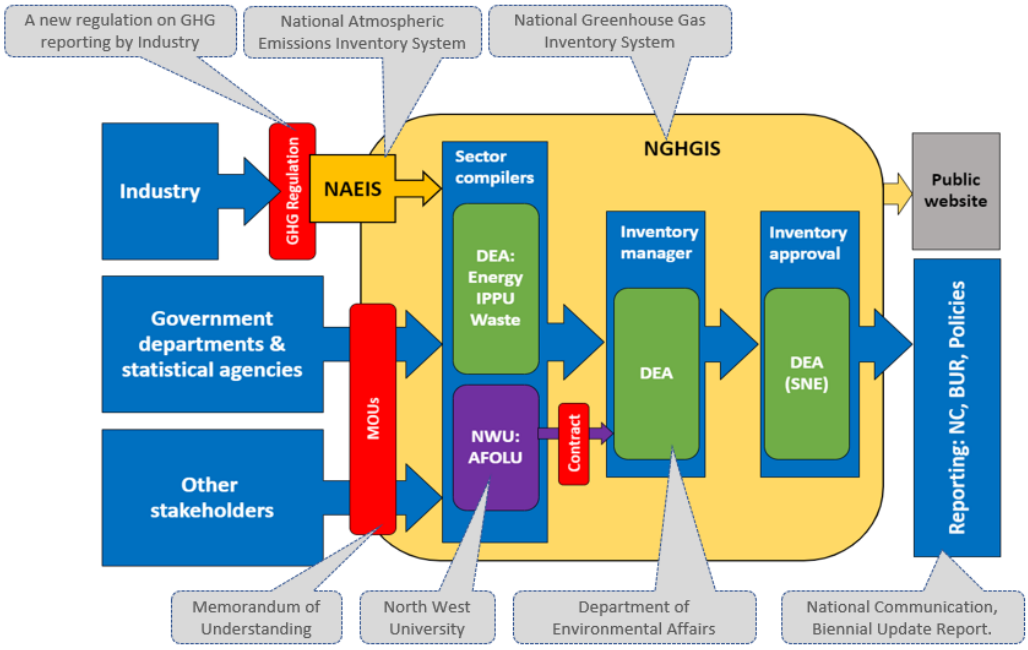
Chapter 3 provides detailed identification of relevant data providers and sources of data. National statistical agencies often have a central role in a country's statistical data collection. Further examples for the formalisation of agreements with data suppliers are provided in section 2.1.8.3.

2.8.1 Datasets and data flows

There are numerous datasets needed for inventory compilation and many data providers (including national statistical agencies, research institutes, government ministries, etc.) who provide them. Approaches for data collection are provided in Chapter 3. Mapping the “flow” of data, in the form of a diagram, from initial data collection to final reporting, further documents and highlights important data providers for the inventory compilation process. An illustrative example of such a diagram for a GHG emissions inventory is provided in Box 2.1.

Box 2.1 Illustrative data flow overview diagram example for South Africa's Greenhouse Gas inventory.

The diagram below presents a simplified view of the key data flows for South Africa's GHG inventory. This data flow diagram is underpinned by a list of datasets used in the GHG inventory which links to the relevant data providers held in a related list in South Africa's National System for GHG Estimation and Reporting[4].



The diagram illustrates the data flows from industrial reporting, government departments and other data sources for South Africa. Industrial reported data are made available to the GHG inventory via the National Atmospheric Emissions Inventory Systems (NAEIS). Reporting industries are mandated to report certain GHG relevant information into the NAEIS by the GHG Regulation that was established in 2016-2017. A number of government departments provide statistical data such as the energy balance, mineral resources and traffic statistics. Other organisations provide data such as that used for country-specific emission factors, certain agriculture and forestry statistics.

More detailed data flows for specific datasets, sectors, or categories can help document the process, improve transparency and build institutional memory.

2.8.2 Archive of datasets

An important component of institutional arrangements is a systematic approach to data management and the collection of data. A first step could be to create and maintain an archive and list of the datasets that are needed for the inventory compilation. This archive and list, which can be established for each sector or as a centralised entity, can help to build and maintain institutional memory and support efficient and transparent compilation of regular updates. An illustrative outline for a list of datasets is presented in **Error! Reference source not found.**.

[4]Own construction based on the South Africa's 2rd Biennial Update Report. (Available at: https://unfccc.int/documents/39835).

Table 2-5 Illustrative list of datasets used in the air pollutant inventory

1.Name	2.Status	3.Description	4.Reference	5.Location	6.Data Provider	7.Sector/ category	8.Update

1. **Name**: This should be a unique name for the dataset.
2. **Status**: Provide a status to indicate if the dataset is received or pending receipt, outdated etc.
3. **Description**: A description of the dataset, including version.
4. **Reference**: A reference or link to a relevant data supply agreement if it exists (see section 2.1.8.3).
5. **Location**: Where the received data are stored within the Inventory archive.
6. **Data Provider**: The provider of the data.
7. **Sector/category**: The sectors/categories of relevance to the dataset.
8. **Update**: The regularity that the dataset is updated.

2.8.3 Data supply agreements (DSAs)

Chapter 3 on data collection refers to the establishment of agreements formalising data supply. A data supply agreement (DSA) is a document that defines what data, from whom, to whom, and when it will be supplied for inventory compilation. Ideally, a DSA is arranged between the inventory SNE and the data supplier. A DSA can be beneficial for both an SNE/inventory compiler and data supplier. A DSA can help secure data provision in the future. Also, a DSA can assist a data supplying organisation by establishing a formally recognized acknowledgement that can promote the allocation resources within the data supplying organisation to deliver high quality data on time.

There are many potential DSA formats. Where there are national laws for data supply, these can be referenced. Where data supply is less formal, DSAs act as an informal specification. Suitable examples of DSAs can be found in many of the countries that have well established entry systems. Possible contents, taken from examples of DSAs,5 that could form part of an agreement document between the Inventory SNE and the data supplier stakeholder are suggested below:

- background on the needs/mandate for the inventory compilation;
- reference to laws/terms of reference and co-operation between the data supplier and the inventory representatives;
- objectives of the agreement with reference to an annex specifying the details;
- confidentiality provisions and commitments;
- procedures that enable the receiving party (the data user, e.g., SNE or inventory agency) to provide feedback to the data supplier on priorities for future improvement of the data set;
- signatures of inventory representative and data supplier, if appropriate;
- technical annex containing details of the data to be supplied, including:
  (i) unique title of the dataset (to avoid confusion with other datasets);
  (ii) confidentiality flags;
  (iii) description including format (electronic format) and scope (time-series, detail, nomenclature, categories, geographies);
  (iv) supplying department/service;
  (v) deadlines for supply;
  (vi) details of QA/QC applied to the data prior to supply;
  (vii) uncertainties in the data.

[5] Examples can be taken from many national inventory systems, including the United Kingdom and Austria

A generic template for the development of a DSA in the form of a memorandum of understanding with a data supplier can be found in the National Greenhouse Gas Inventory Templates developed by the United States Environmental Protection Agency and United States Agency for International Development hosted by the LEDs group (EPA 2016). This can easily be adapted to be suitable for air pollutant emission inventories.

3 The inventory compilation cycle

Inventory compilation an update is a cyclic process. In order to be a useful tool data and time series of the inventory needs to be updated regularly (usually annually). This compilation cycle can be broken down into a series of steps. These steps include data gathering and compilation, QA/QC and documentation activities. These steps can be facilitated by strong, well-coordinated institutional arrangements (see section 2), efficient inventory management tools (see section 4) and clear and rigorous QA/QC (see section 5):

Step 1) **Planning the data gathering, compilation, reporting and QA/QC activities:** This planning phase is important for arranging the team's activities for data collection, QA/QC and compilation.

Step 2) **Data collection**: Data collection will involve stakeholder engagement to identify and obtain data sets. A range of QA/QC activities will be implemented to ensure data collected is appropriate for use. Activities, data sources, methods and assumptions will be documented within the data collection and compilation tools throughout this process.

Step 3) **Data compilation**: The compilation team will make estimates using the collected data. These estimates will be checked for errors within the team. When new methods or assumptions are applied a more independent review will be implemented. Activities, data sources, methods and assumptions will be documented within the data collection and compilation tools throughout this process.

Step 4) **Compilation of reports:** The inventory team will compile the relevant report and apply suitable quality assurance and quality control through check in and review of the outputs. this could include external peer review of reports and tables.

Step 5) **Final endorsement of the inventory** by the national authority.

Step 6) **Inventory review meeting:** Meeting with the inventory team and relevant stakeholders to discuss the compilation cycle and prioritise improvements.

Throughout this compilation cycle the inventory team will be documenting any findings from the quality assurance and quality control process and compiling and prioritising future improvements using the improvement plan (see section 4.3).

4 Inventory management tools

The development of inventory management tools will help to ensure efficiency and transparency in the inventory compilation activities throughout the compilation cycle. Tools include workplans, improvement plans, data management systems, quality systems, training and capacity building and documentation procedures.

The tools in this section should not be considered prescriptive or exhaustive. The sections below provide some suggested approaches and examples demonstrated to be useful when developing sustainable inventory systems that will improve quality[6], timeliness, and use of resources.

4.1 Workplans

National inventories compiled/updated on a regular basis can benefit from the development of a clearly defined workplan, which clarifies the schedule of steps for generating inventory outputs. An illustrative example workplan for a regular inventory update cycle is presented in **Error! Reference source not found.**. Workplans should be reviewed, and where necessary, revised prior to the start of a new inventory update cycle. The inventory manager/coordinator should maintain these workplans and formalize them with inventory compilation contributors through communication of the workplan.

Table 4-1 Illustrative workplan for the preparation of an inventory including an indicative timeline

Example Activity	Illustrative Milestones[7]	Illustrative lead actor/stakeholder
Agreement on the scope of work (including stakeholder consultation and identified improvements and updates to the time-series) and timeframes with stakeholders/steering committee	Week 1	SNE/Inventory manager/coordinator & steering committee engaged for prioritising improvements
Appointing/engaging the team of experts to deliver the scope of work needed (data collection, compilation, QA/QC, documentation and reporting) establishing/revising Terms of Reference: • Roles and responsibilities • Timelines • Deliverables • Time (budgets) allocation	Week 2-6	SNE/Inventory manager/coordinator
Sectoral estimation (e.g. Energy, IPPU, Agriculture and Waste), including: • Collecting data (engaging with data suppliers) and checking data supplied • Agreeing any new methodologies and/or continuation of existing methodologies • Calculation of estimates • QC (checking of all estimates) • QA (peer review of new estimates) • Documentation • Finalisation of reporting formats	Week 3-30	Compilation experts
Collation of sectoral estimates into draft final datasets and national totals and trends (master summary files or database); compilation of uncertainty and *key category* analysis	Week 30-34	Inventory manager/coordinator. Compilation experts where needed for follow-up
QC of draft final estimates and documentation of changes and trends	Week 32-36	
Drafting (collation of the sectoral documentation on methods, data sources and assumptions, *key category* and uncertainty analysis) into the Informative Inventory Report	Week 34-40	
Consultation with stakeholders on draft final estimates and Informative Inventory Report and documented changes and trend features	Week 40-46	(SNE and steering committee engaged for stakeholder review/consultation on outputs)
Finalisation of estimates and the Informative Inventory Report and archiving of the inventory material	Week 46-50	
Reporting and other deliverables to stakeholders and national decision-making processes	Week 50-52	

[6] Transparency, accuracy, completeness, consistency and comparability.

[7] Milestones should be specified as specific calendar dates.

Error! Reference source not found. is only illustrative. It may require adjustment to the specific national circumstances including the timeframes and time period of the inventory cycle which may be more than 1 year (e.g. 2 or 4 years).

4.2 Data management system

The process of preparing and updating a national inventory will involve the use of numerous datasets, documents, references, as well as the application of a range of assumptions, expert judgements, data conversions, and manipulations (e.g., combining data from multiple data sources). Chapter 3 provides guidance on documentation for data collection.

There are many different data management systems used by countries. Some use sophisticated database tools connected to the internet and available for users to upload data and to operate from remote locations. However, many countries currently operate using a collection of spreadsheets, databases and bespoke software systems for calculating estimates. Some key points around the differences between data management systems needed for calculating estimates and for aggregating and reporting inventory data are provided below:

Calculating estimates: Sector compilation experts need flexibility to compile estimates using tools appropriate to national circumstances, including the complexity of their data and methods. Specialised models or spreadsheets may be appropriate. Spreadsheets are often used when starting out and for developing methods, as they are accessible to a range of experts. More complex methods will often entail use of specialised models or databases to facilitate complex calculations and/or the handling of large datasets. Whatever tools are used, applying a common practice for documentation within calculation tools including the following points should be considered:

1. using standard classification and nomenclatures for compilation of estimates (this nomenclature can be based on country-specific or NFR or other recognised classifications (e.g. United Nations Statistics Division (UNSD) classifications8);
2. including metadata in each file and maintaining a master list of the calculation files, their types, authors, and versions;
3. using a standard file naming convention across categories and inventory cycles;
4. documentation in tools with evidence of the implementation of QA/QC procedures;
5. colour coding or other visual formatting to differentiate between areas of data input, calculations, QA/QC checks, explanations, and outputs;
6. documenting where historical data or methods have been revised;
7. documentation of complex models (see section 6); and
8. standard output format for all reported data.

Collation, aggregation and reporting: For analysis and reporting, inventory data needs to be collated, from what can be in the form of differently formatted spreadsheets or calculation models, into a coherent set of tables that can be aggregated to produce detailed reporting formats, national totals, and summary tables. This collation of data into a single format also enables general QA/QC to be applied more easily using tools that can identify anomalies in trends and missing data points. A suggested standardised structure for collating data within a database on emissions, removals, and relevant activity data from the range of categories, gases, fuels and other sub categories is presented in **Error! Reference source not found.**.

[8] https://unstats.un.org/unsd/classifications/.

Table 4-2 Suggested information in a standardised data structure for collating inventory data

1.Year	2.National Nomenclature	3.Reporting Nomenclature	4.Geography	5.Pollutant	6.Type of variable	7.Value	8.Units	9.Notation Keys	10.Reference

1. Year (the year of the value in the time-series).
2. National nomenclature (if relevant the nomenclature used nationally and linked to the statistics, national definitions and/or source data, allowing reports for national use in a nomenclature familiar to national actors and stakeholders).
3. Reporting nomenclature (e.g. NFR categories and fuels/activities).
4. Geography (identifying which part of the national geographical area is represented).
5. pollutant.
6. Type of variable (e.g. emission/removal, activity data, implied emission factor).
7. The variable value.
8. Variable units.
9. Notation key (if relevant).
10. Reference/description of updates since previous compilation; and reference for the source of the value (calculation file).

4.3 Management of QA/QC & documentation

Extensive guidance on QA/QC and documentation is presented section 5. The following components could be considered as part of QA/QC management and documentation of the inventory:

- QA/QC Plan (see below), including general and category-specific quality control procedures and activities designed for independent quality assurance and review of the methods, data sources and assumptions used.
- A log of implemented QA/QC and verification activities with reference to associated documentation and findings (see section 5.3).
- An inventory improvement plan containing potential, planned and implemented improvements. This plan may include a simple table as illustrated in **Error! Reference source not found.**:

Table 4-3 Suggested description of potential, planned and implemented improvements in inventory improvement plan

1. Categorisation	2. Name	3. Description	4.Origin	5.Status	6.Priority	7.Owner

1. The **categorisation** of the improvement. This could include the sector or categories, and the type of improvement activity (e.g. improved QA/QC processes, improved uncertainties or key category analysis, improving activity data, moving to higher tier methods).
2. A short unique **name**.
3. Improvement **description** including information on timeframes and technicalities for development.
4. The **origin** of the improvement (e.g. recommendation or expert suggestion or international review process).
5. The **status** (e.g. suggested, proposed, planned, work in progress, implemented) of the improvement.
6. **The priority** of the improvement (informed by the *key category* analysis).
7. The **owner** is the person or entity responsible for implementing the improvement.

- An inventory archive that structures and stores data on the latest and previous inventory estimates, reports, methodology documents, and calculation files. The archive should include suitably documented information on:
  - responsibilities, institutional arrangements, and procedures for the planning, preparation, and management of the inventory process,
  - names and co-ordinates of responsible individuals within the co-operating institutions,
  - individuals providing expert judgement for emission factors and/or uncertainty estimates and their qualifications to do so;
  - methods used, including those used to estimate uncertainty and those used for recalculation and the rationale for choice of methods,
  - changes in data inputs or methods from previous inventories (recalculations);
  - 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,
  - assumptions and criteria for the selection of activity data and emission factors,
  - information on the uncertainty associated with activity data and emission factors;
  - 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;
  - 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.

4.4 Expert training

Country-specific training material and training activities addressing country-specific methods and data management tools. Suitably trained and/or experienced inventory experts help support the national inventory system to efficiently produce high quality outputs. Ready access to training and regular review participation can help build national capacity, understanding of international reporting requirements, and enhance sustainability of the national inventory arrangements. It may be helpful for the Single National Entity to maintain a roster of identified trainers and archive of training material. Training and experience development can be focussed in three areas:

- Training in the methods in the latest Guidelines available from a number of training services and the EEA.
- Training in the application of relevant Guidelines to the country circumstances. This training may include country-specific or international courses and material.
- Participation in international review processes (e.g. UNFCCC/UNECE/NECD process), which can provide experts with broader experience with inventories undertaken by other countries.

4.5 Education, awareness raising and public access to the information

A national inventory can provide information (e.g. increasing or decreasing trends and sectoral contributions) to support stakeholder decision making. Education-related activities aimed at stakeholders (e.g. relevant government ministries) can help develop their technical capacity, enhance cooperation, and improve their knowledge that can in turn contribute to the continuous improvement of the inventory.

There are activities that can be useful in promoting the inventory processes and outputs. Some examples of such activities include:

- Organizing inventory orientated **workshops with stakeholders**. These can range from technical workshops focused on overall inventory results or on specific sectors to awareness raising events for mass media
- Publication of the inventory data in **user-friendly forms using visual tools** such as infographics to engage with wider stakeholders, students, the press and policy makers.
- Development of **overview and sector specific indicators and factsheets** highlighting key stories on the trends and progress to targets.

5 The inventory quality framework

An important goal of this inventory guidance is to support the development of national air pollutant inventories that meet specific nationally defined requirements on 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 ([9]). These activities form the key functions of the inventory quality framework.

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, see subsection 5.2 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 2019 Refinement of the 2006 Guidelines chapter on 'Quality Assurance/Quality Control and Verification' (IPCC 2019) for further information on techniques that could in general be applied for QA/QC of emission inventories.

From the definition above of 'verification' it follows that this activity is external to the inventory. However it is best seen as part of the inventory improvement program (Section 4 of the present chapter).

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

5.1 Quality principles

The United Nations Economic Commission for Europe (UNECE) Guidelines for reporting emissions and projections data ECE/EB.AIR/125 ([10]) 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 'Transparency' means that the data sources, assumptions and methodologies used for an inventory should be clearly explained, in order to facilitate the replication and assessment of the inventory by users of the reported information. The transparency of inventories is fundamental to the success of the process for the communication and consideration of the information. The use of the Nomenclature For Reporting (NFR) tables and the preparation of a structured Informative Inventory Report (IIR) contribute to the transparency of the information and facilitate national and international reviews

Consistency 'Consistency' means that an annual inventory should be internally consistent for all the reported years for all elements across sectors, categories and pollutants. An inventory is consistent if the same methodologies are used for all of the years of the inventory and if consistent data sets are used to estimate emissions. For projections, consistency also means that a year of the submitted inventory is used as a base year.

Comparability 'Comparability' means that estimates of emissions reported by Parties in their inventories should be comparable. For that purpose, Parties should use the accepted methodologies as elaborated in the Reporting Guidelines and the NFR formats for making estimations and reporting their inventories

Completeness 'Completeness' means that an annual inventory covers at least all sources, as well as all pollutants, for which methodologies are provided in the latest EMEP/EEA air pollutant emission inventory guidebook or for which supplementary methodologies have been agreed to by the Executive Body. Completeness also means the full geographical coverage of the sources of a Party. Where numerical information on emissions under any source category is not provided, the appropriate notation key defined in the Reporting Guidelines should be used when filling in the reporting template and their absence should be documented

Accuracy 'Accuracy' means that emission estimates should be accurate in the sense that they are systematically neither over nor under true emissions, as far as can be judged, and that uncertainties are reduced as far as practicable. Appropriate methodologies should be used, in accordance with section 5.3 below, to promote accuracy in inventories

5.2 Data quality objectives

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 5-1 below outlines some examples of the core elements of the data quality objectives.

([10])The LRTAP Convention Reporting Guidelines and annexes are available online from the CEIP website (www.ceip.at/)

Table 5-1 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 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 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.

5.3 The QA/QC Plan

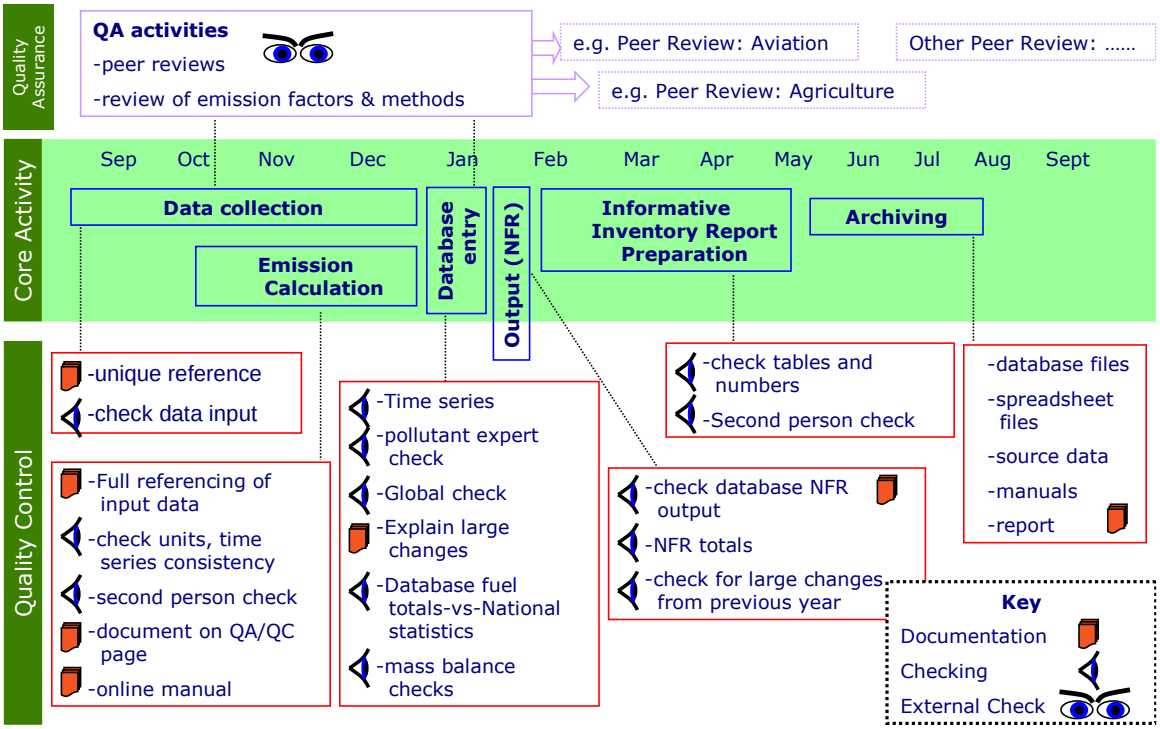
A QA/QC plan is an internal document to organise and implement all activities across all of the emissions inventory activities including:

- 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 (key components illustrated in Figure 5-1) 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 (see section 5.2). Figure 5-1 shows the different QA/QC activities against a typical time scale aimed at submitting an official inventory by mid-February of each year.

Figure 5-1 The key QA and QC elements of a QA/QC plan arranged over an indicative inventory cycle



A key element of a QA/QC plan is a list of data quality objectives (see section 5.2 above), against which an inventory can be measured in a review. 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.

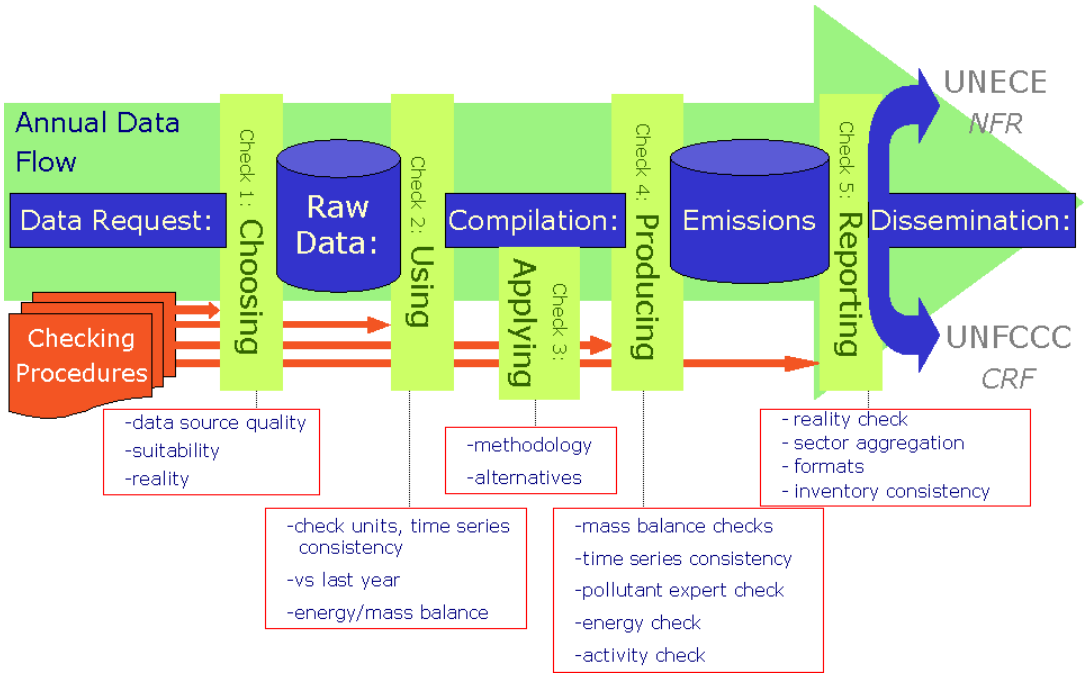
As part of the QA/QC plan, it is good practice to accommodate procedural changes and a feedback of experience aimed at improving the quality of the inventory. Conclusions from previous reviews need to be used to improve the procedures. Such changes can also concern data quality objectives and the QA/QC plan itself. The annual review and revision of the QA/QC plan, as part of the annual inventory management report (section 4), is an important element to drive the continued inventory improvement.

Throughout the inventory compilation cycle (see section 3) a range of quality assurance and quality control activities will need to be undertaken. Some additional guidance on the quality control and quality assurance procedures associated with these steps is presented below.

5.3.1 Quality control (checking)

In general, quality control includes checks to calculations, data processing, completeness, and documentation to ensure repeatability and transparency of estimation activities. These are generally applicable to all inventory source categories. This section highlights some checks a compiler should use and document 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 4.3. Figure 5-2 summarises example QC checks at different stages of the inventory process.

Figure 5-2 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.

Collecting input data

Emission estimate prepared by inventory compiler

In a typical emission inventorying 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 estimates 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;
- confirm that national statistical agencies have implemented equivalent QC procedures.

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.

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.

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

NOTES:

Energy statistics are in many cases available in (equivalent) mass units (tonnes 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.

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.

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.

5.3.2 Quality Assurance

Quality assurance comprises activities that check the integrity of the data outside of the inventory compilation activity. 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.

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.

Public review

Public consultation and public review are becoming increasingly common for quality assurance of inventories. these public reviews include the publication of an inventory report and background calculations with a time frame for public comment. Scientific institutions trade associations industry and academia are encouraged to consider the material and provide written questions and feedback. Feedback is in addressed by adapting the inventory to any new and relevant information provided or the provision of justification or clarification of the methods used.

5.3.3 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

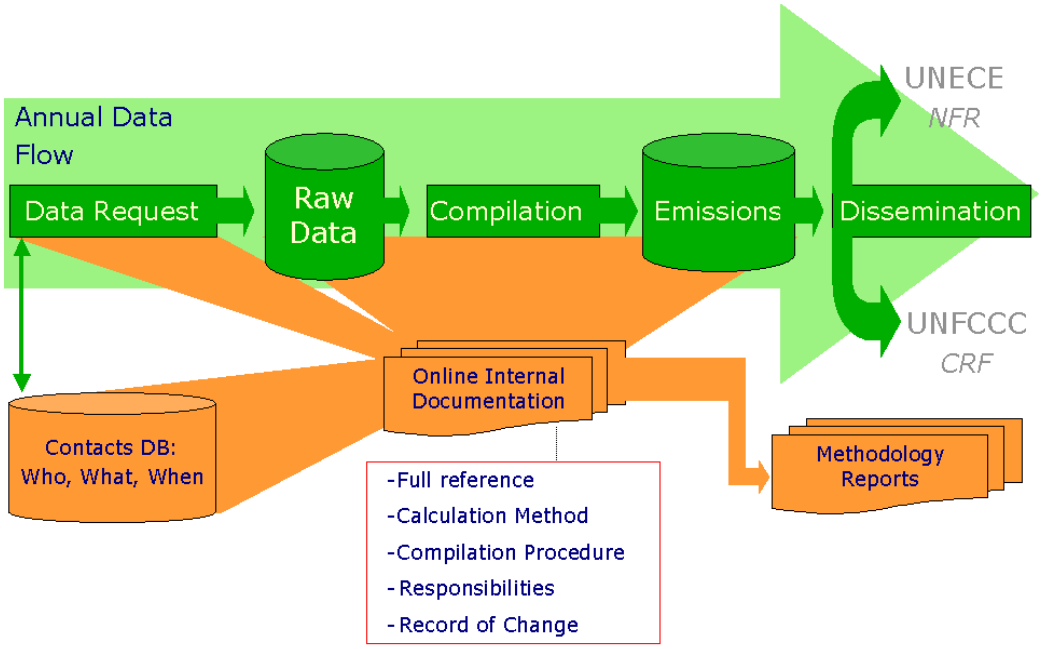
emission factors. The scale of such models can be designed around local, regional, or global boundaries and can provide information on either level or trends in emissions. Further discussion and elaboration on application of these techniques in greenhouse gas emissions can be found in the 2019 Refinement to the 2006 IPCC Guidelines for National GHG Inventories (IPCC 2019).

Where verification techniques are used, it is good practice to reflect their results in the management report 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.

5.4 Inventory documentation

It is good practice to document and archive all information relating to the planning, preparation, and management of inventory activities. Full transparent documentation of the inventory compilation activities (data collection, compilation), QA/QC findings and final methods data sources and assumption can also help improve efficient handover of tasks to new team members. Figure 5-3 shows the ideal coverage of documentation. Detailed documentation is usually within the compilation files and associated manuals. A summary of this information could be included in an internal management report and/or the relevant overview and methodology sections of the Informative Inventory Report.

Figure 5-3 Documentation activities during the inventory process



At the end of the annual inventory cycle a brief internal management report can be used to document the various inventory compilation activities and any issues encountered during the compilation and reporting activities. The report can include the lessons learned during the 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 also an important element to drive the continued inventory improvement. The following elements can be included in the inventory documentation.

- **Methods data sources and assumptions**: Focusing on the key methods data sources and assumptions and any needs for their improvement.
    - 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 activities:** Focusing on quality assurance quality control activities and their findings.
    - 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 5.4). 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:** Highlighting and prioritising improvements to the inventory compilation and management.
    - 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.

6 Use and reporting of models

As the importance of inventories increase, the need to include more complex country specific data and calculations intensifies. Increasingly for key categories, some form of data modelling is used to derive estimates. This could be to estimate the delicate carbon or nitrogen flow around agricultural food production systems or the complex emissions from transport systems. The 2006 IPCC Guidelines Volume 1 Chapter 6 and its 2019 Refinement Volume 1 Section 6.12 provide some guidance on how to ensure that data from models can comply with good practice when used in national GHG inventories. This guidance can also be applied for air pollution inventories. While it is recommended that compilers of air pollutant inventories read the aforementioned GHG guidance, a summary of this information, adapted to air pollutant inventories, is presented below.

6.1 Choosing and using appropriate models

In the application of models in national inventories, a critical issue is suitability. Suitability describes how well the model is able to replicate the real world of emissions it is trying to model. The inventory compiler needs to judge if the model is appropriate and is able to generate suitable outputs that meet the quality objectives of the inventory (see 5.2 above).

Following the identification and/or design of a model for use in estimating emissions, it is good practice to compare model outputs with independent data. This will check whether or not the model behaves as expected and indicates the extent to which the model reproduces the variation in the data that were used to establish its parameter values.

Uncertainty and sensitivity analysis should also be performed so that a measure of model confidence, based on model inputs and structure, can be understood (and reported). When the model is created or materially modified, it is good practice to document the following (preferably in peer reviewed publications which can be referenced by an inventory report to avoid duplication):

- the error distribution of key parameters;
- the covariance matrix of the model parameters (if it is a parametric model);
- results of either error propagation or Monte-Carlo analysis;
- the results of an evaluation of uncertainties from the comparison of model outputs with the independent data;
- the results of a sensitivity analysis or identification of key parameters/inputs to which the model outputs are more sensitive.

6.2 Model transparency

It is crucial that the use of models is documented transparently. Model documentation should include description, suitability, calibration, model evaluation, uncertainty and sensitivities (these elements are elaborated below). Established and well-known models (e.g. some transport models) are usually well documented, calibrated and validated already. For these inventory compilers can rely on published reports and peer-reviewed publications and simply reference this material. There is no need to duplicate the reports, calibration or validation work, or uncertainty analysis.

To ensure transparency in the use of models it is good practice to document the following elements in a suitable methodology report or stand-alone document or manual (references should be made to existing model documentation and publications wherever possible):

- The reason for choosing or designing the model (applicability);
- Basis and type of model (statistical, deterministic, process-based, empirical, etc.).
- Differences in the applied conditions compared to those for which the model was constructed. Whether the model is used outside the range of parameter for which the model was developed;
- If an existing model is being used and adapted: area of application of original model and adaptation of the model (description of why and how the model was adapted for conditions outside the originally intended domain of application);
- Main equations/processes.
- Material assumptions (important assumptions made in developing and applying the model).
- Domain of application (description of the range of conditions for which the model has been developed to apply)11;
- How the model parameters were estimated;
- Description of key inputs and outputs;
- Details of calibration and evaluation with calibration data and independent data (showing intermediate outputs at an adequately disaggregated level);
- Description of the approach taken to the uncertainty analysis and to the sensitivity analysis, and the results of these analyses;
- QA/QC procedures adopted;
- Findings of QA by experts not involved in the model development;
- Interpretation of model results;
- Comparison of model results with lower tier (simpler estimation) approaches[12];

[11] Model outputs should match the definitions and requirements of the Guidelines.

[12] It is not necessary to do this every year, but in establishing a model as part of a national inventory system, the impact of the model results compared with the lower tier approach should be considered. For example, a model may be able to

- References to peer-reviewed literature (where details of the research on the model can be found);

It is also advisable to produce some output indicators comparing the model with other independent data that illustrate how the model performs compared to other estimation approaches and/or measurements. Reporting such indicators and highlighting what they show will demonstrate model robustness and suitability. Examples include:

- Land and agricultural sector models should illustrate that they conserve mass (e.g. Carbon and Nitrogen) and land area through comparisons with mass and area balances of the inputs and outputs;
- Energy sector models should illustrate the conservation of energy and mass in comparison with national energy balances;
- In some complex industrial sectors, it is possible to illustrate a mass balance is possible (e.g. the conservation of carbon in refineries and iron and steel plant);
- Transport models should illustrate the conservation of vehicle number, vehicle km and energy consumption.
- A comparison of implied emission factors with country-specific factors or, if not available, default values. This comparison should also provide an explanation for any significant differences.
- An explanation of any unusual input values and results (i.e. outliers with respect to some reference data).

6.3 Checklist for ensuring good practice in the use of complex, higher tier models in inventories

Section 6.12.7 of Volume 1 of the 2019 IPCC refinement provides a useful checklist for ensuring good practice in the use of complex, higher tier models. This checklist is applicable to air pollutant models as well as GHG inventory estimation models. It includes guidance on model identification, characterization of the model type, identification of the main processes and equations, assumptions used, main applications, calibration checks, documentation of implementation evaluation.

better describe annual temporal changes and so better describe larger year-to-year variability: this would be averaged out in lower tiers.

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
Single national entity	The lead organisation with the responsibility for reporting official national air pollutant estimates.

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

8 References

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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 a annex to the EMEP Emission Reporting Guidelines.

Recommended element	Description

National inventory background	• Explanation of the inventory in a national context, including:
	  ○ geographic scope (e.g. explanation of differences between totals presented in table IV1A);
	  ○ national total for the entire territory;
	  ○ national total for the entire territory;
	  ○ 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)