The 7th Greenhouse Gas Inventory System Training Workshop

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Introduction to QA/QC principles for GHG inventories (TACCC)

Design and documentation of QA/QC activities

Uncertainty Assessment

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UNOSD, ESCAP, United Nations Climate Change, ipcc

What do we want our GHG Inventory to be

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Under the ETF, countries are required to submit their National Inventory as either a standalone document, or within their National Biennial Transparency Report. These GHG Inventories need to be...

High quality inventory of anthropogenic emissions and removals of greenhouse gases that is both credible and convincing

The way in which the quality of an inventory is assessed is based on ts transparency, accuracy, completeness, consistency, and comparability.

What do we need to achieve these qualities...

- ***A good QA/QC system***
- *Tools to focus resources on where we get the maximum benefit*
- *An inventory plan covering **QA/QC, timing**, deliverables and stakeholder involvement*
- ***Consistent management to achieve this***

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What is 'Quality Control' and 'Quality Assurance'

System of routine technical activities to assess and maintain the quality of the inventory as it is being compiled

Performed by personnel compiling the inventory

QC system is designed to:
- Provide routine and consistent checks to ensure data integrity, correctness, and completeness
- Identify and address errors and omissions
- Document and archive inventory material and record all QC activities

Planned system of review procedures conducted by personnel not directly involved in the inventory compilation/development process (preferably by independent third parties)

Performed upon a completed inventory following the implementation of QC procedures
- Verify that measurable objectives were met
- Ensure that the inventory represents the best possible estimates given the current state of scientific knowledge and data availability
- Support the effectiveness of
- the QC programme

and Verification...

- Collection of activities and procedures conducted during the planning and development, or after completion of an inventory that can help to establish its reliability for the intended applications of the inventory
- Methods that are external to the inventory and apply independent data, including comparisons with inventory estimates made by other bodies or through alternative methods
- May be constituents of both QA and QC

QA/QC in the MPGs

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Chapter II. National inventory report of anthropogenic emissions by sources and removals by sinks of GHGs

Report:
QA/QC Plan
QA/QC Implementation

B. National circumstances and institutional arrangements

§19. Each Party shall report on the following functions related to inventory planning, preparation and management:

(a) Its national entity or national focal point with overall responsibility for the national inventory;

(b) Its inventory preparation process, including division of specific responsibilities of institutions participating in the inventory preparation to ensure that sufficient activity data collection, choice and development of methods, emission factors and other parameters are in accordance with the IPCC guidelines referred to in paragraph 20 below and these MPGs;

(c) Its archiving of all information for the reported time series, including all disaggregated emission factors and activity data, all documentation about generating and aggregating data, including quality assurance/quality control (QA/QC), review results and planned inventory improvements;

(d) Its processes for the official consideration and approval of the inventory.

E. Reporting guidance

Information on methods and cross-cutting elements

§46. Each Party shall report the QA/QC plan and information on QA/QC procedures already implemented or to be implemented in the future, in accordance with paragraphs 34−36 above.

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QA/QC in the MPGs

Chapter II. National inventory report of anthropogenic emissions by sources and removals by sinks of GHGs

C. Methods

Quality assurance/quality control

QA/QC Plan

§34. Each Party shall elaborate an inventory QA/QC plan in accordance with the IPCC guidelines referred to in paragraph 20 above, including information on the inventory agency responsible for implementing QA/QC; those developing country Parties that need flexibility in the light of their capacities with respect to this provision are instead encouraged to elaborate an inventory QA/QC plan in accordance with the IPCC guidelines referred to in paragraph 20 above, including information on the inventory agency responsible for implementing QA/QC.

General, category specific QC Procedures QA Peer Review

§35. Each Party shall implement and provide information on general inventory QC procedures in accordance with its QA/QC plan and the IPCC guidelines referred to in paragraph 20 above; those developing country Parties that need flexibility in the light of their capacities with respect to this provision are instead encouraged to implement and provide information on general inventory QC procedures in accordance with its QA/QC plan and the IPCC guidelines referred to in paragraph 20 above. In addition, Parties should apply category-specific QC procedures in accordance with the IPCC guidelines referred to in paragraph 20 above for key categories and for those individual categories in which significant methodological changes and/or data revisions have occurred. In addition, Parties should implement QA procedures by conducting a basic expert peer review of their inventories in accordance with the IPCC guidelines referred to in paragraph 20.

Ref. Approach

§36. Each Party should compare the national estimates of CO_2 emissions from fuel combustion with those obtained using the reference approach, as contained in the IPCC guidelines referred to in paragraph 20 above, and report the results of this comparison in its national inventory report.

TACCC: The Foundation of Credible Climate Governance

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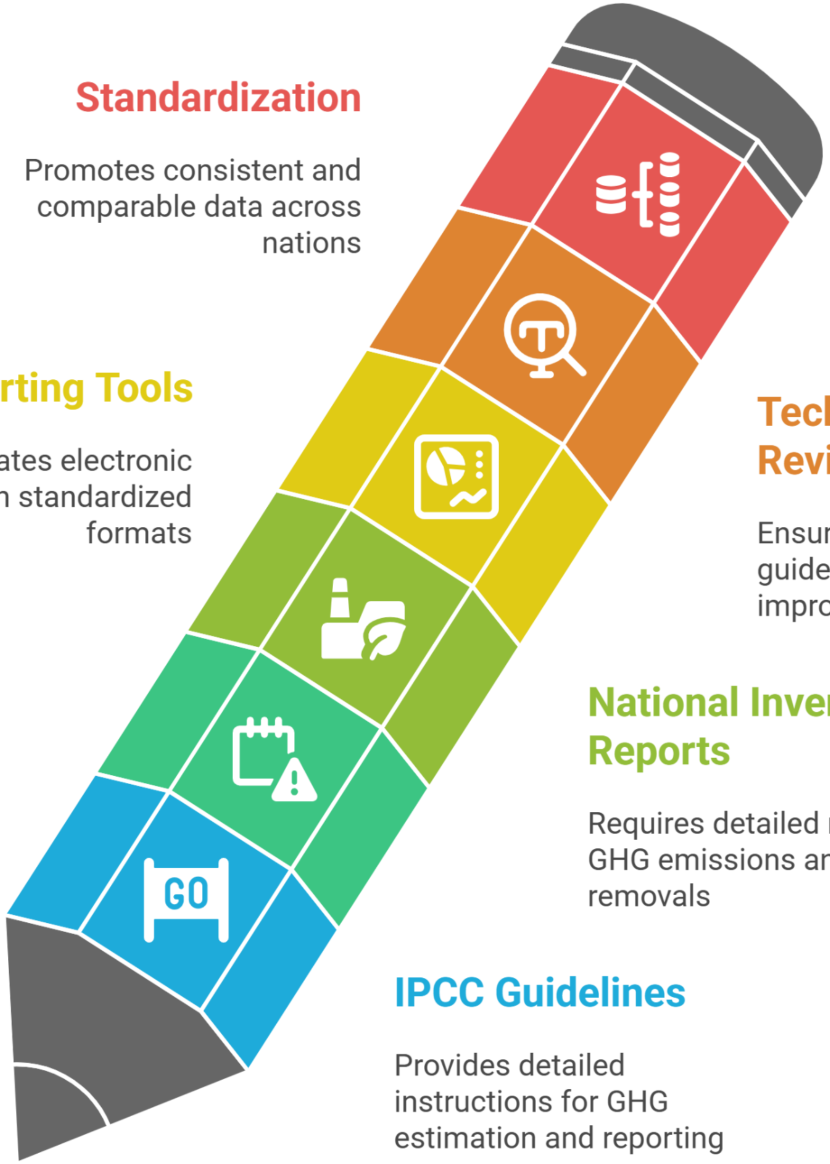

Standardization

Promotes consistent and comparable data across nations

Reporting Tools

Facilitates electronic reporting with standardized formats

Technical Expert Review

Ensures adherence to guidelines and promotes improvement

Biennial Transparency Reports

Mandates submission of reports every two years

National Inventory Reports

Requires detailed reports on GHG emissions and removals

IPCC Guidelines

Provides detailed instructions for GHG estimation and reporting

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TACCC: The Foundation of Credible Climate Governance

- **More than compliance**: TACCC principles transform raw GHG data into actionable intelligence that enables informed decision-making and strengthens global climate governance
- **Interdependent system**: Deficiency in one principal cascades to others - lack of transparency undermines ability to verify consistency or assess accuracy, creating systemic inventory weaknesses
- **Trust and cooperation**: These principles form the essential bedrock for building trust among nations, enabling reliable baselines, effective progress tracking, and meaningful international climate cooperation
- **Policy effectiveness**: Without TACCC adherence, underlying data cannot be fully trusted, directly undermining policymaker ability to establish credible climate policies and compare national efforts globally.

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Definitions and Significance of TACCC Principles in GHG Inventories

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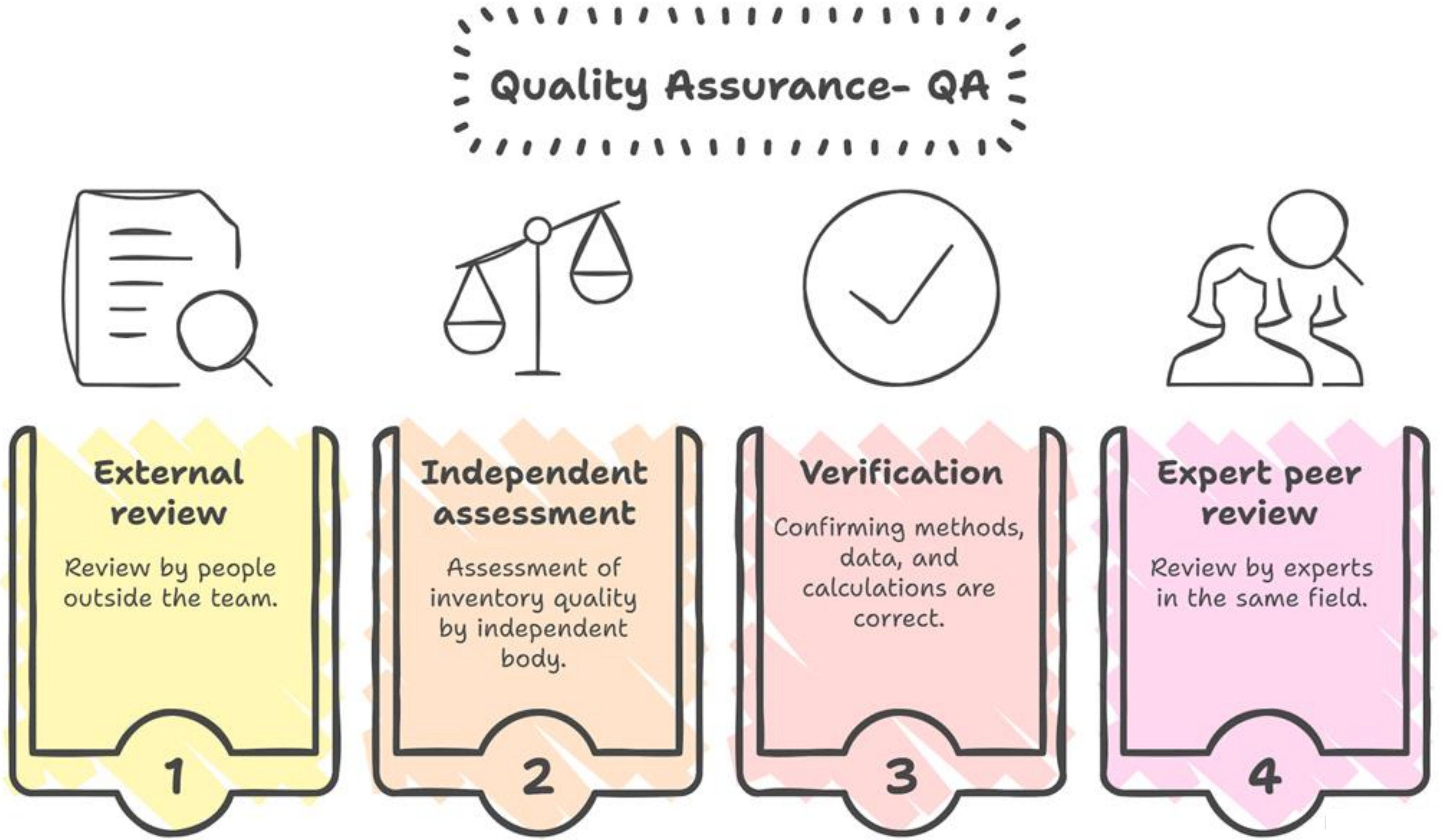
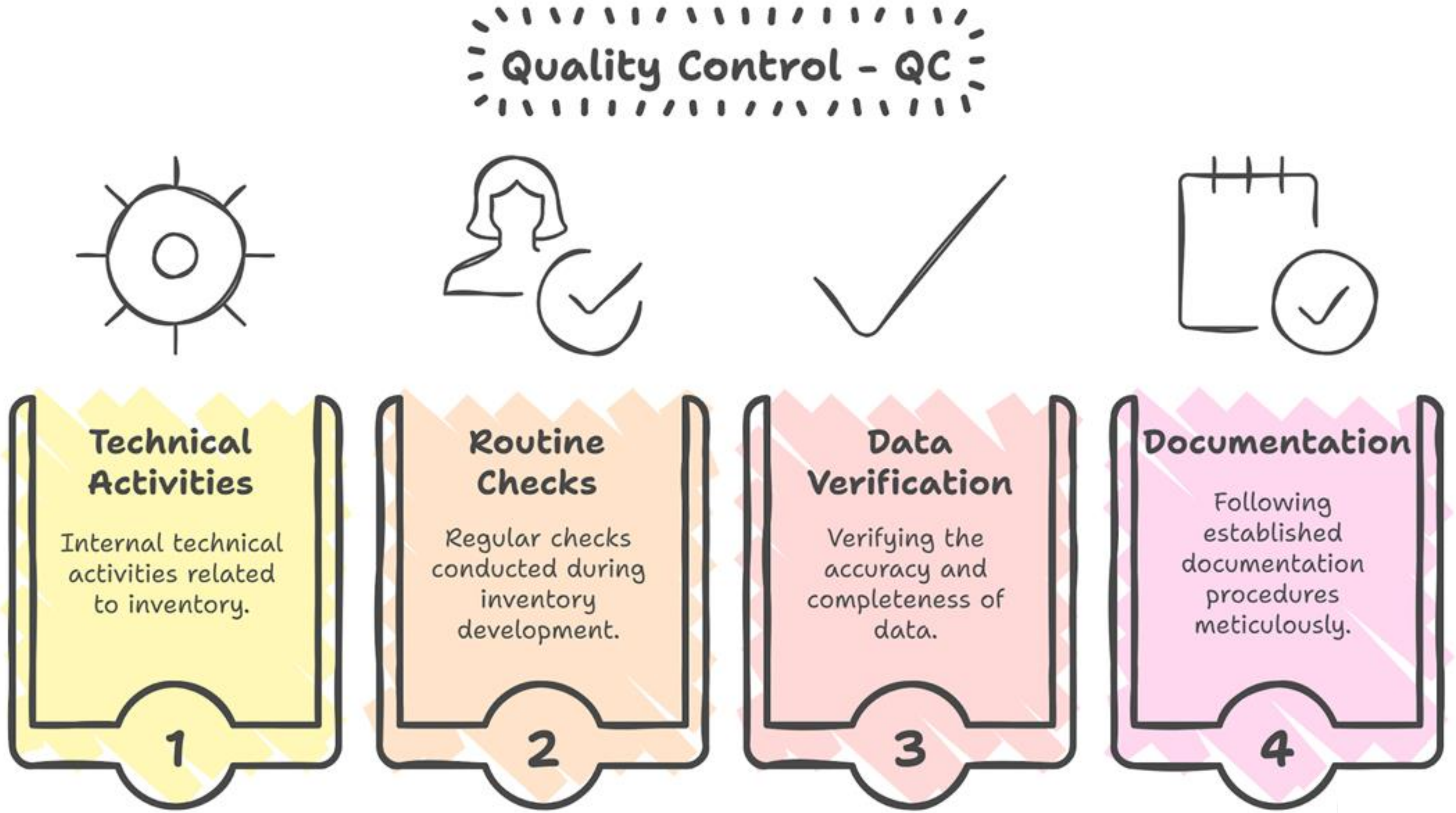
Principle	Definition (IPCC/UNFCCC Aligned)	Significance in GHG Inventory Development	Contribution of QA/QC
Transparency	Assumptions and methodologies are clearly explained to facilitate replication and assessment by users.	Essential for building trust and enabling external scrutiny and understanding of the inventory.	Ensures comprehensive documentation, clear reporting of methods, data sources, and assumptions.
Accuracy	Estimates are systematically neither over nor under true emissions/removals, with uncertainties reduced as far as practicable.	Provides confidence in the quantitative estimates, forming a reliable basis for policy decisions and tracking progress.	Implements checks to identify and reduce errors, validates data against evidence, and quantifies uncertainties.
Consistency	Inventory is internally consistent across elements and with inventories of other years, using same methodologies and datasets.	Allows for robust trend analysis and reliable assessment of emission changes over time, free from methodological artifacts.	Standardizes procedures, ensures consistent application of methods and data across time series and categories.
Comparability	Estimates reported by Parties are comparable among them, achieved through agreed methodologies and formats.	Facilitates global aggregation of efforts, cross-national assessment, and equitable burden-sharing under international agreements.	Promotes adherence to IPCC guidelines and UNFCCC reporting formats, enabling standardized data presentation.
Completeness	Covers all sources, sinks, and gases in IPCC Guidelines, plus country-specific categories, with full geographic coverage.	Ensures a comprehensive accounting of national emissions and removals, avoiding underestimation of total impact.	Establishes systematic checks for all relevant categories, gases, and geographic areas, documenting any exclusions.

Quality Assurance - QA



Quality Control - QC



QA-QC Components

A comprehensive QA/QC plan should include several key components:

- **Organizational Structure:** This component identifies the roles and responsibilities for QA/QC activities within the inventory preparation team and any collaborating agencies. Centralized coordination of QA/QC activities is highly recommended, with oversight from the primary agency responsible for preparing the inventory to ensure consistent implementation of the plan. Assignments for QA/QC responsibility should cover all source categories included in the inventory.
- **General Inventory-Level QC Procedures:** These are routine checks applied across all phases of inventory development. They focus on processing, handling, documenting, archiving, and reporting procedures common to all sources and do not necessarily require specific knowledge of a source category. These checks are preferably performed manually to avoid introducing errors, though automated checks can supplement manual efforts for large datasets.
- **Source-Specific QC Procedures:** These procedures are applied on a case-by-case basis, targeting specific aspects of a source category and requiring specialized knowledge. Recommended activities include quality control of emission factors, activity data, and uncertainty estimates, with the specific QC depending on the estimation approach for a given source category.
- **QA Procedures:** These involve independent, objective reviews and audits to assess the effectiveness of the internal QC program, the inventory's overall quality, and to reduce bias. Expert peer review and independent audits are key components of QA.

Key Internal Review Activities

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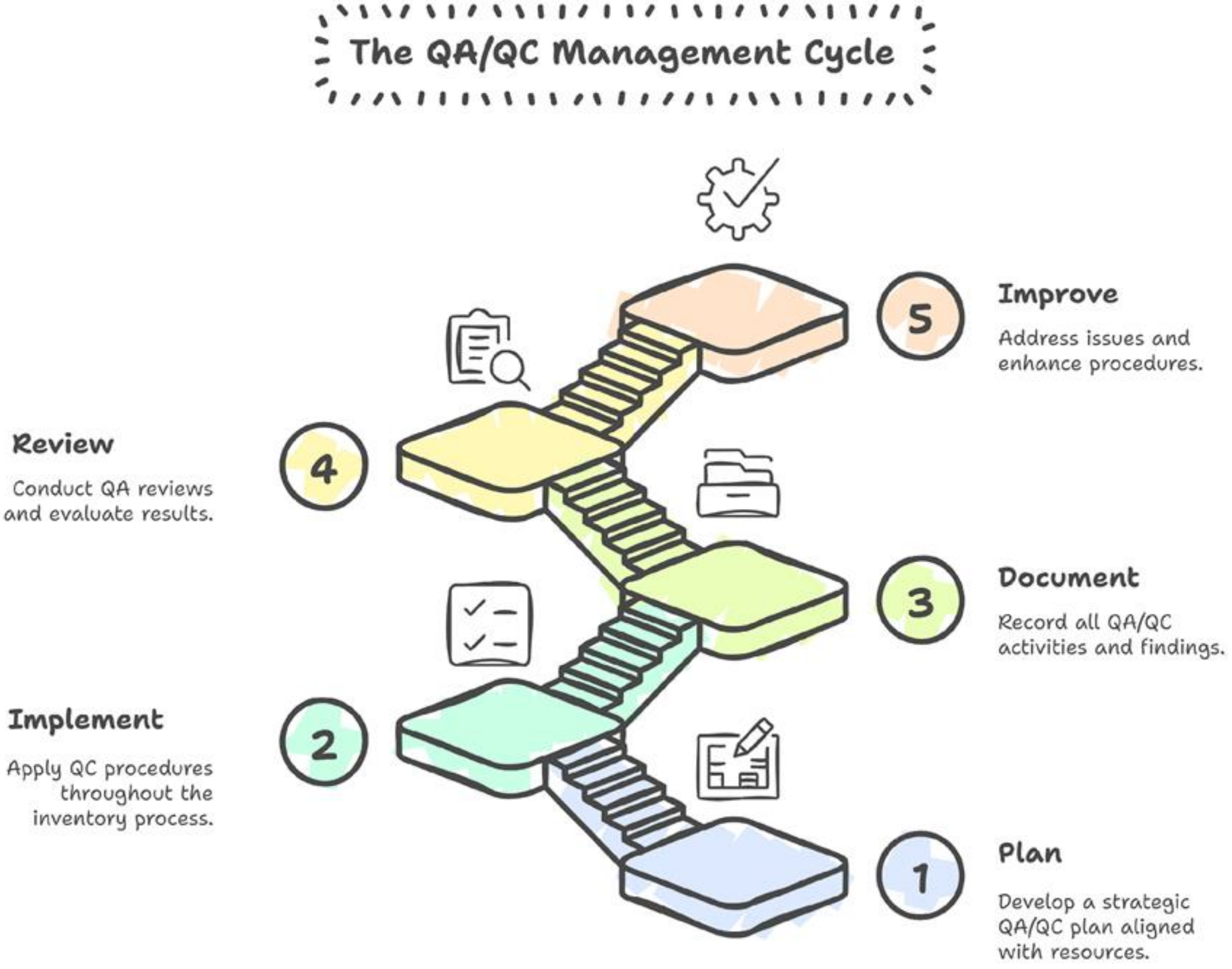
- **Cross-Checking and Recalculation:** Requiring a second person to review or recalculate key emission calculations as a cross-check.
- **Anomaly Detection:** Comparing current year data with historical trends and investigating any significant changes or out-of-range values (e.g., changes over 10% from one year to the next may warrant investigation).
- **Source Document Verification:** Ensuring activity data (e.g., fuel use, electricity consumption) ties back to solid evidence such as utility bills, meter readings, invoices, and production logs. Copies of all such source documents must be maintained, as a verifier will request to see this underlying evidence.
- **Multi-Source Comparison:** Comparing activity data from different sources, such as government surveys or trade association data, with the company's or national data to ensure consistency.
- **Relevance and Accuracy of Other Data:** Checking that data collected for purposes other than GHG inventory (e.g., sales, production data) is relevant, accurate, complete, and consistent with definitions and emission factors for inventory use.
- **Boundary Application Verification:** Confirming that organizational and operational boundary decisions have been consistently applied when collecting activity data.
- **Bias Checks:** Accounting for known biases or characteristics that could affect data quality, such as unintentionally excluding operations from smaller facilities.
- **Quality Management for Ratios:** Applying quality management measures to any additional data used to estimate emission intensities or other ratios.

These internal checks are prepared to provide routine and consistent verification points to ensure data integrity, correctness, and completeness, thereby identifying and reducing errors and omissions before they impact the final inventory.

- **Plan** - Develop QA/QC strategy aligned with resources
- **Implement** - Apply QC procedures throughout inventory process
- **Document** - Record all QA/QC activities and findings
- **Review** - Conduct QA reviews and evaluate results
- **Improve** - Address issues and enhance procedures



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Establishing Effective QA/QC Management

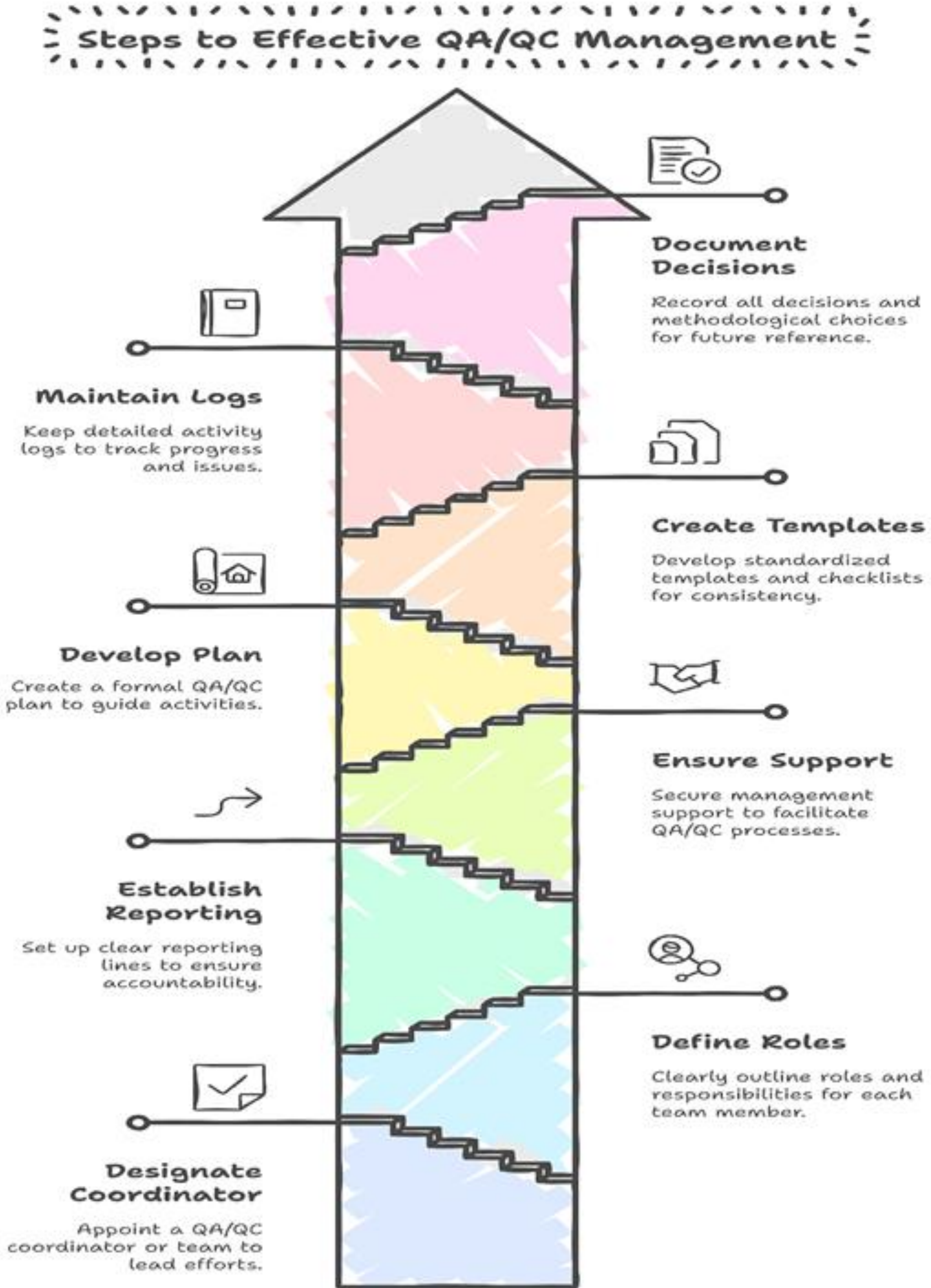
Foundations of QA/QC Management

Organizational Structure

Establishing a clear hierarchy and roles within the QA/QC team.

Documentation

Creating and maintaining formal records and procedures for QA/QC processes.



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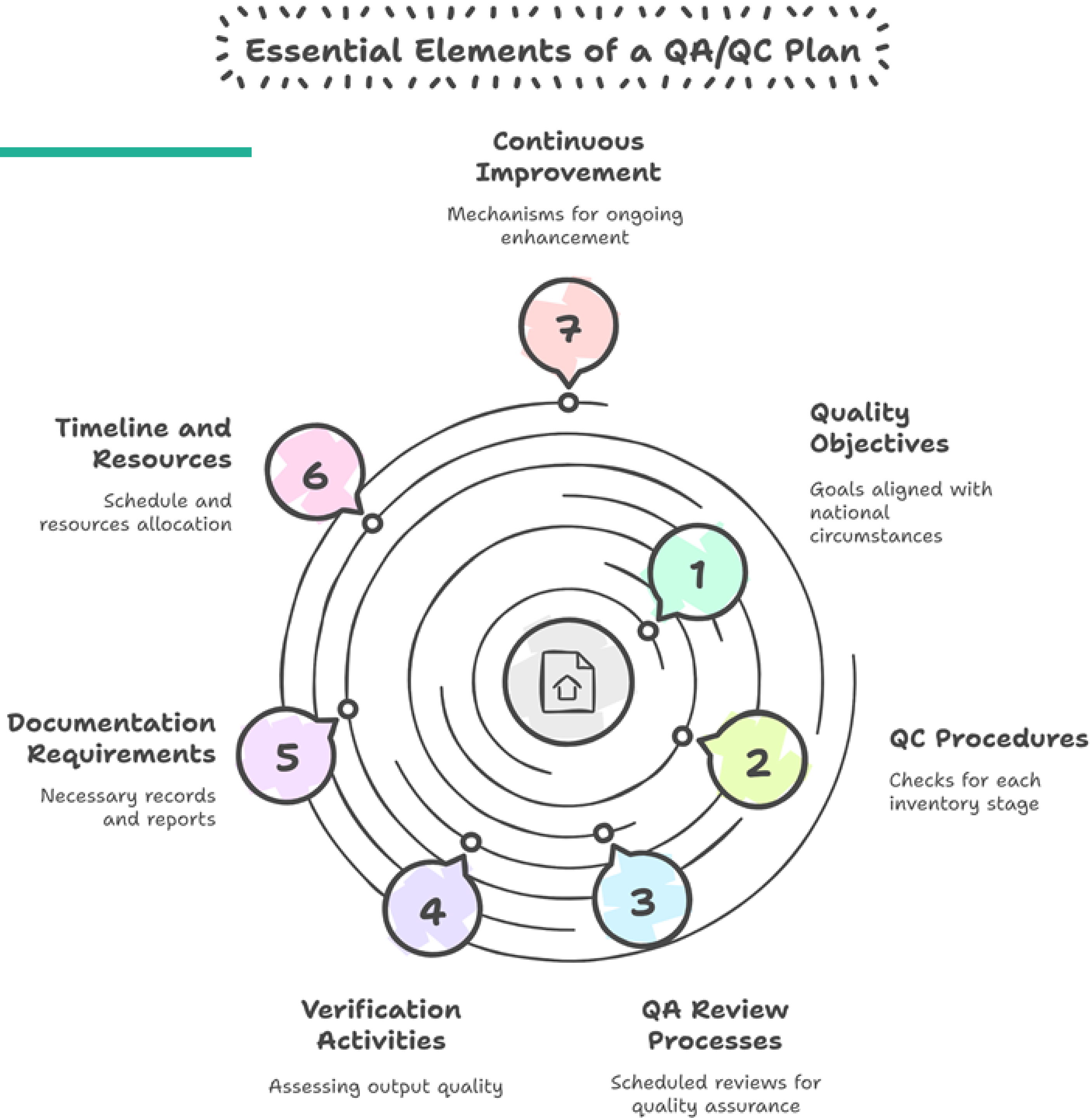
Essential Elements and Prioritizing Efforts

Resource-Efficient Approach:
- Focus intensively on **key categories** (highest emission sources)
- Prioritize areas with **high uncertainty**
- Apply more rigorous checks to **new methodologies or data sources**
- Balance effort according to **IPCC principle of significance**

Example Tiered Approach:
- **Tier 1**: Basic checks for all categories
- **Tier 2**: Detailed checks for key categories
- **Tier 3**: Comprehensive review for complex/high-uncertainty categories



Essential QA/QC Documentation

Checklists

Track progress and completion of QA/QC activities. Templates cover data gathering, input, handling, documentation, calculation, and trend checks.

Verification Protocols

Outline the scope of verification, level of assurance, assessment criteria, sampling plan, evidence required, and methodologies. Includes project details, methodologies, emissions, and compliance.

Corrective Action Logs

Track non-conformances, errors, deficiencies, and actions taken. Includes details such as date, time, reporter, description, corrections, root cause, and completion.

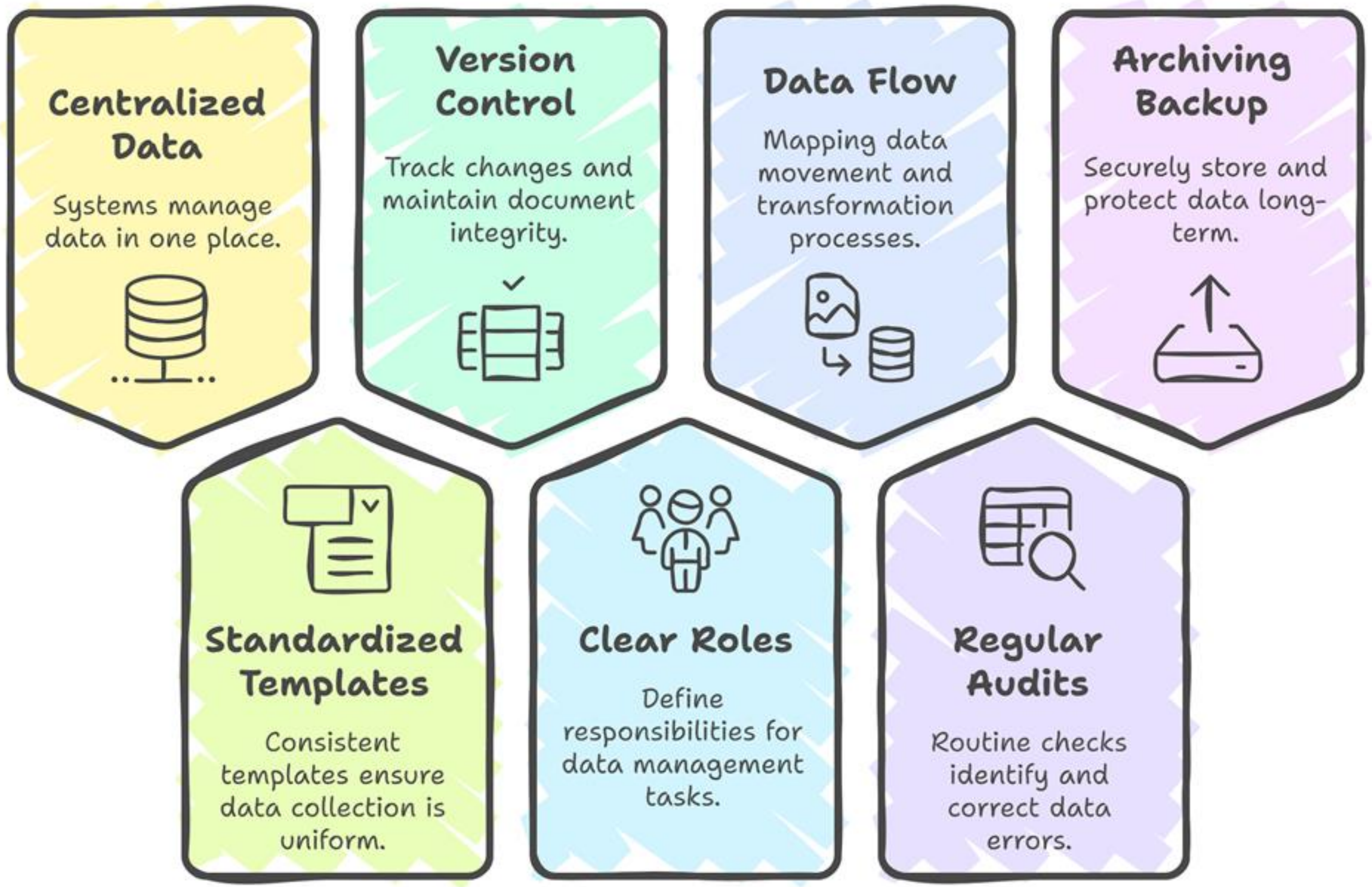
Establishing and Maintaining a Comprehensive Audit

Key aspects of maintaining an audit trail include:

- **Detailed Internal Documentation:** Full documentation of all QA/QC checks, audits, and reviews, including the QA/QC plan, checklists, notes, calculation sheets, and reports, should be retained for each source category. This documentation should detail what was performed, when, by whom, and any resulting corrections.
- **Source Referencing:** Every primary data element must have a clear source reference.
- **Archiving:** Inventory data, supporting data, and records should be archived and stored securely for detailed review. The archive should be closed and securely retained after inventory completion, with the integrity of data archiving arrangements of outside organizations also checked.
- **Reconstruction of Activities:** Good data documentation procedures facilitate the reconstruction of inventory development activities, which in turn provides a means to more thoroughly assess data quality and the accuracy of the inventory. This includes clear documentation of data obtained via telephone or adjusted through engineering judgment, with proper referencing and dating.
- **Consistency and Control:** Formalizing the inventory process in an Inventory Management System (IMS) ensures consistency year after year and makes annual reporting more routine and verification-ready. The IMS typically documents organizational and operational boundaries, methodologies, emission factors, data collection processes, roles, responsibilities, and QA/QC procedures.

The ability to reconstruct the inventory process through a robust audit trail is critical for demonstrating adherence to the TACCC principles, particularly transparency and accuracy. It builds confidence in the reported data, which is essential as verification requirements ramp up across voluntary programs and mandatory regulations.

Managing QA/QC and Data Systems



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Centralisied Data Management Systems

This is a structured database or platform where all inputs data, methods, assumptions and calculations are stored

Why this is important for QA/QC...

- Facilitates consistency across inventory years and sectors.
- Enables traceability of data sources and emission estimates.
- Supports easy retrieval during QC checks or external review.

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Centralized Data Management Systems

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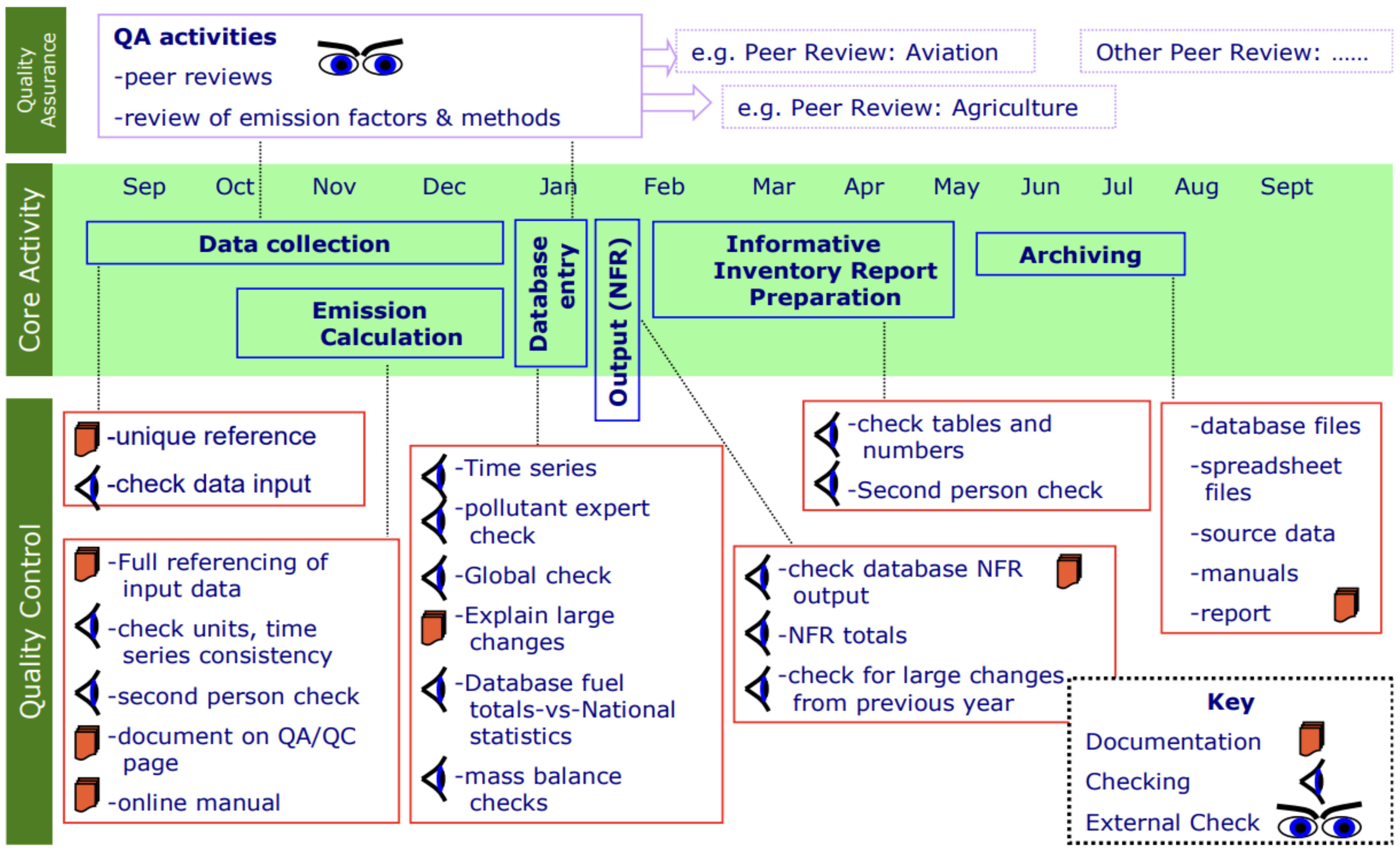
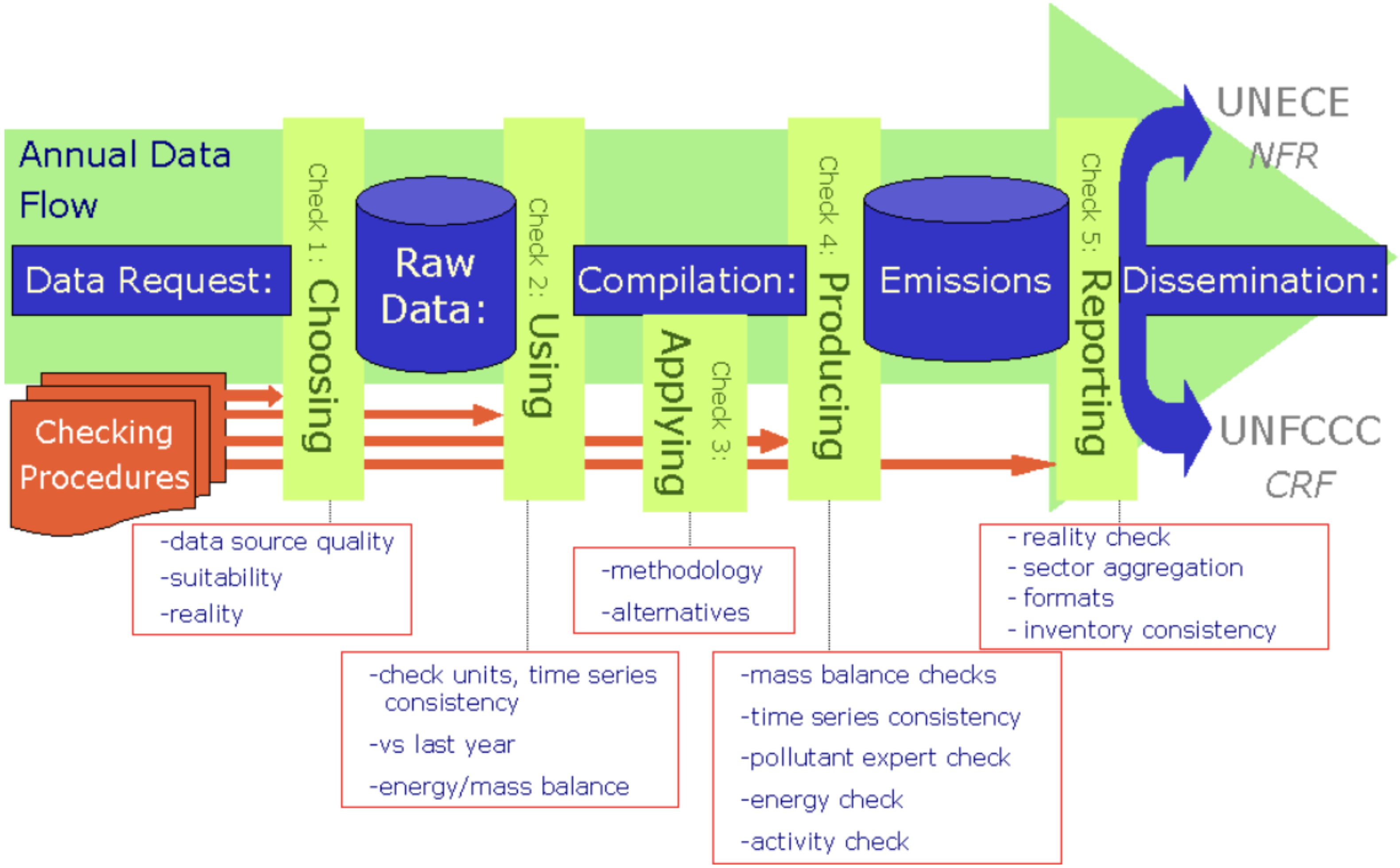
Figure 5-1 The key QA and QC elements of a QA/QC plan arranged over an indicative inventory cycle



Source: EMEP/EEA air pollution emission inventory guidebook 2019 (EEA Report 13/2019)

Centralisied Data Management Systems

Figure 5-2 QC checks during the inventory process



Source: EMEP/EEA air pollution emission inventory guidebook 2019 (EEA Report 13/2019)

How to address common challenges in QA-QC?

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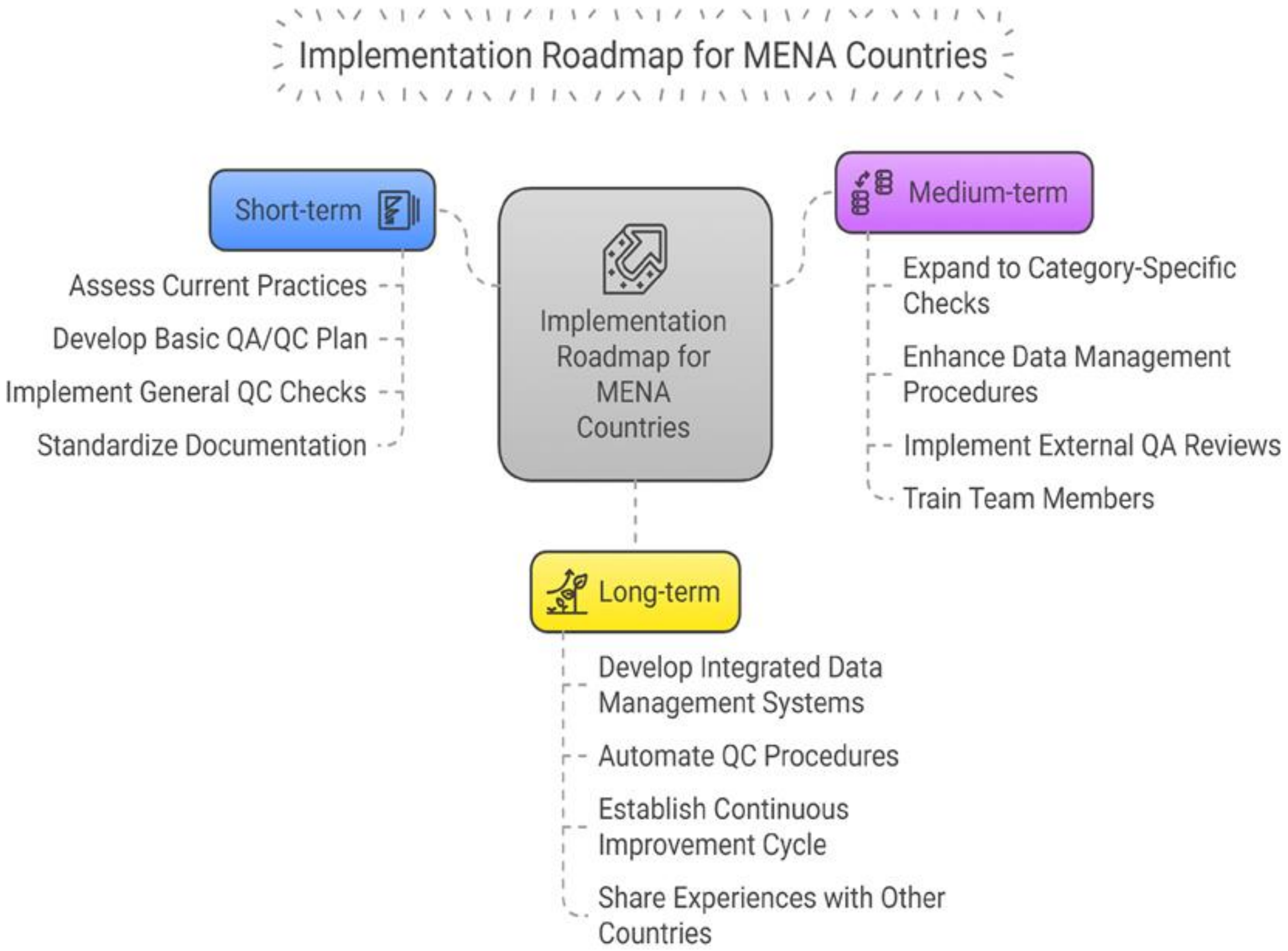
Building Sustainable Systems

Key Success Factors:

- **Institutional arrangements** that formalize roles and responsibilities
- **Documented procedures** that outlast personnel changes
- **Knowledge management** systems to maintain expertise
- **Gradual enhancement** of capabilities aligned with resources
- **Peer learning** and collaboration within the MENA network



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Fundamental Concepts: Sources of Uncertainty, Bias, Random Errors, and Reduction Strategies

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Uncertainty in GHG inventories refers to the lack of knowledge of the true value of a variable, which can be described as a probability density function (PDF). The extent of uncertainty depends on the analyst's state of knowledge, which is influenced by the quality and quantity of applicable data, as well as the understanding of underlying processes and inference methods.

- **Confidence Interval:** A range that encloses the true, but unknown value, with a determined confidence (probability), typically 95 percent in GHG inventories.
- **Probability Density Function (PDF):** Describes the range and relative likelihood of possible values, used to describe uncertainty in the estimate of a quantity whose value is not exactly known.
- **Accuracy:** The agreement between the true value and the average of repeated measured observations or estimates of a variable, indicating a lack of bias or systematic error.
- **Bias (Systematic Error):** A lack of accuracy that can occur due to failure to capture all relevant processes, unrepresentative data, or instrument error. Bias does not cancel out with aggregation.
- **Precision:** The agreement among repeated measurements of the same variable, indicating less random error. Precision is independent of accuracy.
- **Random Errors:** Random variation above or below a mean value, inversely proportional to precision. Quantitative uncertainty analysis primarily deals with random errors. Random errors tend to cancel out at higher levels of aggregation, such as national totals.
- **Sensitivity Analysis:** A method to determine which input uncertainties contribute most substantially to the overall uncertainty of an inventory.

Fundamental Concepts: Sources of Uncertainty, Bias, Random Errors, and Reduction Strategies

Uncertainties in national GHG inventories arise from various sources related to input data:

- **Lack of Completeness:** This introduces bias, for instance, when certain source/sink categories are not included in the inventories (e.g., emissions from coke production, fluorinated gases, methane from enteric fermentation for dairy cows, industrial wastewater).
- **Lack of Data:** This can introduce both bias and random errors, such as when activity data is obtained by interpolation for missing years (e.g., provisional energy balance information, missing cement production, uninformed animal population statistics, municipal solid waste extrapolated from census).
- **Representativeness of Data:** This introduces bias when emission factors are based on particular conditions that may not reflect real-world situations (e.g., N_2O from internal combustion engines from lab tests, CO_2 from steel production based on full load capacity, biomass growth rate from limited sampling, wastewater treatment efficiency from newly built plants).
- **Random Sampling Error:** This introduces both bias and random errors when activity data or emission factors are based on limited sampling (e.g., limited reporting of liquid fuels in transport census, amount of glass recovered, carbon stored in forest from few trees, municipal solid waste treatment distribution from few cities).
- **Measurement Errors and Misreporting:** These also contribute to uncertainty.

Fundamental Concepts: Sources of Uncertainty, Bias, Random Errors, and Reduction Strategies

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Strategies to reduce uncertainty involve improving various aspects of inventory preparation:

- **Improving Accounting:** This includes improving conceptualization by addressing structural assumptions, refining models through better structure and parameterization (e.g., better treatment of seasonality effects, moving to higher tiers for local plant data), and improving representativeness through better sampling strategies (e.g., stratified sampling in forests).
- **Collecting More Measured Data:** Increasing sample size (e.g., for soil organic carbon determination) and using more precise measurement methods (e.g., standardized methods, verifying instrument calibration).
- **Eliminating Known Risk of Bias:** Following decision trees and leveraging expert knowledge, such as moving to higher tiers for national conditions or involving producers to understand assumptions.
- **Improving State of Knowledge:** Enhancing understanding of the categories and processes involved.
- **Sensitivity Analysis:** Identifying categories and key variables that contribute most to the overall uncertainty of the inventory by perturbing one variable at a time and assessing the variation in the result. This helps allocate resources for improvement.

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Common Sources of Uncertainty in GHG Inventory Data and Estimation

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Source of Uncertainty	Description	Type of Error Primarily Introduced	Example
Lack of Completeness	Omission of relevant sources/sinks or gases from the inventory.	Bias (Systematic Error)	Not including emissions from specific industrial processes or certain F-gases.
Lack of Data	Missing activity data or emission factors, requiring interpolation or extrapolation.	Bias & Random Errors	Using interpolated activity data for a missing year in energy balance or cement production.
Representativeness of Data	Emission factors or activity data not reflecting actual national or site-specific conditions.	Bias (Systematic Error)	Applying default IPCC emission factors that do not align with country-specific practices or technologies.
Random Sampling Error	Uncertainty arising from limited sample sizes for activity data or emission factors.	Bias & Random Errors	Activity data based on a small number of surveys or measurements.
Measurement Errors	Inaccuracies due to faulty instruments, calibration issues, or human error during data collection.	Random Errors	Inaccurate meter readings for fuel consumption or imprecise laboratory analysis of emission factors.
Misreporting	Errors in data submission or transcription from primary sources.	Bias & Random Errors	Incorrectly reported production volumes or energy consumption figures.
Model Structure/Conceptual Errors	Flaws in the underlying models or assumptions used for estimation.	Bias (Systematic Error)	Simplified models that do not capture complex seasonal variations or process dynamics.
Expert Judgment	Subjectivity in expert elicitation for parameters when empirical data is scarce.	Bias & Random Errors	Expert estimates for activity data or emission factors without formal elicitation protocols.

Methodologies for Quantifying Uncertainty: Error Propagation (IPCC Tier 1 Approach)

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The Tier 1 analysis utilizes the error propagation equation in a two-step process to estimate uncertainties. This method is based on the propagation of errors and combines the random component of uncertainty associated with activity data and emission factors.

- **Combining Emission Factor and Activity Data:** Rule B approximation is used to combine the uncertainty ranges of emission factors and activity data by source category and greenhouse gas. This rule is applicable for multiplication (e.g., Emission = Activity Data x Emission Factor), where relative uncertainties are combined using the formula: $U = \sqrt{(UAD^2 + UEF^2)}$.
- **Overall Uncertainty and Trend Uncertainty:** Rule A approximation is then applied to combine uncertainties by source category, leading to an overall uncertainty estimate for total national emissions in a given year and the uncertainty in the trend of national emissions over time. This rule is applicable for addition (e.g., Total Emission = E1 + E2 +... + En), where absolute uncertainties are combined using the formula: $UE = \sqrt{((U1 \times E1)^2 + (U2 \times E2)^2 + ... + (Un \times En)^2)} / (E1 + E2 + ... + En)$.
- The Tier 1 approach is implemented using a structured table, often set up in spreadsheet software. This table is populated at the source category level using uncertainty ranges for activity data and emission factors, consistent with sectoral good practice guidance. Different gases are entered separately as CO_2 equivalents, meaning their emissions are multiplied by 100-year Global Warming Potential (GWP) values.

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Methodologies for Quantifying Uncertainty: Error Propagation (IPCC Tier 1 Approach)

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Trend uncertainties in Tier 1 are estimated using two sensitivities:

- **Type A Sensitivity:** This reflects the percentage change in the difference in overall emissions between the base year and the current year, resulting from a 1% increase in emissions of a specific source category and gas in *both* the base year and the current year. This type of sensitivity arises from uncertainties that affect emissions equally in both years and are fully correlated over time, such as emission factor uncertainties.
- **Type B Sensitivity:** This indicates the percentage change in the difference in overall emissions between the base year and the current year, resulting from a 1% increase in emissions of a specific source category and gas in the *current year only*. This sensitivity is associated with uncertainties that are not correlated between years, typically activity data uncertainties.

- Once the uncertainties from Type A and Type B sensitivities are calculated, they are summed using Rule A of the error propagation equation to determine the overall uncertainty in the trend.

- The Tier 1 method assumes small standard deviations (around 30% from the mean), symmetric and normal distributions, and uncorrelated variables. While these assumptions may not always hold true in practice, Tier 1 can still provide an approximate result and valuable insights into how individual source categories and greenhouse gases contribute to uncertainty.[22] It is considered good practice for all countries undertaking uncertainty analysis to report Tier 1 results.

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Methodologies for Quantifying Uncertainty: Error Propagation (IPCC Tier 1 Approach)

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Linear Error Propagation (LEP)

Enter Emissions Data

Data Calculated using simple equations

Table 3.2
Approach 1 uncertainty calculation

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC category	Gas	Base year emissions or removals	Year *t* emissions or removals	Activity data uncertainty	Emission factor / estimation parameter uncertainty	Combined uncertainty	Contribution to Variance by Category in Year *t*	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data Note A	Input data Note A	$\sqrt{E^2+F^2}$	$\frac{(G \bullet D)^2}{(\sum D)^2}$	Note B	$\left\lvert\frac{D}{\sum C}\right\rvert$	$I \bullet F$ Note C	$J \bullet E \bullet \sqrt{2}$ Note D	K^2+L^2
		Gg CO_2 equivalent	Gg CO_2 equivalent	%	%	%		%	%	%	%	%
E.g., 1.A.1. Energy Industries Fuel 1	CO_2											
E.g., 1.A.1. Energy Industries Fuel 2	CO_2											
Etc...	...											
Total		$\sum C$	$\sum D$				$\sum H$					$\sum M$
					Percentage uncertainty in total inventory:		$\sqrt{\sum H}$				Trend uncertainty:	$\sqrt{\sum M}$

Enter Uncertainties

Methodologies for Quantifying Uncertainty: Error Propagation (IPCC Tier 1 Approach)

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AD uncertainties based on source of data

EF uncertainties based on data used

List of source/sinks

Approach 1 uncertainty calculation

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC category	Gas	Base year emissions or removals	Year *t* emissions or removals	Activity data uncertainty	Emission factor / estimation parameter uncertainty	Combined uncertainty	Contribution to Variance by Category in	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national	Uncertainty in trend in national	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data	Input data	$\sqrt{E^2+F^2}$	$\frac{(G \bullet D)^2}{(\Sigma D)^2}$	Note B	$\left\lvert\frac{D}{\Sigma C}\right\rvert$	$I \bullet F$	$J \bullet E \bullet \sqrt{2}$	K^2+L^2
		Gg CO_2 equivalent	Gg CO_2 equivalent	%	%	%		%	%	%	%	%
1.A.1. Energy Industries	CH4	35.5346662	32.9951217	5	25	25.50	0.0	3.20506E-05	0.00010495	0.000801264	0.000742109	1.19275E-06
1.A.2. Manufacturing Industries and Constructio	CH4	57.0302899	51.8776096	5	25	25.50	0.0	4.80131E-05	0.000165011	0.001200328	0.001166804	2.80222E-06
1.A.3. Transport	CH4	81.7067834	37.1466612	5	25	25.50	0.0	-4.94664E-05	0.000118155	-0.00123666	0.000835483	2.22736E-06
1.A.4. Other Sectors	CH4	1041.24025	428.554682	5	25	25.50	0.0	-0.000772946	0.001363136	-0.019323647	0.009638828	0.00046631
1.A.5. Other	CH4	330.338228	97.5658895	5	25	25.50	0.0	-0.000367351	0.000310335	-0.009183772	0.002194401	8.91571E-05
1.B.1. Solid Fuels	CH4	24867.6834	12364.38	10	25	26.93	2.7	-0.011678579	0.039328314	-0.291964463	0.556186352	0.394586505
1.B.2. Oil and Natural Gas	CH4	12570.348	4022.34735	10	25	26.93	0.3	-0.012988732	0.012794183	-0.324718297	0.180937071	0.138180196
2.B. Chemical Industry .	CH4	40.53	37.5018	10	25	26.93	0.0	3.61373E-05	0.000119285	0.000903433	0.001686942	3.66196E-06
4.A. Enteric Fermentation.	CH4	14054.9863	7346.85	15	30	33.54	1.5	-0.005462727	0.023368679	-0.163881819	0.495724537	0.272600067
4.B. Manure Management.	CH4	1903.28061	1199.63088	15	30	33.54	0.0	-8.88245E-05	0.003815756	-0.002664735	0.080944413	0.006559099
4.C. Rice Cultivation.	CH4	522.9	338.94	10	30	31.62	0.0	5.3609E-06	0.001078092	0.000160827	0.015246523	0.000232482
4.F. Field Burning of Agricultural Residues.	CH4	64.3314	3[illegible]	[illegible]	[illegible]	[illegible]6	0.0	-1.24107E-05	0.000119565	-0.000372321	0.003381819	1.15753E-05
6.A. Solid Waste Disposal on Land.	CH4	1959.72	373[illegible]	[illegible]	[illegible]	[illegible]4	0.4	0.00787088	0.011891742	0.236126385	0.252261939	0.119391756
6.B. Wastewater Handling.	CH4	787.08	74[illegible]	[illegible]	[illegible]	[illegible]4	0.0	0.000761896	0.002376612	0.022856865	0.050415547	0.003064164
1.A.1. Energy Industries	CO2	102607.31	9596[illegible]	[illegible]	[illegible]	[illegible]7	11.2	0.094441853	0.305249301	0.472209267	2.158438506	4.881838378
1.A.2. Manufacturing Industries and Constructio	CO2	33991.06	30164[illegible]	[illegible]	5	7.07	1.1	0.02618491	0.095945987	0.130924551	0.678440577	0.477422855
1.A.3. Transport	CO2	23987.07	[illegible]406.48	5	5	7.07	0.1	-0.022453294	0.026739124	-0.11226647	0.189074157	0.048352797
1.A.4. Other Sectors	CO2	[illegible]332.52	11784.04	5	5	7.07	0.2	-0.053800014	0.037482383	-0.269000072	0.265040472	0.14260749
1.A.5. Other	CO2	8370.16	4124.19	5	5	7.07	0.0	-0.004052209	0.013118122	-0.020261045	0.092759127	0.009014766
1.B.2. Oil and Natural Gas	CO2	3408.21	5171.49583	10	15	18.03	0.2	0.009456387	0.016449366	0.141845811	0.232629165	0.074236563
2.A. Mineral Products.	CO2	5744.63	2507.20146	10	15	18.03	0.0	-0.003809586	0.007974844	-0.057143788	0.112781331	0.015985041
2.B. Chemical Industry .	CO2	1355.56	171.93456	10	15	18.03	0.0	-0.002233954	0.000546885	-0.033509311	0.007734125	0.001182691
2.C. Metal Production.	CO2	12932.6799	10507.4715	10	15	18.03	0.9	0.006887639	0.033421905	0.103314586	0.47265712	0.234078657
5.A. Changes in Forest and Other Woody Bioma	CO2	97.19		50	80	94.34	0.0	-0.000199385	0	-0.015950798	0	0.000254428
5.A. Changes in Forest and Other Woody Bioma	CO2	-7810.79	-7721.7341	50	80	94.34	12.9	-0.008539362	0.024561101	-0.683148991	1.736732102	3.482930938
5.B. Forest and Grassland Conversion.	CO2	6.26	280.43888	25	75	79.06	0.0	0.00087917	0.000892013	0.065937785	0.031537424	0.005342401
1.A.1. Energy Industries	N2O	388.516902	328.741673	5	50	50.25	0.0	0.000248607	0.001045653	0.012430334	0.007393886	0.000209183
1.A.2. Manufacturing Industries and Constructio	N2O	112.709781	114.844426	5	50	50.25	0.0	0.000134069	0.000365294	0.006703468	0.002583021	5.16085E-05
1.A.3. Transport	N2O	57.3319301	21.6195922	5	50	50.25	0.0	-4.88495E-05	6.87671E-05	-0.002442474	0.000486257	6.20212E-06
1.A.4. Other Sectors	N2O	194.497577	46.1816455	5	50	50.25	0.0	-0.000252117	0.000146893	-0.01260587	0.001038693	0.000159987
1.A.5. Other	N2O	27.4386549	13.5195061	5	50	50.25	0.0	-1.3288E-05	4.30025E-05	-0.000664398	0.000304074	5.33886E-07
4.B. Manure Management.	N2O	375.1	198.4	15	30	33.54	0.0	-0.000138451	0.000631066	-0.004153541	0.013386927	0.000196462
4.D. Agricultural Soils(2).	N2O	25217.694	9798.17	20	30	36.06	3.0	-0.020551916	0.031165777	-0.616557485	0.881501284	1.157187646
4.F. Field Burning of Agricultural Residues.	N2O	24.304	21.297	20	30	36.06	0.0	1.78812E-05	6.7741E-05	0.000536437	0.001916004	3.95884E-06
6.B. Wastewater Handling.	N2O	452.6	384.4	15	30	33.54	0.0	0.000294175	0.00122269	0.008825264	0.025937172	0.000750622
Keep Blank!	...									0		
Total		314388.7626	202771.1719			Σ H	34.6				Σ M	11.4670044
					Percentage uncertainty in total inventory:		5.880740472				Trend uncertainty:	3.386296561

Comparison of Tier 1 and Tier 2 Uncertainty Methodologies

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Feature	Tier 1: Error Propagation (Approach 1)	Tier 2: Monte Carlo Simulation (Approach 2)
Complexity	Simpler, spreadsheet-based.	More complex, requires specialized software.
Assumptions	Assumes small standard deviations (<30%), symmetric (normal) distributions, and uncorrelated variables.	Relaxes assumptions; handles large standard deviations, skewed distributions, and correlated variables.
Mathematical Basis	Based on first-order Taylor series expansion (Rule A and Rule B).	Numerical, non-deterministic simulation using random sampling from PDFs.
Input Distributions	Typically assumes normal or uniform distributions for simplicity.	Can incorporate any physically possible PDF shape (Normal, Lognormal, Triangular, Gamma, etc.).
Correlation Handling	Assumes independence between variables (e.g., activity data and emission factors) for calculation, though trend analysis considers some correlation.	Explicitly handles varying degrees of correlation between variables and over time.
Output	Provides symmetrical uncertainty ranges (e.g., ±X%).	Can produce asymmetrical uncertainty ranges, reflecting the true distribution of results.
Applicability	Suitable for initial assessments and categories with relatively low uncertainty.	Preferred when uncertainty is large (>30%), distributions are non-normal, or models are complex.
Insights Provided	Good for identifying how individual source categories contribute to overall uncertainty.	Provides deeper insight into the full probability distribution of the inventory and trends.
Good Practice	Recommended for all countries undertaking uncertainty analysis.	Recommended for inventory agencies with sufficient resources and expertise, often in conjunction with Tier 1.

Leveraging Uncertainty Analysis to Enhance Credibility and Inform Decision-Making

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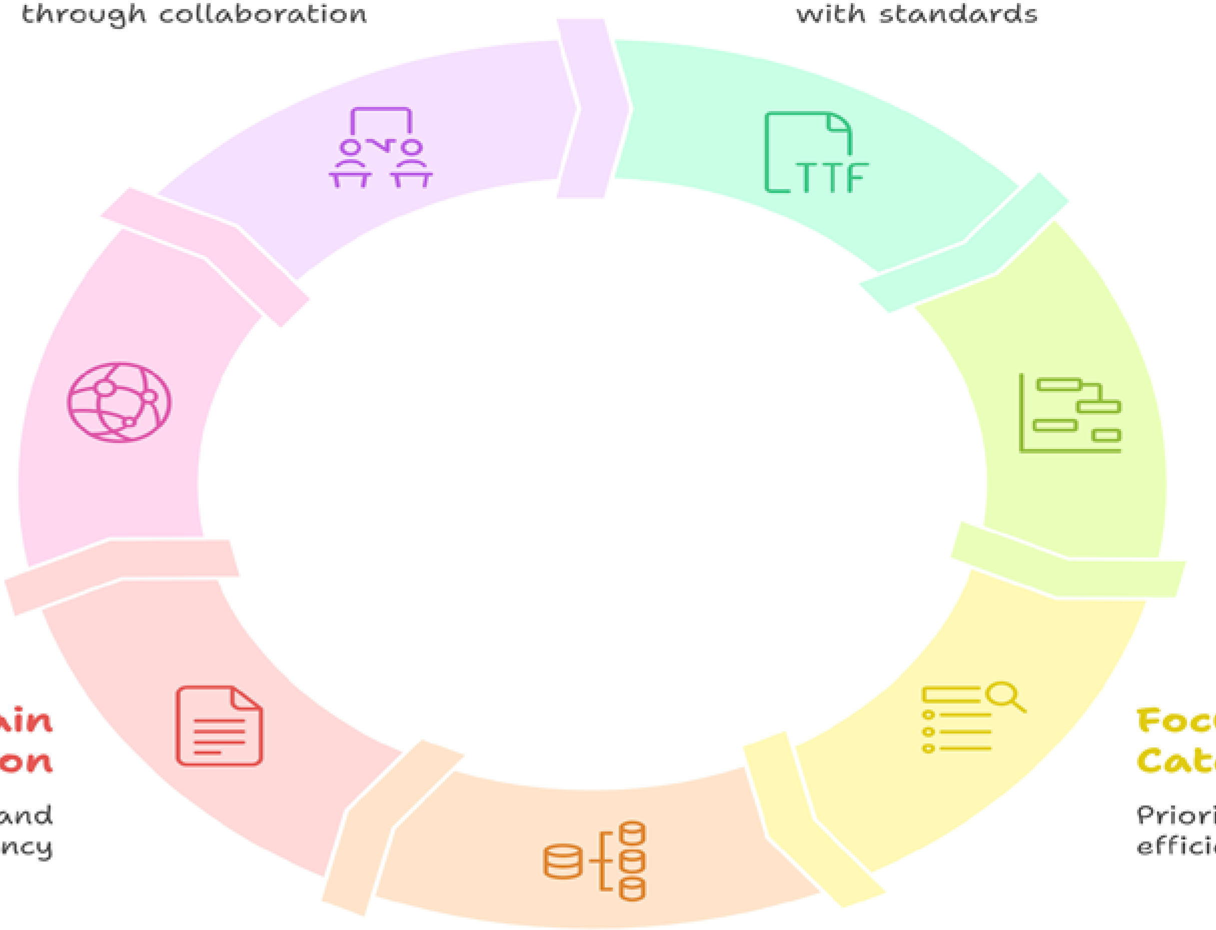
- **Resource Allocation for Improvement:** By identifying categories and key variables that contribute most substantially to the overall uncertainty of the inventory (often through sensitivity analysis), resources can be efficiently allocated to areas where improvements in data collection, measurement methods, or modeling will yield the greatest reduction in uncertainty. This allows nations to focus efforts on "hot spots" for improvement.
- **Methodological Choice:** The results of uncertainty analysis can guide decisions on whether to adopt higher-tier methodologies (e.g., moving from Tier 1 to Tier 2 IPCC methods) for specific categories. If a Tier 1 analysis reveals a disproportionately high uncertainty for a key category, it may justify the investment in more data-intensive and complex Tier 2 methods to reduce that uncertainty.
- **Tracking Progress and Policy Effectiveness:** Understanding the uncertainty associated with emission trends is crucial for assessing the effectiveness of mitigation policies and tracking progress towards Nationally Determined Contributions (NDCs). If the uncertainty in a trend is large, it becomes more challenging to definitively attribute observed changes to specific policies or actions. Conversely, a reduced uncertainty in trends provides stronger evidence of policy impact.
- **Communication and Transparency:** Presenting uncertainty information alongside emission estimates allows for a more nuanced and accurate communication of results. Expressing uncertainty using a 95% confidence interval, for instance, provides a clear range within which the true value is likely to lie, fostering a more informed dialogue among policymakers and the public.
- **Risk Management:** For policymakers, understanding uncertainties helps in evaluating the risks associated with different climate actions and targets. It allows for the development of more robust and adaptive strategies that can account for the inherent variability and incomplete knowledge in emission estimates.

In essence, uncertainty analysis transforms the GHG inventory from a static numerical report into a dynamic tool for continuous improvement and strategic planning. It provides a deeper understanding of data quality, enabling targeted interventions that enhance the reliability of emission estimates and strengthen the foundation for ambitious climate action.

Key Takeaways



Meet ETF Requirements

Ensure compliance with standards

Phased Implementation

Implement gradually based on resources

Focus on Key Categories

Prioritize efforts for efficiency

Integrate with Data Management

Enhance effectiveness through data

Maintain Documentation

Ensure continuity and transparency

Utilize CBIT-GSP Network

Access support and resources

Engage in Peer Learning

Accelerate progress through collaboration

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Thank you for your attention !

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Please reach out to us for any question, comments or suggestions!

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Funded by: gef

Implemented by: UN environment programme

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