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REPUBLIC OF TÜRKİYE
MINISTRY OF ENVIRONMENT,
URBANIZATION AND CLIMATE CHANGE

Promoting Enhanced EU ETS Alignment in Türkiye's Emerging ETS

This activity is part of the European Union Climate Dialogues Project (EUCDs)

Aluminium sector

Fabio Romani and Matias Franke

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MODULE 2 — CBAM-RELEVANT PRODUCT BENCHMARKS BY SECTOR

Online Day 4 — Aluminium: Primary & Secondary

Unwrought aluminium — the primary (electrolytic) benchmark, the pre-bake anode benchmark, the secondary (scrap) fallback, system boundaries, BDR & a full worked case study

Primary aluminium

Pre-bake anode)

Secondary aluminium

Experts: F. Romani / M. Franke · TR ETS Benchmarking Training — EU Climate Dialogues 2, Türkiye



DAY 4

Agenda for the day

1

Introduction: aluminium in the EU ETS and CBAM

2

The two routes & how the CO₂ is counted (MRV)

3

EU ETS benchmarks — primary aluminium & pre-bake anode (and why secondary has none)

4

System boundaries, sub-installations & BDR data

5

CBAM and aluminium

6

Worked calculation: free allocation × CBAM factor

7

Full case study: a secondary-aluminium plant (Schema → MP/MMP → AER → ALC)

Case study



CONTINUITY WITH DAYS 2–3

From steel & cement to aluminium — what carries over, what changes

Same framework as before

- Product benchmarks = average of the 10% best EU installations
- Free allocation = $BM \times HAL \times CLEF \times CBAM \text{ factor}$
- Carbon-leakage list $\rightarrow CLEF = 1$ (100%)
- Sub-installations, BDR data, verified MRV — the same chain

What is different for aluminium

- Two distinct routes: primary (electrolysis) vs secondary (scrap)
- Primary is electricity-intensive $\rightarrow$ indirect (electricity) emissions matter
- Primary emits PFCs (CF_4 , C_2F_6) — not just CO_2
- Secondary has NO product benchmark $\rightarrow$ it uses fallback approaches

As covered in the 2024 training and Days 2–3: the benchmark curve, free-allocation formula and sub-installation logic carry over unchanged.



EU ETS — THE EUROPEAN PICTURE

Why aluminium matters: high value, high carbon intensity, two very different routes

Primary aluminium EU ETS benchmark

1.464 t CO₂e/t

25 EU (sub-) installations · electrolysis

Pre-bake anode EU ETS benchmark

0.312 t CO₂e/t

15 EU (sub-)installations · not CBAM

Secondary aluminium

≈ 5–20× lower CO₂

scrap remelting vs primary — no electrolysis

No product Benchmark



The headline

- Primary aluminium is one of the most CO₂- and electricity-intensive EU ETS products — most of its footprint is the electricity used in electrolysis, plus direct anode CO₂ and PFCs.
- Secondary (recycled) aluminium avoids electrolysis entirely — it only remelts scrap, so its direct emissions are mostly fuel combustion and are far lower.
- Both end up as the same CBAM good (unwrought aluminium, CN 7601) — but with very different embedded emissions.

Sources: benchmark-curve factsheet (12 Oct 2021), applied 2021–25 values & installation counts [research material/]; GD9 §8–9. The 5–20× range is indicative (order-of-magnitude).



CONTEXT — WHY THIS MATTERS FOR TÜRKİYE

Aluminium under CBAM: indirect emissions and the recycling advantage

CBAM scope for aluminium

- Unwrought aluminium (CN 7601) and many downstream products are CBAM goods
- From 2026 importers pay for embedded emissions; EU free allocation phases out
- A domestic carbon price would keep that revenue in Türkiye instead of going to the EU

The strategic message

- Primary producers face a large CBAM bill — hard to avoid without low-carbon electricity
- Secondary (recycled) producers are structurally advantaged — very low embedded emissions
- Accurate, verified data is decisive: weak data forces penalising CBAM default values
- Türkiye's aluminium sector mixes both routes — the pilot must handle each correctly



CONTEXT — TÜRKİYE

Türkiye's edge under CBAM: the recycling advantage

Türkiye — CBAM exposure (all sectors)

top 3 most-exposed origin

with China & Russia · ≈ USD 13.8 bn (OECD)

The structural edge

recycling the secondary route

low-carbon, scrap-based production

The exposure

- CBAM will most affect goods from China, Türkiye and Russia
- Basic metals (steel & aluminium) are a large share of Türkiye's exposure

The advantage

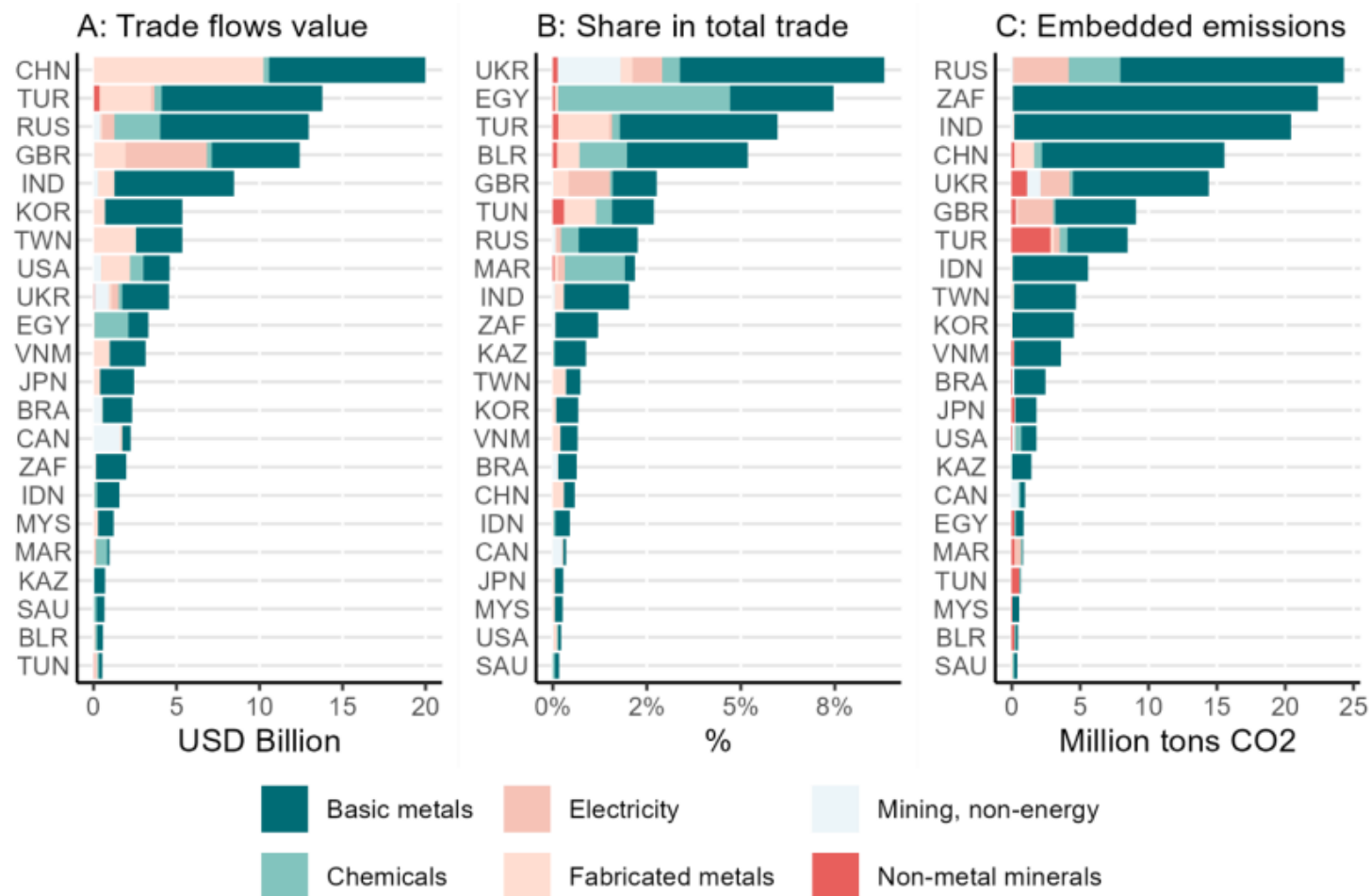
- OECD: Türkiye's competitive edge lies in recycling — e.g. recycled (EAF) steel
- The same logic applies to aluminium: a strong secondary sector is the best CBAM defence
- Today's case study is exactly this — a scrap-based, low-emission plant

Sources: OECD — the potential effects of the EU CBAM along the supply chain; Exposure of Developing Countries to CBAM. [research material/]



CONTEXT — TÜRKİYE

CBAM impact





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THE ALUMINIUM PROCESS

Two technologies to unwrought aluminium

PRIMARY — electrolysis



Carbon anode + O₂ → CO₂

Plus PFCs (CF₄, C₂F₆) during 'anode effects'. Electricity for electrolysis is the dominant footprint (excluded from the EU ETS direct boundary).

SECONDARY — scrap remelting



No electrolysis → no anode CO₂, no PFCs

Direct emissions are essentially fuel combustion (natural gas) to melt the scrap, plus minor non-combustion process CO₂.

Why this matters for the benchmark

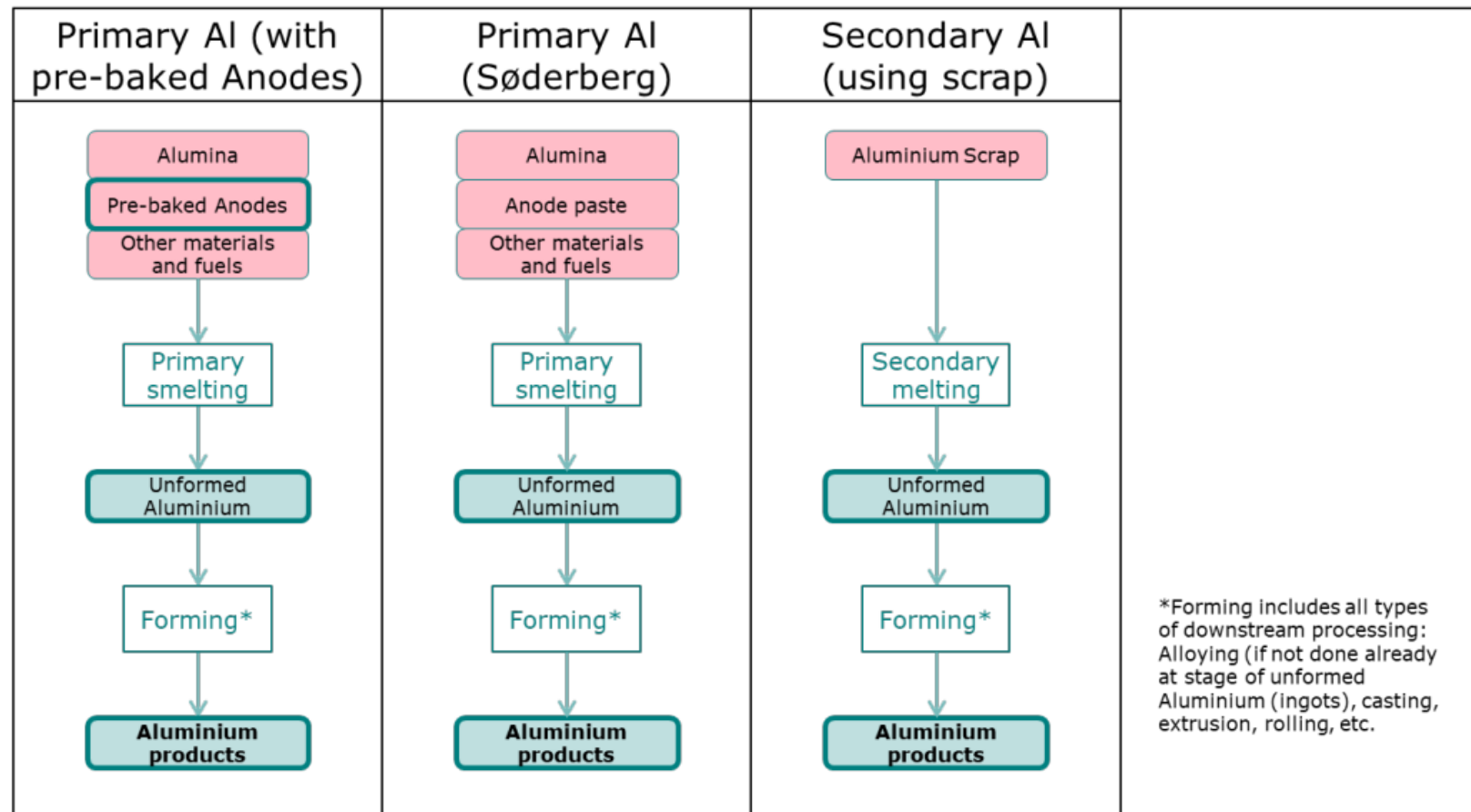
- The EU ETS 'Aluminium' product benchmark (BM9) covers only the PRIMARY electrolysis step — measured as unwrought non-alloy liquid aluminium, before alloys/secondary aluminium are added.
- Secondary aluminium is NOT covered by any product benchmark → these installations fall back to heat / fuel / process-emission sub-installations (the focus of today's case study).



THE ALUMINIUM PROCESS

Routes to unwrought aluminium

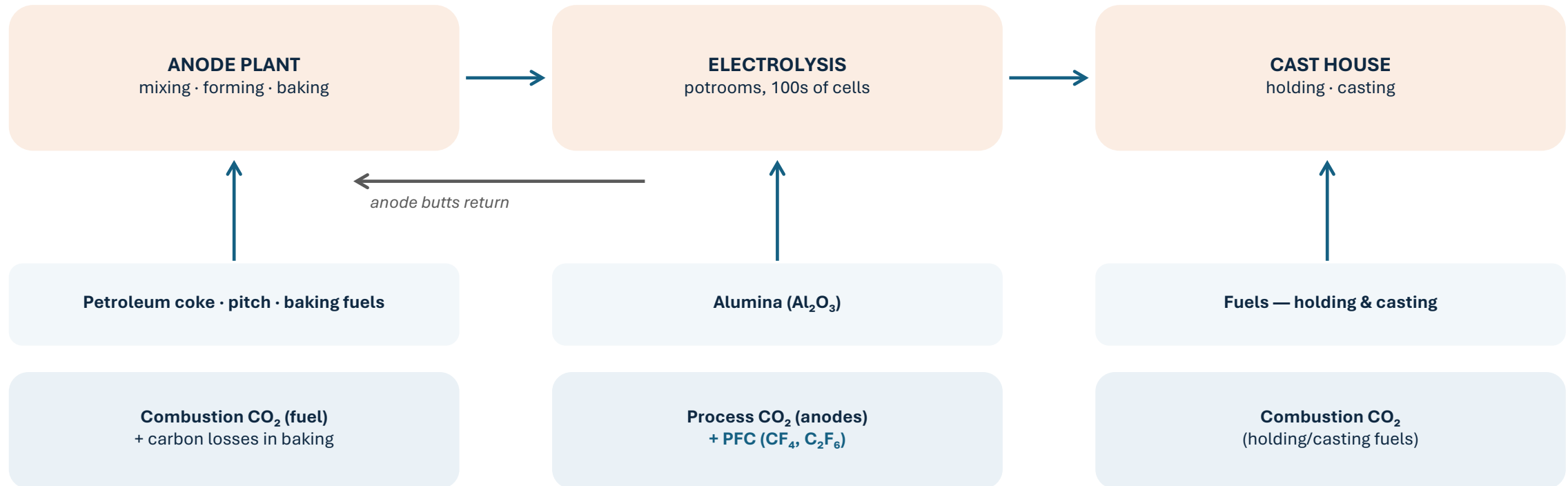
System boundaries and value chain for aluminium products





EMISSIONS ACCOUNTING — PRIMARY

Source streams and emission sources of a primary smelter



Completeness check: soda ash / limestone for waste-gas scrubbing is a carbonate source stream; electricity is NOT a source stream (indirect, outside the direct boundary); every carbon-bearing stream sits in exactly one method — mass balance or combustion, never both.

Sources: MRR (EU) 2018/2066 Annex IV §7 (potential CO₂ sources); GD9 §§8–9 (boundaries). [MRV / ETS/]



EMISSIONS ACCOUNTING (MRV)

How aluminium emissions are counted — primary vs secondary

Primary (electrolysis)

- **Process CO₂ — carbon anodes consumed in the cells:** mass balance (Art. 25, Annex IV §7) — mandatory
- **PFCs (CF₄, C₂F₆) from anode effects:** slope or overvoltage method (Annex IV §8), reported as CO₂e
- **Fuel combustion:** standard methodology (Art. 24) or folded into the mass balance
- **Electricity:** outside the EU ETS direct boundary (indirect-cost compensation instead)

Secondary (scrap remelting)

- **Fuel combustion (the main source):** fuel × NCV × EF × OF (Art. 24)
- **Minor process CO₂** (carbon-bearing additives / fluxes) — a separate source stream
- **No electrolysis** → no anode CO₂, no PFCs
- **Biomass fraction** zero-rated if the sustainability criteria are met

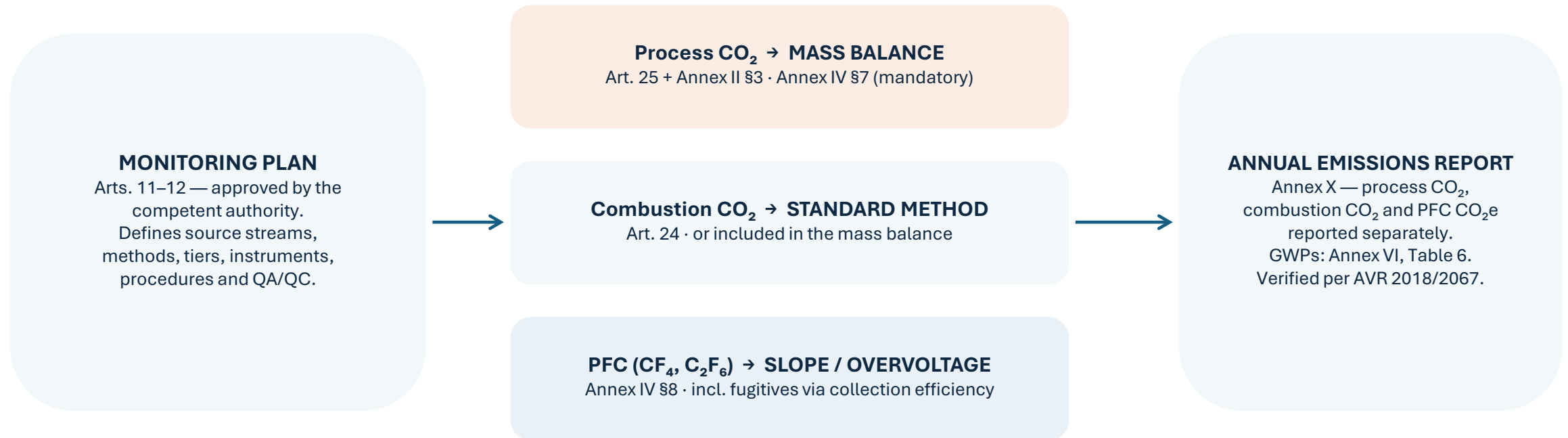
Roadmap: the next slides build the primary-route methodology step by step — process chemistry → mass balance → combustion → PFCs → reporting.

Sources: MRR (EU) 2018/2066, Arts. 24–25, Annex IV §7 (primary aluminium/alumina CO₂) & §8 (PFC). [MRV/]



EMISSIONS ACCOUNTING — PRIMARY

The regulatory map — where each requirement sits in the MRR



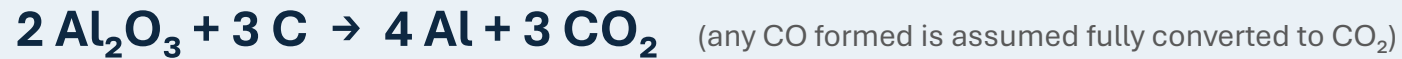
Data quality: tiers per Annex II, installation categories A/B/C per Art. 19, uncertainty limits per parameter — all fixed in the monitoring plan before any number is reported.

Sources: MRR (EU) 2018/2066 — Arts. 11–12, 19, 24–25; Annex II; Annex IV §§7–8; Annex VI Table 6; Annex X. AVR (EU) 2018/2067.



PROCESS CHEMISTRY — PRIMARY

Hall-Héroult electrolysis — why the carbon anode becomes CO₂



Inside the cell

- Alumina (Al₂O₃) dissolved in molten cryolite (Na₃AlF₆) at ≈ 960 °C
- DC current (300–600 kA) reduces Al³⁺ to metal at the cathode
- Oxygen ions discharge on the carbon anode — the anode itself is the reducing agent and is consumed
- Liquid aluminium is tapped from the cell bottom

Carbon demand per tonne of aluminium

- **Stoichiometric minimum:** 0.334 t C/t Al (3×12.01 g C per 4×26.98 g Al)
- **Real net consumption:** ≈ 0.40–0.43 t C/t Al — air burn, CO₂ reactivity, current efficiency (EAA: ≈ 428 kg anode/paste per t)
- **Result:** ≈ 1.5 t CO₂/t Al from the anode alone

Technology note: prebake cells (CWPB/PFPB) use anodes baked in a separate plant; Søderberg cells (VSS/HSS) bake the paste in situ — this distinction drives the mass-balance structure and the PFC factors later.

Sources: GD9 §9 (CO→CO₂ convention, system boundary); bm study aluminium (Ecofys/Fraunhofer 2009), Table 3 & §2. [ETS/]

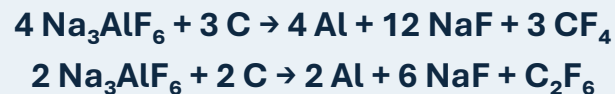


PROCESS CHEMISTRY — PRIMARY

The anode effect — where CF_4 and C_2F_6 come from

What happens in the cell

- Dissolved alumina falls below $\approx 1\text{--}2\%$ $\rightarrow$ normal electrolysis starves
- Cell voltage jumps from $\approx 4\text{ V}$ to $8\text{--}40\text{ V}$ (the 'anode effect')
- The fluoride electrolyte itself is electrolysed at the anode
- Anode carbon reacts with fluorine $\rightarrow \text{CF}_4$ and C_2F_6



Why PFCs dominate the risk register

- **GWP (MRR Annex VI, Table 6):** $\text{CF}_4 = 6\,630$, $\text{C}_2\text{F}_6 = 11\,100\text{ t CO}_2\text{e/t}$
- **Chemically inert**, atmospheric lifetime of thousands of years — no end-of-pipe abatement exists
- **Emitted only during process upsets** $\rightarrow$ quantity depends on operational control, not throughput
- **Prevention:** point feeders dosing alumina, automatic anode-effect detection and fast termination
- **Consequence for MRV:** PFCs are calculated from anode-effect process data — frequency, duration or overvoltage

Sources: MRR (EU) 2018/2066 Annex IV §8 & Annex VI Table 6; GD9 §9 (anode effect description). [MRV/ · ETS/]



EMISSIONS ACCOUNTING — PRIMARY

Choosing the method — what Annex IV §7 prescribes

The rule: mass balance is mandatory

- **Scope:** CO₂ from alumina production, electrode production and electrode consumption — incl. standalone anode plants
- **The balance covers** all carbon in inputs, stocks, products and other exports from mixing, forming, baking and recycling of electrodes, plus electrode consumption in electrolysis
- **Why:** carbon splits between products, butts, dust and CO₂ — only a mass balance guarantees nothing is lost

Prebake vs Søderberg

- **Prebake:** separate balances for anode production and anode consumption — or one common balance
- **Søderberg:** one common mass balance only (the anode is baked and consumed in the cell)

Combustion & PFCs

- **Combustion:** include it in the mass balance or use Art. 24 for part of the streams — no gaps, no double counting
- **PFCs:** never inside the mass balance — always the separate Annex IV §8 calculation

Sources: MRR (EU) 2018/2066 Art. 25 & Annex IV §7 (monitoring rules, prebake/Søderberg provisions). [MRV/]

MASS BALANCE — MRR ART. 25

The mass-balance equation — every variable explained

$$Em [t CO_2] = \sum_k AD_k \times CC_k \times 3.664 \quad (\text{source streams leaving the boundary enter with negative AD})$$

Variable	Meaning	Unit	Data source
AD_k	Quantity of fuel/material k entering (+) or leaving (–) the balance boundary, incl. stock changes	t	Weighbridges, belt scales, anode counting × unit mass, invoices, stock surveys — tier per Annex II §3
CC_k	Carbon content of material k	t C / t	Laboratory analysis (Arts. 32–35) or default values (Annex VI); may be derived from EF
3.664	Molar-mass ratio CO_2/C (44.010 / 12.011)	t CO_2 / t C	Constant

Interpretation: carbon in – carbon out ± stock change = carbon oxidised to CO_2 . No oxidation factor applies — whatever does not leave as product is deemed emitted.

Sources: MRR (EU) 2018/2066 Art. 25 (formula), Annex II §3 (tiers), Arts. 32–35 (analyses), Annex VI (defaults). [MRV/]



MASS BALANCE — MRR ART. 25

What goes in, what comes out — the carbon boundary

Carbon IN (positive AD)

- Petroleum coke and coal-tar pitch (anode plant)
- Green or baked anodes purchased from third parties
- Recycled anodes and anode butts returned to the paste plant
- Other carbonaceous materials — packing coke, ramming paste, cathode carbon
- Fuels, if the operator includes combustion in the balance

Carbon OUT (negative AD)

- Baked anodes or paste sold to other installations
- Anode butts transferred out or sold
- Carbon dust, skimmings, refractory/lining waste removed
- Stock increases of coke, pitch, anodes ($\pm$ stock change)
- Carbon in the metal: negligible — aluminium is $\geq 99\%$ pure

Configuration: prebake sites choose [anode-plant balance] + [electrolysis balance] or one common balance around both. If separate balances are used, butts and anodes moving between them must appear symmetrically in each — the classic double-counting trap.

Sources: MRR (EU) 2018/2066 Annex IV §7 (carbon inputs/outputs of electrode production & consumption). [MRV/]



MASS BALANCE — DATA QUALITY

Tiers, categories and uncertainty — data quality rules

Classify first (Art. 19)

- **Installation categories:** A $\leq$ 50 kt · B 50–500 kt · C $>$ 500 kt CO₂e/yr — most primary smelters are B or C
- **Major source streams:** everything that is not minor or de-minimis
- **Minor:** jointly $<$ 5 kt CO₂/yr or $<$ 10 % (cap 100 kt)
- **De-minimis:** jointly $<$ 1 kt CO₂/yr or $<$ 2 % (cap 20 kt) — estimation methods allowed

Parameter (mass balance / PFC)	T1	T2	T3	T4
AD — inputs & outputs, each material (t)	± 7.5 %	± 5 %	± 2.5 %	± 1.5 %
PFC activity data (Pr(Al), AE data / AEO)	± 2.5 %	± 1.5 %	—	—

Carbon content / calculation factors: tiered from Annex VI defaults up to laboratory analysis per Arts. 32–35 (sampling plan approved by the CA).

The rule: highest tier for major streams in category B/C installations — deviations only if technically infeasible or the costs are unreasonable (Arts. 17, 26), documented in the monitoring plan.

Sources: MRR (EU) 2018/2066 Art. 19 (categories & stream classes), Annex II §§1, 3 (tier tables), Arts. 17, 26, 32–35.

COMBUSTION — MRR ART. 24

Combustion emissions — the standard methodology

$$Em [t CO_2] = AD \times EF \times OF \quad AD = \text{fuel quantity} \times NCV$$

Variable	Unit	Data source / default
AD — activity data	TJ	Gas meters, weighbridges + NCV
NCV — net calorific value	TJ/t · TJ/Nm ³	Lab analysis or Annex VI default
EF — emission factor	t CO ₂ /TJ	Annex VI (natural gas 56.1) or analysis
OF — oxidation factor	—	= 1 (conservative default; tiered)

Where it applies in a smelter

- Anode-baking furnace fuel
- Cast-house holding & casting furnaces
- Boilers, steam, space heating
- **Alternative:** fold these into the mass balance — one method per stream, fixed in the MP

Biomass: the biomass fraction is zero-rated if the RED II sustainability and GHG-saving criteria are met; the preliminary EF and the fraction are reported separately.

Sources: MRR (EU) 2018/2066 Art. 24(1), Annex II §§2, 4 (tiers), Annex VI (default EF/NCV). [MRV/]



PFC monitoring framework — ducts, fugitives, two methods

$$\text{PFC (total)} = \text{PFC (duct)} \div \text{collection efficiency}$$

Scope & structure

- Covers CF_4 and C_2F_6 from anode effects — including the fugitive share escaping the cell hoods
- **Collection efficiency** is measured together with the installation-specific emission factors (IPCC 2006 §4.4.2.4)
- **Non-anode-effect PFCs** (e.g. cell start-up): estimated per industry best practice and Commission guidance

Two permitted calculation methods

- **Method A — slope:** based on anode-effect minutes per cell-day (frequency × duration)
- **Method B — overvoltage:** based on the recorded anode-effect overvoltage (AEO)
- **Both:** convert $\text{CF}_4/\text{C}_2\text{F}_6$ tonnes to CO_2e with Annex VI GWPs

Key idea: PFCs are calculated from cell-control process data multiplied by emission factors — periodic measurement campaigns calibrate the factors; continuous PFC stack monitoring is not the compliance method.

Sources: MRR (EU) 2018/2066 Annex IV §8 (A–B); IAI/US EPA measurement protocols cited therein. [MRV/]

PFC — METHOD A (SLOPE)

Method A — anode-effect minutes per cell-day

$$CF_4 [t] = AEM \times (SEF(CF_4)/1\,000) \times Pr(Al) \quad C_2F_6 [t] = CF_4 \times F(C_2F_6) \quad AEM = \text{frequency} \times \text{duration}$$

Variable	Unit	Source	Tier 1 (Table 1)	SEF(CF ₄)	F(C ₂ F ₆)
AEM — anode-effect minutes	AE-min / cell-day	Cell control system logs	CWPB (prebake)	0.143	0.121
SEF(CF ₄) — slope emission factor	(kg CF ₄ /t Al)/(AE-min/cell-day)	Tier 1 default or Tier 2 measured	VSS (Søderberg)	0.092	0.053
Pr(Al) — annual primary Al production	t	Production records	Tier 2: installation-specific factors from field campaigns, max ±15 % uncertainty, redetermined ≥ every 3 years or after significant cell-control changes.		
F(C ₂ F ₆) — weight fraction	t C ₂ F ₆ / t CF ₄	Tier 1 default or Tier 2 measured			

Note the units: SEF is in kg — the ÷1 000 converts to tonnes. AEM is a per-cell-day average across all cells, so frequency and duration must come from the complete cell population.

Sources: MRR (EU) 2018/2066 Annex IV §8, Method A & Table 1; IPCC 2006 §4.4.2.4 (Tier 2 campaigns). [MRV/]

PFC — METHOD B (OVERVOLTAGE)

Method B — anode-effect overvoltage

$$CF_4 [t] = OVC \times (AEO / CE) \times Pr(Al) \times 0.001 \quad C_2F_6 [t] = CF_4 \times F(C_2F_6)$$

Variable	Unit	Source	Tier 1 (Table 2)	OVC	F(C ₂ F ₆)
OVC — overvoltage coefficient	(kg CF ₄ /t Al) / mV	Tier 1 default or Tier 2 measured	CWPB (prebake)	1.16	0.121
AEO — anode-effect overvoltage	mV	∫(time × voltage above target) ÷ data-collection time — cell controller	VSS (Søderberg)	n.a.	0.053
CE — average current efficiency	%	Production vs. theoretical (Faraday) output	VSS = n.a. → Søderberg cells cannot use Method B at Tier 1; they must apply Method A. Tier 2 rules as for Method A (±15 %, 3-yearly).		
Pr(Al) — annual production	t	Production records; ×0.001 converts kg → t			

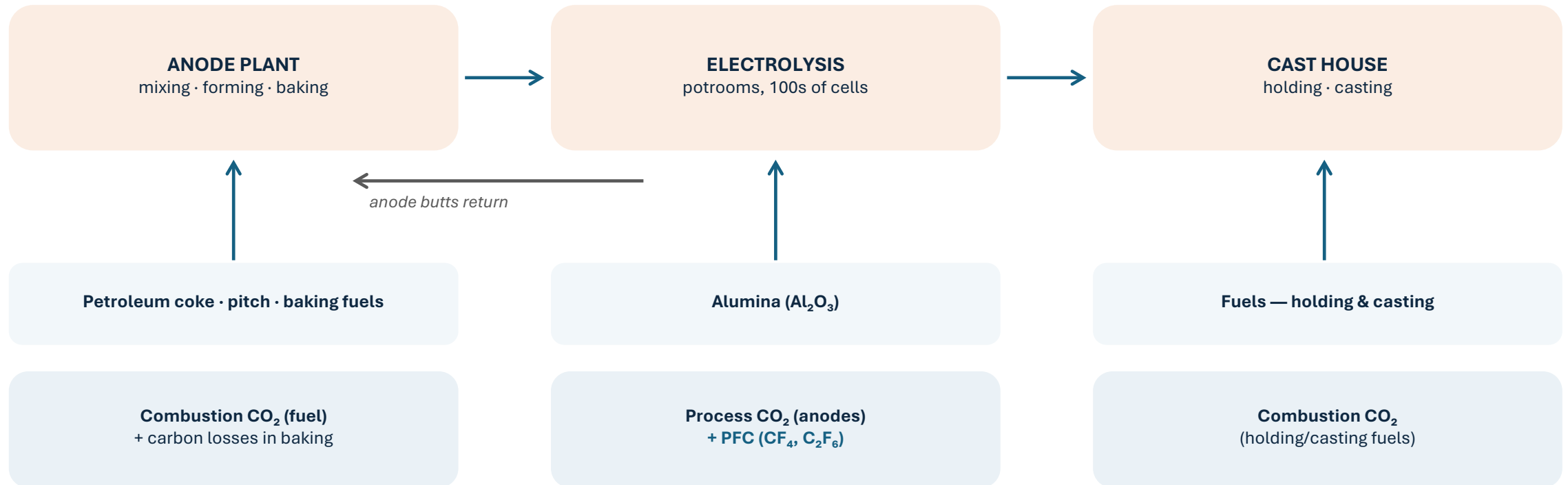
Why choose B: AEO/CE weights anode effects by their electrical intensity, not just their duration — often more representative where modern controllers log overvoltage natively.

Sources: MRR (EU) 2018/2066 Annex IV §8, Method B & Table 2. [MRV/]



EMISSIONS ACCOUNTING — PRIMARY

Source streams and emission sources of a primary smelter



Completeness check: soda ash / limestone for waste-gas scrubbing is a carbonate source stream; electricity is NOT a source stream (indirect, outside the direct boundary); every carbon-bearing stream sits in exactly one method — mass balance or combustion, never both.

Sources: MRR (EU) 2018/2066 Annex IV §7 (potential CO₂ sources); GD9 §§8–9 (boundaries). [MRV / ETS/]



RECAP

What we covered — process & MRV

Primary

Electrolysis: anode CO_2 + PFCs + (dominant) electricity; benchmark covers electrolysis only

Secondary

Scrap remelting: mostly fuel-combustion CO_2 ; no PFCs, no anode CO_2

Different MRV

Mass balance (Art. 25) + PFC slope/overvoltage methods (primary) vs standard combustion method (secondary)

Electricity excluded

Indirect (electricity) emissions sit outside the EU ETS direct boundary

Next: the EU ETS aluminium benchmarks — and why secondary has none.



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Full case study: a secondary-aluminium plant (Schema → MP/MMP → AER → ALC)

Case study

EU ETS

Aluminium-related product benchmarks

Product benchmark	Unit	2021-25	Ph-3 ref.	# EU inst.	CBAM?
Aluminium (primary, unwrought liquid)	t Al	1.464	1.514	25	Yes (factor by year)
Pre-bake anode	t anode	0.312	0.324	15	No (factor = 1)
Secondary aluminium	—	no product benchmark	—	—	Yes (as CBAM good)

How to read this

- Only PRIMARY aluminium and the PRE-BAKE ANODE have product benchmarks. Primary aluminium is a CBAM good; the pre-bake anode is not.
- There is NO product benchmark for SECONDARY aluminium → secondary installations receive free allocation via FALLBACK sub-installations (heat / fuel / process emissions).
- But secondary aluminium products are still CBAM goods, so the CBAM factor still applies to their free allocation.

Note: applied 2021–25 values & EU installation counts from the benchmark-curve factsheet (12 Oct 2021); 2026–30 values will be set by a forthcoming implementing act.



CBAM SCOPE

Which aluminium goods CBAM covers — the full product family

CN	Aluminium good	Made by
7601	Unwrought aluminium (incl. billets)	Primary & secondary
7603	Powders & flakes	Casting
7604	Bars, rods & profiles	Extrusion
7605	Wire	Rolling / extrusion
7606	Plates, sheets & strip (> 0.2 mm)	Rolling
7607	Foil (≤ 0.2 mm)	Foil
7608–09	Tubes, pipes & fittings	Extrusion
7610–16	Structures, tanks & other articles	Fabrication

Why it matters

- CBAM reaches far beyond unwrought metal — into semis and fabricated goods
- Every one of these can be made from the primary OR the secondary route
- So the embedded intensity depends on the route — and must be proven with data
- Our case-study product (billets, 7601) is the precursor for many of these

Sources: JRC 2023 (Table 12), GHG emission intensities — four energy-intensive industries; CBAM Reg 2023/956 Annex I. [research material/ - CBAM/]



BENCHMARK 1 OF 2

Primary aluminium (unwrought, electrolytic)

What it is

- Unwrought non-alloy LIQUID aluminium from electrolysis
- Unit: tonnes, measured between the electrolysis section and the holding furnace of the cast house — before alloys & secondary aluminium are added
- Boundary: all processes linked to the electrolysis step
- Excluded: holding furnaces, casting, anode production, and ALL electricity

Benchmark facts

Unit t unwrought liquid Al
BM (2021–25) 1.464 t CO₂e/t
CLEF 1 (100%)
CBAM scope yes (CN 7601)
PFCs included (CF₄, C₂F₆)

EU ETS benchmark (2021–25)

1.464 t CO₂e/t

weighted avg of all EU inst. 1.641 · 25 installations

CBAM benchmark — primary (K)

1.423 t CO₂e/t

CN 7601 · cols A & B equal · default direct ≈ 0.36

Sources: FAR 2019/331 Annex I; GD9 §9; benchmark-curve factsheet (BM9); CBAM Reg 2025/2620 Annex (7601, indicator K). [ETS/ · CBAM/]



PRIMARY ALUMINIUM

The electricity story — costs vs the direct-only CBAM scope

Mostly an indirect footprint

- Electrolysis is extremely power-hungry — one tonne needs a very large amount of electricity
- Most of primary aluminium's real carbon footprint is that electricity (indirect emissions)
- The direct anode CO₂ (benchmark 1.464) is only part of the story

Two consequences

- EU ETS excludes electricity from the direct benchmark → indirect costs are compensated separately
- Under CBAM, aluminium is an Annex II good → embedded emissions cover DIRECT emissions only
- Electricity still drives costs & competitiveness — via the power bill, not the CBAM levy

Bottom line: a hydropower and a coal-power smelter face similar CBAM bills (direct only) — but very different electricity costs. Secondary (scrap) aluminium sidesteps both.

Sources: GD9 §9 (electricity excluded from the boundary); Reg (EU) 2025/2547 Art. 3(2) & Annex I (direct-only scope for aluminium); JRC 2023. [ETS/ · CBAM/]



BENCHMARK 2 OF 2

Pre-bake anode — an aluminium input, but NOT a CBAM good

What it is

- Anodes for aluminium electrolysis: petrol coke + pitch + recycled anodes, baked to ~1150 °C
- Unit: tonnes of pre-bake anode (an intermediate product)
- Boundary: all processes directly/indirectly linked to anode production
- Söderberg anodes are NOT covered — they use fallback approaches

Benchmark facts

Unit t pre-bake anode
BM (2021–25) 0.312 t CO₂e/t
CLEF 1 (100%)
CBAM scope NO (factor = 1)
EU inst. 15

Consequence

- The pre-bake anode is on the carbon-leakage list (CLEF = 1) but is NOT a CBAM good — its CBAM factor stays at 1, so it keeps full free allocation (no phase-out). EU ETS benchmark 0.312 t CO₂e/t across 15 installations.

Sources: FAR 2019/331 Annex I; GD9 §8 ('Under the CBAM scope: No'); benchmark-curve factsheet (BM8). [ETS/]



SECONDARY ALUMINIUM — KEY SLIDE

No product benchmark → free allocation via fallback approaches

Why there is no benchmark

- No 'secondary aluminium' product benchmark exists in the FAR
- Annex I activity: 'production of secondary aluminium where combustion units > 20 MW operate'
- Emissions are mostly fuel combustion — too plant-specific for a single product benchmark
- So allocation follows the FALLBACK hierarchy instead

The fallback hierarchy (after product BMs)

- 1 **Product benchmark** — not applicable to secondary Al
- 2 **Heat benchmark** — measurable heat (if any)
- 3 **Fuel benchmark** — fuel used for non-measurable-heat purposes
- 4 **Process emissions** — non-combustion $\text{CO}_2 \times 0.97$

Our case study uses two of these: a fuel-benchmark sub-installation (the gas-fired furnaces) and a process-emissions sub-installation — both on the carbon-leakage list and both CBAM (the plant makes billets).

Sources: FAR 2019/331 Arts. 10 & 16 (fallback hierarchy); GD9; Annex I to Directive 2003/87/EC (activity 8). [ETS/]

AT A GLANCE

Primary vs secondary aluminium — the whole distinction on one slide

	Primary (electrolytic)	Secondary (scrap)
Route	Alumina → electrolysis → cast	Scrap → remelting → cast
Main direct CO ₂	Carbon-anode consumption	Fuel combustion (natural gas)
PFCs (CF ₄ , C ₂ F ₆)	Yes — from the anode effect	No
Electricity footprint	Very high (mostly indirect)	Low
EU ETS product benchmark	Yes — 1.464 t CO ₂ e/t	None → fallback (fuel + process)
Allocation basis	Product BM × HAL	Fuel BM × HAL + process × 0.97
CBAM benchmark (CN 7601)	1.423 t CO ₂ e/t (K)	0.091 t CO ₂ e/t (L)
CBAM exposure	High	Low — a structural advantage

Sources: FAR 2019/331 Annex I; GD9 §8–9; benchmark-curve factsheet (BM8, BM9); CBAM Reg 2025/2620 Annex (CN 7601, indicators K & L). [ETS/ · CBAM/ · reasearch material/]



RECAP

What we covered — benchmarks & boundaries

Primary aluminium

Product benchmark 1.464 t CO₂e/t; electrolysis only; CBAM good; PFCs included

Pre-bake anode

Product benchmark 0.312 t CO₂e/t; carbon-leakage but NOT a CBAM good

Secondary aluminium

No product benchmark → fallback (heat / fuel / process)

CBAM still applies

Secondary products are CBAM goods, so the CBAM factor still phases out their allocation

Next: system boundaries, sub-installations & BDR data.



DAY 4

Agenda for the day

1

Introduction: aluminium in the EU ETS and CBAM

2

The two routes & how the CO₂ is counted (MRV)

3

EU ETS benchmarks — primary aluminium & pre-bake anode (and why secondary has none)

4

System boundaries, sub-installations & BDR data

5

CBAM and aluminium

6

Worked calculation: free allocation × CBAM factor

7

Full case study: a secondary-aluminium plant (Schema → MP/MMP → AER → ALC)

Case study



SYSTEM BOUNDARIES

Sub-installations for an aluminium installation

Primary smelter

- Aluminium product-benchmark sub-installation = the electrolysis step
- Pre-bake anode sub-installation (if anodes are made on site)
- Casting / holding furnaces → fallback (fuel / heat) sub-installations
- Electricity is excluded from every direct boundary

Secondary (scrap) plant

- Fuel-benchmark sub-installation = fuel burned in the melting/casting furnaces (CL | CBAM)
- Process-emissions sub-installation = non-combustion CO₂ (CL | CBAM)
- No product-benchmark sub-installation (none exists for secondary Al)
- Heat-benchmark sub-installation only if measurable heat is exported (not here)

No double counting: each emission is attributed to exactly one sub-installation, following the hierarchy product → heat → fuel → process.

Sources: FAR 2019/331 (sub-installation attribution, Art. 10 & Annex VII); GD9 §8–9. [ETS/]



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CBAM INTERFACE

From billet to sheet — how embedded emissions add up



The interface — one dataset, three uses

- The same verified installation data feeds the EU ETS benchmark, the free allocation, AND the importer's CBAM bill.
- A billet's emission number becomes the starting point for any sheet, profile or foil made from it.
- Get the precursor data right and everything downstream follows; get it wrong and default values cascade through the whole chain.

Sources: JRC 2023 (finished products finalised from unwrought metal); CBAM calculation methods — Reg 2025/2620 & Implementing Reg 2023/1773. [research material/ · CBAM/]



CBAM — REG. (EU) 2025/2547

Determining embedded emissions — the 2026 rulebook

What this regulation is

- **Implementing Regulation (EU) 2025/2547** (10 Dec 2025) — calculation methods for embedded emissions under Art. 7(7) of the CBAM Regulation
- **Applies to goods imported from 2026**; supersedes the transitional methodology (Reg. 2023/1773)
- **Explicitly built on EU ETS MRV**: 'calculation methods must be based on the methodology applicable under the EU ETS ... as specified in Reg. 2018/2066' (recital 1)
- **Actual values are the primary route**; default values (Arts. 11–12) are the fallback

1

System boundaries per goods category — Annex I

2

Installation-level monitoring of direct emissions — Annex II

3

Attribution to production processes — Annex III

4

Specific embedded emissions per tonne (+ precursors)

5

Operator emissions report — in English (Art. 10)

Reading key: wherever a rule looks familiar from the MRR, that is by design — we will flag the genuine differences as we go.

Source: Implementing Regulation (EU) 2025/2547 (OJ L, 22.12.2025) — recitals 1–5, Arts. 1–12. [CBAM/]



CBAM — REG. (EU) 2025/2547

Aluminium under CBAM — goods, gases and system boundaries

Aggregated goods categories (Annex I)

- **Unwrought aluminium — CN 7601:** ingots, slabs, billets, granules; liquid Al in integrated plants
- **Aluminium products — CN 7603–7616:** profiles, wire, sheet, foil, tubes, structures...
- **Gases:** CO₂ and perfluorocarbons — for both categories
- **Scrap (CN 7602) is not a CBAM good** — and enters production with zero embedded emissions

Primary (electrolytic) route — direct-emission boundary

- CO₂ from electrode / paste consumption · all fuels used (drying, cell heating, casting) · waste-gas treatment (soda ash, limestone) · PFCs per Annex II B.7

Secondary (recycling) route — direct-emission boundary

- Fuels for scrap pretreatment (de-coating, de-oiling), melting, dross/slag treatment and casting · waste-gas treatment. Unwrought Al added from other sources = a precursor

Direct emissions only: aluminium is listed in Annex II of Reg. (EU) 2023/956 — its embedded emissions cover direct emissions (incl. heat), not electricity (Art. 3(2) of 2025/2547).

Source: Reg. (EU) 2025/2547 — Annex I §§2, 3.17–3.18 (boundaries), Art. 3 (system boundaries), Annex IV §2 (parameters).



CBAM — REG. (EU) 2025/2547

PFCs under CBAM (Annex II B.7) — same methods, finer defaults

Identical equations: Method A (slope, Eqs. 21–23) · Method B (overtoltage, Eqs. 24–25) · collection efficiency for fugitives (Eq. 20) · same GWPs: CF₄ 6 630, C₂F₆ 11 100 (section G)

Slope defaults (Table 2)	SEF(CF ₄)	F(C ₂ F ₆)
PFPB L — point-feed prebake, legacy	0.122	0.097
PFPB M — point-feed prebake, modern	0.104	0.057
PFPB MW — no automated AE intervention	own measurement*	
CWPB — centre-worked prebake	0.143	0.121
SWPB — side-worked prebake	0.233	0.280
VSS / HSS — Søderberg	0.058 / 0.165	0.086 / 0.077

What differs from the MRR

- **Seven technology classes** instead of the MRR's two (CWPB, VSS) — incl. point-feed prebake variants
- **Overtoltage defaults:** CWPB 1.16 · SWPB 3.65 (Table 3)
- **Installation-specific factors** = 'recommended improvement' (±15 %, ≥ every 3 years) — mirrors MRR Tier 2
- ***PFPB MW:** if measurement is infeasible/too costly, CWPB values apply

Source: Reg. (EU) 2025/2547 — Annex II B.7, Tables 2–3, section G Table 6 (GWPs). [CBAM/]

CBAM — REG. (EU) 2025/2547

From installation totals to the production process (Annex III)

$$\text{AttrEm}(\text{Dir}) = \text{DirEm}^* + \text{Em}(\text{H}, \text{imp}) - \text{Em}(\text{H}, \text{exp}) + \text{WG}(\text{imp}) - \text{WG}(\text{exp}) - \text{Em}(\text{el}, \text{prod}) \quad \text{SEE}(\text{Dir}) = \text{AttrEm}(\text{Dir}) / \text{AL}$$

Term	Meaning (period totals, t CO ₂ e)
DirEm*	Direct emissions of the production process (Annex II, section B)
Em(H,imp/exp)	Emissions embodied in measurable heat imported / exported ($Q \times \text{EF}(\text{heat})$, Eq. 52)
WG(imp/exp)	Corrections for waste gases imported / exported
Em(el,prod)	Emissions of electricity produced within the process — deducted
AL	Activity level: tonnes of goods leaving the process (Annex II, section F)

Rules that matter

- Negative AttrEm → set to zero (Eq. 55)
- AL counts only saleable/usable goods — off-spec, by-products, waste and scrap are excluded
- ...and therefore enter downstream processes with zero embedded emissions
- For a standalone smelter: Eq. 55 usually collapses to DirEm*

SEE — specific embedded emissions: t CO₂e per tonne of good, per production process and reference period (calendar year) — the number the importer ultimately declares.

Source: Reg. (EU) 2025/2547 — Annex III §8A.1–A.3 (Eqs. 41–42, 52, 55, 57); Annex II §F; Art. 7 (reference period).



Complex goods — adding the precursors (Annex III B)

$$SEE(g) = (AttrEm(g) + EE(InpMat)) / AL(g) \quad EE(InpMat) = \sum_i M_i \times SEE_i \quad (\text{Eqs. 59–60})$$

How it plays out for aluminium

- **Secondary melting:** purchased unwrought aluminium added to the melt = precursor; scrap = zero
- **Aluminium products (CN 7603–7616):** the unwrought aluminium input is the precursor
- **Same installation:** precursor + complex good may form one common production process (Art. 4(9)) — then no internal precursor accounting

Precursor data set (Annex II E)

- Specific direct & indirect embedded emissions, averaged over the supplier's reference period
- Production route, installation identity, country of origin
- **Several suppliers / periods:** weighted average per CN code (Art. 14)
- **Gaps:** default values may be combined with actual values (Art. 15)

The cascade: the billet's SEE becomes an input to the profile's SEE — one weak link in the data chain and default values propagate downstream.

Source: Reg. (EU) 2025/2547 — Annex III §B (Eqs. 59–60), Annex II §E, Arts. 4(9), 13–15. [CBAM/]

CBAM vs EU ETS

Same engine, different purpose — the comparison

Aspect	EU ETS (MRR 2018/2066)	CBAM (Reg. 2025/2547)
Objective	Installation compliance — surrender EUAs	Embedded emissions of goods for importers
Output	t CO ₂ e per installation-year (AER)	SEE — t CO ₂ e per tonne, per production process
Boundary	The permitted installation	Production process + precursor chain
Methods	Art. 24/25 calculation or measurement	Same equations (Eqs. 5, 11, 12) + same PFC methods
Electricity	Excluded from direct emissions	Excluded for aluminium (Annex II good — direct only)
PFC defaults	2 technology classes (Tier 1)	7 technology classes (Table 2); same GWPs
Data quality	Tier system, CA-approved monitoring plan	Best available data; minimum + recommended; plan in English
Fallback	No defaults — gaps need conservative estimates	Default values permitted (Arts. 11–12, 15)

Bottom line: for an installation with EU ETS-grade monitoring, CBAM is chiefly an attribution and documentation exercise — the measurement layer is already in place.

Sources: MRR (EU) 2018/2066; Reg. (EU) 2025/2547 (Arts. 3–15, Annexes I–IV). [MRV / • CBAM/]



SYNTHESIS

The whole day in one view

Aluminium matters

Two routes: primary (electrolysis, intensive) and secondary (scrap, low-carbon)

Count the CO₂ (MRV)

Primary: anode CO₂ + PFCs + electricity; secondary: fuel combustion

Benchmarks

Primary 1.464, pre-bake anode 0.312 t CO₂e/t; secondary has NO product benchmark

Secondary = fallback

Fuel-benchmark + process-emissions sub-installations (CL | CBAM)

Allocation × CBAM

$F = BM \times HAL \times CLEF \times CBAM \text{ factor} \rightarrow$ phases to 0 by 2034 for CBAM goods

CBAM exposure

Billets: secondary 0.091 vs primary 1.423 t CO₂e/t — recycling is a structural advantage

The same verified emissions & activity data must serve EU ETS free allocation AND CBAM — for both the primary and the secondary route.

Interactive Q&A



partici.fi/23503622





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- 6 Worked calculation: free allocation × CBAM factor**
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Case study



MASS BALANCE — WORKED EXAMPLE

Worked example — electrolysis mass balance (100 kt/yr)

Source stream	AD (t)	CC (t C/t)	Carbon (t C)
Baked anodes set in cells	+ 55 000	0.98	+ 53 900
Anode butts recovered	– 13 000	0.98	– 12 740
Stock change (rodded anodes)	0	—	0
Net carbon oxidised			41 160

$$Em = 41\,160 \text{ t C} \times 3.664 = 150\,800 \text{ t CO}_2$$

$$\rightarrow 1.51 \text{ t CO}_2 / \text{t Al}$$

Read it

- **Net anode consumption** = 0.42 t/t Al — typical for a CWPB smelter
- **CC = 0.98**: monthly lab analyses; ash and sulphur keep it below 1
- **AD**: anodes counted by the crane system × certified unit mass; butts weighed on the return conveyor
- **Consistent with the 1.464 benchmark** (which adds PFCs but excludes anode production and casting)

Check the order of magnitude: $0.42 \text{ t/t} \times 0.98 \times 3.664 \approx 1.5 \text{ t CO}_2/\text{t Al}$ — if a smelter reports far less, look for missing butts symmetry or an inflated carbon output.

Illustrative figures; method per MRR Art. 25 & Annex IV §7. Anode-consumption range per bm study aluminium (2009).



PFC — WORKED EXAMPLE

Worked example — PFCs of the 100 000 t/yr smelter (Method A)

Parameter	Value	Source
Technology	CWPB — Tier 1	Monitoring plan
AE frequency	0.05 AE/cell-day	Cell control logs
Mean AE duration	1.5 min	Cell control logs
AEM = 0.05 × 1.5	0.075 min/cell-day	Calculated
SEF(CF ₄) · F(C ₂ F ₆)	0.143 · 0.121	Annex IV Table 1

$$\text{CF}_4 = 0.075 \times 0.143 / 1\,000 \times 100\,000 = 1.07 \text{ t}$$
$$\text{C}_2\text{F}_6 = 1.07 \times 0.121 = 0.13 \text{ t}$$

Convert to CO₂e (Annex VI, Table 6)

$$1.07 \text{ t CF}_4 \times 6\,630 = 7\,110 \text{ t CO}_2\text{e}$$

$$0.13 \text{ t C}_2\text{F}_6 \times 11\,100 = 1\,440 \text{ t CO}_2\text{e}$$

$$\text{Total} \approx 8\,550 \text{ t CO}_2\text{e} \rightarrow 0.086 \text{ t CO}_2\text{e/t Al}$$

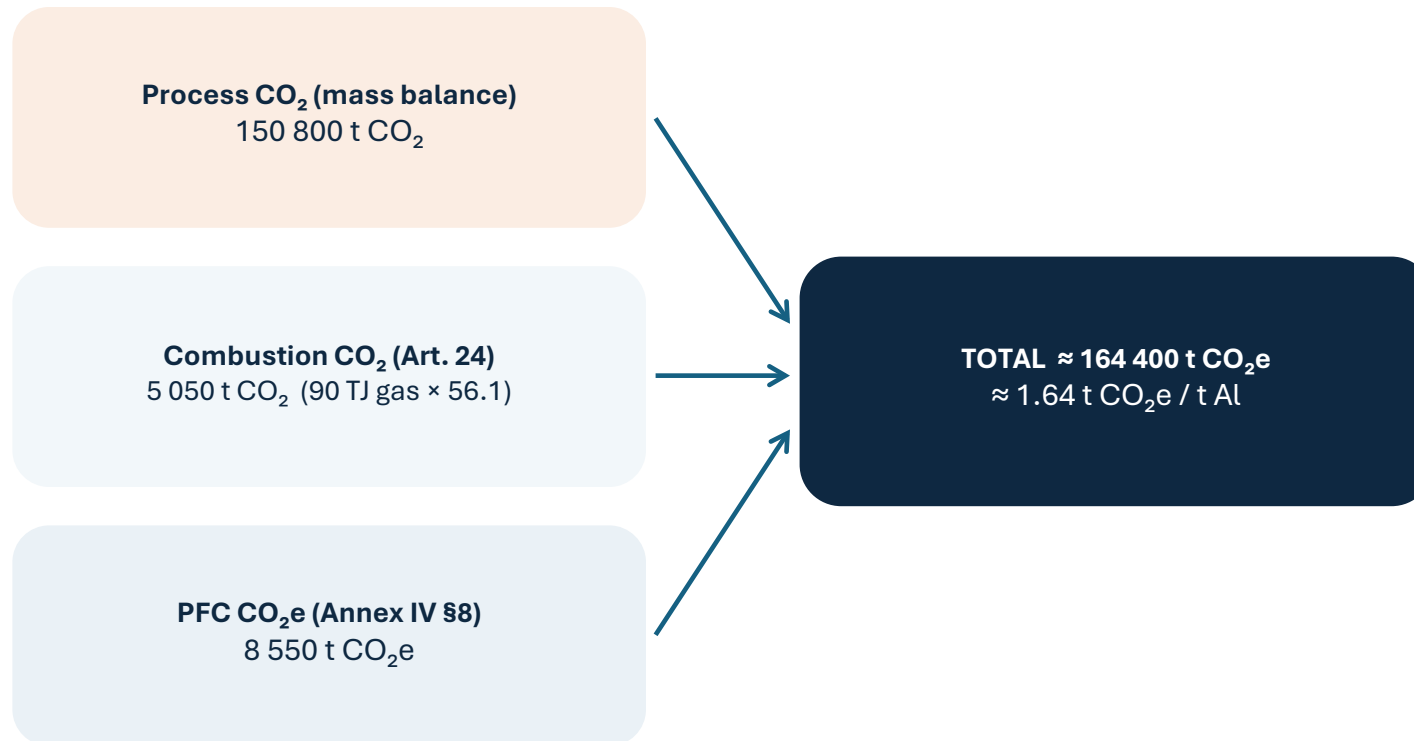
Context: well-controlled modern cells run ≈ 0.02–0.1 t CO₂e/t; poorly controlled or Söderberg plants can be several times higher. Tier 1 defaults are deliberately conservative.

Illustrative figures; method & factors per MRR Annex IV §8 Table 1, GWPs per Annex VI Table 6.



REPORTING — EU ETS

From three calculations to one verified annual report



The AER for aluminium (Annex X)

- Process CO₂, combustion CO₂ and PFC CO₂e reported separately — then summed
- AE frequency & duration (or overvoltage) data reported
- Documentation of Tier 2 factor campaigns and of the collection-efficiency determination
- Verified under AVR (EU) 2018/2067 before 31 March

Same data, three uses: the verified AER feeds compliance, the activity-level reporting for free allocation (MMP/ALR) — and, as we will see, the CBAM embedded-emissions calculation.

Sources: MRR (EU) 2018/2066 Annex X (aluminium-specific AER content), Annex VI Table 6; AVR (EU) 2018/2067.



WORKED CALCULATION

Free-allocation formula and the CBAM factor

$$F_{p,k} = BM_p \times HAL_p \times CLEF_{p,k} \times CBAM_{p,k}$$

- **BM** = benchmark value. For a fuel sub-installation = the fuel benchmark (allowances/TJ); for a process sub-installation = historical process CO₂ × 0.97.
- **HAL** = median historical activity level (TJ of fuel, or t CO₂ of process emissions over the baseline years).
- **CLEF** = carbon-leakage exposure factor = 1 (100%) — secondary aluminium is on the carbon-leakage list.
- **CBAM factor** = phases the free allocation out for CBAM goods: 0.975 (2026) · 0.95 (2027) · 0.90 (2028) · 0.775 (2029) · 0.515 (2030) → 0 (2034).

Note: fuel/heat benchmark and process-factor values follow the Commission P4 NIMs template; the official 2026–2030 fallback values will be set by the implementing act.

Sources: Directive 2003/87/EC Art. 10a (CBAM factor); FAR 2019/331 Arts. 10 & 16; GD2 (free-allocation calculation). [ETS/]



WORKED CALCULATION

Primary aluminium — illustrative product-benchmark allocation

Sub-installation	Benchmark (2021–25)	Annual production (HAL)
Primary aluminium (electrolysis)	Aluminium — 1.464 t CO ₂ e/t	100,000 t Al/yr (illustrative)

Year	CBAM factor	Free allocation = 1.464 × 100,000 × 1 × factor
2025	1.000	146,400 EUA
2026	0.975	142,740 EUA
2028	0.900	131,760 EUA
2030	0.515	75,396 EUA

Read it

- A primary smelter's free allocation roughly halves by 2030 and ends in 2034 — its CBAM exposure is large because the benchmark itself is high (1.464 t CO₂e/t).
- Now compare this with the secondary plant in the case study, where the same CBAM factor applies but the underlying emissions are far lower.

Production figure illustrative; benchmark = official applied 2021–25 value; CBAM factor: Directive 2003/87/EC Art. 10a. Arithmetic by the trainer.



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- 7 **Full case study: a secondary-aluminium plant (Schema → MP/MMP → AER → ALC)**

Case study



CASE STUDY — A REAL SECONDARY-ALUMINIUM PLANT

The installation: what it is and how EUAs are allocated

The installation

- A secondary-aluminium foundry: it remelts aluminium scrap and casts billets
- Annex I activity: 'production of secondary aluminium where combustion units > 20 MW operate' — total rated thermal input $\approx$ 45 MW
- Main fuel: natural gas, fired in melting, casting & homogenising furnaces
- Started operation mid-2020 $\rightarrow$ 2020 is a partial year

How it allocates

- No product benchmark exists for secondary aluminium
- Two fallback sub-installations, both Carbon-Leakage listed and both CBAM:
 - Fuel-benchmark sub-installation (the gas furnaces) $\approx$ 99% of emissions
 - Process-emissions sub-installation (non-combustion CO₂) < 1%
- Product: unwrought aluminium billets, CN 7601 20 40 $\rightarrow$ a CBAM good

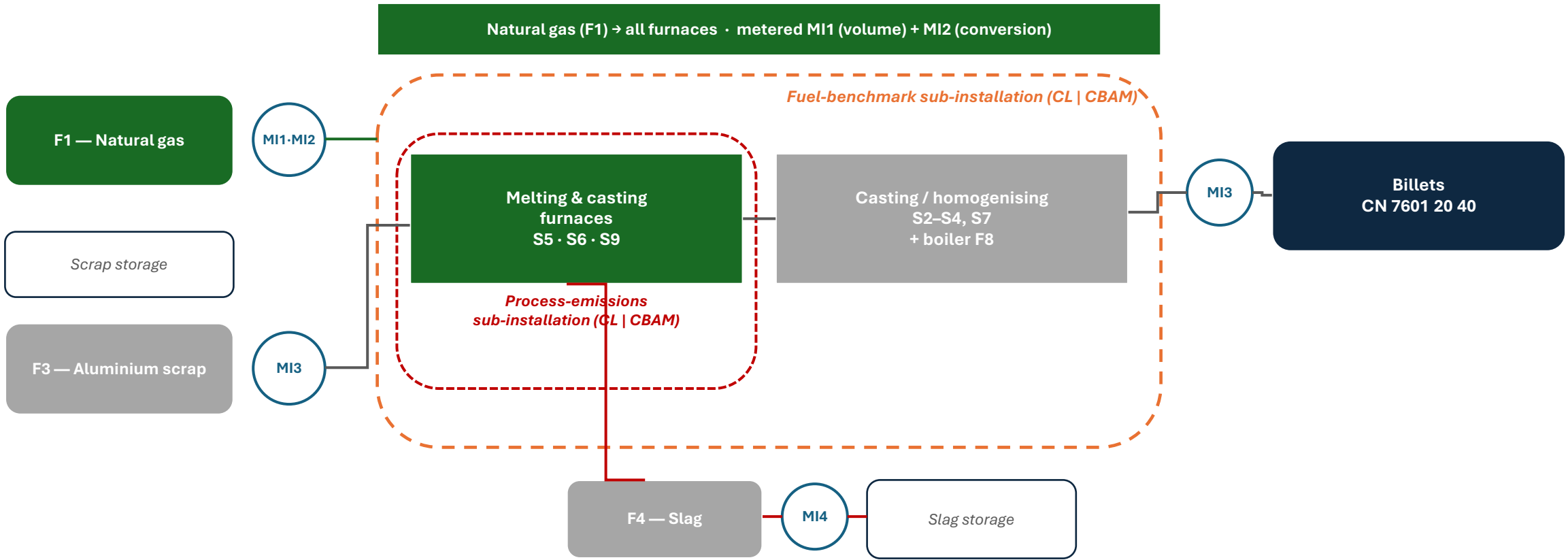
Operator: anonymised · Installation: secondary-aluminium foundry (anonymised) · Permit no.: anonymised · all brand/equipment names removed

Source: anonymised real EU installation — block-flow schema, monitoring plan, MMP, BDR/NIMs baseline & AER. [uploaded example]



CASE STUDY · secondary aluminium plant - Annual emission report

Source streams, emission sources & the two sub-installations



Source: block-flow schema (anonymised real EU secondary-aluminium plant); monitoring plan. Equipment brand names removed. [uploaded example]



CASE STUDY · secondary aluminium plant - Annual emission report

Emission sources, source streams & measuring instruments (anonymised)

Ref.	Emission source (generic)
S1	Generator set (excluded — emergency)
S2	Casting furnace
S3	Homogenising furnace
S4	Batch homogenising furnace
S5	Twin-chamber melting furnace
S6	Twin-chamber melting furnace
S7	Batch homogenising furnace
S8	Sanitary boiler
S9	Melting & casting furnace

Ref.	Source stream	Measured by
F1	Natural gas	S1 volume meter + S2 conversion
F3	Aluminium scrap	S3 weighbridge
F4	Slag	S4 weighbridge

Reading the schema

- Red-outline boxes = major flows; grey-fill = de minimis flows
- Circles = measuring instruments (S1–S4)
- Orange boxes = emission sources (furnaces/boiler)
- Dashed boxes = material storage (no emissions)

Source: schema legend (anonymised); all operator/site/permit identifiers and equipment brands removed. [uploaded example]



What the MP fixes for each source stream

Per source stream, the MP defines

- Monitoring approach — calculation-based
- Natural gas (CM1): standard method 'fuel', MRR Art. 24(1); activity data = gas volume (Nm³)
- Activity data: gas via volume meter (S1) + conversion device (S2); scrap & slag via weighbridge (S3/S4)
- Emission factor, NCV, oxidation factor — and the TIER for each parameter
- Process / non-combustion CO₂: defined as a separate source stream

Why it matters

- The MP is approved by the competent authority
- It is the contract: the AER must follow it, and the verifier checks against it
- A national ETS needs the same: one approved plan per installation

A 'tier' is a predefined level of data quality/accuracy under the MRR (Reg. 2018/2066). Higher tiers require greater accuracy but are more demanding and costly to achieve.

Source: monitoring plan (anonymised real example), sheet 'E_SourceStreams'; MRR (EU) 2018/2066. [uploaded example]



CASE STUDY · secondary aluminium plant - Annual emission report

How the CO₂ is computed — combustion of natural gas

$$E_{\text{CO}_2} = \Sigma (\text{Activity data [Nm}^3 \rightarrow \text{TJ via NCV]} \times \text{EF} \times \text{OF})$$

Natural-gas parameters

- Activity data: gas volume (Nm³) → energy (TJ) via net calorific value (NCV)
- Emission factor (EF) ≈ 56.1 t CO₂/TJ (effective value derived from the data ≈ 56)
- Oxidation factor (OF) = 1; biomass fraction = 0
- Plus a small non-combustion process CO₂ stream (< 1%)

Year	Energy in (TJ)	Combustion CO ₂ (t)
2021	325	17,900
2022	305	16,900
2023	280	15,600

Check: 18,100 t (2021 total) ÷ 325 TJ ≈ 56 t CO₂/TJ — consistent with the natural-gas default. Combustion is ≈ 99% of the total; process CO₂ makes up the rest.

Source: AER (anonymised real example), sheet 'C_SourceStreams'; MRR Art. 24. Gas EF derived from reported totals (the dedicated EF file is encrypted; to be confirmed). [uploaded example]



CASE STUDY · secondary aluminium plant - Annual emission report

What the verified years look like

Year	Total CO ₂ (t)	Fuel comb.	Process	Energy (TJ)
2020 *	8,800	≈ 8,800	≈ 0	160
2021	18,100	17,900	160	325
2022	17,100	16,900	150	305
2023	15,800	15,600	120	280

* 2020 is a partial start-up year (operation began mid-2020).

What it tells us

- Fuel combustion ≈ 99% of CO₂
- Process CO₂ < 1% (≈ 0.75–0.9%)
- No biomass, no PFCs (no electrolysis)
- Emissions track production year to year

Source: EU ETS Annual Emissions Reports + BDR/NIMs baseline 'D_Emissions' (anonymised, figures as reported). [uploaded example]



CASE STUDY · secondary aluminium plant – Free allocation

The plan for the FREE-ALLOCATION data

What the MMP defines

- The MP (Doc 2) covers EMISSIONS; the MMP covers the data needed for FREE ALLOCATION
- Required by FAR Art. 8 — approved by the competent authority
- Methods & procedures to determine the ANNUAL ACTIVITY LEVEL of each sub-installation
- How emissions/energy are attributed to the fuel and process sub-installations
- Feeds the yearly Activity Level Reports (ALR) used to adjust allocation

MP vs MMP

- MP → annual EMISSIONS (MRR)
- MMP → annual ACTIVITY LEVELS & allocation data (FAR)
- BDR/NIMs → the baseline that sets the initial allocation
- ALR → yearly activity levels → annual allocation adjustment

Together they form one verified data system — the same emissions data, used for compliance (MP) and for allocation (MMP).

Source: MMP P4 template (anonymised real example); FAR 2019/331 Art. 8 & Annex VI; GD5. [uploaded example]



CASE STUDY · secondary aluminium plant – Free allocation

How the plant is split for free allocation

Fuel-benchmark sub-installation (CL | CBAM)

- Covers fuel burned in the furnaces for melting, casting & homogenising
- Activity level = energy input from fuel (TJ/yr)
- $\approx 99\%$ of the installation's CO_2
- Allocation = fuel benchmark $\times$ HAL $\times$ CLEF $\times$ CBAM factor

Process-emissions sub-installation (CL | CBAM)

- Covers non-combustion process CO_2 (e.g. carbon-bearing additives/fluxes)
- Activity level = process CO_2 (t/yr)
- $< 1\%$ of the installation's CO_2
- Allocation = process CO_2 (HAL) $\times 0.97 \times$ CLEF $\times$ CBAM factor

Both are on the carbon-leakage list $\rightarrow$ CLEF = 1. Both produce a CBAM good (billets) $\rightarrow$ the CBAM factor applies and the free allocation phases out.

Source: BDR/NIMs baseline, sheet 'G_Fall-back' & 'K_Summary' (anonymised); FAR 2019/331 Arts. 10 & 16. [uploaded example]



CASE STUDY · secondary aluminium plant – Free allocation

From the baseline years to the historical activity level

Sub-installation	2021	2022	2023	HAL (median)
Fuel benchmark — fuel input (TJ)	325	280	305	305 TJ
Process emissions — CO ₂ (t)	160	120	150	150 t CO ₂ e

How HAL is set

- The Historical Activity Level (HAL) = the MEDIAN of the activity level over the baseline years (here the three complete years 2021–2023; the partial 2020 is excluded as non-representative).
- Fuel sub-installation HAL = 305 TJ. Process sub-installation HAL = 150 t CO₂e.

Source: BDR/NIMs baseline 'G_Fall-back' & 'K_Summary' (anonymised); FAR 2019/331 Art. 15 (median rule). [uploaded example]



CASE STUDY · secondary aluminium plant – Free allocation

The worked free-allocation calculation

The two sub-installation formulas

- Fuel sub-installation: $F = \text{Fuel BM (28.05 allow./TJ)} \times 305 \text{ TJ} \times \text{CLEF (1)} \times \text{CBAM factor} \rightarrow \text{base} \approx 8,600 \text{ EUA}$
- Process sub-installation: $F = 150 \text{ t} \times 0.97 \times \text{CLEF (1)} \times \text{CBAM factor} \rightarrow \text{base} \approx 150 \text{ EUA}$

Year	CBAM factor	Fuel sub (EUA)	Process sub (EUA)	Total free allocation
2025	1.000	8,600	150	8,750
2026	0.975	8,390	150	8,540
2027	0.950	8,170	150	8,320
2028	0.900	7,740	140	7,880
2030	0.515	4,430	80	4,510

Note: the fuel benchmark value (28.05 allow./TJ) follows the Commission P4 NIMs template; official 2026–2030 fallback values will be set by the implementing act. Activity levels are real (anonymised).

Source: ALC from BDR/NIMs baseline (anonymised); FAR 2019/331 Arts. 10 & 16; CBAM factor Directive 2003/87/EC Art. 10a. Arithmetic by the trainer.



CASE STUDY · secondary aluminium plant

The squeeze: free allocation shrinks, emissions don't

Actual emissions (avg 2021–23)

≈ 17,000 t CO₂/yr

mostly natural-gas combustion

Free allocation 2026

8,540 EUA

≈ 50% of emissions

Free allocation 2030

4,510 EUA

≈ 27% of emissions

What it means

- Even at the start, free allocation covers only about half the emissions — the fuel benchmark is stringent (≈ 28 vs ≈ 56 t CO₂/TJ for gas).
- The CBAM factor then phases the free allocation down: from ≈ 8,540 EUA (2026) to ≈ 4,510 EUA (2030), ending in 2034.
- Shortfall to cover with purchased allowances (or abatement): ≈ 8,500 in 2026, rising to ≈ 12,500 by 2030.
- Lever: switch to lower-carbon energy, improve furnace efficiency, or increase recycled input.

Free allocation from the ALC (Doc 7); actual emissions from the AER (Doc 4). CBAM factor: Directive 2003/87/EC Art. 10a.

CASE STUDY · THE CBAM SIDE

The billets are a CBAM good — secondary vs primary

CBAM good	CN code	CBAM benchmark — primary (K)	CBAM benchmark — secondary (L)
Unwrought aluminium alloy billets	7601 20 40	1.423 t CO ₂ e/t	0.091 t CO ₂ e/t
Unwrought aluminium (general)	7601	1.423 t CO ₂ e/t	0.091 t CO ₂ e/t

Secondary route (this plant)

0.091 t CO₂e/t

CBAM benchmark, indicator (L) — recycled

Primary route (for comparison)

1.423 t CO₂e/t

CBAM benchmark, indicator (K) — electrolytic

≈ 16× lower. A Turkish secondary-aluminium exporter is structurally far less CBAM-exposed than a primary smelter — provided it can prove the recycled (secondary) emission intensity with verified data.

Sources: CBAM Reg 2025/2620 Annex (CN 7601, indicators K & L); CBAM Reg 2023/956 Annex I (goods scope). [CBAM/]

Interactive Q&A



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CLOSE

Aluminium – Day 4

Questions and discussion · Next: Day 5 — the MRV–allocation interface

Primary sources & references

- Free Allocation Regulation (EU) 2019/331 - Annex I, Annex IV; GD9 sec.8-9 (aluminium, pre-bake anode) [ETS/]
- Benchmark-curve factsheet (12 Oct 2021) - applied values BM8 & BM9 [research material/]
- CBAM Reg 2023/956 (goods scope) + Reg 2025/2620 Annex (CN 7601, indicators K & L) [CBAM/]
- MRR (EU) 2018/2066; AVR (EU) 2018/2067; case study from an anonymised real EU installation [uploaded example]