QA/QC OF INVENTORY SYSTEMS

ACKNOLEDGEMENTS

This paper was written by Joe Mangino (ERG Incorporated).

1 INTRODUCTION

1.1 Background

The *IPCC Guidelines for National Greenhouse Gas Inventories* (*IPCC Guidelines*) describe steps for reporting national inventories (IPCC, 1997). The third step, verification, contains a task labeled "Assessing Quality". The *IPCC Guidelines* call for a self-assessment of the quality of the inventory and provide a table for reporting quality ratings in terms of "high", "medium", and "low" confidence. In order to properly perform and communicate this self-assessment of quality, it is necessary for countries to implement quality assurance (QA) and quality control (QC) procedures as integral parts of inventory development.

The goal of the IPCC *good practice* guidance is to develop emission inventories that "can be readily assessed in terms of quality and completeness." Accomplishing this goal requires that minimum levels of QA/QC be implemented by countries as they develop their emission inventories. This paper identifies and defines fundamental QA/QC programme elements that should serve as the basis for *good practice* in every country's emission estimation processes.

The objective of this paper and of the QA/QC work session at the Scoping Meeting on Managing Uncertainties will be to develop *good practice* guidance on the recommendations and procedures for QA/QC, which can be directly incorporated into the existing *IPCC Guidelines*. The approaches outlined in this paper should serve as guidelines in achieving this objective. The QA/QC good practices that are ultimately developed should reflect practicality, acceptability, cost-effectiveness, existing experience, and potential for codification in order to be implemented uniformly on a worldwide basis.

In the context of the United Nations Framework Convention on Climate Change (UNFCCC) Reporting Guidelines on Annual Inventories (FCCC/SBSTA/1999/L.5), a QA/QC programme is an integral part of *good practice* in inventory development. Elements of a QA/QC programme contribute to the objectives of *good practice* guidance, namely to improve transparency, consistency, comparability, completeness, and accuracy. Also, the UNFCCC Reporting Guidelines state that national inventory reports from countries should include "information on QA/QC procedures implemented" (FCCC/SBSTA/1999/L.5). The procedures outlined in this report can provide information to support these reporting guidelines

1.2 Definitions

The terms 'quality control' and 'quality assurance' are often used interchangeably or interpreted to mean different things. The following definitions of QC and QA will be used for the purposes of updating the *IPCC Guidelines* and framing the recommendations for good practice:

Quality Control is a system of routine technical activities, implemented by inventory development personnel to measure and control the quality of the inventory as it is being developed. The QC system is designed to:

- Provide routine and consistent checks and documentation points in the inventory development process to verify data integrity, correctness, and completeness;
- Identify and reduce errors and omissions;
- Maximize consistency within the inventory preparation and documentation process, and
- Facilitate internal and external inventory review processes.

QC activities include technical reviews, accuracy checks, and the use of approved standardized procedures for emission calculations and measurements.

Quality Assurance activities include a planned system of review and audit procedures conducted by personnel not actively involved in the inventory development process. The review should be performed by an independent, objective third party to assess the effectiveness of the internal QC programme development, to verify that data quality objectives were met, and to reduce or eliminate any inherent bias in the inventory processes.

1.3 Organization of guidance

There are three main steps for countries to follow in order to integrate QA/QC procedures as part of their inventory development process:

- Establish a written QA/QC plan;

- Implement the QA/QC plan, and
- Document and report the QA/QC activities.

In the following sections of the report, *good practice* recommendations are provided for each of the above steps in order to successively implement and demonstrate an inventory quality assessment. In addition, supplementary QA/QC activities are discussed or referenced in the report. These supplementary QA/QC activities are strongly encouraged and can provide valuable information to more completely demonstrate and report on quality assessment.

In addition to this guidance, inventory preparers should refer to the specific QA/QC procedures being developed as part of the *good practice* guidance for individual source categories. The source category guidance reports discuss particularities associated with the QA/QC of individual source categories that are not contained in this document.

2 ELEMENTS OF A QA/QC PLAN

The first step in applying QA/QC procedures is to develop a structured plan of activities. It is recommended that a written QA/QC plan be developed prior to any emissions being calculated or measured. The plan should outline the QA/QC activities that will be implemented, along a scheduled time frame of implementation that follows inventory preparation from its initial development to final reporting. The QA/QC plan should include the following components:

- Organizational structure;
- General inventory level QC procedures;
- Source-specific QC procedures, and
- QA procedures

The written QA/QC plan should not represent an extensive new reporting requirement, but should be utilized as an internal reference to organize, plan, and implement QA/QC activities. The QA/QC plan, once developed, can be referenced and utilized in subsequent inventory developments, with slight modifications when QA/QC activities are modified.

> *Good Practice Recommendation:*
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> *Each country should have a written QA/QC plan that describes the organizational structure for the QA/QC programme and the QA/QC procedures that are implemented. This written plan should be kept as internal documentation at the country level and be available for outside review if necessary.*

The following sections provide guidelines on minimum and supplemental procedures for each of the above components of the QA/QC plan.

2.1 Organizational structure

The organizational structure identifies the roles and responsibilities for QA/QC activities. Centralized coordination of QA/QC activities is recommended for the successful implementation of a QA/QC programme. Centralized coordination means that there should be an organized approach to QA/QC activities, with centralized oversight from the agency charged with preparing the inventory (hereafter called the "preparing agency" or the "inventory agency") to ensure that the QA/QC plan is implemented. QA/QC is a preparing agency function. Depending on the individual circumstances for each country, activities related to QA/QC may be assigned to third parties or consultants, but the plan, integration, and review of these QA/QC activities need to have oversight from the preparing agency.

> *Good Practice Recommendation:*
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> *Assignments for QA/QC responsibility should cover all source categories included in the inventory. If inventory assignments are made to outside agencies or consultants, the inventory preparing agency should specify the minimum required QA/QC elements expected according to good practice guidance and should review the QA/QC activities to ensure that they meet that expectation.*

As supplemental guidance, it is highly encouraged that the inventory preparing agency identifies a QA/QC coordinator, an individual who is responsible for ensuring the objectives of the QA/QC programme are implemented. If at all possible, the QA/QC coordinator should be an individual who is not a member of the inventory staff that is preparing the emission estimates. This organizational structure instills validity in the QA/QC activities and results

since many of the activities rely on a truly objective analysis. Also, an independent QA/QC team can help minimize bias in the overall inventory process.

Supplemental guidance on the use of the International Organization for Standardization (ISO) 9000 series for implementing and organizing QA/QC activities is provided in Annex 1 of this report. The ISO 9000 series is an internationally recognized data quality management programme that could be useful to planning and organizing QA/QC activities for the entire inventory. Such formal data management systems can be adopted as part the written QA/QC plan where appropriate.

2.2 General QC procedures

The written plan should describe the general QC procedures a country plans to undertake. General QC procedures consist of routine checks that are implemented across all phases of inventory development and do not necessitate having specific knowledge of a given source or sink category. The focus of general QC techniques is on the processing, handling, and reporting procedures that are common to all the inventory sources. The other aspect of general QC techniques is that they can be implemented by personnel that do not necessarily have specific knowledge of a particular source category.

Table 1 lists the recommended minimum QC checks that preparing agencies should be routinely using throughout the development of the inventory. The preferred technique for most of the checks shown in Table 1 is to perform the checks manually, by either recalculating by hand or through visual inspection of the records. Manual checks avoid the possibility of introducing error into the QC check itself, which may be possible if only automated programmes are utilized.

> *Good Practice Recommendation:*
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> *The minimum QC procedures listed in Table 1 of this report should be implemented for all source categories. If parts of the inventory are prepared by outside agencies or consultants, the preparing agency should review the general QC procedures implemented by the outside agencies or consultants to ensure that they meet these minimum requirements.*

The QC checks listed in Table 1 are directly applicable to inventory calculations and processing steps conducted by the country's inventory preparing agency. However, in some cases, emission estimates are prepared for the country by outside consultants or agencies. When making inventory assignments to outside consultants or agencies, countries should communicate the need for the minimum QC checks listed in Table 1. This will ensure that the QC activities are accomplished and recorded by the outside agency or consultant, and can be simply reviewed by the country's inventory staff to verify their implementation.

In some cases, it will not be feasible to run all the checks listed in Table 1 on every calculation and every parameter used in the inventory. In these cases, preparing agencies should choose selected subsets of data to perform the checks on. The size of the subset will depend on the overall number of data points, records or calculations that have to be checked, the complexity of the calculations, and the error rate encountered as QC progresses. It is not advisable to develop a sample subset based on a pre-set percentage of data elements (e.g., 10percent of input data points). The risk of accepting a "bad" dataset can be unacceptably high for smaller data sets(e.g., N=100) when pre-set sample percentages are used. To avoid this, it is recommended that sample sizes be set at 100 percent for $N<200$, and preset at 10 percent where $N\geq200$.

> *Good Practice Recommendation:*
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> *When selecting sample subsets of data to perform the minimum QC procedures listed in Table 1 it is recommended that sample sizes be set a 100 percent for $N<200$, and preset at 10 percent for $N\geq200$. Observed trends in errors should be noted as QC progresses and sample sizes should be increased for larger data sets if necessary to correct the error.*

Due to the quantity of data that needs to be checked for certain sources, automated checks are encouraged so as to supplement manual checks and expand the sample size where possible. For example, one of the most common QC activities involves verification that data keyed into a computer database are correct. A QC procedure could be set up to use an automated range check (based on the range of expected values of the input data from the original reference) for the input values as recorded in the database. Since this would verify only that the values in the database fall within the range of values in the original reference, the automated step can be supplemented with a representative sampling of manual checks on specific value transcriptions. Such combined manual and automated checks will typically be the most effective procedures in checking large quantities of input data.

TABLE 1
RECOMMENDED MINIMUM REQUIRED QC PROCEDURES

QC Activity	Procedures
Check the accuracy of data input from the original reference source	1. Confirm that correct references were used. 2. Cross-check sample of input data (either measurements or parameters used in calculations) for transcription errors.
Check that emissions are calculated accurately	1. Use manual recalculation of a representative sample of emission calculations. 2. Recalculation should cover complete set of calculations from beginning to end. 3. Where necessary, mimic complex model calculations with abbreviated manual calculations to judge relative accuracy.
Check that parameter and emission units are correctly recorded and that appropriate conversion factors are used	1. Check that units are properly labeled in calculation sheets. 2. Check that units are correctly carried through from beginning to end of calculations. 3. Check that mass conversion factors are correct. 4. Check that temporal and spatial adjustment factors are used correctly.
Check the integrity of database files	1. Confirm that path of data is correctly represented in database and that all necessary processing steps are accounted for. 2. Confirm that data relationships are correctly represented in database. 3. Ensure that data fields are properly labeled and have correct design specifications.
Check for consistency in data sources where such consistency is expected	1. Identify parameters (e.g., activity levels, constants) that should be common to multiple source categories and confirm that there is consistency in the values used for these parameters in emission calculations.
Check that the movement of inventory data among processing steps is correct	1. Check that emissions data are correctly aggregated from lower reporting levels to higher reporting levels when preparing summaries. 2. Check that emissions data are correctly transcribed between different intermediate products.
Internal Documentation Review	1. Check that there is detailed internal documentation to support the estimates and enable full reconstruction of the estimate. 2. Check that inventory data are archived and stored to facilitate detailed review.

2.3 Source specific QC techniques

Source-specific QC techniques are those that are applied on a case-by-case basis, are directed at specific aspects of a source category, and require specific knowledge of the source. As opposed to general QC techniques, source-specific QC techniques are directed at specific types of data used in the methodologies for individual sources. Due to these differences, source-specific QC techniques require a fundamental understanding of the specific emission source and knowledge in the parameters associated with emissions from the source. From a technical skill level, this differentiation between general QC techniques and source-specific QC techniques will therefore influence staffing decisions.

The recommended source-specific QC activities include the following:

- Emission factor QC;
- Activity level QC, and
- QC of uncertainty estimates

The first two activities relate to the types of data used to prepare the emission estimate for a given source category. The uncertainty estimate QC covers activities associated with determining uncertainties in emission estimates.

The actual QC that needs to be done by the country's inventory agency will depend on the approach used to estimate the emissions for a given source category. The first step in planning these activities is to determine where the inventory estimates originated. If estimates are developed by outside agencies, the country's inventory agency can, upon review, reference the QC activities of the outside agency as part of the QA/QC plan. There is no need to replicate QC activities if the country's inventory agency is satisfied that the QC activities performed by the outside agency meet the minimum requirements recommended in this section.

The next step for implementing source-specific QC is to identify the type of data that are involved in the methodology for the specific source being evaluated. After that has been determined, the following sections provide decision trees for developing QC strategies directed at each of these types of data.

2.3.1 Emission factor QC

QC activities are organized around the three basic options for emission factor data: IPCC defaults, country-specific factors, and factors based on direct emission measurements.

Figure 1 shows the decision tree for planning and implementing emission factor QC for IPCC defaults and country-specific factors. Figure 2 shows the decision tree for QC associated with methodologies that use direct emission measurements from individual sites (either as the basis for a site-specific emission factor or directly for an emission estimate. The following sections describe the minimum recommended procedures for QC checks on IPCC default factors, country-specific factors, and direct emission measurements.

IPCC default factors

> *Good Practice Recommendation:*
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> *The IPCC default factors have been reviewed prior to their publication in the IPCC Guidelines and the QC associated with that review should be referenced directly*.

As a supplemental QC activity, IPCC default emission factor checks could be expanded to include comparisons to site or plant level factors within the country to determine the representativeness of the IPCC default factors to actual sources in the country. This expanded check is strongly encouraged for countries that have site or plant level data available for a source category, even if only for a small percentage of sites/plants. The check should be directed at source categories that contribute a high percentage of emissions to the overall inventory and which also have a high level of uncertainty associated with them

Country-specific factors

"Country-specific" refers to factors that are developed at a national or other aggregated level within the country based on technology groups, local characteristics, or other criteria. They are not site-specific, but are used to represent an entire source category or subset of sources.

Where country-specific factors are used, two essential steps are necessary for emission factor QC. The first step is to evaluate the QC associated with secondary data used to develop the country-specific factor. Country-specific factors are often not developed from primary testing by the inventory preparing agency. Instead, published studies and literature sources (secondary data) are used to derive factors that can be used in the inventory. The common characteristic of secondary data is that the data are not prepared and developed by the inventory preparing agency. Therefore, it must be determined whether the QC activities conducted during the original preparation of the data are consistent with the minimum required QC procedures outlined in Table 1 of this report.

> *Good Practice Recommendation:*
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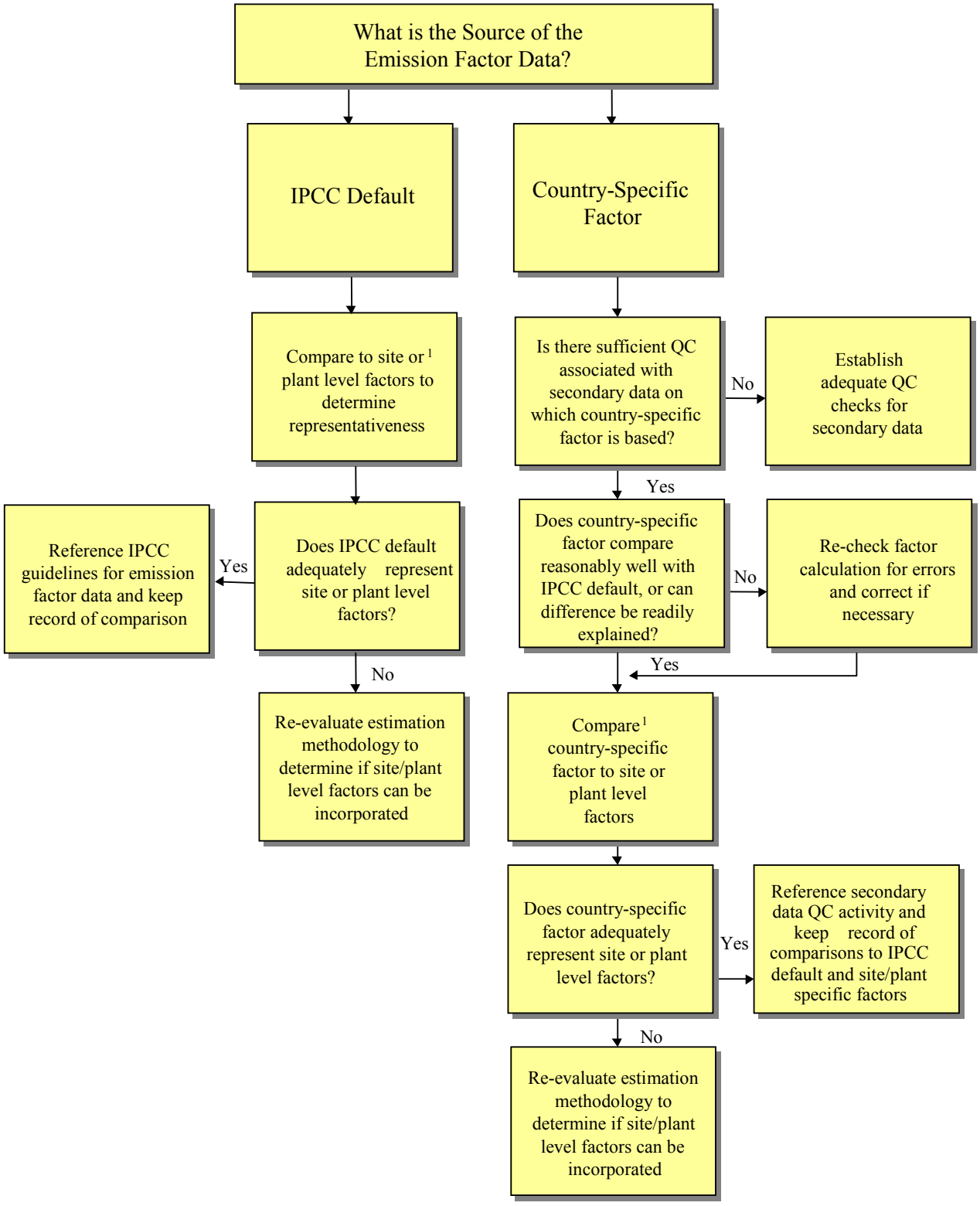
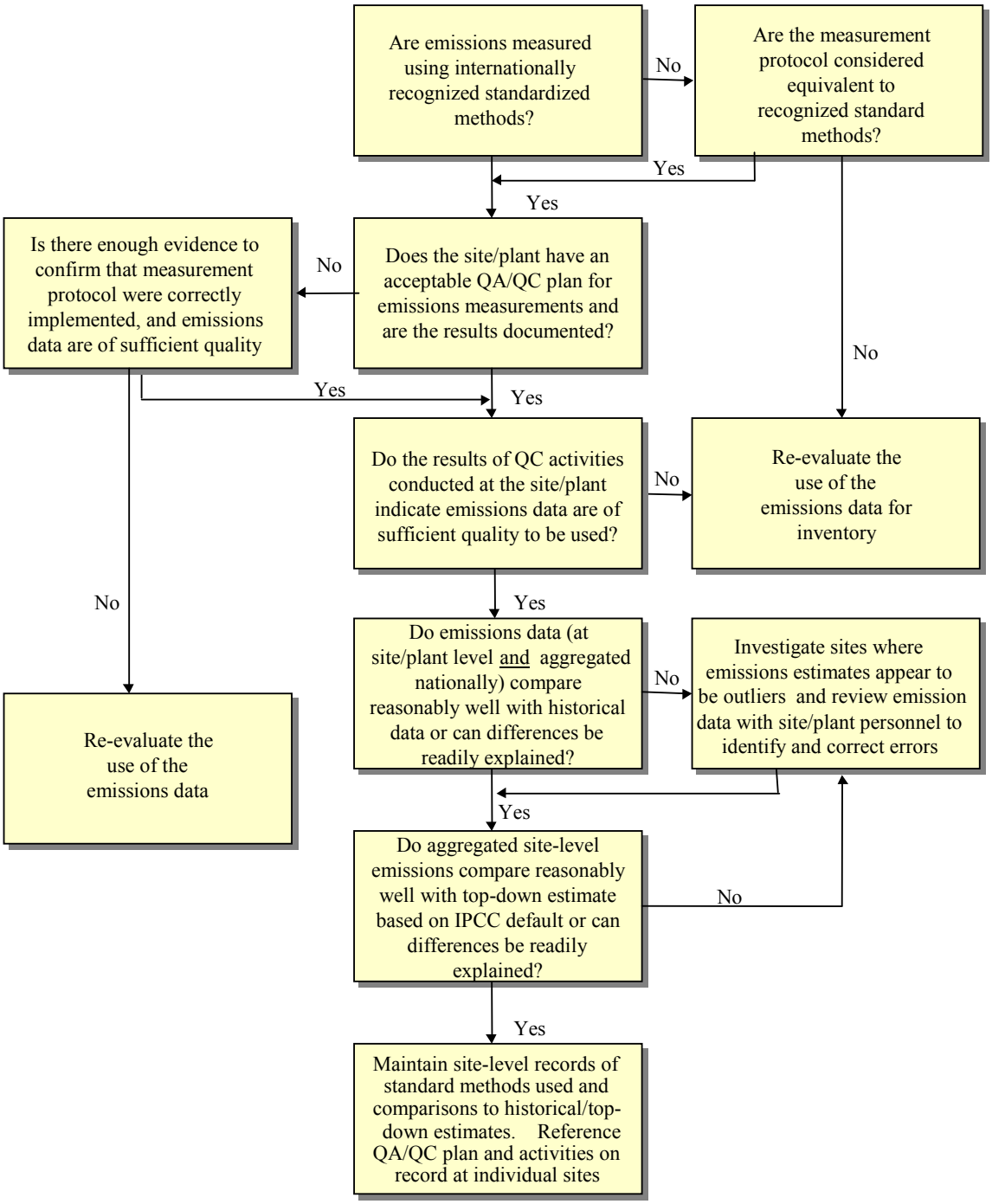
> *The preparing agency should determine if the level of QC associated with secondary data at a minimum includes the same recommended QC procedures listed in Table 1. In addition, the preparing agency should establish if any published data has received peer review of any type. The presence of peer review would help establish the adequacy of the secondary data. If it is determined that the QC associated with the secondary data is inadequate, then the preparing agency must either establish its own QC checks on the secondary data, or alternatively, reconsider the use of the data. If it is determined that the QC associated with the secondary data is adequate, then the inventory preparing agency can simply reference the data source for QC documentation.*

Figure 1 Decision tree for emission factor QC



[1]Comparison to plant/site level factors is a supplemental QC activity that is strongly encouraged where such data are available.

Figure 2 Decision tree for QC of direct emission measurements



The second step in QC review of country-specific factors is to compare the country-specific factor to the IPCC default to see if they compare reasonably well. The intent of this comparison is to see that the country-specific factor is considered reasonable relative to the IPCC default value. If the country-specific factor is significantly different from the IPCC default, this may point to an error in the factor calculation if the extremely large differences between the values cannot be explained otherwise. For example, for CO_2 from fuel combustion, emission factors should be expected to be fairly close in value. However, greater disparities might be explained for non-CO_2 pollutants from fuel combustion due to the uncertainty in the factors for these pollutants.

> *Good Practice Recommendation:*
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> *Compare the country-specific factor to the IPCC default for the source category. Record the difference between the factors and maintain as documentation. If the difference is significant, then check the factor calculation for errors and correct if necessary.*

A supplementary step for country-specific factor QC checks is to compare the country-specific factor to site or plant level factors. For example, if there are emission factors available for isolated plants (but not enough to support a bottom-up approach) these plant-specific factors should be compared to the aggregated factor used in the inventory. This type of comparison provides an indication of both the reasonableness of the country-specific factor and its representativeness. This QC check is strongly encouraged for source categories that contribute a large percentage of the emissions in an inventory and which have a high level of uncertainty associated with the emission estimate.

Direct Emission Measurements

This QC review is directed at estimation methodologies that use direct emission measurements from individual facilities (either as the basis for a site-specific emission factor or directly for an emission estimate). The checks involved in this QC process establish whether measurements at the site were made according to recognized standards, whether there is a QA/QC protocol in effect at the site, and whether the estimates compare reasonably well between sites and top-down estimates.

> *Good Practice Recommendation:*
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> *The preparing agency should determine if emissions were measured using internationally recognized standards of measurement. If the measurements were not made using internationally recognized standards, determine if the measurement protocol used is equivalent to recognized standard methods. If the measurement practices fail each of these criteria, then the emissions data should be re-evaluated for use in the inventory.*

Confirmation that internationally recognized, standard methods were used for measurements is highly recommended. An example of the application of ISO standards can be seen in the area of emissions measurements and monitoring of industrial processes. ISO has published standards that specify procedures to quantify some of the performance characteristics of air quality measurement methods such as bias, calibration, instability, lower detection limits, sensitivity, and upper limits of measurement (ISO,1994). Such standards have direct application to QC activities associated with emissions estimations from industrial sources based on measured values. If it is known that a facility adheres to a set of known measurement standards for developing its emissions data, the inventory preparing agency can use this knowledge in its assessment of data quality. In effect, the application of these standards by the industry becomes part of the formal inventory QC process and can be referenced directly in the documentation of QC activity.

One example is where site-specific emission factors are used for a bottom-up, Tier 1 method for a large stationary fuel combustion source. The inventory agency needs to establish the QC associated with the fuel measurements and analysis that were made at the site to calculate the site-specific emission factor. If it is established that there is insufficient QC control associated with the measurements and analysis used to derive the factor, continued use of the factor may be questioned. Alternatively, if the plant has its own QA/QC plan, uses standardized measurement methods, and its equipment is calibrated and maintained properly, the inventory agency should be more likely to accept the site-specific factor for use in the calculation.

Supplemental QC activity is encouraged for bottom-up methodologies based on site-specific emission factors where significant uncertainty remains in the estimates. Site-specific factors can be compared from site-to-site and also back to IPCC or national level defaults. Significant discrepancies at particular sites may point to errors in the factor calculations for those specific sites.

2.3.2 Activity level QC

Figure 3 shows the decision tree for activity level QC. The first step is to identify the source for the activity level data used in the methodology. Activity data is normally developed at a national level (using secondary data sources) or

from site-specific data collected by the preparing agency. Site-specific activity data are usually prepared by the site or plant personnel from their own measurements. After the source of activity data has been determined, the remaining steps can be followed.

National Level Activity Data

The estimation methodologies for many source categories rely on the use of activity data statistics that are not directly prepared by the inventory agency. Where national activity data from secondary data sources are used in the inventory it is critical for the inventory preparing agency to evaluate and reference QA/QC activities associated with the secondary data preparation. This is particularly important in regards to activity data, since most activity data are originally prepared for purposes other than input to air quality applications. Many statistical organizations, for example, have their own procedures for assessing the quality of the data independent of what the end use of the data may be. If it is determined these procedures satisfy the recommended minimum activities listed in Table 1, the inventory preparing agency can simply reference the QC activity conducted by the statistical organization.

> *Good Practice Recommendation:*
>
> *The preparing agency should determine if the level of QC associated with secondary data at a minimum includes the same recommend QC procedures listed in Table 1. In addition, the preparing agency should establish if any published data have received peer review of any type. The presence of peer review would help establish the adequacy of the secondary data. If it is determined that the QC associated with the secondary data is inadequate, then the preparing agency must either establish its own QC checks on the secondary data, or alternatively, adjust its uncertainty estimates to reflect the results of the QC review. If it is determined that the QC associated with the secondary data is adequate, then the inventory preparing agency can simply reference the data source for QC documentation.*

For example, in the transportation category, countries typically use either fuel usage or mileage statistics to develop emission estimates. The national statistics on fuel usage and miles travelled by vehicles are usually prepared by a separate agency of the government from that which prepares the inventory. However, it is the responsibility of the inventory preparing agency to determine what QA/QC activities were implemented by the agency who prepared the original fuel usage and mileage statistics for vehicles. Questions to ask in this example are:

- Does the agency have a QA/QC plan that covers the preparation of the data?
- What sampling protocol were used to estimate fuel usage/miles travelled?
- Has any potential bias in the data been identified by the agency?
- Has the agency identified uncertainties in the data?
- Has the agency identified any errors in the data that may be carried over to the inventory?

The next QC check for national level activity data requires a comparison to the historical activity data for the source being evaluated. Most source categories do not have dramatic changes in activity levels from one year to another, so a historical comparison should show a consistency in the prevalent trend of activity. If the estimated national activity diverges greatly from this historical trend, either in sharp increases or decreases, the calculation of the current activity should be checked for errors.

> *Good Practice Recommendation*:
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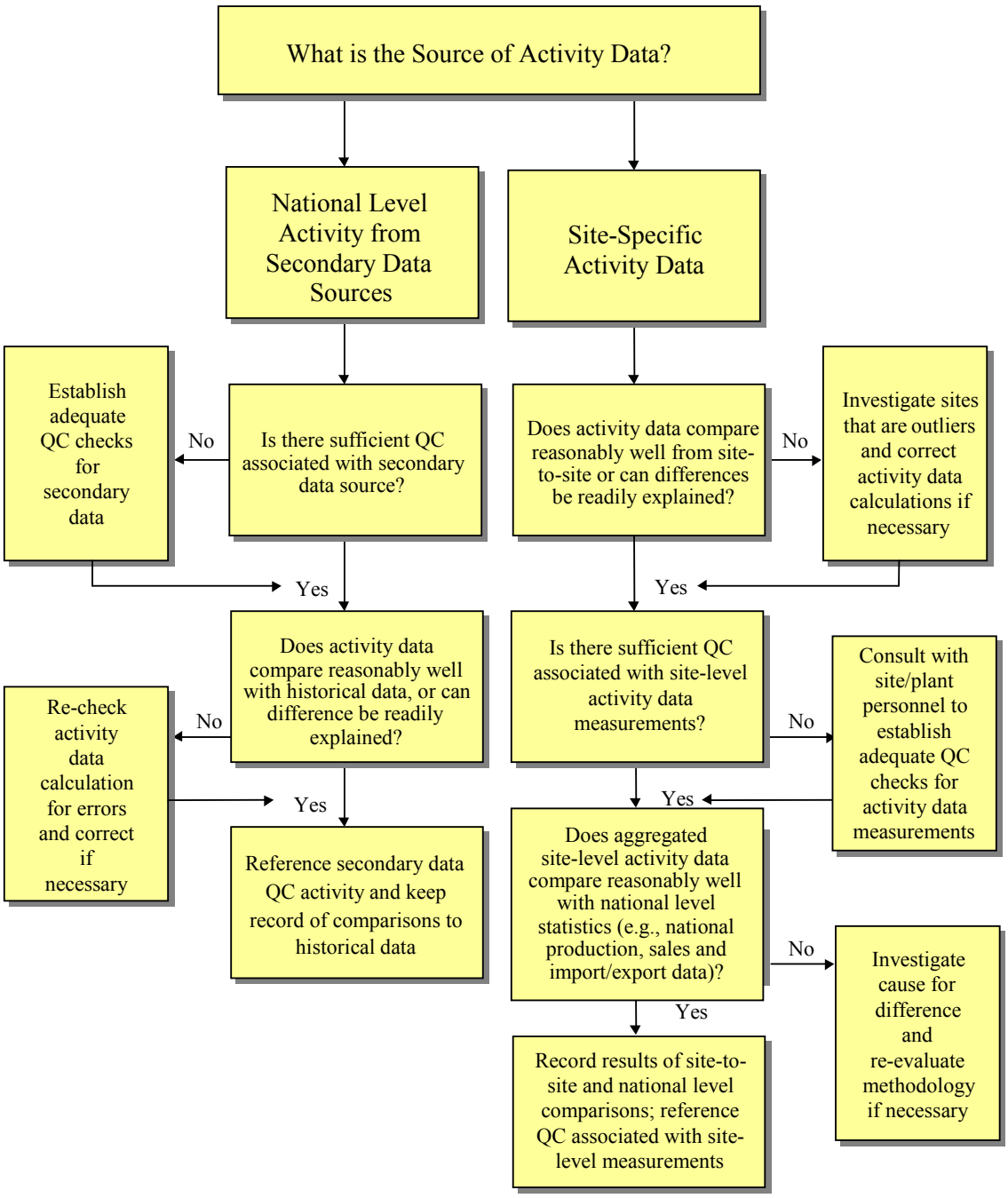
> *Compare current national level activity data to historical activity levels for previous five years. If the current estimated activity level diverges greatly from the historical trend, evidenced either by a sharp increase or decrease, the calculation of the current activity should be checked for errors and corrected if necessary.*

As a supplemental QC activity, a comparison check of activity data from multiple reference sources is encouraged. This is strongly advised for sources that have a high level of uncertainty associated with their estimates. For example, many of the agriculture sources rely on government statistics for activity data such as livestock populations, cultivated acreage, and acres of prescribed burning. Similar statistics are often prepared by industry, university, or alternative agencies which can be used to compare to the standard reference sources. These comparisons may need to be made on a regional level since many alternative references for such activity data will not cover the entire nation. However, the results of such a comparison may point to inaccuracies in the standard national data set and prompt further review of the activity level data.

Figure 3 Decision tee for activity level QC



Site-specific Activity Data

Some methodologies rely on the use of site-specific activity level data used in conjunction with IPCC default or country-specific emission factors. Site or plant personnel typically prepare these estimates of activity, usually for purposes other than as inputs to air quality analysis. QC checks need to focus on inconsistencies between sites, either due to errors or measurement techniques.

> *Good Practice Recommendation:*
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> *The inventory preparing agency should compare the activity data, adjusting for relative size or capacity of the sites, on a site-to-site basis to identify significant outliers. If outliers are identified, they should be investigated to determine if the difference can be explained by unique characteristics of the site or whether there is an error in the reported activity.*

A variety of supplemental QC checks can be utilized to identify errors or misrepresentations of site level activity data. Similar to the QC check on direct emission measurements, it is strongly encouraged that the inventory preparing agency confirm that recognized standards were used in measurements for activity data at the individual sites. Site or plant personnel may have established QC procedures that can be directly referenced and included in the QC plan.

Comparisons of activity data from different reference sources can also be utilized to expand the activity level QC. For example, in estimating PFC emissions from primary aluminium smelter, many countries use smelter-specific activity data to prepare the inventory estimates. A QC check of the aggregated activity level from all aluminium smelters can be made against national production statistics for the industry. Also, production data can be compared across different sites, possibly with adjustments made for plant capacities, to evaluate the reasonableness of the production data. Similar comparisons of activity data can be made for other manufacturing-based source categories where there is published data on national production.

Site-specific activity data checks can be applied to methodologies based on product usage. For example, *good practice* for estimating SF_6 emissions from use in electrical equipment relies on an account balancing of purchase of the gas, sales of gas for recycling, losses to handling, refills on maintenance, and total holding capacity of the system. This account balance system should occur at each facility where the equipment is in place. A QC check of overall national activity could be made by comparing national SF_6 production in the country (if such production exists) adjusted for imports and exports of SF_6, to estimate total national usage of SF_6. This total national usage can then be used as an upper bound on SF_6 emissions, since emissions from each of the sites relies on uncaptured losses of SF_6. Similar accounting techniques can be used as QC checks on other categories based on gas usage (such as the substitutes for ozone-depleting substances) to establish upper boundaries on consumption and emissions.

2.3.3 QC of uncertainty estimates

The calculation of uncertainty estimates for each source category also must undergo QC. *Good practices* for estimating uncertainties are being developed. These practices rely on calculations of uncertainty at the source level, and then combined to summary levels for each sector and the entire inventory. Some of the methods rely on the use of measured data associated with the emission factors or activity data to develop probability distribution functions from which uncertainty estimates can be estimated. Many uncertainty estimates, however, will rely on expert judgement to develop probability distribution functions and uncertainty ranges. In all cases, QC procedures should be applied to the uncertainty estimations to confirm that calculations are correct and that there is sufficient documentation to replicate the development of the uncertainty estimate.

> *Good Practice Recommendation:*
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> *Confirm that uncertainty estimations have been documented for each source category. Cross-check calculations of uncertainty estimates to verify that there are no errors in the calculation of source-specific and combined estimates of uncertainty. For uncertainty estimates involving expert judgement, confirm that there is documentation showing the data considered, literature references, assumptions made, scenarios considered, justifications for the probability distribution functions obtained, and results from reviewers.*

2.4 QA procedures

Good practice for QA procedures requires independent, objective review to assess the effectiveness of the internal QC programme, the quality of the inventory, and to reduce or eliminate any inherent bias in the inventory process.

The use of expert peer review and independent audits is described below. Where there are formal stakeholder and public review mechanisms in place in a country, it is encouraged that these also be used to supplement expert peer review and independent audits.

Expert Peer Review

Expert peer review consists of an independent review of calculations, assumptions, and/or documentation by a knowledgeable expert in the technical field. This is generally accomplished by reviewing documentation associated with the methodology and results, but usually does not include rigorous certification of data or references such as might be done in an audit. The objective of the expert peer review is to ensure that assumptions and procedures used are reasonable as judged by persons knowledgeable in a specific field.

> *Good Practice Recommendation:*
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> *Expert peer review should be applied to those source categories for which there is either a high level of uncertainty in the emission estimate or the source is ranked high in importance due to emissions contribution. The peer review should be performed by someone with a high level of expertise in the particular source category. Expert peer review should be implemented at the following stages: (a) When estimation methodologies are first being adopted or revised; and (b) When the inventory is completed, but prior to its official or public release.*

There are no standard tools or mechanisms for expert peer review, and its use should be considered on a case-by-case basis. If there is a high level of uncertainty associated with an emission estimate for a source category, expert peer review may provide information to improve the estimate, or at least, better quantify the uncertainty. If a source category has a high emissions contribution to the overall inventory, regardless of the uncertainty associated with the estimate, the preparing agency should utilize expert peer review since even minor improvements to the estimate could have a significant effect on the inventory.

When considering personnel for expert peer review it is important to remember that they do not necessarily have to have experience in preparing emission inventories. The expertise should be related to the parameter that the inventory agency wants the review focussed on. For example, the inventory agency may be entirely satisfied with its emission factors for oil and natural gas production activities but has a lot uncertainty associated with its activity level estimates for the category. Experts in the oil and gas industry may be identified that can review the activity estimates, regardless of their experience with estimating emissions. Effective peer reviews often involve identifying and contacting key industrial trade organizations associated with specific source categories. This expert input should be sought early in the inventory development process so that the experts can participate from the start. This is particularly true for source categories for which new methodologies or revisions to methodologies are being considered.

The results of expert peer review, and the response of the inventory agency to those findings, can be extremely important to widespread acceptance of the final inventory. All expert peer reviews should be well documented, preferably in a report or checklist format that shows the findings and recommendations for improvement. Follow-up peer review after corrections or revisions are made is essential to complete the peer review process.

Independent Audits

Audits are managerial tools used to evaluate how effectively the inventory preparation team complies with the minimum QC specifications outlined in the QC plan. An 'independent', sometimes referred to as 'third-party' or 'external', audit is conducted by personnel who are not involved in the emissions inventory development process. It is important that the auditor be independent of the inventory development team so as to be able to provide an objective assessment of the processes and data evaluated.

> *Good Practice Recommendation:*
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> *Independent audits should be used whenever new emission estimation methodologies are adopted, or when there are substantial changes to the existing methodology. Audits should be conducted to determine that the inventory preparation team implemented all recommended minimum QC procedures listed in Table 1 of this report. At a minimum, the audit should replicate the procedures listed in Table 1*

Audit activities replicate internal QC activities in order to verify that they were used. It is desirable for the auditor to develop a schedule of audits at strategic points in the inventory development. For example, audits related to initial data collection and measurement work should be conducted at points during or not long after these inventory steps are completed. In this way, deficiencies can be addressed before they affect the final product.

3 IMPLEMENTING THE QA/QC PLAN

There are key considerations that should be recognized before implementing any QA/QC activities. Decisions have to be made as to which QA/QC techniques will be used, where they will be applied, and when they will be applied. There are both technical and practical considerations in making these decisions.

> *Good Practice Recommendation:*
>
> *The following considerations should be taken into account when implementing QA/QC activities:*
>
> * *Priority of important sources: One of the key criteria in the good practice guidance for selecting emissions estimation methods is the relative importance of the source category. The amount of QA/QC activity devoted to a source category should reflect this criterion, and*
> * *Changes in methodology: Whenever new methods are adopted, or existing methods are revised, there should be increased QA/QC activity associated with these changes. Such changes in methodology may occur when making baseline recalculations and when splicing methodologies.*

Given the importance of focusing resources on the priority areas, it may be possible to minimize QA/QC activities in some areas. If there have been no substantial changes to the methodology for a source category, for example, it may be possible to refer to previous QA/QC efforts regarding emission factor and activity level data sources. For example, if fuel combustion estimates utilize the same standard national reference for fuel usage that was used in a previous inventory submittal, and substantial QA/QC was performed on the previous inventory to ensure the quality of the national reference fuel usage data, it may be satisfactory to reference the previous QA/QC effort for the activity data. In such cases, other routine checks shown in Table 1 should still be performed on the emissions calculation.

4 REPORTING AND DOCUMENTATION

4.1 Internal documentation

Internal documentation refers to the full documentation of all QA/QC checks, audits, and reviews that are maintained at the country level, but which can be produced if necessary for an on-site review. This includes any of the physical records, such as the QA/QC plan, checklists, notes, calculation sheets, and reports that were utilized to conduct and document the QA/QC activity.

> *Good Practice Recommendation:*
>
> *Records of QA/QC results should be retained for each source category where QA/QC activities have been implemented. There should be sufficient documentation of the results to indicate the checks/audits/reviews that were performed, when they were performed, who performed them, and any corrections and modifications resulting from the QA/QC activity.*

4.2 External documentation

External documentation refers to the documentation that is reported to outside parties as part of formal inventory submittals or for end use of the data. The annex to the draft decision on UNFCCC *Guidelines for the Preparation of National Communications* (FCCC/SBSTA/1999/L.5) specifically requests information on implemented QA/QC procedures as part of national inventory reports for Annex I Parties. It is not practical to transfer all the internal documentation that is retained at the country to outside agencies. Therefore it is necessary to summarize and communicate the key findings of the QA/QC programme.

A report summarizing the implemented QA/QC activities on a source category basis should be prepared. This report should be submitted as part of the supplemental reporting material to the IPCC and as part of the national inventory report to UNFCCC. There should be clear delineation in the report as to which activities were performed internally and which were done by external reviewers. Results should be summarized for each type of QA/QC activity performed.

Good Practice Recommendation:

A summary report of QA/QC activity should be prepared. Following are the documentation items that should be included in the summary QA/QC report:

* *Descriptions of the specific QA/QC activities performed by the inventory agency for each source category;*
* *Document, by reference, any QA/QC activity not directly performed by the inventory agency but which is utilized as part of the QA/QC process (e.g., the QA/QC programme of a national statistics agency that provided activity data);*
* *Summary of QA/QC findings and resolution of problems by the inventory agency, and*
* *Unresolved issues that affect inventory quality (e.g., confidentiality issues, data gaps, unfinished QA/QC steps, etc.).*

Much of the input to this QA/QC summary report can come directly from the written QA/QC plan, with additions summarizing the results. The checklist provided in Table 1 of this report can be used to show what activities were accomplished. However, the report should only show those QA/QC activities that were actually implemented. It is not recommended here that audit and general QA/QC checklists be submitted as part of this report due to the volume of material. Such checklists and detailed documentation of QA/QC activities should be maintained on record at the country as internal documentation, however.

In addition to the QA/QC summary report, it is recommended here that a notation key be added as a supplement to the quality assessment codes in the IPCC Overview Table for National Greenhouse Gas Inventories (Table 8A of the IPCC Reporting Instructions). An additional field should be added to the table and labeled as "QA/QC".

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ANNEX I USE OF ISO 9000: A DATA QUALITY MANAGEMENT SYSTEM FOR INVENTORIES

Data quality management systems establish standardized requirements and procedures to ensure that products meet the requirements of its end users. In the context of national GHG inventories, this includes a system of QC activities that the inventory preparer adopts to manage processes and factors that influence the quality of the emission estimates.

As part of its general QC procedures, it is encouraged that the Annex-1 Countries adopt the programme embodied in the International Organization for Standardization (ISO) 9000 series, which provides standards for data documentation and audits that could clearly be useful to the inventory QA/QC process. Some countries (e.g., the United Kingdom and Netherlands) have already adopted ISO 9000 standards either as part of their inventory development process or for the management of their inventory data for end uses. The ISO 9000 series is not designed explicitly for emissions data development and must be adapted for use to the inventory. Also, the adoption of ISO 9000 programme elements must be supplemented by source-specific QA/QC procedures.

Pertinent standards and guidelines published under the ISO 9000 series that should be considered for adoption in inventory development include:

- ISO 9004-1: General quality guidelines to implement a quality system;
- ISO 9004-4: Guidelines for implementing continuous quality improvement within your organization using tools and techniques based on data collection and analysis;
- ISO 10005: Standard provides guidance on how to prepare quality plans for the control of specific projects;
- ISO 10011-1: Guidelines for auditing a quality system;
- ISO 10011-2: Guidance on the qualification criteria for quality systems auditors;
- ISO 10011-3: Guidelines for managing quality system audit programmes;
- ISO 10012: Guidelines on calibration systems and statistical controls to ensure that measurements are made with the intended accuracy, and
- ISO 10013: Guidelines for developing quality manuals to meet specific needs.

At this time, it is encouraged that Annex-1 Countries utilize ISO 9000 series guidelines as self-assessment and quality management tools and to clearly document this usage in their inventory submittal.