QUALITY ASSURANCE / QUALITY CONTROL AND UNCERTAINTY MANAGEMENT PLAN FOR THE U.S. GREENHOUSE GAS INVENTORY:

Procedures Manual for Quality Assurance / Quality Control and Uncertainty Analysis

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Preface

The *Inventory of U.S. Greenhouse Gas Emissions and Sinks* must meet the needs of a diverse collection of stakeholders, ranging from the general public to scientists. The *Inventory* is both a detailed accounting exercise and a rigorous scientific one. In recognition of this composite of purposes, the U.S. Greenhouse Gas Inventory Program has, since its inception, embodied the underlying principle that developing an inventory is more than just a scientific or technical undertaking. It also requires in equal measure a commitment to continuous improvement and quality management.

It is a fundamental axiom of the program that designing quality management processes to support the development of the inventory must recognize the fundamental role of institutional, philosophical, managerial, and procedural subsystems. The current structure of the inventory system, which has evolved and developed over the past decade, reflects these principles. This document provides a rigorous set of procedures for maximizing the quality of the inventory given the resources available.

It is also a fundamental axiom of the program that quality control and quality assurance must be integrated into every step of the inventory development process. Thus, undertaking checks and procedures at every stage of estimation and document development, involving the experts on an ongoing basis, maintaining an open and transparent inventory process, using multiple review processes, and providing for communication and feedback across the participants in the inventory are all part of quality control and improvement. In this context, uncertainty analysis is one of the several tools that can facilitate the process of maintaining and improving quality. A key value of uncertainty analysis is in the qualitative lessons learned about the quality of the data and methods being employed to estimate emissions or removals.

The audience for this document includes the diverse users of the *Inventory*, some of whom may be unfamiliar with the inventory process, as well as anyone else seeking background on how the U.S. Greenhouse Gas Inventory Program functions. We hope that this document will not only serve as useful background to these individuals, but also be of assistance to other countries, States, companies, universities, and interested practitioners involved in conceptualizing, designing, or building a comprehensive inventory system.

Feedback is fundamental to our quality improvement process. This document and its companion document, *Background on the U.S. Greenhouse Gas Inventory Process*, are intended to be "living," in that they will continuously be updated. We encourage you to provide us with comments and suggestions on any aspect of these documents or other products from the U.S. Greenhouse Gas Inventory Program.

Michael Gillenwater
Greenhouse Gas Inventory Program
June 2002

Acknowledgments

This document is the product of a decade of staff experience at the U.S. Environmental Protection Agency in cooperation with other supporting agencies and departments in the United States Government and with contractors. Michael Gillenwater conceived of the project and provided overall direction and a guiding philosophy to the development of this document from its inception in 1996, and has given unwavering and consistent vision to the process. Fran Sussman is the primary author of this document. She has added an invaluable quantity of intelligence, thoroughness, and creativity to both this document and the U.S. Greenhouse Gas Inventory Program. Kamala Rajamani Jayaraman is the primary architect of the chapters and appendix relating to uncertainty analysis, and has developed a detailed and rigorous approach. Jonathan Cohen contributed to the uncertainty material through his careful review and thoughtful comments. Marian Martin Van Pelt and Katrin Peterson, with their considerable knowledge of the process of developing, publishing and submitting the *Inventory*, contributed greatly to the applicability, accuracy, and thoroughness of the document.

Others have also been important contributors if not to this document, then to the overall maturation of the U.S. Greenhouse Inventory Program. Wiley Barbour directed the program with great energy and a wonderful attitude from its early days until recently and set in place its fundamental mission. Craig Ebert of ICF Consulting and Art Rypinski of the Energy Information Administration (EIA), at the time, were both "inventory founders" in that they helped lead technical development of the U.S. inventory. Michael Gillenwater established much of what has become the current U.S. greenhouse gas inventory system, and now Marian Martin Van Pelt of ICF Consulting has furthered that effort and brought an outstanding level of professionalism and acumen to the program. Joe Mangino provided useful review comments based on his valuable experience with QA/QC on air quality inventories. And finally, we would like to thank the rest of the staff at EPA, EIA, ICF Consulting, and other organizations who have worked on the *Inventory* over the years and helped make it such an outstanding product.

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TEXT BOXES

1 INTRODUCTION

Each year, the U.S. Environmental Protection Agency (EPA), in cooperation with other federal agencies, prepares an *Inventory of U.S. Greenhouse Gas Emissions and Sinks (*here referred to as the *Inventory)*. The emission estimates, trends, and other results of the inventory are used for a variety of purposes, including monitoring and tracking the progress of the United States in meeting commitments under the United Nations Framework Convention on Climate Change (UNFCCC). The United States has developed a comprehensive approach to preparing the inventory and the associated official documentation and communications that accompany and report the estimates.

One of the primary goals of the U.S. Greenhouse Gas Inventory Program is to work continually to improve emission estimates. To this end, the U.S. inventory program has adopted a comprehensive and unified approach to managing quality and uncertainty in the inventory estimates. The philosophy underlying the approach is that methodological advances, improvements in documentation and clarity to facilitate transparency, quality control and quality assurance, and uncertainty analysis should all be integrated into one comprehensive greenhouse gas inventory system. This document is one of two complementary documents that together describe and provide guidance on the overall process of preparing, submitting, and disseminating a greenhouse gas inventory that has undergone quality control (QC) and quality assurance (QA) procedures.

The companion document, *Background on the U.S. Greenhouse Gas Inventory Process (Background)*, provides an overview of the inventory process, including the agencies involved and the activities needed to fulfill U.S. commitments under the UNFCCC. The *Background* document also describes the goals of the QA/QC plan and uncertainty analysis, and the role of checks and quality controls in the annual development, and continual improvement over time, of the inventory emissions, the *Inventory* document, and other reports and technical analyses that are produced as part of the inventory process. As described more fully in the *Background* document, experts are consulted and involved throughout the development of the inventory estimates, providing numerous opportunities for evaluation and assessment of the inventory methodologies and data. The current document, *Procedures Manual for Quality Assurance/ Quality Control and Uncertainty Analysis (Procedures Manual),* is designed to add to this foundation a thorough system of quality controls, checks, and documentation, of quality assurance through rigorous review, and of uncertainty analysis of the entire inventory.

In line with the philosophy underlying the U.S. Greenhouse Gas Inventory Program, and as part of efforts to control, document, and improve the quality of its inventory, the United States has developed a set of procedures for conducting QA and QC activities and for estimating uncertainty. These procedures are described in this *Procedures Manual*, which provides guidance to the process of ensuring inventory quality by describing data and methodology checks, processes governing peer review and public comments, and guidance on conducting an analysis of the uncertainty surrounding the emission estimates. The *Procedures Manual* also contains information feedback loops and provides for corrective actions that are designed to improve the inventory estimates over time.

In line with the United States approach to the greenhouse gas inventory, the procedures and templates developed for the *Procedures Manual* are intended to be equally rigorous and comprehensive; thus, it is expected that the initial quality review of the inventory may take several years to complete, and that conducting the review will require heightened coordination and cooperation among the agencies and groups responsible for developing the inventory and its associated documents.

This *Procedures Manual* is intended to be a comprehensive description of the procedures to be followed. It is designed to be used by those involved in inventory preparation, uncertainty analysis, and QC, but may also be of use to those interested in the processes underlying inventory development. The procedures and accompanying forms, templates, and checklists are designed to be a stepwise, thorough, and comprehensive approach to QA/QC and uncertainty analysis; as such, countries developing inventory systems may find the procedures useful in providing a framework or initial point of departure for their own systems.

The remainder of this document lays out the various procedures, and is organized as follows:

- Chapter 2, *Quality Control Procedures for Specific Source Categories*, contains generic procedures for the individual source categories, including quality checks on inventory estimates, documentation, and archiving.
- Chapter 3, *Cross-Cutting Quality Control: Inventory Estimates and Inventory Document*, contains overall procedures and those affecting more than one source category, including checking and maintaining consistency and quality across the inventory estimates for source categories, checking the quality of the overall estimates, and checking official and published documents associated with the inventory estimates.
- Chapter 4 *Procedures for Quality Assurance: Review Processes*, describes the expert review processes and the process.
- Chapter 5, *Uncertainty Analysis: Background, Procedures, and Elicitation Protocol*, lays out procedures for conducting the analysis of the uncertainty around the inventory estimates, including a protocol for eliciting information on uncertainty from experts. It also provides important background information on the methods of uncertainty analysis for the inventory, which should be read by the Source Category Leads and inventory analysts.
- Chapter 6, *References*, presents source information for all references cited in the preceding chapters.

A number of appendices supplement the text of this manual. These appendices provide checklists, forms templates, and other supporting documents for implementing the quality control procedures and to be used in developing, documenting, and recording the results of the uncertainty analysis, as well as example documents. The appendices are:

- Appendix A, *Forms and Checklists for Quality Control for Specific Source Categories*, contains forms and checklists to accompany the source-category specific quality check activities described in Chapter 2.
- Appendix B, *Forms And Checklists For Cross-Cutting Quality Control*, contains forms and checklists to accompany the cross-cutting quality checks described in Chapter 3.
- Appendix C, *Forms for Review Processes*, contains forms and checklists to accompany the review processes described in Chapter 4.
- Appendix D, *Templates and Forms for Uncertainty Analysis*, contains templates and forms to be used as part of the uncertainty analysis described in Chapter 5.
- Appendix E, *Sample Documents*, includes several sample documents from the inventory development process.

The agencies, organizations, and individuals (and their functional responsibilities) contributing directly or indirectly to compiling the inventory are diverse and numerous. Only some of these parties, however, are involved directly in the preparation of the inventory. Those who should read and use this *Procedures Manual* include the following functional positions.

- *Agency Inventory Lead*—overall director responsible for all aspects of the inventory program, including supervising the preparation of the estimates, the uncertainty analysis, and the *Inventory* document and ensuring that corrective actions are taken as needed
- *Data and Document Management Coordinator*—responsible for directly coordinating the preparation of the inventory estimates and text, maintaining the electronic files, and supervising the preparation of docket and archiving materials, as assisted by staff
- *Source Category Leads*—responsible for preparing the inventory estimates and supporting text for the *Inventory* document for a specific source category, for making key decisions and providing critical input into the uncertainty analysis, for taking corrective action in response to QA/QC and uncertainty results, and for supervising source category staff (sometimes referred to as inventory analysts)

- *QA/QC Officer*—directs the overall implementation of QA/QC, including supervising QA/QC staff, overseeing the expert reviews, and is responsible for ensuring the full and adequate implementation of QA/QC elements and the adequate qualifications of source category staff and contractors
- *Uncertainty Analysis Coordinator*—directs the statistical analysis of uncertainty for the inventory estimates in coordination with the Agency Inventory Lead and Source Category Leads, and supervises uncertainty staff (sometimes referred to as uncertainty analysts)
- *Outside Experts*—independent individuals who may contribute data to the inventory estimation (i.e., "data suppliers"), may be involved in improving / examining the inventory methods and data during the inventory development process, or may provide expert review of the emission estimates or inventory document)[1]

Note that a person may hold more than one functional position within the organization. The companion *Background* document describes the agencies, organizations, and functional responsibilities of those involved in compiling the inventory in more detail. In additional, the roles of these functional positions in performing and following up on QA/QC and uncertainty analysis are described in considerably more detail in subsequent chapters of the *Procedures Manual*.

The *Procedures Manual* is designed so that the interested reader or analyst can find needed information without reviewing the entire document. While reading the complete document might be helpful to any of the functional positions involved in preparing the inventory, the *key* chapters and appendices that should be read by the above parties are given in a table below; chapters that they may wish to review for *informational* purposes are listed as well. In order to make each individual chapter and its associated appendix self-contained, some material is repeated in different chapters and certain templates are included in more than one appendix.

Functional Position	Key Procedural Chapters	Other Informational Chapters
Agency Inventory Lead	Should be familiar with entire document	
Data and Document Management Coordinator, staff, and designees	Chapter 3: Cross-Cutting Quality Control: Inventory Estimates and Inventory Document	Chapter 2: Quality Control Procedures for Specific Source Categories Chapter 4: Procedures for Quality Assurance: Review Processes
Source Category Leads, inventory analysis staff, and designees	Chapter 2: Quality Control Procedures for Specific Source Categories Chapter 5: Quantitative Uncertainty Analysis: Background, Procedures and Elicitation Protocol	
QA/QC Officer, QA/QC staff, and designees	Chapter 2: Quality Control Procedures for Specific Source Categories Chapter 4: Procedures for Quality Assurance: Review Processes	Chapter 3: Cross-Cutting Quality Control: Inventory Estimates and Inventory Document Chapter 5: Quantitative Uncertainty Analysis: Background, Procedures and Elicitation Protocol
Uncertainty Analysis Coordinator, uncertainty staff, and designees	Chapter 5: Quantitative Uncertainty Analysis: Procedures, and Elicitation Protocol	Chapter 2: Quality Control Procedures for Specific Source Categories

[1] Outside experts are not actually part of a chain of functional responsibility for producing the inventory. However, they can be important contributors to the inventory and the uncertainty analysis, and are an essential part of the QA process.

2 QUALITY CONTROL PROCEDURES FOR INDIVIDUAL SOURCE CATEGORIES

This chapter describes procedures to be followed both to *control* and to *check* the quality of the inventory estimates and the inventory document, and to manage and handle the data associated with the inventory. Quality Control (QC), as defined by the Intergovernmental Panel on Climate Change (IPCC) in its *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC 2000, here referred to as *IPCC Good Practice Guidance*), is a system of routine technical activities to measure and control the quality of the inventory as it is being developed. A basic QC system should provide routine and consistent checks to ensure data integrity, correctness, and completeness, and to identify and address errors and omissions. It should also provide procedures for documenting and archiving inventory material and recording all QC activities.

Following the terminology developed for the *IPCC Good Practice Guidance*, this chapter describes two categories of controls / checks:

- Section 2.1, *Data Quality Control: General Procedures (Tier 1)* describes the procedures that all source categories should follow when gathering, maintaining, handling, documenting, checking and archiving the data, supporting documents, and files (both text documents and spreadsheets) associated with the inventory. This section also provides checks to ensure that appropriate procedures have been followed.
- Section 2.2, *Data Quality Control: Source Category-Specific Procedures (Tier 2)* describes good practice procedures and checks to assess the representativeness, accuracy, completeness, and quality of the emission estimates for individual source categories, and of the emission factors and activity data comprising the estimates.

Who should read Chapter 2?

The Agency Inventory Lead, Source Category Leads and inventory analysts should read this chapter.

The QA/QC Officer and staff performing quality checks and completing source category-specific Tier 1 and Tier 2 checklists should read this chapter.

The Data and Document Management Coordinator and staff may wish to review this chapter.

The Uncertainty Analysis Coordinator and staff may wish to review this chapter.

When are checks performed?

This chapter includes *procedures* for maintaining quality that should be followed at all times.

Some *checks* of quality occur annually, others periodically (as part of a thorough, multi-year check of the inventory), and other checks will be triggered by events, such as changes in methodology.

What checklists need to be completed?

The primary templates for this chapter are the *Tier 1: Individual Source Category Checklist* and *Tier 2 Source Category Checklist* in Appendix A. These forms provide records of the checks conducted and any corrective actions taken. Appendix A also contains a sample worksheet for tracking data and references for an individual source category.

Appendix A includes a number of templates or checklists to be completed in conformity with the material in these sections.

This chapter should be read by inventory analysts directly responsible for preparing emission estimates for source categories in the inventory. The chapter describes the procedures that all inventory analysts should follow when preparing and documenting the emission estimates and supporting text for the inventory document. The sections also provide for a series of quality checks, and associated templates that can be completed to record the results of the checks, in order to ensure that the procedures are being followed. *Inventory analysts should also be aware of these quality checks as they are preparing estimates.*

This chapter should be read by the QC staff performing quality check activities for a particular source category estimates, who may or may not be inventory analysts preparing the inventory estimate for that source category. These staff should review the "good practice" procedures in this chapter, and should pay close attention to the QC procedures and the checks to be performed. The checklists or templates in Appendix A should be completed when the checks are performed. Once appropriate corrective actions are

taken (if any) as a result of the checks, the forms are to be completed, filed, and submitted to the data and document control manager.

The Data and Document Management Coordinator may wish to review this chapter because of its discussion of the requirements for inventory analysts in the areas of maintaining project files (which contribute to the docket and archives), documents (such as checklists) to be submitted to the Data and Document Management Coordinator, and master file management procedures. The procedures in this chapter should be consistent with those in Chapter 3, *Cross-Cutting Quality Control*.

The checks described in this chapter should be performed annually, or less frequently as needed and as indicated in the relevant section. However, both the analysts preparing—and those checking the inventory—are given considerable latitude in what they actually do and the checks they perform, as long as they stay within the general parameters given and conduct checks that are thorough and that are appropriate to the methodology and data sources of the source category.

2.1 Data Quality Control: General Procedures (Tier 1)

The procedures described in this section promote quality in two ways. First, the section includes general procedures for Source Category Leads and their staff to follow in the areas of documentation, data gathering, emissions calculations, and other activities that are essential to controlling and maintaining quality. Second, the section provides checks—to be performed each year as part of QC activities—of whether the standardized procedures have been followed, and provides templates for documenting the findings and corrective actions or follow-up that is needed.

The QC analyst checking Tier 1 quality for each source category should perform the following general activities:

- *Review*. Understand the procedures described below in this section and the content of the *IPCC Good Practice Guidance*(Chapter 8, *Quality Assurance and Quality Control*).
- *Check*. Check whether spreadsheets for each source category follow these procedures; both general procedures and specific checks are indicated below.
- *Document*. Document the findings and results of the checks, by completing the Tier 1 checklist (*Tier 1: Individual Source Category Checklist*, in Appendix A), including the summaries of Tier 1 results and problems to be corrected. Note that careful documentation is important for two reasons: it enables potential improvements in the inventory to be identified and implemented, and it provides a record over time of when and which checks were performed.
- *Pursue corrective action*. Take any corrective action as needed, documenting (in the appropriate place on the Tier 1 checklist) the actions taken and the results. If appropriate corrective actions are not immediately apparent, the QC staff performing the check should discuss the results of the QC checks and the completed checklists (including summaries) with the Agency Inventory Lead and the QA/QC Officer, and identify and make provisions for any follow-up actions that might be needed.
- *Transmit*. All documentation (including the final completed checklist and any *Supplemental Reports*) should be placed in the project file, with copies given to the Data and Document Management Coordinator.[2]

While procedures for maintaining data quality should be followed at all times, not all checks need to be performed each year that the inventory is modified. Some activities should be conducted *every year* (e.g., reviewing electronic data quality checks or inspecting project files for completeness) or at least routinely (e.g., checking that all primary data points in the spreadsheet have citations to references). Some checks need be performed *thoroughly* once (e.g., checking the entire content of the archives for completeness and consistency) and then only occasionally thereafter. Other procedures or checks are *triggered* by changes that occur (e.g., changes in assumptions or in the calculation methodology). Budgetary resources will, in part, determine how frequently some checks occur.

[2] The contents of the project file are described in §2.1.2.

2.1.1 Data Gathering, Input, and Handling

A number of common sense procedures govern the collection, maintenance, and use of electronic and transcribed data for all activity data, emission factors, and other primary data elements. Appropriate procedures can minimize the extent to which errors in data collection occur; various checks on the data and files can further reduce the errors that occur.

Procedures for the inventory analyst to follow include:

- Electronic data should be used where possible to minimize transcription errors.
- Spreadsheet features should be used to minimize user error or entry error.
  - ✓ avoid hardwiring factors into formulas (see §2.1.3)[3]
  - ✓ create automatic look-up tables or pull down menus that limit permissible entries or, in some cases, automatically enter data
  - ✓ use cell protection so that fixed data cannot accidentally be changed
- If identical data are used by different source categories, the same electronic data file (whether obtained electronically or transcribed) should be used by both source categories.
- Build in computerized checks to highlight possible problems.[4]
  - ✓ set up automatic data screens to detect outliers (range checks based on high and low values or on median or mean value), negative values, or missing data
  - ✓ use spreadsheet features to conduct other checks, such as ensuring that values are appropriate to the variable type
  - ✓ check consistency, e.g., if a certain field has data, then check that other required fields also have data, or calculate ratios between variables to check for expected values
  - ✓ employ quality control features of different Excel add-on software packages
  - ✓ generate "quality check" reports displaying the results of computerized and automated quality checks
- Data flagged as "sensitive" business information should be password protected in the spreadsheets. The information itself is masked by aggregation in the published inventory document.

The QC analyst (or inventory analyst) can perform various hand checks to minimize data input errors. The *Tier 1: Individual Source Category Checklist*, in Appendix A, lists these items. Checks include the following.

- Check for transcription errors among a representative sample of input data by cross checking data against original source—for example, among a sample of parameters used in calculations, activity data, or emission factors.
- Inspect "quality check" reports and follow-up on possible problems highlighted by automated checks. Automated systems should also be reviewed periodically to ensure that they are functioning properly.

The QC analyst should complete these checks as relevant and concurrently identify other checks that may be relevant to the source category. All completed checks should be reported on the Tier 1 checklist.

[3] Suggestion: color code cells to indicate whether data are hardwired, linked within the spreadsheet, or linked to another spreadsheet.

[4] For more information on automated QC screens see EPA (1996-7). For other good practices in data and document handling, see USDOE/EIA (2000).

2.1.2 Data Documentation

Documentation of the inventory should be sufficiently detailed and clear as to allow an independent but knowledgeable analyst to obtain and review the references used and reproduce the emission estimates. Complete and accessible documentation of methods, data and data sources, spreadsheets, phone logs, and other data contacts is important.

Maintaining Project Files

The lead inventory analyst (whether the Source Category Lead or designated source category staff) for a source category should maintain a complete and separate project file for that source category. The intent is that project files should include all the materials the analyst needs to develop the inventory for that year, and that the files should be maintained in a transparent manner; the analyst has considerable discretion over the form and content of the file. If, for example, multiple source categories have common files and are under the purview of one Source Category Lead, appropriate cross-references and documentation across files can reduce duplication of material from one project file to another.

A project file should be maintained for the current year of the inventory and should include all relevant information.

- The file should contain a list of the names and locations of all "working" spreadsheets for the source category, with explanations of links among them, and any recent electronic back-up copies of working drafts of the spreadsheets.[5]
- *Contact Reports* for telephone conversations or meetings, copies of written communications (letters, e-mails, or facsimiles) containing data or other information related to producing emission estimates or evaluating inventory quality should be placed in the file.
- Copies of reference materials or data that are new to that year of the inventory should be included in the project file.[6]
  - ✓ for unpublished data received in hard copy—the complete material, if feasible, and any associated cover material (letters, facsimiles)
  - ✓ for published material—a complete reference citation, the cover page from the document, and, if feasible, selected pages with the relevant data
  - ✓ for data retrieved from the Internet—electronic copy on diskette and/or paper copies, together with appropriate reference information, including date downloaded and website address)
- Copies of proprietary or copyrighted data (unpublished), may be received electronically (on CD-ROM or diskette) or in paper copy; because these data cannot be reproduced, a note should be placed in the project file (and subsequently in the docket) indicating who holds the data, its physical location, and how it can be accessed. Proprietary information should be carefully identified and tracked so that copies are not lost when staff turnover occurs.
- Copies of hand calculations or notes made by the analyst, appropriately documented, should be placed in the file.
- Copies of all checklists completed for QA/QC purposes, together with follow-on or corrective actions, should be placed in the file.

The QC staff should check project files for completeness as part of Tier 1 quality control activities. The *Tier 1: Individual Source Category Checklist*, in Appendix A, contains entries for these checks. Completed checks should be reported on the QC checklist.

[5] It is good practice to routinely make electronic back-up copies of the working drafts of the spreadsheets and *Inventory* document. Analysts may also choose, but are not required, to keep back-up electronic copies of all spreadsheets or inventory drafts that represent significant milestones or changes for the year.
[6] Note that most of this material should be archived as well (see §3.4).

Documenting the Inventory Spreadsheets and the *Inventory* Document

The inventory analyst should ensure that the documentation associated with the inventory is sufficient for an independent analyst to determine the reference source for each piece of data used to calculate emissions, and to locate the data in public sources (if published) or in the project files or inventory archives (for both published and unpublished data). The documentation should also provide complete information on any changes that are made to data sources or methodological changes that occur in a given year. Both the inventory spreadsheets and the inventory document itself should be subject to scrutiny to determine that the references are complete, accurate, and consistent in format. Both the inventory analyst and QC staff should be familiar with the following procedures, which are designed to maintain high quality.

- In the spreadsheets, *every* primary data element (activity data, emission factor, carbon coefficient, etc.) must have a reference—published or unpublished—for the source of the data. *No non-calculated values should appear in the spreadsheets that are not referenced, with the exception of standard unit conversion factors or similar information.*
- In the spreadsheets, citations to reference sources should be attached by Excel "comments" to the data, or by another system of notation. Abbreviated citations can be used in the comments if full citations appear on a bibliography sheet in the spreadsheet (see *Box 2-1*).

Box 2-1. Documenting the Source Category Estimates

For many source categories, either cell comments, or a simple bibliography sheet accompanied by abbreviated references, will be sufficient to identify the references contributing to the emissions estimate.

For source categories that are particularly complex to estimate, documenting the inventory spreadsheets may require more sophisticated methods, however. For example, source categories with large numbers of variable inputs may benefit from dedicated tracking devices.

A sample shell for a detailed reference-tracking sheet is given in Appendix A (see *Sample Data/Reference-Tracking Sheet*). Such a spreadsheet will make the documentation of the spreadsheet transparent for quality control purposes or for a reviewer seeking to duplicate the estimates. The tracking sheet may also benefit the inventory analyst in updating and tracking the data collection effort from year to year.

- Every reference (published or unpublished) cited on the spreadsheet should have a paper copy counterpart either in the current project file or in the existing archives.
- References to unwritten personal communications should be supported by a *Contact Report* providing information on the phone conversation or meeting (see *Contact Report* in Appendix A).
- Every reference citation on the spreadsheet should appear in the reference list of the inventory document, and the same format should be used in both places (see general documentation of references, below).
- Everything—supporting documentation (such as notebooks and *Contact Reports*), comments, and especially all printouts made from spreadsheets—should be dated. (Suggestion: set the footer in Excel to include date, and to use the "=TODAY()" function.)
- The reference, or brief rationale, and individual responsible (generally, the Source Category Lead) for assumptions and criteria for the selection of activity data and emission factors should be documented in an identified section of the spreadsheet or in comment cells.
- Changes from the previous year in assumptions, the methodology, or data sources may be noted by a comment on the spreadsheet, at the analyst's discretion. Any changes noted should indicate the span of the inventory for which the change is made(e.g., the inventory covering 1990-2001). For clarity, notations relevant only to previous years' inventories may be deleted. However, regardless of whether changes are noted on the spreadsheet, these changes should be reported in the section on "Changes in the U.S. Greenhouse Gas Inventory Report" of the *Inventory* document.

The QC staff can perform various checks to verify the adequacy of the documentation of the spreadsheet. The *Tier 1: Individual Source Category Checklist*, in Appendix A, includes these items. Among these checks are:

- Check the spreadsheet for missing citations to the source of data for primary data elements.
- Thoroughly check all citations in the spreadsheets and in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks (*here referred to as the *Inventory)* document for completeness (i.e., include all relevant bibliographical data) and consistency with style guidelines, and to ensure that all documents cited in the spreadsheets appear in the *Inventory*.
- Check that every reference on the spreadsheet physically exists either in the archives or current project files.
- In particular, check that contact sheets, facsimiles, diskettes, and/or data printouts and other supporting information exist for unpublished data.
- Randomly check source write-ups and bibliography for the *Inventory* document to ensure that citations match the information in the spreadsheets and in the original reference document or other source (i.e., transcription errors have occurred) and that the document contains the material or information for which it was referenced.
- Check that assumptions and criteria for selection of activity data are discussed and documented in comment cells on the spreadsheet.

The QC analyst should complete these checks as relevant and concurrently identify other checks that may be relevant to the source category. All completed checks should be reported on the Tier 1 checklist.

General documentation of references

To the extent feasible, effort should be made to ensure the documentation follows a uniform format across the inventory spreadsheets.[7] A list of suggested reference types to include in the documentation is given below. Other reference types may be used as well.

- *Phone and meeting contacts*. Individuals, agency, group, or company providing information by telephone should be identified by full name, association, voice and facsimile numbers, and the date information was provided and to whom. Refer to *Contact Report*, if one was kept.
- *Facsimile, letter, e-mail, or other written contact or unpublished data*. Written information should be annotated with complete information about the individual or agency supplying information (name, title, affiliation, telephone and fax numbers, e-mail address, data supplied, etc.).
- *Published data.* Complete bibliographical information should be provided in references to published information, including: title, author, publisher and city, and copyright date, following an accepted model. Page numbers for the referenced material should be provided.
- *Electronic data.* For information obtained from CD-ROM or a similar source, the provider of the information (name, affiliation, address, telephone and fax number and other relevant information) and format of the data should be recorded. For information obtained from the Internet, the reference information should be as complete as possible, including the web address and the date the information was downloaded.
- *Comments.* It is helpful for comments to include the date inserted and/or the name and affiliation of the individual inserting the comment. (Suggestion: set up Excel so that the name of the user is automatically inserted into the comment.)

The QC staff should review the spreadsheets and the inventory document to assess whether the references conform to these requirements. The *Tier 1: Individual Source Category Checklist*, in Appendix A, includes these reviews. QC staff should report completed checks on the Tier 2 checklist.

[7] The appropriate form for citations and complete references in the inventory may be indicated in the "kickoff" memorandum (see Appendix E).

2.1.3 Calculating Emissions and Checking Calculations

The inventory analyst should adopt appropriate procedures for designing and modifying spreadsheets, in order to reduce calculation errors occurring in the emission estimates. A number of checks will help ensure that appropriate procedures have been followed, as well as catch remaining errors. The *Tier 1: Individual Source Category Checklist*, in Appendix A, includes most of these items. Checks include the following.

- Parameters, emission units and conversion factors for calculations should be clearly labeled and referenced. In addition, the following procedures should be followed to ensure that parameter and emission units are correctly recorded and that appropriate conversion factors are used.
  - ✓ Emission units, parameters, and conversion factors should not be hardwired into formulas; any value used more than once should be included in the spreadsheet (preferably at the head of the page where it first appears and highlighted) and every calculation using that value should reference that cell.
  - ✓ Units should be properly labeled and correctly carried through from beginning to end of calculation.
  - ✓ Conversion factors should be correct.
  - ✓ Temporal and spatial adjustment factors should be used correctly.
- Maintain the integrity of the database files and spreadsheets:
  - ✓ Confirm that the appropriate data processing steps are correctly represented in the spreadsheets (e.g., that the equations are correct).
  - ✓ Confirm that data relationships are correctly represented in the spreadsheets (e.g., that data are in appropriate and comparable units and years).
  - ✓ Clearly differentiate between spreadsheet input data and calculated data (for example, set up and follow a color coding system).
- Check calculations within a source category.
  - ✓ Reproduce a representative sample of emission calculations to ensure mathematical correctness.
  - ✓ Selectively mimic complex model calculations with abbreviated calculations to judge relative accuracy.
  - ✓ Build in automated checks, such as computational checks for calculations, or range checks for input data.
  - ✓ Check that emissions data are correctly (1) aggregated from lower reporting levels to higher reporting levels when preparing summaries and (2) transcribed between different intermediate products.
- Checks can be triggered by specific events, i.e., methodological and data changes have occurred which result in recalculations.
  - ✓ Check for temporal consistency in time series input data for each source category and check the method used to fill in gaps in reported data.
  - ✓ Check for consistency in the algorithm/method used for calculations through the time series.
  - ✓ Check that changes in methods or data are consistent with IPCC guidance on both inventory methods and good practices.

The QC analyst should complete these checks as relevant and concurrently identify other checks that may be relevant to the source category. All completed checks should be reported on the *Tier 1 Individual Source Category Checklist*.

2.1.4 Coordination on Cross Cutting Activities: Maintaining the Master Files

It is critical that the Source Category Lead and supporting analysts follow procedures that are designed to reduce errors not only in the inventory estimates for individual source categories, but in the aggregated estimates that are reported, and in the *Inventory* document and other documents that report the results of the inventory. These cross-cutting activities are described further in successive chapters. Highlights of the procedures that inventory analysts should follow are noted here. The appropriate chapters in this manual should be consulted for more information.

The Data and Document Management Coordinator is the ultimate "sole owner" of the electronic copies of both the inventory, which is a linked set of spreadsheets, and the *Inventory* document. The source category spreadsheets are not only linked to each other, but each is also linked to a summary worksheet that is used to create the tables in the *Inventory* document, and to the United Nations Framework Convention on Climate Change (UNFCCC) Common Reporting Format (CRF) tables. This linking and sole ownership is one of the important QC features of the U.S. inventory system. To promote this system, the following procedures should be followed:

- Each year, Source Category Leads receive the current versions of the inventory spreadsheet(s) and *Inventory* document text (including write-ups and annexes) for their source category from the Data and Document Management Coordinator. These documents constitute the basis for the current year's work and updates. *No other version of the spreadsheet should be used.*
- The format of the source category spreadsheet(s) is determined by the Data and Document Management Coordinator, including any new information to be included (such as a summary worksheet, or a worksheet with data for the UNFCCC CRF). Portions of the spreadsheet that cannot be altered are indicated by the Data and Document Management Coordinator. For example, because the summary worksheet contains tables that correspond to every table in the *Inventory* document, it should not be altered except to add a new row/column for the new year's data; no other rows or columns should be added or deleted.
- Inventory analysts work from the versions provided by the Data and Document Management Coordinator and return revised versions. Once the electronic copies of the inventory spreadsheets and text are returned to the Data and Document Management Coordinator, permission—and a copy of the current version of the text or spreadsheet provided by the Coordinator—is required to make additional changes.

2.2 Data Quality Control: Source Category-Specific Procedures (Tier 2)

Source category-specific, or Tier 2, QC procedures focus on the types of data and methods used for individual source categories. This section describes the checks that can be performed by the inventory analyst or QA/QC staff to verify the quality and appropriateness of the data and methods used for the source category.[8] Two types of checks are relevant:

- The first set of checks is designed to identify potential errors or deficiencies in the emission estimates and whether the emission factors and activity data are applicable to, and representative of, conditions in the source category (§2.2.1 *Data Gathering and Selection*).
- The second set of checks focuses on the quality of secondary data—published literature and studies that provide data for the emission estimates—and on the quality of direct emission measurements that are used to develop emission factors or measure aggregate emissions (§2.2.2 *Quality of Secondary Data and Direct Emission Measurements*).

Both types of checks require considerable information on the data and methodology used for an individual source category, and can be very resource and time consuming to design and implement, and in some cases the requisite data may not be available. Moreover, if any of the checks indicate that a problem may exist in the estimates, more detailed checks may be required.[9] Because of the time and resources required to

[8] Appropriate procedures can be found in the source-specific inventory methods and good practices identified in the IPCC volumes relevant to the individual source category (IPCC/OECD/IEA 1997 and IPCC 2000).
[9] For additional information, consult the relevant chapters on particular source categories in the IPCC *Good Practice Guidance* (IPCC 2000).

conduct Tier 2 quality checks in general, the focus is on key source categories and on source categories where significant methodological and data revisions have taken place.[10] *Not all checks should be performed each year, and a thorough check of the inventory requires several years, depending on available resources.* Because of the detail and time required for some checks, they will be conducted only for key source categories.

The results of Tier 2 investigations are important for both the quality of the inventory estimate and the estimated uncertainty for a particular source category. Hence, careful documentation, follow-up and corrective action (if possible), and attention to the impacts of findings on the uncertainty of the emission estimates are all important components of Tier 2 procedures described in §2.2. Inventory analysts and uncertainty staff should cooperate in developing appropriate checks and investigating data quality for a source category, particularly where secondary data are concerned.

2.2.1 Data Gathering and Selection

The data used to develop emission estimates—which include emission factors, activity data, direct measured emissions, and other data—should be applicable and representative of the source category. A variety of checks can evaluate and improve the quality of the input data and emission estimates. Such checks, which are enumerated below, include assessing the applicability of emission factors to national circumstances and comparing different sources of data to determine the reasonableness of chosen data.

The QC analyst checking Tier 2 quality for each source category should perform the following general procedures. The procedures for checking the quality of data selected and gathered for the emission estimate for a particular source category are:

- *Review*. Understand the procedures described below in this section and the content of the *IPCC Good Practice Guidance* (both Chapter 8, *Quality Assurance and Quality Control*, and appropriate source category-specific chapters).
- *Identify*. Identify the emission estimates and the specific sources of emission factors and activity data for the emission source category.
- *Check*. For each variable or data source, complete the applicable checks identified in the remainder of §2.2.1 below, including any additional detailed checks that are required.
- *Document*. Document the activities and checks that are conducted by completing the *Tier 2 Source Category Checklist: Part A: Data Gathering and Selection*, in Appendix A. For emission factors and activity data, the specific variables and data sources that are checked should be indicated, and also summarized in the appropriate place on the form. The *Supplemental Report* form in Appendix A should be used to provide detailed information, or to report the results of additional detailed checks described below.
- *Pursue corrective action*. Take any corrective action as needed, documenting (in the appropriate place on the Tier 2 checklist) the actions taken and the results. If appropriate corrective actions are not immediately apparent, the QC staff performing the check should discuss the results of the QC checks and the completed checklists (including summaries) with the Agency Inventory Lead and the QA/QC Officer, and identify and make provisions for any follow-up actions that might be needed. If not all corrective actions are taken (for example, because of time or resource constraints), be sure to identify any residual quality issues on the Summary Sheet of the *Checklist*.
- *Transmit*. All documentation (including the final completed checklist and any *Supplemental Reports*) should be placed in the project file, with copies given to the Data and Document Management Coordinator.[11]

[10] For more information on key sources and how they are determined, see the IPCC (2000).
[11] The contents of the project file are described in §2.1.2.

Emissions Data

Some checks can be performed using the total emission estimate for the source category. These checks may indicate areas for further investigation, or indicate potential problems with emission factors or activity data. The following checks should be performed on emissions data for the source category:

- *Emission comparisons.* Estimated emissions for a source category in a given year can be compared with other estimates to ensure that they fall within a range that is reasonable. Unreasonable estimates provide cause for re-checking emission factors or activity data, and determining whether changes in methodology, market forces, or other events caused the change. In most cases, legitimate drivers or causes of the change will be apparent. Comparisons and checks that can be undertaken to identify *potentially anomalous* emissions data include:
  - ✓ comparisons with available historical inventory data for multiple years for unusual magnitudes of change (over 10% change is probably unusual) or unusual fluctuations over time
  - ✓ analogous historical comparisons for significant sub source-categories, to determine whether emissions have risen or fallen substantially over previous years.
  - ✓ calculating annual changes electronically and ranking categories and sub-categories or sources by percent change can facilitate flagging estimates for further investigation.
- *Order-of-magnitude checks.* Other checks on the "reasonableness" of annual emission estimates for a source category or sub-source category include identifying any major calculation errors or excluded major sources. For example, bottom-up and top down comparisons may be performed:
  - ✓ comparing estimates that are calculated using a "bottom-up" methodology with a more approximate "top down" method, e.g., one that uses national figures and IPCC default emission factors
  - ✓ comparing aggregated site-specific information on material balances (purchases, sales, losses, etc.) using a bottom-up approach with an estimate that relies on the same balance approach, but uses national data
- *Reference calculations.* Comparisons of emission inventory estimates obtained using empirical formulas with reference data (See §8.7.1 of the *IPCC Good Practice Guidance* for more information).

The QC analyst should complete these checks, as relevant, and concurrently identify other checks that may be relevant to the source category. All completed checks should be reported on the Tier 2 checklist.

Emission Factors

For a particular source category, calculated emissions will generally rely on emission factors. In turn, emission factors may be IPCC default factors, country-specific emission factors developed for the inventory from modeling results or incorporating site-specific direct emission measurements, or site-specific emission factors. A number of different types of checks on these data are possible, falling within the category of representativeness.

- *Assess representativeness*. Several checks can assess the representativeness, applicability, or reasonableness of emission factors, given national circumstances and the derivation of the emission factors. Checks include, but are not limited to the following.
  - ✓ Where IPCC default emission factors are used, compare U.S. national circumstances to the conditions of the studies on which the default factors are based; also compare to any U.S. site-specific or plant-level data that exist.
  - ✓ Especially for key sources, if IPCC default data are used, evaluate whether and how more representative data might be developed or obtained.
  - ✓ If country-specific emission factors have been developed, these can be compared with IPCC default emission factors; it should be possible to qualitatively explain differences between

the factors by reference to differences between national conditions and the circumstances of the studies on which the default factors are based.

- ✓ If country-specific emission factors are used, they can be compared to any available site-specific or plant-level factors, to indicate both the reasonableness of the aggregated country-specific factor and its representativeness. Methods for developing the factors can also be reviewed.
- ✓ If direct emissions measurements contribute to developing a representative or site-specific emission factor, these factors can be compared between sites—to identify outliers or inconsistencies in the data—and also to IPCC or national level defaults. Differences should be explained with reference to differences in circumstances surrounding the measurements or defaults.

The QC analyst should complete these checks, as relevant, and concurrently identify other checks that may be relevant to the source category. All completed checks should be reported on the Tier 2 checklist.

Activity Data

Checks can be performed on both national and site-specific activity data. As suggested above in the section on emissions, these data can be compared with each other as an additional check.

- *National level activity data*. Where the emission estimate relies on national level activity data, checks that should be performed include the following.
  - ✓ Compare current year data with previous year's data and historical trend. If estimates do not exhibit relatively consistent changes from year to year, but rather undergo sharp increases or decreases, then need to determine whether characteristics of the source category have changed (e.g., coverage or methodology has changed), or errors in transcription may have occurred.
  - ✓ Check activity data from multiple reference sources, e.g., compare government survey data with data compiled independently by trade associations. If alternative data are not available at the national level for comparisons, conduct comparisons at the regional or lower levels. This check is particularly important for sources with a high degree of uncertainty.
  - ✓ Activity data are usually prepared or collated for purposes other than inventory development. Thus, need to check the applicability of the data to inventory purposes, including checking for completeness, consistency with the source category definition, and consistency with the emission sources/sinks covered by the emission factors used for the inventory.
- *Site-specific activity data*. Site-specific activity data are often prepared by site or plant personnel for purposes other than as inputs to the emission inventory. Checks should focus on:
  - ✓ identifying inconsistencies across sites—and whether they represent errors, different measurement techniques, or real differences in emissions, operating conditions or technology
  - ✓ comparing aggregated plant-specific activity data with national activity statistics for the industry
  - ✓ comparing activity data across different sites, possibly with site-specific adjustments (e.g., for plant capacities), to evaluate the reasonableness of the data and to identify any errors (e.g., if find outliers, can they be explained by unique characteristics of the site)
  - ✓ conducting bottom-up and top-down comparisons where possible—e.g., comparing aggregated plant-level account balances (such as those for fuel, feedstock, imports and exports) with national account balance data

The QC analyst should complete these checks as relevant and concurrently identify other checks that may be relevant to the source category. All completed checks should be reported on the Tier 2 checklist.

Detailed Checks

If any of the above checks indicate a problem, more detailed investigation into the accuracy of the inventory estimates may be required. In some cases, the analyst may need to obtain additional information from the providers/originators of the secondary data or direct emissions measurements (e.g., to obtain more information on the coverage of a survey or estimate, or if problems with quality are discovered). In this case, the analyst should coordinate these contact and information gathering efforts with activities to investigate the quality of secondary data, described in §2.2.2 below.

2.2.2 Quality of Secondary Data and Direct Emission Measurements

The quality of secondary data, and of direct emission measurements used to develop emission factors or to estimate emissions directly, will clearly have an impact on the quality of national greenhouse gas emission estimates and the uncertainty surrounding these estimates. This section discusses procedures to compile additional information about secondary data and direct emission measurements, and to delve into the development, handling procedures, and the quality and uncertainty circumstances surrounding the data (additional information can be found in the source category chapters in the *IPCC Good Practice Guidance*).

For quality or uncertainty issues that are uncovered by the procedures described in this section, follow-up actions can take several forms: (1) incorporating the quality and uncertainty information into the uncertainty analysis; (2) searching for additional data or information to reduce quality issues; and (3) working with the providers of the data to improve the relevance of the data for inventory development purposes or to improve data quality and data handling procedures. For the most part, corrective actions will require working with the originators or developers of the data—e.g., working with the agencies that develop the data—and are outside the direct control of the inventory analyst, unlike the procedures and checks described in §2.1 and §2.2.1 above.

Secondary Sources for Emission Factors and Activity Data

Country-specific emission factors and inventory activity data may be derived from secondary data, such as scientific literature, national statistical databases, or other published studies or literature. Often, these studies or information will have been developed for purposes other than inventory development.

Procedures to address the quality of **secondary data** sources can be quite time and resource intensive, and so should be pursued only for key sources or when there is a clear indication of need. Relevant procedures that the QC analyst may perform include the following.

- *Review*. Understand the procedures described below in this section and the content of the *IPCC Good Practice Guidance* (both Chapter 8, *Quality Assurance and Quality Control*, and appropriate source category-specific chapters).
- *Identify*. Determine the types and sources of activity data (particularly national level data) and the secondary data sources used to develop emission factors (such as country-specific emission factors).
- *Check the quality of these inputs*. Many statistical organizations have their own procedures for assessing and reporting on quality of data they provide and publish. Checks may not only require reviewing published information about the data, but also contacting the article authors or agency staff collecting or preparing the data.

  Types of questions to ask to determine the quality of the data include:

  - ✓ Are QC activities conducted during the original preparation of the data (either as reported in published literature or as indicated by personal communications) consistent with and adequate when compared against (as a minimum), Tier 1 QC activities?
  - ✓ Does the statistical agency have a QA/QC plan that covers the preparation of the data?
  - ✓ For surveys, what sampling protocols were used and how recently were they reviewed?

- ✓ For site-specific activity data, are any national or international standards applicable to the measurement of the data; if so, have they been employed?
- ✓ Have uncertainties in the data been estimated and documented?
- ✓ Have any limitations of the secondary data been identified and documented, such as biases or incomplete estimates? Have errors been found?
- ✓ Have the secondary data undergone peer review and, if so, of what nature?

- *Document*. Document the activities that are performed as part of the secondary data assessment on *Tier 2 Source Category Checklist: Part B: Secondary Data and Direct Emission Measurement*, in Appendix A. This form includes information on the variables that were checked; lists the published references and personal communications[12] consulted regarding the quality control procedures associated with the input data and other information; and documents the results of the investigation, including a determination of whether the data are adequate in quality or not. Supplemental sheets (see *Supplemental Report* in Appendix A) should be used where necessary to provide full information.
- *Pursue appropriate corrective action*. Take any corrective action as needed, documenting (in the appropriate place on the Tier 2 checklist) the actions taken and the results. Depending on the outcome of the investigation, follow-up actions may include:
  - ✓ attempting to establish QA or QC checks on the data, if no checks on the data have been made already
  - ✓ reassessing the uncertainty of emissions estimates derived from the secondary data
  - ✓ reevaluating the possibility of using alternative data (including IPCC default data)

  If appropriate corrective actions are not immediately apparent, the QC staff performing the check should discuss the results of the QC checks and the completed checklists (including summaries) with the Agency Inventory Lead and the QA/QC Officer, and identify and make provisions for any follow-up actions that might be needed.[13] If not all corrective actions are taken (for example, because of time or resource constraints), be sure to identify any residual quality issues on the Summary Sheet of the *Checklist*.
- *Transmit*. All completed documentation (the *Tier 2 Source Category Checklist: Part B: Secondary Data and Direct Emission Measurement* and any *Supplemental Reports*) should placed in the project file, and copies given to both the Data and Document Management Coordinator and the Uncertainty Analysis Coordinator. Note that this information is transmitted also to the Uncertainty Analysis Coordinator because it may be relevant to identifying procedures for completing the uncertainty analysis for that source category.

Direct Emission Measurements

In some cases site-specific emissions data, including direct emissions measurement, will be used to develop the national emission inventory estimate directly or indirectly, via a country-specific emission factor. Direct emissions measurement may also be used to develop a representative emission factor for a site, or to compile an annual estimate of emissions for a particular process.

Procedures to address the quality of **direct emission measurements** are analogous to those for secondary data:

[12] *Contact Reports* for meeting or telephone contacts should be carefully kept (see *Contact Report* in Appendix A). All reference formats should follow general procedures outlined for Tier 1 checks in §2.1.2.

[13] Procedures and documents generated by EPA's Quality Staff of the Office of Environmental Information may also be helpful in evaluating the quality management plans of other organizations. See, for example, Checklist for Reviewing EPA Quality Management Plans. Downloaded from the Quality Staff's website at http://www.epa.gov/QUALITY/qs-docs/qmp-checklist.pdf, on October 24, 2001.

- *Identify*. Determine for which variables direct emissions measurement have been used, and the purposes of the measurements in developing the emission factors (e.g., to develop a site specific factor, contributing to a category emission factor, or as part of a bottom-up emissions estimate).
- *Check*. Check the procedures used to measure emissions, including sampling procedures, equipment calibration and maintenance, and other procedures. Identify whether standard procedures have been used, such as standard reference methods for measuring specific greenhouse gas emissions and removals, if they are available, or standards provided by the International Organisation for Standardisation (ISO) for air quality measurement methods.[14]
- *Pursue corrective action*. Take any corrective action as needed, documenting (in the appropriate place on the Tier 2 checklist) the actions taken and the results. If appropriate corrective actions are not immediately apparent, the QC staff performing the check should discuss the results of the QC checks and the completed checklists (including summaries) with the Agency Inventory Lead and the QA/QC Officer, and identify and make provisions for any follow-up actions that might be needed.

  Inventory agencies should encourage the use of recognized standard reference measurement techniques for greenhouse gases, where these techniques exist. Talking to site managers, e.g., managers at plants, farms, and elsewhere, can encourage improvement in the QA/QC practices at the sites.
- *Transmit*. All documentation (the *Tier 2 Source Category Checklist: Part B: Secondary Data and Direct Emission Measurement* and any *Supplemental Reports*) should be placed in the project file and copies given to both the Data and Document Management Coordinator and the Uncertainty Analysis Coordinator. Note that this information is transmitted also to the Uncertainty Analysis Coordinator because it may be relevant to identifying procedures for completing the uncertainty analysis for that source category.

The QC analyst should complete these checks, as relevant, and concurrently identify other checks that may be relevant to the source category. All completed checks should be reported on the Tier 2 checklist. If not all corrective actions are taken (for example, because of time or resource constraints), be sure to identify any residual quality issues on the Summary Sheet of the *Checklist*.

2.2.3 Periodic Coordination with Uncertainty Activities

As part of the inventory process, an assessment of the uncertainty surrounding the inventory estimates is conducted each year. Historically, this assessment has been largely a qualitative statement of inventory quality, such as is reported in the CRF (see §3.3.2 and the *Background* document), or a rough quantitative top-down assessment (i.e., an aggregated assessment relying on intuitive judgments and in some cases simplified statistical equations) of uncertainty, such as is reported in some source category write-ups in the *Inventory* document. The treatment of uncertainty in the U.S. inventory, however, is in the process of evolving into a more detailed and rigorous approach to quantifying uncertainty, using Monte Carlo analysis.

The Monte Carlo method or technique is one means of quantifying the statistical uncertainty associated with an emissions inventory estimate, and is recommended by the *IPCC Good Practice Guidance* as an approach to quantifying uncertainty for the inventory.[15] Monte Carlo analysis uses statistical sampling techniques to obtain a probabilistic approximation to the solution of a mathematical equation or model, and is widely used in scientific applications to simulate a variety of complex phenomena and processes.

In the context of inventory uncertainty, applying the Monte Carlo method requires first specifying the model used to produce the inventory estimate for a source category. This model may be the actual mathematical relationships—or a simplified representation thereof—between the emission factors, activity level, and other parameters used to estimate emissions. In the actual process of estimating emissions for the inventory, all of these parameters or variables are represented by point estimates, such as the rate of

[14] For information on ISO, see http://www.iso.ch/.
[15] See Chapter 6, *Quantifying Uncertainties in Practice*, and Annex 1, *Conceptual Basis for Uncertainty Analysis* (IPCC 2000).

emissions per unit of output, or pounds of fuel. In the Monte Carlo estimation method, however, uncertain variables are represented not by point estimates but by probability distributions that summarize the statistical properties of the variables and the statistical relationships among them.

The Monte Carlo simulation model includes the inventory model, values that are constants, the probability distributions for each variable, and any correlations between model variables. Once this model is developed for a source category, the Monte Carlo method then conducts a series of trials. Each trial represents an estimate of emissions from that source category: a value is chosen randomly (or by another means) from the given distribution for each uncertainty variable; these values are combined according to the inventory formulae to produce an estimate of emissions. A series of trials or simulations produces a probability distribution for the emission estimate for that source category. The statistical properties of the emission estimate—including estimated mean, variance, confidence intervals, and (percentage) uncertainty—can be calculated for this distribution.

Monte Carlo simulations can be performed by several available software packages, including Crystal Ball and @RISK©), the latter of which will be used for the U.S. inventory. Although Monte Carlo analysis can provide a quantitative estimate of the statistical uncertainty associated with an emission estimate, its use in the context of greenhouse gas estimation often relies heavily on expert judgment particularly with regard to the probability distributions assumed for the input parameters, as is described in more detail in Chapter 5. Monte Carlo simulations can also be used to provide qualitative insights into the models being evaluated, such as the overall degree of variability and uncertainty in the inventory and the confidence that can be placed in the inventory, or an understanding of the key sources of variability (in addition to the key source analysis that is routinely performed, as described in the *Background* document).

The Source Category Leads and inventory analysts, and the QC/QA officer and staff, are all integral to the estimation of uncertainty described in Chapter 5 of this manual. Inventory analysts are critical in several stages of the uncertainty estimation process. In particular, inventory analysts will be crucial in developing the estimation model, including (1) providing information on the inventory method and data sources; (2) verifying the accuracy and appropriateness of the representation of the inventory estimation model in the Monte Carlo model; and (3) locating, collecting, and providing any existing written documentation of the statistical properties of the data underlying the inventory estimates. The Source Category Lead and inventory analysts may also participate in the expert elicitation process by assisting and identifying experts, and reviewing any elicitation protocols that are developed. Finally, inventory analysts may assist the uncertainty staff in reviewing and interpreting the results of the uncertainty estimation.

The QA/QC Officer and QC staff are essential to the process of estimating uncertainty as well. While copies of all completed Tier 1 are not routinely provided to the uncertainty staff, completed Tier 2 checklists for individual source categories are provided to both the Data and Document Management Coordinator and to the Uncertainty Analysis Coordinator. These staff may be essential in pinpointing areas in the analysis and data sources—especially the secondary data analysis—that are key components contributing to uncertainty or inventory quality and which should therefore be a key focus of the data collection effort and analysis.

The results of the uncertainty analysis also provide information to both the inventory analysts and the uncertainty staff. This information should ultimately be useful in improving the methods and data sources used for the emission estimates. For example, the uncertainty analysis can provide insights into weaknesses in the estimate, or the greatest contributors to uncertainty, which can assist the Source Category Lead in setting priorities for improving data sources or methodologies in order to reduce uncertainty.

Early in the inventory process each year, both inventory analysts and QC staff should coordinate with the uncertainty staff to identify needs for that year's inventory, and to ensure that time schedules are compatible and consistent.

3 CROSS-CUTTING QUALITY CONTROL: INVENTORY ESTIMATES AND INVENTORY DOCUMENT

This chapter describes procedures to be followed to control and check the quality of the overall inventory and the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (here referred to as the *Inventory*) document. It includes cross-cutting checks that the Data and Document Management Coordinator and staff should perform across the inventory source categories, for both the emissions estimates and the *Inventory* document. It also includes procedures that should be followed for file management and archiving. While no formal checks have been established to ensure that these latter procedures are followed, it is the combined responsibility of the Data and Document Management Coordinator, the Source Category Leads and the source category staff to ensure that these procedures are followed.

Quality is also affected by activities that occur at the start of the annual inventory cycle. The "kickoff" memorandum that initiates the inventory cycle each year also affects data quality. This memorandum (a sample of which is included in Appendix E) is distributed by the Data and Document Management Coordinator and provides information on documentation, data handling procedures, and other good practices that analysts should follow in preparing the inventory estimates. The Data and Document Management Coordinator and the Agency Inventory Lead should review the content of this memorandum for any needed additions or changes each year. In addition, both the Coordinator and the Agency Inventory Lead should, at the start of each year, review checklists and expert review comments from the previous year to determine whether any outstanding quality issues need to be addressed.

Who should read Chapter 3?

The Agency Inventory Lead, and the Data and Document Management Coordinator and staff should read this chapter.

The QA/QC Officer and staff performing quality checks and completing cross-cutting quality checklists should read this chapter. Other QA/QC staff may wish to review the chapter.

When are checks performed?

The procedures for maintaining the integrity of master files and for archiving the annual inventory should be followed for every inventory cycle. The cross-cutting checks and document checks should be performed annually or, in some cases, routinely.

What checklists need to be completed?

The primary template for this chapter is the *Tier 1: Overall Inventory and Cross-Source Category Checklist* in Appendix B. This form provides a record of the checks conducted and any corrective actions taken. Appendix B also includes checklists for reviewing the *Inventory Document* and the *Common Reporting Format*. Finally, Appendix B includes a sample master worksheet for tracking progress on the inventory.

The checks and procedures in this chapter are divided into four sections:

- Section 3.1, *Checks for the Overall Inventory Estimates and Across Source Categories*, describes checks of completeness, accuracy, and consistency for the aggregated estimates or across source categories
- Section 3.2, *Maintaining a Master Inventory File: Spreadsheets, Data, and Reporting Documents*, describes procedures to ensure the integrity of the master files
- Section 3.3, *Checking Reports: Inventory Document and* UNFCCC Common Reporting Format, describes quality control procedures for the documents that are produced as part of the inventory process
- Section 3.4, *Procedures for Archiving*, describes the required content and handling of the archives.

Many of the overall and cross-cutting checks described in this chapter should be performed on the inventory annually (some routinely during the year), or at least periodically. The document checks (§3.3) should be conducted each year. Latitude is given, however, in the checks that are performed; the checklists provided in Appendix B should be viewed as aids rather than as a mandatory format. The procedures for maintaining master files and for archiving are to be followed for every inventory cycle.

This chapter should be read by the Data and Document Management Coordinator and supporting staff, whose responsibility it is to ensure that the procedures are followed and the relevant checks are made. The

QA/QC Officer should also be familiar with the content of this chapter, and may be called on to provide quality control (QC) staff to assist in checks, particularly those in §3.1, which involve the overall checks on calculations and data sources that are similar to those in Chapter 2 for the individual source categories.

3.1 Checks for the Overall Inventory Estimates and Across Source Categories

Some checks are performed for the overall inventory, or require checking data across source categories. Many of these checks are included in *Tier 1: Overall Inventory and Cross-Source Category Checklist*, in Appendix B. Such checks include:

- Checking emission calculations across source categories
  - ✓ Check that sources using the same input data (e.g., animal population data) report comparable values (i.e., analogous in magnitude) for the data.
  - ✓ Check across source categories for identical file references for common data.
  - ✓ Identify parameters (e.g., activity data, constants, conversion factors) that are common to multiple source categories and confirm that the values used for these parameters are consistent across and within the emission calculations (e.g., check that common emission factors, conversion factors and other data inputs are identical).
  - ✓ Check that the number of significant digits or decimal places for common parameters, conversion factors, emission factors, or activity data is consistent across source categories; total emissions should also be reported consistently (in terms of significant digits or decimal places) across source categories.
  - ✓ Check that emissions data are correctly (1) aggregated from lower reporting levels to higher reporting levels when preparing summaries and (2) transcribed between different intermediate products.
- Documentation
  - ✓ Check that internal documentation is comparable across source categories, e.g., check that spreadsheets and references are consistently documented and procedures are consistently applied.
  - ✓ Check that all backup spreadsheets that lead to estimates have been provided along with the master spreadsheet for each source category.
- Completeness
  - ✓ Confirm that estimates are reported for all source categories and for all years from the appropriate base year to the period of the current inventory.
  - ✓ Check that known data gaps that result in incomplete source category emission estimates are documented. Small gaps resulting from the use of preliminary data, missing data, or proxy data should be documented in cell comments in the spreadsheet. Larger gaps should be documented in the spreadsheet and also reported in the "Sources Excluded" Annex of the *Inventory* document. Gaps should also be communicated to the Uncertainty Analysis Coordinator for discussion of missing elements and impacts on uncertainty.
- For national estimates, current inventory estimates should be compared to previous estimates. If there are significant changes or departure from expected trends, re-check estimates and explain any differences.

The QC analyst should complete these checks as relevant and concurrently identify other checks that may be relevant to the source category. All completed checks should be reported on the Tier 1 checklist.

3.2 Maintaining a Master Inventory File: Spreadsheets, Data, and Reporting Documents

The Data and Document Management Coordinator is the "sole owner" of the electronic copies of both the inventory, which is a linked set of spreadsheets, and the *Inventory* document. The source category spreadsheets are not only linked to each other, but each is also linked to a summary worksheet that is used

to create the tables in the *Inventory* document, and to the United Nations Framework Convention on Climate Change (UNFCCC) Common Reporting Format (CRF) tables. This linking and sole ownership is one of the important QC features of the U.S. inventory system. Following a number of procedures will promote this system.

- Each year, the Data and Document Management Coordinator provides Source Category Leads with the current versions of the inventory spreadsheet(s) and *Inventory* document text (including write-ups and annexes) for their source category. These documents constitute the basis for the current year's work and updates.
- The format of the source category spreadsheet(s) is determined by the Data and Document Management Coordinator, including any new information to be included (such as a summary worksheet, or a worksheet with data for the CRF). Portions of the spreadsheet that cannot be altered are indicated by the Data and Document Management Coordinator. For example, because the summary worksheet contains tables that correspond to every table in the *Inventory* document, it should not be altered except to add a new row/column for the new year's data; no other rows or columns should be added or deleted.
- Inventory analysts work from the versions provided by the Data and Document Management Coordinator and return revised versions. Once the electronic copies of the inventory spreadsheets and text are returned to the Data and Document Management Coordinator, permission—and a copy of the current version of the text or spreadsheet provided by the Coordinator—is required to make additional changes.
- The Data and Document Management Coordinator maintains a list of staff at government agencies and of contracting staff responsible for each source category.
- The Data and Document Management Coordinator maintains a list of spreadsheets and document titles for each source category.

There is no checklist to determine whether these practices are being followed. Certain procedures *could be* instituted to make it more likely that procedures are being followed.

- Beginning each inventory year with one or more mandatory attendance meetings for agency and contractor staff, to impress on all staff the importance of maintaining these policies.
- Inserting reminders into the "kickoff" memorandum that initiates work on the inventory cycle each year (see sample in Appendix E).[16]
- Developing and using a tracking system in the form of master spreadsheet for the inventory (see *Sample Master Tracking Sheet* in Appendix B). The spreadsheet facilitates identifying outstanding sources (i.e., sources that have not yet been completed and returned to the Data and Document Management Coordinator) and the timeframe for completing those estimates. Ideally, a separate worksheet would be prepared for each source category. The types of information that could be tracked include the following; the sample sheet tracks most of these:
  - ✓ contact information, including the lead analyst on the source category and supporting staff or contracting staff, other contacts (e.g., individuals responsible for estimates in the past who are no longer involved)
  - ✓ due dates—when updated versions of the estimates are expected
  - ✓ milestones for the estimates—e.g., when the analysts expects to receive critical publications or data that are needed to complete the estimates
  - ✓ timelines in situations where multiple updates to sources are expected
  - ✓ an entry indicating the status of the source category estimates; e.g., the entry would read "revisions expected" when the Source Category lead indicates that new data are expected,

[16] If at some time a third party, independent audit of the inventory and inventory process were conducted, the audit could check whether these master file-handling procedures were being followed.

and "final" when the estimates have been turned over to the Data and Document Management Coordinator and no further changes are expected

3.3 Checking Reports: Inventory Document and UNFCCC Common Reporting Format

This section describes the stages in the production of these documents, and the checks to be performed at each stage, to ensure the quality of both the estimates and the associated text. These checks and the Checklists provided in Appendix A can contribute to thorough and routine examination of the documents before they go out. In addition, the inventory spreadsheets contain replicas of the tables in the *Inventory* document and, in some cases, the CRF tables; these tables are linked electronically to the inventory estimates, in order to reduce transcription errors that occur when transferring the data to the final *Inventory* document and CRF tables.

3.3.1 Inventory Document

The *Inventory* document passes through four critical iterations en route to publication:

- *Expert review draft*. During the expert review process, the emissions inventory is circulated and reviewed by relevant experts in two stages: (1) source experts review the inventory estimates and (2) source experts review the first complete version of the *Inventory* document.
- *Public review draft*. During the public review process the *Inventory* document is placed on the United States Environmental Protection Agency's (EPA) website for comments, and is mailed to EPA's reviewer list and to persons who request copies.
- *Internal final draft (in Microsoft Word)*. This document is the "final" version of document, incorporating any comments received during the review processes, and ready for layout in PageMaker. This is the document that is delivered the UNFCCC.
- *Final document (in PageMaker)*. The PageMaker document, together with a camera-ready Cover, is delivered to the EPA Print Shop, which contracts with the Government Printing Office (GPO) for printing.
- *Printed Inventory*. The GPO produces the printed *Inventory* document. The official release of the printed version of the *Inventory* is then accompanied by a Press Release. The *Inventory* is distributed in a several of ways, including copies mailed out to those on EPA's mailing list and to others on request.

Each of the first three drafts of the *Inventory* document is subject to a more or less complete check. This check includes thorough inspections of consistency in editing, format, and style, and of accuracy in content, and more general assessment of the appearance of the document. Both electronic checks and visual inspections are important. The checks for the fourth (the PageMaker document) and fifth (print ready) versions focus primarily on layout and issues associated with the final printing of the document. Prior to actual printing, the last (fifth) version of the *Inventory* undergoes checks and reviews of layout, to ensure that preparing the document for printing has produced no unintended changes.

The following procedural checks are designed to ensure the high quality of the final published document. Six categories of checks are performed:

- Front Section—accuracy checks of the Cover, front information pages, *Table of Contents*, *Executive Summary*, and *Introduction* of the document
- Tables and Figures—checks of tables and figures both for consistency in formatting and for concurrence between the tables and figures and corresponding data in the spreadsheets
- Equations—checks for consistent formatting in the equations and in the explanations of variables
- References—checks for consistent formatting throughout the reference section and in the citations in the text, and a final check of consistency in citations between text and reference section (see Tier 1 checks)

- General Editing—checks for consistent editing through the document, such as the use of acronyms, spelling, abbreviations, use of symbols, and others, including a visual check of formatting (section headings, bullets, etc.)
- Editing for Content—general proofreading of the entire document, as well as proofing for larger issues that need to be checked through the entire document, such as reviewing all numbers and years, reviewing the discussion of trends, etc.

While it is necessary to perform all of these checks on the entire document, it is not always necessary to check each item at every stage. The Agency Inventory Lead, QA/QC Officer, and Data and Document Management Coordinator should use discretion about how extensive a check is necessary at each of these stages. Text and numbers may both be revised after the review processes, necessitating relatively complete checks on the entire document, prior to declaring the *Inventory* "final." For the fourth draft—i.e., the draft that has been pulled into PageMaker—most of the checks will not need to be repeated; however some additional checks are required.

The categories of document checks to be performed at each of the five stages are:

- *Expert review draft.* All checks should be conducted before the *Inventory* document is sent out for expert review.
- *Public review draft.* Much of the text and some numbers can change after expert review. Prior to sending the document out for public review, all of the front section and formatting should be checked, and other checks should be focus on the sections that have been modified.
- *Internal final to graphics.* Again, comments and even some possible changes to data may require modifications to the *Inventory* between the time of the Public review and when the final document is imported into PageMaker. Therefore, at this stage, all of the front section and formatting should be checked and finalized, and the other checks should be focused on the sections that have been altered.
- *Final to printing.* There should be no changes to the data at this point. The process of importing the document into PageMaker can itself create difficulties, and the errors resulting from software conversions can be unpredictable. For this reason, it is important that someone who is familiar with the document looks at every page for any errors or unusual changes that may occur during the transition.
- *Print-ready version.* EPA is involved in finalizing the document, e.g., reviewing "bluelines" and otherwise checking the final layout of the document, prior to printing. Changes at this point are mostly visual inspections of formatting, layout, and color, rather than text.

To facilitate these checks, two checklists are provided in Appendix B: *Inventory Document Checklist: Part A: Word Document* and *Inventory Document Checklist: Part B: PageMaker Document*. These checklists should be used not only to assist the quality/error check, but also to document findings and results of the check. This documentation includes information on the date and individual checking, the stage at which the check was performed, the results of the check, and any recommendations for procedural modifications that would improve quality in the future.

In summary, appropriate procedures for QC on the *Inventory* document consist of:

- *Identify* the sections of the documents that have changed or other categories of checks that are necessary for the stage of the document.
- *Check* the document thoroughly at each stage of development, using the *Inventory Document Checklists*.
- *Document* the results of the check and any corrective actions taken, and note on the *Inventory Document Checklist* any procedural or other changes that could help to reduce quality control problems in the future.
- *Transmit* the results of the check to the Agency Inventory Lead. The final completed checklist should be placed in the file kept by the Data and Document Management Coordinator and archived.

The QC analyst should complete these checks as relevant and concurrently identify other checks that may be relevant to the source category. All completed checks should be reported on the inventory document checklist.

3.3.2 UNFCCC Common Reporting Format

The CRF tables go through the following steps/stages before being submitted to the UNFCCC Secretariat:

- *Preparation of CRF Tables*. The CRF tables are prepared by linking each cell to the appropriate cell or cells within the Inventory spreadsheets. Much of the emissions data can be found in the Summary spreadsheet, though activity data is usually only located in the individual source spreadsheets.
- *Comparison of the CRF tables to the Inventory.* Once all of the data have been linked and/or calculated and input into the CRF tables, a spreadsheet is created to compare the totals calculated for each gas within each chapter of the inventory against the totals calculated in the CRF tables. In addition, an overall total for each gas is compared to ensure that all data are correctly reported.[17]
- *Review of CRFs.* The draft CRF is reviewed for accuracy by the Agency Inventory Lead, the Data and Document Management Coordinator, the QA/QC Officer, and all Source Category Leads.
- *Finalize the CRF Tables for Printing and Submittal.* This last step is to finalize the files that will be sent to the UNFCCC Secretariat. This includes cutting all of the links and comments from one set of CRF files, checking the final table of the CRF, and printing a copy of all of the tables to be submitted in hardcopy along with the Inventory document.

The following procedural checks are designed to ensure the high quality of the final set of tables. Three categories of checks are performed:

- data checks—it is necessary to check all of the data and links that are entered into the CRFs to make sure they are accurate, up to date, and in agreement with the U.S. *Inventory*
- formatting checks—checks for consistency in formatting and ensuring that the tables are prepared in accordance with the Intergovernmental Panel on Climate Change (IPCC) instructions on filling out the CRFs
- other checks before printing/submitting—the last checks done to ensure that the CRF tables are complete, contain no visual errors (blank numbers and formatting or layout problems), and that they are ready for submittal to the Department of State

While it is necessary to perform all of these checks on the CRF tables before submittal, it is not always necessary to check each item at every stage. The QA/QC Officer and the Data and Document Management Coordinator should decide how and when each check should be performed. In general, the checks should be completed after compiling the CRF tables, in the following order: (1) data checks, (2) formatting checks, and (3) other checks before printing/submitting.

To facilitate these checks, a checklist is provided in Appendix B: *Checklist for Common Reporting Format Tables*. This checklist should be used not only to assist the quality/error check, but also to document findings and results of the check. This documentation includes information on the date and individual checking, the stage at which the check was performed, the results of the check, and any recommendations for procedural modifications that would improve quality in the future.

In summary, appropriate procedures for quality control on the CRF tables are listed below.

- *Complete* the entire set of CRF tables, based on the activity data and resulting emissions from the U.S. *Inventory*, and other information.
- *Check* the tables thoroughly to ensure that they match the information provided in the U.S. *Inventory*, using the *Common Reporting Format Checklist*.

[17] Note that the CRF also contains information beyond the inventory estimates, including a page on "quality." Currently, there is no procedure for checking the validity of that data.

- *Document* the results of the check and any corrective actions taken, and note on the *Common Reporting Format Checklist* any procedural or other changes that could help to reduce quality control problems in the future.
- *Transmit* the results of the check to the Agency Inventory Lead. The final completed checklist should be placed in the file kept by the Data and Document Management Coordinator and archived.

3.4 Procedures for Archiving

The docket is a "running docket," i.e., includes material that is new for that year of the inventory, rather than all the material reported in previous years. The completed docket becomes part of the archives. The archives should be sufficiently complete that an informed analyst could obtain relevant data sources and spreadsheets, reproduce the inventory and review all decisions about assumptions and methodology that were made. It should also be possible to track changes in data and methodology over time.

The completeness of the archives is the responsibility of the Data and Document Management Coordinator and the QA/QC Officer. At the conclusion of the inventory year, the annual docket becomes part of the archives. At that time, the annual docket should be complete, and should contain:

- a paper copy list of the full docket contents for that year
- everything in the project file for each source category (see §2.1.2), including paper copies of references and unpublished materials, should be placed in the docket (those that are new to that year of the inventory)
- copies of all checklist, reports, and forms that were completed as part of quality checks and QC procedures, including inventory tracking forms and document checklists
- paper and electronic copies of each of the four major drafts of the *Inventory* document (see §3.3.1)
- paper and electronic copies of the CRF tables (see §3.3.2)
- electronic copies of all the final, linked source category spreadsheets for the inventory estimates (including all spreadsheets that feed the emission spreadsheets), as well as any important printouts
- for the inventory overall and for individual source categories, the docket should contain adequate explanation of the linkages among the spreadsheets and the *Inventory* document
- reviewer qualification documentation forms, reviewer and comment tracking worksheets, copies of the comments, instruction letters, copies of the federal register notice and press releases, and any other materials from the expert review of the *Inventory* and the public comment period (see Chapter 4)
- the docket does not need to contain copies of proprietary or copyrighted data (e.g., data purchased in CD-ROM form); rather a note in the docket indicates where the information resides
- paper and electronic copies of the uncertainty analysis and all supporting material, including completed templates, *Contact Report*s, and other material (see Chapter 5)

4 PROCEDURES FOR QUALITY ASSURANCE: REVIEW PROCESSES

For the purposes of the Quality Assurance (QA) and Quality Control (QC) process developed for the inventory, Quality Assurance, as defined by the Intergovernmental Panel on Climate Change in its *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC 2000, here referred to as *IPCC Good Practice Guidance*), comprises a "planned system of review procedures conducted by personnel not directly involved in the inventory compilation and development process." The quality assurance process for the U.S. inventory estimates and for the *Inventory of U.S. Greenhouse Gas Emissions and Sinks (*here referred to as the *Inventory)* document includes both expert review and a general public review. These reviews are coordinated by staff designated by the QA/QC Officer and occur annually. This chapter should be read by the QA/QC Officer and all staff who will be involved in the QA process.

The expert review is conducted in two stages: a review of the initial set of draft emission estimates and, subsequently, a review of the estimates and text of the *Inventory* document. In addition, experts are consulted and involved throughout the development of the inventory estimates, providing further review and opportunities for evaluation and assessment of the inventory methodologies and data. The ultimate goal of these expert reviews is to provide an objective review of the inventory in order to ensure that the final inventory estimates and *Inventory* document reflect sound technical information and analysis.

The expert and public reviews each present opportunity to uncover technical issues related to the application of methodologies, selection of activity data, or the development and choice of emission factors. The expert review process can also facilitate developing solutions to pending issues in the preliminary work. The subsequent public review of the draft document offers a broader range of researchers and practitioners in industry and academia, as well as the general public, the opportunity to contribute to the final document. The comments received during these processes are reviewed and, as appropriate, incorporated into the *Inventory* document or reflected in the inventory estimates.

Who should read Chapter 4?

The Agency Inventory Lead should read this chapter

The QA/QC Officer and staff involved in the review process should read this chapter.

The Data and Document Management Coordinator and staff may also wish to review this chapter.

When are checks performed?

This Chapter includes procedures to be conducted every inventory cycle.

What checklists need to be completed?

The primary template for this chapter is the *Expert Review Process: Documentation of Experts' Qualifications* in Appendix C. Appendix C also includes a sample worksheet for tracking reviewers and comments.

Consistent and thorough procedures should be followed throughout the review processes to ensure the highest quality of the final inventory product. During expert review, careful selection of reviewers, clear instructions for reviewers, tracking the status of reviews, and documenting the review process, the comments that are received, and the responses to those comments, are all part of promoting quality. Similarly, ensuring that the public review process is open and accessible, and that comments are reviewed and incorporated as necessary in the inventory, is important to ensuring the quality and transparency of the emission estimates and inventory development process. Procedures that are followed for both the expert and the public review processes are described below.

In addition, both the QA/QC Officer and the Agency Inventory Lead should, at the start of each year, review checklists and expert review comments from the previous year to determine whether any outstanding quality issues need to be addressed.

The remainder of this chapter is divided into three sections:

- Section 4.1, *Expert Review Process*, describes the procedures and forms used to conduct the expert review of the inventory estimates and *Inventory* document text. Appendix C contains forms relevant to the expert review process.

- Section 4.2, *Public Review Process*, describes the activities associated with the public review.
- Section 4.3, *Internal Quality Audits for Tier 1, Tier 2, and Archiving*, is a section that could be developed subsequently to represent a rigorous audit system to supplement the system of QC and checks.

4.1 Expert Review Process

Numerous federal and state government agencies, academic and research institutions, and consultants and other individuals are involved in developing the initial emission estimates (see the separate companion document, *Background on the U.S. Greenhouse Gas Inventory Process*). Participation may take the form of providing activity data, developing source-specific emission factors, and/or actually calculating the emission estimates. The expert reviews of the preliminary estimates and of the draft *Inventory* document provide the opportunity to identify and correct errors that may have been made—either in developing the estimates, or in interpreting and describing the process and results. This section provides guidelines and procedures for conducting expert reviews of the initial emission estimates and of the draft *Inventory*.

4.1.1 Expert Review of Initial Estimates

The first expert review is conducted after the initial set of emission estimates is complete. For each of the source categories in the inventory, Source Category Leads and other internal inventory analysts are asked to review the emission estimates. This initial review is relatively informal, and covers the source category emission estimates and totals. Upon request, the experts can review calculations and methodology. The information received at this stage is used to revise the emission estimates so that the draft *Inventory* will reflect sound technical information and analyses.

Because of the informality of this initial review, the steps and procedures to be followed are relatively simple.

- The Agency Inventory Lead selects experts for review; typically reviewers include the Source Category Leads and selected source category staff, or other persons involved in preparing the inventory.
- The Data and Document Management Coordinator integrates the spreadsheets containing draft estimates for each source category with a summary file, which typically contains a worksheet for each sector, supplemental information (such as emissions from individual source categories and information used to calculate energy-related emissions), and a number of tables and graphs summarizing emissions and trends by sector and in aggregate.
- The Agency Inventory Lead prepares instructions or short cover letter for reviewers (as needed), and distributes any instructions, contact information, and electronic copies of the source category and total estimates to the reviewers (typically the material is distributed electronically by e-mail).
- Comments are received by the Agency Inventory Lead; in consultation with the QA/QC Officer, comments are reviewed and addressed by the Data and Document Management Coordinator and Source Category Leads and staff.

4.1.2 Expert Review of Inventory Document

The second expert review takes place upon completion of the draft *Inventory* document. This review draft reflects comments received on the initial emission estimates (see §4.1.1), and also incorporates the document checks described for the first version of the MSWord document (see §3.3.1). Once the initial draft of the *Inventory* document is prepared, reviews are solicited from those who participated in the review of the initial estimates as well as others the United States Environmental Protection Agency (EPA) identifies as appropriate experts. Comments received at this point are generally in the form of edits to the text, such as suggested language to improve the clarity of definitions or explain the methodologies used, but can also include comments on methodologies and the estimates themselves. This set of comments is evaluated and decisions are made regarding how the remarks may be incorporated into the final draft.

The steps in the process of expert review of the *Inventory* document include:

- The Data and Document Management Coordinator and Staff prepare the initial draft of the *Inventory* document with extensive consultation from the Agency Inventory Lead.
  - ✓ Relative to the *Inventory* from the previous year, the initial draft version for the current year typically includes some new text in the document body and annexes, any new references, and updated versions of the *Executive Summary*, *Introduction* and section on *Changes in this Year's Report*.
  - ✓ Preparation includes conducting document quality checks as indicated in Chapter 3 (§3.3).
- The QA/QC Officer and Agency Inventory Lead together identify and select expert reviewers for the inventory overall and for each source category. The set of reviewers typically includes all those with expertise and involvement in the inventory from within EPA, United States Department Of Energy, United States Department of Agriculture and other relevant agencies (including the Source Category Leads), reviewers from previous years, and any additional persons with relevant expertise as identified by those preparing the inventory.
- The QA/QC Officer and staff document the credentials and contact information of the reviewers using the *Expert Review Process: Documentation of Experts' Qualifications* form in Appendix C.
- The Agency Inventory Lead prepares a personalized form letter (see *Expert Review Request Letter* in Appendix E) for each reviewer that
  - ✓ explains the purpose of the review and the expert's role in the review and inventory development processes
  - ✓ lists specific sections to be evaluated, which generally include the Executive Summary, Introduction, "Changes in this Year's Report," references, annexes, and all sections relevant to the individual reviewers area of expertise
  - ✓ provides specific instructions about the types of issues to be evaluated and questions to keep in mind in reviewing the estimates
  - ✓ contains instructions about the format of comments, such as using page and line numbers for specific comments and providing references if new information is given
  - ✓ lists complete contact information for a person whom the reviewer should contact if s/he has questions (the QA/QC Officer or delegate)
  - ✓ indicates where and how to send the completed review (typically by e-mail, mail, or fax to the QA/QC Officer), and a date by which to return the review
- The QA/QC Officer and staff (or, if designated, the Data and Document Management Coordinator) then
  - ✓ distribute the instructions and draft report to the reviewers
  - ✓ track the status of reviews (when document is distributed, when responses are received, follow-up activities to encourage late reviewers to submit their reviews, date and form of final comments received) using the *Expert Review of Draft Inventory: Tracking Reviewers and Comments* worksheet, a sample of which is included in Appendix C
  - ✓ consolidate the comments received into one document (typically the *Expert Review of Draft Inventory: Tracking Reviewers and Comments* worksheet in Appendix C), in order to provide a record of the comments and how they are addressed
- Once comments are inserted in the *Tracking* worksheet, the QA/QC Officer, the Agency Inventory Lead, and the Data and Document Management Coordinator, in consultation with the Source Category Leads as needed, determine whether any changes are necessary to the estimates or text, and record the decision on the worksheet.
- The QA/QC Officer, on behalf of the Agency Inventory Lead, may choose to respond individually to some or all expert reviewers indicating the response to their comments.

- All significant materials from the process are archived, including the "charge" or instruction letter provided to reviewers, paper copies of all comments, and electronic copies of the tracking and documentation forms, as described in §3.4.

Procedures to be followed for the expert review of the *Inventory* document include the following.

- Whenever possible, qualified technical reviewers should be chosen who have not been involved in developing the inventory. The EPA *Peer Review Handbook* (EPA 1998) recommends including individuals from diverse organizations, such as public interest groups, professional societies, trade or business associations, state organizations or agencies, colleges and universities, and other Federal agencies. The inventory expert pool indeed draws not only on these national groups, but also on international experts and agencies and inventory specialists. In general, however, finding experts that have not been directly involved in the development of the inventory can be difficult because the areas of expertise are highly specialized.[18]
- For ease in coordination, the QA/QC Officer and the Data and Document Management Coordinator should both maintain paper or electronic copies of all comments.
- As described in §3.2, all changes to the estimates or the text of the *Inventory* document are made only to the master file maintained by the Data and Document Management Coordinator.
- The QA/QC Officer should contact individual reviewers as needed to clarify comments or for additional information.
- The Data and Document Management Coordinator should check the previous year's *Tracking* worksheet to determine whether issues that were not addressed the previous year can or should be addressed in the current year. If important issues are identified that cannot be rectified for the current year of the inventory, they should be flagged and identified for future work in the "kickoff" memorandum, which initiates the inventory development process each year (see sample in Appendix E).

4.2 Public Review Process

By providing an opportunity for all interested parties to review the *Inventory*, the public review and comment process can further improve the quality of the inventory. A broad spectrum of groups and individuals may participate in the public review, including interested researchers, non-governmental organizations, trade associations, and other interested in the inventory process. The public review and comment process allows parties that might not be readily identified by another mechanism, such as the expert review, an opportunity to review and comment on the inventory.

The steps in the process of public review of the *Inventory* document include the following.

- Publish a notice in the Federal Register[19] (see sample in Appendix E) announcing the availability of the draft document. The Federal Register notice should contain the exact title of the *Inventory* (including the years for which emission estimates are reported), a general description of the *Inventory* (including a brief statement regarding the gases for which emissions are reported), duration of the comment period (usually 30 to 45 days), detailed information on how interested parties can obtain a copy of the draft document, and contact information (usually the Agency Inventory Lead). Review copies sent by post include the public review cover letter (see sample in Appendix E).
- The Agency Inventory Lead posts the *Inventory* document on EPA's website at www.epa.gov/globalwarming/ and EPA issues a press release announcing the development of the draft *Inventory*, providing information on where it is available, and indicating that is in the process of undergoing public review (see sample in Appendix E).

[18] The EPA *Peer Review Handbook* (EPA 1998) provides additional information on peer review practices for technical and scientific documents produced by the EPA. Many, although not all, of the recommendations in the *Handbook* have been incorporated into this expert review process. Other features could be added in the future.

[19] The Federal Register is published daily by the National Archives and Records Administration (NARA). Access is available through the NARA web site at http://www.access.gpo.gov/nara.

- The Data and Document Management Coordinator and staff consolidate the comments received into one document (typically a *Reviewer Comment Tracking* worksheet similar to the worksheet used for the Expert Review Process); this document describes the source of the comment and records the actual comments.
- Once comments are inserted in the *Tracking* worksheet, the QA/QC Officer, the Agency Inventory Lead, and the Data and Document Management Coordinator, in consultation with the Source Category Leads as needed, determine whether any changes are necessary to the estimates or text, and record the decision on the *Tracking* worksheet.
- All significant materials from the process are archived, including paper copies of all comments, and electronic copies of the tracking worksheets, as described in §3.4.

Procedures to be followed for the public review of the *Inventory* document include the following.

- For ease in coordination, QA/QC Officer and the Data and Document Management Coordinator should both maintain paper or electronic copies of all comments.
- As described in §3.2, all changes to the estimates or the text of the *Inventory* document are made only to the master file maintained by the Data and Document Management Coordinator.

4.3 Internal Quality Audits for Tier 1, Tier 2, and Archiving

In the future, an audit system could be developed to provide additional QA measures. One approach to auditing would be to conduct periodic audits, using internal or external personnel—but excluding the analyst involved in a particular source category. Analysts from other source categories could be used to conduct these audits. The audits would be managed by the QA/QC Officer and staff.

Several types of activities could be conducted during an audit, including duplicating / repeating all the QC procedures, checking the qualifications of staff involved in inventory preparation, checking procedures for centralized / master file maintenance, reviewing organizational functions and knowledge of procedures, etc. Three sub-section of §4.3 that may be developed subsequently to support an audit system are listed below.

4.3.1 Procedures for Conducting Audit

This section may be developed subsequently.

4.3.2 Documentation and Reporting of Results of Audit

This section may be developed subsequently.

4.3.3 Mechanisms for Corrective Action

This section may be developed subsequently.

5 QUANTITATIVE UNCERTAINTY ANALYSIS: BACKGROUND, PROCEDURES, AND ELICITATION PROTOCOL

This chapter presents information to be used in developing quantitative uncertainty estimates for the greenhouse gas inventory. This chapter is intended primarily for the uncertainty staff who are involved in data collection and estimation of quantitative uncertainties for the inventory emission source categories, and to a lesser extent, for the inventory analysts who develop the inventory estimates and the staff who conduct the quality control (QC) of the estimates. The chapter material assumes that the target audience is familiar with the basic concepts of statistical analysis and, hence, such statistical terms have not been defined.[20]

This chapter should be read by the Uncertainty Analysis Coordinator and uncertainty staff, Source Category Leads, and the Agency Inventory Lead. Portions of the chapter should also be read by the source category staff involved in collecting, and in some cases documenting, supporting data for the uncertainty analysis.

All staff involved with the inventory should be at least familiar with this chapter. One important goal of this chapter is to provide procedures that all staff should follow—not only to ensure that the quantitative uncertainty analysis is transparent and the estimation results are accurate—but also to promote coordination between the inventory development efforts and the uncertainty analyses. In addition, the results of the uncertainty analysis should be accessible to the developers of the inventory estimates and be used to improve the quality of inventory estimates.

This chapter recognizes that some staff may be less familiar with quantitative uncertainty analysis. Because cooperation and collaboration among QC staff, source category staff, and staff conducting the uncertainty analysis is essential, a common understanding of the basis for the uncertainty analysis is equally important. This chapter, therefore, provides an overview of uncertainty analysis, including a discussion of the types and sources of uncertainties and the uncertainty estimation methodology is included in this chapter. The chapter is *not*, however, intended to be a complete workbook or reference

Who should read Chapter 5?

The Uncertainty Analysis Coordinator and staff involved in estimating uncertainty for the inventory should read this chapter.

The Agency Inventory Lead and Source Category Leads should also read this chapter. Source category staff involved in collecting published uncertainty estimates should read the first two sections, and may wish to review the rest, of this chapter.

The QA/QC Officer and staff performing Tier 2 quality checks may wish to review this chapter.

The Data and Document Management Coordinator and staff may also wish to review this chapter.

When are procedures and activities performed?

The uncertainty analysis can be updated each year to reflect new emission inventory estimates.

The structure of the uncertainty model and data inputs should be revisited periodically (as part of a thorough, multi-year check of the inventory) to ensure they are up-to-date and accurate.

Some checks or revisions of the uncertainty analysis will be triggered by events, such as a change in the inventory estimation methodology or sources of inventory data, or availability of new statistical information for the inventory data from existing sources.

Currently, no quality checks have been established for the uncertainty analysis.

What templates need to be completed?

The primary templates for this chapter are the *Uncertainty Data Collection and Assessment Form*, the *Pre-Elicitation Preparation and Elicitation Templates* , the *Summary of Uncertainty Inputs and Documentation Form*, and the *Uncertainty Analysis Results Form*, in Appendix D. These forms provide guidance to, and are used to record the inputs and outputs of, the uncertainty analysis. In addition, to provide supporting documentation, *Contact Reports* and *Supplemental Reports* must be completed, as appropriate.

[20] For definitions of the statistical terms used in this chapter and in Appendix D, refer to any introductory or intermediate statistical textbook.

manual for conducting an uncertainty analysis. Additional information on how to assess and quantify uncertainty can be found in the Intergovernmental Panel on Climate Change (IPCC) *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC 2000, here referred to as *IPCC Good Practice Guidance*)—specifically, the discussion of uncertainty methods in Chapter 6, *Quantifying Uncertainties in Practice* and in Annex 1, *Conceptual Basis for Uncertainty Analysis*.

The material in this chapter builds on the documentation, archiving, and other general procedures described in Chapter 2, *Quality Control Procedures for Specific Source Categories*. The activities in this chapter also overlap, and should be coordinated, with the procedures described in §2.2, which addresses source category-specific QC procedures. In addition, because expert judgment is a critical component of estimating uncertainty for many of the source categories in the inventory, this chapter provides guidance for the uncertainty staff on the practices and procedures needed to develop a protocol for eliciting quantitative judgments on uncertainty from experts.

Who is responsible for the uncertainty analysis?

The *Agency Inventory Lead*, *Source Category Leads*, and the *Uncertainty Analysis Coordinator* together conduct the uncertainty analysis of the inventory estimates.

The *Agency Inventory Lead* is the overall director responsible for supervising the uncertainty analysis for the entire *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (here referred to as *Inventory)*.

Source Category Leads are responsible for making key decisions for performing uncertainty analysis for their specific source categories (such as determining the appropriate level of disaggregation for data collection and model development, prioritizing the variables for enhanced input data collection efforts and resource allocation, and identifying experts for elicitation), in consultation with the *Uncertainty Analysis Coordinator* and the *Agency Inventory Lead*. They are also responsible for reviewing the results of uncertainty analysis, identifying corrective actions to be taken, and for ensuring that a summary of the results of uncertainty analysis for their specific source categories is reported in the *Inventory* document.

The *Uncertainty Analysis Coordinator* is responsible for directing the statistical analysis of uncertainty (including obtaining data inputs, eliciting expert judgments, developing the uncertainty model, developing quantitative uncertainty estimates, and interpreting the results of the uncertainty analysis) for the entire *Inventory*, in consultation with *Source Category Leads* and the *Agency Inventory Lead*. The *Coordinator* is also responsible for supervising the uncertainty analysts.

In order to develope credible uncertainty estimates, it is essential that there is complete coordination among these three functional positions in all decisions and activities that relate to conducting the uncertainty analysis.

The remainder of this chapter is divided into four sections:

- Section 5.1, *Overview of Uncertainty Analysis*, briefly describes the major types of uncertainties associated with greenhouse gas emission estimation and summarizes the inputs and the methodology for developing quantitative uncertainty estimates for emission sources.
- Section 5.2, *Procedures for Quantitative Uncertainty Analysis*, describes the steps in conducting an uncertainty analysis and some of the general procedures that analysts can follow to ensure that technically credible and defensible input data are developed for the uncertainty analysis.
- Section 5.3, *Developing an Elicitation Protocol*, describes the procedures for developing a good uncertainty elicitation protocol.
- Section 5.4, *Quality Control for Uncertainty Analysis*, briefly summarizes the types of activities needed to check the quality of the uncertainty analyses.

5.1 Overview of Uncertainty Analysis

The uncertainty analysis has two key goals:

- to develop quantitative estimates of the uncertainties surrounding the inventory estimates for key sources to the extent possible
- to develop information—about the relative importance, including the magnitude of uncertainties, of the underlying input data comprising the inventory estimates—that can be used to minimize or reduce uncertainty (associated with inventory estimates) over time

Meeting both these goals requires understanding the types of uncertainty associated with the inventory estimates, the methods to identify and quantify the uncertainties, and the techniques to minimize or reduce various sources of uncertainties.

Note that quantitative uncertainty analysis is not an end in itself; the ultimate objective of the uncertainty analysis is to build inventory data quality improvement processes through improved communications between all the participants in the national system of inventory development. Consequently, the process of estimating inventory uncertainty focuses on learning and on the quality of the input data for the inventory, and is integrated with the process of improving the inventory estimates. The uncertainty analysis also provides a mechanism for working directly with data suppliers and, thus, a means by which to build quality throughout the participants in the national system of inventory development.

5.1.1 Types and Sources of Uncertainty

The inventory estimates are subject to several types of uncertainty. Only some of these types of uncertainty are amenable to quantitative analysis. As described below, the uncertainties associated with the parameters—e.g. the activity data and emission factors—used as inputs into the emission estimation model are the primary focus of the quantitative uncertainty analysis. Thus, statistical (or random) uncertainty, as well as systematic uncertainty (or bias), in the inventory estimates is relevant for this analysis.

Uncertainties associated with greenhouse gas inventory source categories can be broadly categorized into two groups: *scientific* uncertainty and *estimation* uncertainty. Scientific uncertainty arises only when the science of actual emission and/or removal process is *not* completely understood for an inventory source or sub-source category. Emissions from or removals by some inventory source categories, such as nitrous oxide (N_2O) emissions from agricultural soils, are associated with significant scientific uncertainty. Analyzing and quantifying such scientific uncertainty in the context of uncertainty estimation is beyond the scope of the analyses described in this chapter.

Estimation uncertainty arises when the emissions and the removals are quantified. Hence, "estimates" of emissions from, or removals by, all greenhouse gas sources and sinks are associated with estimation uncertainty, which is the primary focus of this chapter. Estimation uncertainty associated with greenhouse gas inventory estimates can be further classified into two groups: *model* uncertainty and *parameter* uncertainty.

Model uncertainty refers to the uncertainty associated with developing mathematical equations (i.e., models) to characterize the emission and/or removal processes. For example, the model uncertainty may arise either due to the use of an incorrect mathematical model to characterize the greenhouse gas emission or removal process, or due to the use of inappropriate inputs in the greenhouse gas estimation model. Model uncertainties can be identified through QC analysis (see §2.2, *Data Quality Control: Source Category-Specific Procedures (Tier 2))*. The model uncertainties can be evaluated by comparing the model results with the results of other models that are developed to characterize the same emission generation process and through sensitivity analyses.

Various panels of the IPCC periodically evaluate the model uncertainties associated with greenhouse gas inventory estimates and revise the inventory estimation methods to minimize those uncertainties. At the national level, the U.S. Environmental Protection Agency (EPA) periodically evaluates the model uncertainties and revises the inventory estimation models so that those uncertainties are reduced. The uncertainty associated with the model used to estimate emissions for each source category needs to be evaluated periodically, subject to the availability of resources. Further, evaluation of model uncertainty requires comprehensive research and analysis by scientists and inventory source experts. Therefore, analyzing and quantifying this type of uncertainty is beyond the scope of this chapter.

Parameter uncertainty refers to the uncertainty associated with quantifying the parameters used as inputs (e.g., activity data and emission factors) to the models for estimating emissions. Parameter uncertainties can be evaluated through statistical analysis and/or expert elicitation. Quantifying the parameter uncertainties and then estimating the greenhouse gas inventory source uncertainties based on the parameter uncertainties is the primary focus of this chapter.

Both the model predictions and the parameters may be subject to systematic uncertainty (or bias). In addition, the parameters are also subject to statistical (or random) uncertainty.[21]

[21] Morgan and Henrion (1990), Frey (1992), and the IPCC *Good Practice Guidance* (IPCC 2000) summarize various sources of model and parameter uncertainties.

- *Bias* or *systematic* (or non-random) uncertainty occurs when the expected value of the measured or estimated value does not exactly equal (i.e., always less or greater than) the true value.[22] Bias arises from several factors, such as failure to identify all of the relevant source activities or categories, use of non-representative samples, or use of incorrect or incomplete estimation procedures to estimate emissions, and use of faulty instruments or equipment to measure emissions, emission factors, or activity data. Because the true value is unknown, bias cannot be detected through repeated experiments and, therefore, cannot be quantified through statistical analysis. However, bias can be identified and, sometimes, quantified through a thorough Quality Control (see §2.2, *Data Quality Control: Source Category-Specific Procedures (Tier 2))* and based on expert judgments.

- *Random* or *statistical* uncertainty arises from naturally occurring variations, such as the real variation in emissions from different coal mines or the natural variations in human reaction times in taking measurements. Random uncertainty can be detected through repeated experiments. This type of uncertainty can be quantified through statistical analysis when sufficient data are available, or through an elicitation protocol (which is detailed in §5.3).

The QC process described in §2.2 facilitates identifying various sources of bias associated with the parameters used in inventory estimation. Biases do not have to be constant from year to year, but may still exhibit a pattern (e.g., may be growing or falling). Quantitative estimates of bias can be developed using expert judgments, obtained using a carefully developed elicitation protocol.[23]

Ideally, random uncertainties should be statistically estimated using available empirical data. However, if insufficient data are available to facilitate valid statistical estimation, the uncertainty estimates for those parameters can also be developed using expert judgments, obtained using a carefully developed elicitation protocol. Thus, to identify and quantify the various types of uncertainties associated with inventory emission estimates, it is imperative that the uncertainty analysts coordinate with the inventory analysts that perform inventory estimation and QC of inventory estimates.

5.1.2 Monte Carlo Uncertainty Estimation Model

Quantitative estimates of uncertainties associated with the inventory sources and their sub-sources can be developed using either a Monte Carlo analysis or a simpler error propagation model (i.e., first order error analysis).[24] A Monte Carlo uncertainty model is used for estimating uncertainties associated with the U.S. greenhouse gas inventory, using @RISK© software.

The Monte Carlo uncertainty model develops estimates of uncertainties associated with the greenhouse gas inventory sources based on (1) the mathematical models used for estimating source category-specific inventory estimates, (2) source category-specific input variables, (3) the characteristics of the source category-specific input variables, as defined by their underlying probability density functions, and (4) the coefficient of correlation (or the measure of the strength of linear relationship) between the variables within and across inventory source-categories.

The Monte Carlo uncertainty estimation technique entails five steps.[25]

- *Step 1:* Identify probability density functions of source category-specific input variables, and develop quantitative estimates of underlying parameters of the probability density functions and correlations of the input variables.

- *Step 2:* Using the software, specify the inventory estimation model, probability density functions, and the underlying characteristics of the input variables, including correlation.

[22] Roughly speaking, the expected value is the average value across an infinitely large number of independent measurements or estimates.
[23] Experts, here, refer to those who are considered to have expertise on a particular (GHG estimation model) input parameter of interest. However, on occasions, inventory source experts may also be able to provide quantitative judgments on uncertainty associated with specific parameters associated with the inventory source category.
[24] Refer to Chapter 6, *Quantifying Uncertainties in Practice*, of the IPCC *Good Practice Guidance* (IPCC 2000) for a description, and pros and cons, of these two uncertainty estimation techniques.
[25] Refer to Chapter 6, *Quantifying Uncertainties in Practice*, of the IPCC *Good Practice Guidance* (IPCC 2000) for more details on each of these five steps.

- *Step 3:* For each input variable, the software selects values of random variables, based on the characteristics of its specified probability density function. The number of values that will be generated for each input variable will equal the number of iterations specified.
- *Step 4:* For each source category, the software develops inventory estimates, using the values of the randomly selected input variables and the pre-specified inventory estimation model.
- *Step 5:* For each source category (and for the entire inventory, if all the source categories are linked through mathematical models), the software stores the results of each iteration and presents the summary results. The results include:
  - ✓ the range of simulated inventory estimates for the source category (and the sub-source categories) at a pre-specified confidence interval (such as 95%, which will provide lower and upper uncertainty bounds at the 2.5% and 97.5% probabilities)
  - ✓ graphs and the parameters of probability density functions of the simulated inventory estimates
  - ✓ the relative impacts of the parameter uncertainties on inventory estimates based on sensitivity analyses

Box 5-1 lists the inputs required for developing quantitative estimates of uncertainties associated with inventory source categories using the Monte Carlo approach.[26]

Box 5-1. Data Required for Developing Quantitative Uncertainty Estimates for an Inventory Source Category Using the Monte Carlo Approach

To estimate quantitative uncertainty associated with an inventory source category, the following data are required.

- Mathematical model that describes the relationship between all the input parameters (i.e., both variables and constants) used for estimating emissions from, or removals by, the particular inventory source category.
- Greenhouse gas inventory estimated values for every input variable (e.g., activity data and emission or removal factor). Although these values are not required for the Monte Carlo analysis, using these values will facilitate in verifying whether the inventory estimation model has been specified correctly for the analysis.
- Characterization of the unconditional probability distribution for each input variable. This can be done based on available empirical data, if sufficient data are available, or on expert judgments.
- Numerical values of the key parameters of the probability distributions of each input variable. The key parameters may include minimum, maximum, and mean values, and the standard deviation. Typically, these key parameters are expressed as percentages of the greenhouse gas inventory estimated values. In the case of unbounded distributions, such as the normal distribution (which ranges from $-\infty$ to $+\infty$), realistic values for minimum and maximum can be used.
- Characterization of the inventory value of the input variable (used in inventory emission estimation), relative to the key parameters of its probability distribution (such as whether it is the mean value, or an individual observation).
- Numerical values of correlation (or covariance) between input variables.

5.2 Procedures for Quantitative Uncertainty Analysis

This section describes the procedures to be followed when conducting an uncertainty analysis of the U.S. greenhouse gas inventory.[27] These procedures are designed to ensure that the uncertainty estimates being developed are based on credible and defensible technical inputs that reflect full cooperation among analysts developing the inventory estimates, performing QC activities, and estimating uncertainty. The section is divided into two parts: §5.2.1 provides details on the specific activities and procedures involved in developing and documenting the uncertainty analysis, including completing the templates and forms in

[26] For a more detailed list of inputs required for, and steps involved in preparing a transparent uncertainty analysis, refer to Chapter 6, *Quantifying Uncertainties in Practice*, and Annex 1, *Conceptual Basis for Uncertainty Analysis* of the IPCC *Good Practice Guidance* (IPCC 2000).

[27] Box A1.2 in Annex 1 of the IPCC *Good Practice Guidance* (IPCC 2000) summarizes the key features of good practice for the determination of uncertainty in emission and sink estimates.

Appendix D that aid in the analysis; and §5.2.2 identifies the types of general procedures and good practices that should be followed, including documentation conventions, coordination, and follow-up.

5.2.1 Activities, Steps, and Procedures in Performing an Uncertainty Analysis

Over time, it is advisable to conduct a thorough review and assessment of the uncertainty associated with each of the source categories in the U.S. greenhouse gas inventory. Because of the time and resources required to conduct an uncertainty analysis, however, not all of the activities will be conducted in all years.

Once the uncertainty model and its inputs have been developed, it is relatively straightforward to update the uncertainty analysis to reflect new annual estimates for inventory emissions. However, developing the uncertainty analysis in the first place, updating the analysis to reflect new data or changes in methodologies, or periodically checking the assumptions and data underlying the analysis for an individual source category can be a significant undertaking. Thus, in developing the uncertainty analysis, available resources should be focused on key sources; in updating the model resources should be focused on source categories for which the inventory estimation methodology or input data are changing, or for which the emissions estimates are growing significantly. In both cases, available resources and time for the analysis may dictate not only the source categories for which analyses are to be conducted, but also the level of detail and depth of the analysis.

Below, the complete set of steps to develop a thorough uncertainty analysis of a given source category is described, including the use of the forms in Appendix D. In addition to initial model development and analysis, some of the activities should be repeated over time, although not necessarily each year (as discussed above). The circumstances under which the uncertainty analysis may be revisited in a particular year include the following.

- In general, the uncertainty estimates for the underlying variables should be revisited periodically to ensure that the data have not changed.
- Carefully reviewing the input data for the uncertainty analysis may be appropriate if the data sources for a source category or sub-source category and/or inventory estimation methodology have changed significantly.
- If resource constraints do not permit expert elicitation during the initial construction of the uncertainty analysis for a particular source category, over time elicitation may become higher priority if the source grows in significance, or if uncertainty about the estimates becomes a greater concern.
- QC activities conducted on the inventory may indicate that the quality of secondary data has changed, suggesting that the uncertainty analysis be revisited.

This section discusses five steps or sets of procedures in performing an uncertainty analysis:

- collecting and assessing the quality of readily available (generally published) uncertainty data
- conceptualizing the uncertainty estimation methodology and determining appropriate methods of collecting uncertainty input data for variables for which available (published) data are inadequate and for which no published data are available
- conducting elicitations, as needed, including preparing elicitation templates and recording the results of the elicitations
- summarizing (and documenting the rationale for the choice of) the final input uncertainty data for Monte Carlo uncertainty analysis
- developing the uncertainty model, conducting the analysis, and reporting its results

Forms and templates that can be used to guide this five-step process are included in Appendix D and are referenced below.

Step 1: Collect and Assess the Quality of Published Uncertainty Data

The first step is to collect readily available information on the statistical properties of the data underlying the inventory estimates. This information includes details on the characteristics of input data, including any uncertainty estimates that are available. To the extent that data are readily available (generally this means published literature or unpublished background documents obtained from data suppliers), the information needed for the uncertainty analysis should be obtained at the same time as the inventory analysts research and obtain the information needed for the inventory estimates. Where inventory input data are published, statistical data on the characteristics of the inventory inputs may be similarly published. In other cases, data suppliers may provide additional reports or analysis of the statistical characteristics of the input data.

For some variables and source categories, a complete set of uncertainty data—i.e., type of probability distribution, standard deviation, or standard error and its associated confidence interval, and upper and lower bound of the inventory estimates and their associated cumulative probability levels—may be readily available. In many cases, however, some or no information may be available. Thus, in addition to collecting readily available information, the process of data collection (as described below) is iterative—involving collection, assessment, and searches for additional data by uncertainty staff and inventory analysts.

Note:

The *Uncertainty Data Collection and Assessment Form* in Appendix D provides a model or guide to initial stages in the process of collecting and assessing uncertainty data inputs for the uncertainty analysis. It is intended to provide stepwise, formal documentation of the information found and decisions that are made. This form must be completed to ensure that the data collection and assessment efforts are carefully conducted, and that final determinations and decisions about data sources are clearly explained. In addition, as appropriate, the *Contact Reports* and the *Supplemental Reports* should be completed. The final input data used for uncertainty analysis must be documented in the *Summary of Uncertainty Inputs and Documentation Form* in Appendix D, as discussed below.

The following procedures should be adopted during collection and assessment of the uncertainty data.

- The source category staff should provide information on the level of disaggregation of the inventory data and estimation methodology in Part A of the *Uncertainty Data Collection and Assessment Form* in Appendix D.
- The source category staff should collect readily available (generally, from the published literature) uncertainty data for all the input variables or their components that are used to estimate emissions for a source category. Staff should record this uncertainty-related data for each variable or its components (as appropriate) in Parts A and B of the *Uncertainty Data Collection and Assessment Form* in Appendix D.
- The uncertainty staff should assess the completeness and reliability of the uncertainty data collected and reported by the source category staff in Parts A and B. Uncertainty staff should then identify any data deficiencies or discrepancies in these data. This assessment, together with possible improvements, should be reported in Part C of the *Uncertainty Data Collection and Assessment Form* in Appendix D.
- If the collected uncertainty data for the inventory variables or their components are inconsistent or deficient, the uncertainty staff should work with the Source Category Lead and other inventory analysts to identify alternative data collection efforts, such as searching for other published data, or obtaining additional unpublished data from the data suppliers, to supplement those data. The uncertainty staff should then try to obtain the necessary additional data through appropriate follow-up efforts. These newly collected data should be documented in Part D on the *Uncertainty Data Collection and Assessment Form* in Appendix D.
- The Uncertainty Analysis Coordinator and staff should once again assess the completeness and consistency of the supplemental uncertainty data collected by the uncertainty staff through follow-up efforts, along with the original set of uncertainty data collected by the source category staff, for each inventory variable or their components. Their findings, along with the summary of

uncertainty estimates should be recorded in Part E of the *Uncertainty Data Collection and Assessment Form* in Appendix D.

- Complete references for all published and unpublished references, personal communications, and other data sources should be recorded in Part F of the *Uncertainty Data Collection and Assessment Form* in Appendix D. Shortened citations for these references can be used in other Parts of this form.

It should be noted that uncertainty data may not need to be collected each year and the collection of uncertainty data for all source categories and all of their constituent variables may be spaced out over multiple annual inventory cycles. Therefore, for each variable, it is important to document the year to which the collected uncertainty data corresponds.

Step 2: Develop the Uncertainty Model Structure and Data Sources

The second step has two parts (1) conceptualizing the inventory model for purposes of the uncertainty analysis, based on the data available at the conclusion of the first step, and (2) determining whether informal or formal elicitation of expert judgments is needed. This step is two-part because the variables for which uncertainty data must be collected through expert judgments should first be identified based on the uncertainty estimation methodology conceptualized for each inventory source or sub-source category.

The uncertainty estimation methodology may be identical to the inventory estimation methodology or may be a simplified version of the inventory estimation methodology for an inventory source or sub-source category, depending on the data and the resource availability. The mathematical models underlying both the inventory and the uncertainty methodologies must yield the same inventory estimates. The levels of aggregation adopted for variables are likely to be the main difference between the inventory and the uncertainty estimation methodologies. The uncertainty estimation methodologies tend to have fewer variable components (i.e., are less disaggregated) than the inventory estimation methodologies. The preferred levels of variable disaggregation for uncertainty estimation methodologies for each variable in every source and sub-source category should be determined by the availability of uncertainty data inputs, in conjunction with the resource availability and the relative importance of the source/sub-source category (e.g., if it is a key source).

Once the levels of disaggregation for each of the variables have been determined, it is important to assess the quality of available data, and whether gaps and inconsistencies in the uncertainty data remain that need to be addressed. If, at the conclusion of the first step, consistent and complete uncertainty data are still unavailable for some inventory variables or their components, it will be necessary to conduct an *elicitation*. In this Manual, the process of eliciting quantitative judgments from the inventory experts that are directly involved in the inventory is referred to as "informal interview," and from outside experts is referred to as "expert elicitation."

- Additional information for variables or their components may be developed via *informal interviews* with inventory experts (which may include Source Category Leads and inventory analysts, or other experts in the government or among contractors directly involved in developing the inventory).
- Alternatively, developing needed data may require a more *formal elicitation* process focusing on outside experts who are responsible for collecting, compiling, and/or estimating inventory variables, or those that have other demonstrated expertise of the inventory variables, and so will have more detailed knowledge about the statistical properties of the variables, parameters, and other data underlying the inventory estimates.

Informal interview, thus, is a more modest process of elicitation, involving information collected through less formal discussions with inventory experts that are intimately familiar with the inventory source category. Less formal elicitation or informal interview may be warranted in certain situations, such as (i) the emission source is not a key inventory source category and so is a small contributor to inventory emissions, (ii) only a small number of variables have missing data, (iii) knowledgeable outside experts on the underlying variables and data are unavailable, or (iv) resources for conducting an elicitation are limited. The *Elicitation Template* (which is explained in detail in the next section) in Appendix D should be used to elicit and record quantitative judgments during informal interview. In addition, as appropriate, the *Contact*

Reports and *the Supplemental Reports* in Appendix D (see below for details) should be completed. The *Pre-elicitation Template* in Appendix D (also explained in detail in the next section) may be completed prior to, and in preparation for, informal interview. However, completing the *Pre-elicitation Template* is optional for an informal interview.

In other situations, it may be necessary to conduct a full-blown expert elicitation (see next step). An expert elicitation is a highly resource-intensive activity. In consultation with the Agency Inventory Lead, the Uncertainty Analysis Coordinator, and staff inventory analysts, the Source Category Lead will identify the appropriate method of collecting uncertainty data, including the personnel to be interviewed for obtaining the expert judgments for each of the relevant inventory variables or its components.

The results of all discussions with the Agency Inventory Lead and Source Category Leads, including the rationale for choosing particular methods of data collection for each variable or its components, should be recorded on supplemental sheets (see the *Supplemental Report* in Appendix D). All communications, including those with prospective experts identified for purposes of eliciting expert judgments, should be documented in a *Contact Report* (included in Appendix D).

Step 3: Conduct and Document Expert Elicitations

The Agency Inventory Lead and the Source Category Leads will together identify the outside experts to be interviewed for each inventory variable or its components and arrange for their expert elicitations. The following procedures should be followed in identifying experts for elicitation and in preparing templates prior to, and for recording the results of, elicitation.

- The experts chosen for elicitation interviews should be those that are familiar with the input variable used in the inventory model; ideally, they should be familiar with the data collection, compilation, and verification processes, and be capable of assessing the quality of the data in quantitative terms.
- Quantitative judgments should be elicited for the relevant input parameters using a carefully developed elicitation protocol custom-tailored to the expert to be interviewed and the variable for which elicitations are sought (see §5.3 for a generic Elicitation Protocol). As a part of the elicitation protocol, a *Pre-elicitation Preparation Template* and an *Elicitation Template* in Appendix D should be completed.
- In some cases, an expert may be asked to provide judgments on two or more variables, depending on his expertise. In some other cases, if two or more experts jointly manage the data collection and verification efforts for a particular type of variable, expert elicitations may be sought from more than one expert on the same variable, A separate *Pre-elicitation Preparation Template* (see Appendix D) should be prepared for each inventory variable and each expert to be interviewed.
- The *Pre-elicitation Preparation Template* lays out the key activities that should be completed by the uncertainty staff in order to prepare for an elicitation interview with an expert. This template is to be completed by the uncertainty staff, in consultation with the QA/QC staff, the Source Category Lead and staff inventory analysts, the Agency Inventory Lead. Some of the key procedures to be followed while preparing a *Pre-elicitation Preparation Template* (see Appendix D) are listed below.
  - ✓ With the help of source category specialists (for each inventory variable for which expert elicitation is sought), the uncertainty staff should identify alternative levels of disaggregation (e.g., national, regional, and state-level) that may be *realistically* adopted for eliciting expert judgments and developing uncertainty estimates.
  - ✓ The uncertainty staff (with other inventory specialists, as needed) should communicate with the outside expert prior to the interview on the subject matter of elicitation. At the minimum, the pre-elicitation communication materials to be sent to the expert should include:
    - a detailed, precise description of the variable for which elicitation is sought
    - the reason for elicitation
    - an overview of the inventory estimation methodology for that source category

- the kind of information for which the quantitative judgments are sought
- an explanation of the basic idea of probabilistic assessment and the rationale for using it
- alternative levels of disaggregation for the variable
- a description of the elicitation process
- a response form for the expert to complete and return, communicating his/her preferred (a) level of disaggregation, (b) unit of measurement (e.g., pound or kilogram, cubit feet or cubic meter, mile or kilometer, etc.) (c) rounding precision (e.g., rounded to the nearest 10, 100, or million), and (d) terminology for providing probabilistic judgments (i.e., odds or probability) for the elicitation interview
- a list of common biases that may arise in expert elicitation (see *Box 5-2* in §5.3.1) and some suggestions on how to avoid them (see *Box 5-3* in §5.3.2), so that the expert can be cognizant of the potential pitfalls and be careful to avoid them during the elicitation interview

✓ The expert's preferred level of disaggregation, unit of measurement, and the rounding precision for providing quantitative judgments for this variable should be recorded in this template upon receiving the response from the expert. In addition, the expert's preferred terminology to provide probabilistic judgments (i.e., probability or odds) on this variable should be recorded. Identifying the expert's preferences earlier will facilitate focusing on specific QA/QC issues and preparing appropriate questions for the elicitation interview. Based on the expert's preferred level of disaggregation, also specify the total number of variables for which the elicitation judgments will be sought from this expert.

✓ Key inventory issues, the results of the Tier 1 and Tier 2 QC reviews, the relationship between the variable or its components for which elicitation is sought and other variables in the same and other source categories should be analyzed and recorded in this template. These factors can be identified through consultation with the inventory and the QA/QC staff and the Agency's source expert.

✓ The elicitation protocol (see §5.3) should be thoroughly reviewed and the various sources of potential biases should be identified and the steps to avoid those biases should be developed.

✓ All communications with the identified experts should be recorded in the *Pre-elicitation Preparation Template* (see Appendix D).

- Elicitation interviews should be attended by the Agency Inventory Lead and the Source Category Lead (or their designees), as well as by the Uncertainty Analysis Coordinator and analytical staff conducting the interview.
- The results of the elicitations should be recorded in the *Elicitation Template* (see Appendix D). Some of the key procedures to be followed prior to and during elicitation interview with an expert are listed below.

✓ For each inventory variable, a separate *Elicitation Template* (see Appendix D) should be completed.

✓ If elicitations are obtained for the individual components of an inventory variable, the relevant sections of the *Elicitation Template* (see Appendix D) should be replicated as many times as the number of variable components to facilitate recording the elicitations for each individual component.

✓ Prior to the elicitation interview, the Uncertainty Analysis Coordinator and the staff should thoroughly review the *Pre-elicitation Preparation Template* (see Appendix D) prepared in preparation for an elicitation interview with the expert.

✓ During expert elicitation interviews, the interviewer (usually the Uncertainty Analysis Coordinator or staff) should ask questions to obtain unbiased and consistent quantitative judgments. Reviewing the completed *Pre-elicitation Preparation Template* (see Appendix

D) and the salient features of an elicitation protocol (see §5.3) prior to the interview will facilitate in achieving this objective.

- ✓ The expert's quantitative judgments elicited during the interview for each of the disaggregated variables for which elicitations are sought should be encoded separately in graph sheets at the time of an elicitation interview.
- ✓ The encoded graphs of the probability and the cumulative probability distributions of the variables should be shown to the expert at the end of the elicitation interview for review and approval. The expert's review comments and approval should be recorded in the *Elicitation Template* (see Appendix D). The expert approved-graphically encoded elicitations for each of the disaggregated variables (for which elicitations were sought from the expert) should also be attached to the *Elicitation Template* (see Appendix D). Illustrations of graphically encoded probability and cumulative probability distributions are included in the *Elicitation Template* (see Appendix D) for reference.

Step 4: Summarize and Document the Input Data for Monte Carlo Analysis

Once published and unpublished data have been collected and analyzed, inventory experts (such as the Source Category Lead and knowledgeable inventory analysts) have been informally interviewed if necessary, and any expert elicitations have been completed, the Uncertainty Coordinator and uncertainty staff are in a position to finalize the inputs for the uncertainty analysis. The uncertainty inputs for each variable or its components in every inventory source and sub-source category collected through these various means (e.g. through research from published and unpublished documents or developed through expert judgments) should be analyzed for consistency, differences reconciled, and the estimates should be synthesized and finalized for performing the Monte Carlo analysis.

The uncertainty estimation model for each source and sub-source category will be developed based on these summary data inputs. The summary data should be recorded in the *Summary of Uncertainty Inputs and Documentation Form* in Appendix D, together with the rationale for decisions, and references to supporting published and unpublished material. The uncertainty staff with the help of the source category staff should complete this form. **It is important that this form be carefully and thoroughly completed and documented.**

Step 5: Conduct and Document Monte Carlo Analysis

After the summary input data are finalized, the uncertainty estimation model should be set up for each inventory source and sub-source category in accordance with the conceptualized uncertainty estimation methodology appropriate for the Monte Carlo uncertainty analysis.

An important consideration is that the same source-category-specific input variable may appear more than once in the source-category inventory model. For example, the same emission factor or its components may be applicable to more than one sub-source category, e.g. typical animal mass of dairy cows (used in the estimation of inventory emissions from the two source categories, nitrous oxide from manure management and methane from manure management). Similarly, the activity levels for different sources might all be based on a single input variable, e.g., the size of cattle population (used in the estimation of methane emissions from enteric fermentation and from manure management, and nitrous oxide emissions from agricultural soils). To avoid underestimating the overall uncertainty, the relevant input variable should be given the same name wherever it appears, so that the Monte Carlo simulation will select the value only once per iteration. For example, if the emission factors for light trucks is assumed to be the same as for cars (either because no light truck data are available, or because the relevant study did not separate these two vehicle classes), then the emission factor might be named as "CO_2 emission factor - cars and light trucks" even if the activity levels for cars and light trucks are independently estimated.

Next, the models should be executed to develop uncertainty estimates for each inventory source and sub-source category and the results of the models should be analyzed, the models revised as needed, and the results finalized.

The final model results, including the results of the sensitivity analysis, should be recorded in the *Uncertainty Analysis Results Form* (see Appendix D). This form summarizes the model results, including a

brief description of the inventory estimation model, the level of disaggregation of the source-category for uncertainty estimation, the simulated mean values of emission estimates, the estimated ranges of total source and major sub-source emissions at a 95 percent confidence level, the deviations of the high and low range of emissions from the inventory estimates, and the results of the sensitivity analysis (indicating input variables that account for much of the variation in the total source emissions, and quantifying the extent of their variation). The uncertainty staff should complete this form; when completed, it will serve as the summary of the uncertainty analysis results for each inventory source category.

5.2.2 General Procedures for Good Practice in Data Handling, Coordination, and Follow-up

Following a number of general procedures will help to ensure that the uncertainty analysis is of high quality and that the results contribute to improving the quality of the inventory emission estimates. In particular, the uncertainty analysis should follow the same types of procedures for careful data management and documentation as are followed for the inventory. The uncertainty analysis also requires a high degree of coordination and follow-up among nearly all parties involved in the process of developing and checking the inventory and its associated documents.

In general, the procedures to be followed in developing the data inputs for, and in conducting, the uncertainty analysis involve following good practices in data collection and handling, in documentation, in coordination, and in corrective action.

- *Data handling and general quality control.* The good practices described in §2.1 for gathering and handling input data, constructing and documenting the assumptions in the model and the model spreadsheets, checking calculations, and other procedures to produce high quality estimates should also be followed for the uncertainty analysis.
- *Coordination in data collection and preparation.* The Uncertainty Analysis Coordinator, the Source Category Lead, and the QA/QC Coordinator, together with their relevant staff, should all work closely together to develop the information and inputs needed for the uncertainty analysis.
  - ✓ Inventory analysts should be aware of the types of statistical data needed for the uncertainty analysis and should make an effort to collect relevant published data at the time that they collect or update the inventory data.
  - ✓ Elicitation interviews should be attended by the Agency Inventory Lead and the Source Category Lead (or their designees), as well as by the Uncertainty Analysis Coordinator and relevant uncertainty staff.
  - ✓ In addition to conducting the uncertainty analysis, the uncertainty staff should also contribute to the Tier 2 QC activities described in §2.2, *Data Quality Control: Source Category-Specific QC Procedures*, particularly where secondary data are concerned.
  - ✓ Note that the QC checks in Chapter 2 and the uncertainty investigations may require contacting the same persons or organizations. For example, an input parameter expert or data supplier (who oversees data collection, compilation, verification, and publication of the input variable of interest) may be contacted by the QC staff to find out the details on the types of data management and QC systems exist for the data, and also by the uncertainty staff to collect information relevant for quantitative uncertainty estimation. To the extent that such overlap occurs, both the questions and contacts should be coordinated (possibly with all relevant individuals involved in each meeting), to avoid duplicative questions and multiple points of contact.
- *Feedback from quality control into uncertainty analysis.* In developing the inputs to the quantitative uncertainty analysis, the Uncertainty Analysis Coordinator and/or staff should
  - ✓ review the results of all Tier 1 quality checks performed (by the QC staff) for individual source categories and overall inventory estimates

- ✓ review the results of all Tier 2 quality checks performed (by the QC staff) pertaining to selection of model and parameters, and collection of data for input variables of individual source categories
- ✓ review any relevant *Supplemental Reports* and *Contact Reports* that have been prepared to document inventory estimates and their underlying assumptions
- ✓ work with inventory analysts and QC staff conducting Tier 2 checks to identify the sources of uncertainties and other considerations in developing the data inputs for the uncertainty estimation

- *Documentation, project file maintenance, and archiving conventions.* Citations should conform to the inventory documentation conventions, the model and results should be completely documented, and all relevant files should be archived.
  - ✓ In citing published and unpublished material, documentation conventions described in §2.1.2 should be followed. In particular, all relevant conversations, including those associated with seeking clarification on the published data on parameter uncertainties, such as the method of estimation to assess the accuracy and reliability of the data, should be reported on the *Contact Report* in Appendix D, or an equivalent document that provides a record of attendees and contact information, as well as recording substantive aspects of the telephone conversation or meeting.
  - ✓ The electronic file containing the uncertainty model should include full documentation, including the mathematical models used to estimate emissions and removals used for inventory estimation, inventory estimates of the input parameters and the source categories, probability distributions of each input variable, parameters of the probability distributions of each input variable, correlation (or covariance) between input variables, and assumptions implicit in the model construction, if any.
  - ✓ All final versions of the forms and templates completed for the uncertainty analysis, including data collection forms, templates related to any elicitations that occur, summary forms, results forms, and any relevant *Contact Reports* or other *Supplemental Reports* or material that are used for the uncertainty analysis, should be maintained in a project file by the uncertainty staff and included in the annual docket, which is archived each year, as described in §3.4. The annual docket should also contain electronic copies of the model, electronic copies of model results, and any relevant printouts.
- *Interpretation of results.* The Uncertainty Analysis Coordinator, the Source Category Lead, and the QA/QC Coordinator, together with their relevant staff, should all work closely together to interpret the results. If the results of the uncertainty analysis reveal potential areas of improvement for the inventory, or indications for future research or quality improvements, these should be transmitted back to the Agency Inventory Lead as well.
- *Dissemination of results.* After the uncertainty analysis is completed, a brief summary of the results of the analysis (as documented in *Uncertainty Analysis Results Form* in Appendix D) should be reported in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (here referred to as the *Inventory*) document. The summary should include
  - ✓ a brief, qualitative description of the sources of uncertainty (recorded in Part B of the *Form*)
  - ✓ a summary of the quantitative uncertainty estimated developed by the Monte Carlo analysis (recorded in Part D of the *Form*)

5.3 Developing an Elicitation Protocol

The uncertainty of an inventory estimate for a particular source or sub-source category depends on the estimated uncertainties associated with the input variables underlying the inventory estimate (e.g., the activity data and emission or removal factors). In some cases, information on the characteristics of the probability distributions underlying these variables may have been developed using empirical data and those results may be readily available. In other cases, such as when bias or other sources of non-random uncertainty are significant, or when expert opinion is itself a significant contributor to identification and

selection of the input variable (e.g., an emission factor), the requisite number of empirical observations needed to estimate uncertainty of the input parameters statistically will not be readily available.

In cases in which the statistical data needed to estimate uncertainty are unavailable, uncertainty estimates of those input parameters should be developed based on expert judgments. The term “elicitation protocol” refers to the formal method of developing probability density functions of parameters, based on the quantitative judgments of experts. In the context of this chapter, an elicitation protocol refers to the set of procedures to be used by the uncertainty analysts who interview experts for purposes of developing quantitative uncertainties of the input variables (hereafter referred to as "elicitors") and, thereby, of the inventory estimates of source categories.

Developing an elicitation protocol is the key to generating uncertainty estimates that are credible and defensible. In this section, a *generalized* elicitation protocol is developed to include procedures and techniques to motivate and condition the experts to fully understand, and to enthusiastically participate in, the elicitation process, such that biases can be consciously avoided, and independent and reliable quantitative judgments on the characteristics of the variables of interest can be developed. The general elicitation protocol developed in this section is based on the salient features of various elicitation protocols described by Morgan and Henrion (1990), Cohen (1998), and the *IPCC Good Practice Guidance*, and is structured similarly to the well-known Stanford/SRI elicitation protocol.

The actual elicitation process will, however, likely require developing a protocol that is specific to the source category, parameters, and background of the expert in question. In particular, the elicitation protocol should be specific to each input variable in the inventory source category. The protocol should also be designed to match the background and knowledge level of the expert. In many cases, the expert might not be familiar with inventory techniques, although he or she may have been the supplier of primary data used in the inventory estimation. Further, the expert may not be familiar with statistical techniques. The elicitation protocol should be tailored accordingly.

Thus, developing a specific protocol can require considerable knowledge on the part of the elicitor regarding the methodology for estimating emissions and the sources of data, as well as the process of estimating uncertainty. Therefore, it is imperative that the elicitor consults the inventory staff and the QA/QC staff in preparing a specific protocol for each inventory variable for which elicitation is sought. Further, each specific protocol prepared by the elicitor must be reviewed, revised if necessary, and approved by the Uncertainty Analysis Coordinator, the appropriate Source Category Lead, and the Agency Inventory Lead, prior to elicitation interviews with every expert. Finally, because some of the key characteristics of the expert, such as his knowledge of the inventory source category or familiarity with statistical concepts, may not be known prior to the interview, an elicitation protocol developed specially for a source parameter may need some impromptu adjustments during the interview. Note that, as stated earlier, the Agency Inventory Lead, the Source Category Lead, and the Uncertainty Analysis Coordinators (or their designees) should all be present at the interview.

The expert elicitation protocol developed in this section consists of six stages.[28]

1. *Research and Planning* for meeting with the expert
2. *Motivating* the expert
3. *Structuring* the uncertainty quantity to be elicited
4. *Conditioning* the expert to think fundamentally about his or her judgment and to avoid cognitive bias
5. *Encoding* of expert’s probabilistic judgments
6. *Verifying* with the expert that the quantitative judgment s/he has provided correctly reflects his or her beliefs

The first stage is the one during which the elicitors prepare for the interview, including doing research, contacting the experts, developing questions, and other activities. The remaining five stages are stages in the actual interview with the expert. However, to save time during the actual interview, most of the second

[28] Stages 2 through 5 correspond to the Stanford/SRI elicitation protocol stages.

and the third stage tasks can be performed prior to the actual interview by sending the relevant information along with other pre-elicitation communication material (see Step 3 in §5.2.1 and *Pre-elicitation Preparation Template in Appendix D*). During the actual interview, the information pertaining to stages two and three may be quickly reviewed and the expert's questions, if any, can be answered. On occasions, the last stage may occur after the interview. Each of these six stages is discussed below in detail.

5.3.1 Research and Planning

This stage is the preparatory stage, in which the experts are identified, the interview dates are set, and the elicitors prepare themselves for interviewing the experts. The process of identifying experts is analogous to the process followed for identifying reviewers for QA/QC in Chapter 4.

Various elicitation protocols recommend that two or more elicitors be present to elicit and encode the quantitative judgments from each expert. Further, it is also recommended that the elicitors meet with the expert at his/her home institution so that the expert will have full access to all the files and the data. If more than one expert is contacted for eliciting information about a particular input parameter, it is recommended that they be contacted individually, so that each one will be able to provide his/her own judgments without being influenced by others' arguments or personalities (Morgan and Henrion 1990). A modification of this approach is to elicit information individually from experts, and then summarize the information collected from all the experts and ask them (individually or collectively based on consensus) to rank or assign weights to each of the expert responses.

Prior to interviews with experts, the elicitors should prepare themselves to be able to effectively elicit information from the expert. Hence, to prepare sufficiently for the interview, during this stage, the elicitors are recommended to undertake the following tasks.

- Familiarize themselves with details of the inventory source category and its sub-source categories, inventory estimation methodology, all the inputs of the inventory estimation model, and the relationship of the model inputs of a source- or a sub-source category to the model inputs of other source and sub-source categories.
- Coordinate with the inventory analysts that develop inventory estimates to understand the assumptions underlying the inventory estimation methodology and the input variables used in the inventory estimation.
- Discuss with in-house inventory source experts and inventory analysts that conduct QC of source-specific categories and identify various sources of uncertainties associated with input variables.
- Be aware of various types of conscious and unconscious biases that might affect the objective and independent quantitative judgments of experts. *Box 5-2* summarizes most common types of biases.
- Review the biases listed in *Box 5-2* and identify those biases that might interfere with the expert's objective and independent quantitative judgments.[29]
- Identify ways to avoid such biases, such as choosing an alternative level of aggregation. *Box 5-3* identifies some techniques that can be adopted to ensure that the expert judgments will not be affected by such biases.
- Prepare inventory estimates at two or three different possible levels of aggregation (such as national level, regional level, and state level) at which the input parameter (for which expert elicitation is to be sought) could be used in inventory estimation and familiarize themselves with the implications of such alternative levels of aggregation on the expert's elicitation.
- Complete a *Pre-elicitation Preparation Template* (as in Appendix D) for each variable for which expert elicitation is sought.
- Prepare an *Elicitation Template* (as in Appendix D) and take several copies of the template and graph sheets for the interview with the expert, since each copy of the template and a graph sheet

[29] Refer to Morgan and Henrion (1990), Frey (1992), and the IPCC *Good Practice Guidance* (IPCC 2000) for detailed discussions of various sources of bias and how to avoid them. Text Box 5-3 in this section also provides an illustration of how to avoid some of these biases.

will be required for documenting the elicitation results for the variable for each of its disaggregated categories (such as the state-level or regional level).

Box 5-2. Common Biases in Expert Elicitation

Biases can be categorized into unconscious biases and conscious biases.

Unconscious biases are usually introduced by the rules of thumb (sometimes referred to as *heuristics*) that experts use when formulating judgments about uncertainty. Conscious biases may be introduced when an expert believes that his or her interests will be affected by the outcome of the elicitation. The most common unconscious biases are:

- *Availability or Memory Bias* . This type of bias arises when judgments are formulated based on outcomes that are more easily remembered.
- *Representativeness Bias.* This type of bias arises when judgments are formulated based on limited data and experience without fully considering other relevant evidence.
- *Anchoring and Adjustment Bias.* This type of bias arises due to fixating on a particular value in a range and making insufficient adjustments away from it in developing an uncertainty estimate.
- *Sequential Bias.* This type of bias arises when successive judgments are formulated based on the previous judgments.

Some of the most common conscious biases are:

- *Motivational Bias.* This type of bias arises when the expert desires to influence the outcome or to avoid contradicting prior positions on an issue.
- *Expert Bias.* This type of bias arises from an unqualified expert's desire to appear as a true expert in the field.
- *Management Bias.* This type of bias arises when the expert provides quantitative judgments that achieve the expert's organizational goals, rather than judgments that reflect the actual state of knowledge regarding inventory inputs.
- *Selection Bias.* This type of bias arises when the expert is selected due to his or her pre-disposition to provide favorable quantitative judgments, rather than judgments that reflect the actual state of knowledge regarding inventory inputs.

5.3.2 Motivating

This stage involves motivating the expert to cooperate in eliciting his quantitative judgment on the probabilistic distribution of the variable of interest. This process begins by developing initial rapport with the expert. Some of the guidelines that the elicitor is encouraged to follow in this stage are listed below.

- Describe the emission source and the model that is used to estimate emissions from that source.
- Explain the role of the variable of interest (for which information on probabilistic judgments are to be elicited from the expert) in the estimation of emissions from a particular source category.
- Explain the basic idea of probabilistic assessment and provide the rationale for using it.
- Describe the kind of information desired, the underlying population to be considered, and the set of other factors that the expert should consider while providing his/her quantitative judgments.
- Discuss the reason for elicitation. It is important to note that because sufficient empirical data points are not available to statistically estimate uncertainty estimates, the expert's quantitative judgments on the characteristics of the variable would help in formulating uncertainty estimates for that variable.
- Systematically identify various possibilities that might motivate a biased response from the expert and ask the expert to beware of those biases and be careful that those biases do not interfere with his judgments. In support of this effort, discuss psychological issues, such as mental strategies and heuristics (or rules of thumb) and of some of the difficulties these can lead to. Morgan and Henrion (1990), Cohen (1998), and IPCC (2000) describe various potential sources of bias that

might affect expert judgments. *Box 5-3* provides an illustration of how an expert could be motivated to avoid biases and provide reliable information.[30]

Box 5-3. An Illustration of How to Motivate an Expert

An excerpt from an elicitation protocol prepared by Wallsten and Whitfield (1986) is presented below as an illustration.

Be aware of your natural cognitive biases and try to avoid them consciously. To avoid sequential effects, keep in mind that the order in which you think of the issues should not influence your final decision. It may be helpful to note down the important facts you are considering and then reorder them in two or more sequences. Try to keep an open mind until you have gone through all the evidence, don't let the early information you consider sway you more than is appropriate.

To avoid memory effects, define various classes of information that you deem relevant and then search your memory for examples of each. Don't restrict your thinking only to items that stand out for specific reasons. Make a special attempt to consider conflicting evidence, and to think of data that may be inconsistent with a particular theory. Also be careful to concentrate on the given probability judgment and not let your own values (i.e., how you would make the decision yourself) affect those judgments.

To accurately estimate the reliability of information, pay attention to such matters as sample size and power of statistical tests. Keep in mind that data are probabilistic in nature, subject to elements of random error, imprecise measurements, and subjective evaluation and interpretation. In addition, the further one must extrapolate, or generalize, from a particular study to a situation of interest, the less reliable is the conclusion and the less certainty should be attributed to it. Rely more heavily on information that you consider more reliable, but do not treat it as "absolute truth."

Keep in mind that the importance of an event or an outcome should not influence its judged probability. It is rational to let the costliness or severity of an outcome influence which action is taken with respect to it, but not the judgment that is made about the outcomes' likelihood.

Finally, in making probability judgments, think primarily in terms of the measure (probability or odds) with which you feel most comfortable, but sometimes translate to the alternative scale, or even to measures of other events (e.g., probability of the event not happening). When estimating very small or very large likelihood of events occurring, it is usually best to think in terms of odds, which are unbounded, instead of probabilities, which are bounded. For example, one can more easily conceptualize odds of 1:200 than a probability of 0.005.

5.3.3 Structuring

This stage involves defining the uncertainty quantity to be evaluated in unambiguous terms such that the expert will be able to provide reliable judgments.

- Define the variable for which probabilistic judgment is elicited precisely, such as in relation to time, regional applicability, unit of measurement, etc. For example, in the case of cattle population, it should be specified as to (a) which year cattle population is of interest; (b) whether the national U.S. cattle population or regional/state (if so, be specific which region or state) cattle population is of interest; (c) whether the interest is in the entire cattle population or only components of it, such as cow or beef population; and (d) state the age group (such as the weanlings, the yearlings, or the adult cows) of the specific category of cattle population for which information is sought.
- Define the parameters in units that the experts are the most comfortable with, which can be ascertained by talking to the expert. This will avoid the need for the expert to engage in unit conversion or other mental exercises to be able to respond to the questions posed.

5.3.4 Conditioning

This stage involves conditioning the expert to think fundamentally about the process that he or she will adopt to make probabilistic judgments and to avoid cognitive biases.

Considerable conditioning could be required if the expert is not familiar with providing quantitative judgments. Asking proactive or leading questions on various aspects of the input variable (for which quantitative judgment is sought) can enable the expert to think about those issues systematically when providing quantitative judgments. Some of the key tasks that the elicitor can undertake in this stage are described below.

[30] This illustration, developed by Wallsten and Whitfield (1986), was adapted from Morgan and Henrion (1990).

- Ask the expert to explain how he will go about making his probability judgments: what data sets and other information he has available and how he plans to make use of this information.
- Ask the expert leading questions, such as:
  - ✓ How were the data collected or estimated?
  - ✓ What are the important factors (such as regional, local, or national considerations) for estimating the value of this input parameter accurately?
  - ✓ Are the data used in sub-national or sectoral calculations representative?
  - ✓ Are there any sources of bias, such as reasons for over- or under-estimation or omission of one or more sub-source category?
  - ✓ Are there better data available?
  - ✓ What are the ways to improve the quality of the data?
- Encourage the expert to consider other possible ways of thinking about, or getting insight on, the problem. While the expert explains, the elicitor should listen carefully and identify possible sources of cognitive biases and plan his or her elicitation such that the impacts of biases are minimized.
- Ask the expert to explain why certain outcomes may result; or ask the expert to invent explanatory scenarios for a given set of outcomes. Discuss both scenarios leading to likely outcomes and extreme outcomes. Such explanations will provide insight to the interviewer about the problem at hand and thus facilitate him/her to structure questions (for eliciting information from the expert) accordingly.

5.3.5 Encoding

This stage is the crux of the entire elicitation protocol. In this stage, the quantitative probabilistic judgments of the experts are elicited and encoded. Encoding involves completing the *Elicitation Template* (in Appendix D) and plotting the elicited quantitative judgments on graph sheets in the form of probability density function of the variable. Some of the key guidelines that elicitors are encouraged to adopt in this stage are listed below. Some of these guidelines pertain to ascertaining the preferences of the expert in terms of the level of aggregation, the terminology for providing quantitative judgments, unit of measurement, and degree of precision, which the expert may have communicated prior to the actual interview (i.e., during pre-elicitation communication). Nonetheless, the elicitor is strongly urged to confirm those preferences once again with the expert during the actual interview, so that subject matter of elicitation is clearly and precisely understood by all the participants of the elicitation interview.

- Talk to the expert and identify the level of aggregation at which the expert is comfortable providing quantitative judgments about the parameter of interest and structure questions at that level.
- Talk to the expert and identify whether the expert is comfortable with providing quantitative judgments in terms of odds or probability. Ask questions only using that terminology the expert is comfortable with.
- Talk to the expert and identify the unit of measurement (e.g., pound vs. kilogram, short ton vs. metric ton, and cubic feet vs. cubic meter) and the degree of precision (e.g., rounded to the nearest 10, 100, 1000, or million) at which the expert is comfortable providing quantitative judgments about the parameter, and ask questions only in that measurement unit and at that precision level. Also, recognize that rounding the numbers leads to a range of values associated with the parameter. Because, in the case of a continuous probability density function, the probability of a specific value occurring is zero, rounding the parameter value facilitates eliciting both realistic and statistically consistent responses from the expert. Therefore, in the context of expert elicitation, it is assumed in this chapter and in the *Elicitation Template* in Appendix D that the parameter values are rounded and, hence, any reference to a particular value actually implies a particular range of values.

- Ask what the expert considers as the extreme values (i.e., realistic values for the minimum and maximum) for the parameter, for which probabilistic judgment is sought.
- Ask the expert to explain scenarios that might lead to such extreme values.
- Ask for probabilities that the outcomes will lie outside the extreme values.
- Ask both for the probability of a particular value (or range of values) resulting, and the value (or range of values) that is associated with a particular probability of occurrence. For example, ask for the probability of exceeding 10 and also ask for the value exceeded by 10 percent of the values.
- Ask the expert about the point of indifference (i.e., the value associated with 50^{th} percentile).
- Take a set of values of the parameter of interest and ask the expert what the probabilities or odds are of those outcomes.[31] Ensure that the initial two values or probabilities are easy to estimate.
- Do not ask the questions about values or probabilities in a particular sequence. For example, if the elicitor intends to obtain the expert's quantitative judgments of values that correspond to 1%, 5%, 10%, 25%, 50%, 75%, 90%, 95%, and 99% probabilities, after asking the expert about the value that will correspond to 5% probability, ask him about the value that will correspond to 75% probability. It is believed that such out of sequence elicitation will result in independent and reliable response and, thus, avoid anchoring and sequential bias.
- Next, use the interval technique to elicit values for the median and the quartiles. For example, to obtain the value for the median, ask the expert to choose a value of an emission factor such that it is equally likely that the true emission factor would be higher or lower than the value of the emission factor specified. Then, to obtain values pertaining to the third quartile (i.e., 75^{th} percentile) and the first quartile (i.e., 25^{th} percentile), divide the upper and the lower range of values to the median into two separate bins, and ask the expert to choose a value of the emission factor such that it is equally likely that the true emission factor would be higher or lower than the value of the emission factor specified.
- Ask about the most likely value or the range of values (i.e., the mode).
- Ask about the probability that the most likely value will occur.
- Ask about the average of the values or mean.
- Plot the responses as probability density functions (PDFs) and cumulative probabilities (or cumulative distribution functions (CDFs) on charts, as the responses are elicited. Remember that the quantitative judgments are actually elicited on a range of parameter values of the inventory variable. Do NOT show the plots to the expert at this point, as this will interfere with his independent judgment of other responses. Beware that the expert responses may not be logically or probabilistically consistent. For example, the estimated value corresponding to 90 % probability may be higher than the value corresponding to 80 % probability, or the probabilities of being above and below a given value may sum to more than one. These inconsistencies can be cleared out during the verification stage.
- Eliciting information on correlation is complex. Although some experts can provide information on correlation directly as the strength of the linear slope, many experts may not be able to provide this information. This requires careful planning and motivating by the elicitors. As a first, step, explain correlation and using an example, explain the reasons for correlations. Sometimes a correlation can be evaluated by helping the expert to think about common explanatory factors that might affect different input variables.
- Throughout the process of encoding, ensure that the assumptions underlying the expert's responses are clearly understood. **Always ask the expert to explain the rationale behind his or**

[31] While Morgan and Henrion (1990) recommend the use of a probability wheel (a physical device), they also state that they are unaware of any systematic experimental evaluations of the use of a probability wheel. Further, it may also be considered a distraction. Hence, in this protocol, we have not made any explicit reference to the use of a probability wheel. Refer to Chapter 6 of Morgan and Henrion (1990) on a detailed discussed about the use of a probability wheel.

her quantitative judgments. Otherwise, the elicitor might need to return to the earlier steps, such as conditioning, to get the expert to think and explain how he or she would go about providing quantitative judgments for the parameter of interest.

5.3.6 Verifying

This stage involves confirming with the expert that the results of the elicitation process—i.e., the interpretation of expert's answers and subsequent encoding based on the quantitative information provided by the expert—accurately reflect the expert's true judgments. One approach is to construct PDFs and CDFs and check with the expert that the interpretation of his or her quantitative information is correct. Verification may result in revising the results to reflect comments and suggestions of the expert.

5.4 Quality Control for Uncertainty Analysis

IPCC Good Practice Guidance recommends checking that uncertainties in emissions and removals are estimated and calculated correctly, including:

- Checking that qualifications of individuals providing expert judgment for uncertainty estimates are appropriate
- Checking that qualifications, assumptions and expert judgments are recorded, and that calculated uncertainties are complete and calculated correctly
- If necessary, duplicating error calculations for some of calculations

Documentation should be sufficient to support the estimates and enable duplication of the uncertainty estimates. In addition, sector-specific recommendations for QC of uncertainty estimates from the *IPCC Good Practice Guidance*, Chapters 2 through 5, should be followed.

Currently, the U.S. Inventory Program has no formal procedures or checklists for checking the quality of the uncertainty estimates.

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APPENDIX A

FORMS AND CHECKLISTS FOR QUALITY CONTROL FOR SPECIFIC SOURCE CATEGORIES

This appendix contains a number of suggested forms to accompany Chapter 2 of the QA/QC Manual. ***A table of source category names and abbreviations to be used in completing the forms is included as part of the front material to this appendix.***

The order in which the forms appear is:

The following table provides a list of source category names and abbreviations to be used when filling out the forms in this Appendix. Please use the entire source category name on the top of each form, and the abbreviations within the form and as the reference numbers for the Contact Report *(Form A4) and* Supplemental Report *(Form A5).* Contact Reports *should be labeled with CR-source abbreviation-date (month/day/year), and the initials of the individual preparing the form; for example* **CR-coal-7/6/01-KRJ***.* Supplemental Reports *should be labeled with SR-source abbreviation-date (month/day/year), and the initials of the preparer; for example* **SR-coal-7/6/01-KRJ***. A suffix of a, b, etc., can be used to identify multiple reports prepared on the same day by the same individual.*

Table A-1. List of source category names and abbreviations

Chapter/Source	Abbreviation
Energy	
Carbon Dioxide Emissions from Fossil Fuel Combustion	CO_2 FFC
Carbon Stored in Products from Non-Energy Uses of Fossil Fuels	Carbon Stored
Stationary Source Fossil Fuel Combustion (excluding CO_2)	Stationary
Mobile Source Fossil Fuel Combustion (excluding CO_2)	Mobile
Coal Mining	Coal
Natural Gas Systems	Natural Gas
Petroleum Systems	Petroleum
Natural Gas Flaring and Ambient Air Pollutants from Oil and Gas Activities	Flaring
International Bunker Fuels	Bunker
Wood Biomass and Ethanol Consumption	Biomass
Indirect CO_2 from CH_4 Oxidation	Indirect
Municipal Solid Waste Combustion	Waste
Industrial Processes	
Cement Manufacture	Cement
Lime Manufacture	Lime
Limestone and Dolomite Use	Limestone/dolomite
Soda Ash Manufacture and Consumption	Soda Ash
Carbon Dioxide Consumption	CO_2 Consumption
Iron and Steel Production	Iron and Steel
Ammonia Manufacture	NH_4
Ferroalloy Production	Ferroalloy
Petrochemical Production	Petrochemical
Silicon Carbide Production	SiC
Adipic Acid Production	Adipic
Nitric Acid Production	Nitric
Substitution of Ozone Depleting Substances	ODS
Aluminum Production (CO_2)	Aluminum (CO_2)
Aluminum Production (PFCs)	Aluminum (PFCs)
Titanium Dioxide Production	TItanium
HCFC-22 Production	HCFC-22
Semiconductor Manufacture	Semiconductor
Electrical Transmission and Distribution Systems	ET&D
Magnesium Production and Processing	Mg
Industrial Sources of Ambient Air Pollutants	Indust. Ambient
Solvent Use	Solvent
Agriculture	
Enteric Fermentation	Enteric
Manure Management	Manure
Rice Cultivation	Rice
Agricultural Soil Management	Ag Soil
Agricultural Residue Burning	Ag Res
Land-Use Change and Forestry	
Changes in Forest Carbon Stocks	Forest Carbon
Changes in Carbon Stocks in Urban Trees	Urban Carbon

Chapter/Source	Abbreviation
Changes in Agricultural Soil Carbon Stocks	Ag Soil Carbon
Changes in Yard Trimming Carbon Stocks in Landfills	Landfill Carbon
Waste	
Landfills	Landfills
Wastewater Treatment	Wastewater
Human Sewage	Sewage
Waste Sources of Ambient Air Pollutants	Waste Ambient

A1. TIER 1: INDIVIDUAL SOURCE CATEGORY CHECKLIST

Inventory Report: 1990-_____ Source Category:[1] _____

Title(s) and Date(s) of Inventory Spreadsheet(s): _____

Source category estimates prepared by (name/affiliation): _____

INSTRUCTIONS FOR COMPLETING THIS FORM:

This form is to be completed annually for each source category, and provides a record of the checks performed and any corrective actions taken. The form may be completed by hand or electronically. If appropriate actions to correct any errors that are found are not immediately apparent, the QC staff performing the check should discuss the results with the Agency Inventory Lead and the QA Officer. Once completed, the form should be filed in the project file, with copies to the Data and Document Management Coordinator. Additional information on the activities indicated on the form may be found in Chapter 2 *of the* QA/QC Manual*.*

The first page of this form summarizes the results of the checks (once completed) and highlights any significant findings or actions. The remaining pages in this form list categories of checks to be performed. The analyst has discretion over how the checks are implemented. Not all checks will be applicable to every source category; checks/rows that are not relevant or not available should indicate "n/r" or "n/a" (not be left blank or deleted). Rows for additional checks that are relevant to the source category should be added to the form.

The column for supporting documentation should be used to reference any relevant Supplemental Reports (*Form A5) or* Contact Reports *(Form A4) providing additional information. Note that, if a source-category specific QC plan has been developed and implemented, this Tier 1 form should still be completed. Any documents associated with the source-category specific plan should be clearly referenced in the column for supporting documentation.*

Summary of Tier 1 Source Category Checks and Corrective Action

Summary of results of checks and corrective actions taken:

Suggested checks to be performed in the future:	Any residual problems after corrective actions are taken:

[1] Use the source category names in Table A-1 of this appendix.

Checklist for Tier 1: Individual Source Category (abbreviation):

Item		Check Completed			Corrective Action		Supporting documents (provide reference)
		Date	Individual (first initial, last name)	Errors (Y/N)	Date	Individual (first initial, last name)	
DATA GATHERING, INPUT, AND HANDLING ACTIVITIES: QUALITY CHECKS							
1.	Check a sample of input data for transcription errors						
2.	Review spreadsheets with computerized checks and/or quality check reports						
3.	Identify spreadsheet modifications that could provide additional controls or checks on quality						
4.	Other (specify):						
DATA DOCUMENTATION: QUALITY CHECKS							
5.	Check project file for completeness						
6.	Confirm that bibliographical data references are included (in spreadsheet) for every primary data element						
7.	Check that all appropriate citations from the spreadsheets appear in the *Inventory* document						
8.	Check that all citations in spreadsheets and inventory are complete (i.e., include all relevant information)						
9.	Randomly check bibliographical citations for transcription errors						
10.	Check that originals of new citations are in current docket submittal						
11.	Randomly check that the originals of citations (including *Contact Reports*) contain the material & content referenced						
12.	Check that assumptions and criteria for selection of activity data and emission factors are documented						
13.	Check that changes in data or methodology are documented						
14.	Check that citations in spreadsheets and inventory document conform to acceptable style guidelines						
15.	Other (specify):						
CALCULATING EMISSIONS AND CHECKING CALCULATIONS							
16.	Check that all emission calculations are included (i.e., emissions are not hard-wired)						

Checklist for Tier 1: Individual Source Category (abbreviation):

Item		Check Completed			Corrective Action		Supporting documents (provide reference)
		Date	Individual (first initial, last name)	Errors (Y/N)	Date	Individual (first initial, last name)	
17.	Check whether emission units, parameters, and conversion factors are inappropriately hardwired						
18.	Check if units are properly labeled and correctly carried through from beginning to end of calculation						
19.	Check that conversion factors are correct						
20.	Check that temporal and spatial adjustment factors are used correctly						
21.	Check the data relationships (comparability) and data processing steps (e.g., equations) in the spreadsheets						
22.	Check that spreadsheet input data and calculated data are clearly differentiated						
23.	Check a representative sample of calculations, by hand or electronically						
24.	Check some calculations with abbreviated calculations						
25.	Check the aggregation of data within a source category						
26.	When methods or data have changed, check consistency of time series inputs and calculations						
27.	Check for consistency with IPCC inventory guidelines and good practices, particularly if changes occur						
28.	Other (specify):						

A2. TIER 2 SOURCE CATEGORY CHECKLIST

Inventory Report: 1990-_____ Source Category:[1] _____

Key source category (or includes a key source sub-category): (Y / N)_____

Title(s) and Date(s) of Inventory Spreadsheet(s):_____

Source category estimates prepared by (name/affiliation): _____

GENERAL INSTRUCTIONS FOR COMPLETING THIS FORM:

Tier 2 checks focus on the data and methodology used for an individual source category. Not all Tier 2 checks occur each year; the specificity and frequency of Tier 2 checks will vary across source categories. The form may be completed by hand or electronically. Once completed, the form should be filed in the project file, with copies to the Data and Document Management Coordinator.

The first table on this form summarizes generally the results of the Tier 2 checks and highlights any significant findings or corrective actions. If appropriate actions—to correct any errors that are found or to follow up on the investigation—are not immediately apparent, the QC staff performing the check should discuss the results with the Agency Inventory Lead and the QA Officer.

The remaining pages in this form are lists of categories of checks to be performed or types of questions to be asked. PART A checks are designed to identify potential problems in the estimates, factors, and activity data. PART B checks focus on the quality of secondary data and direct emission measurement. The analyst has discretion over how the checks are implemented. Checks/rows that are not relevant or not available should indicate "n/r" or "n/a" (not be left blank or deleted). Rows for additional checks that are relevant to the source category should be added to the form. Additional information on the activities indicated on the form may be found in Chapter 2 *of the* QA/QC Manual*, and in the* IPCC Good Practice Guidance*.*

The column for supporting documentation should be used to reference any relevant Supplemental Reports (*Form A5) or* Contact Reports *(Form A4) that provide additional information. Other sources may be included here, if they can be clearly referenced. Note that, if a source-category specific QC plan has been developed and implemented, this Tier 2 form should still be completed. Any documents associated with the source-category specific plan should be clearly referenced in the column for supporting documentation.*

[1] Use the source category names in Table A-1 of this appendix.

Summary of All Tier 2 Activities
Individual Source Category (abbreviation):

Summary of results of checks and corrective actions taken:

Suggested Checks to be performed in the future:	Any residual problems after corrective actions are taken:

ADDITIONAL INSTRUCTIONS FOR PART A. The checklist below indicates the types of checks and comparisons that can be performed and is not intended to be exhaustive. Supplemental Reports, Contact Reports*, or other documents may be used to report detailed information on the checks conducted. For example, a* Supplemental *Report could provide information on the variables or sub-variables checked, comparisons made, conclusions that were drawn and rationale for conclusions, sources of information (published, unpublished, meetings, etc.) consulted, and corrective actions required.*

Checklist for Tier 2: Part A, Data Gathering and Selection
Individual Source Category (abbreviation):

Item	Check Completed			Corrective Action		Supporting documents (provide reference)
	Date	Individual (first initial, last name)	Errors (Y/N)	Date	Individual (first initial, last name)	
EMISSION DATA QUALITY CHECKS						
1. Emission comparisons: historical data for source, significant sub-source categories						
2. Order of magnitude checks						
3. Reference calculations						
4. Completeness checks (see Overall Inventory checklist, as well)						
5. Other (detailed checks)						
EMISSION FACTOR QUALITY CHECK						
6. Assess representativeness of emission factors, given national circumstances and analogous emissions data						
7. Search for options for more representative data?						
8. Other (detailed checks)						
ACTIVITY DATA QUALITY CHECK: NATIONAL LEVEL ACTIVITY DATA						
9. Check historical trends						
10. Compare multiple reference sources						
11. Check applicability of data						
12. Check methodology for filling in time series for data that are not available annually						
13. Other (detailed checks)						
ACTIVITY DATA QUALITY CHECK: SITE-SPECIFIC ACTIVITY DATA						
14. Inconsistencies across sites						
15. Compare aggregated and national data						
16. Other (detailed checks)						

ADDITIONAL INSTRUCTIONS FOR PART B. Completing the Tier 2 checks on secondary data and direct emission measurement may require consulting the primary data sources or authors. The checklist below is intended to be indicative, not exhaustive. Additional information on appropriate checks can be found both in Chapter 2 *of the* QA/QC Manual *and in the Source Category Chapters of the* IPCC Good Practice Report*.*

Additional documentation is likely to be necessary to record the specific actions taken to check the data underlying the source category estimates. For example, Supplemental Reports *may be needed to record the data or variables that were checked, and the published references and individuals or organizations consulted as part of the investigation.* Contact Reports *should be used to report the details of personal communications.* Supplemental Reports *may also be used to explain the rationale for a finding reported in the summary, the results of research into the QC procedures associated with a survey, or checks of site measurement procedures. Be sure to provide references to all supporting documentation.*

Checklist for Tier 2. Part B: Secondary Data and Direct Emission Measurement
Individual Source category (abbreviation):

Item		Check Completed			Corrective Action		Supporting documents (provide reference)
		Date	Individual (first initial, last name)	Errors (Y/N)	Date	Individual (first initial, last name)	
SECONDARY DATA: SAMPLE QUESTIONS REGARDING THE QUALITY OF INPUT DATA							
1.	Are QC activities conducted during the original preparation of the data (either as reported in published literature or as indicated by personal communications) consistent with and adequate when compared against (as a minimum), Tier 1 QC activities?						
2.	Does the statistical agency have a QA/QC plan that covers the preparation of the data?						
3.	For surveys, what sampling protocols were used and how recently were they reviewed?						
4.	For site-specific activity data, are any national or international standards applicable to the measurement of the data; if so, have they been employed?						
5.	Have uncertainties in the data been estimated and documented?						
6.	Have any limitations of the secondary data been identified and documented, such as biases or incomplete estimates? Have errors been found?						
7.	Have the secondary data undergone peer review and, if so, of what nature?						
8.	Other (detailed checks)						
DIRECT EMISSION MEASUREMENT: CHECKS ON PROCEDURES TO MEASURE EMISSIONS							
9.	Identify which variables rely on direct emission measurement						

10.	Check procedures used to measure emissions, including sampling procedures, equipment calibration and maintenance.						
11.	Identify whether standard procedures have been used, where they exist (such as IPCC methods or ISO standards).						
12.	Other (detailed checks)						

A3. SAMPLE DATA/REFERENCE TRACKING SHEET

This sample form illustrates a spreadsheet that can be developed to track the data sources used for each variable in the inventory from year to year. The particular citation, reference, contact person, form in which data is received, or other information is indicated for each variable. This tracking will be particularly useful for sources, such as CO_2 from fossil fuels, that have a large number of variables to be tracked. The spreadsheet can easily be expanded to include each new inventory year, and so is useful for tracking sources of data over time. In the sample, color- and pattern-coding in a cell is used to indicate, for the current inventory year, whether the analyst has received or is still waiting for data, or other "status" of the data. Note that the form is intended as a sample; at a minimum, the columns should be wider to accommodate the necessary data. Different formats may be needed to accommodate sources with different data characteristics.

Inventory Report: 1990-_____ Source Category:[1] _____

Key source category (or includes a key source sub-category): (Y / N)_____

Title(s) and Date(s) of Inventory Spreadsheet(s):_____

Source category estimates prepared by (name/affiliation): _____

Color key code

	No action yet taken
	Source investigated, but awaiting arrival or publication
	Source obtained
	Not obtained/needed

Spreadsheet Name	**Worksheet Name**	**Data needed (variable / parameter)**	**1998 data source**	**1999 data source**	**2000 data source**
Insert spreadsheet name	Insert name of worksheet within spreadsheet	Give name of data item on worksheet	Provide citation or individual	Provide citation or individual	Provide citation or individual

[1] Use the source category names in Table A-1 of this appendix.

Reference: CR-_____

A4. CONTACT REPORT

This form is to be used to record personal communications, including telephone conversations or meetings. It can also be used, as necessary, as a cover sheet for facsimile or e-mail communications.

To reference this form use CR-source abbreviation-date (month/day/year)-initials, for example CR-coal-7/6/01-KRJ*. The abbreviations to be used can be found in Table A-1.*

Date: _____ Originator _____

CONTACT BY : Telephone _____ Meeting _____ Other (specify) _____

Contact Name:
Title and Organization:
Phone number:
Fax number:
Address:
e-mail address:

Purpose and/or Subject of contact:

Attendees or participants in meeting/telephone conversation (name, affiliation):

Summary of meeting:

Recommended Follow-up Actions:

Reference: SR-_____

A5. SUPPLEMENTAL REPORT

This form is to be used as needed to provide additional documentation or explanation of QA/QC activities, and to supplement other checklists and forms that are completed. Among other uses, it can record information gathered from sources other than a personal communication (e.g., internet sites or published sources), describe in detail the results of an investigation, or be a cover page for other supporting documentation (such as a source category specific QA/QC plan).

To reference this form use SR-source abbreviation-date (month/day/year)-initials, for example SR-coal-7/6/01-KRJ*. The abbreviations to be used can be found in Table A-1.*

Date:	Source Category:
Subject:	
If part of another report, provide the report name and purpose of supplemental report: Example: Tier 2 secondary data checks for Nitric acid production; detailed checks on emission factors Example: Tier 1 checks for fossil fuel combustion; hand calculations to confirm specific computations.	
If not part of another report, provide purpose: Example: Additional documentation of changes in assumptions made and the rationale for changes.	
Sheet # __ of _____	Name, affiliation:

Discussion:

APPENDIX B

FORMS AND CHECKLISTS FOR CROSS-CUTTING QUALITY CONTROL

This appendix contains a number of suggested forms to accompany Chapter 3 of the QA/QC Manual. ***A table of source category names and abbreviations to be used in completing the forms is included as part of the front material to this appendix.***

The order in which the forms appear is:

The following table provides a list of source category names and abbreviations to be used when filling out the forms in this Appendix. Please use the entire source category name on the top of each form, and the abbreviations within the form and as the reference numbers for the *Contact Report* (Form B6) and *Supplemental Report* (Form B7). *Contact Reports* should be labeled with CR-source abbreviation-date (month/day/year), and the initials of the individual preparing the form; for example ***CR-coal-7/6/01-KRJ***. *Supplemental Reports* should be labeled with SR-source abbreviation-date (month/day/year), and the initials of the preparer; for example ***SR-coal-7/6/01-KRJ****. Reports that are not specific to a source category should use the abbreviation "cross", e.g.,* ***SR-cross-7/6/01-KRJ****. A suffix of a, b, etc. can be used to identify multiple reports prepared on the same day by the same individual.*

Table B-1. List of source category names and abbreviations

Chapter/Source	Abbreviation
Energy	
Carbon Dioxide Emissions from Fossil Fuel Combustion	FFC
Carbon Stored in Products from Non-Energy Uses of Fossil Fuels	Carbon Stored
Stationary Source Fossil Fuel Combustion (excluding CO_2)	Stationary
Mobile Source Fossil Fuel Combustion (excluding CO_2)	Mobile
Coal Mining	Coal
Natural Gas Systems	Natural Gas
Petroleum Systems	Petroleum
Natural Gas Flaring and Ambient Air Pollutants from Oil and Gas Activities	Flaring
International Bunker Fuels	Bunker
Wood Biomass and Ethanol Consumption	Biomass
Indirect CO_2 from CH_4 Oxidation	Indirect
Municipal Solid Waste Combustion	Waste
Industrial Processes	
Cement Manufacture	Cement
Lime Manufacture	Lime
Limestone and Dolomite Use	Limestone/dolomite
Soda Ash Manufacture and Consumption	Soda Ash
Carbon Dioxide Consumption	CO_2 Consumption
Iron and Steel Production	Iron and Steel
Ammonia Manufacture	NH_4
Ferroalloy Production	Ferroalloy
Petrochemical Production	Petrochemical
Silicon Carbide Production	SiC
Adipic Acid Production	Adipic
Nitric Acid Production	Nitric
Substitution of Ozone Depleting Substances	ODS
Aluminum Production (CO_2)	Aluminum (CO_2)
Aluminum Production (PFCs)	Aluminum (PFCs)
Titanium Dioxide Production	TItanium
HCFC-22 Production	HCFC-22
Semiconductor Manufacture	Semiconductor
Electrical Transmission and Distribution	ET&D
Magnesium Production and Processing	Mg
Industrial Sources of Ambient Air Pollutants	Indust. Ambient
Solvent Use	Solvent
Agriculture	
Enteric Fermentation	Enteric
Manure Management	Manure
Rice Cultivation	Rice
Agricultural Soil Management	Ag Soil
Agricultural Residue Burning	Ag Res
Land-Use Change and Forestry	
Changes in Forest Carbon Stocks	Forest Carbon

Chapter/Source	Abbreviation
Changes in Carbon Stocks in Urban Trees	Urban Carbon
Changes in Agricultural Soil Carbon Stocks	Ag Soil Carbon
Changes in Yard Trimming Carbon Stocks in Landfills	Landfill Carbon
Waste	
Landfills	Landfills
Wastewater Treatment	Wastewater
Human Sewage	Sewage
Waste Sources of Ambient Air Pollutants	Waste Ambient

B1. TIER 1: OVERALL INVENTORY AND CROSS-SOURCE CATEGORY CHECKLIST

Inventory Report: 1990-_____

Source Categories included in check: _____

_____

_____

Title(s) and Date(s) of Inventory Spreadsheet(s): _____

_____

Source category estimates prepared by (name/affiliation):_____

INSTRUCTIONS FOR COMPLETING THIS FORM:

This form is to be completed annually, and provides a record of the checks performed and any corrective actions taken. The form may be completed by hand or electronically. The checklist below should be completed as a record of the checks conducted. It should include information on the variables or sub-variables checked, comparisons made, conclusions that were drawn and rationale for conclusions, sources of information (published, unpublished, meetings, etc.) consulted, and corrective actions required. If appropriate actions to correct any errors that are found are not immediately apparent, the QC staff performing the check should discuss the results with the Agency Inventory Lead and the QA Officer. Once completed, the form should be filed in the project file, with copies to the Data and Document Management Coordinator. Additional information on the activities indicated on the form may be found in Chapter 3 of the QA/QC Manual.

The first page of this form summarizes the results of the checks (once completed) and highlights any significant findings or actions. The remaining pages in this form list categories of checks to be performed. The analyst has discretion over how the checks are implemented. Rows for additional checks that are relevant should be added to the form.

The column for supporting documentation should be used to reference any relevant Supplemental Reports *(Form B7) or* Contact Reports *(Form B6) providing additional information.*

Summary of Tier 1 Overall and Cross-Category Checks and Corrective Action
Summary of results of checks and corrective actions taken:

Suggested checks to be performed in the future:	Any residual problems after corrective actions are taken:

Detailed Checklist for Tier 1: Overall Inventory Quality and Cross-Source Categories

Item		Check Completed			Corrective Action		Supporting documents (provide reference)
		Date	Individual (first initial, last name)	Errors (Y/N)	Date	Individual (first initial, last name)	
CHECKING EMISSION CALCULATIONS ACROSS SOURCE CATEGORIES							
1.	Check that sources using same data inputs (e.g. animal population data) report comparable values (i.e., analogous in magnitude)						
2.	Check across source categories that same electronic data set is used for common data						
3.	Identify common parameters across source categories and check for consistency						
4.	Check that the number of significant digits or decimal places for common parameters, conversion factors, emission factors, or activity data is consistent across source categories						
5.	Check that total emissions are reported consistently (in terms of significant digits or decimal places) across source 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 source categories						
9.	Other (specify)						
COMPLETENESS							
10.	Check for completeness across source 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	Have file control procedures been followed?						
15.	Other (specify)						
OTHER							
12.	Specify						
13.	Specify						

14. Specify						

B2. SAMPLE MASTER TRACKING SHEET FOR INVENTORY

Most recent Inventory Report: 1990-_____

Tracking form prepared by (name/affiliation): _____

Date of most recent update: _____

INSTRUCTIONS FOR USING THIS TRACKING SHEET:

This sample form illustrates a spreadsheet that can be developed to track the status of the inventory spreadsheets and inventory document during the process of developing and updating the greenhouse gas inventory each year. The same form could be used to track either the inventory spreadsheets, or the text for the inventory document. In the example, each row represents a sector or source category. Columns should be self-explanatory. Note that the form below is intended as a sample; at a minimum, the columns should be wider to accommodate the necessary data. Different formats or columns may be used to reflect preferences of the Data and Document Management Coordinator or to accommodate changes in the methodological structure or organizational assignments of the inventory. The comment column can be used to record other relevant information, such as the cause of a delay, when new data supporting data is expected and from whom, when the revised document/estimates are expected, or dates on which revised drafts were submitted.

		Source Responsibilities						
Sector / Source Category	**Annex Included (letter)**	**EPA Staff**	**Contractor / Contact**	**Date due?**	**Delivered Date?**	**Expect mods?**	**Current Owner?**	**Comments**
Give sector & source category name	Give letter of relevant annex, if any	Lead at EPA for source category	Contractor involved in analysis, or other contact	Date that first draft was due	Date of most recent draft	Y/N—whether modifications to latest draft are expected	Who has the original spreadsheet or text, currently	Any other important information

B3. INVENTORY DOCUMENT CHECKLIST
Part A: MSWord Document

Inventory Report: 1990-_____ Stage of Document: _____

Circle all categories of checks conducted: Front Section, Tables & Figures, Equations,

References, General Editing, Editing for Content

INSTRUCTIONS FOR COMPLETING THIS FORM:

This form is to be completed annually, and provides a record of the checks performed and any corrective actions taken. The form may be completed by hand or electronically. The checklist below should be completed as a record of the checks conducted. If appropriate actions to correct any errors that are found are not immediately apparent, the QC staff performing the check should discuss the results with the Agency Inventory Lead and the QA Officer. Once completed, the form should be filed in the project file, with copies to the Data and Document Management Coordinator. Additional information on the activities indicated on the form may be found in Chapter 3 of the QA/QC Manual.

The first page of this form summarizes the results of the checks (once completed) and highlights any significant findings or actions. The remaining pages in this form list categories of checks to be performed. The analyst has discretion over how the checks are implemented. Rows for additional checks that are relevant should be added to the form.

The column for supporting documentation should be used to reference any relevant Supplemental Reports *(Form B7) or* Contact Reports *(Form B6) providing additional information.*

Summary of Document Check

Summary of results of checks and corrective actions taken:

Suggested checks to be performed in the future:	Any residual problems after corrective actions are taken:

Detailed Checklist for Inventory Document

Item		Check Completed			Corrective Action		Supporting documents (provide reference)
		Date	Individual (first initial, last name)	Errors (Y/N)	Date	Individual (first initial, last name)	
FRONT SECTION							
1.	Cover page has correct date, title, and contact address						
2.	Document number listed on title page						
3.	Correct footer on every section (draft/date, correct Inventory title, page numbers)						
4.	Tables of contents/tables/figures are accurate: titles match document, page #s match; numbers run consecutively and have correct punctuation						
5.	The Executive Summary and Introduction are updated with appropriate years and discussion of trends						
TABLES AND FIGURES							
6.	All numbers in tables match numbers in spreadsheets						
6a.	All numbers in tables match in the Executive Summary						
6b.	All numbers in tables match in the Changes Section						
6c.	All numbers in tables match in the Introduction						
6d.	All numbers in tables match in the Energy Chapter						
6e.	All numbers in tables match in the Industrial Processes Chapter						
6f.	All numbers in tables match in the Solvent Use Chapter						
6g.	All numbers in tables match in the Agriculture Chapter						
6h.	All numbers in tables match in the LUCF Chapter						
6i.	All numbers in tables match in the Waster Chapter						
6j.	All numbers in tables match in the Annexes						
7.	Check that all tables have correct number of significant digits (1 decimal for Tg. CO_2 Eq., 0 decimals for Gg)						
8.	Check alignment in columns and labels						
9.	Check all symbols in tables (“+”)						
10.	Check bold in tables						
11.	Table formatting is consistent						

Detailed Checklist for Inventory Document

Item		Check Completed			Corrective Action		Supporting documents (provide reference)
		Date	Individual (first initial, last name)	Errors (Y/N)	Date	Individual (first initial, last name)	
12.	Check that all figures are updated with new data and referenced in the text						
13.	Check table and figure titles for accuracy and consistency with content						
14.	Include all figures with drafts (they are in separate file)						
EQUATIONS-SHOULD ALL HAVE THE FOLLOWING TRAITS							
15.	Equation as follows: (hard return) x + y = z						
16.	Use times symbol (×), not the letter x or the * symbol						
17.	Equation centered						
18.	Following the equation use: where, (return) (definition of variables)						
19.	Definition of variables are indented and in Table Text style (and first word capitalized)						
REFERENCES							
20	Check consistency of references used in multiple sections (e.g., IPCC Guidance not IPCC Guidelines)						
21.	In text, citations and references match						
22.	Style of references is consistent						
23.	Use of a,b,c is consistent for same author and year references						
24.	Web addresses should not be hyperlinks, should be enclosed with <> and not hyperlinked or underlined (<www.epa.gov>)						
GENERAL FORMAT							
25.	All acronyms are spelled out first time and not subsequent times throughout each chapter						
26.	All dashes are the same–use insert symbol to insert a long “em” dash (—)						
27.	All fonts in text, headings, and subheadings are consistent						
28.	All headers/titles are consistent						
29.	All highlighting, notes, and comments are removed from document						
30.	Annex referencing in text matches correct Annex letters						

Detailed Checklist for Inventory Document

Item		Check Completed			Corrective Action		Supporting documents (provide reference)
		Date	Individual (first initial, last name)	Errors (Y/N)	Date	Individual (first initial, last name)	
30.	Autonumbering for tables and figures sometimes inserts hard return, check all table citations and fix						
31.	Heading formats are used appropriately						
32.	All gases, such as CO_2 and N_2O use the letter "O" rather than the number "0"						
33.	All occurrences of "percent" are spelled out, not % (except in tables)						
34.	All numbers that should be subscripted are subscripted (e.g., CO_2, SF_6, CH_4, N_2O, etc.)						
35.	No comma in citations (IPCC, 2000)						
36.	No periods in "Washington, DC"						
37.	Notes under tables should be in smaller font than text of document						
38.	Number of decimal points used in the text is consistent (0 for Gg, 1 for Tg CO_2 equivalent).						
39.	Section breaks: (1) Each section starts on right-hand (i.e., "odd") side (2) All sections in landscape move to and from landscape properly						
40.	Size, style, and indenting of bullets are consistent						
41.	Spaces–two after a period, one everywhere else						
42.	Spelling check is complete						
43.	Table/figure/box numbering and referencing in text is correct						
445.	U. S. is spelled out 'in the United States' and abbreviated 'U.S. emissions'						
OTHER ISSUES							
45.	All numbers in text match tables						
46.	Each section is updated with current year						
47.	In discussion of "Recent Trends in U.S. Greenhouse Gas Emissions," all years and explanations are updated						
48.	Other (specify)						
49.	Other (specify)						
50.	Other (specify)						

B4. INVENTORY DOCUMENT CHECKLIST
Part B: Pagemaker Document

Inventory Report: 1990-_____ Stage of Document: _____

Circle all categories of checks conducted: Front Section, Tables & Figures, Equations,

References, General Editing, Editing for Content

INSTRUCTIONS FOR COMPLETING THIS FORM:

This form is to be completed annually, and provides a record of the checks performed and any corrective actions taken. The form may be completed by hand or electronically. The checklist below should be completed as a record of the checks conducted. If appropriate actions to correct any errors that are found are not immediately apparent, the QC staff performing the check should discuss the results with the Agency Inventory Lead and the QA Officer. Once completed, the form should be filed in the project file, with copies to the Data and Document Management Coordinator. Additional information on the activities indicated on the form may be found in Chapter 3 of the QA/QC Manual.

The first page of this form summarizes the results of the checks (once completed) and highlights any significant findings or actions. The remaining pages in this form list categories of checks to be performed. The analyst has discretion over how the checks are implemented. Rows for additional checks that are relevant should be added to the form.

The column for supporting documentation should be used to reference any relevant Supplemental Reports *(Form B7) or* Contact Reports *(Form B6) providing additional information.*

Summary of Inventory Document Check: Pagemaker Document

Summary of results of checks and corrective actions taken:

Suggested checks to be performed in the future:	Any residual problems after corrective actions are taken:

Detailed Checklist for Inventory Document

Item		Check Completed			Corrective Action		Supporting documents (provide reference)
		Date	Individual (first initial, last name)	Errors (Y/N)	Date	Individual (first initial, last name)	
FRONT SECTION							
1.	Cover page has correct date, title, and contact address						
2.	Cover has EPA logo and photo is positioned correctly, not too dark or light, not jagged						
3.	Document number listed on title page						
4.	Correct footer on every section (correct Inventory title and page number)						
5.	Footer should be in color						
6.	Table of contents/tables/figures etc. is accurate						
TABLES AND FIGURES							
7.	Check alignment in columns and tables						
8.	Check all symbols in tables ("+")						
9.	Check bold in tables						
10.	All line widths are consistent in tables						
11.	All column widths are consistent in tables						
12.	Table formatting is consistent						
13.	All figures have been inserted into text and are accurate (correct proportions, etc.)						
EQUATIONS-SHOULD ALL HAVE THE FOLLOWING TRAITS							
14.	Equation as follows: (hard return) x + y = z						
15.	Equation centered						
GENERAL FORMAT							
16.	All dashes are the same–use insert symbol.						
17.	All fonts are consistent						
18.	All headers/titles are consistent						
19.	All numbers that should be subscripted are (CO_2, SF_6, CH_4, N_2O, etc.)						
20	Notes under tables should be in smaller font than text of document						
21.	All sections in Landscape go to and from landscape properly						
22.	Size and style of bullets is consistent						
23.	Spaces–two after a period, one everywhere else						

Detailed Checklist for Inventory Document

Item		Check Completed			Corrective Action		Supporting documents (provide reference)
		Date	Individual (first initial, last name)	Errors (Y/N)	Date	Individual (first initial, last name)	
24.	No widows/orphans in document						
25.	Fractions are formatted correctly						
OTHER ISSUES							
25.	Bookmarks are correct and function properly						
26.	The entire document has been scanned for any erroneous looking items or data that may have been altered during the software transition						
27.	Other (specify)						
28.	Other (specify)						
29.	Other (specify)						

B5. COMMON REPORTING FORMAT CHECKLIST

Inventory Report: 1990- _____ Stage of CRF: _____

Circle all categories of checks conducted: Data checks, Formatting checks, Pre-printing checks

INSTRUCTIONS FOR COMPLETING THIS FORM:

This form is to be completed annually, and provides a record of the checks performed and any corrective actions taken. The form may be completed by hand or electronically. The checklist below should be completed as a record of the checks conducted. If appropriate actions to correct any errors that are found are not immediately apparent, the QC staff performing the check should discuss the results with the Agency Inventory Lead and the QA Officer. Once completed, the form should be filed in the project file, with copies to the Data and Document Management Coordinator. Additional information on the activities indicated on the form may be found in Chapter 3 of the QA/QC Manual.

The first page of this form summarizes the results of the checks (once completed) and highlights any significant findings or actions. The remaining pages in this form list categories of checks to be performed. The analyst has discretion over how the checks are implemented. Rows for additional checks that are relevant should be added to the form.

The column for supporting documentation should be used to reference any relevant Supplemental Reports *(Form B6) or* Contact Reports *(Form B6) providing additional information.*

Summary of CRF Check
Summary of results of checks and corrective actions taken:

Suggested checks to be performed in the future:	Any residual problems after corrective actions are taken:

Detailed Checklist for Common Reporting Format Tables (note: that all checks should be done for each CRF year)

Item		Check Completed			Corrective Action		Supporting documents (provide reference)
		Date	Individual (first initial, last name)	Errors (Y/N)	Date	Individual (first initial, last name)	
Data Checks							
1.	Create an Excel sheet to check emissions and consumption from each chapter, each gas, and overall totals. Ensure that CRF data and emissions match totals in Summary spreadsheet. Note: if totals are inconsistent, work from broad to specific categories to locate the error.						
2.	Make sure all duplicate data is linked to the same source or each other (e.g., aluminum production)						
3.	Make sure all of the links go to the most recent spreadsheets and the correct year on the Data and Document Coordinator's computer						
4.	Ensure all "business sensitive" information is appropriately hidden (ODS substitutes, industrial activity data)						
5.	Make sure potential emissions are larger than actual emissions						
6.	Check that IE, NA, NO, and NE are used appropriately (refer to CRF instructions for definitions)						
7.	Make sure the explanations for IE and NE are filled out (Table 9)						
8.	Make sure all changes from the previous year's submittal are explained in Table 8						
9.	Check the Reference Approach separately						
10.	Make sure all units are correct within the CRF sheets (they often need to be converted from Inventory units) Example - Activity data for primary aluminum production is requested in units of kilotons in Table 2(I).A-Gs2, but is requested in units of tons in Table 2(II).C,E						
11.	Make sure no cells are blank unless instructed by the IPCC						
12.	Make sure SO_2 is entered the same in both Table 6, cell H21 and Summary1As2, cell Q8						
Formatting Checks							
13.	Make sure "Sheet 1" has correct information for current Inventory year						

Detailed Checklist for Common Reporting Format Tables (note: that all checks should be done for each CRF year)

Item		Check Completed			Corrective Action		Supporting documents (provide reference)
		Date	Individual (first initial, last name)	Errors (Y/N)	Date	Individual (first initial, last name)	
14.	Check range names to make sure they did not get changed (especially in documentation boxes and areas where rows were inserted)						
15.	Check all table borders						
16.	Make sure that text fits in all documentation boxes, or increase size						
17.	Check the widths on Tables 8 and 9 to make sure all text is visible						
Other Checks Before Printing/Submitting							
18.	Make sure contact information is current						
19.	Cut all links and delete all comments that have been inserted. Check to see if the Macro that performs this function changed any formatting, especially in areas where rows were inserted.						
20.	Fill out the last table (Table 11)						

Reference: CR-_____

B6. CONTACT REPORT

This form is to be used to record personal communications, including telephone conversations or meetings. It can also be used, as necessary, as a cover sheet for facsimile or e-mail communications.

To reference this form use CR-source abbreviation-date (month/day/year)-initials, for example CR-coal-7/6/01-KRJ. The abbreviations to be used can be found in Table B-1.

Date: _____ Originator _____

CONTACT BY : Telephone _____ Meeting _____ Other (specify) _____

Contact Name:
Title and Organization: Phone number:
Fax number: Address: e-mail address:

Purpose and/or Subject of contact:

Attendees or participants in meeting/telephone conversation (name, affiliation):

Summary of meeting:

Recommended Follow-up Actions:

Reference: SR-_____

B7. SUPPLEMENTAL REPORT

This form is to be used as needed to provide additional documentation or explanation of QA/QC activities, and to supplement other checklists and forms that are completed. Among other uses, it can record information gathered from sources other than a personal communication (e.g., internet sites or published sources), describe in detail the results of an investigation, or be a cover page for other supporting documentation (such as a source category specific QA/QC plan).

To reference this form use SR-source abbreviation-date (month/day/year)-initials, for example SR-coal-7/6/01-KRJ. The abbreviations to be used can be found in Table B-1.

Date:	Source Category:
Subject:	
If part of another report, provide the report name and purpose of supplemental report: Example: Tier 2 secondary data checks for Nitric acid production; detailed checks on emission factors Example: Tier 1 checks for fossil fuel combustion; hand calculations to confirm specific computations.	
If not part of another report, provide purpose: Example: Additional documentation of changes in assumptions made and the rationale for changes.	
Sheet # __ of _____	Name, affiliation:

Discussion:

APPENDIX C

FORMS FOR REVIEW PROCESSES

C1. EXPERT REVIEW PROCESS:
DOCUMENTATION OF EXPERTS' QUALIFICATIONS
(Note same form used for both estimates and the inventory document)

C2. REVIEWER TRACKING FORM

Note: this form may be used for both expert and public review periods

C1. EXPERT REVIEW PROCESS: DOCUMENTATION OF EXPERTS' QUALIFICATIONS

Name:
Title and Organization:
Phone number:
Fax number:
Address:
e-mail address:

Area of expertise:

Summarize prior experience reviewing or developing the U.S. greenhouse gas emissions inventory:

Summary bio information (indicate whether resume is attached)

Recommended by (include names and contact information for recommendations)

Above information reviewed by (name/affiliation): _____

_____ Date: _____

Approved for: initial draft estimates: _____ for inventory document: _____

C2. REVIEWER TRACKING FORM

Inventory Report: 1990-_____ Review (circle one): Expert or Public

Tracking form prepared by (name/affiliation): _____

This sample form illustrates a spreadsheet that can be developed to track the status of each reviewer and each comment received. The same form could be used to track comments either from the expert review or the public review period. In the example, each row represents one comment. Columns should be self-explanatory. Note that the form below is intended as a sample; at a minimum, the columns should be wider to accommodate the necessary data. Different formats or columns may be used to reflect preferences of the Data and Document Management Coordinator.

Reviewer	**Review Draft Sent Out**	**Comments Received**	**Contact information**	**Comments**	**Inventory Lead**	**Comment Addressed**
Full name of Reviewer	Y/N—if reviewer was sent a draft inventory	Y/N—if reviewer commented on the draft inventory	All current information for the reviewer, including title, affiliation, address, phone, fax, and e-mail (can use separate columns for each)	One row for each comment received	Name of person responsible for addressing each comment	Why or why not and how comment was addressed

APPENDIX D

TEMPLATES AND FORMS FOR UNCERTAINTY ANALYSIS

This appendix contains a number of templates and forms to accompany Chapter 5 of the *QA/QC Manual*. The templates/forms can be completed manually or electronically. Note that, if the templates/forms are completed manually, it may be necessary to re-size the boxes and other cells with sufficient space (to allow entering all the relevant information). It also may be necessary to replicate some sections (to facilitate recording the relevant information for all the component disaggregate variables of each inventory variable, as appropriate) before printing and completing the templates/forms.

A table of source category names and abbreviations to be used in completing the templates/forms is included as part of the front material to this appendix.

The order in which the templates/forms appear is:

D1. UNCERTAINTY DATA COLLECTION AND ASSESSMENT FORM

D2. PRE-ELICITATION PREPARATION TEMPLATE

D3. ELICITATION TEMPLATE

D4. SUMMARY OF UNCERTAINTY INPUTS AND DOCUMENTATION FORM

D5. UNCERTAINTY ANALYSIS RESULTS FORM

D6. CONTACT REPORT

D7. SUPPLEMENTAL REPORT

The following table provides a list of source category names and abbreviations to be used when filling out the forms in this Appendix. Please use the entire source category name on the top of each form, and the abbreviations within the form and as the reference numbers for the Contact Report *(Form D6) and* Supplemental Report *(Form D7).* Contact Reports *should be labeled with CR-source abbreviation-date (month/day/year), and the initials of the individual preparing the form; for example* ***CR-coal-7/6/01-KRJ****.* Supplemental Reports *should be labeled with SR-source abbreviation-date (month/day/year), and the initials of the preparer; for example* ***SR-coal-7/6/01-KRJ****. A suffix of a, b, etc. can be used to identify multiple reports prepared on the same day by the same individual.*

Table D-1. List of source category names and abbreviations

Chapter/Source	Abbreviation
Energy	
Carbon Dioxide Emissions from Fossil Fuel Combustion	FFC
Carbon Stored in Products from Non-Energy Uses of Fossil Fuels	Carbon Stored
Stationary Source Fossil Fuel Combustion (excluding CO_2)	Stationary
Mobile Source Fossil Fuel Combustion (excluding CO_2)	Mobile
Coal Mining	Coal
Natural Gas Systems	Natural Gas
Petroleum Systems	Petroleum
Natural Gas Flaring and Ambient Air Pollutants from Oil and Gas Activities	Flaring
International Bunker Fuels	Bunker
Wood Biomass and Ethanol Consumption	Biomass
Indirect CO_2 from CH_4 Oxidation	Indirect
Municipal Solid Waste Combustion	Waste
Industrial Processes	
Cement Manufacture	Cement
Lime Manufacture	Lime
Limestone and Dolomite Use	Limestone/dolomite
Soda Ash Manufacture and Consumption	Soda Ash
Carbon Dioxide Consumption	CO_2 Consumption
Iron and Steel Production	Iron and Steel
Ammonia Manufacture	NH_4
Ferroalloy Production	Ferroalloy
Petrochemical Production	Petrochemical
Silicon Carbide Production	SiC
Adipic Acid Production	Adipic
Nitric Acid Production	Nitric
Substitution of Ozone Depleting Substances	ODS
Aluminum Production (CO_2)	Aluminum (CO_2)
Aluminum Production (PFCs)	Aluminum (PFCs)
Titanium Dioxide Production	TItanium
HCFC-22 Production	HCFC-22
Semiconductor Manufacture	Semiconductor
Electrical Transmission and Distribution	ET&D
Magnesium Production and Processing	Mg
Industrial Sources of Ambient Air Pollutants	Indust. Ambient
Solvent Use	Solvent
Agriculture	
Enteric Fermentation	Enteric
Manure Management	Manure
Rice Cultivation	Rice
Agricultural Soil Management	Ag Soil
Agricultural Residue Burning	Ag Res
Land-Use Change and Forestry	
Changes in Forest Carbon Stocks	Forest Carbon

Chapter/Source	Abbreviation
Changes in Carbon Stocks in Urban Trees	Urban Carbon
Changes in Agricultural Soil Carbon Stocks	Ag Soil Carbon
Changes in Yard Trimming Carbon Stocks in Landfills	Landfill Carbon
Waste	
Landfills	Landfills
Wastewater Treatment	Wastewater
Human Sewage	Sewage
Waste Sources of Criteria Pollutants	Waste Ambient

D1. UNCERTAINTY DATA COLLECTION AND ASSESSMENT FORM

Inventory Report: 1990-_____ Source Category:[1] _____

Applicable Sub-source Category: _____

Variable Name: _____

Inventory analyst (name/affiliation) completing this form: _____

_____

Uncertainty staff (name/affiliation) completing this form: _____

_____

GENERAL INSTRUCTIONS FOR COMPLETING THIS FORM:

This form is for recording uncertainty-related data for each variable (as appropriate) used to estimate emissions for a source category. This form is to be completed periodically, and provides a record of the data and information available for developing the uncertainty analysis. A copy of this form should be completed for each variable in the inventory. Source category staff should complete Parts A, B, and F of the form. Uncertainty staff should assess the data recorded in Parts A and B and should complete Parts C, D, and E (and F, if applicable) of the form. The template may be completed by hand or electronically. Once completed, the template should be filed in a project file by the uncertainty staff and included in the annual docket. As relevant, copies may be provided to Source Category Leads or the Agency Inventory Lead for follow-up.

When completed, this form will facilitate developing a complete set of the uncertainty data required for performing uncertainty analysis in two ways. For some variables, the necessary data (such as standard deviation and other statistical data) will be available in the published literature or unpublished background documents obtained from data suppliers. For other variables—those for which less information is readily available—completing the form will facilitate identifying those variables for which uncertainty data need to be supplemented through information collected by alternative means, such as informal interview, expert elicitation or additional contacts with the supplier of the primary data used in inventory estimation.

The form should be used the first time an uncertainty analysis is performed for a source category. It should be updated each time the uncertainty analysis is revisited, when input data or inventory methodologies change for the source category or sub-source category, when new information on the statistical characteristics of the input data is obtained, or any time changes occur that affect the uncertainty analysis.

Statistical data will often be collected at a disaggregated level, i.e., for each component of the variable (which is often referred to as "disaggregate variable"). Therefore, it will be necessary to replicate and complete Parts B, C, D, and E for each disaggregate variable that has its own statistical properties. For example, if a variable has data for each of five regions, each region's data comprises a "disaggregate" variable. Uncertainty data on the characteristics of the variable must be collected for each of the five disaggregate variables, i.e., for each of five regions. Thus, Parts B, C, D, and E must be replicated five times.

The column for supporting documentation should be used to reference any relevant Supplemental Reports *(D7) or* Contact Reports *(D6) providing additional information. Complete citations of the documents from which the published uncertainty-related data were collected should be recorded in Part F of this form by either the inventory analyst or the uncertainty staff, as appropriate. Additional information on preparing this template can be found in Chapter 5 of the* QA/QC Manual*.*

[1] Use the source category names in Table D-1 of this appendix.

ADDITIONAL INSTRUCTIONS FOR COMPLETING PART A. The following table is for recording the levels of disaggregation at which the inventory data and the uncertainty data are collected (i.e., whether the inventory and the uncertainty estimates are developed at the national level, regional level, sectoral level, etc.). The appropriate level of disaggregation for collecting uncertainty data is the same level of disaggregation adopted for inventory estimation. However, the level of disaggregation at which uncertainty data are reported for a variable may differ from the level of disaggregation adopted for inventory estimation.

For example, if cow population data are reported by each state based on a state's own data collection and estimation methodology, a separate set of uncertainty data for each state's cow population data may be available. However, if the data were collected by national or regional agencies using the same type of survey instrument and methodology, the uncertainty data may only be available at the national or regional level.

Therefore, the inventory analyst should collect uncertainty data for variables at the levels of aggregation at which they are reported. In some cases, published uncertainty data, along with the methodological information, can be collected from the publication from which data for inventory estimates are collected.

Uncertainty Data Collection and Assessment: Part A, Level of Disaggregation

Specify if the inventory data for this variable are collected at the national, regional, sectoral, industry, state, county or other (specify) level	
For how many regions, sectors, or groupings are inventory data available? **For example, if the inventory data for the U.S. pig population are collected by state (and if the data are collected only from 48 states), the total number of groupings is 48.**	
Specify if the uncertainty data for this variable are collected at the national, regional, sectoral, industry-, state-, county- or other (specify) level.	
For how many regions, sectors, or groupings are uncertainty data available? **For example, if uncertainty data for the U.S. pig population are reported at the regional level for each of all five regions, the total number of groupings in this case is 5.**	

ADDITIONAL INSTRUCTIONS FOR PART B. The data requested in this part should be obtained or collected at the same time that the data for the inventory are collected each inventory cycle. Part B contains 5 tables. All tables in this part are to be completed for each disaggregate variable (see Part A) for which uncertainty data are collected from readily available (generally published) sources. Any cells that are not relevant or for which data are unavailable should indicate "n/r" or "n/a," respectively (not be left blank or deleted). Replicate Part B for each disaggregate variable.

Uncertainty Data Collection and Assessment: Part B, Published and Unpublished Readily Available Uncertainty Data

Name of the variable, including its disaggregate (e.g., U.S. pig population, for a variable that is not disaggregated; or cow population – Southern U.S., for a variable that is disaggregated)	
Sequential variable number (e.g., "1 of 1" if the variable is not disaggregated, and "1 of 4", if this is the first of four disaggregate variables):	
Estimated value in the inventory. Indicate the appropriate unit of measurement, such as million barrels, 1,000 cubic feet, or percentage.	

B1. Probability Distribution Function

The following table is to be used to record the probability distribution function of the disaggregate inventory variable. In some instances, information on the probability distribution of a variable (or disaggregate variable) may have been reported explicitly in a study. Based on the information available, check the appropriate cell and cite the reference in the table below.

Type of Probability Distribution	Check Below	Cite Reference (include table and/or page number, as appropriate) (E.g., Table 2-1, EPA 2000; p.68, EIA 2001; Johnson & Kent 1999)
No information available		
Normal		
Lognormal		
Uniform		
Triangular		
Other Specify:		

B2. Average Values

The following table is to be used to enter the quantitative estimates of the measures of central tendency of the distribution of the inventory variable. In some cases, more than one type of these average values may be available. All those available values should be reported here.

Average Value	Quantitative Estimates (include appropriate unit of measurement) (E.g., ± 2% or 22.5 million acres)	Cite Reference (include table and/or page number, as appropriate) (E.g., Table 2-1, EPA 2000; p.68, EIA 2001b)
No information available		
Arithmetic Mean		
Median (50th percentile)		
Mode		
Geometric Mean		
Other Specify:		

B3. Data Variability and Correlation

Quantitative measures of variability related to the inventory variable may be reported in publications using several different terminologies. Some of the most commonly used terminologies are listed in the table below.[1] Quantitative estimates may have been reported in published literature or unpublished documents for one or more of these terms. For example, quantitative estimates may be reported for the standard deviation, variance, and coefficient of variation—all available estimates should be reported here. Enter the appropriate measure of variability as reported in the published or unpublished documents in the table below. Enter the term as reported in the document. In addition, also report available information on correlation between pairs of variables. No interpretation of these data is required at this time, unless otherwise explicitly asked to do so.

Type of Data	Check Below	Quantitative Estimates[1] (include appropriate unit of measurement) (E.g., 2% or 22.5 million acres)	Associated Confidence Intervals / Probability levels (e.g., 0%, 5%, 10%, 90%, 95%, 99%, 100% or unknown)[2]	Cite References (include table and/or page number, as appropriate) (E.g., Table 2-1, EPA 2000; p.163, Johnson and Kent 1999)[3]	Cite Supporting Documents (i.e., reference #s for Supplemental and Contact Reports)
Data not available					
Confidence Interval (uncertainty interval)					
Sampling Error (or sampling uncertainty)					
Estimation Error					
Statistical Error					
Standard Error					
Standard Deviation					
Variance					
Coefficient of Variation (put % in quantitative estimates column, if it is expressed in %)					
Geometric Standard Deviation					
Lower-bound Estimate (or the realistic minimum value) of the variable					
Upper-bound Estimate (or the realistic maximum value) of the variable					
Estimate of Bias (include the direction of bias as positive, negative, or unknown, using "+" or "-" sign or "unknown", respectively, along with the estimate in the "Quantitative Estimates" column)					
Other Specify:					

[1] While two or more of these terms may be identical in terms of their statistical meaning, others may be more unique. Refer to any introductory or intermediate statistical text book for definitions of these terms. While a good understanding of these different terms will be helpful, it is not required for completing this form.

Type of Data	Check Below	Quantitative Estimates[1] (include appropriate unit of measurement) (E.g., 2% or 22.5 million acres)	Associated Confidence Intervals / Probability levels (e.g., 0%, 5%, 10%, 90%, 95%, 99%, 100% or unknown)[2]	Cite References (include table and/or page number, as appropriate) (E.g., Table 2-1, EPA 2000; p.163, Johnson and Kent 1999)[3]	Cite Supporting Documents (i.e., reference #s for Supplemental and Contact Reports)
Estimates of Correlation (specify the quantitative estimates or direction of correlation coefficients with the "+" or"-" sign as appropriate, for each pairs of correlated inventory variables, with source category names in parentheses) **E.g., Yearling population (Enteric) and Weanling population (Enteric) (+0.8):**					

[1] If a publication reports an interval such as "40 tons ± 5%", it is necessary to find out what the 5% represents, and clarify the information while reporting it. For example, if 5% refers to 5% of 40 tons, enter the interval in the appropriate row as, "40 tons ± 5% of 40 tons."

[2] For the realistic minimum or maximum values, enter the associated cumulative probability levels, such as 2.5%, 5%, or 10% for the realistic minimum value and 90%, 95%, or 97.5% for the realistic maximum value. For example, if the paper gives a 95% confidence level, enter 2.5% cumulative probability level for lower-bound and 97.5% cumulative probability level for upper-bound. Similarly, if the paper gives a 90% confidence level, enter 5% cumulative probability level for lower-bound and 95% cumulative probability level for upper-bound. If the lower- and upper-bound values are certain, enter 0% and 100% as the cumulative probability levels for the lower- and upper-bound, respectively.

[3] If two or more reports or publications produced by an agency or written by the same author(s) in a particular year were referred for collecting these data, differentiate them in the reference citation by adding a sequential lower case alphabetical letter, beginning with "a", at the end of the year of publication (E.g., Table 5-3, NOAA 2000a; and p.145, NOAA 2000b). Full details of each of these citations must be included in the Reference Portion of this form.

B4. Uncertainty Data Estimation Methodology

The uncertainty data may have been estimated in several ways, such as through statistical analysis or expert judgment. Briefly summarize the estimation methodology as described in the publication in the following table. Photocopy the relevant pages of the document, attach the pages to a supplemental report, and also cite the report in the following table.

Briefly summarize the uncertainty data estimation methodology (as described in the document from which uncertainty data were obtained and/or from another appropriate related document) **If no details are available, state so.**	
Cite references (include table and/or page number, as appropriate) **(E.g., Table 2-1, EPA 2000; p.68, EIA 2001; Johnson & Kent 1999)**	

B5. Inventory Data Particulars

This part is to be completed to briefly summarize the data collection and estimation methodology of the inventory variable to facilitate future inference of the underlying characteristics of the inventory data. In many instances, information on the probability density function and certain other uncertainty-related characteristics of the inventory variable (or disaggregate variable) such as confidence intervals might not be reported. Such information may need to be inferred from other information on the characteristics of the inventory data (such as the type of the inventory data, and data collection, estimation, or extrapolation methodology). For example, some data may have been collected using sample or census survey; whereas, others may have been extrapolated based on selected case studies or limited survey data, or derived through laboratory experiments. The confidence intervals of these data may differ based on these methodologies. Similarly, details on the data characteristics of a variable may also facilitate in determining the underlying probability density function of that variable.

In general, details on the characteristics of inventory variable are reported in the data collection and/or estimation methodology, statistical analysis, data analysis, survey methodology, and/or Quality Assurance and Quality Control (QA/QC) sections of the publication from which inventory data are collected.

Briefly summarize the data collection, estimation, and extrapolation methodology for the inventory variable (as described in the document from which the inventory data were collected and/or from another appropriate related document) **If no details are available, state so.**	
Cite References (include table and/or page number, as appropriate) **(E.g., Table 2-1, EPA 2000a; p.68, EIA 2001; Johnson & Kent 1999)**	

ADDITIONAL INSTRUCTIONS FOR PART C. Part C is to be completed for each disaggregate variable (see Part A) after uncertainty analysts review the uncertainty-related information collected and reported in Parts A and B of this form by the inventory analyst. Do not delete any cells or rows. Replicate Part C for each disaggregate variable, as needed.

The purpose of Part C is to assess whether the quantitative estimates reported in Part B of this form are complete and sufficient for the purposes of uncertainty analysis, and to determine next steps for rectifying any data deficiencies. Part C1 should be used to identify data deficiencies and discrepancies. Part C2 should be used to report uncertainty staff suggestions for possible methods that could be used to rectify the deficiencies, and to describe the next steps, or follow-up actions, that relevant staff (such as the uncertainty staff) should undertake, after consultation with the Agency Inventory Lead and the Source Category Lead (or designate). See also Chapter 5 of the Procedures Manual.

Uncertainty Data Collection and Assessment:
Part C, Uncertainty Data Assessment

Name of the variable, including its disaggregate (e.g., U.S. pig population, for a variable that is not disaggregated; or cow population – Southern U.S., for a variable that is disaggregated):	
Sequential variable number (e.g., "1 of 1" if the variable is not disaggregated, and "1 of 4", if this is the first of four disaggregate variables):	
Estimated value in the inventory (Indicate the appropriate unit of measurement, such as million barrels, 1,000 cubic feet, or percentage):	

C1. Uncertainty Data Assessment Summary

Evaluate whether the uncertainty data collected from published sources by the inventory staff are complete and consistent, and explain the associated data deficiencies and discrepancies, if any, in the table below.

Data Evaluation Element	YES / NO	Description of the Associated Data Deficiencies / Discrepancies
Is the probability distribution of this variable fully and uniquely specified? **Specify YES / NO**		
Are data on all the necessary uncertainty components available for this (disaggregate) variable for purposes of uncertainty analysis? **Specify YES / NO**		
If multiple parameters are provided, are these values consistent? **Specify YES / NO**		

Data Evaluation Element	YES / NO	Description of the Associated Data Deficiencies / Discrepancies
Are there any other data deficiencies or discrepancies? **Specify YES / NO** **If YES, specify:**		

C2. Next Steps or Follow-up Actions to be Taken

For each of the data elements identified to be deficient or discrepant for purposes of uncertainty analysis and thus reported in part C1, summarize the possible or the proposed methods to rectify those deficiencies and discrepancies in the table below. Also, specify the agreed-upon methods (i.e., the follow-up actions elected to be undertaken after discussions with the Source Category Leads and the Agency Inventory Lead) for supplementing the existing data or generating new data below. Alternative methods to supplement existing uncertainty input data collected by the inventory staff include clarifying some information with the inventory and uncertainty data suppliers (i.e., appropriate personnel of the agencies that are responsible for collecting and compiling that information) by contacting them and obtaining other appropriate publications, reports, and other documents. In addition, new data can be collected through expert elicitation, informal interview—i.e., discussions with experts in the inventory source category (which may include Source Category Leads, other "inventory experts" in the government or among contractors involved in preparing inventory estimates), and/or researching other publications and documents (include citations).

Deficient or Discrepant Data Element	Possible or Proposed Methodology for Data Improvement	Agreed-upon, Follow-up Methodology for Data Improvement

ADDITIONAL INSTRUCTIONS FOR PART D. Part D is to be completed for each disaggregate variable (see Part A). This part is to be completed to summarize the outcome of the follow-up activities identified in Part C after they are completed. Do not delete any cells or rows. Replicate Part D for each disaggregate variable, as needed.

Uncertainty Data Collection and Assessment: Part D, Follow-up Uncertainty Data Collection Efforts	
Name of the variable, including its disaggregate (e.g., U.S. pig population, for a variable that is not disaggregated; or cow population – Southern U.S., for a variable that is disaggregated):	
Sequential variable number (e.g., "1 of 1" if the variable is not disaggregated, and "1 of 4", if this is the first of four disaggregate variables):	
Estimated value in the inventory. Indicate the appropriate unit of measurement, such as million barrels, 1,000 cubic feet, or percentage.	

Report the results of follow-up efforts below. For example, if the confidence interval associated with the standard error for a (disaggregate) variable was not reported in the publication from which data were collected (and thus reported in Part C1 of this form), the uncertainty staff may contact the appropriate agency lead or research other related publications to ascertain that information. If the additional information collected to identify the confidence interval associated with the standard error is sufficient, report in the table below the confidence interval associated with the standard error data, a rationale for using the data, and the name and organizational affiliation of the personnel contacted. In addition, the uncertainty staff must prepare contact reports and/or supplemental reports, as appropriate and include short citations to these reports under the column, "Cite References" in the table below.

Results of Follow-up Data Collection Efforts	**Cite References (include published documents, reports, and Supplemental and Contact Reports) E.g., Table 2-1, EPA 2001; SR-102601-HL; CR-100801-TS**

ADDITIONAL INSTRUCTIONS FOR PART E. Part E is to be completed for each disaggregate variable (see Part A). Part E records the final results of information collection efforts reported in this Form, i.e., after Parts A through D have been completed. It does NOT include the results of any expert elicitation or informal interview that might be conducted. It does NOT represent the final inputs that will be used for the uncertainty estimation, but contributes to that decision (see Form D4). Do not delete any cells or rows. Replicate Part E for each disaggregate variable, as needed.

Uncertainty Data Collection and Assessment:
Part E, Summary of Uncertainty Estimates

Item	Parameter Information for Uncertainty Estimation	
	Quantitative estimate	Unit of measurement
Disaggregate Variable Name		
Are the collected uncertainty input data for this disaggregate variable complete and consistent for the purpose of uncertainty analysis? **Specify YES/NO**		
Type of probability distribution		
Parameter 1 (of the probability distribution)[1] **Specify (e.g., Arithmetic Mean or Geometric Mean or Logarithmic Mean or Minimum):**		
Parameter 2 (of the probability distribution)[1] **Specify:**		
Parameter 3 (of the probability distribution)[1] **Specify:**		
Absolute lower-bound value for truncated distribution		
Absolute upper-bound value for truncated distribution		
Is this variable correlated with any other variable in this or other inventory source category? **If YES, report estimates of correlation (including the sign, "+" or " – ") for each pair of variables. Also, include the source category names, if variables belong to other source categories.**		

[1]For a normal distribution, parameter 1 is the arithmetic mean, parameter 2 is the (arithmetic) standard deviation; for a lognormal distribution, usually parameter 1 is the geometric mean, logarithmic mean (i.e., mean of the logarithms), or arithmetic mean and parameter 2 is the geometric standard deviation, logarithmic standard deviation, or (arithmetic) standard deviation; and for a triangular distribution, parameter 1 is the minimum value, parameter 2 is the most likely value, and parameter 3 is the maximum value.

ADDITIONAL INSTRUCTIONS FOR PART F. Part F should be used by the inventory and the uncertainty staff to record complete citations of the publications, documents, and reports from which uncertainty-related information was collected. One copy of this table should be prepared for each variable (or disaggregate variable) for which input uncertainty data are sought. Short citations should be provided in the tables above.

Example citation: EPA (2001) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1999. Office of Air and Radiation, U.S. Environmental Protection Agency, Washington, D.C. 20460. EPA 236-R-01-001.

Uncertainty Data Collection and Assessment:
Part F, References

D2. PRE-ELICITATION PREPARATION TEMPLATE

Inventory Report: 1990-_____ Source Category:[1] _____

Applicable Sub-source Category: _____

Variable for which elicitation is sought:_____

Is this template prepared for expert elicitation or informal interview?[2]_____

Expert to be interviewed (name/affiliation):_____

Template completed by (name/affiliation): _____

GENERAL INSTRUCTIONS FOR COMPLETING THIS TEMPLATE:

This template is to be completed prior to, and in preparation for, expert elicitation. The purpose of this template is to lay out the key activities that must be completed by the uncertainty staff in order to prepare for an elicitation interview with an expert. However, completing this template is optional in the case of informal interviews.

This template is to be completed by the uncertainty staff, in consultation with QA/QC staff, the Agency Inventory Lead, the Source Category Lead, and other inventory analysts (particularly those who are experts in the source category). A template should be completed either manually or electronically for each variable (or its component disaggregate variables) for which elicitation is sought from an expert.

In some cases, an expert may be asked to provide judgments on two or more variables, depending on his/her expertise. In some other cases, expert elicitations may be sought from two or more experts on the same variable—for example, if two or more experts jointly manage the data collection and verification efforts for a particular variable.

Uncertainty estimates for each variable may not be revised every year. Therefore, this template needs to be completed only when the uncertainty estimates for variables are revised based on expert elicitations. The Agency Inventory Lead and the Source Category Lead will identify the outside experts for each variable for which elicitation is desired and arrange for expert elicitations.

Specific instructions are provided in each part of this template. The completed template should be filed in a project file by the uncertainty staff and included in the annual docket. Additional information on preparing this template can be found in Chapter 5 of the QA/QC Manual*.*

Pre-Elicitation Preparation:
Part A. Elicitation Variable and its Composition

Specify the variable for which elicitation is sought and its value in the inventory. Provide the inventory estimation equation for this source category that involves this variable. Briefly describe the variables used in this equation. After consulting with the Source Category Lead and other "inventory experts" in the government or among contractors that prepare this inventory estimate, report the alternative levels of disaggregation (e.g., national, regional, and state-level) for this variable that may be realistically adopted for eliciting expert judgment and developing uncertainty estimates.

[1] Use the source category names in Table D-1 of this appendix.

[2] Expert elicitation is the process of eliciting quantitative judgments from outside experts that have the expertise of the variable for which elicitation is sought. Informal interview is the process of eliciting quantitative judgments from inventory source category experts (which may include Source Category Leads or other experts in the government or among contractors directly involved in developing the inventory) through less formal discussions.

Pre-Elicitation Preparation:
Part B. Expert's Qualifications

Briefly describe the expert's qualifications and provide a rationale for choosing him or her for eliciting expert judgments on this particular variable.

Pre-Elicitation Preparation:
Part C. Pre-Elicitation Expert Communication

In consultation with the Agency Inventory Lead and the Source Category Lead, the uncertainty staff should communicate with the expert prior to the interview on the subject matter of the elicitation. At a minimum, the pre-communication materials to be sent to the expert should include:

- a detailed, precise description of the variable for which elicitation is sought
- the reason for elicitation
- an overview of the inventory estimation methodology for that source category
- the kind of information for which the quantitative judgments are sought
- an explanation of the basic idea of probabilistic assessment and the rationale for using it
- alternative levels of disaggregation for the variable
- a description of the elicitation process, a response form for the expert to complete and return, communicating his/her preferred level of disaggregation, units of measurement, rounding precision, and the preferred terminology for providing probabilistic judgments (i.e., odds or probability) for the elicitation interview, and other questions, if any; and
- a list of common biases that may arise during elicitation (see Box 5-2 in Chapter 5 of the Manual) and some suggestions on how to avoid them (see Box 5-3 in Chapter 5 of the Manual)

In the box below, indicate whether copies of e-mails, cover letter, facsimiles, and other materials sent to the expert, as well as the response letter received from the expert, have been placed in the project file, or otherwise documented. If not, then provide below a list of the materials that were provided to the expert, and specify the dates when the materials were sent and their modes of transmission. If a copy of the response letter has not been placed in the file, specify the date when the response form was received.

Pre-Elicitation Preparation:
Part D. Expert's Elicitation Preferences

Specify the expert's preferred level of disaggregation, units of measurement (e.g., pounds vs. kilograms) and the rounding precision (e.g., rounded to the nearest 10, 100, or million) for providing quantitative judgments for this variable. Also state the expert's preferred terminology to provide probabilistic judgments on this variable. Identifying the expert's preferences earlier will facilitate focusing on specific QA/QC issues and preparing appropriate questions for the elicitation interview. Based on the expert's preferred level of disaggregation, also specify the total number of (disaggregate) variables for which the elicitation judgments will be sought from this expert.

Pre-Elicitation Preparation:
Part E. Key Issues related to the Variable

Briefly summarize the key inventory issues and the results of the Tier 1 and Tier 2 QC reviews related to the variable for which elicitation is sought. Also, briefly describe how this variable is related to the other variables in the same source category and other source categories of the GHG inventory, if applicable. Briefly describe the linear and the non-linear relationships between this variable and other variables in this or other inventory source categories in terms of equations or in narrative form. These factors can be identified through consultation with the *experts in the source category (which may include Source Category Leads or other "inventory experts" in the government or among contractors involved in preparing inventory estimates), an*d the QA/QC staff. The expert's preferred level of disaggregation is the appropriate level of disaggregation to analyze these issues, as it will be the level at which expert elicitation will be sought.

Pre-Elicitation Preparation: Part F. Potential Expert-Specific Biases and Techniques to Avoid Them

Based on a review of the expert's qualifications and agency affiliation, and other key issues related to the variable for which elicitation is sought, briefly describe the potential biases (that are specific to the expert) that can arise during expert elicitations and identify techniques to avoid these biases. Refer to §5.3 of Chapter 5 of the *QA/QC Manual* for a list of potential biases and techniques to avoid them.

Pre-Elicitation Preparation: Part G. Conditioning Questions

These questions are intended to prepare the expert to think fundamentally about his or her quantitative judgments and to avoid cognitive bias. These questions can be posed to the expert prior to elicitation. Refer to Chapter 5 of the *QA/QC Manual* for additional information on conditioning. In the following table, list the questions that can be asked of the expert to condition him or her for elicitation.

Pre-Elicitation Preparation: Part H. Elicitation Materials

List the materials that must be provided to the expert during elicitation. Also include a list of other materials that will be needed for the elicitation interview. Among other things, these materials will include multiple copies of the elicitation template and a sufficient number of graph sheets to encode expert elicitations and then to revise them, if needed.

Pre-Elicitation Preparation: Part I. Other Notes/Comments

Include other notes and comments on pre-elicitation preparation that are not included in the other parts of this template.

D3. ELICITATION TEMPLATE

Inventory Report: 1990-_____ Source Category:[1] _____

Applicable Sub-source Category: _____

Variable for which elicitation is sought:_____

Is this an expert elicitation or informal interview?_____

Expert to be interviewed (name/affiliation):_____

Template completed by (name/affiliation): _____

Expert's contact information (address, telephone, fax, and e-mail): _____

_____

Total number of interviewers present:_____

Interviewers (names/affiliation):_____

_____

Date and Location of the interview:_____

Template prepared by (name/affiliation): _____

GENERAL INSTRUCTIONS FOR COMPLETING THIS TEMPLATE:

This template is to be completed manually or electronically by the uncertainty staff or the uncertainty coordinator. Once completed, the template should be filed in a project file by the uncertainty staff and included in the annual docket.

Part A of this template must be completed prior to the elicitation interview, based on earlier communications with the expert. However, the preferences of the expert noted in this part must be confirmed with the expert once again at the time of the elicitation interview. Parts B and C must be completed during the interview. Part D can be completed during or subsequent to the elicitation interview, depending on the available information. Part E will have to be completed subsequent to the interview. Notes and comments, not included in other parts of this template, should be recorded in Part F. Additional information may be found in Chapter 5 of the QA/QC Manual*. Specific instructions are also provided in each part of this template, as necessary.*

[1] Use the source category names in Table D-1 of this appendix.

ADDITIONAL INSTRUCTIONS FOR PART A. The following information must be completed prior to the elicitation interview. During the interview, first, the preferences of the expert regarding the level of disaggregation, rounding precision, and the terminology for providing probabilistic judgments must be confirmed and revised, if needed, in the last column of the following table.

Elicitation Template:
Part A. Elicitation Subject

Item	Original Preferences	Final Preferences
Expert's preferred level of disaggregation:		
The total number and the names of disaggregated variables for which elicitations are being sought from this expert:		
Expert's preferred unit of measurement (e.g., lb or kg, cubic feet or cubic meter, short ton or metric ton, etc.)		
Inventory estimates of these variables (include units of measurement): (disaggregated variables/ estimates)		
Expert's preferred level of rounding precision for providing quantitative judgment on these variables (e.g., rounded to the nearest 10, 100, or million):		
Expert's preferred terminology to provide probabilistic judgments (i.e., odds—e.g., 1 in 20 chance—or probability—e.g., 5%):		

ADDITIONAL INSTRUCTIONS FOR PART B. This part must be completed individually for each disaggregated variable for which expert elicitation is sought during the interview. It is recommended that one interviewer encode the elicitation in a graph sheet in the form of probability and cumulative probability distributions, so that, at the end of the interview, the probability distributions can be shown to the expert for confirmation and/or revision (see Part C of this template for specific instructions and graphical representation). Include additional tables to record elicitation data, as necessary, for each additional variable (or disaggregate variable) for which elicitation is sought.

To elicit independent responses to each question and to avoid sequential bias, elicitation should not follow any expected sequence. For example, after eliciting the value of an input parameter at 5% percent probability, do not ask for the value at 10% probability; instead, ask for the value at 95% or 75% probability. An example of randomly ordered probability levels include: 2.5%, 50%, 97.5%, 50%, 5%, 75%, 25%, 95%, 10%, 60%, 20%, 90%, 30%, 70%, and 40%. If the expert is more comfortable with the terminology of odds, rather than probability, change the questions in this part accordingly.

Further, careful elicitation of several data points that cover the entire range of the probability density function will facilitate developing a probability distribution function that approximates the true probability density function for that input parameter. Accordingly, the list of questions in this part can be increased to cover other data points, for example, at 5, 10, and 20 percent probability.

Also, if the expert is more confident to provide quantitative judgments on the values of the variables at other probability levels than the ones specified below, the questions in this part of the template should be altered to reflect the preferences of the expert. For example, the expert may be more comfortable to provide an estimated value of the variable such that there is a 5 percent (and not a 2.5 percent) probability that the true values of the variable could be lower than that value. If so, revise the relevant question in the following table to 5 percent from 2.5 percent.

In addition, to ensure consistency in elicitation, the interviewer can also ask the expert additional questions regarding the probabilities corresponding to different possible values of the disaggregated variables (e.g., what is the probability that the values of the variable "x" will be greater than or equal to value "y"?).

Therefore, prior to the elicitation interview, re-size parts of these templates as necessary to include sufficient number of additional rows to record elicitation data at other randomly ordered probability levels and possible values. This must be done to record data either manually or electronically. The number of data points to be elicited from the expert should be determined based on the expert's comfort level and the scheduled time limit for the elicitation interview. The responses received from the expert prior to elicitation (and recorded in the Pre-elicitation Preparation Template) will facilitate determining the number of data points to be elicited from the expert. On occasions, this decision may need to be revised during the elicitation interview. At a minimum, the data points for the probability levels and values listed in Part B of this template must be elicited and recorded.

Elicitation Template:
Part B. Elicitation

Enter a sequential number for this disaggregated variable, for which elicitation is sought from the expert (e.g., 1 of 1, 1 of 4, etc.):	
Enter the name of this disaggregated variable:	
What are the realistic values for the minimum and the maximum of this variable? **Minimum:** **Maximum:** **What are the circumstances under which the values of this variable will lie outside the min-max range?** **What are the probabilities that the values of this variable will lie outside of the min-max range?** **Less than Minimum:** **Greater than Maximum:**	
What are the most frequent values (i.e., mode values) of this variable? **What is the probability that each of the most frequent values will occur?** **Explain the rationale.**	
Estimate the value of the variable such that there is only 2.5 percent probability that the true values of the variable could be lower or higher than that value. **Lower value (at 2.5% probability):** **Higher value (at 97.5% probability):**[1] **(These values could be changed to 5% and 95% probability levels, respectively, if the expert is comfortable only with those values)** **Explain the rationale.**	
What is the mean (or average) of this variable? **Is this different from the inventory estimate? If so, why?**	
Estimate the value of the variable such that the true value is equally likely to be higher or lower than that estimated value (i.e., the value associated with 50% probability or median)? **Explain the rationale.**	
Estimate the lower and the upper bound values of the variable such that there is only 25% probability that the true values will be lower or higher than those estimated values. **Lower bound value (at 25% probability):** **Upper bound value (at 75% probability):**[2] **Explain the rationale.**	

[1] These lower and higher values indicate the range of estimated values within which the true values of the variable will lie 95 percent of the time (or with 95 percent probability).
[2] These lower and higher values indicate the range of estimated values within which the true values of the variable will lie 50 percent of the time (or with 50 percent probability).

Elicitation Template:
Part B. Elicitation

Based on your knowledge, is this variable correlated with (i.e., linearly related to) any other variable that is used in the inventory estimation of this source or any other GHG inventory source category, either by nature, or due to estimation or extrapolation methodology, or assumption, used in the inventory estimation?[1] **If so, list the variables that are correlated with this variable.** **Specify the functional relationship between the correlated variables, if known. (E.g., if variables, X and Y are related to each other, such that they together add up to a fixed value of one, the functional form between these two variables is: X+Y=1.)** **For each pair of correlated variables whose relationship cannot be expressed using functional forms, please state the direction of correlation (i.e., positive or negative) and the extent of correlation (which should lie within the range of –1 to +1).** **Explain the rationale.**	

[1] It should be noted that only "rank correlation" between variables is taken into account while performing the simulation analysis by the simulation software, such as @RISK. Hence, it is important to express correlation between variables in terms of "rank correlation" between them. Refer to any intermediate statistical textbook for a discussion of rank correlation and other types of correlations. Further, it should be noted that only "linear" relationships between variables are quantified using correlation coefficients.

ADDITIONAL INSTRUCTIONS FOR PART C. The expert's quantitative judgments elicited during the interview for each of the disaggregated variables for which elicitations are sought must be encoded separately in graph sheets at the time of the elicitation interview. The encoded graphs of the probability and the cumulative probability distributions of the variables must be shown to the expert at the end of the elicitation interview for review and approval. The expert's review comments and approval must be recorded in the table below. The expert approved-graphically encoded elicitations for each of the disaggregated variables (for which elicitations were sought from the expert) must then be attached to this part. Illustrations of graphically encoded probability and cumulative probability distributions are included below for reference.

Elicitation Template:
Part C. Graphical Encoding of Elicitations

Does the graphical representation of the probability distribution drawn based on elicitations represent your (i.e., the expert's) belief of the probability distribution of this variable? **If not, please explain why.** **Please revise the quantitative estimates provided earlier such that they represent your (i.e., the expert's) beliefs.**	

Figure 1. Probability Density Function (PDF)

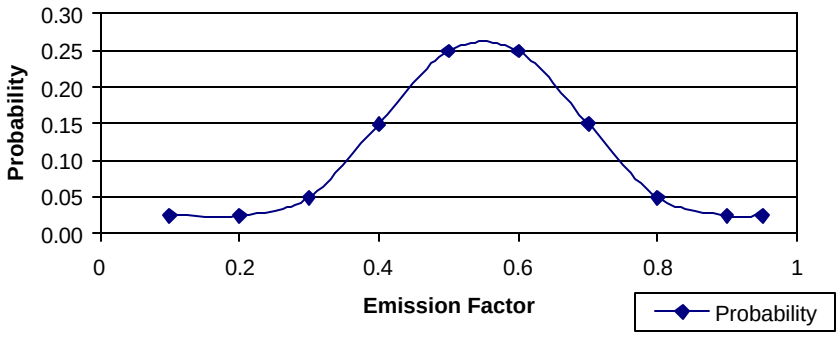
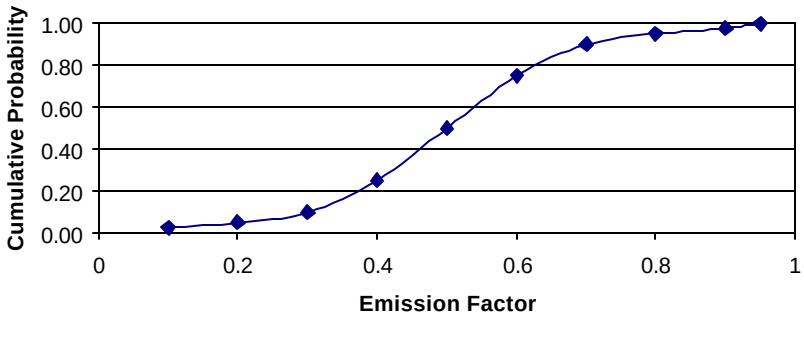


Figure 2. Cumulative Distribution Function (CDF)



ADDITIONAL INSTRUCTIONS FOR PART D. The status of the elicitation interview must be completed for each disaggregated variable, for which elicitation is sought. Include additional tables as necessary for each additional variable for which elicitation is sought.

Elicitation Template:
Part D. Interview Status

Were the revised probability distributions (i.e., PDF and CDF) approved by the expert at the end of the interview? (YES/NO) **If NO, explain why.** **Briefly explain plans to reconcile the differences.**	
Is a follow-up interview with the expert needed? (YES/NO) **If YES, planned date and location of the follow-up interview.** **Briefly summarize the purpose of, and the proposed agenda for, the follow-up meeting.**	

ADDITIONAL INSTRUCTIONS FOR PART E. This part lists the general steps that must be followed after the elicitation interview in order to finalize the probability distributions for the uncertainty estimation model. This part must be completed after reviewing and analyzing the expert elicitations. Any inconsistencies in the expert's judgments identified while developing uncertainty estimates must be first communicated to the Agency's inventory coordinator and the issue must be resolved in consultation with the inventory coordinator. Based on the findings of the review and analysis, and the Agency's inventory coordinator's decisions to reconcile the differences, this part must be completed. The questions in this part may be revised, as appropriate.

Elicitation Template:
Part E. Interpretation and Reconciliation

Report the finalized probability distributions (e.g., normal, lognormal, custom, triangular, etc.) for these disaggregated variables for which elicitations were sought, to be used in the uncertainty estimation model: (variable names / prob. distribution names)	
If the finalized probability distribution for any of the disaggregate variables is truncated, include the truncation information (such as absolute lower- and/or upper-bound values) for each disaggregate variable. Explain the rationale.	
Briefly describe, if any curve smoothing had to be done to finalize the probability distributions of any of the disaggregated variables. Explain the rationale.	
Also briefly explain the differences between the finalized probability distributions and the probability distributions drawn at the time of the elicitation interview and approved by the expert. What are the implications of these differences?	
Was the expert contacted to review and comment on the finalized probability distributions for these variables? If YES, briefly summarize his comments. If NO, explain why.	
Has the Agency's inventory coordinator been notified of such curve smoothing and the comments received, if any, from the expert on curve smoothing for these variables?	

Elicitation Template:
Part F. Other Notes/Comments

Report other notes and comments on elicitation and subsequent review and decisions, not included in the other parts of this template in this part.

D4. SUMMARY: UNCERTAINTY INPUTS AND DOCUMENTATION FORM

Inventory Report: 1990-_____ Source Category:[1] _____

Applicable Sub-source Category: _____

Title(s) and Date(s) of Inventory Spreadsheet(s): _____

_____

Title(s) and Date(s) of Uncertainty Model Spreadsheet(s):_____

_____

Template completed by (name/affiliation): _____

Date template completed/revised: _____

GENERAL INSTRUCTIONS FOR COMPLETING THIS FORM:

This form is to be completed the first time uncertainty is estimated for a specific source/sub-source category, and should be updated and revised each time the uncertainty analysis is updated—particularly when the inventory methodology changes, new data sources are used, or other changes occur that affect the uncertainty analysis. It does not need to be completed annually. The form may be completed by hand or electronically. Once completed, the form should be filed in the project file by the uncertainty staff and included in the annual docket.

This form provides documentation on the inputs used to complete the uncertainty analysis for this source/sub-source category. The uncertainty estimation model for each source category will be developed based on this form. This Summary Form contains three tables. The first table reports the inventory estimation model and its inputs, the second table reports the statistical properties of the data inputs and variables, and the third table provides space for notes and comments.

Note that some of the information reported on this Form may appear to repeat information contained on other forms. This may occur because the inputs reported here represent a synthesis of available information by the uncertainty analyst. In particular, Forms D1 and D3 must be reviewed (and in some cases completed) by the uncertainty analyst before completing Form D4. These forms contain information on the inventory methodology provided by the inventory analysts, statistical data relevant to the inventory estimates that appears in the published literature, unpublished information provided by data suppliers and others familiar with the input data, mathematical estimations, and the results of any elicitations that are conducted. Thus, the Summary Form is completed after Forms D1 through D3. It is essential that this Form D4 be completed because it represents a synthesis and assessment of the information needed to develop the uncertainty model and includes information that will not be reported on any other form. .

As necessary, the form should reference supporting documentation or additional information contained on Supplemental Reports *(Form D7) or* Contact Reports *(Form D6).*

[1] Use the source category names in Table D-1 of this appendix.

ADDITIONAL INSTRUCTIONS FOR PART A. In the section below, describe the uncertainty estimation model, including the equations used to estimate inventory emissions (at the level of disaggregation that is appropriate, given both the inventory model and the characteristics of the input data), and the input variables. The discussion cell should be used to explain the rationale for decisions that were made (e.g., a decision to conduct the uncertainty estimation at a level of aggregation different from that of the inventory model), or to reference any relevant Supplemental Reports *(Form D7) or* Contact Reports *(Form D6) that describe the rationale for decisions. The discussion may also, as needed, refer to information contained on Forms D1 through D3.*

Summary Uncertainty Form: Part A. Uncertainty Estimation Model
Individual source (abbreviation)/sub-source category:

Presentation of Equations:

Description of Input Variables

Discussion

ADDITIONAL INSTRUCTIONS FOR PART B: In the part below, document the decisions made regarding the statistical properties of the inputs into the uncertainty estimation model. Published or unpublished references should be cited following procedures established by the QA/QC Manual*. The column for supporting documents should be used to reference any relevant Supplemental Reports (Form D7) or* Contact Reports *(Form D6). For example, a supplemental report may be used to describe the decision that was made to conduct an elicitation and how the elicited information was combined with published and unpublished data to construct a quantitative estimate of the statistical properties of a particular variable. The column for supporting documents or discussion in supplemental reports may also, as needed, refer to information contained on Forms D1 through D3.*

Summary Uncertainty Form: Part B. Uncertainty Estimates for Variables
Individual source (abbreviation)/sub-source category:

Item	Parameter Information for Uncertainty Estimation				
	Quantitative estimate	Unit of measurement	Inventory year of the latest estimate [1]	Cite Reference	Supporting documents (provide reference)
Sub-source Category:					
Sequential variable number in this sub-source category (e.g., 1 of 4)					
Variable name:					
Inventory estimate:					
Type of probability distribution: **Normal ❑ Lognormal ❑ Triangular ❑ Uniform ❑** **Other ❑ Specify:**					
Mean value (of the distribution):					
Standard Deviation:					
Absolute lower-bound value in the case of truncation:					
Absolute upper-bound value in the case of truncation:					
Is this variable correlated with any other variable in this or other inventory source category? **If YES, report estimates of correlation for each pair of variables. Also, include source category names, if variables belong to other source categories:**					

[1]This refers to the most recent inventory year for which the uncertainty-related parameter estimate for this variable was developed or updated and used in the uncertainty estimation model (e.g., 1990-XXXX).

ADDITIONAL INSTRUCTIONS FOR PART C. In the part below, include a brief summary of other supplemental notes or comments, if any, that have not been reported through Supplemental Reports *(Form D7) or* Contact Reports *(Form D6). The discussion may also, as needed, refer to information contained on Forms D1 through D3.*

Summary Uncertainty Form: Part C. Uncertainty Estimates for Variables
Individual source (abbreviation)/sub-source category:

Discussion

D5. UNCERTAINTY ANALYSIS RESULTS FORM

Inventory Report: 1990-_____ Source Category:[1] _____

Applicable Sub-source Category: _____

Title(s) and Date(s) of Uncertainty Model Spreadsheet(s):_____

_____

Form completed by (name/affiliation): _____

Date form completed/revised: _____

GENERAL INSTRUCTIONS FOR COMPLETING THIS FORM:

This form is to be completed the first time uncertainty is estimated for a specific source/sub-source category, and should be updated and revised each time the uncertainty analysis is updated or revised.

This form is to be completed by the uncertainty analysis staff to document the results of the uncertainty estimation model for each source category. This form, when completed, will serve as the summary of the uncertainty analysis results for each inventory source category. This form should be completed electronically for each of those source categories for which the uncertainty estimation models and the required parameters for estimating uncertainties have been fully developed. Once completed, the form should be filed in a project file by the uncertainty staff and included in the annual docket. Additional information on preparing this form can be found in Chapter 5 of the QA/QC Manual*.*

Uncertainty Analysis Results:
Part A. Inventory Estimation Methodology

Provide a very brief overview of the inventory estimation methodology for this source category, including any change in the current estimation methodology, relative to the previous year. Highlight any new data sources.

[1] Use the source category names in Table D-1 of this appendix.

Uncertainty Analysis Results:
Part B. Sources of Uncertainties

For each inventory variable in this source category, describe the various sources of uncertainties (e.g., systematic and random uncertainties) associated with the inventory estimates. Refer to Chapter 5 for a discussion of various types and sources of uncertainties.

Uncertainty Analysis Results: Part C. Uncertainty Estimation Methodology

Describe the estimation methodology used to develop quantitative uncertainty estimates. Specify the level of disaggregation chosen for uncertainty estimation and the rationale for it. Describe how the correlations between input variables were quantified and incorporated in the uncertainty estimation methodology. Also, report any change in the current uncertainty estimation methodology and/or updates to the model parameters, relative to the previous year.

Uncertainty Analysis Results: Part D. Uncertainty Model Results

Summarize the results of the quantitative uncertainty analysis. Report the uncertainty estimates at 2.5% and 97.5% probability levels, and the relative (i.e., percentage) deviation of these uncertainty estimates from the inventory estimates, for the overall source category and for each of the major sub-source categories. Report the results of sensitivity analyses. Also, briefly describe how these model results compare with the previous year model results and explain the reasons for significant differences in the model results, if any. Also summarize the results of sensitivity analysis.

Reference: CR-_____

D6. CONTACT REPORT

This form is to be used to record personal communications, including telephone conversations or meetings. It can also be used, as necessary, as a cover sheet for facsimile or e-mail communications.

To reference this form use CR-source abbreviation-date (month/day/year)-initials, for example CR-coal-7/6/01-KRJ. The abbreviations to be used can be found in Table D-1.

Date: _____ Originator _____

CONTACT BY : Telephone _____ Meeting _____ Other (specify) _____

Contact Name:

Title and Organization:

Phone number:

Fax number:

Address:

e-mail address:

Purpose and/or Subject of contact:

Attendees or participants in meeting/telephone conversation (name, affiliation):

Summary of meeting:

Recommended Follow-up Actions:

Reference: SR-_____

D7. SUPPLEMENTAL REPORT

This form is to be used as needed to provide additional documentation or explanation of QA/QC activities, and to supplement other checklists and forms that are completed. Among other uses, it can record information gathered from sources other than a personal communication (e.g., internet sites or unpublished sources), describe in detail the results of an investigation, or be a cover page for other supporting documentation (such as a source category specific QA/QC plan).

To reference this form use SR-source abbreviation-date (month/day/year)-initials, for example SR-coal-7/6/01-KRJ. The abbreviations to be used can be found in Table D-1.

Date:	Source Category:
Subject:	
If part of another report, provide the report name and purpose of supplemental report: Example: Tier 2 secondary data checks for Nitric acid production; detailed checks on emission factors Example: Tier 1 checks for fossil fuel combustion; hand calculations to confirm specific computations.	
If not part of another report, provide purpose: Example: Additional documentation of changes in assumptions made and the rationale for changes.	
Sheet # __ of _____	Name, affiliation:

Discussion:

APPENDIX E

SAMPLE DOCUMENTS

E1. KICK OFF MEMORANDUM

E2. EXPERT REVIEW REQUEST LETTER

E3. FEDERAL REGISTER NOTICE FOR PUBLIC REVIEW

E4. PRESS RELEASE FOR PUBLIC REVIEW

E5. PUBLIC REVIEW LETTER

E1. KICK OFF MEMORANDUM

1850 K Street, NW, Suite 1000
Washington, DC 20006-2213
202/862-1129 Fax 202/862-1144

MEMORANDUM

DATE: Early July
TO: All Sector Leads
FROM: Data and Document Manager
CC: Agency Lead and Other Relevant Staff
(*Note: Please circulate to other relevant staff and contractors!*)
SUBJECT: 2000 Base Year Greenhouse Gas Inventory Preparation Guidelines
(EPA Contract, WA, Task)

The purpose of this memorandum is to provide guidelines for those involved in preparing source category estimates and associated text for the new 2000 Base Year Greenhouse Gas Inventory report (i.e., 1990-2000). The issues addressed below relate to our documentation procedures, data management practices, and to the structure of this year's report write-up. **Please read this entire memo,** even if it looks familiar to you – there are some important pieces that have been added for this inventory year. If anything is unclear from this memo, please contact me as early as possible to avoid any misinterpretations or misunderstandings.

I have included a list of all sources and the staff we understand are currently responsible for each one. Please pay close attention to the items that have been added this year, which include close coordination between your estimates and the data required for the Common Reporting Format (CRF) tables, plus the new focus on QA / QC and uncertainty analysis. In addition, it will be necessary for you to review the new IPCC report on *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* when developing this year's estimates. You can obtain a copy of these two references below:

CRF Tables:	http://www.unfccc.de/resource/docs/cop5/07.pdf
Good Practice report:	http://www.ipcc-nggip.iges.or.jp/gp/report.htm

Schedule

All final emission estimates are to be submitted by the close of business on **Friday, September 7th**. These final emission estimates are to be in the form of a fully documented MS Excel spreadsheet based on the one used for the 1900-1999 inventory. The spreadsheet is to contain a time series of emissions from 1990 to 2000 in the summary sheet in units of both **gigagrams (Gg)** and **teragrams of carbon dioxide equivalents (Tg CO_2 Eq.)**.

For the Inventory document, "write-ups" (discussed below) must be started from the final text used in the 1999 Base Year report. This text is available now, and if it is not sent to you, please request it from me. Final write-ups are to be submitted to me by the close of business on **Monday, October 1st**. These final write-ups are to be based on those contained in the 1900-1999 inventory document. Please note that it is required that you **provide docket**

material when you provide the write-ups. This material must include all new references used in the text or the spreadsheet that were not included in the previous year's report, including phone logs. It is much easier to forward this information when it is collected rather than searching for it next April when we'll be looking for it.

It is important to realize that these dates correspond to when the final versions of both spreadsheets and write-ups are to be submitted to EPA. For those source categories funded under separate EPA work assignments or task orders, it is important to factor in the time needed for EPA staff to review estimates and text and for revisions to be made. In these cases, the deadlines below correspond to when spreadsheets and write-ups are to be *received* by the inventory coordinator, via the appropriate EPA staff.

	Date	Task
♦	**Oct. 1**	**Final estimates/spreadsheets due to M. Martin**
♦	**Oct. 1**	**Final write-ups, annexes, and docket/archive due M. Martin**
	Oct. 2 – Nov 16	Prepare draft document
	Oct. 30	Expert reviewer list and transmittal letter completed
♦	Nov 16	Draft 2000BY Inventory document due
	Nov 19	Distribute draft 2000BY Inventory for expert review
	Nov. 19 – Dec 21	Expert review period
	Dec 7	Submit request for federal register notice
	Dec 21	Approval of federal register notice
--	**Dec 21**	**Expert review comments due and final date for changes!**
	Dec 21-Jan 21	Incorporate expert comments
	Jan 21	Public review draft 2000BY Inventory document due
	Jan 21	Upload public review draft on EPA website
♦	Jan 21	Appearance of federal register notice
	Jan 21 – Mar 1	Public review period
♦	Mar 1	Public review comments due
	Mar 1-Apr 5	Incorporate public review comments
♦	Apr 5	Final 2000BY Inventory document due
	Apr. 8	Deliver document to U.S. Department of State
♦	Apr. 15	Inventory due to UNFCCC Secretariat

Documentation

It is essential that material for the Greenhouse Inventory be well documented and reproducible. Because both the methods employed and the staff that use them are always changing, for us to maintain consistency we need excellent and detailed documentation. We are also required to prepare a "Docket" including all the references used in our analyses and in producing the Inventory. With that in mind, please follow the guidelines below:

> ***Required***: Every primary data element (e.g., activity data, emission factors, carbon coefficients, etc.) is to have a reference—published or unpublished—for the source of the data. There should be no non-calculated values in the spreadsheets that are not referenced short of unit conversion factors and the like. [Suggestion: It is easy to include such references as an Excel comment or cell note.]

Required: Everything should be dated, especially all printouts from spreadsheets. [Suggestion: Set footer in Excel to include date, or use the "=TODAY()" function in a cell.]

Required*:* For the Docket, a list of all references AND a copy of the actual reference itself is required for each new addition to the reference list since last year's inventory (e.g., for a report, the cover page and most relevant pages are sufficient; if the entire report was used extensively, then simply a copy of the cover page will suffice). In the case of personal communication, a short memorandum including the relevant information or data will be necessary. This material is to be submitted to the inventory coordinator with your source write-up.

Spreadsheet Management

The following points are guidelines for managing spreadsheets. Because each source has its own specific characteristics, we have not attempted to create a generic template. If any of these guidelines are unclear, please contact the inventory coordinator.

Required: Everyone (without exception) must obtain their spreadsheet from me. We have done quite a lot of work integrating and modifying the spreadsheets so that the formats are fairly consistent and numbers update automatically. Failure to begin with the immediately previous version of 1999 spreadsheets will cost everyone lost time and resources. If you are unsure please contact me. You will be asked to provide a new 1990-2000 version of your spreadsheet. Also, note that all historical estimates are to be revised (i.e., if revised activity data for 1999 or earlier is now available, then your spreadsheet should reflect those revised numbers. We are not just adding 2000 estimates, but revising the full time series of 1990 through 2000). Keep in mind that we will be asked to explain any historical revisions in great detail in the CRF tables, so **please review the CRF** and provide me with language for why these estimates have changed.

Required: If not already included in spreadsheet, create a page within each spreadsheet just behind the "Summary" page that's titled "CRF Input," and list all data points that are needed for the CRF tables that are not contained within the "Summary" page. Label the values clearly and provide units. Please note that only the white cells within the CRF tables are input cells, the rest are calculated by the CRF. Values such as implied emission factors are calculated by the CRF table and cannot be over-written. Please review the entire CRF carefully to ensure that each data point required is submitted within the "CRF Input" page of your spreadsheet. If the information is not available to fill in every white cell within your source category, please review the CRF instructions and provide the appropriate code (e.g., "IE" for "included elsewhere," "C" for "confidential," etc.)

Required: Every primary data element (e.g., activity data, emission factors, carbon coefficients, etc.) is to have a reference—published or unpublished—for the source of the data, and this reference should be identified in the spreadsheet itself (no exceptions). There should be **no non-calculated values** in the spreadsheets that are not referenced short of unit conversion factors and the like. [Suggestion: It is easy to include such references as an Excel comment or cell note.] Provide the data source as part of your docket submission.

Required: Spreadsheets must have a summary sheet (titled "Summary") consisting of a table of the 1990-2000 annual emission totals for each source in gigagrams (Gg) of gas emitted and million metric tons of carbon dioxide equivalents (Tg of CO_2 Eq.) emitted. The GWP value you use should be entered in a single cell from which calculations are done (i.e., include it in the cell equation as an absolute reference to a cell where the GWP value is entered). Note: This summary page is linked to a variety of other spreadsheets once it becomes part of my Inventory spreadsheet "system," for that reason

do not alter the existing location (row and column) of 1990-1999 data on the summary page.

Suggestion: Do not "hide away" values such as conversion factors or other numbers inside cell formulas. Enter such numbers in clearly marked separate cells and perform calculations using references to those cells. Such practices are more transparent to others viewing and using your spreadsheets in the future.

Required: When you have completed your estimates, electronic copies of your spreadsheets must be transferred to me. Once you have transferred your 1990-2000 spreadsheet(s), the official copy to which all future changes are to be made (including updates with estimates for succeeding years), must be made to the version residing on my computer – if changes are required after the spreadsheet has been submitted, call me and we can get together to make any changes. **Please provide every "linked" supporting spreadsheet that is used.**

Suggestion: Please make efforts of better label and "organize" your spreadsheets where possible, keeping it in mind that they should be as transparent as you can make them (i.e., someone unfamiliar with it should be able to open it and quickly extract information and understand what is going on.)

Report Write-up

The box below provides guidelines for preparing the text for the 2000 Base Year report. The text from the 1999 Base Year report, including the text from appendices, will be forwarded to you by email for you to edit. If you do not receive these files, please contact me. In order to quickly integrate the complete document, meet our schedule, and maintain quality control, we are assuming that only minor revisions, in most cases, will be needed to update the text from the 1999 Base Year report.

Required: Everyone (without exception) must use the MS Word versions of the write-ups and annexes that I will provide. If you are unsure if you have the right files, please contact me. Each write-up has been edited (as much as possible) to fit into a standard and consistent format and writing style. It is critical that you do not "monkey" with the formatting, styles, margins, etc.! Simply revise the text and add columns to tables for the 2000 data.

Suggestion: In order to ensure that styles are not compromised, set Word with the following settings:

(a) Work in "Normal" view

(b) Within the "Tools" menu, select "Options" and, under the "View" tab, check "field shading - always" (which will allow you to see fields such as automatic numbering) and also provide a non-zero value (~0.25) for the "Style area width" (which will allow you to see the font styles that you should be using… check out how they are set when you get the file, and that will give you a good idea of what styles are appropriate – normal for most paragraphs, "table text" for tables, etc.)

All text should be written to correspond to the structure described below. Contact the inventory coordinator if you have any questions regarding the write-up.

1.1 Source Discussion

- Discussion on the emissions source and pathway (i.e., how and why emissions are produced).
- Trends in emissions from 1990 to 2000 (e.g., rate of increase) and reasons for observed behavior. Specific changes from 1999 estimate (e.g., percent change and/or absolute change and why). A future expectation only if something dramatic is anticipated to happen (e.g., significant reductions or growth in emissions) in the near future.
- If relevant, the avoided emissions from mitigation programs such as methane recovery from landfills. Quantify if possible.
- A simple table with emission estimates in gigagrams (Gg) and teragrams of carbon dioxide equivalents (Tg CO_2 Eq.).
- Recommendations for additional tables and/or graphics to augment text in addition to basic emission estimates are also welcome. Before making such changes, please confer with inventory coordinator.

1.2 Methodology Discussion

- Methodology discussion explaining briefly how emissions were estimated. Again, text from the 1999 Base Year report should be sufficient unless revisions have been made.

1.3 Data Sources

- Discussion and identification of all primary data sources (e.g., for activity and emission factor data). Also include tables with actual primary data where reasonable (i.e., use your best judgment or ask the inventory coordinator).

1.4 Uncertainty and QA/QC Discussion

- A discussion on—and quantification of when possible—the uncertainty in emission estimates and QA/QC measures taken. Again, text from the 1999 Base Year report should be adequate, although revisions are welcome.

1.5 Changes from last year's version

- Do not include a discussion of how this years' Inventory estimates differ from last year's estimates within the body of the text above, such as within the discussion of methodology. If the entire time series has changed due to a change in methodology, explain only this year's methodology under the Methodology discussion, and include how the new methodology differs from that used last year under a heading of "Changes" at the end of your section. Similarly, note any changes in data points that result in the modification of any value (1990-1999) as compared to the 2000 BY inventory. Keep in mind that an explanation of any such changes will also be required in the CRF tables, and provide appropriate language.

Uncertainty Analysis and QA/QC

The IPCC has prepared both general and source-specific guidance for "good practices" in preparing GHG inventories. In accordance with procedures described in the IPCC *Good Practice* report, the U.S. is beginning to develop and implement a long-term system for QA / QC and uncertainty analysis. This effort is part of a three-year plan to complete a thorough assessment—including quantitative uncertainty analysis—of all data elements and source categories of the U.S. greenhouse gas inventory. As a first step in this effort, we are asking you to **collect readily available or easily acquired information** on the data quality and uncertainty characteristics of the activity, emissions, and other data that comprise your emission estimates. This information should be collected at the same time you are gathering information to prepare your inventory estimates. In addition, you may want to review the IPCC report for QC, data management, and other recommendations for good practices for your source category.

For those sources that have been identified as those for which more thorough QA / QC and uncertainty analysis will be performed this year, please refer to the draft document "Quality Assurance / Quality Control Plan for the U.S. Inventory" for specific information on what activities should be conducted in support of this effort. If you have any questions on data collection for uncertainty or QA / QC, please contact [QA / QC Officer] at (202) xxx-xxxx.

Annexes

Each of the source-specific methodological annexes (Annexes A through W) are to focus on providing additional information to that already given in the Methodology section of the main text that provides full reproducibility of the calculations, or if that is impossible to accomplish given the volume of data, then to provide full methodological transparency. Your write-up of the methodology for the Annex should be done in terms of "Steps." You should walk the reader through the calculations, providing transparency and if possible reproducibility.

Work Break-down Structure (see attachment)

The attached table lists sources / sections in the greenhouse inventory and attributes ownership in terms of the EPA staff that has primary responsibility and the ICF staff or other contractor whom we expect to be performing the work (I apologize for any errors in attribution).

Please review this table carefully. If you have any questions, concerns, or revisions needed please contact me.

2000 BASE YEAR INVENTORY WORK BREAK-DOWN STRUCTURE

Sector/Source Category	Annex Included	Source Responsibilities: EPA Staff	Source Responsibilities: Contractor/Contact(s)
Energy			
Carbon Dioxide Emissions from Fossil Fuel Combustion			
Carbon Stored in Products from Non-Energy Uses of Fossil Fuels			
Stationary Source Fossil Fuel Combustion (excluding CO_2)			
Mobile Source Fossil Fuel Combustion (excluding CO_2)			
Coal Mining			
Natural Gas Systems			
Petroleum Systems			
Natural Gas Flaring and Ambient Air Pollutants from Oil and Gas Activities			
International Bunker Fuels			
Wood Biomass and Ethanol Consumption			
Indirect CO_2 from CH_4 Oxidation			
Municipal Solid Waste Combustion			
Industrial Processes			
Titanium Dioxide Production			
Cement Manufacture			
Lime Manufacture			
Limestone and Dolomite Use			
Soda Ash Manufacture and Consumption			
Carbon Dioxide Consumption			
Iron and Steel Production			
Ammonia Manufacture			
Ferroalloy Production			
Petrochemical Production			
Silicon Carbide Production			
Adipic Acid Production			
Nitric Acid Production			
Substitution of Ozone Depleting Substances			
Aluminum Production (CO_2)			
Aluminum Production (PFCs)			
HCFC-22 Production			
Semiconductor Manufacture			
Electrical Transmission and Distribution			
Magnesium Production and Processing			
Industrial Sources of Ambient Air Pollutants			
Solvent Use			
Agriculture			
Enteric Fermentation			
Manure Management (CH_4)			
Manure Management (N_2O)			
Rice Cultivation			
Agricultural Soil Management			
Agricultural Residue Burning (CH_4, N_2O)			
Agricultural Residue Burning (CO, NO_x)			

(Table continued)

Sector/Source Category	Annex Included	Source Responsibilities: EPA Staff	Source Responsibilities: Contractor/Contact(s)
Land-Use Change and Forestry			
Changes in Forest Carbon Stocks			
Changes in Carbon Stocks in Urban Trees			
Changes in Agricultural Soil Carbon Stocks			
Changes in Yard Trimming Carbon Stocks in Landfills			
Waste			
Landfills			
Wastewater Treatment			
Human Sewage			
Waste Combustion			
Waste Sources of Ambient Air Pollutants			
Other Sections			
Executive Summary			
Introduction			
Emissions by Economic Sectors			
Potential Emissions of HFCs, PFCs, and SF_6			
Carbon Intensity Box			
Common Reporting Format Tables			
Annexes			
A. Methodology for Estimating Emissions of CO_2 from Fossil Fuel Combustion			
B. Methodology for Estimating Carbon Stored in Products from Non-Energy Uses of Fossil Fuels			
C. Methodology for Estimating Emissions of CH_4, N_2O, and Ambient Air Pollutants from Stationary Combustion			
D. Methodology for Estimating Emissions of CH_4, N_2O, and Ambient Air Pollutants from Mobile Combustion			
E. Methodology for Estimating CH4 Emissions from Coal Mining			
F. Methodology for Estimating CH4 Emissions from Natural Gas Systems			
G. Methodology for Estimating CH4 Emissions from Petroleum Systems			
H. Methodology for Estimating CO_2 Emissions from Municipal Solid Waste Combustion			
I. Methodology for Estimating Emissions from International Bunker Fuels Used by the U.S. Military			
J. Methodology for Estimating HFC and PFC Emissions from Substitution of Ozone Depleting Substances			
K. Methodology for Estimating CH_4 Emissions from Enteric Fermentation			
L. Methodology for Estimating CH_4 and N_2O Emissions from Manure Management			
M. Methodology for Estimating N_2O Emissions from Agricultural Soil Management			
N. Methodology for Estimating Net Changes in Forest Carbon Stocks			
N. Global Warming Potential Values			
O. Methodology for Estimating CH_4 Emissions from Landfills			
P. Key Source Analysis			
Q Global Warming Potential Values			
R. Ozone Depleting Substance Emissions			
S. Sulfur Dioxide Emissions			
T. Complete List of Source Categories			
U. IPCC Reference Approach for Estimating CO_2 Emissions from Fossil Fuel Combustion			
V. Sources of Greenhouse Gas Emissions Excluded			
W. Constants, Units, and Conversions			
X. Abbreviations			
Y. Chemical Symbols			
Z. Glossary			

E2. EXPERT REVIEW REQUEST LETTER

UNITED STATES
ENVIRONMENTAL
PROTECTION AGENCY
Office of Air and
Radiation

November 1, 2000

Dear <Title>. <First Name> <Last Name>,

On behalf of EPA's Office of Atmospheric Programs, I am pleased to provide you a copy of the draft *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 –1999* for your review. You have been identified as an expert in one or more of the greenhouse gas emission or sink source categories, and we hope that you will be able to find the time to participate in our annual government and expert review process.

Please note, however, that during this government and expert review process only relevant technical experts are being asked to contribute as individual reviewers or to delegate the review to other technical experts. During December and January there will be a much longer public review process—following the receipt of your comments and a federal register notice—during which interested organizations and individuals are encouraged to comment.

All reviewers are asked to evaluate the section entitled "Changes in this Year's Report," the Executive Summary, the References chapter, and the annexes of this document, in addition to the chapters specifically related to the reviewer's expertise. All peer review comments will be collated and considered in the preparation of a revised draft of this document, in accordance with EPA's Science Policy Council Peer Review Handbook (EPA 100-B-98-001). Please bear in mind that this document is in draft form; all estimates are still considered preliminary, so please do not cite or quote. Also, please note that the Land-Use Change and Forestry chapter is incomplete, the Manure Management section has not been fully integrated, and a section on Carbon Stored in Products from Non-Energy Uses of Fossil Fuels has been added.

This year's coverage, scope, and methodological approach are consistent with those used for the previous 1990-1998 report released in April of this year (EPA 236-R-00-001), which you can find on the EPA website at http://www.epa.gov/globalwarming/publications/emissions/us2000/.

In order to meet our reporting obligation to the UNFCCC Secretariat, we are requesting that you **submit your comments in writing by December 1st**. You may send written comments to me at the address on the letterhead, or send email comments to [agency inventory lead]@epa.gov. If you have any questions or comments please don't hesitate to call me at (202) xxx-xxxx, or fax at (202) xxx-xxxx.

Sincerely,

[Agency Inventory Lead]

E3. FEDERAL REGISTER NOTICE OF PUBLIC REVIEW

[Federal Register: January 9, 2001 (Volume 66, Number 6)]

[Notices]

[Page 1674-1675]

From the Federal Register Online via GPO Access [wais.access.gpo.gov] [DOCID:fr09ja01-64]

ENVIRONMENTAL PROTECTION AGENCY

[FRL-6931-6]

Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1999

AGENCY: Environmental Protection Agency (EPA).

ACTION: Notice of document availability and request for comments.

SUMMARY: The Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1999 is available for public review and comment. Annual U.S. emissions for the period of time from 1990-1999 are summarized and presented by source category and sector. The inventory contains estimates of carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), Hydrofluorocarbons (HFC), perfluorocarbons (PFC), and sulfur hexafluoride (SF6) emissions. The inventory also includes updated estimates of carbon sequestration in U.S. forests and soils. The technical approach used in this report to estimate greenhouse gas emissions from sources and removals by sinks is consistent with the methodologies recommended by the Intergovernmental Panel on Climate Change (IPCC). The Inventory of U.S. Greenhouse Gas Emissions and Sinks is the latest in a series of annual U.S. submissions to the Secretariat of the United Nations Framework Convention on Climate Change.

DATES: To ensure your comments are considered for the final version of this document, please submit your comments prior to February 20, 2001.

However, comments received after that date will still be welcomed and will be considered for the next edition of this report.

ADDRESSES: Comments should be submitted to [Agency Inventory Lead] at: U.S. Environmental Protection Agency, Office of Atmospheric Programs, Market Policy Branch (MC: 204N), 1200 Pennsylvania Avenue NW., Washington, DC 20460, Fax : (202) xxx-xxxx.

If you wish to send an email with your comments, you may send the email to barbour.wiley@epa.gov.

FOR FURTHER INFORMATION CONTACT: [Agency Inventory Lead], Environmental Protection Agency, Office of Atmospheric Programs, (202) xxx-xxxx.

SUPPLEMENTARY INFORMATION: You may view and download the document referenced above on the US EPA global warming site at http://www.epa.gov/globalwarming/publications/emissions/.

Dated: January 3, 2001.

Robert Perciasepe, Assistant Administrator, Office of Air and Radiation.

[FR Doc. 01-567 Filed 1-8-01; 8:45 am]

BILLING CODE 6560-50-P

E4. PRESS RELEASE FOR PUBLIC REVIEW

FOR RELEASE: THURSDAY, JAN. 11, 2001

DRAFT REPORT REVEALS INCREASE IN U.S. GLOBAL WARMING EMISSIONS

U.S. greenhouse gas (GHG) emissions rose 0.9 percent from 1998 to 1999, according to a draft EPA report recently released for public comment. Total GHG emissions of the six main greenhouse gases (weighted to reflect equivalent emissions of carbon dioxide or CO2), rose from 6,689 to 6,748 million metric tons. These gases include: CO2, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride. The CO2 from fossil fuel combustion at power plants and factories is the largest source of all greenhouse gases, accounting for 80 percent of all emissions in 1999. Fossil fuel combustion was responsible for 88 percent of total greenhouse emission growth from 1990 to 1999. The study also shows that from 1990 - 1999, GHG emissions from cars, trucks and buses rose 21 percent, while total highway miles traveled climbed 13 percent.

The report, "Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 - 1999," is required of the United States under its responsibilities as a party to the Framework Convention on Climate Change, which was signed in June 1992 at the Rio Earth Summit. Under the Framework Convention, the United States and other developed countries agreed to submit greenhouse gas emission reports annually to the Secretariat of the Convention. The report is available at: www.epa.gov/globalwarming/publications/emissions.

A Federal Register notice announcing a 30-day public comment period on the report was published Jan. 9. To receive a hard copy of this document, fax a request to the Agency at 202-xxx-xxxx, or write to the following address: U.S. EPA, Office of Atmospheric Programs, Market Policy Branch (MC: 6204N), 1200 Pennsylvania Avenue NW., Washington, DC 20460. For technical information, call [Agency Inventory Lead] of EPA's Office of Air and Radiation at 202-xxx-xxxx.

E4. PUBLIC REVIEW LETTER

UNITED STATES
ENVIRONMENTAL
PROTECTION AGENCY
Office of Air and Radiation

February 12, 2002

On behalf of EPA's Office of Atmospheric Programs and the dozens of other government agencies who have collaborated with us, I am pleased to provide you a copy of the draft *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2000* for your review.

The emissions estimates contained in this report, along with future updates, will be used to monitor and track the progress of the United States in meeting the its commitments under the United Nations Framework Convention on Climate Change (UNFCCC). Decision 3/CP.1 under the UNFCCC states that Annex I Parties should submit "National inventory data on emissions by sources and removals by sinks," and that this information "…should be provided annually on 15 April." To meet this commitment to the UNFCCC this document is produced annually.

Reviewers are encouraged to evaluate the front section on changes since last year's report, the executive summary, introduction chapter, reference sections, and annexes of this document in addition to the chapters specifically related to the reviewer's expertise. All review comments will be collated and considered in the preparation of the final report and later reports, in accordance with EPA's Science Policy Council Peer Review Handbook (EPA 100-B-98-001). Please bear in mind that this document is in draft form; all text and estimates are still considered preliminary. Specifically, we regret that the chapter on land use change and forestry is in an early draft stage.

This year's coverage, scope and methodological approach are consistent with those used for the previous 1990-1999 report released in April of last year (EPA-236-R-00-001), which you can find on the EPA website at www.epa.gov/globalwarming/publications/emissions/.

I would also like to draw your attention to a few areas of significant improvement. A new section of the report allocates emissions to "economic sectors," which is intended to more intuitively communicate the broad categories of economic activity that directly result in greenhouse gas emissions. The Energy Information Administration has developed fuel consumption data for a "comprehensive electric power industry sector." Previously fuel consumed by the growing number of non-utilities was hidden within the industrial sector, thereby leading to a mistaken picture of emissions associated with electricity generation. A series of improvements were also made to the estimates of CO_2 emissions and carbon storage from the non-energy use of fossil fuels for industrial feedstocks. Emissions from industrial wastewater and changes in carbon stocks from urban trees have been included for the first time. Finally, newly reported data on SF_6 emissions from magnesium production and processing and electric power transmission and distribution systems has been incorporated.

In order to meet our reporting obligation to the UNFCCC Secretariat, the review period has been limited to 30 days. You may send written comments to me at the address below or by email to gillenwater.michael@epa.gov.

Sincerely,

M.W. Gillenwater

Michael Gillenwater
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