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

Background on the U.S. Greenhouse Gas Inventory Process

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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.

The philosophy that the inventory program has developed—as it tries to balance the needs of its diverse audience—focuses on credibility, objectivity, and transparency. The program fosters a high level of credibility and objectivity by striving for unbiased quantitative estimates of emissions and sinks (i.e., removals) and for conservative and factual qualitative findings. In turn, detailed documentation—of results, methods, data, and evaluation of uncertainties—ensures transparency. Thus, the overall system is designed to maximize efficiency and quality at every level.

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 an overview of this system, which includes both processes for producing the inventory and procedures to manage its uncertainty and quality.

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, *Procedures Manual for Quality Assurance / Quality Control and Uncertainty Management*, 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 outgrowth of a decade of experience of staff 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. Melinda Harris took on the daunting task of developing an early draft describing the process of producing the *Inventory of U.S. Greenhouse Gas Emissions and Sinks*. However, it is Fran Sussman who 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. 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 document's accuracy and completeness.

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. And finally, we would like to thank the rest of the staff at EPA, EIA, ICF Consulting, and other organizations that have worked on the *Inventory* over the years and helped make it such an outstanding product.

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1 INTRODUCTION

Each year, the U.S. Environmental Protection Agency (EPA), in cooperation with other government agencies, prepares the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (referred to here as the *Inventory*). A wide range of agencies and individuals are involved in supplying data to, reviewing, or preparing portions of the U.S. inventory—including federal and State government authorities, research and academic institutions, industry associations, and consultants. The information reported in the *Inventory* includes estimates of annual emissions and sinks and trends over time, as well as other information and analyses on the sources of emissions and the methods by which emissions and sinks are calculated.

The *Inventory*—and the information it contains—serves a number of purposes, foremost of which is fulfilling our international commitments to report under the United Nations Framework Convention on Climate Change (UNFCCC). In addition to satisfying this formal commitment, the inventory data are critical to monitoring and tracking the progress of the United States in meeting commitments under the UNFCCC. The preparation of the greenhouse gas inventory is also part of a broader program of technical and policy support, and contributes to technical, scientific, and policy research aimed at understanding the relative contribution of different emission sources and sinks to overall emissions, the future time path of emissions and atmospheric greenhouse gas concentrations, and the potential cost of limiting emissions from different gases and sources. The inventory program also focuses on improving methodologies, on developing estimates for new source categories, and on finding new and improved activity data, emission factors, and direct measurements that go into the process of estimating the inventory.

The development of the national greenhouse gas inventory reflects a long history of U.S. leadership and active participation in international efforts to develop credible, high quality guidance and methods for estimating emissions and removals. The assumptions and methodologies used in the U.S. inventory are based on guidelines and recommended good practices developed cooperatively—with the assistance of countries like the United States—by the Intergovernmental Panel on Climate Change (IPCC/OECD/IEA 1997, IPCC 2000) on behalf of the UNFCCC. These reports are the basis of inventories produced by diverse countries worldwide.

The official national and international prominence of the U.S. Greenhouse Gas Inventory Program and the *Inventory*, as well as the program's varied audiences and uses, dictate that it meet high standards. The IPCC inventory guidelines and good practice guidance for preparing inventories are intended to promote quality along a number of dimensions. Foremost is the goal of reducing uncertainty in the emissions and sinks estimates, so that countries produce inventories "that are accurate in the sense of being neither over nor underestimates so far as can be judged, and in which uncertainties are reduced as far as practicable" (IPCC 2000). Further, an inventory program should include activities that both *promote* and *check* the accuracy, completeness, consistency, transparency, and comparability of the inventory to international methodologies, and that control other dimensions of quality. As stated in the IPCC guidance (IPCC 2000) document,

> Good practice guidance. . .supports the development of inventories that are transparent, documented, consistent over time, complete, comparable, assessed for uncertainties, subject to quality control and assurance, efficient in the use of the resources available to inventory agencies, and in which uncertainties are gradually reduced as better information becomes available.

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 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 must all be integrated into one comprehensive greenhouse gas inventory system. Thus, quantitative uncertainty analysis is not an end in itself; rather the method used to estimate uncertainty, and the estimated uncertainty values, are less

important than the institutional benefits of improved communications and building quality improvement feedback processes. As a result, the process in the inventory program of estimating uncertainty focuses on learning and quality and is integrated with the process of improving the inventory. The uncertainty analysis provides a mechanism for working directly with data suppliers and, thus, also provides a means by which to build quality throughout the participants in the national system of inventory development.

In line with the philosophy underlying the inventory program, and as part of efforts to control, document, and improve the quality of its inventory, the United States has developed a plan for conducting quality assurance (QA) and quality control (QC) activities and estimating uncertainty. This plan is an integral part of the U.S. Greenhouse Gas Inventory Program and has several distinct components. The first element is a set of processes and procedures intended to control, maintain, and check the quality of the inventory. The second element is a set of guidance material and processes, data collection and analysis, and empirical work designed to understand the sources of uncertainty in the U.S. greenhouse gas inventory and to estimate the magnitude of uncertainty surrounding the inventory estimates. The third element is a clear set of organizational roles and responsibilities. The fourth element in the U.S. plan for improving the inventory over time is the stated goal of conducting a thorough quality review and uncertainty analysis within the next few years. The final element involves unifying the information loops and corrective actions that, together with other feedbacks and interactions within the U.S. Greenhouse Gas Inventory Program, are designed to improve the quality of the U.S. greenhouse gas inventory over time.

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 and quality assurance procedures, and that describe the procedures for both quality control and estimating uncertainty. These documents are intended to be "living," that is, to evolve as new information arises or as procedures or organizational structures are tested, modified, or formalized.

This *Background* document provides an overview of the underlying organizational structure and process by which the *Inventory* and its supporting documentation are produced (including the points at which QA and QC occur and uncertainty is estimated). The audience for the current document includes those involved in preparing and checking the inventory and its associated documentation, as well as the general public and other parties interested in understanding the inventory process. The companion document, *Procedures Manual for Quality Assurance / Quality Control and Uncertainty Analysis* describes a comprehensive set of procedures that the United States is implementing in order to check and continually improve the quality of the inventory estimates and the documents in which these estimates are reported, and to estimate the uncertainty surrounding the inventory estimates.

The remainder of this document is organized into five chapters as follows:

- Chapter 2, *Overview of the U.S. Greenhouse Gas Inventory Process*, provides information on the inventory, its contributors, and the methods used to calculate emissions and sinks.
- Chapter 3, *Process and Organizational Structure: Developing the Inventory, Conducting QA/QC and Estimating Uncertainty*, describes the functional responsibilities for the inventory.
- Chapter 4, *The Inventory Program and Process for Developing the Inventory*, describes the process of producing and submitting the *Inventory* and related official documents, presents a sample schedule for the inventory development process, and indicates other features of the U.S. Greenhouse Gas Inventory Program.
- Chapter 5, *QA/QC Procedures and Uncertainty Analysis*, explains the general approach and goals for inventory quality and uncertainty analysis, and presents the integrated process of producing the inventory and conducting QA/QC.
- Chapter 6, *References*, presents source information for all chapters cited in the preceding chapters.

2 OVERVIEW OF THE U.S. GREENHOUSE GAS INVENTORY PROCESS

Under a decision of the Conference of the Parties[1] to the United Nations Framework Convention on Climate Change (UNFCCC), Annex I parties are required to provide national greenhouse gas inventories to the UNFCCC Secretariat each year by April 15. The information to be submitted covers annual emissions and removals data for the year 1990 (or other relevant base-year), and subsequent years up to two years prior to the year of submission.[2] As a signatory to the UNFCCC, therefore, the United States has a commitment to develop, update, publish, and make available a comprehensive national inventory of anthropogenic emissions of greenhouse gases to the atmosphere (by sources) and removals from the atmosphere (by sinks).[3] The U.S. Environmental Protection Agency (EPA) works cooperatively with the State Department and other federal agencies and departments to prepare this inventory of emissions and removals.[4]

Each year, the United States estimates greenhouse gas emissions and sinks for a series of years—starting with 1990 and ending with the most recent year for which reliable data are available (typically the calendar year prior to the year in which the inventory is being estimated). The inventory estimates are officially summarized and documented in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (here referred to as the *Inventory*). Thus, for example, the estimation process for the 1990-2000 inventory begins in 2001, and the official *Inventory* for 1990 to 2000 is submitted to the UNFCCC on April 15, 2002.

The *Inventory* document reports annual emissions and sinks of greenhouse gases, presents emission trends and their relationship to economic indicators, and describes the methodology and data sources used to compute the inventory. In accordance with UNFCCC guidelines on reporting and review (adopted by the Conference of the Parties at its fifth session), the inventory covers anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol.[5] At a minimum, inventories must include information on the following greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). The *Inventory* also reports emissions of ambient air pollutants (specifically nitrogen oxides (NO_x), carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs), and sulfur dioxide (SO_2)), which contribute indirectly to the greenhouse effect. In accordance with the UNFCCC guidelines, the United States reports aggregate emissions in CO_2 equivalent terms using Global Warming Potential (GWP) values provided by the Intergovernmental Panel on Climate Change (IPCC) in its Second Assessment Report (IPCC 1996).[6]

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[1] The Conference of the Parties is the supreme body of the UNFCCC, comprising more than 170 nations that have ratified the UNFCCC. Thirty-six parties are listed in Annex I to the UNFCCC, including most countries belonging to the Organisation for Economic Co-operation and Development (OECD).

[2] See "*Review of the Implementation of Commitments and of Other Provisions of the Convention: UNFCCC guidelines on reporting and review.*" FCCC/CP/1999/7, 16 February 2000. Available at http://www.unfccc.de/resource/docs/cop5/07.pdf.

[3] The term anthropogenic refers to greenhouse gas emissions and removals that are the direct result of human activities or natural processes that have been affected by human activities.

[4] This role was established when Congress passed the Global Climate Protection Act of 1987 (see 15 U.S.C. Sec. 2901, Section 1103). The Act gives the Secretary of State the responsibility of coordinating U.S. policy requiring action through the channels of multilateral diplomacy, and also directs the Secretary of State to work jointly with the Administrator of the EPA and other U.S. agencies. See Appendix A for the relevant language.

[5] See "*Review of the Implementation of Commitments and of Other Provisions of the Convention: UNFCCC guidelines on reporting and review.*" FCCC/CP/1999/7, 16 February 2000. Available at http://www.unfccc.de/resource/docs/cop5/07.pdf.

[6] The IPCC recently published its Third Assessment Report (IPCC 2001). This report revises the global warming potential of several gases relative to the IPCC's Second Assessment report (IPCC 1996).

2.1 Uses of the National Greenhouse Gas Inventory and the Inventory Program

The development of the U.S. greenhouse gas inventory is part of a broader inventory program that goes beyond preparing and disseminating the *Inventory* document. The objectives of this inventory program are driven by U.S. commitments under Articles of the UNFCCC and by activities undertaken to support U.S. policy-making.

Articles 4 and 12 of the UNFCCC require that Parties to the UNFCCC develop, periodically update, publish, and make available to the Conference of the Parties national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled under the Montreal Protocol.[7] In addition, future commitments may require estimating emissions and removals as part of ensuring that Parties are in compliance with emission limits, that they have a national system for estimating sources and sinks of greenhouse gases, that they submit an inventory annually, and that they formulate national programs to improve the quality of emission factors, activity data, or methods.

The objectives of the U.S. Greenhouse Gas Inventory Program extend beyond the direct requirements of U.S. commitments under the UNFCCC. The United States participates in international and domestic efforts to refine and develop the methodologies used to prepare emission inventories and to advance and incorporate scientific research, and works to foster consistent estimation approaches across domestic agencies and programs. The EPA provides technical support and methodological information to State and local governments for inventories and other climate change analyses. The greenhouse gas inventory, and analyses that rely on inventory data, provide information to U.S. officials in support of international negotiations on climate change, meetings to define and understand the implications of future provisions under the UNFCCC, and efforts to assess progress in meeting domestic goals.

The audiences for the *Inventory* reflect its several roles in the broader inventory program. For example, the international climate change community relies on the *Inventory* for information about U.S. emissions and removals and evaluates the quality and consistency of the greenhouse gas inventory. Domestically, Congress and decision makers and policy advisors rely on the *Inventory* and related products for information on the U.S. contribution to global emissions and removals and on contributions by key industries, as well as for estimating the impacts of existing and planned policies on greenhouse gas emissions. States and localities, the general public, special interest groups, and businesses also use the *Inventory*, as do scientists and researchers employed in climate and economic modeling and other climate change issues.

2.2 Developing the U.S. Inventory: IPCC Methodology

The IPCC, working in cooperation with scientists, national experts, and inventory specialists from around the world (including significant participation by the United States), has developed methodological guidelines for preparing national greenhouse gas emission inventories. The IPCC guidelines are designed to ensure that the national inventories submitted to the UNFCCC are consistent and comparable across sectors and nations. In developing its national greenhouse gas inventory, the United States employs methods, data sources, and analytical approaches that are consistent with the IPCC guidelines.

The most recent version of the IPCC guidelines, the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC/OECD/IEA 1997, here referred to as the *IPCC Revised Guidelines*), is the basis for national inventories prepared worldwide. Additional guidance on good practices in preparing emission inventories and on improving the quality of and reducing the uncertainty in, emission estimates is provided by a companion IPCC document, *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC 2000, here referred to as *IPCC Good Practice Guidance*).

The *IPCC Revised Guidelines* provide technical information for estimating anthropogenically-induced emissions and removals of greenhouse gases. Both the *IPCC Revised Guidelines* and the *IPCC Good Practice Guidance* cover six broad categories (i.e., sectors) of sources of emissions or removals (energy, industrial processes, solvent use, agriculture, land-use change and forestry, and waste), each with multiple

[7] Chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), and halons (halocarbons that contain bromine) are greenhouse gases that are also stratospheric ozone depleting substances under the Montreal Protocol.

source categories. Because estimates of greenhouse gas emissions at the national level are generally calculated rather than directly measured, the process of estimating emissions usually focuses on summing the products of activity data (measures of the occurrence of activities that produce greenhouse gas emissions in a given source category) and emission factors (the quantity of emissions per unit of the activity).[8] These products are calculated with varying degrees of complexity depending on the source category. Removals by sinks are calculated in analogous ways.

The *IPCC Revised Guidelines* and *IPCC Good Practice Guidance* are designed to be followed by diverse nations, each with unique national circumstances. Countries vary in the sources and sinks that are considered "key" (i.e., contribute significantly to national emission estimates and so are high priority for quality assurance and quality control activities), and in the availability of both the data and the resources needed to develop a greenhouse gas inventory.[9] Consequently, the *IPCC Revised Guidelines* permits alternative approaches to calculating an inventory of emissions and sinks, including employing relatively simple methods that use national activity data and default average emission factors (generally referred to as Tier 1) for use by countries where country-specific data on key variables may be unavailable or difficult to obtain. The *IPCC Revised Guidelines* also provides technical information and guidance for more detailed inventory methods (generally referred to as Tier 2 or greater).[10] These methods may require a country to develop and use emission factors and other data specific to the country.

For some emission sources, the United States uses IPCC default methodologies and factors. However, for emission source categories that are significant sources of emissions, the United States applies a more detailed analysis. In accordance with the *IPCC Revised Guidelines*, whenever the United States' approach involves a more rigorous calculation or method than the *IPCC Revised Guidelines* provides, the *Inventory* reports and explains the approach in a clear and transparent manner. For comparison purposes, the *Inventory* also includes estimates prepared using the IPCC Reference Approach for CO_2 emitted during fossil fuel combustion.

To the extent possible, the U.S. emission estimates rely on published activity data and emission factors. Much of the data underlying the emission estimates comes from government statistics, including published or unpublished data supplied by agencies and departments such as the Energy Information Administration (EIA) of the U.S. Department of Energy (DOE) and the U.S. Forest Service (USFS) of the U.S. Department of Agriculture (USDA). State agencies and trade associations also supply important data. Some emission estimates, such as those for nitrogen oxides (NO_x), carbon monoxide (CO), and nonmethane volatile organic compounds (NMVOCs) are taken directly from EPA estimates of emissions of ambient air pollutant emissions, which are prepared to determine progress in meeting national standards for air pollution promulgated under the authority of the Clean Air Act and its amendments.

2.3 Contributors to the Inventory

Developing the emission estimates and the *Inventory* document is an extensive effort, involving modeling and estimation by many federal and State government agencies, research institutions, universities, and consultants. In addition, numerous statistical and informational databases compiled by all levels of government, by trade and research associations, and by other public and private institutions, are valuable source of data inputs, or may supply secondary data sources, to the inventory development process.

The U.S. Greenhouse Gas Inventory Program within EPA's Office of Atmospheric Programs (OAP) provides technical oversight, performs quality assurance on all aspects of inventory development, and coordinates the expert and public review processes. Also within EPA, several offices coordinate in

[8] Some sources are actually measured using direct monitoring. For example, emission factors are often developed using measurements. For most sources, however, the U.S. inventory relies on activity based estimation methods.

[9] A key source category is defined such that the estimated emissions have a "significant influence on a country's total inventory of direct greenhouse gases in terms of the absolute level of emissions, the trend in emissions, or both" (IPCC 1997).

[10] Note that these Tiers should not be confused with the *quality control* Tiers described in Chapter 2 of the *Procedures Manual*.

researching emission pathways and developing new procedures for estimating greenhouse gas emissions and removals:

- The Clean Air Markets Division within OAP is home to the overall U.S. Greenhouse Gas Inventory Program. It is responsible for reporting to the UNFCCC and publishing the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* each year. It also prepares fossil fuel combustion emission estimates along with estimates from a variety of other source categories.
- The Climate Protection Partnerships Division within OAP produces annual estimates of CH_4 and N_2O emissions from a variety of agricultural, waste, energy, and other source categories. They also work with USDA and USFS to produce estimates of CO_2 fluxes from land use change and forestry activities.
- The Global Programs Division within OAP tracks emission trends for the ozone depleting substances and their substitutes, including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). They also track emissions from other industrial sources of these gases.
- The Office of Research and Development (ORD) conducts research into a variety of source categories.
- The Office of Solid Waste and Emergency Response (OSWER) provides additional information on landfills and solid waste management systems, as well as the fate of products in landfills. These statistics contribute to estimates of methane emissions.
- The Office of Water (OW) provides information on domestic and industrial wastewater that is used in calculating emissions.
- The Office of Transportation and Air Quality (OTAQ) develops emission factors and detailed emission estimates for the transportation sector. Together with the Federal Highway Administration, OTAQ reports vehicle miles traveled, which are used to develop methane, nitrous oxide, and trace gas emission estimates.
- The Office of Air Quality Planning and Standards (OAQPS) provides estimates of emissions of ambient air pollutants (including CO, NO_x, and NMVOCs).

In addition to the EPA, a number of U.S. agencies and departments are important contributors to the greenhouse gas emission inventory. A partial list of the roles of different federal government entities supplying data for the inventory or contributing directly to its preparation includes the following:

- The Energy Information Administration (EIA) gathers and compiles detailed information on energy production and consumption, which forms the foundation for the energy-related greenhouse gas emission estimates. The EIA also reports on the carbon content of fossil fuels consumed in the United States and develops emission factors that relate carbon emissions to fuel quantity burned. Likewise, the U.S. Department of Energy (DOE) provides review and analysis.
- The U.S. Department of Agriculture (USDA) compiles and reports information on fertilizer use, crop production statistics, and agricultural practices. The U.S. Forest Service (USFS) regularly assembles and reports an inventory of forest and soil carbon in the United States. This forest inventory, along with the National Resource Inventory, is used to track net CO_2 fluxes from land use change and forestry activities. The EPA works closely with the USFS to expand the analysis of land use change, and forestry-related carbon fluxes.
- The Department of Transportation, the Federal Highway Administration, the Treasury Department, the Federal Aviation Administration, the Department of Commerce, the Bureau of Census, the U.S. Geological Survey, and the Bureau of Transportation Statistics are sources of valuable information.

Private groups publish several reference materials that provide data on industrial production and chemical use that are key to inventory development. State government agencies, academic researchers, consultants, and others also contribute to developing inventory estimates or serve as reviewers of the final estimates.

3 PROCESS AND ORGANIZATIONAL STRUCTURE: DEVELOPING THE INVENTORY, CONDUCTING QA/QC, AND ESTIMATING UNCERTAINTY

A variety of staff contributes to the inventory process. The inventory "team" includes agency and department staff, contractors, and other persons involved directly and indirectly in preparing or handling the inventory estimates and the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (referred to here as the *Inventory*) or other official documents. Inventory staff or special staff may be assigned to check the quality of the inventory as it is developed, including routine checks to ensure data integrity, correctness, and completeness. Staff also estimate the uncertainty surrounding the inventory estimates, and conduct expert and public reviews associated with quality assurance (QA).

The organization of the team for inventory development and quality assurance / quality control (QA/QC) results in supervision of all aspects of the inventory development activities, of the quality checks and uncertainty analysis, and of the expert review process. The functional responsibilities and informal titles of those responsible for these activities include the following (Appendix B provides contact information for the persons directly involved in preparing the inventory):

- *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, 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*—supervises the overall implementation of QA/QC procedures, including overseeing the expert reviews and other components, and is responsible for ensuring the full and adequate implementation of QA/QC and the adequate qualifications of inventory staff and contractors
- *Uncertainty Analysis Coordinator*—directs the 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)[11]

The organizational structure of the team is depicted in Exhibit 3-1. As illustrated in this exhibit, the Agency Inventory Lead has overall leadership responsibility for all activities associated with the inventory, including the preparation of the inventory estimates and text, QA/QC, uncertainty analysis, and the

[11] 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.

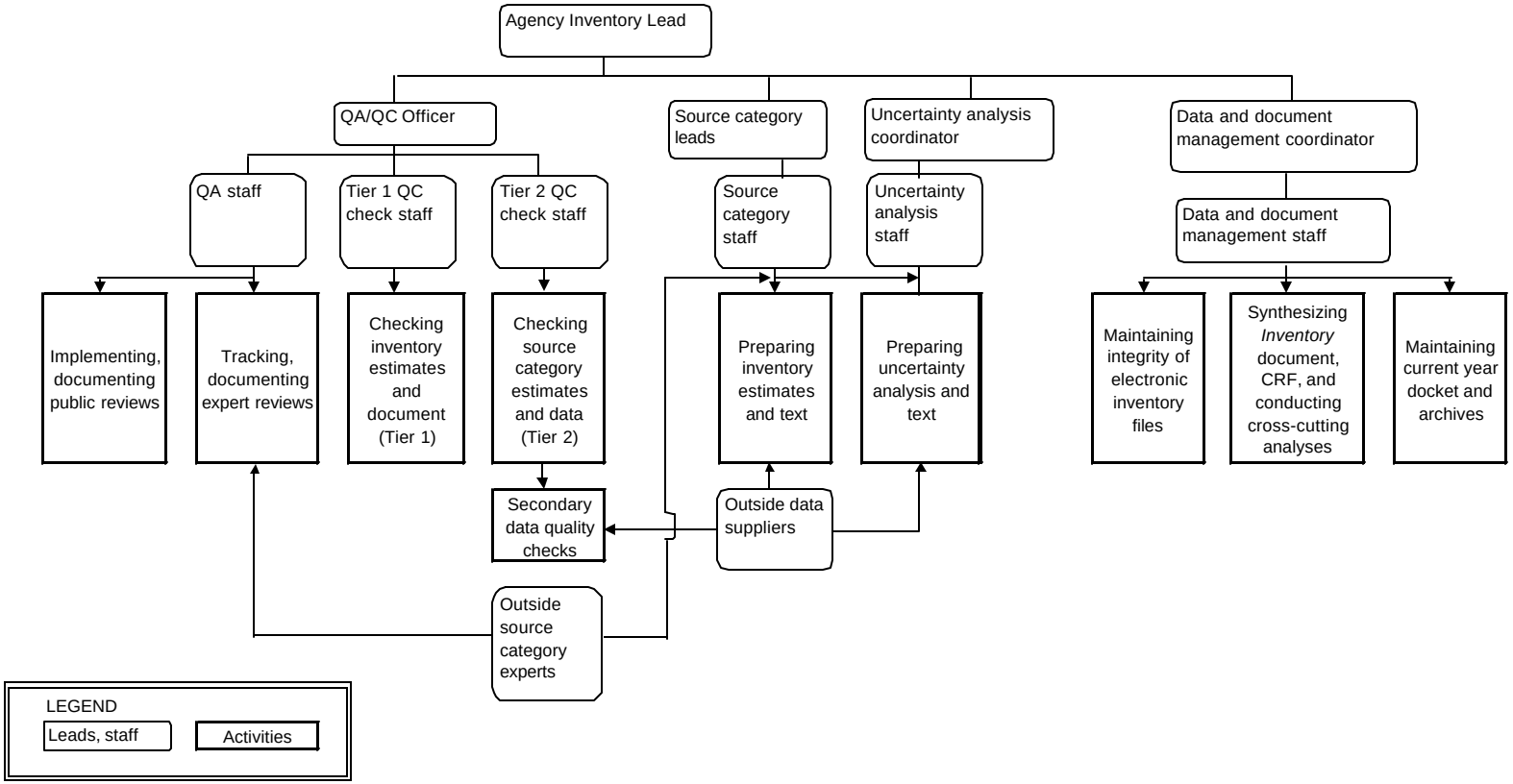
centralized document and file handling and archiving. In addition to the Agency Inventory Lead, staff are divided into four basic teams or groups. Note that QA/QC staff, data and document management staff, uncertainty staff, and inventory staff are not necessary distinct, but may include overlap among the persons involved.

Source Category Leads and associated staff have responsibility for preparing the inventory estimates and document text, including obtaining all relevant data, developing methodologies, and coordinating among government and contracting staff. QA/QC staff, under the direction of the QA/QC Officer, undertake quality assurance activities (primarily the inventory review processes) and quality control, which includes both of what 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*), identifies as Tier 1 checks (mostly general and computational checks) of the inventory estimates, and as Tier 2 checks (detailed source category-specific checks of both the estimates and the data sources). The Data and Document Management Coordinator and staff have responsibility for synthesizing the work of the source category inventory staff, including integrating the spreadsheets across the source categories, preparing the *Inventory* document and drafting language on trends and aggregate results, synthesizing the Common Reporting Format (CRF) tables performing cross-cutting analyses (see Chapter 4), and controlling all the facets of electronic file and document management.

The uncertainty analysis of the inventory estimates is a coordinated effort among all the groups. The Uncertainty Analysis Coordinator and staff have primary responsibility for 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 entire *Inventory*. The Source Category Leads are responsible for making key decisions and providing key input into the uncertainty analysis for specific source categories (such as determining the appropriate level of disaggregation for data collection and model development, deciding which variables require enhanced input data collection efforts, and identifying experts for elicitation). They are also responsible for reviewing the results of uncertainty analysis, identifying corrective actions to be taken, and ensuring that a summary of the results of uncertainty analysis is reported in the *Inventory* document. QA/QC staff, by conducting the Tier 2 reviews that identify quality issues associated with secondary data, also contribute to the uncertainty analysis.

Many of the individuals that fulfill the functions described above will be directly involved in the U.S. Environmental Protection Agency (EPA) office supervising the development of the inventory. However, other offices in EPA or other agencies, as well as contractors or other designated entities, may fulfill or contribute to fulfilling portions of the functional responsibilities described above. In addition, one individual may fulfill more than one functional role (e.g., the QA/QC Officer may be the Uncertainty Analysis Coordinator as well). Similarly, as noted above, inventory staff may also function as QC staff, or data and document management staff may assist in the quality assurance review processes. The specific activities and checks that are part of QA/QC and the uncertainty analysis are discussed in the companion to this document, *Procedures Manual for Quality Assurance / Quality Control and Uncertainty Management.*

Exhibit 3-1. Organizational Structure and Division of Responsibilities: Inventory Development, QA/QC, and Uncertainty



4 THE INVENTORY PROGRAM AND PROCESS FOR DEVELOPING THE INVENTORY

The *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (here referred to as the *Inventory*) is a key component of U.S. commitments under the United Nations Framework Convention on Climate Change (UNFCCC). The United States published the first official *Inventory* in 1994, covering emissions from 1990 to 1993. Prior to that year, however, inventory estimates had been prepared beginning with the year 1988. At the first Conference of the Parties, 1990 became the base or "benchmark year;" since that time, 1990 has been the initial year of reporting for the U.S. *Inventory*. The UNFCCC Common Reporting Format (CRF) tables that depict the activity data and other information used to compile the inventory, and the national communication, which contains a variety of technical, economic, and policy information are also part of the U.S. commitment under the UNFCCC.

This chapter provides an overview of the components of the inventory program, focusing primarily on the activities needed to develop the inventory and related documents—which activities are also the key focus of the quality assurance / quality control (QA/QC) procedures and uncertainty analysis presented in the companion *Procedures Manual*. Over the years, the United States has developed a structured process for preparing its greenhouse gas emission estimates, the inventory document in which the estimates and methodology are reported (*Inventory of U.S. Greenhouse Gas Emissions and Sinks*), and the official submissions of the results to the international community. This process successfully coordinates the diverse set of activities required to produce, review, and submit the inventory and its related activities—including drawing on the expertise and data at the agencies and institutions described in Chapter 2. The United States has also developed a process for conducting both public and peer reviews of the document, and for preparing formal submissions of the inventory and CRFs to the international community.

The discussion below focuses on four distinct aspects of the inventory program: (1) preparing the inventory and inventory document; (2) meeting international reporting requirements; (3) cross-cutting activities associated with the inventory; and (4) technical and policy support. The discussion does not include QA/QC and uncertainty analysis and their integration into the inventory process (see Chapter 5), with the exception of expert review. Although expert review is technically part of the QA/QC process, it is essential to the preparation of the inventory and so is discussed here.

4.1 Drafting and Finalizing the Inventory Document

The steps required to develop the U.S. submission are described below.

Getting Started. Initiating the annual development of the inventory requires coordinating diverse Source Category Leads and supporting staff at the U.S. Environmental Protection Agency (EPA), Outside Experts in the source category, such as representatives from other federal agencies, and contractors providing technical support to the inventory. This coordination is initiated by a meeting called by the Agency Inventory Lead in which new developments or changes to the process are highlighted. As part of the initiation process, the Data and Document Management Coordinator distributes the text and spreadsheet files from the previous years' inventory to the designated Source Category Leads. The Agency Inventory Lead also distributes a "kickoff memorandum" that outlines the preparation guidelines for both the text and the spreadsheets and includes a schedule for the upcoming year. Once files are received, Source Category Leads begin the inventory development.

Methodology Development and Data Collection. Source Category Leads begin the process of collecting input data and, as necessary, evaluating or developing the estimation methodology for the individual source categories. (Chapter 2 provides additional information on the estimation methodology.)

For most source categories, the methodology for the previous year is applied to the new "current" year of the *Inventory* , and it will be necessary for inventory analysts to collect any new data or update data that have changed from the previous year. [12]

If estimates for a new source category are being developed for the first time, or if the methodology is changing for an existing source category (e.g., the United States is implementing a higher Tiered approach for that source category), then the process is less straightforward; the Source Category Lead and staff will need to develop the new methodology and set of spreadsheets, which also requires gathering activity data and emission factors (or in some cases direct emission measurements) for the entire time series.[13] During methodology development and data collection, staff consult various experts throughout the federal government, academia, and research institutions to provide both data and advice on the most appropriate methods and data available.

Estimate Emissions and Sinks and Prepare Write-up. Once the methodology is in place and the data are collected, Source Category Leads develop emissions and sinks estimates. Source Category Leads and their staff update the relevant text and accompanying annexes for the *Inventory*. For new source categories, new information is written. The Source Category Lead delivers all completed inventory estimates and a well-documented analysis tool (typically Excel spreadsheets) to the Agency Inventory Lead and the Data and Document Management Coordinator.

Compile Summary Spreadsheet. The Data and Document Management Coordinator aggregates the estimates for the individual source categories into an inventory of emissions for the United States and develops a summary spreadsheet to link the individual source category spreadsheets together. This summary sheet contains all of the essential data in one central location, in formats commonly used in the document. In addition to the data from each source category, national trend and related data is also gathered in the summary sheet for use in the Executive Summary and Introduction.

Draft Inventory Document. The Data and Document Management Coordinator replaces the new and updated text into the appropriate chapter in the body of the report and in the Annexes. In addition, a brief overview of each chapter is created that summarizes the emissions from all sources discussed in the chapters.

Also at this time, the Introduction and Executive Summary are revised to reflect the trends for the most recent year of the current *Inventory*. The analysis of trends necessitates gathering supplemental data including weather and temperature conditions, economic activity and GDP, population changes, atmospheric conditions, and the annual consumption of electricity, energy, and fossil fuels. Changes in these data are used to explain the trends observed in greenhouse gas emissions in the United States. Furthermore, specific factors that affect individual sectors are researched and discussed. Many of the factors that affect emissions are included in the inventory document as separate analyses or side discussions in boxes within the text. There are also boxes created that look at the data aggregated in different ways than in the remainder of the document, such as a focus on transportation activities or emissions from electric utilities.

Expert and Public Review Periods. The entire document is sent to a select list of recipients, generally Outside Source Category Experts, for expert review. Once comments are received and addressed, the document is released for public review by inserting a notice in the Federal Register and posting the document on the EPA Web site. The document will again be revised, as needed, to reflect public comments received.

Graphical Layout and Preparation for Printing. The final step in the inventory process is to have the document laid out in PageMaker. During this process, the Data and Document Coordinator and the Agency Inventory Lead check the document to ensure that the final content is accurate. After layout of the document is complete, the EPA sends the document to the Government Printing Office for printing. The completed document is distributed by U.S. postal mail, and posted on the EPA Global Warming web page.

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[12] The "current" year is the year being added to the *Inventory*; for example, in the 1990-2000 *Inventory*, 2000 is the current year.

[13] In this case, Tier refers to the choice of estimation method, with Tier 1 being the most simple (often using default data) and the higher Tiers increasing in complexity.

4.2 Fulfilling International Reporting Requirements

Under Article 4 of the UNFCCC, the United States and other Parties to the Convention must "develop, periodically update, publish, and make available…national inventories of anthropogenic emissions by source and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies." Parties also commit under Article 4 to formulate, implement and publish other information, such as programs to mitigate emissions, and to cooperate in and promote a variety of activities, including technology transfer, preparing for adaptation, and research. Under Article 12, Parties to the Convention must communicate to the Conference of the Parties, through the Secretariat, a number of elements of information, including a national inventory of emissions, steps taken to implement the UNFCCC, and other information. These requirements have been operationalized in a number of UNFCCC decisions and formalized in UNFCCC reporting guidelines.

The U.S. submission in fulfillment of the requirement has several components. The *Inventory* document contains information on methodologies and national annual greenhouse gas inventory estimates. The UNFCCC CRF tables aggregate the *Inventory* data in a format easily compared to other countries' data. The completed *Inventory* document and the UNFCCC CRF tables are printed in hard copy and placed in binders. The Agency Inventory Lead is responsible for delivering both the binders and electronic copies (which are placed on CD-Rom and also e-mailed) to the UNFCCC Secretariat to fulfill the U.S. reporting requirements. The final document is due to the UNFCCC Secretariat on April 15 of each year. In addition, under the UNFCCC reporting guidelines and associated decisions, the United States is required periodically to submit a *national communication* that includes a variety of information on national circumstances.

These reporting requirements, as summarized in the *UNFCCC guidelines on reporting and review*, are described below.[14]

The Common Reporting Format. The UNFCCC CRF is a standardized set of tables for reporting estimates of greenhouse gas emissions and removals and other relevant information. By using a common format across all countries, the UNFCCC CRF presents the inventory data in a way that facilitates improved handling, processing, and analysis of inventory information, including cross comparisons across among submitting countries and easy identification of possible mistakes, misunderstandings, and omissions. The completed UNFCCC CRF is submitted to the UNFCCC Secretariat.

The CRF consists of: (a) summary and overview tables; (b) sectoral background data tables for reporting aggregate emission factors and activity data; (c) a comparison of national estimates with estimates obtaining using the Intergovernmental Panel on Climate Change (IPCC) reference approach for CO_2 emissions from fossil fuel combustion; and (d) tables for reporting information on a variety of items, including recalculations, completeness, and QA/QC. To prepare the U.S. tables, the U.S. inventory spreadsheets are linked to the appropriate location and year within the UNFCCC CRF tables. In addition, text explanations are provided for items such as sources excluded and data changes from the previous year's submission.

National Inventory Report. The national inventory report contains detailed and complete information on the inventory for all years from the base year to the year of the current annual inventory submission. The *Inventory* document fulfills the U.S. requirement to produce a national inventory report. The purpose of the report is to ensure the transparency of the inventory. The national inventory report is submitted annually to the Conference of the Parties through the UNFCCC Secretariat and must also be published and/or maintained in its entirety on a national web site.

The national inventory report includes: (a) annual inventory information for the base year to the year of the current submission; (b) a description of the specific methodologies and assumptions used in each sector, including an indication of the level of complexity (IPCC tiers); (c) references or sources of information used for the inventory estimates; (d) information on assumptions underlying the estimates and the rationale for their selection; (e) specific information on feedstocks and bunkers; (f) information on

[14] See "*Review of the Implementation of Commitments and of Other Provisions of the Convention: UNFCCC guidelines on reporting and review.*" FCCC/CP/1999/7, 16 February 2000. Available at http://www.unfccc.de/resource/docs/cop5/07.pdf.

recalculations, uncertainties, and quality assurance / quality control procedures; and (g) a section identifying changes with respect to the previous years. The national inventory report

The National Communications. The purpose of national communications is to fulfill Annex I Parties' commitments under Articles 4 and 12 of the Convention. Every three to five years, the United States issues its National Communication on climate change. This document includes both emissions data from the inventory, as well as projections and mitigation strategies and other data relating to the fulfillment of commitments under the convention. The document to be submitted to the UNFCCC has several required components: (a) an executive summary; (b) a description of national circumstances relevant to greenhouse gas emissions and removals; (c) greenhouse gas inventory information (including summary tables and a descriptive summary; (d) policies and measures adopted to implement commitments; (e) projected trends in emissions and removals with policies and measures in place; (f) a vulnerability assessment; (g) details on financial resources and technology transfer; (h) actions relating to research and systematic observation; and (h) actions relating to education, training, and public awareness. Much of the information presented in the national communication is supported by the technical and policy work that is done under the broader inventory program.

4.3 Cross-Cutting Activities

The United States undertakes a number of cross-cutting analyses in conjunction with the U.S. Greenhouse Gas Inventory Program.[15] Foremost among these activities is the ***key source analysis***. A key source is "one that is prioritized within the national inventory system because its estimate has a significant influence on a country's total inventory of direct greenhouse gases in terms of the absolute level of emissions, the trend in emissions" (IPCC 2000). The IPCC report, *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC 2000, here referred to as *IPCC Good Practice Guidance*), recommends conducting a key source analysis for each year's inventory. Two quantitative approaches to identifying key source categories are described.

The first type of key source analysis (a Tier 1 approach) identifies the contribution of individual source categories to the absolute overall level of national emissions (called a level assessment).[16] In addition, for countries such as the United States that have a time series of emission estimates, the investigation of key sources should also include evaluating the influence of trends in individual source categories on the overall inventory trend (called a trend assessment). The Tier 2 approach is a more detailed analysis that builds on the Tier 1 approach by incorporating national uncertainty estimates into the Level and Trend assessment.). The key source analysis should also include applying qualitative criteria, such as identifying source categories that are changing significantly because of mitigation technologies, or that have high expected-emissions-growth.

4.4 Technical and Policy Support

Although the core of the U.S Greenhouse Gas Inventory Program is the development and preparation of the *Inventory* document and associated national greenhouse gas emission and sink information, the inventory program also fills a number of other roles. Its ability to support these other functions is a direct result of the staff's expertise in greenhouse gas emissions and other climate change-related data analysis.

Reliable and thorough technical analysis is a crucial input to the policy making process. The Greenhouse Gas Inventory Program supports EPA and other federal agencies, such as the State Department or the President's Council on Environmental Quality, by providing timely support on climate change and environmental policy issues. This support can take the form of assessing U.S. greenhouse gas emissions in comparison to emissions globally, assessing inventories from other countries, or helping to determine

[15] A number of cross cutting activities are not discussed here but are covered in the companion document, *Procedures Manual for Quality Assurance / Quality Control*. These include QA/QC activities and the estimation of uncertainty, both of which are discussed in Chapter 3 of this document. These and other activities, such as centralized archiving and documentation procedures for the inventory, are also discussed further in the *Procedures Manual*.

[16] Note that these Tiers are distinct from both the Tiers that represent complexity levels in the choice of the inventory methodology and the Tier 1 and Tier 2 quality controls and checks that can be performed.

emission trends for particular domestic sectors or industries. This latter type of analysis is also an important input to the design of new government emission reduction (i.e., mitigation) programs and to measuring the effectiveness of existing programs.

The UNFCCC Secretariat and the IPCC Working Groups and Technical Support Unit on greenhouse gas inventories both depend greatly on experts from individual countries, such as the United States, which are Parties to the UNFCCC. The U.S. Greenhouse Gas Inventory Program supports the UNFCCC process through its participation in technical workshops and on teams charged with reviewing inventories submitted by Parties to the UNFCCC. Support to the IPCC usually takes the form of participation in developing improved technical guidance and supporting the broader scientific mission of the IPCC through its analysis of emission projections and other issues. All of this support is made possible and reinforced by U.S. leadership in developing rigorous methodologies for estimating emissions and removals of greenhouse gases by anthropogenic activities.

The *Inventory* serves as an immensely valuable resource for others around the world working on their own emission estimates for individual source categories or complete greenhouse gas inventories. In addition to providing this resource, the United States provides bilateral and multilateral support to many developing and Economy in Transition countries (i.e., Eastern European countries and republics from the former Soviet Union) to improve their greenhouse gas inventories. Similarly, the technical guidance and information provided by the inventory program is also used by many State and local governments, corporations, and other organizations in the preparation of their own inventories. Because the *Inventory* serves as such an important resource for so many, the staff of the inventory program often serves as an informal clearinghouse for inventory-related technical information.

Finally, as part of its continual improvement process, the inventory program maintains a research and development effort into new or improved methodologies, data sources, emission factors, and estimates for excluded source or sink categories. This effort may be performed by inventory program staff or take the form of directed financial support to researchers in academic or other institutions. The results of this research are eventually reflected and documented in the published *Inventory* report.

4.5 Illustrating the Inventory Development Process

The above processes are depicted in flowchart form in Exhibit 4-1, and a time line of milestones for the *Inventory* document and its delivery to the UNFCCC is displayed in Exhibit 4-2. The flowchart illustrates the major stages and components of the inventory development process: estimating emissions and developing the draft *Inventory* document; conducting expert and public reviews and finalizing the inventory document; preparing associated materials (key source analysis, UNFCCC CRF, national communications); and designing, printing, and distributing the final document. The flowchart also indicates the process of submitting the *Inventory*, CRF, key source analysis, and national communication to the UNFCCC.

Exhibit 4-2 provides a timeline for key milestones in the process of developing and submitting the inventory to the UNFCCC, for a sample inventory year. As illustrated by the Exhibit, in order to produce the inventory by April 15 each year, the inventory team follows a highly structured process, operating within a tight timeframe. Although the schedule indicates only the events leading up to the submittal of the inventory, it is clear from the flowchart that a number of events are occurring concurrently with these activities, including preparation of the CRF and key source analyses, and other activities in the inventory program, such as support to State and local governments, outreach, and other facets of the program.

Exhibit 4-1. U.S. Inventory Program and the Inventory Development Process

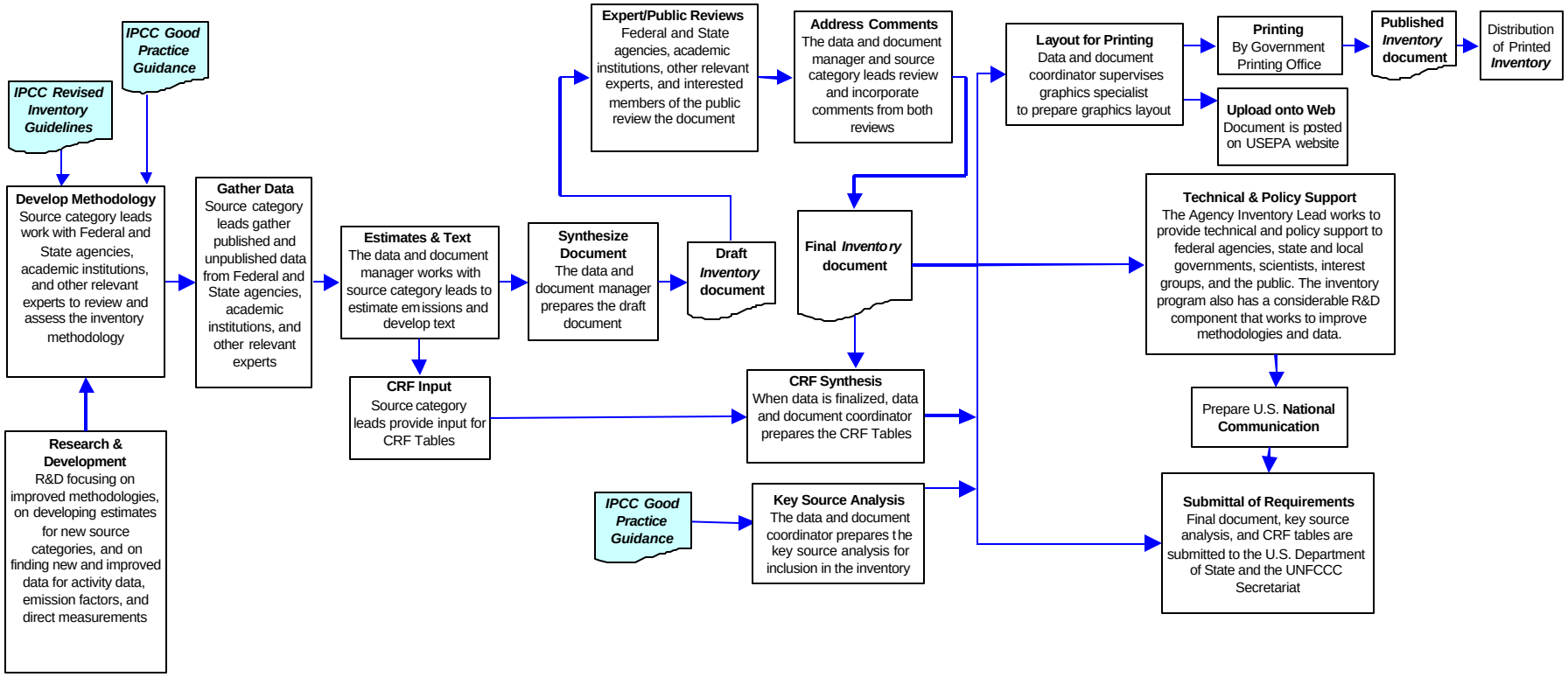


Exhibit 4-2. General Schedule for Completing the Annual
Inventory of U.S. Greenhouse Gas Emissions and Sinks

Date	Task
1st week Oct	Final estimates/spreadsheets due to Data and Document Management Coordinator
1st week Oct	Final write-ups, annexes, and docket/archive due To Data and Document Management Coordinator
Oct – Mid Nov	Prepare draft document
End of Oct	Expert reviewer list and transmittal letter completed
Mid Nov	Expert review draft of *Inventory* document due
Mid Nov	Distribute draft *Inventory* for expert review
Mid Nov – Late Dec	Expert review period
1st week Dec	Submit request for federal register notice
Late Dec	Approval of federal register notice
Late Dec	Expert review comments due and final date for changes!
Late Dec – Late Jan	Incorporate expert comments
Late Jan	Public review draft of *Inventory* document due
Late Jan	Upload public review draft on EPA's Global Warming web page
Late Jan	Appearance of federal register notice
Late Jan – 1st week Mar	Public review period
1st week Mar	Public review comments due
1st week Mar – 1st week Apr	Incorporate public review comments
1st week Apr	Final *Inventory* document due
2nd week Apr	Deliver document to UNFCCC Secretariat and State Department
Apr 15	*Inventory* due to UNFCCC Secretariat
Mid – Late Apr	*Inventory* posted on EPA's Global Warming web page
May – June	*Inventory* printed and distributed to mailing list

5 QA/QC PROCEDURES AND UNCERTAINTY ANALYSIS

The U.S. Greenhouse Gas Inventory Program serves a number of uses for a diverse audience, and the quality and accuracy of the inventory estimates and analyses must be sufficient for these purposes. A key goal of the inventory program is ensuring the transparency, consistency, comparability, completeness, and accuracy of the inventory and the documents—such as the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (referred to here as the *Inventory*), the United Nations Framework Convention on Climate Change (UNFCCC) Common Reporting Format (CRF), and the national communications—in which inventory results are reported. The U.S. inventory system is designed and operated to ensure the quality of the inventory through planning, preparation and management of inventory activities. As part of this approach, quality assurance (QA) and quality control (QC) procedures, coupled with uncertainty analysis, are designed to enhance and continually to improve inventory quality over time. The United States has developed a comprehensive greenhouse gas inventory system that combines methodological improvements, an integrated approach to improved methodologies, transparency improvements, quality assurance / quality control, and uncertainty analysis.

5.1 Goals for Inventory Quality, Implementation of QA/QC Procedures, and Uncertainty Analysis

The Intergovernmental Panel on Climate Change (IPCC) has prepared *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC 2000, here referred to as *IPCC Good Practice Guidance*). The *IPCC Good Practice Guidance* is designed as a companion to the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC/OECD/IEA 1997, here referred to as the *IPCC Revised Guidelines*). The goal of *IPCC Good Practice Guidance* is to assist countries to produce greenhouse gas inventories that are accurate (i.e., are neither over nor underestimates) and in which uncertainties are reduced—both to the extent practicable. In addition, *IPCC Good Practice Guidance* "supports the development of inventories that are transparent, documented, consistent over time, complete, comparable, assessed for uncertainties, subject to quality control and assurance, efficient in the use of the resources available to inventory agencies, and in which uncertainties are gradually reduced as better information becomes available."

The IPCC (IPCC 2000) defines QA and QC as follows:

- *Quality Control* (QC) 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; identify and address errors and omissions; and document and archive inventory material and record all QC activities.
- *Quality Assurance* (QA) comprises a planned system of review procedures conducted by personnel not directly involved in the inventory compilation and development process.

Thus, QC includes general procedures such as checking the accuracy of data and calculations and that standardized practices are followed in calculating emissions, estimating uncertainties, compiling and archiving the docket, and reporting. A higher tier QC system would also include technical reviews of source categories, activity and emission factor data, and methods.[17] QA reviews, which should be performed if possible by independent third parties, are designed to verify that data quality objectives are met, and ensure that the inventory represents the best possible estimates of emissions and sinks given the current state of scientific knowledge and available data. Both QA and QC refer to actions that inventory

[17] A higher "Tier" in this case refers to source-specific QC activities, and is different from the "Tier" designation used by the *IPCC Revised Guidelines* (IPCC/OECD/IEA 1997), which refers to the level of detail and specificity of the methodology and data sources used to calculate emissions.

agencies can take with regard to their own inventories, and not to international review or similar procedures.

The IPCC (2000) also defines good practice in estimating and reporting uncertainties associated with both annual estimates of emissions and emission trends over time. Two tiers are provided for combining source category uncertainties into an uncertainty estimate for total national emissions. Tier 1 uncertainty calculation and reporting, which relies on simple error propagation, has one line for each source category, fuel (where appropriate), and greenhouse gas. This method does not account for correlation and dependency between source categories that may occur because the same activity data or emission factors may be used for multiple estimates. The Tier 2 method, which has been adopted by the United States, estimates uncertainty by source category using Monte Carlo analysis.[18]

Both the *IPCC Revised Guidelines* and *IPCC Good Practice Guidance* recognize that governments do not have unlimited resources, and so the quality of the inventory, the extent of QA and QC, and the breadth of the uncertainty analysis may reflect these limitations, or require focusing resources on key or significant emission sources. An integrated system for conducting QA/QC and analyzing uncertainty is part of ensuring that the inventory meets its data quality objectives. Developing and following a plan—which should include both quality assurance (QA) / quality control (QC) activities and a detailed analysis of uncertainty—is itself good practice and an integral part of ensuring that good practices are followed throughout the development, release, and archiving of the inventory.

The goal of the United States in integrating QA and QC activities into its inventory development process and assessing the uncertainty of the resulting estimates is achieving not only high quality, but also assessment, transparency, and credibility (see Box 5-1):

- To demonstrate—by adequate documentation, archiving, and other processes—the transparency of the process of estimating greenhouse gas emissions and producing the inventory
- To assess (qualitatively and quantitatively) the quality and accuracy of the inventory estimates in a several year process—including the quality of the data from suppliers
- To achieve continual improvement in the inventory processes and products
- To ensure that the estimates produced by the inventory apply consistent approaches and produce comparable numbers across the source categories, and relative to the *IPCC Revised Guidelines* and *IPCC Good Practice Guidance* and the methods employed to produce other nations' inventories
- To produce emission estimates by sources and sinks that are complete, reproducible, and defensible and thereby further promote the credibility of, and confidence in, the U.S. national inventory.

Box 5-1. *Reporting Guidelines*

Transparency means the assumptions and methodologies used for an inventory should be clearly explained to facilitate replication and assessment

Consistency means that the inventory uses the same methodologies for the base and subsequent years, and consistent data across sources or sinks (subject to some exceptions.

Comparability means that estimated emissions are comparable across Parties, i.e., that they use comparable methodologies and formats, including the allocation of different source/sink categories.

Completeness means that an inventory covers all sources and sinks, as well as all gases, included in the IPCC Guidelines.

Accuracy is a relative measure of the exactness of an emission or removal estimate, i.e., estimates should not systematically over- or under-estimate true emissions or removals, and uncertainties should be reduced as far as practicable.

Source: "Review of the Implementation of Commitments and of Other Provisions of the Convention: UNFCCC guidelines on reporting and review." FCCC/CP/1999/7.

5.2 The U.S. Approach to QA/QC

As part of efforts to achieve the stated goals for

[18] The principle of Monte Carlo analysis is to select random values of emission factor and activity data from within their individual probability density functions and to calculate the corresponding emission values. Repeating this process many times results in an assessment of the statistical properties—including uncertainty—of the overall emission estimate for a source category or for the inventory as a whole.

inventory quality, transparency, and credibility, the United States has developed a quality assurance and quality control plan designed to check, document and improve the quality of its inventory over time. Many of these features have been under development over the years since the inventory was first published; others—including the detailed *Procedures Manual*—are the more recent result of activities taken partly in response to *IPCC Good Practice Guidance*.

In particular, key attributes of the plan or program components include:

- The plan includes specific detailed procedures (or protocols) and templates (or forms) that serve to standardize the process of documenting and archiving information, as well as to guide the implementation of QA/QC and the analysis of the uncertainty of the inventory estimates (see companion document, *Procedures Manual*).
- The plan includes expert review as well as QC—for both the inventory estimates and the *Inventory* (which is the primary vehicle for disseminating the results of the inventory development process). In addition, the plan provides for public review of the *Inventory*.
- The QC process includes both Tier 1 (general) and Tier 2 (source-specific) quality controls and checks, as recommended by *IPCC Good Practice Guidance.*
- Investigations of secondary data quality and source-specific quality checks (Tier 2 QC) are conducted in parallel and coordination with the uncertainty assessment; the development of protocols and templates provides for more structured communication and integration with the suppliers of secondary information.
- The plan provides for a complete Monte Carlo-based assessment of uncertainty for the inventory, including coordinated data collection and analysis, with input from virtually all the organizational and functional roles involved in producing the inventory.
- The plan contains record keeping provisions to track what procedures have been followed, and the results of the QA/QC and uncertainty analysis, and contains feedback mechanisms for corrective action based on the results of the investigations, thereby providing for continual data quality improvement and guided research efforts.
- The plan is designed so that quality control and/or assurance procedures are implemented throughout the whole inventory development process—from initial data collection, through preparation of the emission estimates, to publication of the *Inventory*.
- The plan includes a schedule for multi-year implementation, and includes checks from year to year to ensure that all quality control findings from previous years are adequately addressed.
- The plan promotes and involves coordination, interaction, and quality control within the U.S. Environmental Protection Agency (EPA), across Federal agencies and departments, State government programs, and research institutions and consulting firms involved in supplying data or preparing estimates for the inventory.

The plan—including the *Procedures Manual* and this *Background* document—is a "living" document, i.e., the plan is intended to be revised and reflect new information that becomes available as the program develops, methods are improved, or additional supporting documents become necessary. For example, the availability of new information or additional detail on techniques or procedures for checking the quality of data inputs or emission calculations could necessitate revising the procedures in the *Procedures Manual* or preparing a background paper expanding on procedures to be used. Although it is not included in the current plan, an internally conducted or third-party review of the methodologies used to calculate emissions could also include an assessment of the extent to which the methods conform to the *IPCC Good Practice Guidance* prepared for individual sectors.

Similarly, some features of the plan—such as management functions and organization—are less developed than others, and could be expanded over time. If the United States at some point decides to incorporate the principles of ISO 9000, it may be necessary to expand the structure or content of the Plan. The inventory program could, potentially in conjunction with EPA's Office of Quality Assurance, initiate a third Party

assessment or audit of the plan—focusing on the effectiveness and appropriateness of the systems and management established to control data quality. Such review might also result in alterations or additions to the plan.[19]

The quality checking and control activities described in this QA/QC plan occur throughout the inventory process; QA/QC is not separate from but an integral part of the preparing the inventory. As illustrated in Exhibit 5-1, quality control—in the form of both good practices (such as documentation procedures) and checks on whether good practices and procedures are being followed—is applied at every stage of inventory development and document preparation. In addition, quality assurance, or expert review, occurs at two stages. Public review, while not necessarily a significant contributor to inventory quality, is essential to promoting the openness of the inventory development process and the transparency of the inventory data and methods themselves.

5.3 The U.S. Approach to Uncertainty Analysis

Both the QC and uncertainty analyses are part of a learning process. While the uncertainty analysis provides a standalone quantitative assessment of the inventory, its primary function in the U.S. Greenhouse Gas Inventory Program is as an integral component of efforts to understand what produces uncertainty and how to improve inventory quality. Conversely, the outcome of the QC evaluation may result in a reassessment of inventory or source category uncertainty. In addition, the quality checks of the data suppliers and the methodologies they use not only provides information on the quality of the data underlying the inventory estimates, but more importantly creates lines of communication with suppliers and opportunities for understanding and improving the quality of the data and the quality control activities used by suppliers. Thus, by identifying potential areas of improvement in the estimates, procedures to check quality, the uncertainty analyses, and the review processes can all work to reduce the uncertainty of the estimates over time.

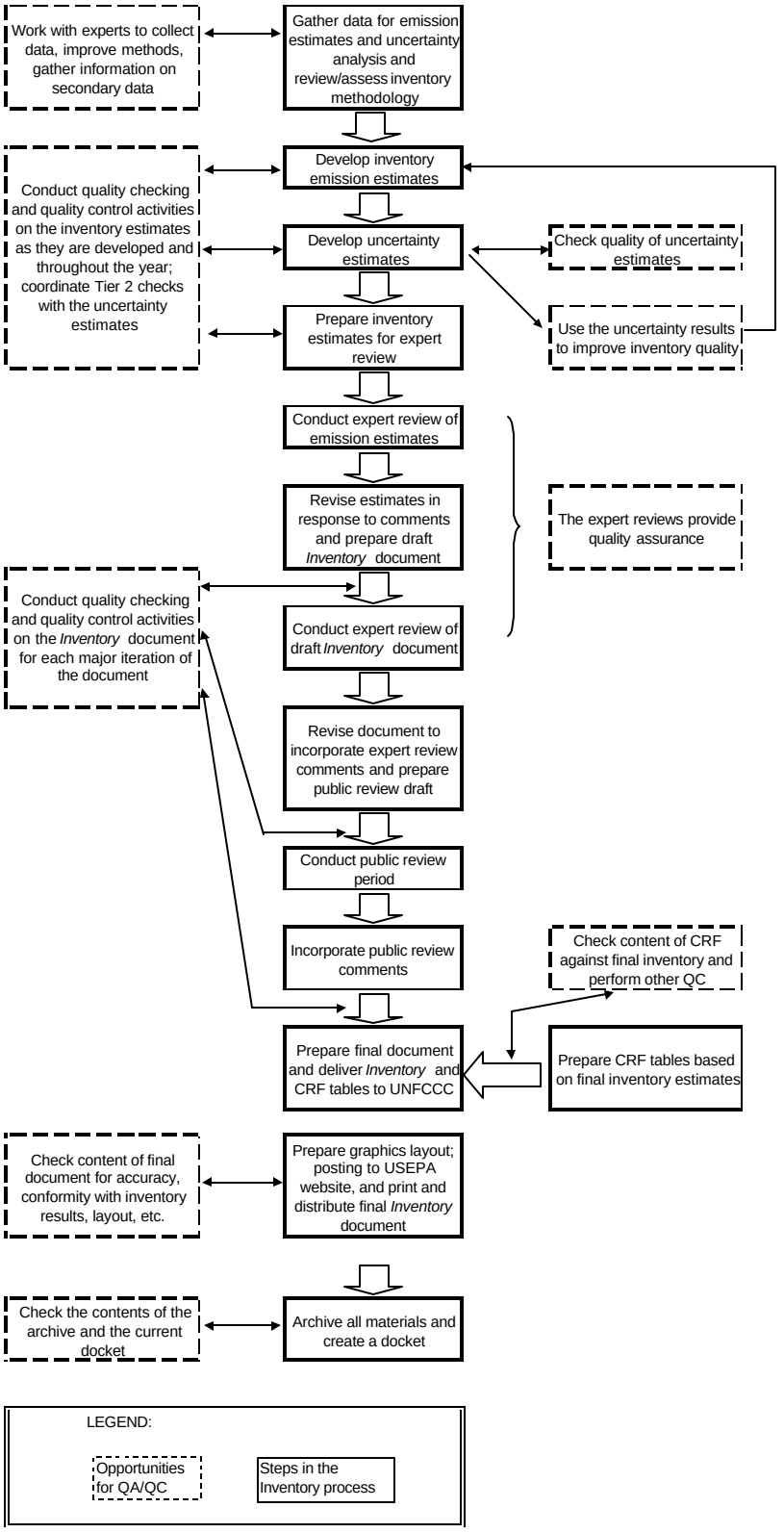
The *IPCC Good Practice Guidance* recommends treating uncertainty estimates as an essential element of a complete inventory of emissions and sinks. Uncertainty information is not intended to dispute the validity of the inventory estimates, but to help set priorities across efforts to improve the accuracy of inventories in the future and guide decisions on methodological choice. Even an inventory that is carefully prepared following accepted inventory methods will be subject to uncertainty; national inventories will typically contain a wide range of emission estimates, varying from carefully measured and demonstrably complete data on emissions of certain engineered chemicals, to order of magnitude of estimates of highly variable nitrous oxide (N_2O) fluxes from soils and waterways (IPCC 2000).

Uncertainty arises when the emissions and removals in the inventory are quantified. This type of uncertainty—referred to as estimation uncertainty—has several sources. First, the estimates can be subject to random or statistical uncertainty; this uncertainty results from variations in the underlying data (such as the activity data or emission factors). This variation can be the result of naturally occurring variation (e.g., emission rates vary over a given time period) or variations in human reactions or in the measurement equipment. In some cases, information may be available that quantifies the statistical properties of measured data. Second, the estimates can be subject to non-random uncertainty, or bias; if estimates are biased, the average of the measured or estimated value is always less or greater than the true value. Bias can arise, for example, because emissions factors are constructed from samples are non-representative, or the use of faulty equipment. Uncertainty arising from bias cannot easily be quantified based on measured data, but must rely on expert judgment.

Estimating uncertainty is as much an art as a science. The pragmatic approach to producing quantitative uncertainty estimates for the greenhouse gas inventory estimates is to combine the available measured data with expert judgments of the magnitude of the estimation uncertainty that cannot be measured. Even given this flexible approach, not all forms of uncertainty can be captured in a quantitative estimate. For example, uncertainty does not only arise during estimation; rather, scientific uncertainty—which is not amenable to quantification—arises when the science of actual emission and/or removal processes is not completely understood. Research conducted by the United States, by the IPCC and by other Parties to the UNFCCC,

[19] See EPA QA/QMP materials, which can be downloaded at: http://www.epa.gov/quality/

Exhibit 5-1. The Roles of Quality Assurance, Quality Control, and Uncertainty Analysis in the Inventory Process



seeks to improve the sources of data and methodologies used to calculate emissions inventories. Analyzing uncertainty is a part of this effort to understand and reduce the uncertainty associated with inventory estimates. Uncertainty for the inventory can be analyzed both qualitatively and quantitatively. Uncertainty can be assessed *qualitatively*—i.e., as high, medium, or low. The United States is engaged in a multi-year effort to assess uncertainty *quantitatively* for the inventory. This effort has several components:

- a centralized approach to developing uncertainty estimates, to ensure consistency in the approach used across source categories and consistency with IPCC recommended methods
- the development of a Monte Carlo model for estimating uncertainties, based on (1) the mathematical models used for estimating source category-specific estimates, (2) source category-specific input parameters, (3) the statistical properties of the source category-specific parameters, and (4) other statistical relationships across the inventory source categories
- the use of statistical data to quantify uncertainty where possible, and careful and detailed methods for eliciting expert judgment in cases where statistical data are unavailable
- coordination between the uncertainty analysis and the detailed checks conducted on source category estimates as part of QC procedures, including the use of quality check information in the uncertainty analysis (such as the information obtained on the quality of data supplied by outside sources)
- using the uncertainty analysis to inform directions for methodological and data development, including working with data suppliers to improve the quality of information

Procedures, templates, and other information on the workings of the uncertainty analysis are part of the overall *QA/QC and Uncertainty Management Plan for the U.S. Greenhouse Gas Inventory*. As with QA/QC procedures and the templates and other documents designed to support the procedures, the uncertainty analysis plan—including its procedures and templates—is a "living" document, that is, intended to be revised and reflect new information that becomes available as procedures are implemented and tested, as methods are improved, or additional supporting documents become necessary.

Despite the careful procedures being undertaken under the U.S. Greenhouse Gas Inventory Program to develop both the inventory and the uncertainty estimates, the uncertainty estimates must themselves be considered highly uncertain. Types of uncertainty, such as scientific uncertainty or the uncertainty associated with estimates of global warming potential, which are omitted from the quantitative uncertainty estimates, contribute to the uncertainty surrounding the uncertainty estimate. In addition, the process of estimating uncertainty surrounding the emissions estimate for a number of the greenhouse gas source categories (or the estimated sinks) will, of necessity, have many elements that are highly *subjective.* In many cases, expert judgment will be required to quantify the statistical properties of the variables underlying the inventory values. Such judgment is not only uncertain, but also difficult to obtain in a comparable and consistent manner across source categories and across inventories prepared by different countries.

Consequently, the uncertainty analysis is most useful as a qualitative measure of uncertainty and as part of an educatory process and feedback loop that allows us to improve the inventory estimates over time. For example, collecting the information needed to determine the statistical properties of the activity data and emission factors underlying the emission estimates forces the researcher to ask hard questions and to carefully and systematically investigate data quality. Similarly, the uncertainty analysis provides a vehicle for setting priorities in research into alternative data sources and methodologies, and for communicating with data suppliers and initiating a dialogue that can ultimately provide a clearer understanding of the quality of the data underlying the inventory estimates and potentially improve that data over time.

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APPENDIX A: GLOBAL CLIMATE PROTECTION ACT OF 1987: SECTION 1103

The Global Climate Protection Act of 1987 is codified as 15 U.S.C. Sec. 2901. Section 1103 states the responsibilities of the State Department and the U.S. Environmental Protection Agency with regard to inventories.

"SEC. 1103. MANDATE FOR ACTION ON THE GLOBAL CLIMATE.

"(a) Goals of United States Policy. - United States policy should seek to -

> "(1) increase worldwide understanding of the greenhouse effect and its environmental and health consequences;
>
> "(2) foster cooperation among nations to develop more extensive and coordinated scientific research efforts with respect to the greenhouse effect;
>
> "(3) identify technologies and activities to limit mankind's adverse effect on the global climate by -
>
> > "(A) slowing the rate of increase of concentrations of greenhouse gases in the atmosphere in the near term; and
> >
> > "(B) stabilizing or reducing atmospheric concentrations of greenhouse gases over the long term; and
>
> "(4) work toward multilateral agreements.

"(b) Formulation of United States Policy. - The President, through the Environmental Protection Agency, shall be responsible for developing and proposing to Congress a coordinated national policy on global climate change. Such policy formulation shall consider research findings of the Committee on Earth Sciences of the Federal Coordinating Council on Science and Engineering Technology, the National Academy of Sciences, the National Oceanic and Atmospheric Administration, the National Science Foundation, the National Aeronautic and Space Administration, the Department of Energy, the Environmental Protection Agency, and other organizations engaged in the conduct of scientific research.

"(c) Coordination of United States Policy in the International Arena. - The Secretary of State shall be responsible to coordinate those aspects of United States policy requiring action through the channels of multilateral diplomacy, including the United Nations Environment Program and other international organizations. In the formulation of these elements of United States policy, the Secretary of State shall, under the direction of the President, work jointly with the Administrator of the Environmental Protection Agency and other United States agencies concerned with environmental protection, consistent with applicable Federal law.

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