Cascale

HIGG ASSESSMENT MODEL

# GHGP Scope 1 & 2 Alignment Guide

Version ham-v0.4.0 · 25 September 2026

This document maps the FEM energy and emissions data — the Assessment, FacilityType, ReportedEnergyUse, EnergyUse, and Emissions records — against the GHG Protocol's scope 1 and scope 2 inventory guidance. It is written for data consumers (brands,...

# Contents

**Alignment at a glance** ..... **3**
The figures a report carries ..... 3
The requirements behind the figures ..... 6
**Reference guidance** ..... **9**
**What a FEM is, in GHGP inventory terms** ..... **10**
**The five accounting principles, scored** ..... **10**
**Alignment detail** ..... **11**
Organizational boundaries ..... 11
Operational boundaries and scope assignment ..... 11
Gases and global warming potentials ..... 13
Scope 1 — stationary combustion ..... 13
Scope 1 — mobile combustion ..... 13
Scope 1 — fugitive emissions (refrigerants) ..... 14
Scope 1 — process emissions ..... 15
Biogenic emissions ..... 16
Scope 2 — location-based method ..... 17
Scope 2 — market-based method ..... 18
Emission factor provenance ..... 19
Activity data collection and quality control ..... 19
Verification ..... 20
Base year and recalculation ..... 20
Uncertainty ..... 20
**Working with the records: practical rules** ..... **21**
**Summary** ..... **21**
**Known implementation issues (as of August 2026)** ..... **22**
**Cadence applicability** ..... **22**
**Appendix A: the wastewater treatment calculation** ..... **23**
Source methodology ..... 23
The calculation ..... 24
Worked example ..... 24
How the FEM's two reporting shapes are handled ..... 24
Assumptions a consumer inherits ..... 25
What is deliberately not modelled ..... 25
Guards ..... 25
Reading absence: `wastewater_emissions_status` ..... 25

This document maps the FEM energy and emissions data — the `Assessment`, `FacilityType`, `ReportedEnergyUse`, `EnergyUse`, and `Emissions` records — against the GHG Protocol's scope 1 and scope 2 inventory guidance. It is written for **data consumers** (brands, analysts, inventory builders) who fold facility data into their own GHG accounting and need to know, per accounting requirement:

- what data the FEM collects and what HAM computes from it,
- what assumptions stand in where data is missing,
- where the methodology **aligns** with the guidance, where it aligns **with caveats** a consumer must carry, and where there is a **gap** the consumer must fill from outside the FEM.

It is a companion to `guidance-ghgp-fem.md` (the methodology itself, cadence by cadence) and `guidance-eeci.md`. This document does not repeat the calculation mechanics; it judges them against the guidance.

Verdict vocabulary used throughout:

- ✅ **Aligned** — use the data as-is for this requirement.
- ⚠ **Aligned with caveats** — the mechanism is GHGP-shaped, but there are assumptions or coverage limits you must disclose or correct for.
- ❌ **Gap** — the FEM does not carry this; fill it yourself or scope it out of your inventory explicitly.

# Alignment at a glance

Two slices of the same alignment. The first table takes the lens of the **figures and statements a GHGP report is expected to carry** — the Corporate Standard's required reporting information (chapter 9) plus the Scope 2 Guidance's dual-reporting figures — and answers, per line item: can you produce this from HAM, and with what attached? The second slices by the accounting requirements behind those figures. Verdicts use the vocabulary above; where a line item splits (one part met, another not), both verdicts appear. Each row links to the section carrying the full reasoning — the caveats here are the headline, not the whole story.

## The figures a report carries

| Reported figure / statement | Verdict | Where it lives | Caveats / reasoning |
|---|---|---|---|
| **Total scope 1 emissions ($CO_2e$)** | ⚠ | `Assessment.total_market_scope_one_emissions` / `total_location_scope_one_emissions` | Covers stationary and mobile combustion, plus refrigerant fugitives and wastewater $CH_4$ from fem2023. It is a **floor** for facilities with chemical process emissions (not quantified) or refrigerant releases beyond annual top-ups. Excludes biogenic $CO_2$ (memo'd separately, as GHGP requires). |
| **Total scope 2, location-based ($CO_2e$)** | ✅ electricity, ⚠ steam/heat/cooling | `Assessment.total_location_scope_two_emissions` | Electricity is priced at per-country IEA grid averages for the cadence's own year — exactly the method. Purchased steam / district heat / chilled water ride single- |

| Reported figure / statement | Verdict | Where it lives | Caveats / reasoning |
|---|---|---|---|
| | | | assumption models (coal-remainder at 80% efficiency, COP 3.0) that can materially overstate clean district systems. Pre-fem2023, genuinely on-site wind/hydro/ geothermal is grid-priced by assumption. |
| **Total scope 2, market-based ($CO_2e$)** | ⚠ | `Assessment.total_market_scope_two_emissions` | Dual reporting is native — every row exists in both methods. EAC-adjusted figures are facility-attested, not criteria-audited (no vintage, market boundary, or serial IDs); the residual mix reaches European AIB members from fem2025 only, so elsewhere untracked consumption equals the location figure; pre-fem2023 the market figure is meaningful only where geothermal/ hydro/wind was reported. |
| **Emissions per gas — each Kyoto gas in tonnes and $CO_2e$** | ✕ | — | Fuel factors are blended $CO_2e$; no $CO_2$/$CH_4$/$N_2O$ decomposition exists anywhere. The per-gas exceptions (wastewater $CH_4$/$CO_2$ rows, refrigerant-keyed fugitive rows) do not extend to combustion, so a gas-by-gas inventory cannot be assembled from FEM data. |
| **Biogenic $CO_2$, memo item outside the scopes** | ⚠ | `Assessment.total_market_biogenic_emissions` / `total_location_biogenic_emissions`; `Emissions` rows flagged `biogenic` | The memo structure is native. The totals cover fuel combustion only — add the wastewater $CO_2$ rows for a complete memo; the split is per-source, not per-gas (a biogenic fuel's $CH_4$/$N_2O$ share lands in the memo — immaterial); `fabricwaste`'s 33% biogenic fraction is provisional. |
| **Scope 1 by source category (stationary / mobile / fugitive / process)** | ⚠ fem2023+, ✕ earlier | `Emissions` rows: `emission_type` + `coverage` | Derivable from fem2023: `coverage: ["vehicle"]` isolates mobile, `emission_type` separates fugitive and process from |

| Reported figure / statement | Verdict | Where it lives | Caveats / reasoning |
|---|---|---|---|
| | | | combustion. Earlier cadences cannot isolate vehicle energy and carry no fugitive or process rows at all. |
| **Reporting period covered** | ⚠ | the cadence year, by convention | Calendar-year alignment is program convention stated in question guidance, not a data field — no period start/end exists, and partial-year operation is invisible. State the cadence year and the convention; you cannot evidence more. |
| **Consolidation approach & entities covered** | ⚠ | implicit in the record shape | One FEM = one site under de-facto 100% operational control — statable as such, but there is no ownership-share or entity data to support an equity-share or financial-control consolidation, and shared sites or landlord/tenant splits are invisible. |
| **Base year, base-year emissions, recalculation policy** | ✗ | — | No base-year concept exists; the self-reported baseline year is a target-setting input, not a recalculable base year. You own the base year, triggers, and threshold — HAM's consistent re-derivation of every historical cadence is the substrate for your restatements. |
| **Methodologies and emission-factor sources** | ⚠ | this guide + `guidance-ghgp-fem.md`; citations on fem2020+ factors | Documented and citable, with two disclosures: records apply the **latest** fuel-EF vintage to all cadences and the latest IEA edition's grid factor for each cadence's own year (cite the release, not the FEM year), and pre-fem2020 citation fields are empty. IEA grid factors are licensed — the data carries computed emissions, never the factors. |
| **GWP values and source** | ⚠ combustion, ✗ refrigerants | factor citations | Combustion (and wastewater $CH_4$) use documented IPCC AR6 |

| Reported figure / statement | Verdict | Where it lives | Caveats / reasoning |
|---|---|---|---|
| | | | GWPs. The refrigerant GWP table mixes sources and vintages, and 15 of 127 refrigerants have none — those top-ups produce no row, flagged `refrigerants_status: unmodeled`. |
| **Excluded sources, disclosed** | ⚠ | `ghgp_completion_status`, `data_quality_flags`, the `*_status` fields | Facility-specific gaps are identifiable: per-source completeness on every cadence, tracking-status fields from fem2023. The **structural** exclusions — non-wastewater process emissions, wastewater $N_2O$, T&D losses — are the model's, and your disclosure must state them. |
| **Offsets, reported separately from the scopes** | ☑ | offset questions on the assessment (type, quantity, reference) | Collected and — correctly — never netted against scope 1 or 2 in any record or total. The instruments' quality and retirement are not evidenced beyond the facility's answers. |
| **Contractual-instrument disclosures (market method)** | ⚠ | EAC questions: instrument type, retired MWh, ownership attestation, generation mix, certificate upload | Enough to describe the instruments, not enough to audit them: vintage, market/grid boundary, and registry serial IDs are absent. If your program requires criteria-conformant instruments, request the uploaded certificates. |

## The requirements behind the figures

| Requirement (GHGP) | Verdict | Caveats / reasoning |
|---|---|---|
| Consolidation approach & organizational boundary | ⚠ | Implicit model is 100% operational control of one site — the right shape for facility data, but there is no ownership-share data to weight a corporate roll-up, and shared sites, on-site subcontractors, and landlord/tenant splits are invisible. Lease treatment matches operational control. |
| Reporting period | ✕ | Calendar-year alignment is a program convention stated in question guidance, not a data field. No period start/end fields; |

| Requirement (GHGP) | Verdict | Caveats / reasoning |
|---|---|---|
| | | partial-year operation is not captured. |
| Scope assignment & separate scope 1/2 reporting | ⚠ | Every row carries an explicit `scope`; per-method scope totals sit on `Assessment`. Caveats: sold-certificate on-site generation is re-labelled scope 2 (per Scope 2 Guidance Table 6.1 / §6.4.1); pre-fem2023 renewables are scope-attributed by assumption because on-site/ off-site was never asked; `FacilityType` carries no scope split. |
| All seven Kyoto gases / per-gas reporting | ✗ | Fuel factors are single blended kg $CO_2e$/MJ values — no $CO_2$/$CH_4$/$N_2O$ breakdown exists anywhere in the data, so gas-by-gas disclosure cannot be derived. |
| GWP vintage & source | ⚠ combustion, ✗ refrigerants | Combustion factors use documented IPCC AR6 GWPs — blended factors are standard corporate-inventory practice. Refrigerant GWPs mix sources and vintages; 15 of 127 refrigerants have no GWP and produce no row (surfaced as `refrigerants_status: unmodeled`). |
| Scope 1 — stationary combustion | ☑ | Purchase-records method: annual quantity + unit per fuel, systematic unit conversion, IPCC-derived factors, blend and biomass-mix decomposition. Disclose: latest-EF vintage is applied to all historical cadences; HHV/LHV basis is not declared per fuel. |
| Scope 1 — mobile combustion | ⚠ | Fuel quantity only — no vehicle counts, classes, or distances, so no fuel-economy cross-checks and no $CH_4$/$N_2O$ refinement by vehicle technology. The vehicle coverage split and `vehicle_energy_status` exist from fem2023 only. |
| Scope 1 — fugitive emissions (refrigerants) | ⚠ | Annual top-up is a recognised sales-based proxy but a floor: no installation/disposal losses or equipment inventory, and top-ups are lumpy year to year. On the records from fem2023 only; GWP gaps drop rows visibly rather than zeroing them. A screening estimate, understated by construction. |
| Scope 1 — process emissions | ⚠ wastewater, ✗ other | On-site wastewater treatment is priced from volume × BOD5 drop (fem2023+): $CH_4$ as scope 1, $CO_2$ as biogenic. $N_2O$ is not modelled (no nitrogen data); aerobic units and |

| Requirement (GHGP) | Verdict | Caveats / reasoning |
|---|---|---|
| | | facultative lagoons default to the lower-emitting published parameters. All other process emissions are qualitative presence/absence only — fill from outside the FEM. |
| Biogenic $CO_2$ as a separate memo item | ⚠ | The memo structure is native: biogenic is excluded from scope totals and carried in its own totals. Caveats: the split is per-source, not per-gas (a biogenic fuel's $CH_4$/$N_2O$ share lands in the memo — immaterial but real); the memo totals cover fuel combustion only (wastewater $CO_2$ must be summed from rows); `fabricwaste`'s 33% biogenic fraction is provisional. |
| Scope 2 — location-based method | ✅ electricity, ⚠ steam/heat/cooling | Purchased electricity uses per-country IEA grid averages for the cadence's own reporting year, from the latest licensed edition — exactly the location-based method. Steam and district heating model unknown sources as coal at 80% boiler efficiency, chilled water as grid electricity at COP 3.0 — deliberately conservative, and can materially overstate clean district systems. Facility-reported supplier EFs are collected but unused. |
| Scope 2 — market-based method & dual reporting | ⚠ | Dual reporting is native — every row and total exists in both methods. Caveats: EAC Quality Criteria are only partially evidenced (no vintage, market boundary, or registry serial IDs — trust the arithmetic, not criteria conformance); residual mix covers European AIB members from fem2025 only, with a one-year lag — elsewhere market-based grid electricity equals location-based. |
| Emission factor documentation | ✅ fem2020+, ⚠ earlier | fem2020+ factors carry citations; pre-fem2020 citation fields are empty (factors carried forward from earlier program years). IEA grid factors are licensed and not republished — consume the computed emissions. |
| Activity-data quality control | ⚠ | Per-source completeness is signalled on every cadence and fails `pass_data_quality`, but only six record-level checks exist (energy range, completeness, negative values, the EAC/renewables double |

| Requirement (GHGP) | Verdict | Caveats / reasoning |
|---|---|---|
| | | entry, LNG magnitude, refrigerant plausibility): no year-over-year screens within an assessment, no cross-facility benchmarks, no unit-conversion audits. Add your own screens; unit confusion is the dominant error class. |
| Third-party verification | ⚠ | Posting status (`posted_by_verifier` et al.) distinguishes verifier-corrected records from self-assessed ones on every surface. Assurance detail — verifier identity, body, accreditation, level — is absent everywhere and cannot be derived. |
| Base year & recalculation policy | ✗ | No base-year concept exists; the self-reported baseline year is a target-setting input, not a recalculable GHGP base year. The consumer owns base year, recalculation triggers, and significance threshold; HAM's consistent re-derivation of every historical cadence is the substrate for restatement. |
| Quantified uncertainty | ✗ | Nothing quantified. The `provenance` modeled/reported label on every row is the structural stand-in — use the modeled share as a first-order proxy, noting the conservative defaults make modeled rows skew high. |
| Offsets kept out of scopes | ☑ | Offsets are collected (type, quantity, reference) and never netted against scope 1 or 2 in any record or total. |

# Reference guidance

The alignment below is anchored to the two normative GHG Protocol documents:

1. **GHG Protocol Corporate Accounting and Reporting Standard** (revised edition, PDF) — the foundational standard: principles, boundaries, scopes, gases, base years.
2. **GHG Protocol Scope 2 Guidance** (2015 amendment, PDF) — dual reporting, the market-based method, contractual-instrument Quality Criteria, residual mix. Chapter and table numbers cited in this document (e.g. Table 6.1, §6.4.1) refer to this edition.

**On sector guidance.** There is no GHG Protocol sector edition for apparel, footwear, or textiles covering scope 1 and 2 inventory methodology. The apparel-specific material that exists (notably the SBTi Apparel and Footwear guidance) addresses target setting, and for a facility's own scope 1 and 2 accounting it defers to the Corporate Standard. This document therefore judges the FEM against the two standards above directly. Where it borrows practical inventory advice that is not itself a normative requirement — the "investigate year-over-year changes above 10%" screen, for

example — that advice comes from the GHG Protocol's *Scope 1 & 2 GHG Inventory Guidance* (November 2019), a dairy-processing sector edition reviewed by the GHG Protocol for conformance with the Corporate Standard. It is cited as a source of practice, not as an authority for apparel facilities.

# What a FEM is, in GHGP inventory terms

A FEM is an **annual, single-site facility self-assessment**, optionally corrected by an accredited verifier. Translated into the handbook's inventory-design vocabulary:

- **Reporting entity** = one facility site. There is no corporate roll-up, no subsidiary structure, and no consolidation-approach question (equity share / financial control / operational control). The implicit model is *100% operational control of a single site*.
- **Reporting period** = the FEM reporting year (e.g. FEM 2025 reports calendar year 2025 data). There are **no explicit period-start/period-end fields** on the assessment or the records; calendar-year alignment is a program convention stated in question guidance, not a data field. Partial-year operation is not captured.
- **Role in a consumer inventory**: a facility's scope 1 and scope 2 data is, for most data consumers, an input to *their* scope 3 (purchased goods & services). The scope labels on the records are the facility's scopes, not yours.

Everything below judges the facility-level inventory the records represent.

# The five accounting principles, scored

The Corporate Standard's five principles, applied to the FEM records:

| Principle | Verdict | Basis |
|---|---|---|
| **Relevance** | ☑ | Facility boundary matches what consumers need for supply-chain accounting; segmentation (country, facility type, industry sector, tier) is carried on every record. |
| **Completeness** | ⚠ | Energy-related scope 1 + scope 2 are covered, and refrigerant fugitives are on the records from fem2023 (top-up basis). Process emissions are still not quantified; see the gap table. Whether a facility reported *all* its energy sources is on the records as `ghgp_completion_status` for every cadence, and incomplete assessments fail `pass_data_quality`. |
| **Consistency** | ⚠ | One methodology across all cadences and facilities, recomputed from source on every release. Fuel EFs on the records use the **latest** factor for all historical cadences, and grid EFs the latest |

| Principle | Verdict | Basis |
|---|---|---|
| | | IEA edition at each cadence's own year (deliberately, for cross-year comparability) — which means record values can differ from the in-product FEM numbers a facility saw, whose grid factors are locked to the vintage at release. |
| **Transparency** | ☑ | Every modeled row is labeled `provenance: "modeled"`; assumptions are documented; this document and the methodology guide disclose limitations. |
| **Accuracy** | ⚠ | Data-quality flags exist but are few (six per-assessment checks, plus the cross-assessment rules) and carry no year-over-year screens within an assessment; posting status is on the records, but assurance detail (verifier identity, body, accreditation, level) is unavailable; see Known issues. |

# Alignment detail

## Organizational boundaries

**Guidance:** choose equity share, financial control, or operational control; apply it consistently to all scope 1 and 2 sources; classify leased assets accordingly.

**FEM:** no consolidation concept exists. One FEM = one site, implicitly 100% operational control. Vehicles are explicitly bounded as "owned and controlled … e.g., leased vehicles that are used by the facility" — operating-leased vehicles the facility uses are **in** boundary, which matches the operational-control treatment of leases.

**Verdict:** ⚠ **Aligned with caveats.** For a consumer, the caveat is aggregation-side: if you consolidate facilities into a corporate view, the equity/control decision is yours, and the FEM gives you no ownership-share data to weight by. Shared sites, on-site subcontractors, and landlord/tenant splits are invisible.

## Operational boundaries and scope assignment

**Guidance:** categorize each source as scope 1 (owned/controlled combustion, process, fugitive) or scope 2 (purchased electricity, steam, heat, cooling); report scopes separately.

**FEM:** every energy source carries an explicit per-cadence scope in the reference data, and every `EnergyUse`/`Emissions` row carries a `scope` field. Current (fem2023+) assignment:

- **Scope 1** — all on-site combusted fuels (coal, natural gas, LNG/CNG, LPG/propane, diesel, petrol, fuel oil, biomass variants, biogas, biodiesel, ethanol, fabric waste, hydrogen), on-site generation (solar PV, solar thermal, wind, micro-hydro), and all vehicle fuels.
- **Scope 2** — purchased electricity, purchased renewable electricity, purchased steam, district heating, purchased chilled water.

Notable movements across cadences (relevant if you consume multiple years): `wind` was scope 2 in fem2017–fem2022 and is scope 1 (on-site generation) from fem2023; `geotherm`/`hydro` were scope 2

options through fem2022 and are only reachable as mix components afterwards; `microhydro` has always been scope 1.

### Why the older cadences differ: no on-site/off-site distinction

Those movements are not reclassifications for their own sake. **Before fem2023 the FEM did not ask whether a renewable source was on-site or off-site.** A facility reporting "wind" could equally have meant a turbine on its roof or a wind tariff from its utility, and nothing in the answer distinguished the two.

Rather than leave those volumes unattributed, the model resolves each pre-fem2023 renewable to its **most common real-world case**. Geothermal, hydro, and wind are treated as *off-site* — purchased generation whose attributes arrive with the electricity — so under the location-based method they are re-attributed to purchased grid electricity. The attribution is a fixed list applied at record-generation time:

```
# location-method attribution, FEM 2017–2022 model
offsite_renewables = [
    "geotherm",
    "hydro",
    "wind",
    "purchrenew",
]
source = this.row["_source"]
if this.row["_source"] in offsite_renewables:
    source = "electricpurch"
else:
    source = EMISSIONS[this.row["_source"]].constant(
        "attributed source", this.row["_source"]
    )
```

`microhydro`, `solarphoto`, and `solarthermal` are absent from that list because they are unambiguously on-site by nature, and stay at their own zero emission factor under both methods.

Two consequences for a consumer of pre-fem2023 records:

- **A facility that genuinely had on-site wind is overstated** under the location-based method — its generation is priced at the grid factor. There is no field that lets you identify or correct those facilities; the information was never collected.
- **The market-based method is where the assumption shows.** These sources keep their own zero factor under the market method (the modeled case is off-site generation with retired certificates), so geothermal, hydro, and wind are the *only* sources whose market and location rows differ before fem2023. See "Cadence applicability".

From fem2023 the distinction is a reported fact rather than an assumption: on-site generation is its own question set, and the facility's own answer about selling certificates drives the attribution.

**Verdict: ⚠ Aligned with caveats.** Two caveats:

1. **Scope-level totals are on the `Assessment` record**, in both methods: `total_market_scope_one_emissions`, `total_market_scope_two_emissions`, and their `location` counterparts. Like `total_*_emissions` they exclude biogenic, which the memo totals carry, so scope 1 + scope 2 accounts for the whole non-biogenic figure with nothing left over.

   `FacilityType` does **not** carry a scope split — GHGP reports scopes at the entity level, and a facility type is a sub-facility breakdown. If you need one, sum the `Emissions` rows filtered to one `scope_two_method` and grouped by `scope`.

2. **Sold-certificate volumes are split across scopes.** On-site generation whose certificates were sold is re-priced at the grid factor under the market method, and those rows carry `scope: "two"`; the retained share keeps `scope: "one"`. This follows Scope 2 Guidance Table 6.1 (*owned/operated*

*generation → certificates sold to 3rd party*) and §6.3, which puts consumption from owned generation whose attributes were sold into scope 2 activity data — §6.4.1 requires it to be treated "as though it were purchased from the grid". The standard's carve-out ("scope 1 reporting shall still reflect any emissions from the generator") does not apply, because none of the affected sources — solar PV, solar thermal, wind, micro-hydro — combusts anything.

Note this is the one place where the scope label does **not** follow the reported source. Elsewhere it always does: purchased steam decomposed into its coal fraction stays scope 2, because the supplier burned the coal, not the facility.

## Gases and global warming potentials

**Guidance:** account for all seven Kyoto gases; use 100-year GWPs from the most recent IPCC assessment report, consistently across years; report the GWP source.

**FEM:**

- Fuel emission factors are **single blended kg $CO_2e$/MJ values** — derived from IPCC stationary-combustion defaults with AR6 GWPs (fem2025 citations; ethanol from US EPA 2025). There is **no per-gas ($CO_2$/$CH_4$/$N_2O$) breakdown anywhere** in the data.
- Refrigerant GWPs (in-assessment only, see Fugitives) come from **mixed sources and vintages** — IPCC AR6 for a subset, plus vendor tables, EU F-gas documents, EPA tools, and older Kyoto-era values; some entries have no value at all and compute as zero.

**Verdict:** ⚠ **for combustion $CO_2e$** (blended factors are standard practice for corporate inventories; the vintage is documented), ✗ **for per-gas reporting** (if your program requires gas-by-gas disclosure — e.g. $CH_4$ and $N_2O$ reported separately — you cannot derive it from FEM data), and ✗ **for refrigerant GWP consistency** (no single AR vintage; treat any refrigerant-derived number as indicative).

The refrigerant GWP caveat bites on the fugitive rows described under "Scope 1 — fugitive emissions": those values are only as good as the GWP table behind them. Refrigerants with no authoritative GWP produce no row at all rather than a zero, so the effect of a gap is an understatement you can see, not a wrong number you cannot.

## Scope 1 — stationary combustion

**Guidance:** collect fuel quantities per source from meters or purchase records; convert physical units to energy; apply fuel-appropriate emission factors; document heating-value basis.

**FEM:** facilities report annual quantity + unit per fuel source (the purchase-records method, in the handbook's terms). Unit conversion to MJ is systematic (GNU `units`-derived conversion tables, with volume/mass/energy paths per fuel). Fuel EFs are IPCC-derived per source. Blends are split: diesel/biodiesel by reported percentage; petrol/ethanol by volume-weighted share. Biomass with certificates and generated biomass can be decomposed into sub-source mixes (agricultural residue, crops, forest residue, mill residue, solid wood) by reported percentages.

**Verdict:** ☑ **Aligned**, with two disclosures to carry:

- The records apply the **latest** fuel EF vintage to all cadences (methodological-consistency choice, documented in the methodology guide). If you need vintage-of-year factors, recompute from the reported MJ (`EnergyUse.value`) with your own factors.
- Heating-value basis (HHV vs LHV) is not declared per fuel in the data; the factors follow their IPCC/EPA sources' conventions.

## Scope 1 — mobile combustion

**Guidance:** include owned/leased vehicles under your control; collect fuel consumed (minimum), ideally distance and vehicle characteristics.

**FEM:** a dedicated vehicle-energy table (15 fuel options including electric, hydrogen, and renewable purchase) collects annual fuel quantity per source for "owned and controlled vehicles" (leases included). Rows carry `coverage: ["vehicle"]` and flow through the same EF machinery. Vehicle blends (diesel/biodiesel, petrol/ethanol) are split like stationary blends.

**Verdict:** ⚠ **Aligned with caveats.** Fuel-quantity-only: no vehicle counts, classes, or distances, so no fuel-economy cross-checks and no $CH_4$/$N_2O$ refinement by vehicle technology (subsumed in the blended $CO_2e$ factor). Vehicle electricity is re-attributed like facility electricity (grid factor), which is correct. The coverage split (production / domestic / vehicle) only exists from **fem2023**; earlier cadences cannot isolate vehicle energy.

An assessment with no vehicle rows is ambiguous on its own; `vehicle_energy_status` on `Assessment` (fem2023+) tells the cases apart: `not_applicable` (the facility reports no company owned and controlled vehicles), `untracked` (vehicles are reported but the tracking opt-in is anything short of a full "yes", no fuel sources are reported for them, or a reported source is missing the quantity or unit its row needs), or `tracked` (every reported fuel source carries what its row needs). Like `ghgp_completion_status`, tracked means *completely* tracked — one gap drops the signal. Undefined before fem2023 and while the vehicle questions are unanswered. The domestic-coverage rows carry the analogous `domestic_energy_status`, whose `not_applicable` also covers the facility that reports domestic energy *combined* with production — there the data is in the combined-coverage rows, not missing.

## Scope 1 — fugitive emissions (refrigerants)

**Guidance:** quantify refrigerant losses via screening, sales-based, or mass-balance methods; account per gas because GWPs differ; small releases matter.

**FEM:** collects, per refrigerant type, the **quantity added to existing equipment during the reporting year** (Q6.1.2) — a top-up proxy roughly equivalent to the service component of the sales-based method. In-assessment calculations multiply by per-refrigerant GWPs into `totalRefrigerantEmissions`, which joins the in-product `totalGHGemissions` figure.

**Verdict:** ⚠ **Aligned with caveats.** Refrigerant releases are on the records from fem2023, as `Emissions` rows carrying `emission_type: "fugitive"` and `scope: "one"`, identified by refrigerant through `reported_source_key`. They are emitted under both accounting methods, so a scope 1 total filtered to either sees the same figure, and they roll up into `total_<method>_scope_one_emissions`.

They are deliberately **not** in `total_*_emissions` or EECI, which stay pinned to energy-derived rows so their meaning did not change when fugitives were added. Filter on `emission_type` when you sum this table yourself, and note that a refrigerant key will not join against the energy source reference data.

Carry these caveats:

- Top-up-only is a floor: no installation/disposal losses, no beginning/ending inventory, no equipment capacity. Note this is a *methodological* floor, not an error — annual top-up is the service-component proxy the sales-based method recognises. What it cannot capture is the year in which equipment is installed or decommissioned.
- Top-ups are **lumpy in a way annual reporting does not smooth.** Equipment is often recharged every few years rather than annually, so a single reporting year can show a large top-up against neighbouring years showing none. The reported figure is a faithful record of that year's service, but it is a poor estimate of that year's *leakage rate*. Averaging across consecutive assessments is the right correction and is not something the FEM can do for you today — each assessment is evaluated in isolation.
- The GWP table has mixed vintages, and **15 of the 127 refrigerants offered have no GWP value.** Those produce **no row at all** rather than a zero-valued one — a missing row is a visible gap, whereas a zero would assert that the release had no warming effect. For four of them (`r717` ammonia, `r718` water, `r728` nitrogen, `r740` argon) zero would have been approximately right anyway; for the rest it would not, `r400` being a CFC blend whose true GWP is in the thousands.

Populating these is in progress; until then a facility reporting one of the fifteen contributes nothing to the fugitive total — but not silently: `refrigerants_status` reports it (see below).
- No refrigerant data exists before fem2023.
- **Implausible top-ups fail the data-quality gate (HAM 0.3).** A refrigerant total of at least 10,000 t $CO_2e$ that also exceeds the assessment's entire energy-related scope 1 + 2 raises `Assessment: Refrigerant emissions of … kg CO2e are implausibly high against energy-related emissions of … kg CO2e` and fails `pass_data_quality`. The ceiling is the most a single very large industrial system can release in a year (IPCC 2006 Vol. 3 Ch. 7 Table 7.9: ~10 t charge at 7–25 %/yr, at the highest GWPs), and a facility running several has an energy footprint far above it; below the ceiling, reported refrigerant emissions run 1–10 % of a facility's energy emissions, the flagged ones 15× to 20,000× — a kilogram entered as a tonne, or a charge entered as a top-up. The fugitive rows are still published, so the entry can be inspected; the assessment simply drops out of `pass_data_quality`-filtered analysis. In FEM 2024 the flag removes ~11 Mt of spurious scope 1 (two self-assessed filings hold 10 Mt of it); other cadences lose under 1 Mt.

An assessment with no fugitive rows is ambiguous on its own; **`refrigerants_status`** on `Assessment` (fem2023+) tells the cases apart:

- `not_applicable` — no refrigeration, cooling or air-conditioning emission sources; no rows are expected.
- `unmodeled` — a positive refill was reported for a refrigerant with no authoritative GWP. The rows understate the facility's releases, and no answer the facility could give would fill the gap — reported ahead of the other states because it taints whatever rows do exist.
- `untracked` — refrigerant use applies but the facility does not know which refrigerants it uses, its tracking answer is anything short of a full "yes", or a declared refill is missing the quantity or unit its row needs. **Missing rows here mean missing data, not absent releases.**
- `tracked` — every declared refill carries what its row needs. A year with no refills is tracked with no rows — zero releases, not missing data (though see the lumpiness caveat above).

The field is undefined before fem2023 and while the air-emission source questions are unanswered — deliberately not `not_applicable`, since the facility never said either way.

Treat the figure as a screening estimate that is understated by construction, not as a complete fugitive inventory.

## Scope 1 — process emissions

**Guidance:** include process emissions (chemical/physical transformations) in scope 1 where they occur.

**FEM:** the air-emissions section collects a *qualitative* inventory of emission sources (boilers, generators, incinerators, ovens, production processes: dyeing, printing, solvents, ODS use, etc.) and compliance status — but **no quantities** except refrigerant top-ups. Nothing from it enters the records.

**Verdict: ⚠ Aligned with caveats for wastewater, ✗ Gap otherwise.**

**On-site wastewater treatment is on the records** from fem2023, as `Emissions` rows with `emission_type: "process"`. Each wastewater stream is priced on the organic load it sheds — volume × the drop in BOD5 across treatment — times a per-process yield from the US EPA's biogenic-emissions estimation methodology, and reported as two rows:

- **$CH_4$** under `wastewater_ch4`, `scope: "one"`. Methane is scope 1 even though its carbon is biogenic; the Corporate Standard's biogenic carve-out is for $CO_2$ only.
- **$CO_2$** under `wastewater_co2`, flagged `biogenic: true`. It is therefore excluded from the scope rollups, as biogenic $CO_2$ should be.

Both of the FEM's BOD5-monitoring shapes are covered: a facility reporting one before/after pair per stream produces one row pair per stream, and a facility monitoring at sub-process level

produces one row pair per treatment stage. The full derivation — equations, parameters, and the assumption each parameter choice carries — is in Appendix A.

Because rows only materialize when they carry a positive value, an assessment with no wastewater rows is ambiguous on its own. The `Assessment` record disambiguates it with **`wastewater_emissions_status`**:

- `not_applicable` — no on-site (or zero-liquid-discharge) treatment with a secondary (biological) stage; no rows are expected.
- `untracked` — treatment is applicable but the facility does not monitor BOD5 in a usable shape, or reported no stream with the volume and before/after readings the calculation needs. **Missing rows here mean missing data, not absent emissions** — fill from outside the FEM or treat as a coverage gap.
- `tracked` — the rows reflect reported treatment data.

The field is undefined before fem2023 and when the wastewater routing questions are unanswered — deliberately not `not_applicable`, since the facility never said either way.

Three caveats:

- Two of the yield parameters stand in for conditions the FEM does not ask about: aerobic units are priced as **well-managed** (the FEM carries no overloaded-aeration signal) and facultative lagoons as **shallow** (no depth question). Both are the lower-emitting of their published alternatives; Appendix A quantifies the sensitivity.
- **$N_2O$ is not modelled.** The IPCC method derives it from nitrogen load, which the FEM does not collect.
- The wastewater $CO_2$ does **not** appear in `total_*_biogenic_emissions`, which remains an energy-combustion total. Sum the rows on `biogenic` if you want a complete biogenic memo across all emission types.

Beyond wastewater, process emissions remain a gap. The air-emissions section gives presence/absence signals only, so chemical-process emissions must be filled from outside the FEM.

## Biogenic emissions

**Guidance:** report biogenic $CO_2$ from biomass combustion **separately from the scopes** (memo item); biogenic $CH_4$/$N_2O$ belong in scope 1 proper.

**FEM:** `Emissions` rows carry a `biogenic` boolean (from the attributed source's category), and the assessment totals implement the memo-item structure: `total_market_emissions` / `total_location_emissions` **exclude** biogenic; `total_market_biogenic_emissions` / `total_location_biogenic_emissions` carry it separately.

**Verdict: ⚠ Aligned with caveats.**

- The split is **per-source, not per-gas**: a biogenic fuel's entire blended $CO_2e$ (including its $CH_4$/$N_2O$ component, which GHGP would keep in scope 1) lands in the biogenic memo. The scope-1 line you derive from FEM data is therefore slightly *under* the GHGP definition for facilities burning biomass, and the memo slightly over. The misallocated portion is the $CH_4$/$N_2O$ share of a biogenic fuel's blended factor, which is a low-single-digit fraction of its $CO_2e$ — so this is **very unlikely to be material** at facility level. It is disclosed for completeness rather than because it needs correcting; if your programme reports biogenic memo items to a materiality threshold, check it against your own rather than assuming.
- **The two partly-biomass waste fuels are split.** `fabricwaste` and `muniwaste` carry blended emission factors covering both a biomass and a fossil fraction. Rather than leave the whole figure in the scopes, the records attribute the biomass share to a `<source>_biogenic` counterpart — `fabricwaste_biogenic`, `muniwaste_biogenic` — which is flagged biogenic and therefore lands in the memo totals, while the remainder stays in scope 1 (or scope 2 for `muniwaste`, which only reaches a facility inside a purchased steam mix, where the supplier did the burning).

The split **re-allocates and does not re-price**: both halves carry the parent's emission factor, so a facility's total $CO_2e$ is unchanged and only its distribution between the scope totals and the biogenic memo moves.

Fractions used: `muniwaste` **50%**, which its factor citation states outright. `fabricwaste` **33%**, which is *provisional* — that factor blends a biological component modelled as biomass municipal waste with a synthetic component modelled as industrial waste, but the ratio was never recorded. Back-solving the published factor against the IPCC defaults those components come from puts the biological share between 0.27 and 0.34, and roughly a third is also the global natural-fibre share. **Treat the `fabricwaste` biogenic/fossil split as indicative until the derivation is confirmed**; the totals it feeds into are not affected either way.

- Biogenic totals cover **fuel combustion only**. Wastewater $CO_2$ is biogenic and on the records, but is not in these totals — sum the `Emissions` rows on `biogenic` for a complete memo.

## Scope 2 — location-based method

**Guidance:** grid-average factors appropriate to the facility's location; totals for all purchased electricity, steam, heat, cooling.

**FEM:**

- **Electricity**: per-country grid factors, IEA-derived. The records price every cadence from the latest licensed edition (today the 2026 edition) at the cadence's own reporting year, as a CO2e of electricity-only generation including CH4 and N2O. The in-product FEM factors are locked to the vintage at release instead (fem2025: the 2024 edition's CO2 figure for 2022 / provisional 2023; fem2026 and fem2027: the 2026 edition's 2024 / provisional 2025 CO2e); the differences are ordinary grid drift, and the gases add about 0.5% across the FEM population. Factors are licensed and not republished in the data — records carry computed emissions only.
- **Steam**: energy density from facility-reported temperature and pressure per steam source (defaults 200 °C / 1 unit-converted pressure), fuel mix reported by the facility, remainder modeled as **coal** at **80% boiler efficiency** — a deliberately conservative unknown-source assumption.
- **District heating**: modeled as coal at 80% efficiency (fem2023+); volume-reported heat converted via inlet/outlet temperature delta.
- **Chilled water**: modeled as grid electricity at **COP 3.0**. Note that chilled-water rows carry `energy_form: "thermal"` even though they are attributed and priced as grid electricity. This is deliberate and not an inconsistency: `energy_form` describes **how the facility consumes the energy**, not what was burned to produce it. Chilled water is generated off-site and piped in, so like purchased steam and district heating it is a thermal delivery. The electricity appears in the *attribution* (`attributed_source_key`), which is where a consumer building a generation-side split should look. If you are building consumption-side electric/thermal splits or EECI-style intensity metrics, `energy_form` is the correct field and needs no adjustment.
- The facility's own utility emission factor (Q1.5.1) is **collected but deliberately not used** from FEM 2024 on (unverifiable self-reports moved the program to uniform grid factors). Supplier-specific EF questions for chilled water, district heating, and purchased renewables are likewise collected-but-unused.

**Verdict:** ✅ **Aligned for electricity** (grid-average by location is exactly the location-based method), ⚠ **for steam/heat/cooling** (single-assumption models; the coal-remainder and COP defaults are conservative and can materially overstate clean district systems — if you have verified supplier factors, the collected-but-unused questions tell you which facilities have them, and you can recompute from `EnergyUse.value`).

## Scope 2 — market-based method

**Guidance (Scope 2 Guidance):** report market-based alongside location-based (dual reporting); use supplier/contract-specific factors where instruments meet the Quality Criteria; use the **residual mix** for untracked consumption where available, else the grid average; instruments must be retired, uniquely claimed, and plausibly matched in market and vintage.

**FEM:** the dual structure is native — every reported energy row generates both a `scope_two_method: "market"` and a `"location"` row, and all totals exist in both flavors. Market-method mechanics:

- **EACs** (Q3): facilities report instrument type (REC, GO, REGO, I-REC, TIGR, Green-e, EKO, other), **retired** MWh (explicitly retired-not-purchased, registered to the facility's own legal entity and address), a certificate upload, and the generation-source mix. Covered volume is re-attributed to the certified sources; uncovered volume stays on the grid factor.
- **Purchased renewables without EACs**: count as renewable under the market method **only if** the facility attests it owns the attributes (PPA-ownership question); otherwise the full volume is re-attributed to grid electricity. Unknown-source renewables (`renewunknown`) always fall to the grid factor — the can't-substantiate-it-don't-credit-it rule.
- **On-site generation**: the share of certificates *sold* is re-priced at the grid factor (the attributes left the facility) and carries `scope: "two"`; the retained share stays zero-emission at `scope: "one"`. This applies under **both** methods, per Table 6.1 and §6.4.1 — a sold certificate means the electricity is accounted for "as though it were purchased from the grid" in the location-based total as well as the market-based one. The two methods differ in what the grid share *costs*: the market side uses the residual mix where one is published, the location side always the grid average.
- **Residual mix**: per-country AIB residual-mix factors price market-method grid electricity from fem2025, with a fall-back to the location factor wherever none is published.

**Verdict: ⚠ Aligned with caveats — structurally one of the strongest areas, with two material caveats:**

1. **Quality Criteria are only partially evidenced.** Retirement, ownership, registry family, and a certificate file are collected; **vintage (generation year), market/grid boundary, and registry serial IDs are not**. You can trust the arithmetic; you cannot audit Scope 2 Quality Criteria conformance from FEM data alone. If your program requires criteria-conformant instruments, request certificates (the upload exists) or treat EAC-adjusted figures as facility-attested.
2. **Residual mix reaches Europe only, from fem2025.** Untracked consumption is priced at the AIB European Residual Mix where one is published and at the grid average everywhere else — which the Scope 2 Guidance permits where no residual mix exists. Four boundaries to carry:
   - **European coverage only.** AIB has ~34 member countries; the rest of the world keeps the grid average, so for untracked consumption the two methods agree there.
   - **fem2025 onward.** AIB began publishing per-country $CO_2$ factors with its 2024 results; earlier workbooks carry the generation mix but no emission factors. fem2023 and fem2024 keep the grid average.
   - **A one-year lag.** AIB publishes a year's mix in May of the following year, after the cadence is built, so fem2025 carries the 2024 mix.
   - **Non-participating members fall back.** A member that did not report shows a residual mix of zero at source; those countries keep the grid average rather than being credited as carbon-free. Austria and Switzerland are both in that position for 2024.

   Expect market-based emissions for European facilities without certificates to be **materially higher than location-based**: a residual mix excludes certificate-backed generation, so it exceeds the grid average by construction. For Germany's 2024 mix the gap is roughly 120%.

Carbon **offsets** are collected (type, quantity, reference) and — correctly — never netted against scope 1 or 2 in any record or total.

## Emission factor provenance

**Guidance:** use context-appropriate factors; document sources.

**FEM:** fem2020+ fuel EFs carry citations (IPCC Stationary Combustion defaults + AR6 GWPs; US EPA for ethanol; modeling notes for derived fuels like fabric waste, coal-water slurry, steam). Pre-fem2020 factors have **empty citation fields**. Grid factors are IEA-licensed (values not redistributable — consume the computed emissions, not the factors). Known factor-level modeling notes worth carrying into your disclosures: CNG/LNG factors exclude compression/liquefaction energy (scope 3 in GHGP terms); hydrogen is zero at point of use with upstream explicitly deferred to scope 3; biomass certification does not change the EF.

**Verdict: ✅ for fem2020+, ⚠ for older cadences** (undocumented citations; factors were carried forward from earlier program years).

## Activity data collection and quality control

**Guidance (handbook):** standardize collection; investigate >10% year-over-year changes; verify unit conversions; cross-check against reference sources.

**FEM/HAM:** in-form validations catch structural errors at entry time (mix percentages, implausible totals, unit constraints), but those never reach the records. On the records themselves there are exactly **six** per-assessment data-quality checks: assessment total energy implausibly high (>$10^{10}$ MJ) or low (<38,574 MJ, including missing-entirely), an energy source answered "not tracked" (`ghgp_completion_status: incomplete`), negative reported values, purchased-renewables exactly equal to EAC MWh×3.6 (a common data-entry confusion), implausibly high LNG (>$10^9$ MJ, the LNG/m³-vs-MJ confusion), and — from HAM 0.3 — **refrigerant plausibility**: fugitive scope 1 of at least 10,000 t $CO_2e$ that also exceeds the assessment's energy-related scope 1 + 2 (see the fugitive-emissions chapter). Cross-assessment rules (the section after this one in the methodology guide) add flags from a facility's other cadences. `pass_data_quality` is all-or-nothing: one flag fails the whole assessment, and it is stamped on every record row.

The two flag fields answer different questions, and it is worth keeping them apart when you build screens:

- `pass_data_quality` — did the *whole assessment* pass? Carried identically on every record row, so it is the field to filter on.
- `data_quality_flags` — *what* went wrong, at the grain of the row you are reading. On `Assessment` this is every flag raised anywhere. On `FacilityType` it is the field-level flags raised by rows attributed to that facility type, which is what lets you tell which facility type a bad figure came from. Assessment-wide flags are not repeated onto facility-type rows, so a facility type can have an empty `data_quality_flags` while `pass_data_quality` is false — the failure belongs to the assessment as a whole, or to a sibling facility type.

**Verdict: ⚠ Aligned with caveats.** No year-over-year discontinuity checks, no cross-facility benchmarks, no unit-conversion audits reach the records. The flags are a floor, not an assurance mechanism. Consumers doing serious QA should add their own screens (energy intensity vs production volume, YoY deltas, unit-magnitude checks) — aggregate FEM experience says unit confusion (kWh/MWh, LNG volume) is the dominant error class.

Two structural limits are worth planning around:

- **Completeness is signalled on every cadence.** The FEM asks, per energy source, "Does your facility track its energy use from this source?". Where a facility says it *uses* a source and then says it does *not* track it, the assessment is reported `incomplete` on `ghgp_completion_status`, and a data-quality flag naming that source is raised — so the assessment fails `pass_data_quality` and drops out of any filtered analysis by default, without you having to know this check exists. Use the flags to see which sources are missing.

A blank answer is *not* treated as a gap: only an explicit "I use this and don't track it" counts, so the check never manufactures failures for facilities that left irrelevant rows alone.

The question changes shape across cadences and the check follows it. From fem2023 each track question is paired with a "do you use this source?" column, so a gap is unambiguous. In fem2017-fem2022 there is no such pairing and the answer list includes **unknown**, which counts as a gap in its own right — a facility saying it does not know whether it tracks a source is exactly the uncertainty this check exists to surface. Because every cadence carries the check, `pass_data_quality` means the same thing across the whole record set.

- **There are no year-over-year checks**, because each assessment is evaluated in isolation — the model has no access to a facility's other assessments at evaluation time. This is why the handbook's "investigate changes above 10%" screen has no counterpart here, and why lumpy refrigerant top-ups cannot be smoothed. Cross-year screens remain consumer-side work.

## Verification

**Guidance:** third-party verification recommended; document assurance.

**FEM:** a verification program exists (accredited verifiers, per-question verification tags, verifier-corrected data). When an assessment is verifier-posted, the records are computed from verifier-corrected data.

**Verdict: ⚠ Aligned with caveats.** Posting status is on the `Assessment` record — `posted_by_verifier`, `posted_by_facility` and `assessment_status` — on every surface, so you can distinguish a self-assessed FEM from a verifier-corrected one without joining platform metadata. **`posted_by_verifier` is the assurance signal to filter on:** when it is true, the records were computed from verifier-corrected answers.

Read an undefined value as *unknown*, not as unverified. The fields are populated by the host that supplies the assessment, so they are present on the analytics tables and the platform API; the raw evaluate endpoint takes a caller-supplied context verbatim and will only carry them if the caller does. (The analytics tables additionally carry `status`, `facility_posted` and `verifier_posted` as platform columns; those predate these fields and say the same thing.)

What does not exist anywhere, on any surface, is **assurance detail**: verifier identity, verification body, accreditation, and assurance level are not present in the data the model receives, so they cannot be derived. Exposing them requires a change to the upstream platform contract and is being pursued separately. If your programme needs to evidence *who* verified an assessment and to what standard, that remains an out-of-band request rather than something the records can answer.

## Base year and recalculation

**Guidance:** set a base year; recalculate it for structural changes, methodology changes, and significant errors; define a significance threshold.

**FEM:** none of this exists at the record level. Facilities declare an energy **baseline year** for target-setting questions, but it is a self-reported performance-target input, not a recalculable GHGP base year. Posted FEMs are immutable by design; methodology does evolve between cadences (and the records deliberately re-derive historical cadences under the latest fuel EFs).

**Verdict: ✕ Gap — by design.** Base-year policy is the consumer's: you own the base year, the recalculation triggers, and the significance threshold. What HAM gives you is the ability to recompute any historical cadence consistently (the whole model is re-evaluated from source data on every release), which is the right substrate for consumer-side restatement.

## Uncertainty

**Guidance:** assess and document measurement/estimation uncertainty.

**FEM:** no quantified uncertainty. The structural signal is `provenance` on every `EnergyUse`/`Emissions` row: `"reported"` (attribution follows facility-specific information) vs `"modeled"` (an assumption was applied — unknown steam source → coal, chilled water → grid electricity, unowned renewable attributes → grid, …).

**Verdict:** ⚠. Use the modeled-share of a facility's emissions as a first-order uncertainty proxy; the conservative defaults mean modeled rows skew high.

# Working with the records: practical rules

Hard-won rules for anyone assembling an inventory from the tables:

1. **Always filter to one `scope_two_method`.** Every reported row exists twice (market + location); summing across both double-counts everything, including scope 1.
2. **Scope totals are on `Assessment`** — use `total_<method>_scope_one_emissions` / `..._scope_two_emissions` rather than deriving them. They exclude biogenic, matching the other `total_*_emissions` fields. Only `FacilityType` needs a hand-rolled split, from the `scope` field on the `Emissions` rows.
3. **Do not treat `emissions` as a complete mirror of `energy_use`.** Zero-emission rows (renewables, zero-MJ entries) are dropped from `emissions`; join back to `energy_use` for energy accounting.
4. **`ReportedEnergyUse` is not for GHGP reporting** — it is raw, pre-attribution, pre-modeling (steam un-grossed, chilled water un-divided). Use it for data-quality work only.
5. **Domestic/vehicle breakouts are exact-coverage sums**: facilities that do not track domestic separately report combined production+domestic rows, which the `*_domestic_*` fields do **not** include (grand totals always include everything). All domestic/vehicle breakouts are `undefined` before fem2023. `domestic_energy_status` and `vehicle_energy_status` disambiguate an empty breakout: `not_applicable` means no such rows are expected (combined reporting / no company vehicles), `untracked` means the data is missing, `tracked` means the breakout is complete.
6. **`FacilityType` allocation is approximate**: domestic and vehicle energy is split *evenly* across the assessment's facility types, and per-type rows only materialize when the facility can report per-type (fem2023+) or has exactly one type (earlier).
7. **Historic-cadence records ≠ what the facility saw.** The records apply the latest fuel EFs and current methodology to all cadences; the in-product FEM numbers used cadence-vintage factors. This is deliberate (comparability) — cite the release, not the FEM year, as your factor vintage.

# Summary

**Aligned — consume as-is:**

- Facility-level activity data collection for stationary and mobile combustion (purchase-records method, systematic unit conversion)
- Location-based scope 2 for purchased electricity (IEA grid averages by country and cadence)
- Dual market/location reporting structure and totals
- Scope 1 / scope 2 rollups on `Assessment`, in both methods
- Refrigerant fugitives as scope 1 `Emissions` rows (fem2023+)
- On-site wastewater $CH_4$ (scope 1) and $CO_2$ (biogenic) as `Emissions` rows (fem2023+)
- Tracking-status signals on `Assessment` (fem2023+): `wastewater_emissions_status`, `domestic_energy_status`, `vehicle_energy_status` and `refrigerants_status`, separating not-applicable from untracked data — with `refrigerants_status` additionally flagging refills the GWP table cannot price as `unmodeled`

- Posting status on `Assessment`, so verifier-corrected records are distinguishable from self-assessed ones
- Per-source completeness signalling on every cadence, failing `pass_data_quality` so incomplete assessments self-exclude
- Offsets excluded from scopes; unknown-provenance renewables not credited
- Biogenic combustion $CO_2e$ as a separate memo total, including the biomass fraction of the partly-biomass waste fuels
- Modeled-vs-reported provenance labeling

**Aligned with caveats — disclose or correct:**

- Blended $CO_2e$ factors; no per-gas breakdown
- Latest-EF re-derivation of historic cadences
- Steam/district-heat/chilled-water single-assumption models (coal-remainder, 80% efficiency, COP 3.0)
- EAC Quality Criteria only partially evidenced (no vintage, market boundary, or serial IDs)
- Residual mix covers European AIB members from fem2025 only; elsewhere and in earlier cadences, market-based grid electricity equals location-based
- Sparse data-quality checks beyond completeness; an absent source with no tracking answer still means “unknown”, not “zero”
- No year-over-year checks — assessments are evaluated in isolation
- Assurance detail (verifier identity, body, accreditation, level) is absent everywhere; only posting status is available
- Biogenic split is per-source, not per-gas (immaterial)
- `fabricwaste`’s biogenic fraction (33%) is provisional pending confirmation of how its blended factor was derived

**Gaps — fill from outside the FEM:**

- Consolidation approach / ownership shares (single-site 100% operational control is assumed)
- Reporting-period fields (calendar-year is convention, not data)
- Process emissions other than wastewater (qualitative presence only)
- Wastewater $N_2O$ (no nitrogen data collected)
- Per-gas ($CH_4$/$N_2O$) reporting
- Base year, recalculation policy, significance threshold
- Quantified uncertainty
- Electricity T&D losses and other scope 3 adjacencies (explicitly out of scope)

# Known implementation issues (as of August 2026)

None outstanding. Current-behavior notes a consumer should account for appear here as they are found; the deviations previously listed — sold-certificate scope labelling and the location-method treatment of certificate sales — are both resolved and described in place above.

# Cadence applicability

The alignment above describes the current methodology (fem2024 through fem2027, which are calculation-identical). Earlier cadences differ materially:

| Cadences | Differences that affect alignment |
|---|---|
| fem2023 | No biomass sub-source mixes; single-source steam detail; purchased-renewables remainder labeled `reported` rather than `modeled`. |
| fem2020–fem2022 | No EAC/blend/REC-sale logic; fixed off-site-renewables re-attribution list (geothermal, hydro, wind, purchased renewables → grid under location); static steam density; no coverage (domestic/vehicle) split; no refrigerant GWPs. |
| fem2017–fem2019 | As above minus purchased renewables; numeric country/unit codes (handled transparently by the records). |

For consumers, the practical line is: **full market-based accounting and domestic/vehicle segmentation are meaningful from fem2023 onward.**

That does not make the earlier market-based rows empty, and it is worth being precise about what they do carry. Because geothermal, hydro, and wind are modeled as off-site generation with retired certificates (see "Why the older cadences differ" above), those three sources are **zero-rated under the market method and priced at the country grid factor under the location method** in fem2017–fem2022. That divergence is real and is the pre-fem2023 market/location signal — for a facility reporting meaningful geothermal, hydro, or wind volume, the two methods give genuinely different answers and the market figure reflects the modeled certificate claim.

What the earlier cadences lack is everything *else* the market method normally involves: no EAC reporting, no PPA-ownership attestation, no certificate-sale adjustment on on-site generation, and no residual mix. Purchased renewables (`purchrenew`, fem2020+) look like they should diverge but do not — they re-attribute to grid electricity under both methods, so they contribute nothing to the market/location difference.

So: treat pre-fem2023 market-based totals as meaningful **only to the extent the facility reported geothermal, hydro, or wind**, and as equivalent to location-based otherwise. And carry the modeling assumption with them — the market figure is only as good as the "these renewables were off-site" premise, which the data cannot confirm.

# Appendix A: the wastewater treatment calculation

This appendix documents the calculation behind the `wastewater_co2` and `wastewater_ch4` rows — what is computed, where every number comes from, and which assumptions a consumer inherits by using them.

## Source methodology

The calculation implements the wastewater-treatment method of:

> RTI International for the US EPA, *Greenhouse Gas Emissions Estimation Methodologies for Biogenic Emissions from Selected Source Categories: Solid Waste Disposal, Wastewater Treatment, Ethanol Fermentation* (draft, December 14, 2010), PDF — Section 3.2.1, Equations 3-1 and 3-2, with the Table 3-1 default parameters.

The EPA method prices the $CO_2$ and $CH_4$ from a biological treatment unit on the **oxygen demand it removes**: influent flow × influent oxygen demand × removal efficiency, times per-gas conversion factors. The FEM collects exactly the inputs that product needs — annual wastewater volume per stream ($m^3$) and BOD5 concentrations before and after treatment (mg/L) — so the method transfers without gap-filling on the activity side.

## The calculation

Because 1 mg/L = 1 g/m³, the organic load removed is a mass:

```
BOD removed (g) = volume (m³) × (BOD5_before − BOD5_after) (mg/L)
```

Each gram of removed BOD is converted at (Equations 3-1/3-2):

```
CO₂ (g/g) = 44/32 × (1 − MCF × BG) × (1 − λ)
CH₄ (g/g) = 16/32 × (MCF × BG) × (1 − λ)
```

- **44/32** and **16/32** are stoichiometric ceilings: the mass of $CO_2$ (or $CH_4$) obtainable per unit of oxygen demand.
- **MCF** (methane correction factor) is the fraction of the removed oxygen demand converted under anaerobic conditions.
- **BG = 0.65** is the document's default fraction of anaerobically converted carbon leaving the biogas as $CH_4$ (the rest leaves as $CO_2$).
- **λ** (biomass yield) is the fraction of removed carbon incorporated into new biomass — sludge — rather than emitted as gas.

With the Table 3-1 defaults, per FEM process choice:

| FEM answer | Table 3-1 row | MCF | λ | $CO_2$ g/g | $CH_4$ g/g |
|---|---|---|---|---|---|
| Aerobic | Aerated treatment process, well managed | 0 | 0.65 | 0.48125 | 0 |
| Anaerobic | Anaerobic treatment process (e.g. anaerobic reactor) | 0.8 | 0.10 | 0.594 | 0.234 |
| Facultative | Facultative lagoon, shallow (< 2 m deep) | 0.2 | 0 | 1.19625 | 0.065 |

The $CH_4$ mass is converted to $CO_2e$ at **27.2 kg $CO_2e$/kg $CH_4$** — the IPCC AR6 100-year GWP for **non-fossil** methane, the correct variant here because the carbon is biogenic, and the same AR6 vintage the fuel emission factors use. The $CO_2$ row carries its mass directly (GWP 1) and is flagged `biogenic: true`.

## Worked example

1,000 m³/yr treated anaerobically from 300 mg/L down to 30 mg/L removes 1,000 × 270 = 270,000 g of BOD. The records carry:

- `wastewater_co2`: 270,000 × 0.594 / 1000 = **160.38 kg $CO_2$** (biogenic memo)
- `wastewater_ch4`: 270,000 × 0.234 / 1000 = 63.18 kg $CH_4$ × 27.2 = **1,718.50 kg $CO_2e$** (scope 1)

## How the FEM's two reporting shapes are handled

The FEM asks how BOD5 is monitored, and the answer routes the facility to one of two mutually exclusive question sets:

1. **One before/after pair per stream** (combined, domestic, and/or industrial wastewater). Each stream is priced on its own volume and its own BOD drop — streams are never pooled, because summing concentrations across streams of different volumes is meaningless. A stream reporting **several process kinds** against its single before/after pair has its removed load **split equally** between them, each share priced at its own yield: one pair carries no information about how much each stage removed, and an equal split is the assumption-minimal reading. (The split matters: a worst-case-wins reading would price the whole load anaerobically and roughly double the methane of an aerobic/anaerobic train, while ignoring the anaerobic stage would eliminate it.)
2. **One before/after pair per treatment sub-process** (up to ten stages). Each stage is a unit in series: its own removed load, priced by its own declared process kind, against the annual volume of the wastewater stream it declares. Per-stage removals telescope to the whole-train

removal, so the stage rows sum without double counting — and unlike the single-pair shape, this one needs no apportionment assumption at all.

## Assumptions a consumer inherits

Two Table 3-1 parameters answer questions the FEM does not ask, and both default to the **lower-emitting** published row:

- **Aerobic units are priced as well-managed** (MCF 0, λ 0.65). The overloaded row (MCF 0.3, λ 0.45) would raise the aerobic $CO_2$ yield by about a quarter and add a methane term worth over twice the $CO_2$ on a $CO_2e$ basis. The FEM collects no aeration-loading signal to distinguish the two.
- **Facultative lagoons are priced as shallow** (MCF 0.2). The deep (≥ 2 m) row carries MCF 0.8, which on a $CO_2e$ basis is roughly 2.6× the shallow total once the methane is weighted. The FEM has no lagoon-depth question.

If your program needs conservative (high-side) wastewater figures, treat facilities reporting facultative treatment as the sensitive population; the underlying volumes and BOD values are on the assessment should you need to re-price them.

## What is deliberately not modelled

- **Sludge digestion** (source document Equations 3-4 through 3-7). The λ term already keeps sludge-routed carbon out of the treatment rows; pricing its later digestion needs sludge flow, solids concentration, and digester-type data the FEM does not collect.
- **Biogas capture and combustion** (Section 3.2.2). The FEM does not ask whether methane is captured or flared, so all computed $CH_4$ is assumed vented. For a facility that captures and burns its biogas, the methane row overstates — conservatively — what actually reached the atmosphere.
- **$N_2O$** (Section 3.3). The method derives it from influent nitrogen (TKN), which the FEM does not collect; no defensible default exists.

## Guards

Rows materialize only when they carry a positive value: a stream or stage with no tracked volume, no BOD answers, or a post-treatment reading at or above its pre-treatment reading produces **no row** — never a zero-valued or negative one. This is the same absent-not-asserted convention the refrigerant rows use.

## Reading absence: `wastewater_emissions_status`

Because of the no-zero-rows convention, "no wastewater rows" has two very different readings, and the `Assessment` field `wastewater_emissions_status` tells them apart:

| Value | Meaning | What to do with it |
|---|---|---|
| `not_applicable` | The facility has no on-site (or ZLD) treatment with a secondary — biological — stage, or a stream is discharged untreated (which suppresses the FEM's treatment questions entirely). | No rows expected; nothing to fill. |
| `untracked` | Treatment is applicable, but BOD5 is not monitored in a shape the calculation can use (not at all, or before-only / after-only), or no stream or stage carries the volume plus before/after readings it needs. | Missing rows are a data gap, not absent emissions. Estimate from outside the FEM or disclose the coverage hole. |
| `tracked` | At least one stream or sub-process stage carries a tracked volume with both BOD5 readings. | Rows reflect reported treatment. |

Applicability mirrors the FEM's own gate on the BOD5-monitoring questions — the same conditions that decide whether the facility is ever asked for treatment data: an on-site, on-site-and-offsite, zero-liquid-discharge, or septic-combination discharge route, plus "secondary treatment" among the facility's water pretreatment types. The field is undefined for cadences without the treatment tables (pre-fem2023) and when the routing questions are unanswered — deliberately not reported as `not_applicable`, since the facility never said either way.

Note that `tracked` asserts the *inputs* exist, not that emissions were positive: a facility whose effluent BOD5 equals its influent produces no rows while still reporting `tracked`, which is the honest reading — it measured, and the measurement showed nothing removed.