WUDBOX | CARBON INTELLIGENCE

Carbon Data Quality framework for removing Uncertainty and Errors

A practical framework for improving the reliability, traceability and decision-usefulness of enterprise greenhouse gas data.



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Executive Perspective

Enterprise carbon inventories increasingly inform transition planning, customer disclosures, procurement, regulatory responses and management performance. Yet many inventories combine data of very different quality: calibrated meter readings, invoices, production records, supplier estimates, industry averages and proxy emission factors. Presenting the total as a single precise number can hide key differences and mask data points.

KEY INSIGHT A carbon figure is not decision-ready simply because it has been calculated. Leaders need to know where it came from, how representative it is, what could change it, and who owns the controls.



Prepared for sustainability leaders, CFOs, finance controllers, EHS heads, operations leaders and enterprise carbon-accounting teams.

The problem for leadership teams

The question is not only "What are our emissions?" It is also: "Which parts of this inventory are reliable enough for the decision we are making? Where are the material weaknesses? What should we improve first?"

Four controls that make carbon data decision-useful

Control	What it establishes	Evidence leadership should expect
Data quality	Whether inputs are complete, valid, representative and fit for purpose	Source records, quality scores, exception log
Uncertainty	How limitations or variability affect estimates	Documented drivers, ranges or qualitative assessment
Traceability	How reported values connect to source data and methods	Calculation lineage, factor versions, approvals

Control	What it establishes	Evidence leadership should expect
Governance	Who owns data, methods, review and correction	Named owners, review cadence, sign-off and change log

What this framework is — and is not

- It is a practical management framework to prioritise improvements and strengthen controls across a multi-site enterprise.
- It is not a replacement for the GHG Protocol, ISO 14064-1, applicable reporting rules, sector-specific methods or assurance requirements.
- It does not promise that every source can be measured precisely. It requires material limitations to be visible, managed and disclosed appropriately.

DECISION RULE Prioritise data improvements where emissions are material, uncertainty or weakness is significant, and the result could change a business decision or reported conclusion.

Defining quality before scoring it

A single “data quality” score is easy to communicate but can conceal important weaknesses. Assess quality across several dimensions, retain the underlying evidence and avoid allowing a strong score in one area to compensate silently for a critical failure in another.

Dimension	Practical test	Warning signal
Completeness	Are all relevant sources, sites, periods and records included?	Missing sites, unexplained gaps or exclusions
Accuracy / validity	Are values plausible, units correct and calculations applied correctly?	Outliers, unit errors, manual overrides without evidence
Representativeness	Does the data match the activity, technology, geography and time period?	Generic proxy used for a materially different process
Consistency	Are methods and boundaries applied consistently across sites and years?	Unexplained method changes or incomparable periods
Traceability	Can a reviewer follow the result back to its source and calculation?	No source file, factor reference, version or approval
Timeliness	Is data aligned to the reporting period and available when needed?	Stale data or estimates carried forward without review

Dimension	Practical test	Warning signal
Control strength	Are review, access, correction and approval controls operating?	One person creates, changes and approves data without checks

Using Quality Scores Responsibly

A workable internal scale is 1–5: 1 = weak/unsubstantiated; 2 = significant gaps; 3 = usable with limitations; 4 = strong and controlled; 5 = high-quality, representative and traceable. Define the scoring rubric before use, require evidence for each score, and document exceptions. These are proposed internal management ratings, not a prescribed GHG Protocol or ISO scoring system.

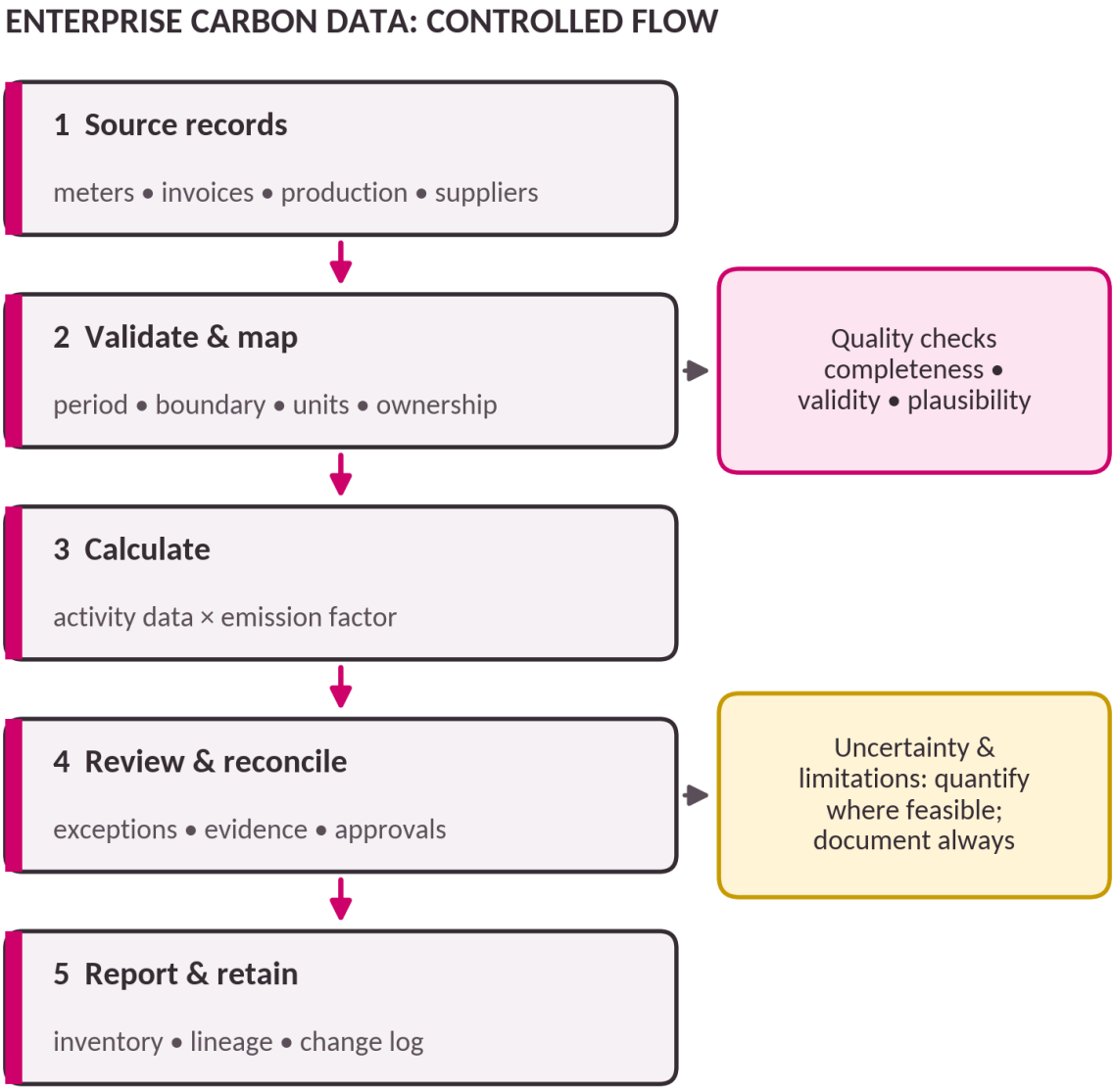
Distinguishing Data Quality from Uncertainty

Quality describes the fitness and strength of the data and process. Uncertainty describes the range of plausible values or the limits of confidence in an estimate. A dataset can be well documented but still have material uncertainty; conversely, a point estimate may look precise while being based on weak proxy data.

> **WHAT TO AVOID** Do not average all dimensions into one enterprise score and report it without showing the underlying profile. A low score for completeness or traceability may be a hard control issue even if other dimensions score well.

Building a Reliable Enterprise Carbon Inventory

Apply the same controlled workflow across sites and business units, while allowing source-specific checks for electricity, fuels, refrigerants, process emissions, purchased goods and logistics.



Feedback loop: correct errors • improve source systems • update methods under change control

Control gates

Gate	Minimum control	Exception response
1. Capture	Source, owner, period, units and boundary are recorded	Request missing evidence; flag estimates
2. Validate	Completeness, range, unit and duplicate checks	Hold or correct invalid records

Gate	Minimum control	Exception response
3. Calculate	Approved method and emission-factor version used	Document substitutions and method rationale
4. Reconcile	Compare with energy, production, procurement or finance records where relevant	Investigate material variances
5. Approve	Reviewer signs off exceptions and inventory version	Escalate unresolved material issues
6. Retain	Archive source, calculation, changes and approvals	Maintain retrievable audit trail

A failed control should create a recorded exception, not an invisible spreadsheet adjustment. The exception record should identify the affected value, potential impact, owner, due date, resolution and approver.

IMPLEMENTATION TIP Use common data definitions and control requirements across sites. Do not force every site to use the same source system if local systems differ; standardise the fields, checks and evidence expected.

Understanding and managing uncertainty

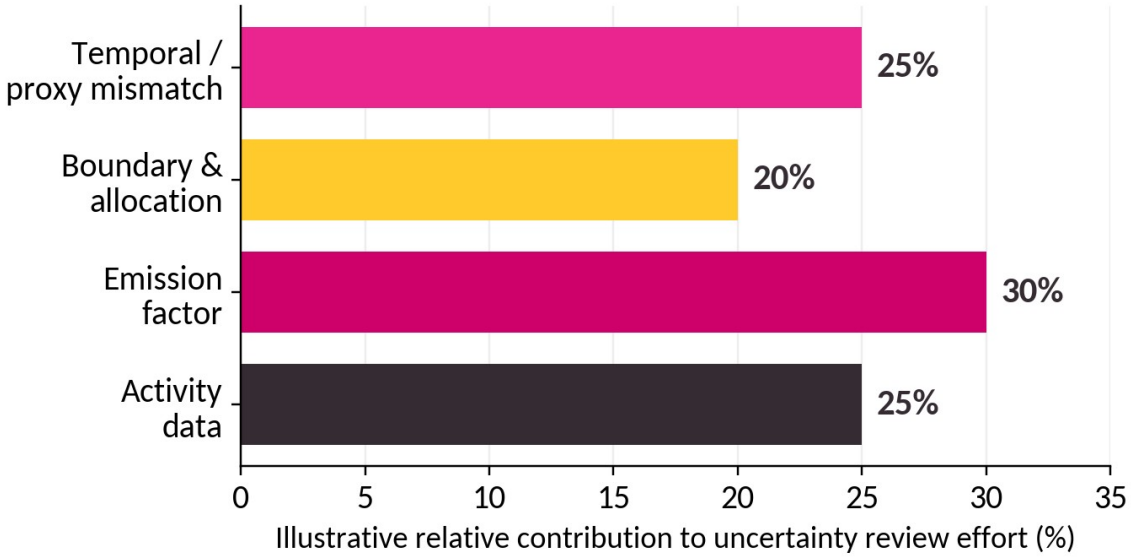
Uncertainty is not a reason to avoid reporting. It is a reason to understand the estimate's limitations and decide whether better evidence is needed. The appropriate method depends on the source, available data, significance and purpose of the inventory.

Where Uncertainty Enters the Inventory

Driver	Example	Improvement lever
Activity data	Estimated fuel consumption where meter records are missing	Metering, invoice completeness, reconciliation
Emission factor	Generic factor with limited geographic or technology fit	Use a more representative, documented factor where available
Time mismatch	Prior-year data used for the current reporting period	Obtain current data or justify the proxy and adjustment

Driver	Example	Improvement lever
Allocation	Shared energy or materials allocated across products/sites	Improve allocation basis and retain calculations
Boundary / classification	Sources omitted, double-counted or assigned inconsistently	Clarify boundaries, category mapping and consolidation rules
Supplier data	Spend-based or industry-average estimate substitutes for supplier-specific data	Segment suppliers and target primary data for material categories

WHERE TO INVESTIGATE UNCERTAINTY FIRST



Illustrative prioritisation only; these values are not statistical uncertainty estimates.

Choosing and Documenting an Uncertainty Method

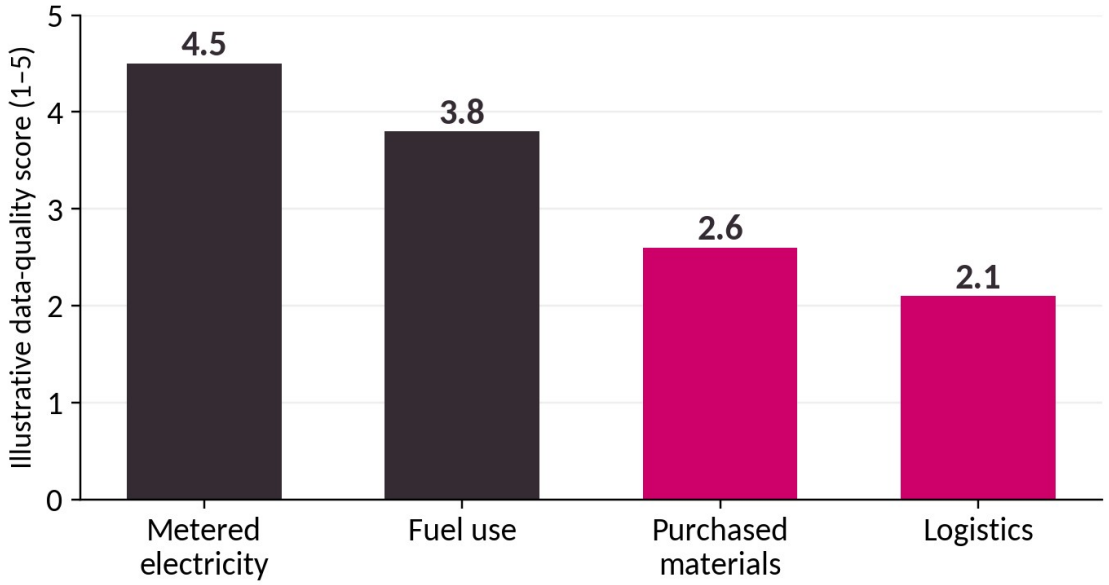
- Where reliable input ranges and a suitable method exist, estimate the effect of uncertainty quantitatively and state the method, assumptions and limitations.
- Where quantification is not defensible, use a qualitative assessment: likely direction, materiality, evidence gaps and actions needed.
- Avoid adding percentage uncertainties mechanically. Correlated inputs, shared emission factors and allocation methods can make simple aggregation misleading.
- Do not present a data-quality score as a statistical confidence interval.

PRIORITISATION Focus first on sources that are both material and weakly evidenced, especially where improved data could alter reported performance, a customer response, a compliance conclusion or an investment decision.

Prioritising Data Gaps and Improvement Opportunities

Executives and leaders need a view that connects quality gaps to business materiality. A useful dashboard shows where emissions sit, how strong the supporting data is, what uncertainty remains and what action is being taken.

EXAMPLE: PRIORITISE DATA IMPROVEMENT BY QUALITY GAP

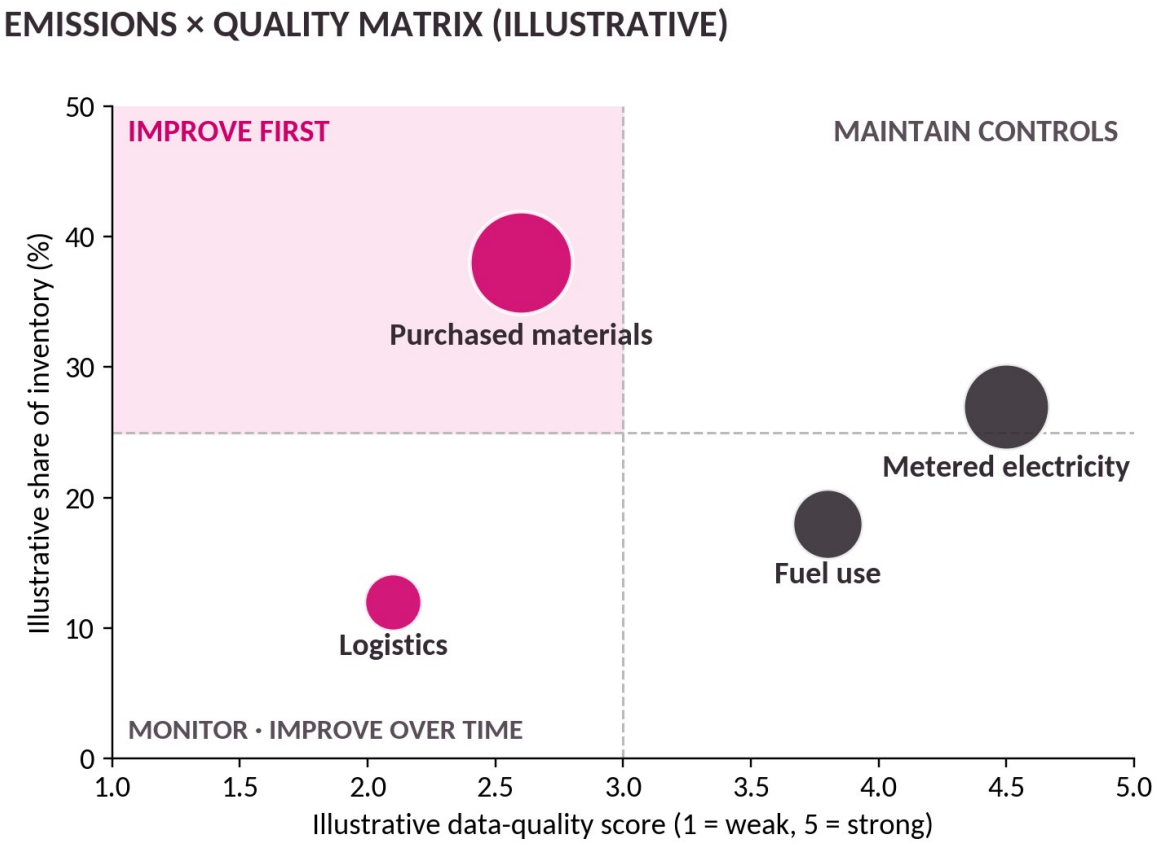


Illustrative only — scores are not measured company data.
Higher score = stronger data quality.

Management Views That Support Decisions

Visual	What it answers	Suggested fields
Emissions × quality matrix	Which material sources need attention first?	tCO_2e; quality score; uncertainty flag; owner
Site heat map	Where are control weaknesses concentrated?	Site; scope/category; missing data; overdue exceptions
Trend / variance bridge	Why did emissions change year on year?	Operational change; factor update; boundary; data correction
Data lineage view	Can we trace reported values to evidence?	Source ID; calculation version; factor; approver

Visual	What it answers	Suggested fields
Action tracker	Are weaknesses being closed?	Issue; risk; owner; due date; status; residual risk

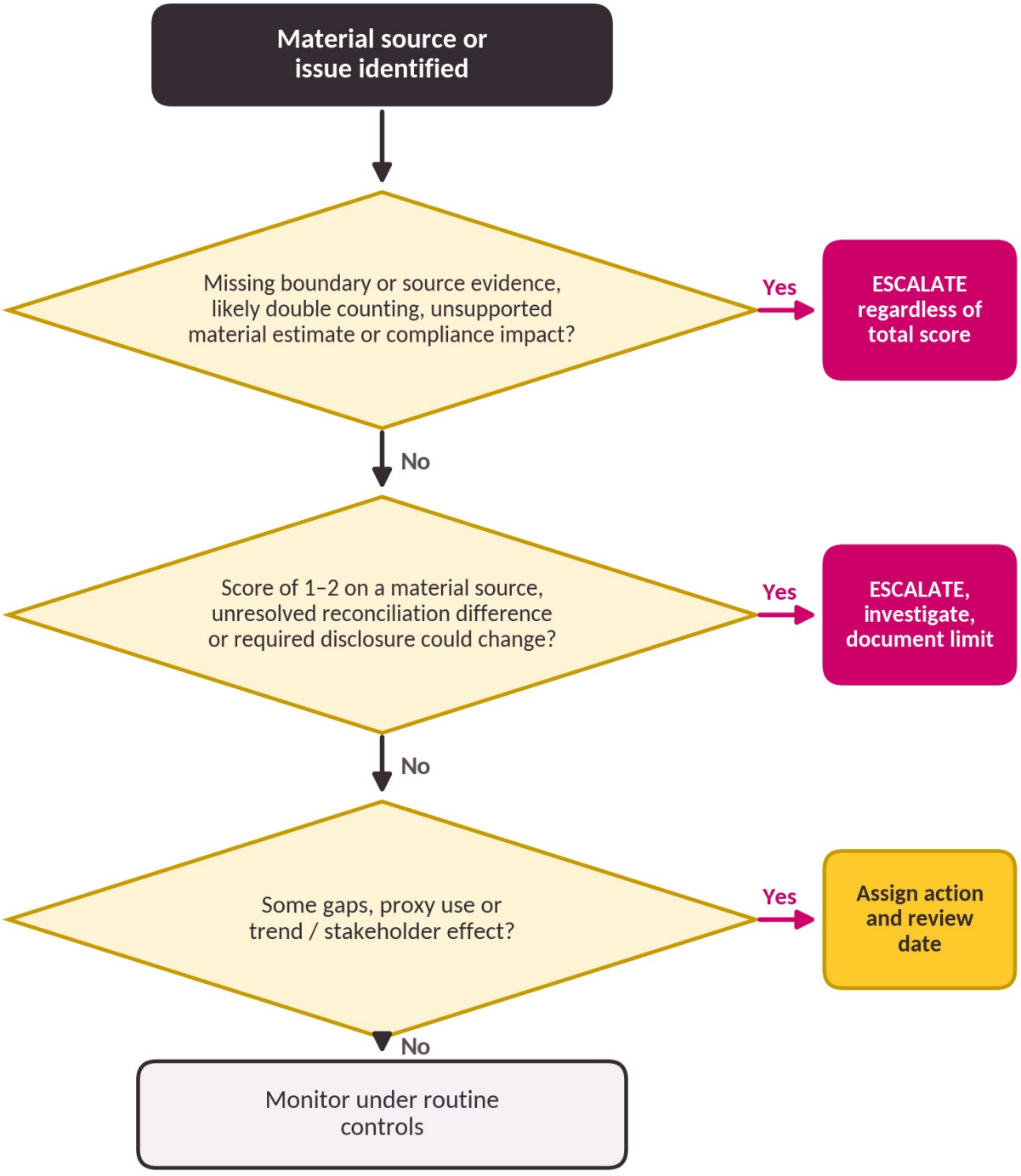


Illustrative only — not measured company data. Bubble size reflects share of inventory. A smaller source may still need immediate action if it creates a compliance or classification error.

Illustrative priority rule

A practical triage rule is to prioritise sources with high emissions contribution, low quality scores, large unresolved uncertainty, or a high consequence if wrong. Do not rely on a quality score alone. A smaller source may still need immediate correction if it creates a compliance or classification error.

ILLUSTRATIVE TRIAGE FLOW FOR DATA GAPS

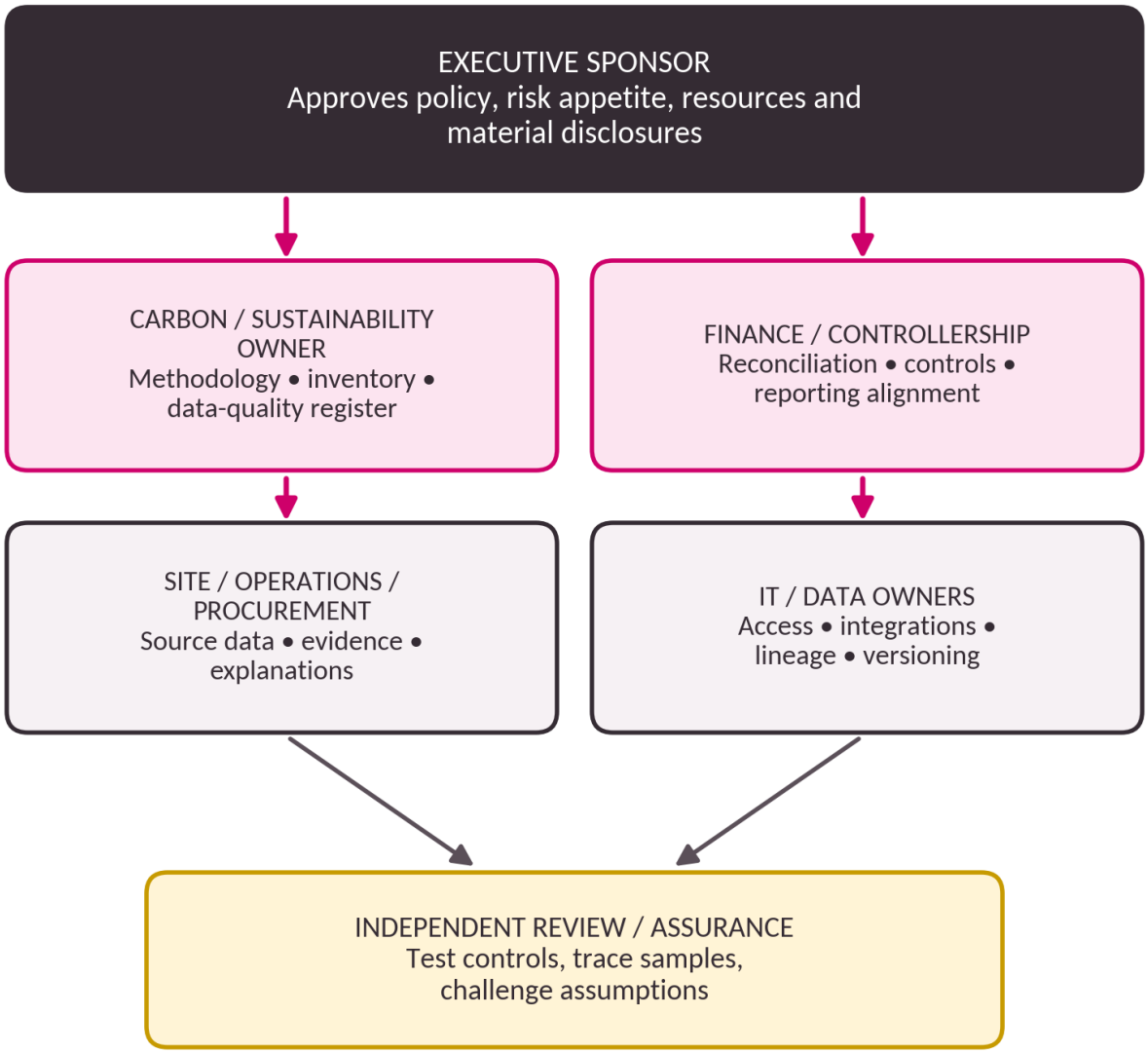


VISUAL DESIGN PRINCIPLE Use consistent definitions and clear legends. Label illustrative data as illustrative. Keep measured emissions, estimated values, quality ratings and uncertainty ranges visually distinct.

Establishing Accountability and Internal Controls

Carbon data quality is a cross-functional control issue. Sustainability teams often coordinate the inventory, but source data usually sits with operations, energy, procurement, finance, IT and suppliers. A robust model names one accountable owner for each control and separates data preparation from review where practical.

GOVERNANCE BLUEPRINT:
ACCOUNTABILITY BY CONTROL LAYER



Roles and Accountabilities

Role	Accountability
Executive sponsor	Approves policy, resources, materiality thresholds and significant disclosures
Carbon / sustainability owner	Owns inventory methodology, data-quality framework, factor register and consolidated reporting
Site / functional data owner	Provides complete source data, evidence and explanations for exceptions
Finance / controllership	Reconciles relevant records, tests controls and aligns reporting periods
IT / data owner	Maintains access, system interfaces, data lineage, version control and retention
Independent reviewer / assurance provider	Challenges methodology and tests selected evidence and controls; independence requirements apply

Review and Control Cadence

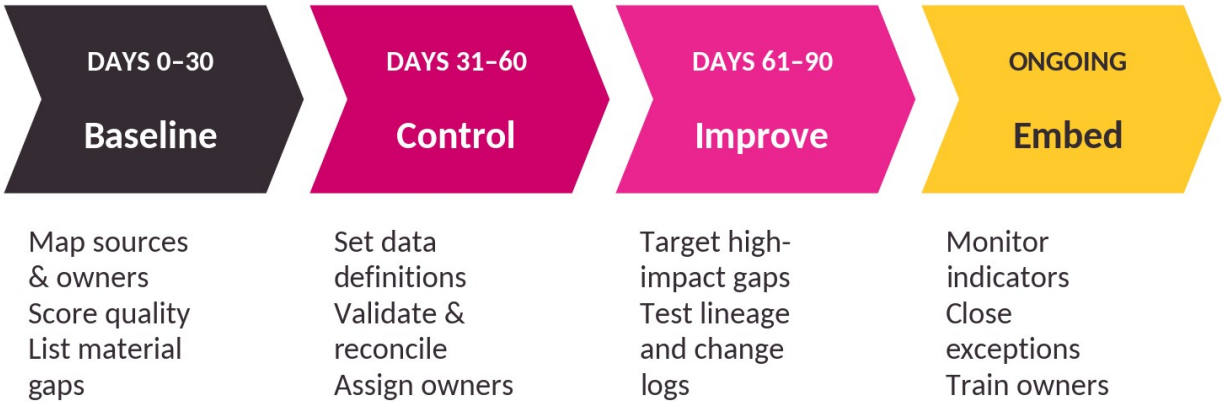
- **Monthly or quarterly:** source completeness, exception review and reconciliation according to source risk and reporting cycle.
- **Each reporting period:** method and factor review, inventory approval, material-variance explanation and archive.
- **At least annually and when triggered:** reassess boundaries, material sources, quality scores, uncertainty drivers and improvement priorities.
- **On change:** document new sites, acquisitions, process changes, new data systems, factor updates and methodology changes.

The governance model should be proportionate to the organisation's size, complexity and reporting obligations. A central policy with local execution and clear escalation is often more workable than either fully centralised data collection or uncontrolled site-by-site methods.

A practical improvement roadmap

Do not attempt to perfect every data point in the first cycle. Establish a baseline of quality, prioritise material weaknesses and improve the source systems and controls that will have the greatest effect.

90-DAY IMPROVEMENT ROADMAP



Phase	Actions	Outputs / evidence
Days 0–30 **Baseline**	Map sources and owners; identify methods and factors; score quality; list material gaps	Source register; quality profile; initial risk-ranked issue log
Days 31–60 **Control**	Set data definitions; implement validation and reconciliation; assign exception owners; define approval rules	Control checklist; reconciliation records; responsibility matrix
Days 61–90 **Improve**	Target high-impact data gaps; improve meters, supplier requests or allocation methods; test lineage and change logs	Improvement plan; updated evidence; sample traceability test
Ongoing **Embed**	Monitor indicators; review methods; close exceptions; train owners; refresh materiality assessment	Management dashboard; periodic review minutes; archived inventory versions

Measures of Progress

- Percentage of material emissions supported by source-specific activity data.
- Percentage of inventory records with complete source, period, unit, method and factor references.
- Number and age of unresolved material data exceptions.

- Percentage of material sources reconciled to independent records where feasible.
- Percentage of data owners completing review and approval on time.
- Number of material changes to methods, boundaries or factors with documented rationale and approval.

Set targets only after establishing a baseline. KPIs should reward stronger evidence and timely resolution, not encourage teams to hide exceptions or overstate the precision of estimates.

SUCCESS CRITERION The framework is working when leadership can identify the weakest material sources, understand their potential impact, see who is accountable, and track whether the gap is being reduced.

APPENDIX A

Carbon Data Quality Assessment Tool

Use this worksheet for each material emissions source, site or category. Score each dimension from 1 (weak) to 5 (strong), record evidence, and assign actions. The scoring system below is an internal assessment aid, not a formal assurance opinion.

Assessment field	Record / prompt
Source / category	e.g., purchased electricity, natural gas, purchased steel, freight
Site / business unit	Where the activity occurs or is managed
Reporting period	Start and end date; note any time mismatch
Emissions estimate	tCO_2e and calculation version
Activity data source	Meter, invoice, ERP extract, supplier response, estimate
Emission factor	Source, geography, year, technology and version
Method / boundary	Calculation method, included activities and exclusions
Evidence location / owner	Link or reference; named accountable owner

Data Quality Assessment

Dimension	Score (1–5)	Evidence / gap
Completeness		
Accuracy / validity		
Representativeness		
Consistency		
Traceability		
Timeliness		
Control strength		

Uncertainty, Corrective Action and Residual Risk

Question	Assessment
Main uncertainty drivers	
Could the issue change a material decision or disclosure?	Yes / No / Unclear — explain
Action, owner and due date	
Reviewer / approval date	
Residual limitation to disclose	

Suggested triage: escalate any score of 1 or 2 on a material source; any missing boundary or source evidence; unresolved material reconciliation differences; or any issue that could change a required disclosure. Define thresholds to fit the organisation and applicable requirements.

From carbon estimates to controlled intelligence

A mature carbon data system does not eliminate every estimate. It makes the difference between measured data, calculated values, proxies and unresolved gaps visible — and manages each according to its materiality and use.

Questions for Each Reporting Cycle

- Which material emissions sources rely on proxy or secondary data, and why?
- Where are the largest data-quality gaps, and who owns their resolution?
- What changed in the inventory because of operations versus methodology, factors, boundaries or corrections?
- Can we trace a sample of reported values back to source evidence and approved calculations?
- Which uncertainty could materially change a business decision or external claim?
- Are unresolved exceptions disclosed, escalated and carried forward with a clear improvement plan?

Reference standards and guidance

Use the requirements applicable to the organisation, reporting programme, sector and intended disclosure. The framework in this document is an implementation aid, not a substitute for the full standards.

- **GHG Protocol Corporate Accounting and Reporting Standard —** https://ghgprotocol.org/standards
- **U.S. EPA — Inventory Management Plan Guidance —** https://www.epa.gov/climateleadership/inventory-management-plan-guidance
- **ISO 14064-1:2018 — Organizational-level GHG quantification and reporting —** https://www.iso.org/standard/66453.html
- **India GHG Program — Corporate Standard —** https://indiaghgp.org/corporate-standard
- **GHG Protocol — Standards and Guidance, including Scope 3 Calculation Guidance —** https://ghgprotocol.org/standards-guidance

Important note

This document provides general implementation guidance. It does not constitute legal, assurance or certification advice. Confirm applicable reporting obligations, sector methods, emission-factor sources and assurance criteria before use. All charts labelled illustrative are conceptual examples and must not be represented as measured enterprise results.

> **WUDBOX INSIGHT** Reliable carbon data is built through disciplined source data, transparent methods, clear accountability and continual improvement — not by adding more decimal places to an estimate.

Technical Methods and Application

This supplement strengthens the framework with source-specific controls, a practical uncertainty method, a prioritisation model and a worked example. Use it alongside the main report; it does not replace applicable reporting standards or assurance criteria.

Applying Data Quality Controls Across Emissions Sources

Emissions source	Typical data inputs	Common quality risks	Priority controls
Scope 1: fuel combustion	Fuel invoices, tank levels, meters, operating hours, fuel properties	Estimated consumption, missing periods, unit conversion errors	Reconcile purchases and stock movement; validate units; document fuel properties and factor source
Scope 1: process / fugitive	Production data, process chemistry, refrigerant purchases and service logs	Incomplete process coverage, leakage estimates, missing service records	Use process-specific methods; retain service records; check completeness against equipment and production registers
Scope 2: purchased energy	Utility bills, interval meters, contracts, supplier factors	Estimated bills, incorrect period mapping, factor mismatch	Reconcile bills and meter data; record location- or market-based method as applicable; retain factor and contract evidence
Scope 3: purchased goods	Spend, quantities, bills of materials, supplier-specific footprints	Spend-based proxies, weak supplier coverage, inconsistent product boundaries	Prioritise material categories and suppliers; document data hierarchy and boundaries; improve primary data selectively
Scope 3: logistics / travel	Distance, weight, mode, fuel, shipment records, travel reports	Missing distance or load data, generic mode assumptions, double counting	Use shipment-level activity where feasible; validate mode and units; define rules for outsourced transport and duplicate records

Do not assume every category can be measured with the same precision. Apply source-specific controls and prioritise primary data where materiality, decision impact and feasibility justify the effort.

A Practical Method for Quantifying Uncertainty

Step 1 — Define the estimate. Confirm organisational and operational boundaries, reporting period, activity data, emission factor, calculation method and intended use.

Step 2 — Identify uncertainty drivers. Assess activity-data variability, factor uncertainty, temporal or geographic mismatch, allocation, completeness and model assumptions.

Step 3 — Choose a defensible method. Use qualitative ratings when evidence is insufficient. Where reliable input ranges or distributions exist, use sensitivity analysis or quantitative uncertainty propagation. Monte Carlo simulation can be appropriate for complex models with multiple uncertain inputs, but only when distributions and dependencies can be justified.

Step 4 — Document the result. Record inputs, sources, assumptions, method, correlation/dependency considerations, output range or qualitative judgement, limitations and reviewer.

Step 5 — Decide whether it matters. Compare the uncertainty or data weakness with inventory materiality, trend interpretation, disclosure requirements and the decision being supported.

Method	Use when	Caution
Qualitative assessment	Data are limited or the estimate cannot support defensible numeric ranges	State the basis and direction of concern; do not imply a numeric confidence interval
Sensitivity analysis	You can vary key inputs to see which assumptions drive the result	Sensitivity is not, by itself, a probability distribution or confidence interval
Analytical propagation	Input uncertainties and a suitable calculation relationship are known	Check assumptions, dependencies and whether the method fits the calculation
Monte Carlo simulation	Several uncertain inputs can be described with defensible distributions and dependencies	Do not invent distributions or present simulation outputs as more certain than the inputs

Never add uncertainty percentages mechanically across sources. Shared emission factors, correlated activity data and common assumptions can create dependencies. Follow the applicable accounting method and document simplifications.

Assessing Materiality and Setting Improvement Priorities

Use this matrix to decide where to improve data first. Score each dimension using an agreed internal rubric, then apply escalation rules for critical control failures.

Dimension	Low	Medium	High
Emissions materiality	Small share of inventory	Meaningful share or important category	Large share, key category or material disclosure
Data quality weakness	Strong, traceable source data	Some gaps or proxy use	Missing, weakly supported or unrepresentative data
Decision / disclosure consequence	Unlikely to change action or reported conclusion	Could affect a trend or stakeholder response	Could alter compliance, a material claim or an investment decision
Recommended response	Monitor under routine controls	Assign improvement action and review date	Escalate, investigate promptly, document limitation and approve treatment

A simple internal triage score can be used (for example, 1–3 for materiality, weakness and consequence), but do not let a summed score override a critical issue. Missing boundary data, likely double counting, unsupported material estimates or a potential compliance impact should trigger escalation regardless of the total.

Case Example: Electricity Data at a Manufacturing Site

(Hypothetical example only)

Assume a site reports 1,000 MWh of purchased electricity and applies an illustrative emission factor of 0.70 tCO_2e/MWh. The calculated estimate is 700 tCO_2e. These numbers are invented to demonstrate the method and are not a benchmark or a real factor.

Check	Finding	Framework response
Source and completeness	One month is based on an estimated utility bill	Flag period; request final bill or interval-meter record
Reconciliation	Annual total differs from the energy-management system by 4%	Investigate timing, meter coverage and unit conversions before adjustment
Emission factor	Factor source and version are recorded, but geographic applicability needs confirmation	Verify the appropriate factor and document selection

Check	Finding	Framework response
Quality score	Illustrative scores: completeness 3/5; traceability 4/5; representativeness 3/5	Retain dimension-level scores; do not collapse into a single unqualified rating
Uncertainty method	No defensible numeric uncertainty range is yet available	Use qualitative assessment until input ranges and method are supported
Action and review	Energy manager to reconcile source records; carbon owner to confirm factor; controller to review	Record owner, due date, evidence and residual limitation

Illustrative calculation: 1,000 MWh × 0.70 tCO_2e/MWh = 700 tCO_2e. If later evidence changes activity data or the factor, recalculate using the approved method, record the reason and preserve the prior inventory version. Do not invent an uncertainty percentage simply to complete the worksheet.

Reporting Integrity, Assurance and Change Control

- Maintain an evidence register linking each material reported value to source records, calculation files, factor references, method versions, approvals and reporting period.
- Define change triggers: new site or acquisition, process change, revised emission factor, improved primary data, boundary change, corrected error or methodology update.
- Document whether a change affects current-period emissions, historical comparability or the base year; apply the organisation's applicable recalculation policy and reporting requirements.
- Separate preparation, review and approval where practicable. Independent assurance is distinct from management review and must follow the relevant assurance scope and criteria.
- Record unresolved limitations, estimated values, material exceptions and corrective actions transparently. A high internal quality score is not an assurance opinion.

Additional Fields for the Assessment Tool

Field	Prompt
Emissions contribution	Estimated tCO_2e and percentage of the inventory/category
Data source and evidence	Source system/file, owner, period, unit and retention location
Quality dimensions	Score each dimension 1–5 and cite evidence; define anchors before scoring
Uncertainty approach	Qualitative, sensitivity, analytical or simulation; explain why appropriate

Field	Prompt
Materiality / consequence	Could the issue affect a disclosure, target, customer response, compliance or investment decision?
Action and residual risk	Corrective action, accountable owner, due date, reviewer and remaining limitation

Sustainability Partner for Conscious Companies

Wudbox works with manufacturing & industrial organisations to translate sustainability intent into operationally sound, auditable, and future-ready frameworks.

Our focus is not on isolated reporting or short-term compliance, but on building the systems, governance, and internal capability required to sustain environmental performance over time.

We partner closely with leadership and operational teams to ensure sustainability becomes embedded within decision-making, aligned with business priorities, regulatory expectations, and stakeholder confidence.

Beyond strategy, we serve as a dedicated on-ground execution and implementation partner, working alongside your teams to turn high-level frameworks into tangible, daily operational reality.



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