Development of Quality Control (QC) and Quality Assurance (QA) Plan for Green House Gas Inventory

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Abbreviations

AFOLU	Agriculture, Forestry and Other Land Use
CDIAC	Carbon Dioxide Information and Analysis Centre
CEM	Continuous emissions monitoring
EDGAR	Emission Database for Global Atmospheric Research
FAO	Food and Agriculture Organization
GHG	Green House Gas
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
TACCC	Transparency, Accuracy, Consistency, Comparability and
UNFCCC	United Nations Framework Convention on Climate Change
QA/QC	Quality Assurance and quality control
IPPU	Industrial Process and Product Use
PFC	Phosphor-fluorocarbons
SF6	Sulfur hexafluoride

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1. INTRODUCTION

1.1 Background Information

A greenhouse gas inventory is an accounting of greenhouse gases (GHGs) emitted to or removed from the atmosphere. An inventory will list, by source, the amount of GHG emitted to the atmosphere during a given time period (annual. emission estimates from a base year to the latest year). Internationally, the reporting of national inventories is part of the UNFCCC management of GHG emissions. Inventories are used to monitor progress towards reduction targets and to enable countries to access climate finance mechanisms.

An important goal of Intergovernmental Panel on Climate Change (IPCC) inventory guidance is to support the development of national greenhouse gas inventories that can be readily assessed in terms of quality. It is good practice to implement quality assurance/quality control (QA/QC) and verification procedures in the development of national greenhouse gas inventories to accomplish this goal. The procedures as described in this chapter also serve to drive inventory improvement. The guidance is designed to achieve practicality, acceptability, cost-effectiveness, incorporation of existing experience, and the potential for application on a world-wide basis. A QA/QC and verification system contributes to the objectives of good practice in inventory development, namely to improve transparency, consistency, comparability, completeness, and accuracy of national greenhouse gas inventories.

The implementation of quality assurance, quality control (QA/QC) and verification procedures is an important part of the development of national greenhouse gas inventories, and accounting and reporting on Green House Gas (GHG) mitigation actions (hereafter commonly called 'GHG inventory'). As described in the IPCC 2006 Guidelines, an adequate QA/QC plan helps improve transparency, consistency, comparability, completeness, and confidence in national GHG inventories.

An important goal of IPCC inventory guidance is to support the development of national greenhouse gas inventories that can be readily assessed in terms of quality. It is good practice to implement quality assurance/quality control (QA/QC) and verification procedures in the development of national greenhouse gas inventories to accomplish this goal. The procedures as described in this chapter also serve to drive inventory improvement. The guidance is designed to achieve practicality, acceptability, cost-effectiveness, incorporation of existing experience, and the potential for application on a world-wide basis.

QA/QC and verification activities should be integral parts of the inventory process. The outcomes of QA/QC andverification may result in a reassessment of inventory or category uncertainty estimates and to subsequent improvements in the estimates of emissions or removals. For example, the results of the QA/QC process may point to particular variables within the estimation methodology for a certain category that should be the focus of improvement efforts.

1.2 Principles

The GHG inventory is guided by transparency, accuracy, consistency, comparability and completeness (TACCC). These are defined by IPCC 2006 Guidelines as follows:

- **Transparency -** means that the inventor complier should provide sufficient and clear documentation and report a level of disaggregation that sufficiently allows individuals or groups other than the compiler team to understand how the inventory was compiled and assure it meets good practice requirements for national greenhouse gas emissions inventories. The transparency of emission reporting is fundamental to the effective use, review and continuous improvement of the inventory.
- **Accuracy** - means that emissions are neither overestimated nor underestimated, as far as can be judged. This implies all endeavors to remove bias from the inventory estimates.
- **Consistency -**means that estimates for any different inventory years, gases and categories are made in such a way that differences in the results between years and source categories reflect real differences in emissions. Annual emissions, as far as possible, should be calculated using the same method, and data sources for all years, and resultant trends should reflect real fluctuations in emissions and not the changes resulting from methodological differences. Consistency also means that, as far as practicable and appropriate, the same data are reported under different international reporting obligations.
- **Comparability -** means that the national inventory is reported in such a way that allows it to be compared with national inventories of other countries. This can be achieved by following IPCC Guidelines and i.e. appropriate choice of key categories, using the reporting guidance, tables, classification and definition of categories of emissions as presented in IPCC 2006 Guidance, Volume 1, Chapter 8 on Reporting Guidance and Tables.
- **Completeness -**means that estimates are reported for all pollutants, all relevant source categories and all years and within the entire territorial boundaries of the country. Where elements are missing their absence should be clearly documented together with a justification for exclusion.

1.3 Definitions of QA/QC and verification

Quality control and quality assurance measures are two distinct types of activities. The IPCC defines them as follows:

Quality Control (QC) is a system of routine technical activities implemented by the inventory compilers to measure and controls the quality of the inventory as it is prepared. 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 standardized procedures for emission and removal calculations, measurements,

estimating uncertainties, archiving information and reporting. QC activities also include technical reviews of categories, activity data, emission factors, other estimation parameters, and methods.

Quality Assurance (QA) is a planned system of review procedures conducted by personnel not involved in the inventory development process. QA procedures are performed upon a completed inventory following the implementation of QC procedures and preferably by independent third parties. A basic expert peer review is part of this 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.

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 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.

This means that QC is part of the inventory compiler's day-to-day work. In contrast, external staffs who are not involved in the inventory compilation perform QA as an additional quality check. Verification activities may be constituents of both QA and QC, depending on the methods used and the stage at which independent information is used.

QC is further divided into general and category-specific QC procedures. General QC procedures include generic quality checks related to calculations, data processing, completeness, and documentation that are applicable to all inventory sources and sink categories. Category-specific QC procedures complement general inventory QC procedures. Category-specific QC is directed at specific types of data used in the methods for individual source or sink categories. These procedures require knowledge of the specific category, the types of data available, and the parameters associated with emissions or removals, and are performed in addition to the general QC checks.

QA and QC are critical components of an inventory management system because when they are implemented effectively, they drive inventory improvement. Therefore, a fundamental element of the inventory management system is a written QA/QC plan. This plan outlines QA/QC activities to be performed, the personnel responsible for these activities, the schedule for completing these activities, and a list of future planned QA/QC improvements.

1.4 Key Points Considered in Developing QA/QC and Verification Systems

In practice inventory compilers do not have unlimited resources. Quality control requirements, improved accuracy and reduced uncertainty need to be balanced against requirements for timeliness and cost effectiveness. A good practice system for QA/QC and verification seeks to achieve that balance, and also

to enable continuous improvement of inventory estimates. Judgments to select the respective parameters will need to be made on the following:

- Resources allocated to QA/QC for different categories and the compilation process;
- Time allocated to conduct the checks and reviews of emissions and removal estimates;
- Frequency of QA/QC checks and reviews on different parts of the inventory;
- The level of QA/QC appropriate for each category;
- Availability and access to information on activity data, emission factors and other estimation parameters, including uncertainties and documentation;
- Acquisition of additional data specifically required, e.g., alternative data sets for comparisons and checks;
- Procedures to ensure confidentiality of inventory and category information, when required;
- Requirements for documenting and archiving information;
- Whether increased effort on QA/QC will result in improved estimates and reduced uncertainties;
- Whether sufficient independent data and expertise are available to conduct verification activities.

2. ELEMENTS OF A QA/QC AND VERIFICATION SYSTEM

The following are the major elements of a QA/QC and verification system to be implemented in tracking inventory compilation. An effective QA/QC plan includes the following elements:

- Personnel responsible for coordinating QA/QC activities;
- A QA/QC plan;
- General QC procedures that apply to all inventory categories;
- Category-specific QC procedures;
- QA and review procedures;
- QA/QC system interaction with uncertainty analyses;
- Verification activities;
- Reporting, documentation, and archiving procedures

General QC procedures should be applied routinely to all categories and to the inventory compilation as a whole. An initial step towards developing a QA/QC Plan is to appoint one person to be the QA/QC coordinator. This is the main person responsible for developing, maintaining and implementing the QA/QC plan. Ideally, this person will be knowledgeable about each sector of the GHG inventory in order to understand the implications of ensuring quality in each of the sectors. If the inventory team is small, it is possible for one or more people to may have multiple roles. A large QA/QC team is not a necessity – the key is to ensure that the QA/QC system is efficient and effective and helps drive inventory

improvement.

The QA/QC coordinator should develop the QA/QC plan with input from each of the sector leads and ensure each receives the final plan. The QA/QC Coordinator should also regularly review the plan and modify it to reflect new processes, implement recommended improvements, or support the objectives of the National Inventory Improvement Plan. This is particularly important to do at the start of each GHG inventory compilation cycle. Related to this, the QA/QC coordinator should keep records about how improvements have been implemented.

3. Roles and Responsibilities of GHG Compiler

The inventory compiler should be responsible for coordinating the institutional and procedural arrangements for inventory activities. In Ethiopian case this part shall be done by all line ministry CRGE (MRV unit) or experts. It is good practice for the inventory compiler to define specific responsibilities and procedures for the planning, preparation, and management of inventory activities, including:

- Data collection;
- Selection of methods, emission factors, activity data and other estimation parameters;
- Estimation of emissions or removals;
- Uncertainty assessment;
- QA/QC and verification activities;
- Documentation and archiving.

The inventory compiler is also responsible for ensuring that the QA/QC plan is developed and implemented. It is good practice for the inventory compiler to designate a QA/QC coordinator as the person responsible for ensuring that the objectives of the QA/QC process as set out in the QA/QC plan.

4. Roles and Responsibilities of National GHG Inventory Coordinator (NIC)

The NIC is typically responsible for managing all aspects of National GHG Inventory development, including providing technical and coordination assistance to all members of the National GHG Inventory Team, ensuring funding is in place, briefing senior management, and establishing the overall National Inventory Schedule. In Ethiopian case this activity shall be done by national MRV system coordinator. The coordinator should have a comprehensive understanding of the UNFCCC reporting requirements, IPCC guidelines, and a general understanding of all GHG sectors.

- Manage and support the National GHG Inventory staff, schedule, and budget in order to develop the inventory in a timely and efficient manner to meet national priorities, along with international reporting needs.
- Prepare a detailed work plan for producing the National GHG Inventory, including interim deliverables/ outputs, in close consultation with inventory leads/coordinators and relevant data providers.

- Establish internal processes and schedule to ensure that the national inventory team has sufficient time for to apply QA/QC procedures and assess uncertainties of emission estimates.
- Develop scope of work documents and procure contracts with consultants to support inventory cross-cutting and report compilation tasks.
- Oversee sector leads/consultants responsible for report compilation both at the sector level and at the level of aggregate results (reflect all sector estimates combined) to ensure incorporation of the inventory in the NC and Biennial Update Report (BUR) for submittal to the UNFCCC.
- Schedule periodic meetings to check in on status of work and periodically brief inventory agency management on progress and results.
- Assist sector leads to prepare and implement sector specific work plans, including interim outputs/deliverables, as well as identify, collect, and organize data for inclusion in the inventory.
- Assist sector experts with the use of activity data and select and apply appropriate IPCC Good Practice Guidance to improve existing methodologies and emission factors
- Assign cross-cutting roles and responsibilities, including those for Quality Assurance/Quality Control (QA/QC), archiving, key category analysis (KCA), uncertainty analysis, and compilation of the inventory section of the NC and/or BUR.
- For all project activities (i.e., QA/QC, uncertainty analysis, archiving, etc.), coordinate with cross-cutting leads to convey responsibilities to sector leads, consultants, national agencies and institutions.
- Review the UNFCCC Consultative Group of Experts (CGE) training materials on the preparation of GHG inventories for reporting obligations (e.g., national communications (NCs)).
- Review the UNFCCC guidelines/manuals related to NCs and Biennial Update Reports (BURs).
- Review the IPCC Guidelines to understand the default methods, data sources, basic QA/QC, uncertainty assessment and reporting procedures
- Review existing software packages for developing inventory estimates country-specific software.

5. Data Providers

Data collection procedures include finding and processing existing data, (i.e., data that are compiled and stored for other statistical or administrative uses than the inventory), as well as generating new data by surveys or measurement campaigns. During the data collection for the greenhouse gas inventory, interactions between the inventory compilers and stakeholders will take place. According to our country context the data collection for GHG inventory should be done by national statics agency to avoid the confusions and overlapping of the works.

6. Verification

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. It can verify the quality of data used and availability of the information to be collected, and the design of quantification methodologies, emission monitoring methods and verification activities. Specifying the information to be reported (for instance fuel quantity, carbon content, heat content, etc.) and methods appropriately, will assist in achieving the quality and transparency required for the type of inventory integration intended. In our case the verification system should be done by the national MRV directorate and across all the sectors.

7. Related Terminologies relevant for QA/QC Implementations

7.1. Enhanced Transparency Framework (ETF)

The Enhanced Transparency Framework (ETF) is a crucial component of the Paris Agreement, designed to provide a better understanding of actual progress in climate action, as well as better accountability of the resources assigned and outcomes achieved in the process. The objective of this ETF is to build mutual trust and confidence and to promote effective implementation, to provide clear understanding on climate action, including clarity on progress towards achieving parties Nationally Determined Contributions (NDC), to provide clarity on support provided and received and inform the global stock take process. QA/QC is one of the requirements in GHG inventory report preparation to make it clear and transparent the overall process of the inventory preparation.

Parties to the Paris Agreement may continue to report a separate national communication (NC) every four years, or may choose to submit a single Biennial Transparency Report (BTR)/NC report in the years a NC is submitted, following the modalities, procedures and guidelines for BTRs.

7.2. Current QA/QC Implementation Status and Institutional Arrangement

The government has established the CRGE governance system, which enables to monitor and evaluate the implementation progress of CRGE targets in the whole country. Environmental protection authority is primarily mandated to lead the coordination of MRV implementation at the national level, while line ministries have their own departments dealing with CRGE implementation, where MRV related issues are embedded. This means that all CRGE implementing line ministries have a standing institutional arrangement that can easily facilitate all activity data collection, report preparation and monitoring. More over these all institutions have a mandate to check the QA/QC in their respective organizations starting from the grass root level data collection to the ministries. Except Ministry of Industry all the rest line ministries are collect the activity data from the lower administration and try to do the QA/QC. But Ministry of Industry would collect the activity data from different industries in collaboration with the institutes under the Ministry of Industry.

8. OBJECTIVES OF THE ASSIGNMENT

8.1 General Objective

Develop Quality Assurance (QA) and Quality Control (QC) improvement Plans for Greenhouse Gas Inventory

8.2 Specific Objectives

- To assess current National GHG inventory situational analysis report
- To develop Detail general, sector-specific, and cross-cutting QA/QC plan
- To develop Quality assurance (QA) reviews procedures;
- Reporting, documentation, and archiving procedures
- To develop Detail National GHG inventory estimation improvement plan

9. Methodology of the Assessments

The methodology used to do this assessment was survey of different related documents (articles and journals) from several sources. In addition to this questioner were developed and used to assess the current QA/QC implementation status. More over about 16 key informant information and 7 Focused Group Discussion (16 KII and 7 FGD) were used for data collection. Cross-Checking the approach to validate the responses of KIIs and FGDs also done. The questioners developed for this assessment were annexed to the report. For this assessment the KII and FGD targets are selected from all line ministry of CRGE expert by selecting the expert who are doing as MRV expert.

10. Main Findings and Discussions

Based on the responses or information found from the all sectors 16 key informant information and 7 Focused Group Discussion (16 KII and 7 FGD), the findings of the assessment were explained accordingly as a general and sector specific as follow. As a general perspective, the response found from all selected target groups show that, the GHG inventory QA/QC implementation in all CRGE implementers would be an infant stage that needs radical action. This means that there is no organized and well documented QA/QC Plan for GHG inventory at all level. In some part QA/QC activities have been tried at the federal level that lack uniform and consistent working modalities at regional, zonal and Woreda level. QA/QC implementation needs a very good institutional arrangement form federal to the Woreda level, that makes the data follow more easier and somewhat improve the implementation of QA/Qc. But the finding shows that there is no institutional arrangement in place that links the federals with the regions and the regions with the zones and zones with Woredas until this study data collection was made. In addition to this, limitation of the expert capacity to do the QA/QC in all sectors is the main finding that needs urgent intervention. Moreover, the data management system is the fundamental problem exists in all sectors, starting from the federal to the woreda level and the roles and responsibility of the sector expertise in GHG inventory is note clearly articulated. This means that the roles and responsibility of data collector, the roles and responsibility of data encoder, the roles and responsibility of data compiler, and the roles and responsibility of the data coordinator is not clearly indicated as a national

level. Finally, there is no QA/QC implementation plan and GHG inventory gap improvement plan and documentation of GHG inventory system in all sectors. The findings across the sector would be discussed as follow.

1. **Ministry of Agriculture**: sector showed better performance than other sectors as there is role and responsibility in the sectors. In this sector the institutional setup is better, which help the sector to do all the activities regarding the GHG inventory and QA/QC. But there is challenging of planning the QA/QC and gap improvement across the data source of the sectors and as well as the data management system is limited.
2. **Ministry of Industry**: The activity data used for GHG inventory was collected from the institutes, established under ministry of industry. This sector is basically working with the private sectors that make difficulty to get raw data from them because of their confidentiality. This means that the sector has no institutional arrangement that links the federal sectors with the regions and lower administrations. The other problem that this study found is the poor data management and documentations system of the GHG inventory. Moreover, this sector has no QA/QC plan, gap improvement plan and no clear indication of the actors in the GHG inventory system. (Roles and responsibility of the federal experts, institutes and factories experts are not clearly indicated)
3. **Ministry of Urbanization & Infrastructure:** sectors showed more dedication to have a written QA/QC plan developed prior to any emissions being calculated or measured. This sector will need intensive monitoring and evaluation. There is no QA/QC plan, gap improvement plan and has limited data management system.
4. **Ministry of Transport & Logistics:** In the sector there is one directorate that facilitates the CRGE activities integrating the MRV work. As the expert indicates the higher officials are not give attention for this directorate to do the MRV/CRGE activities in the way that the EPA would like to plan and disaggregate the targets. In this sector there is no QA/Qc plan, gap improvement plan and data management system established. Furthermore, the capacity of the experts to do the QA/QC would be limited that needs the actions from EPA.
5. **Ministry of Health:** Showed good practices in data collection procedure up to grass root level. However, the sector doesn't have institutional data flow system to check QA/QC activities for GHG Inventory. The sector could not have any QA/QC plan and gap improvement plan.
6. **Ministry of Mine & Petroleum:** There is a need to improve the practice of the CRGE/MRV implementation. The higher officials could not give attention for the MRV/CRGE activities. There is no QA/QC plan, gap improvement plan and limited data management system in the sector.
7. **Forest Sector:** the forest sector is relatively good in the implementation of the GHG inventory and as well as the data management system. In the sector there is MRV data management lab for forest and non-forest monitoring of the forest. The limitation found in this sector was there is no QA/QC and gap improvement plan.

Generally, all the sectors have no QA/QC and gap improvement plan and as well as data management system in place. Moreover, in all sectors there is poor institutional arrangement and imitated technical capacity to do the QA/QC and gap improvement plan that needs urgent intervention.

11. RECOMMENDATION OF CURRENT SITUATIONAL ANALYSIS REPORT

- Capacitate the sectors experts in a Training of Trainers (TOT) for the federal experts to overcome the limited technical capacity of the expert and for using them as trainer for regions, Zones and Woredas.
- As a nation there should be the development of strategy or policy that give hint how all the national MRV data would be managed. Our strong recommendation on data management was the Ethiopian Statistics Agency should overtake the activity data collection through dealing with the EPA and plan and development minister. This may needs discussion with the technical expert of line ministries and national MRV directorate to understand and identify the key activity data collected by statistics agency for all sectors.
- Developing uniform data collection and reporting mechanisms should be worked on it, in the context of specific sectors.
- Short-medium-and-long term capacity development plans by specific sectors at all levels.
- Linkages between target sectors, institutions such as Universities and Research, and private sectors.
- Develop QA/QC and gap improvement plan and improvement of data recording and management system for all sectors.

12. DETAIL GENERAL, SECTOR-SPECIFIC, AND CROSS-CUTTING (QA/QC) PLAN

A QA/QC plan is a fundamental element of a QA/QC and verification system. The plan should, in general, outline the QA/QC and verification activities that will be implemented and the institutional arrangements and responsibilities for implementing those activities. The plan should include a scheduled time frame for the QA/QC activities that follows inventory preparation from its initial development through to final reporting in anyyear.

The QA/QC plan is an internal document to organize and implement QA/QC and verification activities that ensure the inventory is fit for purpose and allow for improvement. Once developed, it 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). A key component of a QA/QC plan is the list of data quality objectives, against which an inventory can be measured in a review. Data quality objectives are concrete targets to be achieved in the inventory preparation.

As part of the QA/QC plan, it is good practice to accommodate procedural changes and feedback of experience.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 periodic review and revision of the QA/QC plan is an important element to drive the continued inventory improvement.

12.1 Convene a QA/QC Plan Launch Meeting and Identify QA/QC Personnel

Convene a meeting with all team members to initiate the development of the QA/QC plan. Identify the people that could be involved in the plan. The plan should apply to the whole team (including consultants, universities, etc.) that is involved in the estimation and reporting of the GHG inventory.

- Identify the QA/QC coordinator. This is the main person responsible for developing, maintaining, and implementing the QA/QC plan.
  - Clarifies and communicates QA/QC responsibilities to inventory members.
  - Develops and periodically reviews and updates the QA/QC checklists appropriate to various inventory team member roles (or ensures that these tasks are accomplished).
  - Determines an overall QA/QC timeline and when external reviews will occur, and ensures the timely and accurate completion of QA/QC checklists and related activities.
  - Manages and delivers documentation of QA/QC activities to the NIC (National Inventory coordinator) and archive coordinator.
  - Coordinates external reviews of the inventory document and ensures that comments are incorporated into the inventory.
- Identify key QA/QC personnel and any additional country-specific QA/QC responsibilities.
- Complete the table below with the names and contact information of the appropriate staff.
- Insert as many rows within the table as necessary to include all personnel who will be responsible for QA/QC activities, and all QA/QC responsibilities,

Note that the roles are flexible and may overlap. Therefore, one staff member might cover a large number of categories or even cover a whole sector. Inventory staff may have a joint inventory compilation-QA/QC role. It is unnecessary to limit one person's role to coordinating inventory QA/QC. It is important that QA/QC efforts be focused on key categories but are applied to the whole GHG inventory.

Table 1: Personnel Responsible for QA/QC Activities filled by all sectors

Role	QA/QC Responsibility	Name	Organization	Contact Information
National Inventory Coordinator (MRV Directorate)	All aspects of the inventory program, cross-cutting QA/QC			
QA/QC Coordinator	Develop and implement the overall QA/QC plan			
Sector or Category Lead(s)	Develop and implement general, sector-specific (as appropriate) and/or category specific (as appropriate) QA/QC procedures listed in Tables 2 and 3 below. Focus on Key Categories			
Outside Expert(s)	Expert review of the inventory. Ensure the role of the expert is carefully defined and agreed upon. The expert can be within the country, or an international expert			

12.2 Develop a Timeline for QA/QC Plan Implementation

It is essential to communicate the contents of the QA/QC plan to inventory team members and outside experts involved in quality assurance of the GHG inventory so that the procedures can be effectively implemented, evaluated, and improved. The QA/QC coordinator should develop a timeline for taking the following actions:

- Creating or updating the QA/QC plan
- Participating in an inventory inception meeting with all of those working on the inventory (including consultants, universities, etc.), and at the meeting, introducing the plan to all team members required to perform QA/QC, and distributing QC checklists
- Checking that members of the inventory team understand the purpose and outcomes of the QA/QC plan, and updating the plan to address any questions
- Periodically reminding team members of their QA/QC responsibilities and the overall QA/QC schedule

- Use the table below to develop a QA/QC plan distribution timeline. Add rows as needed to accommodate additional tasks.

Table 2: QA/QC plan Disseminate timeline

Task	Timeline (When the task will occur)	Outcome (Description of the results of the task)	Potential Improvements (How the task may be modified to produce a better outcome)
Create (or update) the QA/QC plan			
Identify the best way to distribute the plan to each team member or external expert			
Distribute the QA/QC plan			

13. GENERAL QUALITY CONTROL (QC) PROCEDURES

General QC procedures are designed to be implemented for all categories and on a routine basis, it may not be necessary or possible to check all aspects of inventory input data, parameters and calculations every year. Checks may be performed on selected sets of data and processes. A representative sample of data and calculations from every category may be subjected to general QC procedures each year. In establishing criteria and processes for selecting sample data sets and processes, it is good practice for the inventory compiler to plan to undertake QC checks on all parts of the inventory over an appropriate period of time as determined in the QA/QC plan.

The first part of developing the QA/QC Plan is to establish general QC procedures. These include generic quality checks related to calculations, data processing, completeness, and documentation that are applicable to all inventory sources and sink categories and should be implemented each year. A minimum set of QC procedures should be followed each year for all categories to ensure that basic standards of quality are met. These standards generally focus on the processing, handling, documenting, archiving, and reporting procedures common to all categories.

Table 3 below lists the QC activities that should be performed at the category or subcategory level by staff compiling these estimates.

- The Procedures column includes a description of tasks that could be done as part of each QC activity. It is not necessary to complete all of these tasks, but you are encouraged to ensure that as many of them as possible are completed. Volume 1, Chapter 6.6 of the 2006 IPCC Guidelines provides further useful guidance.

- Modify these activities and their associated procedures as needed, and add as many rows as necessary. For each procedure, record the name of the person responsible for the item and the date of completion.

According to the 2006 IPCC Guidelines, though general QC procedures are designed to be implemented routinely for all categories, it may not be necessary or possible to check all aspects of inventory input data, parameters, or calculations every year. Instead, you may apply general QC procedures to a representative sample of data and calculations each year. In establishing criteria and processes for selecting sample data sets and processes, it is good practice for the inventory compiler to undertake QC checks on all parts of the inventory over an appropriate period as determined in the QA/QC plan.

Table 3: Shows detail general QC procedures filled by all sectors

QC Activity	Procedures	Task Completed		Corrective Measure Taken (if applicable)	Supporting Documents
		Name/ Initials	Date		
Data Gathering, Input, and Handling Checks					
Check those assumptions and criterion for the selection of activity data, emission factors, and other estimation parameters are documented.	• Cross check descriptions of activity data and emission factors with information on categories and ensure that these are properly recorded and archived. • Record if there are multiple sources of the same activity data, and if possible, document the reasons for any differences.				
Check for transcription errors in data input and references	• Confirm that bibliographical data references are properly cited in the internal documentation (see completed Template 3, Methods and Data Documentation, if applicable). • Cross check a sample of input data from each category (either measurements or parameters used in calculations) for transcription errors. Record the findings of these cross checks. Pay particular attention to systematic differences. Identify steps to reduce the error rate in the future. Add these improvement steps to the QA/QC development plan.				

QC Activity	Procedures	Task Completed		Corrective Measure Taken (if applicable)	Supporting Documents
		Name/ Initials	Date		

	• Utilize electronic data where possible to minimize transcription errors.
	• Check that spreadsheet features are used to minimize user/entry error:[1]
	  ○ Do not "hardwire" factors into formulas.
	  ○ Create automatic look-up tables for common values used throughout calculations.
	  ○ Use cell protection so fixed data cannot accidentally be changed.
	  ○ Build in automated checks, such as computational checks for calculations, or range checks for input data, mass balance checks, and internal consistency checks within and between spreadsheets.
	  ○ Ensure spreadsheets have clear instructions for updating and a description of how the spreadsheet works.
	  ○ Ensure spreadsheets include a record of how they have been implemented and checked.				

QC Activity	Procedures	Task Completed		Corrective Measure Taken (if applicable)	Supporting Documents
		Name/ Initials	Date		
Check that emissions/removals are calculated correctly	• Reproduce a representative sample of emissions/removals calculations. • If higher-tier methods or models are used, selectively reproduce complex model calculations with abbreviated calculations to judge relative accuracy. This could be done using IPCC Tier 1 methods. • In all cases, record the work done and the findings. Record any improvements identified (in the appropriate Templates, if applicable).				
Check that parameter and emission/removal units are correctly recorded and that appropriate conversion factors are used	• Check that units are properly labeled in calculation sheets and the completed Template 3, Methods and Data Documentation, if applicable. • Check that units are correctly carried through from beginning to end of calculations. • Check that conversion factors are correct. • Check that temporal and spatial adjustment factors are used correctly.				
Check the integrity of database files	• Confirm that the appropriate data processing steps are correctly represented in the database. • Confirm that data relationships are correctly represented				

QC Activity	Procedures	Task Completed		Corrective Measure Taken (if applicable)	Supporting Documents
		Name/ Initials	Date		
	in the database. • Ensure that data fields are properly labeled and have the correct design specifications. • Ensure that adequate documentation of database and model structure and operation are archived.				
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 emissions/removals calculations. • If using Excel, establish a "master set" of constants that all spreadsheets refer to rather than a set of constants in each spreadsheet.				
Check that the movement of inventory data among processing steps is correct	• Check that emissions/removals data are correctly aggregated from lower reporting levels to higher reporting levels when preparing summaries. • Check that emissions/removals data are correctly transcribed between different intermediate products.				
Check that confidential data are appropriately protected	• Check that only the GHG inventory compilation team can handle/access confidential data. • Check that such data are reported in compliance with				

QC Activity	Procedures	Task Completed		Corrective Measure Taken (if applicable)	Supporting Documents
		Name/ Initials	Date		
	requirements agreed on with the data source (if applicable).				
Check those uncertainties in emissions and removals are Estimated and calculated correctly.	• If using expert judgement, check that qualifications of individuals providing expert judgement for uncertainty estimates are appropriate. • Check that qualifications, assumptions and expert judgements are recorded. • Check that calculated uncertainties are complete and calculated correctly. • If necessary, duplicate uncertainty calculations on a small sample of the probability distributions used by Monte Carlo analyses (for example, using uncertainty calculations according to Approach 1).				
Data Documentation					
Review internal documentation and archiving	• Check that there is detailed internal documentation to support the estimates and enable duplication of calculations, using completed Template 3, Methods and Data Documentation, if applicable. • Check that every primary data element has a reference for the source of the data (via cell comments or another				

QC Activity	Procedures	Task Completed		Corrective Measure Taken (if applicable)	Supporting Documents
		Name/ Initials	Date		
	system of notation). • Check that inventory data, supporting data, and inventory records are archived and stored to facilitate detailed review. • Check that the archive is closed and retained securely following completion of the inventory. • Check integrity of any data archiving arrangements of outside organizations involved in inventory preparation.				
Calculation Checks					
Check methodological and data changes resulting in recalculations	• Check for temporal consistency in time series input data for each category. • Check for consistency in the algorithm/method used for calculations throughout the time series. • Reproduce a representative sample of emission/removal calculations to ensure mathematical correctness.				

QC Activity	Procedures	Task Completed		Corrective Measure Taken (if applicable)	Supporting Documents
		Name/ Initials	Date		
Check time series consistency	• Check for temporal consistency in time series input data for each category. • Check for consistency in the algorithm/method used for calculations throughout the time series. • Check methodological and data changes resulting in recalculations. • Check that the effects of mitigation activities have been appropriately reflected in time series calculations. Higher IPCC methodologies might be needed to accurately capture the effects of mitigation activities				
Check completeness	• Confirm that estimates are reported for all categories and for all years from the appropriate base year over the period of the current inventory. • For subcategories, confirm that the entire category is being covered. • Confirm that if an emissions or removal estimate is omitted for any given category, documentation to explain or clarify the omission is included, and notation keys are used for that category. (This may include categories that were also omitted from the previous inventory.)				

QC Activity	Procedures	Task Completed		Corrective Measure Taken (if applicable)	Supporting Documents
		Name/ Initials	Date		
	• Provide clear definitions of "Other" type categories. • Check that known data gaps that result in incomplete category emissions/removals estimates are documented, including qualitative evaluation of the importance of the estimate in relation to total net emissions (e.g., subcategories classified as "not estimated").				
Trend checks	• For each category, compare current inventory estimates to previous estimates, if available (e.g., archived Template 2). If there are significant changes or departures from expected trends, re-check estimates and explain any differences. Significant changes in emissions or removals from previous years may indicate possible input or calculation errors. • Check value of implied emission factors (aggregate emissions/removals divided by activity data) across time series to confirm that changes in emissions or removals are being reported. • Check if there are any unusual or unexplained trends in activity data or other parameters across the time series.				
Source: The checks identified are from the 2006 IPCC Guidelines for National GHG Inventories.					

In applying general QC procedures, particular attention should also be given to parts of the inventory development that rely on external, and shared databases. Note that this requirement also includes the case of confidential data. The inventory compiler needs to confirm that quality control of data coming from integrated databases has taken place, or QC should be conducted by the inventory compiler if existing protocols from the data provider are not adequate. Due to the quantity of data that needs to be checked for some categories, automated checks are encouraged where possible.

14. DETAIL SECTOR CATEGORY-SPECIFIC QC PROCEDURES

Category-specific QC complements general inventory QC procedures. Category-specific QC focuses on specific types of data used in the methods for individual source or sink categories. These procedures require category-specific knowledge, and knowledge of the types of data available and parameters associated with emissions or removals. For future UNFCCC reporting, countries should apply category-specific QC procedures for key categories and for those individual categories in which significant methodological changes and/or data revisions have occurred in accordance with the 2006 IPCC guidelines and as resources allow.

Table below, lists the category-specific QC procedures that should be performed;

- The Procedures column includes a description of activities that could be done as part of each QC activity. It is not necessary to complete all of these tasks, but you are encouraged to ensure that as many of them as possible are completed. Volume 1, Chapter 6.6 of the 2006 IPCC Guidelines provides further useful guidance.
- Modify these activities and their associated procedures as needed, and add as many rows as necessary.
- Replicate the table for as **many categories** as required.
- For each procedure, record the name of the person responsible for the item and the date of completion.

Category-specific QC activities include both emissions (or removals) data QC and activity data QC. The relevant QC procedures will depend on the method used to estimate the emissions or removals for a given category. If outside agencies develop estimates, the inventory compiler may, upon review, reference the QC activities of the outside agency as part of the QA/QC plan. There is no need to duplicate QC activities if the inventory compiler is satisfied that the QC activities performed by the outside agency meet the requirements of the QA/QC plan.

14.1. Emissions Factor QC

QC checks on IPCC default emission factors, country-specific emission factors, and direct emission measurements from individual sites (used either as the basis for a site-specific emission factor or directly for an emissions estimate). While the term 'emissions' is used in this section, the same types of activities are applicable to calculation parameters for 'removals' as well.

14.1.1 IPCC Default Emission Factors

When using IPCC default emission factors, it is good practice for the inventory compiler to assess the applicability of these factors to national circumstances. This assessment may include an evaluation of national conditions compared to the context of the studies upon which the IPCC default emission factors were based. If there is insufficient information on the context of the IPCC default emission factors, the inventory compiler should take account of this in assessing the uncertainty of the national emissions estimates based on the IPCC default emission factors.

14.1.2 Country-Specific Emission Factors

Country-specific emission factors may be developed at a national or other aggregated level within the country based on prevailing technology, science, local characteristics and other criteria. These factors are not necessarily site-specific, but are used to represent a source/sink category or subcategory of the country. The following types of QC checks should be used to evaluate the quality of country-specific factors.

QC checks on the background data used to develop emission factors: It is important to assess the adequacy of the emission factors and the QA/QC performed during their development. If emission factors are based on site-specific or source-level testing, then the inventory compiler should check if the measurement programme included appropriate QC procedures.

If the QA/QC associated with the secondary data is inadequate, the inventory compiler should attempt to establish QA/QC checks on the secondary data. The inventory compiler should also reassess the uncertainty of any emissions estimates derived from the secondary data. The inventory compiler may also want to consider if any alternative data, including IPCC default values, may provide a better estimate of emissions from this category.

QC checks on Models: Because models are means of extrapolating and/or interpolating from a limited set of known data, they often require assumptions and procedural steps to represent the entire inventory area. If QA/QC associated with models is inadequate or not transparent, the inventory compiler should attempt to establish checks on the models and data. In particular, the inventory compiler should

check the following:

- Appropriateness of model assumptions, extrapolations, interpolations, calibration-based modifications, data characteristics, and their applicability to the greenhouse gas inventory methods and national circumstances;
- Availability of model documentation, including descriptions, assumptions, rationale, and scientific evidence and references supporting the approach and parameters used for modelling;
- Types and results of QA/QC procedures, including model validation steps, performed by model developers and data suppliers. Responses to these results should be documented;
- Plans to periodically evaluate and update or replace assumptions with appropriate new measurements. Key assumptions may be identified by performing sensitivity analyses;
- Completeness in relation to the IPCC source/sink categories.

Comparison with IPCC Default Factors: Inventory compilers should compare country-specific factors with relevant IPCC default emission factors, taking into consideration the characteristics and properties on which the default factors are based. The intent of this comparison is to determine whether country-specific factors are reasonable, given similarities or differences between the national source/sink category and the 'average' category represented by the defaults.

Comparisons of emission factors between countries: Between-country emission factor comparisons can be combined with historic trends by plotting, for different countries, the reference year value (e.g., 1990), the most recent year value, and the minimum and maximum values. This analysis could be made for each source/sink category and possible aggregations. Comparisons between countries can also be made using aggregate emissions divided by activity data (implied emission factors). This type of comparison may enable outlier detection based on the statistical distribution of values from the sample of countries considered. When using between-country emission factor comparisons as a QC check, it is important to investigate similarities and differences in national circumstances for the relevant category.

Comparison to Plant-Level Emission Factors: A supplementary step is to compare the country- specific factors with site-specific or plant-level factors if these are available. For example, if there are emission factors available for a few plants (but not enough to support a bottom-up approach) these plant-specific factors could be compared with the aggregated factor used in the inventory.

14.1.3 Direct Emission Measurements

Emissions from a category may be estimated using direct measurements in the following ways:

- Sample emissions measurements from a facility may be used to develop a representative emission factor for that individual site, or for the entire category (i.e., for development of a national level emission factor);
- Continuous emissions monitoring (CEM) data may be used to compile an annual estimate of emissions for a particular process. Properly implemented, CEM can provide a complete set of quantified emissions data across the inventory period for an individual facility process, and does not have to be correlated back to a process parameter or input variable like an emission factor.

The data provider should check all measurements as part of the QC activities. The use of standard measurement methods improves the consistency of resulting data and knowledge of the statistical properties of the data. If standard reference methods for measuring specific greenhouse gas emissions (and removals) are available, inventory compilers should encourage plants to use these. Plants and facilities that implement direct measurements as part of official regulatory requirements may have mandated measurement QC standards already in place. If specific standard methods are not available, the inventory compiler should confirm whether nationally or internationally recognized standard procedures to quantify performance characteristics of air quality measurement (such as ISO 10012) are used to characterize the measurements, and whether the measurement equipment is calibrated, maintained, and situated such that it gives a representative result.

Where direct measurement data from individual sites are in question, discussions with site managers can be useful to encourage improvement of the QA/QC practices at the sites. Also, supplementary QC activities are encouraged for bottom-up methods based on site-specific emission factors where significant uncertainties remain in the estimates. Site-specific factors can be compared between sites and also to IPCC or national level defaults.

Table 4: Detail sector-specific QC Procedures, emission factor QC procedures

Category code and name: Note "KC" if it is a key category					
QC Activity	**Procedures**	**Task Completed**		**Corrective Measure Taken (if applicable)**	**Supporting Documents**
		Name/ Initials	**Date**		
Assess the applicability of IPCC default emission factors	• Evaluate whether national conditions are similar to those used to develop the IPCC default factors. • Compare default factors to site or plant-level factors. • Consider options for obtaining country-specific factors. • Document results of this assessment.				

Review country-specific emission factors	• QC the background data used to develop the country-specific factor to assess adequacy of the emission factors and the QA/QC performed during their development
	  ○ E.g., if based on measurement studies, did measurement program included QC procedures
	  ○ E.g., understand characteristics of data (e.g. completeness, etc.)
	• Assess whether secondary studies used to				

	develop country-specific factors used (at a minimum) general QC activities. • Compare country-specific factors to IPCC defaults; document any significant discrepancies. • Compare country-specific factors to site or plant-level factors. • Compare to factors from other countries (using UNFCCC review tools, reported factors in inventory submissions, and/or IPCC Emission Factor Database). • Conduct reference calculations that use stoichiometric ratios and conservation of mass and land. • Document results of this assessment.				
Review measurements	• Determine if national or international (e.g., ISO) standards were used in measurements. • Ensure measurement equipment is calibrated and maintained properly. • Compare direct measurements with IPCC or other published default factors; document any significant discrepancies.				

15. The Roadmap for QA/QC Improvement

The road map is intended to provide steps that must be followed by Ethiopia to have a fully functional QA/QC procedure in the inventory process. In this regard, the plan will facilitate the long-term improvement of the planning and implementation of the QA/QC from the current QA/QC tier 1 to the most desirable higher tier (tier 2). The implementation of the road map must be prioritized and occur within a reasonable time frame, with adequate capacity, commitment and should be adequatelyfinanced.

The proposed steps to ensure the move from the current QA/QC practices to a more improved one must be linked to the continuous improvement of the inventory (Table 5). The sequencing of the steps in the road map into short, medium and long term must take cognizance of the importance attached to the specific areas of the inventory that requires immediate attention such as the key categories, areas where methodological and data changes are taking place and the areas with the categories that contribute most to total inventory uncertainty.

Table 5: Activity plan for QA/QC road map

Overall objectives /Goal		To move from the current QA/QC practice to desirable a higher tier by 2024 and beyond, taken account capability available in the country					
Short –term objective		Have functional tier 1 in the next inventory cycle (2022-2023) that ensures both general and sector specific QC Practices are implemented.					
Medium –term objective		Have a functional tier 1 for the general QA/QC and tier 2 for sector specific QC in the inventory cycle (2023-2025)					
Long-term objective		Put a functional tier 2 in place for the general QC and a higher tier for sector specific (beyond 2025)					
Tasks		Priority	Time frame	Resources	Action by	Assumption(s)	QC Outcome
Assess capacity and resource gaps for QA/QC	Stag	High	2021	MRV expert	EPA, MRV directorate	Funds would be secured	Understand strength/weakness and prioritize improvement efforts.
Appoint QA/QC		High	2021	MRV, sectors experts	EPA/MRV director	Give clear terms of reference or MOU	QA/QC procedures streamlined.

Lead	e						
Regular hands-on training on key QA/QC topics for inventory compilers and data owners	I (2021-2022)	Medium	2023	Trainers, Software, Training manuals, Funds	QA/QC Lead/EPA/ MRV directorate	Funds secured Software and training manuals available	Improve technical capacity to roll out QC procedures.
Gather meta data on key categories and activities where the changes in data and methodology are taking place.		High	2022/23	Funds, skilled personnel,	Data providers and QA/QC Lead (sectors)	Meta data exist but not published, data providers are willing to gather meta data where it does not exist	Improved transparency, accuracy of inventory
Provision of materials for QA/QC activities		High	2021/2/3	QC templates, referencing guide, QC timelines,	QA/QC Lead Sectors leads	The general and sector specific QC procedures are available, funds are secured	Improvement in documentation and archiving
Storage/Archiving of all data, reports and references		High	2023	Files Servers External drive	QA/QC Lead Sector leads	Storage devices are made available	Improve data retrieval and easy referencing
Ensure rigorous external review of data and methodological choices and estimates		Medium	2023	Personal, task sheets	QA/QC Lead	QA task sheet prepared, funds	Improve transparency and accuracy. Detect error at early stage.

Continuous methodological refinement for estimating emissions in key categories and support for research	Stage 2 (2023-2025)	High	2025	Funds, Equipment, training	EPA	Funds are made available, access research result are publicly available, competent experts are accessible	Ensured accuracy and consistency
Begin implementation of sector specific QC procedures starting with major sectors or categories		High	2025	Training, funds	QA/QC Lead/ Sector leads/ data owners	Data is available at sector level. Sector/category specific QC working template	Improved transparency in the key sector/categories
Promote adoption of based QC standards for Industry sector		Low	2025	Training, funds Regulatory framework	EPA/ QA/QC Lead/ Sector leads/ data owners	Industry willing to adopt ISO QC standard	Enhanced transparency and accuracy
Organize policy review and reality check QA for key Ministries		Medium	2023	Logistics	EPA/MRV directorate	Logistics are secured. Willingness of sectors to participate	Enhanced confidence and acceptability of the inventory results.
Organize regular meetings with universities to identify areas in the inventory that need further research.		Medium	2024	Logistics	EPA/MRV	Logistics are secured. Willingness of Universities to engage with the process.	Improved methodology and data for the inventory
Develop and implement QC protocols for “primary	Stage 3 (Beyond	High	2025	Funds, researchers,	Data owners/ EPA/QA/QC	Funds secured, Inventory sectors have capacity to	Strengthened sector/category QC

data generation" (emission factors activity data)	2025)			equipment, training, QC protocol templates	Lead	implement, QC protocol template is available	procedures.
Create a functional central climate data sharing port which could be hosted by Ethiopian statistics Agency		Medium	2026	Funds, IT infrastructure, Training	EPA/Central statistics agency, Sector leads	Funds are provided; IT infrastructure is in place, Willingness of institutions to participate.	Improved timely access and retrieval of data
Continuous methodological refinement for estimating emissions in key categories and support for research		Medium	Continuous process	Funds, Equipment, training	EPA, Sector leads	Funds will be secured	Ensured accuracy and consistency

15.2 Activity Data Quality Control (QC)

The estimation methods for many categories rely on the use of activity data and associated input variables that are not directly prepared by the inventory compiler. Activity data at a national level are normally drawn from secondary data sources or site-specific data prepared by site or plant personnel from their own measurements. Inventory compilers should take into account the practical considerations.

15.2.1 National Level Activity Data

Following are fundamental QC checks that should be considered for assessing the quality of national level activity data. In all cases, it is important to have a well-defined and documented data set from which appropriate checks can be developed.

QC checks of Reference Source for National Activity Data: When using national activity data from secondary data, it is good practice for the inventory compiler to evaluate and document the associated QA/QC activities. This is particularly important with regard to activity data, since most activity data are originally prepared for purposes other than as input to estimates of greenhouse gas emissions.

Comparisons with independently compiled data sets: Where possible, a comparison check of the national activity data with independently compiled activity data sources should be undertaken. For example, many of the agricultural source-categories rely on government statistics for activity data such as livestock populations and production by crop type. Comparisons can be made to similar statistics prepared by the United Nations Food and Agriculture Organization (FAO). Similarly, the International Energy Agency (IEA) maintains a database on national energy production and usage that can be used for checks in the energy. Industry trade associations, university research, and scientific literature are also possible sources of independently derived activity data to use in comparison checks.

Comparisons with samples: The availability of partial data sets at sub-national levels may provide opportunities to check the reasonableness of national activity data. For example, if national production data are being used to calculate the inventory for an industrial category, it may also be possible to obtain plant-specific production or capacity data for a subset of the total population of plants. Extrapolation of the sample production data to a national level can then be done using a simple approximation method. The effectiveness of this check depends on how representative the sub-sample is of the national population, and how well the extrapolation technique captures the national population.

Trend checks of activity data: National activity data should be compared with previous year's data for the category being evaluated. Activity data for most categories tend to exhibit relatively consistent changes from year to year without sharp increases or decreases. If the national activity data for any year diverge greatly from the historical trend, they should be checked for errors. If a calculation error is not detected, the reason for the sharp change in activity should be confirmed and documented.

15.2.2 Site-Specific Activity Data

Some estimation methods rely on the site-specific activity data used in conjunction with IPCC default or country-specific emission factors. Site or plant personnel typically prepare these estimates of activity, often for purposes not related to greenhouse gas inventories. QC checks should focus on any inconsistencies between sites to check whether these reflect errors, different measurement techniques, or real differences in emissions, operating conditions or technology. A variety of QC checks can identify errors in site-level activity data.

16. Practical Steps to Assess Data Quality

Generating activity data and emission factors, either through physical measurements or modeling carries certain levels of uncertainty. Datasets that are produced through such processes introduce inherent uncertainties into the inventory. In addition, the reliance on secondary activity data and default emission factors for the inventory estimation further contribute to uncertainty levels. This is because in many cases the suppliers of secondary data hardly provide information on metadata or sampling framework. Such information is crucial to understand the sources of errors, level of errors and how the errors have been managed in the generation of Activity Data (AD) and Emission Factors (EF). Another source of uncertainty in the use of default emission factors from the IPCC emission factor database.

The use of the default AD and EF, particularly, for key category activities is a major source of uncertainty in the inventory. According the current inventory report, many of the key categories are in the transport, electricity generation, solid waste management and land management activities, therefore, the expectation is that since they contribute most emissions, if the errors in their AD and EF are high, it pushes up overall uncertainty in the inventory. In order to improve on the uncertainty assessment in the inventory having in mind the gaps in the current practice, it is important that attention is given to the practical steps that need to be taken by the inventory compilers to improve selection of AD and EF to reduce uncertainties.

16.1 Guiding principles for the assessment of activity data quality assessment

- Use expert information to validate activity data reported by the district assemblies through research in selected sectors.

- Select data that have clear source and can be referenced (table 6). Dated and attributed to a source.
- Select or use nationally approved sources when there are variations in the same data from international sources.
- Use data from mandated national institution in the case where there is variation in the same data from multiple agencies unless the authenticity is not in doubt using any available documentary evidence.
- As much as possible official data which report legal economic activities in the country, however, in the event, the data would have to expanded to include "informal activities" (for instance, quantities of smuggled fuel, illegal timber etc), use peer reviewed data.
- In cases where it is not possible to access disaggregated data from industry, security agencies and academic sources, for reasons of confidentiality, use the aggregated data supplied to you.
- In using expert judgment, the inventory compilers must take the following into account:
    - consistency in the application of the expert judgment to similar situations in the inventory;
    - documentation of assumptions and how the expert judgment has been applied across the inventory;
    - determination of the conditions that warrant the use of expert judgment and
    - Reasonableness of underlying factors of the expert judgment in relation to the use of empirical data.
    - Exercise caution in throwing out data which appear to be an outlier unless you have reasons to do so.
- Seek a second or third expert opinion in using data from expert judgment and document.
- In some cases, in Ethiopia, activity data are generated for reasons other than the inventory and in different format. The original state of the data may not permit its use in the inventory. In such situations, process the data to useable format where the technical condition permits without compromising its quality.

Table 6: Template for tracking QC issues

No	Key QC/QA Issues	Sector	Key category	Gas	Description of key issues	Action taken	Status	Outstanding task

QC Checks of Measurement Protocol: The inventory compiler should establish whether individual sites carried out measurements using recognized national or international standards. If the measurements conform to recognized national or international standards and a QA/QC process is in place, then no further QA/QC will be necessary. Acceptable QC procedures in use at the site may be directly referenced**.**

Comparisons between sites and with national data: Comparisons of activity data from different reference sources and geographic scales can play a role in confirming activity data. For example, in estimating perfluorocarbon (PFC) emissions from primary aluminum smelting, many inventory compilers use smelter-specific activity data to prepare the inventory estimates. A QC check of the aggregated activity data from all aluminum smelters against national production statistics for the industry can identify major omissions or over-counting. Also, a comparison of production data across different sites, possibly with adjustments made for plant capacities, can indicate the reasonableness of the production data. Similar comparisons of activity data can be made for other manufacturing-based source categories where there are published data on national production. Any identified outliers should be investigated to determine if the difference can be explained by the unique characteristics of the site or there is an error in the reported activity data.

Production and consumption balances: Site-specific activity data checks may also be applied to methods based on product usage. For example, one method for estimating SF_6 emissions from the use in electrical equipment relies on an account balance of gas purchases, gas sales for recycling, the amount of gas stored on site (outside of equipment), handling losses, refills for maintenance, and the total holding capacity of the equipment system. This account balance system should be used at each facility where the equipment is in place. A QC check of overall national activity could be made by performing the same kind of account balancing procedure on a national basis. This national account balancing would consider national sales of SF6 for the use in electrical equipment, the nation-wide increase in the total handling capacity of the equipment that may be obtained from equipment manufacturers, and the quantity of SF_6 destroyed in the country. The results of the bottom-up and top-down account balancing analyses should

agree, or large differences should be explained. Similar accounting techniques can be used as QC checks on other categories based on gas usage, e.g., substitutes for ozone-depleting substances, to check consumption and emissions.

Table 7: Detail sector-specific QC procedures, activity data QC

Category code and name: Note "KC" if it is a key category					
QC Activity	**Procedures**	**Task Completed**		**Corrective Measure Taken (if applicable)**	**Supporting Documents**
		Name/ Initials	**Date**		
Review national-level activity data	• Determine the level of QC performed by the data collection agency. If inadequate, consider alternative data sources such as IPCC defaults and international activity data sets (e.g., IEA, FAO). Adjust the relevant uncertainty accordingly. • Compare activity data from multiple references (e.g., other independently compiled data) if possible (e.g., IEA, FAO, etc.), including data time series				
Review site-specific activity data	• Determine if national or international (e.g., ISO) standards were used in collecting or generating data. • Compare aggregated site-specific data (e.g., production) to national statistics/data. • Compare data across similar sites. • Compare top-down and bottom-up estimates for similar orders of magnitude.				
Trend checks of activity data	• Compare data to previous year's data and review any sharp increases or decreases. • If national activity data for any year diverge greatly				

	from the historical trend, they should be checked for errors. • If a calculation error is not detected, the reason for the sharp change in activity should be confirmed and documented.				
QC uncertainty estimates	• Apply QC techniques to uncertainty estimates. • Review uncertainty calculations. • Document uncertainty assumptions and qualifications of any experts consulted.				

17. Document recommendations received as a result of experts' QA activities

Quality Assurance involves expert reviewers not involved in preparing the inventory, and a basic peer review process. QA activities follow QC activities and complement QC activities. Expert review offers the opportunity to uncover technical issues related to the application of methodologies, selection of activity data, and development and choice of emission factors. The comments of the expert reviewers should be reviewed and addressed, as appropriate, prior to the submission of the Inventory, and documented/archived appropriately to ensure transparency and for reference of future compilation teams.

Experts should be independent of the inventory agency, and affiliated with other national agencies, research facilities, international organizations, or other organizations with relevant expertise in GHG emission estimation methodologies, activity data, or other parameters. If third party reviewers are unavailable, staff from another part of the inventory agency not involved in the portion of the inventory under review can fulfill this role. Key categories should be given priority for review, as well as source categories where significant changes in methodology or data have been made.

Using Table 6, below, identify the experts who are reviewing the GHG inventory. In the Comment Summary column, summarize experts' recommendations regarding specific improvements that could be made to the GHG inventory as a result of experts' QA activities

Table 6: Shows external reviewers

Name	Organization	Area of Expertise	Contact Information	Date Comments Received	Comment Summary

17.1 Calculation-Related QC

The principles described above for the input data are similarly applicable to all calculation procedures used to prepare a national greenhouse gas inventory. Checks of the calculation algorithm will safeguard against duplication of inputs, unit conversion errors, or similar calculation errors. These 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. Further checks on the calculation procedure will require external data.

It is a prerequisite that all calculations leading to emission or removal estimates should be fully

reproducible. 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. The next section provides practical hints how to record a calculation procedure in standard spreadsheet or database calculations. Such an approach allows for intrinsic documentation of the work, and for easy understanding of the calculation procedure. The documentation should be retained with the material archived in support of the completed inventory.

17.2 Documentation of Calculations

i. When using spreadsheets:

- Clearly reference to the data source of any numbers typed into the spreadsheet (see above documentation criteria for data sources),
- Provide subsequent calculations, in the form of formulas, so that auditing tools can be used to track back from a result to the source data, and calculations can be evaluated by analyzing the formulae,
- Clearly mark cells in the spreadsheet containing derived data as 'results' and annotate them as to how and where they are then used,
- Document the spreadsheet itself specifying its name, version, authors, updates, intended use and checking procedures so that it can be used as a data source of the derived results and referenced further on in the inventory process.

ii) When using databases

- Clearly reference the source data tables using a referencing column that links to the data source,
- Use queries when processing the data, where practical, as these provide the means to track back to the source data tables,
- Where queries are not practical and new tables of data need to be generated, make sure that scripts or macros of the commands used to derive the new data set are recorded and referenced in a referencing column of the dataset,
- Document the database itself specifying its name, version, authors, intended use and checking procedures so that it can be used as a data source of the derived results and referenced further on in the inventory process.

18. QUALITY ASSURANCE (QA) PROCEDURES

Quality assurance comprises activities outside the actual inventory compilation. Good practice for QA procedures includes reviews and audits to assess the quality of the inventory, to determine the conformity of the procedures taken and to identify areas where improvements could be made. QA procedures may be taken at different levels (internal/external), and they are used in addition to the general and category-

specific QC procedures. The inventory may be reviewed as a whole or in parts. The objective of QA implementation is to involve reviewers that can conduct an unbiased review of the inventory and who may have a different technical perspective. It is important to use QA reviewers that 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. Where third party reviewers who are independent from the inventory compiler are not available, persons who are at least not involved in the portion being reviewed can also perform QA.

It is good practice for inventory compilers to conduct a basic expert peer review of all categories before completing the inventory in order to identify potential problems and make corrections where possible. However, this will not always be practical due to timing and resource constraints. Key categories should be given priority as well as categories where significant changes in methods or data have been made. Inventory compilers may also choose to perform more extensive peer reviews or audits as QA procedures within the available resources. In smaller countries, where there may not be external expertise in all technical areas, the inventory compiler should 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.

18.1 Expert Peer 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 greenhouse gas 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 organizations 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 inventory compiler conducts internal consistency review on all the sector spreadsheets before they put together for further analysis. Although the focus of this review is to pick up time series and internal inconsistencies in the inventory, it could also serve as a useful way to identify errors that were omitted (Table 9).

The results of expert analyses from the UNFCCC processes should also be considered as part of the overall QA improvement process. Results and suggestions from these processes can provide valuable feedback on areas where the inventories can be improved.

Table 8: Template for Keeping Records on Internal Reviews

Name of Internal Reviewer			Date of Review:
Sector	Main QC/QA Identified	Review method used	Remarks for future improvement

18.2 Audits

For the purpose of good practice in inventory preparation, audits may be used to evaluate how effectively the inventory compiler complies with the minimum QC specifications outlined in the QC plan. It is important that the auditor be independent of the inventory compiler as much as possible so as to be able to provide an objective assessment of the processes and data evaluated. Audits may be conducted during the preparation of an inventory, following inventory preparation, or on a previous inventory. Audits are especially useful when new estimation methods are adopted, or when there are substantial changes in existing methods. In contrast to an expert peer review, audits do not focus on the result of calculation. Instead, they provide an in-depth analysis of the respective procedures taken to develop an inventory, and on the documentation available.

19. QA&QC AND UNCERTAINTY ESTIMATES

The QA/QC process and uncertainty analyses provide valuable feedback to one another. Staff involved in the QA/QC and uncertainty analyses can identify critical components of the inventory estimates and data sources that contribute to both the uncertainty level and inventory quality and which should therefore be a primary focus of inventory improvement efforts. This information should ultimately be useful in improving the methods and data sources used for the estimates.

Some of the uncertainty estimation methods rely on the use of measured data associated with the

emission factors or activity data to develop probability density functions from which uncertainty estimates can be made. Inthe absence of measured data, many uncertainty estimates will rely on expert judgment. It is good practice to apply QC procedures to uncertainty estimation to confirm that calculations are correct and data and calculations well documented. The assumptions on which uncertainty estimation has been based should be documented for each category. Calculations of category-specific and aggregated uncertainty estimates should be checked and anyerrors addressed.

20. 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 thenational 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.

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. Not all approaches will be available to every inventory compiler due to some of these criteria, particularly the techniques included in ‘comparisons with atmospheric measurements. However, there are a number of relatively simple, comparison techniques that should be available to most inventory compilers, and that can be valuable tools in the overall QA/QC and verification system. As much information required may be available on a national level, we will refer to these as national activities.

Where verification techniques are used, they should be reflected in the QA/QC plan. The limitations and uncertainties associated with the verification technique itself should be thoroughly investigated prior to its implementation so that the results can be properly interpreted.

19.1 Comparisons of National Estimates

There are a number of practical verification techniques that do not require specialized modeling expertise or extended analyses. Most of these can be considered as method-based comparisons that consider the differences in national estimates based on using alternative estimation methodologies for the same category or set of categories. These comparisons look for major calculation errors and exclusion of major source categories or sub source categories. Method-based comparisons can be

designed around the multi-tier level of methods outlined for each category in the sector guidance, through comparisons to independent estimates developed by other institutions, and, to a limited extent, through cross-country comparisons. The choice of method will depend on the method used in the inventory, a clear definition and correlation of categories between methods, and the availability of alternative data.

20.1.1 Applying Lower Tier Methods

Lower tier IPCC methods typically are based on 'top-down' approaches that rely on highly aggregated data at a summary category level. Inventory compilers using higher tier, 'bottom- up' approaches may consider using comparisons to lower-tier methods as a simple verification tool. As an example, for carbon dioxide (CO_2) from fossil fuel combustion, a reference calculation based on apparent fuel consumption per fuel type is specified as a verification check in the Energy Sector procedures. This reference approach estimate can be compared to the sum of sectoral-based estimates from a Tier 1, 2, or 3 approach. While the quality of the reference approach is typically lower than that of the sectoral approach,it remains useful as a simple approximation method.

The check of emission estimates would consist of the comparison between the sum of the individual plant-level emission estimates and a top-down emission estimate based on national nitric acid production figures and IPCC default Tier 1 factors. Large differences do not necessarily indicate that there are problems with the inventory estimate. As lower tier methods typically rely on more highly aggregated data, there may be relatively large uncertainties with the Tier 1 approach compared to an inventory estimated using a bottom up approach based on good practice. If differences cannot easily be explained, the inventory compiler may consider the following questions in any further QA/QC checks:

- Are there inaccuracies associated with any of the individual plant estimates (e.g., an extreme outlier may be accounting for an unreasonable quantity of emissions)?
- Are the plant-specific emission factors significantly different from each other?
- Are the plant-specific production rates consistent with published national level production rates?
- Is there any other explanation for a significant difference, such as the effect of controls, the manner in whichproduction is reported or possibly undocumented assumptions?

20.1.2 Applying Higher Tier Methods

Higher tier IPCC methods typically are based on detailed 'bottom-up' approaches that rely on highly disaggregated data and a well-defined sub categorization of sources and sinks. Inventory compilers may find that they cannot fully implement a higher tier approach because they are lacking sufficient data or

resources. However, the availability of even partial estimates for a subcategory of sources may provide a valuable verification tool for the inventory. An estimate based on higher tier data derived from a proportion of the total sources in a country can be extrapolated to the national level, provided that the sample is representative. Such an extrapolation can be used to corroborate the national estimate.

20.1.3 Comparisons with Independently Compiled Estimates

Compiled inventory data on national level (if available) are a quick option to evaluate completeness, approximate emission (removal) levels and correct category allocations. Although the inventory compiler is ultimately responsible for preparing the national greenhouse gas inventory, other independent publications on this subject may be available e.g., from scientific literature or publication by other institutes or agencies. For example, national level CO_2 emissions estimates associated with the combustion of fossil fuel are compiled by the International Energy Agency (IEA) and the Carbon Dioxide Information and Analysis Centre (CDIAC). Estimates of emissions of other pollutants are available from the Emission Database for Global Atmospheric Research (EDGAR) (http://www.mnp.nl/edgar/). If independently compiled datasets use IPCC Tier 1 methodologies, the same considerations discussed above will apply. While national data are normally considered more reliable as they are able to accommodate more detailed country-specific information, and international data are normally compiled at a lower tier, these international data sets provide a good basis for comparison as they are consistent between countries. The comparisons can be made for different greenhouse gases at national, sectoral, category, and subcategory levels, as far as the differences in definitions enable them. Before conducting these types of comparisons, it is important to check the following items.

- Confirm that the underlying data for the independent estimate are not the same as that used for the inventory; a comparison is only meaningful if data being compared are different,
- Determine if the relationships between the sectors and categories in the different inventories can be defined and matched appropriately,
- Account for the data quality (e.g., QA/QC system or review) and for any known uncertainties in the estimate used for the comparison to help interpret results.

20.1.4 Comparisons of Intensity Indicators between Countries

Emission (removal) intensity indicators, e.g., those commonly referred to as ‘implied emission (removal) factors', may be compared between countries (e.g., emissions per capita, industrial emissions per unit of value added, transport emissions per car, emissions from power generation per kWh of electricity produced, emissions from dairy ruminants per tonne of milk produced). These indicators provide a preliminary check and verification of the order of magnitude of the emissions or removals. Different

practices and technological developments as well as the varying nature of the source categories will be reflected in the emission intensity indicators. Thus differences between countries need to be expected. However, these checks may flag potential anomalies at the country or sector level.

20.1.5 Comparisons with Atmospheric Measurements

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 recent scientific advances allow using such data as a basis for emission modeling. 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.

In contrast to the other methods described in this chapter, comparisons with atmospheric measurements cannot therefore be a standard tool for verification to be applied by an inventory compiler. Still a considerable scientific progress in this area needs to be noted and inventory compilers may wish to take advantage of the potential of this approach, as it gives independent data for verification. If applicable, national inventory compilers may also consider joining forces with neighboring countries, in cases when emission modeling from atmospheric measurement is more reliable for larger entities than countries.

Despite the limitations given, there are a number of evolving techniques that deserve to be mentioned here:

20.1.6 Inverse Modelling

The concentrations of greenhouse gases in air samples are measured at monitoring sites and can be used to provide emission estimates by a technique known as inverse modeling. Inverse models calculate emission fluxes from concentration measurements and atmospheric transport models. For local and regional estimation, complex mathematical and statistical models are required together with continuous, or quasi-continuous, measurements that capture all pollution incidents. The source discrimination of air sampling derived emissions requires highly precise and labor-intensive analysis, which may prevent the applicability of inverse modeling approaches to source-specific emissions verification. In contrast to national inventories, flux assessments from inverse modeling include the effect of natural sources/sinks as well as international transport.

Considering the limited monitoring network currently available for many of the greenhouse gases and the resulting uncertainties in the model results, inverse modeling is not likely to be frequently applied as a verification tool of national inventories in the near future. Even the availability of satellite-borne sensors for greenhouse gas concentration measurements (see Bergamaschi *et al.*, 2004) will not fully resolve this

problem, due to limitations in spatial, vertical and temporal resolution. However, there is increasing scientific recognition for the potential of these techniques for both level and trend verification of national inventories.

Fluorinated gases and methane (CH_4) are considered the most suitable greenhouse gases for which inverse modeling could provide verification of emission. The fluorinated compounds are considered good candidates for inverse modeling verification because: they have virtually no natural source interference in the atmospheric measurements, there can be considerable uncertainties in inventory methods, they are long-lived, and the loss mechanisms are well known. Methane is considered a favorable candidate because of the generally high uncertainty in emission estimates resulting from inventory methodologies, and the strong atmospheric signal to noise ratio of measurements. Modeling of CO_2 emissions for national inventory verification is probably not a priority since the inventory methods already have low uncertainties, except where agriculture, forestry and other land-use is dominant. The impacts of large natural sources and sinks on atmospheric measurements make a correlation to strictly anthropogenic sources difficult. However, it may improve understanding of contributions from forests and natural sources and sinks. Due to the large uncertainties associated with some of the N_2O inventory methodologies verification through atmospheric measurements would be desirable. However, the influence of natural sources and sinks on measurements, as well as the long atmospheric lifetime lead to a poor signal to noise ratio in measured concentrations. Thus further investigations are required before inverse modeling can successfully be applied to the verification of inventories of N_2O.

20.1.7 Continental Plumes

Strong difference between source and non-source regions may generally be found between a continent and an ocean where routine measurements of the difference between background air concentrations and the offshore plume concentrations, coupled with wind vector analysis or trajectory analysis, may provide an indication of emissions on a broad scale.

20.1.8 Use of Proxy Emission Databases

In the cases where one of the components measured in the air samples has a well characterized emission inventory (a ‘marker’ or ‘tracer’ compound), the emissions of greenhouse gases may be estimated from atmospheric measurements of their concentration ratio to this marker compound.

20.1.9 Global Dynamic Approaches

Trends over time in the atmospheric concentration of particular compounds may also indicate a change in the global balance between sources and sinks and give an estimate of the globally aggregated emissions, constraining the total of national emissions from an aggregate perspective and possibly indicating areas of

weakness in the inventories. Such approaches have been taken for CH4, sulphur hexafluoride (SF6), PFC-14 and carbon tetrafluoride (CF4). These methods can be applicable to cover a large proportion of global emissions, and monitoring is possible on a routine basis.

21. DOCUMENTATION, ARCHIVING AND REPORTING

21.1 Internal Documentation and Archiving

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

- Responsibilities, institutional arrangements, and procedures for the planning, preparation, and management of the inventory process;
- Assumptions and criteria for the selection of activity data and emission factors;
- Emission factors and other estimation parameters used, including references to the IPCC document for default factors or to published references or other documentation for emission factors used in higher tier methods;
- Activity data or sufficient information to enable activity data to be traced to the referenced source;
- Information on the uncertainty associated with activity data and emission factors;
- Rationale for choice of methods;
- Methods used, including those used to estimate uncertainty and those used for recalculations;
- Changes in data inputs or methods from previous inventories (recalculations);
- Identification of individuals providing expert judgment for uncertainty estimates and their qualifications to do so
- 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;
- Final inventory report and any analysis of trends from previous years;
- QA/QC plans and outcomes of QA/QC procedures;
- 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.

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.

21.2 Reporting

It is good practice to report a summary of implemented QA/QC activities and key findings as a supplement to each country's national inventory, which itself is described in Volumes 2-5 and by the tables in this volume. However, it is not practical or necessary to report all the internal documentation that is retained by the inventory compiler. In this summary, the inventory compiler should focus on the following activities.

Reference to a QA/QC plan, its implementation schedule, and the responsibilities for its implementation should be discussed.

- Describe which activities were performed internally and what external reviews were conducted for each source/sink category and on the entire inventory.
- 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.
- Explain significant trends in the time series, particularly where trend checks point to substantial divergences. Any effect of recalculations or mitigation strategies should be included in this discussion.

22. QA/QC PLAN (GHG INVENTORY IMPROVEMENT PLAN)

22.1. Importance of QA/QC plan

Preparation of the QA/QC plan is part of the on-going reforms in the national GHG inventory system. The QA/QC plan will be the fundamental document upon which the inventory is anchored. It establishes all the activities, procedures, techniques to be observed and implemented in the fulfillment of quality objectives that will be set in the inventory. The purpose of the plan is to streamline and formalize existing QA/QC procedures and communicate with clear set of objectives to the inventory team. This will ensure that the inventory becomes more transparent, credible and defensible. The plan will also give tasks to institutions and individuals who are involved in the inventory with set targets and timeframe.

22.2. Objectives of QA/QC plan

- Provide guidance to develop QA/QC procedures based on the IPCC guidelines and taking into account capabilities.
- Identify past and current QA/QC procedures in order to streamline what is being and build on to become a functional and reliable system to the quality of GHG inventory.
- Define roles and responsibilities, i.e., who is responsible for reviewing the estimates, documentation, who has the final authority to approval what data goes into the accounting.
- Establish the overall schedule for the QC plan, which should occur throughout the inventory process.
- Detect errors/ blunders in the calculation of emissions and reduce uncertainty as early as possible before the inventory is made public or subjected to official reviews.

National Inventory Improvement Plan (NIIP) presents options for improving the national GHG inventory system to support compilation of a high-quality inventory consistent with the 2006 IPCC Guidelines. The NIIP will guide future efforts to increase the transparency, consistency, comparability, completeness, and accuracy of future inventories. It will inform the overall improvement of the national GHG inventory over the coming years. These improvements have been identified through general documentation of existing the following theme areas

- Institutional Arrangements
- Methods and Data Documentation
- Description of QA/QC Procedures
- Description of Archiving System

- Key Category Analysis

22.3 Inventory Improvement Areas

- Identifying availability of better-quality data
- Facilitating coordination among institutions to support data collection efforts
- Adopting a higher Tier methodology
- Training of current staff members
- Hiring additional staff

22.4 Steps to Develop National GHG Inventory Improvement Plan

Step 1. Define Objectives for Developing a NIIP that includes;

Synthesize findings of previous templates, identify areas for improvement, guide and inform future efforts and teams and adhere to UNFCCC Inventory Principles

Objectives: the national inventory plan presents actions that countries have identify to improve its national system. The NIIP will guide future efforts to increase the transparency, consistency, comparability, completeness and accuracy of the future inventories. The plan addresses many of the shortcomings of the previous and will inform future inventory teams of needed improvements. These improvements have been identified though an assessment of key source in a country, methodology and data used to estimate emission and existing institutional arrangement.

Step 2. Summarize Key Categories

Sources with the most significant influence on a country's total emissions like Level Analysis, Trend Analysis. The concept of key category was created by the IPCC as a tool to help countries prioritize contribution for improving national GHG. Key source categories have the greatest contribution to the overall level of national emission. Key source categories can also be those categories that have a large influence on the trend emission over time. To improve the national GHG inventory, it may be necessary to consider more accurate methodologies, develop country specific emission factors, or collect more detail activity data. These activities all require additional resources, and it is not possible to make improvements for every source category. The primary purpose of analysis will provide a quantitative tool for the national GHG inventory team to use develop an inventory improvement plan. A secondary purpose is to provide more complete and transport information for the national communication.

Step 3 Describe individual source category improvements

These steps explain the detail specific source of GHG emission for category improvements. This includes:

- Review completed Source by Source documentation,
- Determine improvements for improving estimates for source categories,
- Describe problem and list improvement,
- Obtain more complete activity data,
- Higher Tier methodology,
- Regional or country specific emission factors,
- Activity Data (like conduct fuel combustion survey, carry out a waste composition study),
- Other (Conduct QA/QC measures for fossil fuel combustion and forestland, Conduct an emission trend analysis over multiple years),
- Emission Factors (Conduct a clinker carbon analysis /emission factor for cement sector), and
- Methodologies (Use an agriculture/land use or ecosystem process model).

Step 4: Summarize Improvements to Institutional Arrangements,

This is basically focus on the overall work integration of the sectors starting from plan, implementation, data collection and communication and as well as reporting.

- Agreements between lead inventory agency,
- National inventory management team, data providers
- Use of already identified the institutional arrangements template
- Transfer them in, discuss how identified
- Types of Potential Improvements to Institutional Arrangements
- Identify additional institutions to support inventory development
- Improve information sharing among relevant agencies
- Hire additional qualified staff
- Develop better archiving systems

Step 5 Prioritize the Most Important Improvements

Because of the budget scarcity and the time all the key category would not put as improvement plan. Selecting the main challenges for the improvements of the GHG emission inventory improvement is very important. Identify the most critical areas for improvements; rank the challenges by using high, medium, low, considering significance in Key Category Analysis, confidence in emissions estimate, towards a

higher quality inventory and a sustainable inventory management system and make consensus by discussing highest priorities

Step 6 Communications, Outreach, and Training

Raise awareness of inventory efforts

Discuss importance and benefits of producing a regular national inventory

Identify and invite experts to comment on and improve the inventory

Train inventory staff on national inventory system

23. **COMMUNICATION**

Develop or improve the national inventory website

Publish soil and land use maps

Develop brochure on national inventory and circumstances

Add an annex to the national communications to include more complete methodological explanations, Information on sources not estimated, etc

Outreach

Schedule meetings with key stakeholders

Raise awareness with government, academia, and the public

Create a process for expert or public review

Create a national forum or participate in regional forums

Training

Provide feedback to government and associated institutions

Train or hire inventory staff

Improve methods for reporting and documentation

Develop a quality assurance/ quality control plan

23.1 Sectorial Inventory Improvement Plan

Sectors and Categories

Greenhouse gas emission and removal estimates are divided into main sectors, which are groupings of related processes, sources and sinks:

- Energy
- Industrial Processes and Product Use (IPPU)
- Agriculture, Forestry and Other Land Use (AFOLU)

- Waste and
- Other (e.g., indirect emissions from nitrogen deposition from non-agriculture sources) sector comprises individual categories (e.g., transport) and sub-categories (e.g., cars). Ultimately, countries will construct an inventory from the sub-category level because this is how IPCC methodologies are set out, and total emissions calculated by summation.

The inventory improvement plan was done based on the main sectors (Energy, IPPU, AFOLU and waste) division to make it simple for the implementation and as well as to follow the IPCC 2006 GHG inventory report preparation guideline.

23.3.1 Energy sector GHG improvement Plan

In the energy sector the challenges that the sector face for GHG inventory was technical capacity of data collection and management at regions, Zones and Woreda, lack of improving tier 1 to the higher tier, sectoral approach GHG inventory methodology and institutional arrangement gap.

Table 9: priority areas of improvement for key source categories of energy sector

Sector	Source category	Describe problem	Potential improvement
Energy	CO_2 emission from mobile combustion road vehicles and other energy production facility	Fuel consumption data are highly uncertain for sectoral approach	Identify alternative source of data. This effort may require coordination with the ministry of transport
	Higher Tier methodology	Analysis the key category for the sector	Coordinate with the sectors of energy related data collection and research, universities for developing emission factor. This effort may require coordination with the ministry of transport, Mining and petroleum, Ministry of industry, ministry of urban development and housing.
	Data collection and management system	Data collection and management system starting from the Woreda to the line ministry was uncertain.	Develop automate data management system that links woreda with zones, zones with regions, regions with line ministries and line ministries with Federal EPA (Create a centralized

			statistical database to automate data management and sharing)
	Technical capacity gap	Because of technical capacity gap all the key category data of the sectors was not collected and managed.	Continuous Capacity building on activity data collection, IPCC 2006 guideline and software for the specific technical experts of the sector.
	No institutional arrangement that links the federal organizations with lower administrations	Poor or limited activity data collection, poor report preparation and planning	Develop institutional arrangement that links the federal organizations with the lower administrative

23.3.2 Industrial Process and Product Use (IPPU) GHG improvement plan

Greenhouse Gas (GHG) emissions are produced as by-products of non-energy industrial processes in which raw materials are chemically transformed to final products. During these processes different GHGs such as carbon dioxide (CO_2), methane (CH_4) or nitrous oxide (N_2O) are released into the atmosphere. In this sector the challenges for GHG inventory is technical capacity of data collection and management at institutes and industries, lack of improving tier 1 to the higher tier (2 and 3) for the key category.

Table 10: Priority areas of improvement for key source categories for IPPU sector

Sector	**Source category**	**Describe problem**	**Potential improvement**
IPPU	Data of CO2 emission from cement production was uncertain	Emission from source has been uncertain due to lack of country specific emission factor.	Research analysis for possible source of activity data. Coordinate with the ministry of industry, research institutes, and universities to analysis and develop the emission factor for clinker.
	Data collection and management system	Data collection and management system starting from the Woreda to the line ministry was uncertain.	Develop automate data management system that links institutes, industries with line ministries and line ministries with Federal EPA (Create a

			centralized statistical database to automate data management and sharing)
	Technical capacity gap	Because of technical capacity gap all the key category data of the sectors was not collected and managed.	Continuous Capacity building on activity data collection, IPCC 2006 guideline and software for the specific technical experts of the sector.
		Tier 1 was used due to the unavailability of clinker fraction data. Default Cement Kiln Dust (CKD) value used from IPCC Guidelines	Collect clinker data and calculate GHG emissions using tier 2. Collect data on CKD from the individual plants and calculate the CKD value for the country.
		Data collection and management system starting from the factory, institutes to the ministry of industry were uncertain	Develop MOU with the sectors and work on awareness creation
		Because of technical capacity gap all the key category data of the sectors was not collected and managed.	Continuous Capacity building on activity data collection, IPCC 2006 guideline and software for the specific technical experts of the sector. In addition to that increasing awareness on data management system and improve reporting system.

23.3.3 AFOLU Sector GHG Improvement Plan

Ethiopia's GHG profile is dominated by emissions from the agriculture sector, followed by land-use change and forestry (LUCF). The agricultural activities that contribute the most to the sector's emissions are enteric fermentation (52%), manure left on pasture (37%), and burning of the savanna (4%). High

methane (CH_4) emission occurs mainly as a result of enteric fermentation whereas agricultural soil management contributes to high nitrous oxide (N2O) emission in the agriculture sector. Domestic livestock are the major source of CH_4 emissions from agriculture, both from enteric fermentation and manure management. The challenge faced in doing GHG inventory of the sector was lack of data management system, technical capacity gap for activity data collection, using IPCC software, lack of acquiring or developing GIS land use maps matrix.

Table 11: priority areas of improvement for key source categories for AFOLU sector

Sector	**Source category**	**Describe problem**	**Potential improvement**
AFOLU	Data collection and management system	Data collection and management system starting from the woreda to the line ministry was uncertain.	Develop automate data management system that links woreda with zones, zones with regions and regions with line ministries and line ministries with Federal EPA (Create a centralized statistical database to automate data management and sharing)
	Technical capacity gap	Because of technical capacity gap all the key category data of the sectors was not collected and managed.	Continuous Capacity building on activity data collection, IPCC 2006 guideline and software for the specific technical experts of the sector.
	Improve data collection and report on fertilizer usage	Activity data collected from fertilizer usage was uncertain	Collect activity data annually for accurately and transparently report of N_2O emission from managed soil

23.3.4 Waste Sector GHG Improvement Plan

Waste management activities, such as disposal and biological treatment of solid waste, incineration of waste as well as wastewater treatment and discharge, can produce emissions of GHGs including methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O). The challenges faced by this sector for GHG inventory was activity data collection and management system, limitation of going to higher tier, technical capacity gap for activity data collection and IPCC software using, lack of getting amount of waste generated and its characterization and lack of improve waste composition assessments.

Table 12: priority areas of improvement for key source categories for waste sector

Sector	**Source category**	**Describe problem**	**Potential improvement**
Waste	amount of waste generated per capital or per person and its characterization	Because of there is no data as a national that tell us amount of waste generation and its characterization getting amount of waste generated and its characterization is difficult	Doing assessment to overcome the gap by integrating with the research institutes and universities. coordinate with the ministry of Urban and House development,
	Data collection and management system	Data collection and management system starting from the woreda to the line ministry was uncertain.	Develop automate data management system that links woreda with zones, zones with regions and regions with line ministries and line ministries with Federal EPA (Create a centralized statistical database to automate data management and sharing)
	Technical capacity gap	Because of technical capacity gap all the key category data of the sectors was not collected and managed.	Continuous Capacity building on activity data collection, IPCC 2006 guideline and software for the specific technical experts of the sector.

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7. UNFCCC- Resource Guide for Preparing the National Communications of Non-Annex-I parties, Module 1, Available at: https://unfccc.int/resource/docs/publications/09_resource_guide1.pdf

Annex I: QA/QC coordinator checklist

Activities	Task Completed	
	Name	**Date**
1. Clarify and communicate QA/QC responsibilities to inventory team members.		
2. Develop and QA/QC checklists appropriate to roles on the inventory team.		
3. Distribute QA/QC checklist to appropriate inventory team members and set deadline for completion.		
4. Ensure the timely and accurate completion of QA/QC checklists and related activities by checking in with team members.		
5. Collect completed QA/QC checklists and forms.		
6. Review completed QA/QC checklists and forms for completeness and accuracy.		
7. Deliver documentation of QA/QC activities to the inventory lead and archive coordinator.		
8. Coordinate external reviews of the inventory document and ensure that comments are incorporated into the inventory. Steps to coordinating external reviewers include: i. Identify external reviewers (e.g. through category leads). ii. Set review schedule. iii. Establish review format (e.g., digital mark-up in Word or Excel). iv. Contact external reviewers informing them of the schedule and expectations. v. Work with NIC to distribute Inventory draft for review. vi. Collect and compile review comments. vii. Deliver compiled comments to national inventory and sector leads to address. viii. Update inventory, as appropriate based on comments. ix. Deliver compiled comments and responses to archive coordinator, to retain for reference.		

Annex II: National inventory coordinator checklist: Cross-cutting checks for overall inventory quality

Activities	*Task Completed*	
	Name	**Date**
Emission Calculations Across GHG Emission and Removal Categories		
1. Identify parameters that are common across categories (e.g., conversion factors, carbon content coefficients, etc.) and check for consistency		
2. Check those calculations using same data inputs (e.g. animal population data) report comparable values (i.e., analogous in magnitude)		
3. Check across categories to ensure that same electronic data set is used for common data (e.g., linking animal population data to both enteric fermentation and manure management calculations)		
4. Check that the number of significant digits or decimal places for common parameters, conversion factors, emission factors, or activity data is consistent across categories		
5. Check that total emissions are reported consistently (in terms of significant digits or decimal places) across categories		
6. Check that emissions data are correctly aggregated from lower reporting levels to higher reporting levels		
7. Other (specify):		
Documentation		
8. Check if internal documentation practices are consistent across categories		
9. Other (specify):		
Completeness		
10. Check for completeness across categories and years		
11. Check that data gaps are identified and reported as required		
12. Compare current national inventory estimates with previous years'		

13. Other (specify):		
Maintaining Master Inventory File: Spreadsheets and Inventory Document		
14. Follow file control procedures		
15. Other (specify):		

Annex III: National inventory coordinator checklist: Detailed checklist for inventory document

Activities	*Task Completed*	
	Name	**Date**
Front Section		
1. Cover page has correct date, title, and contact address		
2. Tables of contents, tables, and figures are accurate: titles match document, page numbers match; numbers run consecutively and have correct punctuation		
3. The Executive Summary and Introduction are updated with appropriate years and discussion of trends		
4. Other (specify):		
Tables and Figures		
5. All numbers in tables match numbers in spreadsheets		
6. Check that all tables have correct number of significant digits		
7. Check alignment in columns and labels		
8. Check that table formatting is consistent		
9. Check that all figures are updated with new data and referenced in the text		
10. Check table and figure titles for accuracy and consistency with content		
11. Other (specify):		
Equations		
12. Check for consistency in equations		
13. Check that variables used in equations are defined following the equation		
14. Other (specify):		

References		
15. Check consistency of references, and that citations in text and references match		
16. Other (specify):		
General Format		
17. All acronyms are spelled out first time and not subsequent times throughout each chapter		
18. All fonts in text, headings, titles, and subheadings are consistent		
19. All highlighting, notes, and comments are removed from document		
20. Size, style, and indenting of bullets are consistent		
21. Spell check is complete		
22. Other (specify):		
Other Issues		
23. Check that each section is updated with current year (or most recent year that inventory report includes)		
24. Other (specify):		