QA/QC AND VERIFICATION

April/May 2024

U.S. Environmental Protection Agency

What is Quality Assurance?

A planned system of review procedures conducted by personnel **not directly involved** in the inventory compilation/development process.

- From the *2006 IPCC Guidelines*

Reviews, *preferably by independent third parties*, are performed upon a completed inventory following quality control procedure. Reviews:

- Verify the data quality objectives were met;
- Ensure that the inventory represents the best possible estimates of emissions and sinks;
- Support the quality control program.

WHAT IS QUALITY CONTROL?

A system of routine technical activities to assess and maintain the quality of the inventory as it is being compiled. **It is performed by personnel compiling the inventory**.

- From the *2006 IPCC Guidelines*

The system is designed to:

- Provide routine and consistent checks to ensure data integrity, correctness, and completeness;
- Identify and address errors and omissions;
- Document and archive inventory material and record all QC activities;
- Check data acquisition, calculations, and procedures;
- Document technical reviews of data, methods, and results

IMPORTANCE OF QA/QC – WHY BOTHER?

Helps identify areas for improvement!

Builds confidence in national GHG inventories!

VERIFICATION (TYPE OF QA)

- Verification refers to the collection of activities and procedures conducted during the planning and development, or after completion of an inventory that can help to establish its reliability.

- Verification activities include comparisons with emission or removal estimates prepared by other bodies and comparisons with estimates derived from fully independent assessments.

Example from 2006 IPCC Guidelines

The IPCC provides potential outside verification checks in the national level CO_2 emissions estimates compiled by the International Energy Agency (IEA)

General QC Procedures

Apply at category and cross-cutting levels

- Data gathering, input, and handling activities
- Data documentation
- Calculating emissions and checking calculations
- Check overall data has been aggregated properly from lower levels
- *Consider adding QC procedures relevant to country specific compilation processes (e.g., figure data QC)*

See Volume 1, Table 6.1 and additional examples for documenting QC implementation are in Annex 6A1)

Table 6.1
General inventory QC procedures

QC Activity	Procedures
Check that assumptions and criteria for the selection of activity data, emission factors, and other estimation parameters are documented.	• Cross-check descriptions of activity data, emission factors and other estimation parameters with information on categories and ensure that these are properly recorded and archived.
Check for transcription errors in data input and references.	• Confirm that bibliographical data references are properly cited in the internal documentation. • Cross-check a sample of input data from each category (either measurements or parameters used in calculations) for transcription errors.
Check that emissions and removals are calculated correctly.	• Reproduce a set of emissions and removals calculations. • Use a simple approximation method that gives similar results to the original and more complex calculation to ensure that there is no data input error or calculation error.
Check that parameters and units are correctly recorded and that appropriate conversion factors are used.	• Check that units are properly labelled in calculation sheets. • Check that units are correctly carried through from beginning to end of calculations. • Check that conversion factors are correct. • Check that temporal and spatial adjustment facto
Check the integrity of database files.	• Examine the included intrinsic documentation (s - confirm that the appropriate data proc represented in the database. - confirm that data relationships are cor database. - ensure that data fields are properly labe design specifications. - ensure that adequate documentation of da and operation are archived.
Check for consistency in data between categories.	• Identify parameters (e.g., activity data, const multiple categories and confirm that there is co for these parameters in the emission/removal cal
Check that the movement of inventory data among processing steps is correct.	• Check that emissions and removals data are lower reporting levels to higher reporting summaries. • Check that emissions and removals data are co different intermediate products.
Check that uncertainties in emissions and removals are estimated and calculated correctly.	• Check that qualifications of individuals provi uncertainty estimates are appropriate. • Check that qualifications, assumptions and expe • Check that calculated uncertainties are complete • If necessary, duplicate uncertainty calculations probability distributions used by Monte Carlo a uncertainty calculations according to Approach
Check time series consistency.	• Check for temporal consistency in time series in • Check for consistency in the algorithm/met throughout the time series. • Check methodological and data changes resultin • Check that the effects of mitigation activitie reflected in time series calculations.

Table 6.1 (Continued)
General inventory QC procedures

QC Activity	Procedures
Check completeness.	• Confirm that estimates are reported for all categories and for all years from the appropriate base year to the period of the current inventory. • For subcategories, confirm that entire category is being covered. • Provide clear definition of 'Other' type categories. • Check that known data gaps that result in incomplete estimates are documented, including a qualitative evaluation of the importance of the estimate in relation to total emissions (e.g., subcategories classified as 'not estimated', see Chapter 8, Reporting Guidance and Tables).
Trend checks.	• For each category, current inventory estimates should be compared to previous estimates, if available. If there are significant changes or departures from expected trends, re-check estimates and explain any differences. Significant changes in emissions or removals from previous years may indicate possible input or calculation errors. • Check value of implied emission factors (aggregate emissions divided by activity data) across time series. - Do any years show outliers that are not explained? - If they remain static across time series, are changes in emissions or removals being captured? • Check if there are any unusual and unexplained trends noticed for activity data or other parameters across the time series.
Review of internal documentation and archiving.	• Check that there is detailed internal documentation to support the estimates and enable reproduction of the emission, removal and uncertainty estimates. • Check that inventory data, supporting data, and inventory records are archived and stored to facilitate detailed review. • Check that the archive is closed and retained in secure place following completion of the inventory. • Check integrity of any data archiving arrangements of outside organisations involved in inventory preparation.

Category-Specific Checks

- Activity data checks
  - Assess quality of data, i.e., understand standards applied in collecting data, data provider QA/QC, etc.
- Emission factor checks
  - Assess background data used for country-specific EFs for representativeness
  - Comparisons with defaults
  - Comparisons with other countries
- Model QC
- Calculation QC

PROCEDURES TO APPLY QC

Example General QC Checks

1. Check that spreadsheets use consistent units, properly labelled
2. Check that estimates are reported for all source categories and for all years
3. Cross-check spreadsheet values to publication values
4. Trend checks (e.g., can be automated, i.e., to check implied EF over time series, check for unexplained trends)

Example Category-Specific QC Checks

1. Energy, Stationary Combustion - Some countries estimate emissions from fuel consumed and the carbon contents of those fuels. In this case, the carbon contents of the fuels should be regularly reviewed.

EXAMPLE GENERAL QC PROCEDURE

AG12

	A	B	C	D	E	F	AC	AD	AE	AF
1	**CO_2 EMISSIONS FROM CEMENT PRODUCTION**									
2			**1990**	**1991**	**1992**	**1993**	**2016**	**2017**	**2018**	**2019**
3	Clinker Production	(Thousand metric tons)	64,355	62,918	63,411	66,957	75,633	76,678	77,112	79,000
4	CO_2 Released	(Thousand metric tons)	32,828	32,095	32,346	34,155	38,581	39,114	39,335	40,298
5	CKD CO_2 Release*	(Thousand metric tons)	657	642	647	683	772	782	787	806
6	**Total CO_2 Release**	**(thousand metric tons CO_2 Eq.)**	33,484	32,736	32,993	34,838	39,352	39,896	40,122	41,10
7		**(million metric tons CO_2 Eq.)**	**33.5**	**32.7**	**33.0**	**34.8**	**39.4**	**39.9**	**40.1**	**41**
8										

QC Procedure #1:

Cross-check spreadsheet values to publication values ✓

Document implementation in checklist

CEMENT

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2020, U.S. portland cement production increased slightly to an estimated 87 million tons, and masonry cement production decreased slightly to 2.3 million tons. Cement was produced at 96 plants in 34 States, and at 2 plants in Puerto Rico. Texas, Missouri, California, and Florida were, in descending order of production, the four leading cement-producing States and accounted for nearly 45% of U.S. production. Overall, the U.S. cement industry's growth continued to be constrained by closed or idle plants, underutilized capacity at others, production disruptions from plant upgrades, and relatively inexpensive imports. In 2020, shipments of cement were essentially unchanged from those of 2019 and were valued at $12.7 billion. In 2020, it was estimated that 70% to 75% of sales were to ready-mixed concrete producers, 10% to concrete product manufacturers, 8% to 10% to contractors, and 5% to 12% to other customer types.

Salient Statistics—United States:[1]	**2016**	**2017**	**2018**	**2019**	**2020**[e]
Production:					
Portland and masonry cement[2]	84,695	86,356	86,368	[e]88,000	89,000
Clinker	75,633	76,678	77,112	79,000	79,000
Shipments to final customers, includes exports	95,397	97,935	99,419	103,000	103,000
Imports for consumption:					
Hydraulic cement	11,742	12,288	13,764	[illegible]	15,000
Clinker	1,496	1,209	967	1,160	1,400
Exports of hydraulic cement and clinker	1,097	1,035	919	1,002	1,000
Consumption, apparent[3]	95,150	97,160	98,500	[e]103,000	102,000
Price, average mill value, dollars per ton	111	117	121	[e]123	124
Stocks, cement, yearend	7,420	7,870	8,580	[e]7,140	7,800
Employment, mine and mill, number[e]	12,700	12,500	12,300	12,500	12,500
Net import reliance[4] as a percentage of apparent consumption	13	13	14	14	15

Recycling: Cement is not recycled, but significant quantities of concrete are recycled for use as a construction aggregate. Cement kilns can use waste fuels, recycled cement kiln dust, and recycled raw materials such as slags and fly ash. Various secondary materials can be incorporated as supplementary cementitious materials (SCMs) in blended cements and in the cement paste in concrete.

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7		**(million metric tons CO_2 Eq.)**	33.5	32.7	33.0	34.8	39.4	39.9	40.1	41.1
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QC Procedure #2:

Check that spreadsheets use consistent units and are properly labelled

Document implementation in checklist

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Document implementation of QC

- Create standard checklist for leads to use
- Example in 2006 IPCC guidelines, Vol. 1, Chapter 6, Annex 6A.1
  - Sample forms can be implemented as an MS Word form or in xlsx
- Checklists also provided in EPA's Toolkit for Building National Inventory Systems (https://www.epa.gov/ghgemissions/greenhouse-gas-inventory-tools)

DOCUMENT IMPLEMENTATION OF QC

Completed checklists should be submitted by leads with final files, and collated in inventory archives upon completion of Inventory

Item		Check Completed			Corrective Action		Supporting documents (provide reference)
		Date	Individual (first initial, last name)	Errors (Y/N)	Date	Individual (first initial, last name)	
DATA GATHERING, INPUT, AND HANDLING ACTIVITIES: QUALITY CHECKS							
1.	Check a sample of input data (e.g., activity data, emission factors, uncertainty inputs) for transcription errors. Check a random sample of data in each worksheet. (VMT, Aircraft fuel consumption)	1/24 3/24	S Brown L O'Rourke S. Johnson	N N N			
2.	Review spreadsheets with automatic checks and/or quality check reports. Perform a random check of cell formulas to assure that the formula is correct in each source sheet.	12/23 3/24	S Brown T Atwood L O'Rourke	Y	12/23 3/24	T Atwood L O'Rourke S Brown	Corrections made to change proxy formulas to refer to new data available

Where to Apply the QC

General QC checks are applicable to **all inventory categories and all types of data**

Questions to consider for prioritizing your QC process:

1. Is the source/sink a key category?
2. Has a category's methodology or data changed?
3. Is there a high level of uncertainty for the category?
4. When was the last time this category went through the QC check?

Some categories need more QA/QC than others!

When to Apply the QC

What level of QC is needed annually?

- Appy general checks to a sample of data and calculations from each category each year
- QC should be performed prior to any peer review
- Apply if you update data prior to finalizing inventory

Some QC is needed only periodically.

- Category-specific procedures may only be applied every other year, and can be prioritized for key categories
- EF/AD QC may only need to be implemented when there are changes (e.g., in activity, data sources, or science)

Quality Assurance Procedures

- Expert peer review (should)
  - Provide an objective review of methods, data and results and ensure it is reasonable/technically sound
  - Involve reviewers or experts not involved in preparing the inventory
  - Can focus on whole report and/or parts
    - Prioritize key categories and areas with methodological refinements,
- Audits
  - Provide an in-depth analysis of the procedures taken to develop an inventory, based on the documentation available

ANNUAL REVIEW (QA) PHASES: INVENTORY OF U.S. GHG EMISSIONS AND SINKS

Two-phase domestic review process, followed by multilateral peer review

Expert Review (30 days)	Public Review (30 days)	Paris Agreement Review
~Late Oct-Nov 2023	**Mid-Feb/March 2024**	**TBD**

• Draft sectoral chapters shared with experts (overall expert list includes ~360 experts, including state experts)
• Follows EPA Peer Review Handbook practices:
  • Guidance memos including objectives, charge questions and supplemental technical information outlining changes to facilitate review
  • Publish comments and responses
	Offer a broader range of researchers and practitioners in industry and academia, as well as the general public, the opportunity to contribute to the final report
	
	• Publish draft report on EPA web site
	• Federal Register Notice
	• Publish comments and responses
		• Occurs post-submission to UNFCCC
		• Review completed by team experts from other countries
		• Assess transparency, accuracy, consistency, completeness, and comparability of report and consistency with reporting guidelines (includes application of IPCC methods)
		• Review report published on UNFCCC web site
		• Report on status of issues in next GHGI report
		• Participate in reviews of other country submissions

Improvements identified from reviews are addressed in future Inventories (i.e., noted in planned improvements sections across report)

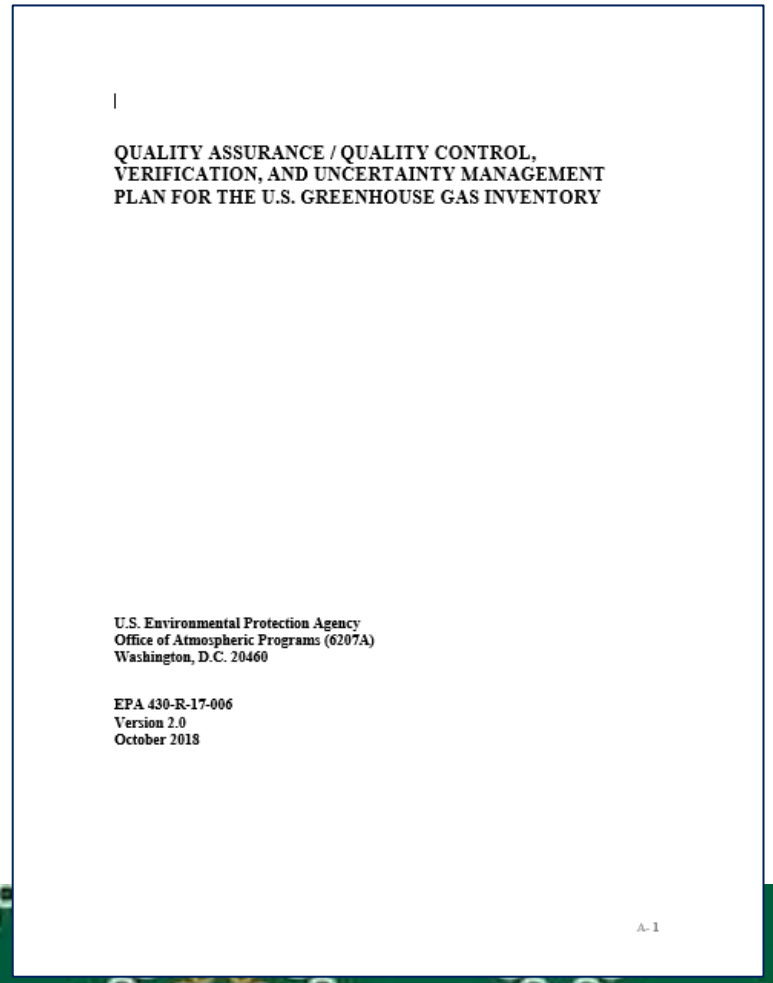
QA/QC PLAN VS. GENERAL PROCEDURES

QA/QC Plan

- Includes data quality objectives (e.g. transparency, accuracy, completeness, consistency, comparability, timeliness and continuous improvement)
- Describes QA/QC arrangements
- Outlines the QA/QC and verification activities implemented
  - **General QC procedures (part of plan)**
  - Other QC procedures (category-specific QC implement, likely includes calculation)
  - QA procedures
  - Verification procedures
  - Feedback mechanisms, etc.

QA/QC PLAN

- *Quality Assurance / Quality Control, Verification, and Uncertainty Management Plan for the U.S. Greenhouse Gas Inventory* (in place since 2002)
- Provides a rigorous set of procedures for maximizing the quality of the inventory
- Plan includes forms and checklists to standardize QA/QC application and documentation
- Plan closely adheres to IPCC guidance and good practices
- Reflects EPA's Guidance for Data Quality Assessment and EPA's Peer Review Handbook
- *Update in progress with aim to finalize in summer 2024 (last update in 2018)*



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

U.S. Environmental Protection Agency
Office of Atmospheric Programs (6207A)
Washington, D.C. 20460

EPA 430-R-17-006
Version 2.0
October 2018

A-1

QC BOTTOM LINE

- Check your work i.e., implementing and documenting QA/QC steps assures inventory quality and builds confidence in national data
- Start with general QC checklist included in IPCC guidance
- Consider a team peer QC process
- Identifies areas for improvement (beyond identifying basic errors)
- Develop a basic QC plan to check all estimates, and add additional checks prioritizing more significant categories (i.e., key categories)
    - Assign roles/responsibilities (e.g., a QA/QC coordinator to track implementation of QC and maintain QA/QC plan)
    - Consider if you can include additional QC checks for key categories
    - Communicate plan and outputs to inventory compilation team
    - Establish a process and schedule for QA

Discussion