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ADVANCED TECHNICAL GUIDE TO GREENHOUSE GAS ACCOUNTING

From activity data to a traceable and verifiable greenhouse gas inventory

Inventory boundaries · Calculation methods · Emission factors · Data quality · Uncertainty · Verification

01	**Technical reference** GHG Protocol · ISO 14064-1:2018 · ISO 14064-3:2019 · ISO 14067:2018
02	**Reporting applications** Organisational inventories · Scopes 1/2/3 · IFRS S2 · Relevant CBAM requirements
03	**Fully worked illustration** Hypothetical industrial inventory, evidence register, QA/QC tests and reporting checklist

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01 / METHODOLOGY

Technical framework and inventory deliverables

A greenhouse gas (GHG) inventory is not merely a single emissions figure. A defensible statement specifies **what was measured, why, how, using which evidence and within what boundaries**. Methodological choices must be set before calculating the results.

Assignment objective	Principal accounting reference	Expected controlled output
Organisation-wide inventory	GHG Protocol Corporate Standard; ISO 14064-1	Annual inventory defined by entity, sources, boundaries and reporting period
Purchased electricity	GHG Protocol Scope 2 Guidance	Location-based and market-based results where applicable
Value-chain inventory	GHG Protocol Scope 3 Standard	Assessment of the 15 Scope 3 categories, estimation methods and data limitations
Product carbon footprint	ISO 14067 and suitable life-cycle assessment principles	$kgCO_2e$ per functional or declared unit within defined life-cycle boundaries
Validation/verification	ISO 14064-3 and relevant programme rules	A verifiable GHG statement, not an unsupported self-declaration

02 / PRINCIPLES

Five principles to demonstrate

1. Relevance and completeness

Include material sources, operations, entities and gases; explain exclusions and their justification.

2. Consistency and comparability

Apply a consistent policy between years; disclose changes to factors, base year and structural boundaries.

3. Accuracy and uncertainty

Use supported activity data and suitable factors; document missing data, uncertainty and consistent units.

4. Transparency and traceability

Identify the owner, source, version, aggregation logic, calculation and edit history for every input.

Fifth principle — impartiality

Separate data preparation, internal review, management approval and external verification where practicable. Any verification claim must identify its criteria, scope and output.

Technical distinction

ISO 14064-1:2018 organises direct and indirect emissions into its own reporting categories. These do not correspond word-for-word to the GHG Protocol's Scope 1/2/3 labels. Prepare an explicit crosswalk instead of changing terminology automatically.

03 / BOUNDARIES

Define inventory boundaries before calculation

Specify the reporting year, legal entities and site register. Select the organisational consolidation approach—**operational control, financial control or equity share**—consistent with the applicable framework. Then define activities, emission sources, leased assets, shared services and rules for including or excluding facilities.

Boundary decision	Reviewer question	Effect on reported inventory
Entities and sites	Are the factory, logistics depot and offices included?	Determines included sources and activity populations
Control/equity approach	Who controls operations or owns the relevant equity?	Determines consolidation of entity emissions
Base year	Which historical year is representative and has adequate records?	Enables meaningful performance tracking and recalculation
Shared infrastructure	How is shared steam or power apportioned?	Requires an evidenced and reproducible allocation basis
GHGs and GWP	Which gases and 100-year GWP values were adopted?	Determines consistent conversion to CO_2e

04 / GHG PROTOCOL SCOPES

Emission-source map

Scope 1 — Direct emissions

- Fuel combustion in controlled boilers, furnaces and vehicles.
- Process emissions from calcination, reduction and chemical reactions.
- Fugitive refrigerant and industrial-gas losses, as applicable.

Scope 2 — Acquired energy

- Purchased and consumed electricity.
- Purchased steam, heating and cooling, when relevant.
- Applicable location-based and market-based approaches, factors and contractual instruments.

Scope 3 — Value chain

Other indirect emissions from purchased goods, capital goods, transport, waste, travel, use of sold products, investments and related activities are organised into 15 GHG Protocol categories. Assess applicability, overlaps, exclusions and evidence gaps before quantification.

Base-year comparability

Adopt a documented policy and materiality threshold for recalculation following acquisitions, disposals, significant method changes or material errors. Higher absolute emissions do not automatically imply poorer efficiency when output volumes or boundaries have changed.

05 / QUANTIFICATION

Core equations and unit discipline

Source-by-source calculation maximises traceability. For each source, retain activity measurements, the selected factor, the factor source and version, the included gases and all unit conversions.

E (tCO_2e) = Activity data × Emission factor × GWP ÷ 1,000 (when units require)

If the emission factor already has units of **$kgCO_2e$ per activity unit**, its CO_2-equivalent conversion is embedded and GWP must **not** be applied again. If the factor is in kilograms of an individual gas, apply the specified GWP100. Double application of GWP is a material error.

Source type	Illustrative calculation expression	Result unit
Fuel combustion	Fuel quantity × NCV × gas-specific EF × GWP	tCO_2e
Fuel with composite factor	Litres of fuel × $kgCO_2e$/litre ÷ 1,000	tCO_2e
Grid electricity	kWh × $kgCO_2e$/kWh ÷ 1,000	tCO_2e
Refrigerant leakage	kg of leaked refrigerant × GWP100 ÷ 1,000	tCO_2e
Carbon mass balance	Net oxidised carbon × (44/12)	tCO_2
Freight transport	Tonne-km × $kgCO_2e$/tonne-km ÷ 1,000	tCO_2e

06 / TECHNICAL TESTS

Technical checks for every equation

- **Activity:** reconcile the invoice, meter, inventory movement or laboratory record; test the date and unit.
- **Emission factor:** inspect country, year, fuel and technology, and whether the value reports CO_2 only or CO_2e.
- **Boundaries:** exclude out-of-period activities and repeated sources.
- **Conversion:** distinguish Nm^3/m^3, tonnes/kg, NCV/GCV, CH_4 and N_2O, and keep unit transformations explicit.
- **Change control:** preserve original files; record the reason, owner and approver of a correction.

Biogenic CO_2

Under the GHG Protocol, CO_2 from biomass combustion is reported separately from fossil Scope 1 CO_2 totals as required by the accounting framework; relevant CH_4 and N_2O emissions must still be addressed.

07 / DATA CONTROLS

Source register and emission-factor selection

Many material errors arise before arithmetic: a source is misclassified, activity data are unreliable or a factor is inappropriate. Maintain a source register that enables another qualified reviewer to reproduce the reported result.

Register field	Minimum record	Quality-control test
Source ID / site	Unique ID, operating unit, responsible person	No duplicates or ownerless sources
Activity and period	Quantity, unit, start and end date	Cross-check meters/invoices and missing months
EF and reference	Value, gases, unit, issue, country and year	Technological and temporal suitability
GWP reference	Selected gas values and reporting version	Consistent basis across the inventory
Calculation and evidence	Workbook cell, version and proof link	Reperformance from source to result
Review/approval	Preparer, reviewer, date and review comments	Segregation of duties and closure

08 / RELIABILITY

Hierarchy of activity-data reliability

Priority 1 Traceable primary measurements: calibrated meters, scales, accredited laboratory results and validated supplier-specific data.

Priority 2 Secondary factors that are geographically, temporally and technologically representative, with disclosed limitations.

Priority 3 Proxies and estimation models, supported by sensitivity analysis, a gap record and an improvement plan.

09 / FACTOR SELECTION

Practical emission-factor selection rules

- Check system boundaries: direct combustion, upstream emissions, full life cycle or a multi-gas composite.
- For electricity, use the appropriate grid, reporting year, accounting approach and contractual instruments where relevant.
- Do not silently mix $kgCO_2$/litre with $kgCO_2e$/litre: their included gases differ.
- Review annual changes in factors; an inventory movement may come from a changed factor rather than different consumption.
- Retain a dated source citation or captured record for every material factor and GWP.

Evidence-chain rule

Reported result → formula → activity/factor inputs → source register → original document → responsible data owner. Digital traceability supports readiness for verification; it is not itself an independent verification opinion.

10 / CASE STUDY

Worked illustration: hypothetical industrial facility

Assume a facility produces **10,000 tonnes** of product during one year. Every activity quantity and factor below is **invented for training**, not an official factor for Egypt or any other location. Do not reuse them in compliance reporting or a verified statement.

Emission source / scope	Illustrative activity	Illustrative factor	tCO_2e
Diesel — Scope 1	50,000 litres	2.68 $kgCO_2e/L$	134.0
Natural gas — Scope 1	200,000 Nm^3	2.00 $kgCO_2e/Nm^3$	400.0
Refrigerant loss — Scope 1	8 kg	GWP100 = 1,000	8.0
Purchased electricity — Scope 2	1,200,000 kWh	0.42 $kgCO_2e/kWh$	504.0
Outbound freight — Partial Scope 3	800,000 tonne-km	0.09 $kgCO_2e$/tonne-km	72.0

Scope 1 = 134 + 400 + 8 = 542 tCO_2e

Scope 2 = 1,200,000 × 0.42 ÷ 1,000 = 504 tCO_2e

Illustrated sources = 542 + 504 + 72 = 1,118 tCO_2e

Illustrated sources

1,118

tCO_2e / training only

Illustrated intensity

0.1118

tCO_2e per tonne of product

11 / REVIEW FINDINGS

Recalculation and interpretation

- Reconcile Scope 1 separately from Scope 2; the 72 tCO_2e shown is **one selected Scope 3 source**, not a complete value-chain inventory.
- Electricity accounts for 504 ÷ 1,118 ≈ **45.1%** of the **illustrated subset only**, not the facility's full footprint.
- A market-based electricity result may differ from a location-based one, depending on eligible evidence and selected factors.
- Interpret emissions intensity with production volume, allocation approach and product mix; facilities with different boundaries cannot be compared uncritically.

Evidence limitation

The illustration excludes process emissions, a complete Scope 3 assessment and a full uncertainty budget. It must not be labelled the facility's definitive carbon footprint or used to substantiate a carbon-neutrality claim.

12 / VALUE CHAIN

Scope 3 is not a single residual category

The GHG Protocol groups Scope 3 into **15 upstream and downstream categories**. Start with applicability, likely magnitude and data availability; then select supplier data, activity-based factors or spend-based estimates, explaining the limitations of each approach.

Upstream categories 1–8	Downstream categories 9–15
1. Purchased goods and services	9. Downstream transportation and distribution
2. Capital goods	10. Processing of sold products
3. Fuel- and energy-related activities not in Scopes 1 or 2	11. Use of sold products
4. Upstream transportation and distribution	12. End-of-life treatment of sold products
5. Waste generated in operations	13. Downstream leased assets
6. Business travel	14. Franchises
7. Employee commuting	15. Investments
8. Upstream leased assets	—

13 / SCREENING

Materiality and estimation screening

Expected scale

Evaluate spend, tonnage, sold product use, logistics volume or financed portfolio size—even when supplier data are incomplete.

Data fitness

Consider supplier specificity, reporting year, geography, technology and possible duplication between categories.

Decision relevance

Assess purchasing choices, design, product life cycle, reputational and regulatory risks.

Data improvement

Begin with defensible estimates and progressively replace generic averages with more representative supplier or product information.

14 / DECARBONISATION

Emission-reduction priorities

- Identify hotspots using absolute emissions and operational materiality, not percentages alone.
- Compare efficiency, redesign, energy substitution and supplier alternatives with measurable KPIs.
- Distinguish physical reductions from offsets, credits and removals; do not double count benefits.
- Present the base year, recalculation rules and effects of structural, capacity or volume changes.

Disclosure boundary

Spend-based estimates may be necessary for screening, but are not always an adequate substitute for reliable activity or supplier data. Disclose which Scope 3 categories were included, excluded, estimated or improved.

15 / QA/QC

Quality assurance, quality control and evidence

Professional QA/QC tests **completeness, correctness, consistency and traceability**, not only spreadsheet arithmetic. Control design should target risks specific to each source and measurement process.

Control test	Practical implementation	Assurance purpose
Completeness	Every month × site × source; reconcile production and fuel	Avoid omission of periods or operating units
Reconciliation	Meters, invoices, opening and closing stocks	Detect data inconsistency and misstatements
Trend and range	Monthly intensity and prior-year changes	Investigate unusual values
Units and duplicates	Consistent conversions, locked source IDs	Prevent 1,000-fold errors or duplicate records
Traceability	Source ID → evidence → EF → formula → version	Permit independent recalculation
Governance	Preparer / reviewer / approver and change log	Document control and accountability

16 / UNCERTAINTY

Illustrative combined uncertainty

If activity-data and emission-factor uncertainties are **statistically independent**, with negligible correlation or systematic bias, their relative standard uncertainties may be combined by root-sum-of-squares. This is a teaching approximation, not a substitute for a project-specific uncertainty budget.

$$u_{combined} \approx \sqrt{(u_{activity}^2 + u_{factor}^2)} = \sqrt{(3\%^2 + 5\%^2)} = 5.83\%$$

For the illustrated electricity source, 504 × 5.83% ≈ **29.4 tCO_2e**. This describes only that source under those assumptions—not the total inventory margin of error. Boundary choices, data gaps and model bias can add other material uncertainty.

17 / AUDIT FILE

Evidence package for independent review

- Original activity register identifying meter, calibration, reading date, invoice or contract.
- Version-controlled factor and GWP library showing source, unit, region and period.
- Protected calculation files, clearly identified inputs, validation checks and fixed versions.
- Documented assumptions, justified exclusions, data-gap treatment and boundary decisions.
- Finding/correction log identifying ownership, dates, evidence and closure.

18 / REPORTING FRAMEWORKS

Verification and regulatory uses: alignment, not substitution

A common emissions database can support multiple reporting outputs, but **the reports themselves are not interchangeable**. Each programme establishes its own boundaries, allocation, factors, disclosure rules and level of independent assessment.

Reporting route	Unit / system boundary	Key distinction
ISO 14064-1 organisational inventory	tCO_2e per year and defined organisational boundaries	Direct/indirect categories, entities and gases
GHG Protocol Scopes 1–3	tCO_2e per year including relevant value-chain categories	Scope 2 methods, Scope 3 coverage and duplication
ISO 14067 product footprint	$kgCO_2e$ per defined unit and life-cycle boundary	Functional unit, system boundary and allocation
EU CBAM definitive regime	Embedded emissions for covered goods under EU rules	Production processes, precursors, allocation and verification
IFRS S2 climate disclosures	Emissions, climate risk/opportunity information	Connection to sustainability-related financial reporting

19 / VERIFICATION

Technical steps in an independent verification engagement

- **Criteria and scope:** identify the GHG statement, period, entity, intended use and assurance criteria.
- **Risk assessment:** identify sources and estimates most prone to error, fraud or duplication.
- **Evidence plan:** perform recalculation, document testing, controls tests, interviews and site visits as necessary.
- **Evaluation:** examine misstatements, deviations, alternative evidence and uncorrected findings.
- **Reporting:** issue the appropriate verification or assurance report, with stated criteria, scope, level and limitations.

20 / CBAM

CBAM definitive implementation in 2026

The definitive EU Carbon Border Adjustment Mechanism phase began on **1 January 2026**. Embedded-emissions determination is subject to **Regulation (EU) 2023/956** and applicable implementing rules, including **(EU) 2025/2547** for calculation and **(EU) 2025/2546** for verification principles. Check amended legislation and sector-specific rules before use: an organisational factor does not replace CBAM's treatment of precursors and allocation.

Professional distinction

ISO 14064-3 validation/verification of GHG information differs from sustainability assurance engagements under ISSA 5000. An organisation's accreditation or content licence is not an endorsement of its digital platform by an accreditation or standards body.

21 / SIGN-OFF

Professional close-out checklist before releasing an inventory

Close-out control	Evidence to retain
01. Purpose and reference	Reporting framework, intended users, documented scope
02. Organisational boundaries	Entity/site schedule and selected consolidation method
03. Operational boundaries	Scope / ISO category register, source list and exclusions
04. Base year	Comparative basis and recalculation policy
05. Gases and GWP	Gas register and documented GWP100 source/version
06. Activity data	Source register, periods, readings, documents and owners
07. Emission factors	Versioned library with references, geography and units
08. Calculations	Protected formulas, unit checks, totals tests and file versions
09. QA/QC and uncertainty	Missing data, sensitivity analyses and estimates
10. Disclosure/approval	Draft statement, explanatory notes, management sign-off and closure log

22 / REFERENCES

Principal technical references

- [1] GHG Protocol — Corporate Accounting and Reporting Standard: ghgprotocol.org/corporate-standard
- [2] GHG Protocol — Scope 2 Guidance: ghgprotocol.org/scope-2-guidance
- [3] GHG Protocol — Scope 3 Calculation Guidance: ghgprotocol.org/scope-3-calculation-guidance-2
- [4] ISO 14064-1:2018 — Organization-level GHG quantification and reporting: iso.org/standard/66453.html
- [5] ISO 14067:2018 — Carbon footprint of products: iso.org/standard/71206.html
- [6] IFRS Foundation — IFRS S2 Climate-related Disclosures: ifrs.org
- [7] European Commission — CBAM legislation and guidance: taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism/cbam-legislation-and-guidance_en

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