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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)

Iron & steel

Fabio Romani and Matias Franke

23 – 07 - 2026

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MODULE 2 — CBAM-RELEVANT PRODUCT BENCHMARKS BY SECTOR

Online Day 2 — Iron & Steel

Free allocation benchmarks · system boundaries · BDR data · worked calculation

BF / BOF integrated route

DRI / EAF gas-based primary

Scrap / EAF secondary route

Experts: F. Romani / M. Franke

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Training Presentation: iron & steel

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DAY 2

Agenda for the day

1	Introduction: Routes and benchmark map (EU ETS ↔ CBAM)	
2	How emissions are counted (MRV & mass balance)	
3	The production routes in technical detail & the benchmark curve	Detailed sector: Iron&steel
4	System boundaries and relation between EU ETS benchmarks and CBAM	Detailed sector: Iron&steel
5	Full worked calculation EAF – high alloy steel (Emissions + allocation + CBAM factor)	Case study: Iron&steel
6	Example of a full integrated plant (Emissions + allocation) - *overview*	Case study: Iron&steel
7	Q&A	

CONTINUITY

What is new in 2026

Covered in the 2024 training (Day 2)

- EU ETS iron & steel product benchmarks
- Blast-furnace and EAF system boundaries
- ETS layout of a steel plant

New focus in 2026

- The EU ETS ↔ CBAM interface
- Route-based CBAM benchmarks
- Crude-steel routes
- Free-allocation of iron and steel

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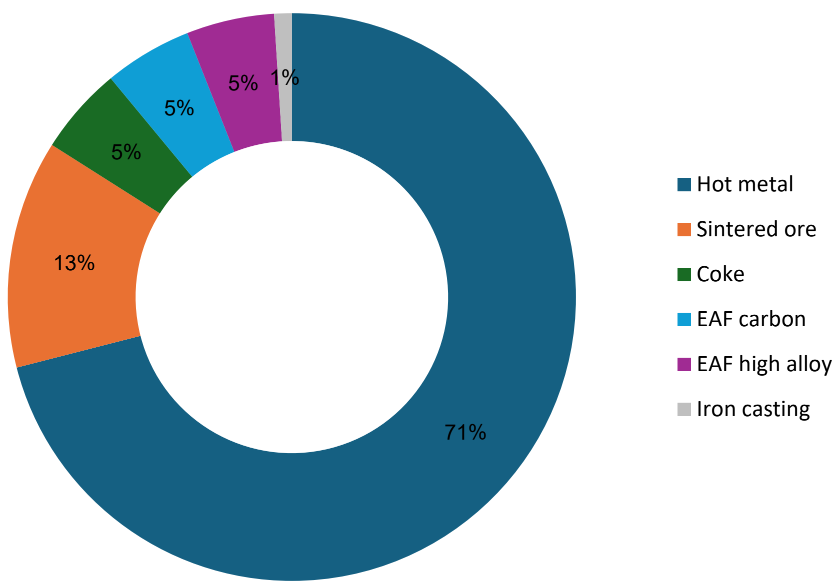
CONTEXT

Why iron & steel: weight in the EU ETS and CBAM

- Iron & steel is the largest product-benchmark sector in the EU ETS
- Hot metal dominates emissions within the sector
- All iron & steel benchmarks are on the carbon-leakage list (CLEF = 1)
- All are within CBAM scope — so free allocation is being phased out

Benchmarked emissions, metal sector (2016/17 avg)



Source: EU benchmark-curve factsheet, 12 Oct 2021 (attributed 2016/17 emissions). [reasearch material/]

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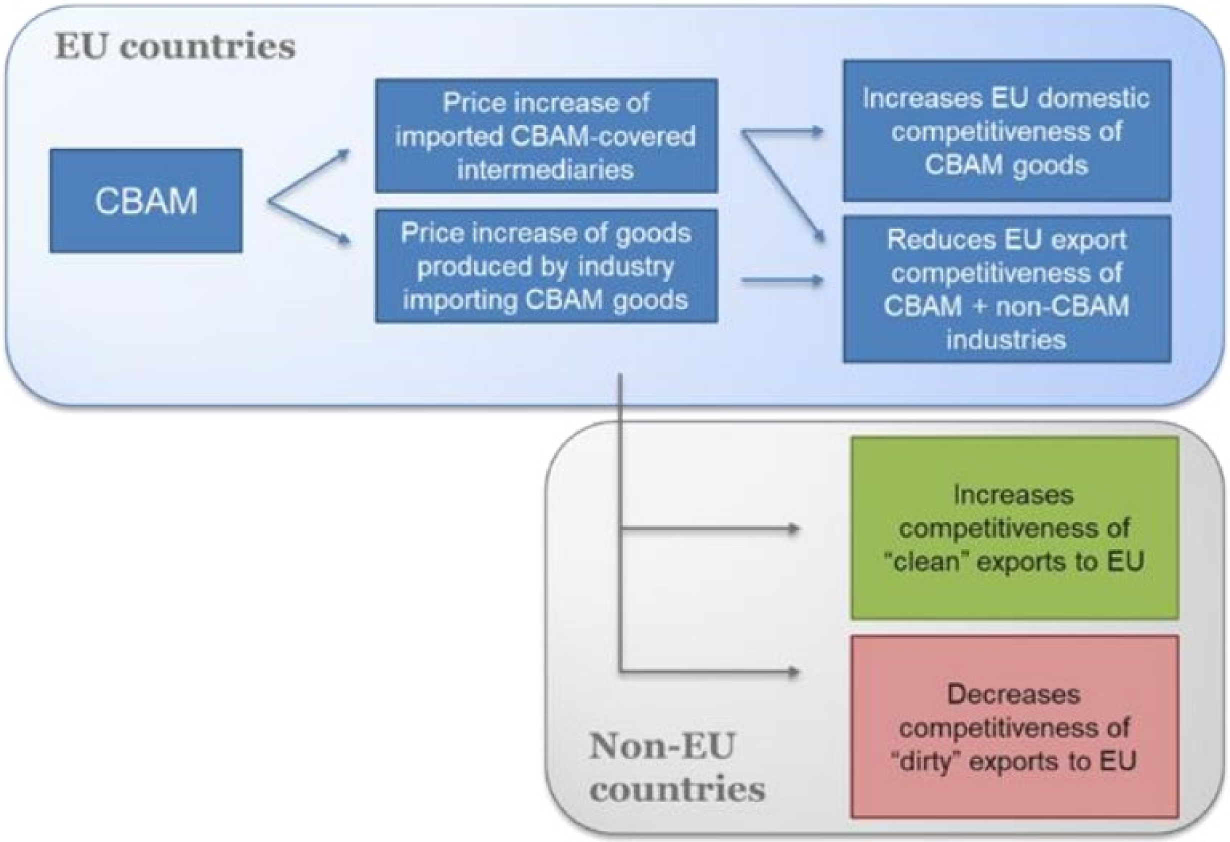
OECD - Carbon Border Adjustments: The potential effects of the EU CBAM along the supply chain

Value of imports covered by CBAM by exporting sector, 2022.



EU Countries

- Price increase of imported CBAM-covered intermediaries
- Price increase of goods produced by industry importing CBAM goods
- Increases EU domestic competitiveness of CBAM goods
- Reduces EU export competitiveness of CBAM + non-CBAM industries

Non-EU Countries

- Increases competitiveness of "clean" exports to EU
- Decreases competitiveness of "dirty" exports to EU

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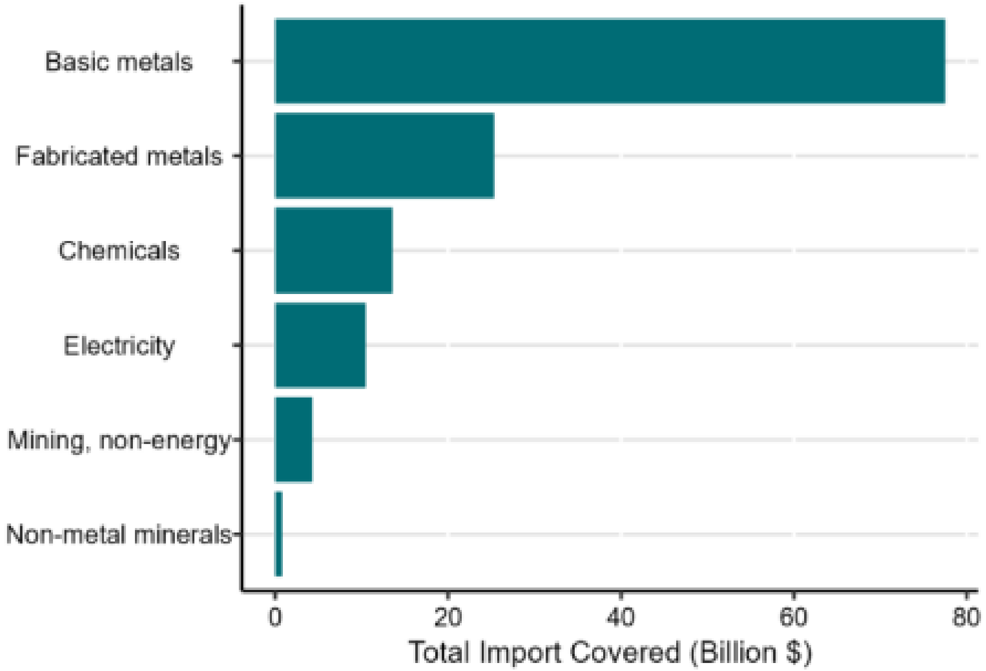
OECD - Carbon Border Adjustments: The potential effects of the EU CBAM along the supply chain

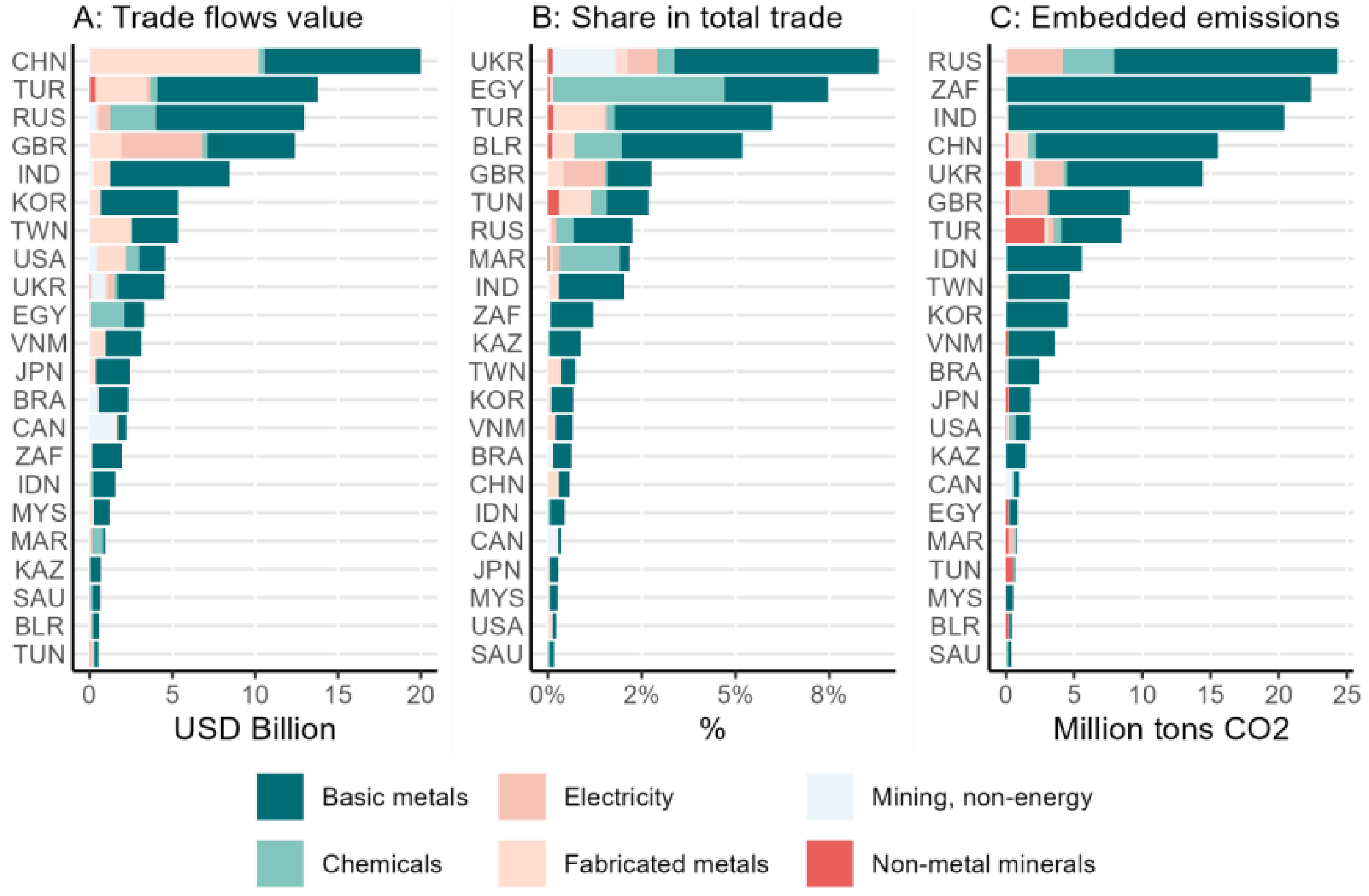
Value of imports covered by CBAM by exporting sector, 2022.



- **Basic metals** → Iron, steel, aluminium.
- **Fabricated metals** → Tubes, pipes, structures, screws, bolts, containers, cables, etc.
- **Chemicals** → Fertilisers and hydrogen.
- **Electricity** → Electrical energy.
- **Mining, non-energy** → Kaolinic clays and clinker.
- **Non-metal minerals** → Cement and clinker.

OECD - Carbon Border Adjustments: The potential effects of the EU CBAM along the supply chain

Trade and emission flows covered by the CBAM by exporting country and producing sector, 2022



- A: trade covered by CBAM
- B: that trade as a share of the exporter's total trade, and
- C: the resulting Scope 1 embedded emissions.
- Bars are split by sector and exporting country, using Comtrade data and 2019 emission intensities.
- Note: This reflects coverage, not the final cost, as existing carbon pricing abroad is not deducted.

CONTEXT — RESEARCH MATERIAL

CBAM coverage in numbers — where Türkiye stands

USD 132 billion covered

Only 0.37% of global trade in goods and services — but 3% of all non-EU exports to the EU

171 Mt CO_2e embedded

Emissions embedded in covered imports; ≈24% of them are Scope 2 and 3 (electricity, precursors)

Türkiye is No. 2

Covered trade by origin (2022): China USD 20.0 bn · Türkiye USD 13.8 bn · Russia USD 12.9 bn — mostly basic metals

≈ EUR 14.7 bn / year

Potential CBAM revenue at EUR 80/t CO_2 — a carbon price paid at origin is deducted and stays at home

Source: OECD — The potential effects of the EU CBAM along the supply chain (2022 trade data). [reasearch material/]

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Results

		EU ETS price	CBAM	Removal of free allowances
Baseline		EUR 25	No	No (2019 free allowance endowment)
Policy Scenarios	Scenario 1	EUR 80	No	Only non-EITE sectors
	Scenario 2	EUR 80	No	Non-EITE sectors and CBAM sectors
	Full Policy Mix	EUR 80	Yes	Non-EITE sectors and CBAM sectors

Baseline:
- The starting point: 2019 economy with a low carbon price (€25).
- No CBAM, and all sectors receive free allowances as they did that year.

Policy Scenario 2
- Builds on Scenario 1: the €80 carbon price remains.
- Now, free allowances are also removed for CBAM sectors.
- However, no CBA
M is in place yet, so these sectors face the full carbon price without border protection.

Full Policy Mix
- The most complete scenario: €80 carbon price, free allowances removed for both non-EITE and CBAM sectors, and CBAM is now introduced.
- This is the closest representation of the actual EU regulation – industries lose free allowances but gain border carbon adjustment protection via CBAM.

Policy Scenario 1
- Only the EU ETS reform is applied: carbon price jumps to €80.
- Free allowances are removed, but only for non-EITE sectors.
- CBAM sectors are still fully protected – they keep 100% of their free allowances.
- No CBAM is introduced.

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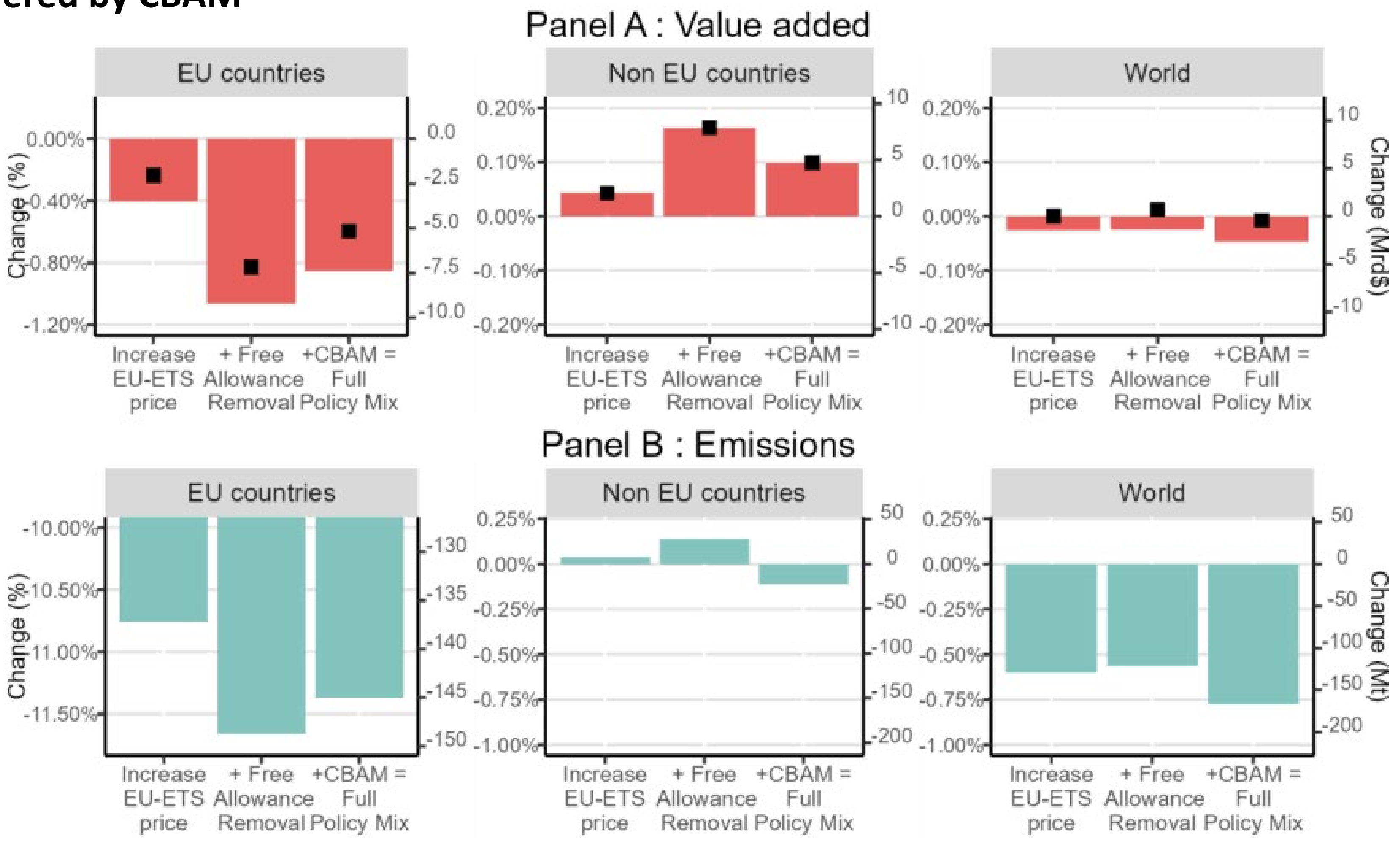
OECD - Carbon Border Adjustments: The potential effects of the EU CBAM along the supply chain

Results: only in the industries covered by CBAM



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CONTEXT — RESEARCH MATERIAL

Effects along the supply chain — beyond the covered sectors

Downstream cost push

Non-covered sectors (construction, electrical equipment, machinery) face higher input costs and lose competitiveness

83% of the loss

Non-targeted sectors carry 83% of the total EU value-added loss — the indirect, supply-chain effect dominates

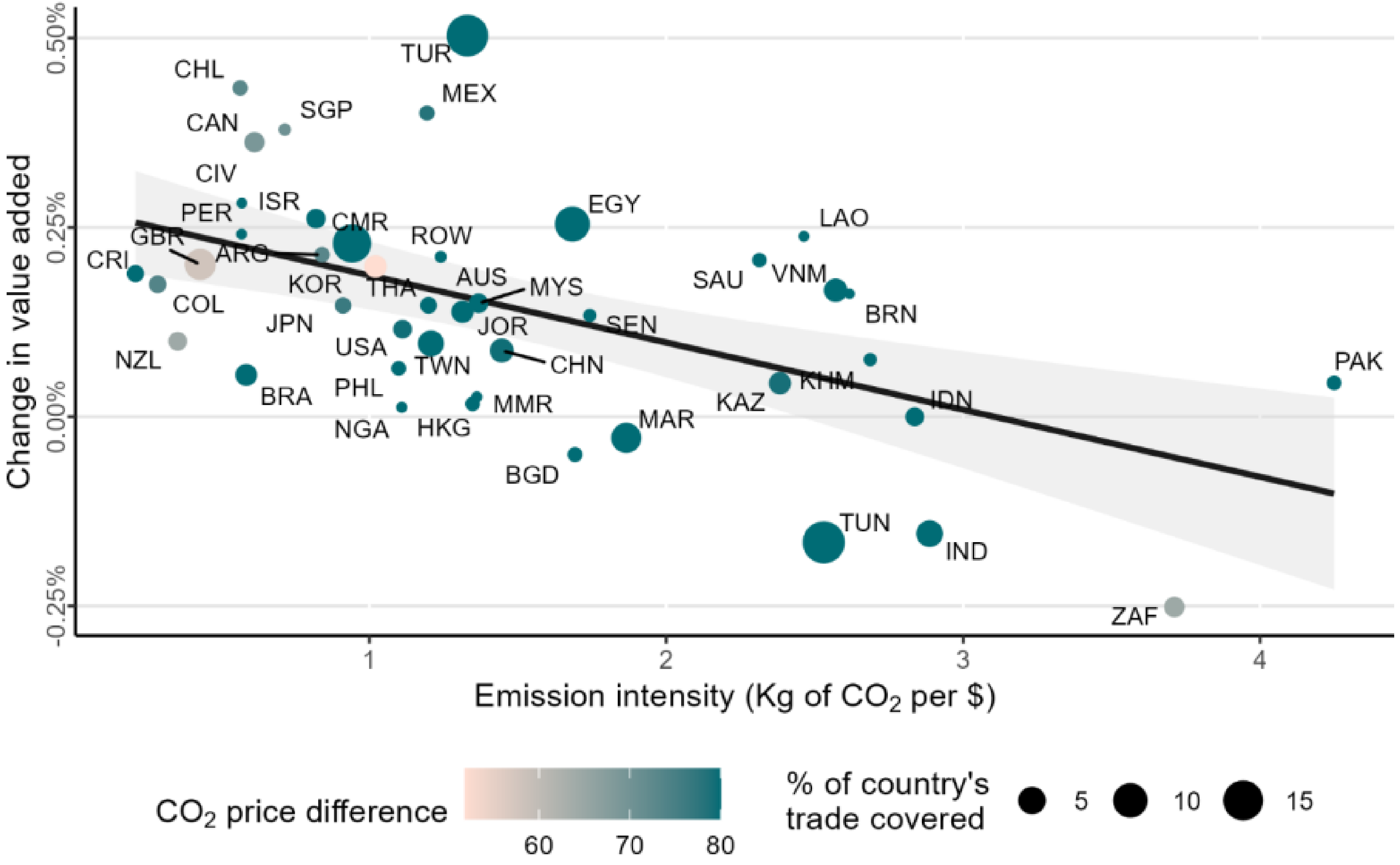
Macro effect unchanged

EU-wide value added falls ≈0.29% with or without CBAM — downstream losses offset gains in covered industries

Leakage reversed

Without CBAM, 0.19 t leak abroad per t saved in the EU; with CBAM, sourcing shifts to cleaner origins — global cuts rise 36%

Source: OECD — The potential effects of the EU CBAM along the supply chain. [reasearch material/]


Change in value added
0.50%
0.25%
0.00%
-0.25%
Emission intensity (Kg of CO2 per $)
1
2
3
4
TUR
CHL
MEX
SGP
CAN
CIV
ISR
EGY
PER
CMR
LAO
GBR
ROW
CRI
ARG
SAU
VNM
KOR
THA
AUS
MYS
COL
BRN
JPN
SEN
JOR
USA
NZL
CHN
TWN
PAK
PHL
KHM
BRA
MMR
KAZ
IDN
NGA
HKG
MAR
BGD
TUN
IND
ZAF
CO2 price difference
60
70
80
% of country's trade covered
5
10
15

CBAM — MAIN ELEMENTS

Five CBAM definitions to keep for the day

- **Embedded emissions** — direct (production) + indirect (electricity) emissions in a good, in t CO_2e/t — Reg (EU) 2023/956, Art. 3
- **Default values** — fallback emission intensities per CN code, used when actual data are missing — Reg (EU) 2025/2621
- **Precursor** — a CBAM good consumed to make another CBAM good; its embedded emissions carry into the final good
- **Verification** — declared embedded emissions checked by accredited verifiers — Reg (EU) 2025/2546
- **Transitional → definitive** — 2023–25 reporting only; certificates from 2026; 50 t/yr de-minimis exempts small importers — Reg (EU) 2025/2083

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Free allocation, carbon leakage and the road to CBAM

How free allocation works

- Given on product benchmarks: hot metal, sintered ore, EAF carbon/high alloy steel, coke, iron casting
- On the carbon-leakage list → CLEF = 1 (100%): maximum protection
- Allocation = Benchmark × historical activity level × CLEF × CBAM factor

Sector specifics

- Most allocation under activity code 24 (hot metal, incl. blast-furnace waste gases)
- Benchmarks re-set each period (Phase IV → 2021–30; −0.2 – 2.5 %/yr).

From 2026 the CBAM factor gradually replaces free allocation — it falls to 0% by 2034 while CBAM rises on imports. This is the EU ETS ↔ CBAM bridge we develop today.

Sources: Oeko-Institut/UBA (Climate Change 56/2024) §2.5.1; FAR (EU) 2019/331; Directive 2003/87/EC Arts. 10a–10b. [reasearch material/ · ETS/]

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WORKED CALCULATION · THE CBAM SIDE

How CBAM certificates are calculated

Specific emissions covered by free allocation [t CO_2/t goods]

Specific emissions already paid for under a carbon price [t CO_2/t goods]

Number of certificates

(Actual specific embedded emissions [t CO_2/t goods] − (CBAM benchmark [t CO_2/t goods] × CBAM factor [%] 97.5% in 2026) − ((Carbon price already paid [EUR/t CO_2] × Actual specific embedded emissions [t CO_2/t goods]) ÷ CBAM certificate price [EUR/t CO_2])) Number of certificates

We will see the example at the end of the day

- The lower the embedded emissions of the good, the lower the CBAM cost
- Türkiye's steel production relies heavily on the scrap-based EAF route, which accounts for around 70–72% of crude steel output and generally has a lower carbon intensity than the BF-BOF route. This structural advantage helps limit the embedded emissions of Turkish steel and reduces potential CBAM costs.

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RECAP

What we covered — Introduction: the EU ETS ↔ CBAM picture

Biggest ETS emitter

Iron & steel ≈ 200 Mt CO_2 (2019), ≈13% of the whole EU ETS — the largest industrial source

Route drives carbon

BF/BOF ≈ 1.85 vs scrap-EAF ≈ 0.15 t CO_2/t; BF/BOF = 59% of output but 89% of emissions

EU ETS protection

Free allocation on benchmarks; sector on the carbon-leakage list → CLEF = 1 (100%)

Türkiye & CBAM

From 2026 CBAM replaces free allocation; steel is the most resilient sector

Next: how emissions are counted (MRV & mass balance).

DAY 2

Agenda for the day

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4. System boundaries and relation between EU ETS benchmarks and CBAM
5. Full worked calculation EAF – high alloy steel (Emissions + allocation + CBAM factor)
6. Example of a full integrated plant (Emissions + allocation) - *overview*
7. Q&A

Detailed sector: Iron&steel

Case study: Iron&steel

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How emissions are counted: the calculation toolkit

Combustion	Process	Mass balance
Em = Fuel × NCV × EF × OF	Em = Activity data × EF × Conversion factor	Em = Σ (ADi × Ci) × 3.664 (inputs +, outputs −)

- Or measurement-based (CEMS): continuous CO_2 monitoring in the stack
- Every fuel/material is a source stream; 3.664 = molar mass CO_2 ÷ carbon (44/12)
- Tier system = data-quality levels (higher tier = higher accuracy); fixed in the Monitoring Plan, with an uncertainty assessment
- For an integrated steel works the mass balance — carbon in minus carbon out — is the workhorse method

Sources: Monitoring & Reporting Regulation (EU) 2018/2066 (Arts. 24–25); EU ETS M&R training material. [ETS/ · ETS/training material/]

EU ETS — EMISSIONS ACCOUNTING EXAMPLE

Worked example: mass balance of an integrated works

Emissions = (carbon IN − carbon OUT not emitted) × 3.664

Carbon IN (+)

- Coke & coking coal
- Pulverised coal injection (PCI)
- Natural gas, fluxes (limestone)
- Electrodes, alloying carbon

Carbon OUT (−, not emitted)

- Carbon in the crude steel (≈ 0.2–0.5%)
- Carbon in slag and dust
- Waste gases exported off-site
- Carbonates to stock

Per tonne of crude steel (illustrative)	tC/t	→ t CO_2
Carbon in (coke + …)	0.80	0.80 × 3.664 × t
Carbon out, not emitted (steel)	- 0.003	- 0.003 × 3.664 × t
$\sum All\ products\ - mass\ balance\ and\ combustion$		Total emissions

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PRODUCTION ROUTES — TECHNICAL DETAIL

The three main steelmaking routes

BF / BOF	Iron ore →	Sinter →	Blast furnace →	Hot metal →	BOF →	Crude steel
DRI / EAF	Ore + gas →	DRI reactor →	Sponge iron →	EAF →	Crude steel	
Scrap / EAF	Steel scrap →	EAF →	Crude steel			

Same final product (crude steel) — very different emissions per tonne

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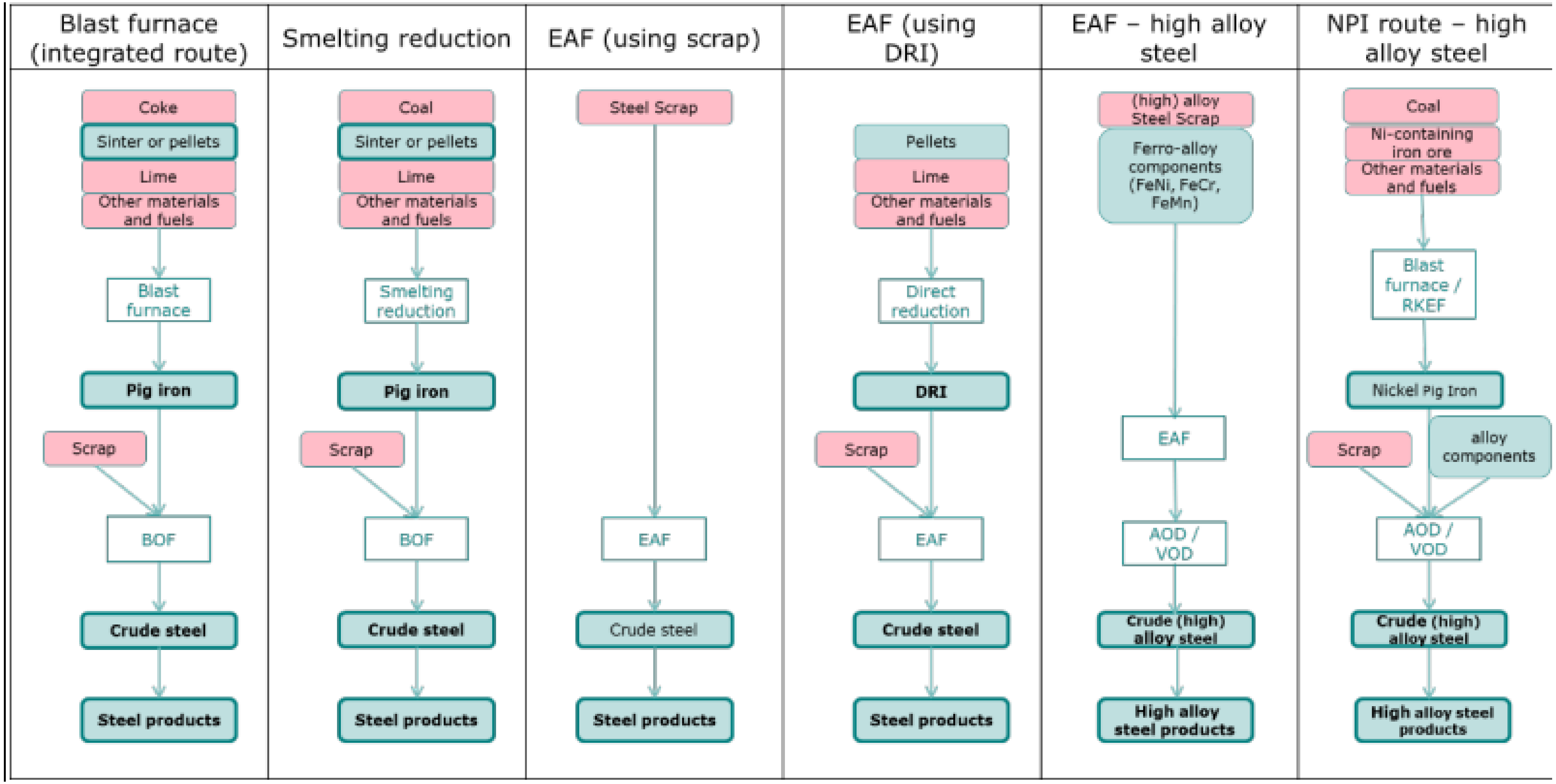
PRODUCTION ROUTES — TECHNICAL DETAIL



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PRODUCTION ROUTES — TECHNICAL DETAIL

Production Routes — Benchmark Map

Blast furnace
integrated route

Coke · sinter · lime
↓
Blast furnace
↓ pig iron
BOF → cast
↓
Crude steel

Coke BM 0.143 + Aggl. ore BM 0.086

Hot metal BM 1.248 — BF→BOF→caster

Smelting reduction

Coal · sinter or pellets
↓
Smelting reduction
↓ pig iron
BOF → cast
↓
Crude steel

Hot metal BM 1.248 — same liquid iron product

No coke ovens → no coke BM

EAF
using scrap

Steel scrap
↓
EAF → cast
↓
Crude steel

EAF carbon steel BM 0.142 — ex-caster

EAF
using DRI

Pellets · lime
↓
Direct reduction
↓ DRI (+ scrap)
EAF → cast
↓
Crude steel

Hot metal BM 1.248 — DRI (since 2026)

EAF carbon BM 0.142 — minus sponge-iron share

EAF
high alloy steel

Alloy scrap · FeCr FeNi FeMn
↓
EAF → AOD/VOD → cast
↓
Crude high alloy steel

EAF high alloy BM 0.176 — ≥ 8 % alloying

Ferro-alloys not covered by hot metal BM

NPI route
high alloy steel

Ni-containing ore · coal
↓
BF / RKEF
↓ nickel pig iron
AOD/VOD → cast
↓
Crude high alloy steel

EAF high alloy BM 0.176 — ex-caster

NPI ≈ ferroalloy → outside hot metal BM (fallback)

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PRODUCTION ROUTES — TECHNICAL DETAIL

Benchmark	Unit of product	Measurement point	2021–25	2026–30	CBAM good
2 · Coke	Tonnes of dry coke	Discharge of coke oven	0.217	**0.143**	No — CBAM factor = 1
3 · Agglomerated iron ore	Tonnes of agglomerated ore	Leaving the sinter plant	0.157	**0.086**	Yes — factor of the year
4 · Hot metal	Tonnes of hot metal	BF exit (liquid iron) or DRI exit (sponge iron)	1.288	**1.248**	Yes — factor of the year
5 · EAF carbon steel	Tonnes of crude secondary steel	Ex-caster	0.215	**0.142**	Yes — factor of the year
6 · EAF high alloy steel	Tonnes of crude secondary steel	Ex-caster	0.268	**0.176**	Yes — factor of the year
7 · Iron casting	Tonnes of liquid iron	Melting shop (liquid iron alloyed)	0.282	**0.163**	Partly — CBAM / non-CBAM split

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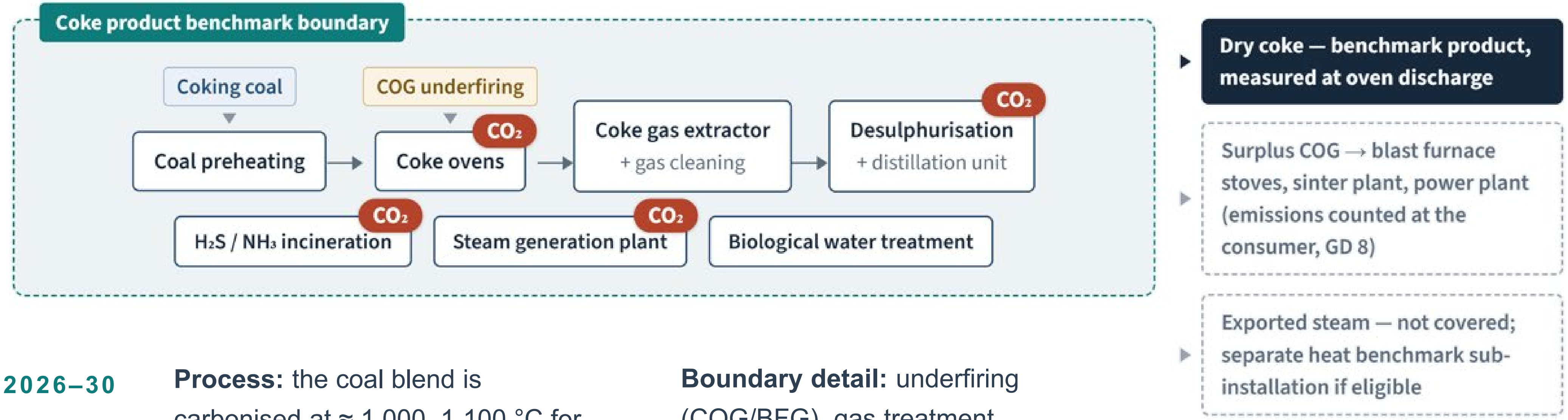
Coke



Excluded: lignite coke, coking in refineries (CWT methodology), emissions of consumed electricity.

Benchmark
2 · Coke
3 · Agglomerated iron ore
4 · Hot metal
5 · EAF carbon steel
6 · EAF high alloy steel
7 · Iron casting

BM VALUE 2026–30

0.143

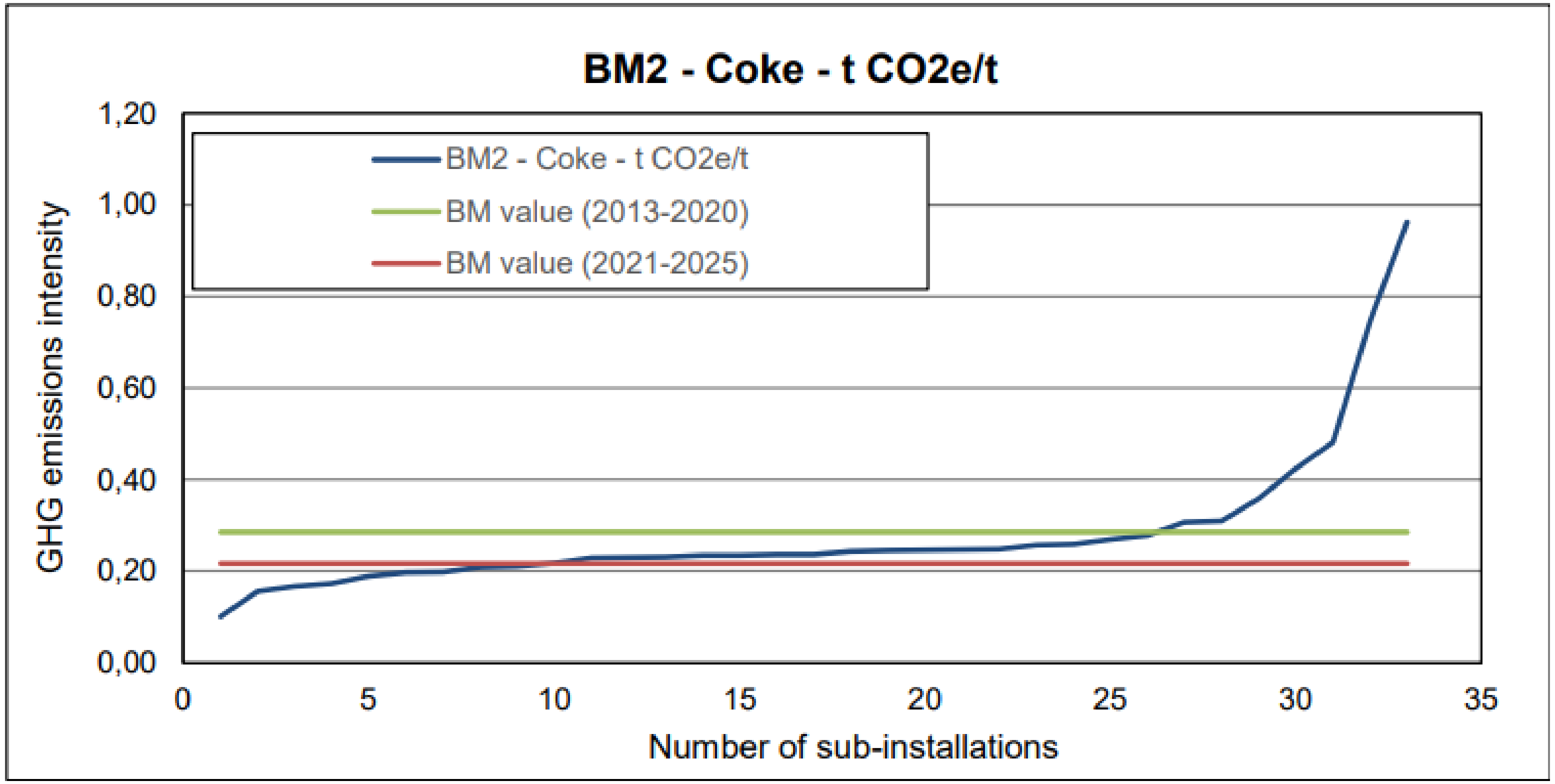
allowances / t dry coke · C(2026) 4372

Process: the coal blend is carbonised at ≈ 1 000–1 100 °C for 15–20 h in the absence of air. Volatiles leave as raw coke oven gas (≈ 55–60 % H_2, ≈ 25 % CH_4); gas cleaning recovers tar, benzole and sulphur, and the clean COG underfires the ovens or is exported.

Boundary detail: underfiring (COG/BFG), gas treatment, desulphurisation and steam generation are inside; the measurement point is **dry coke at oven discharge** .

PRODUCTION ROUTES — TECHNICAL DETAIL

Coke



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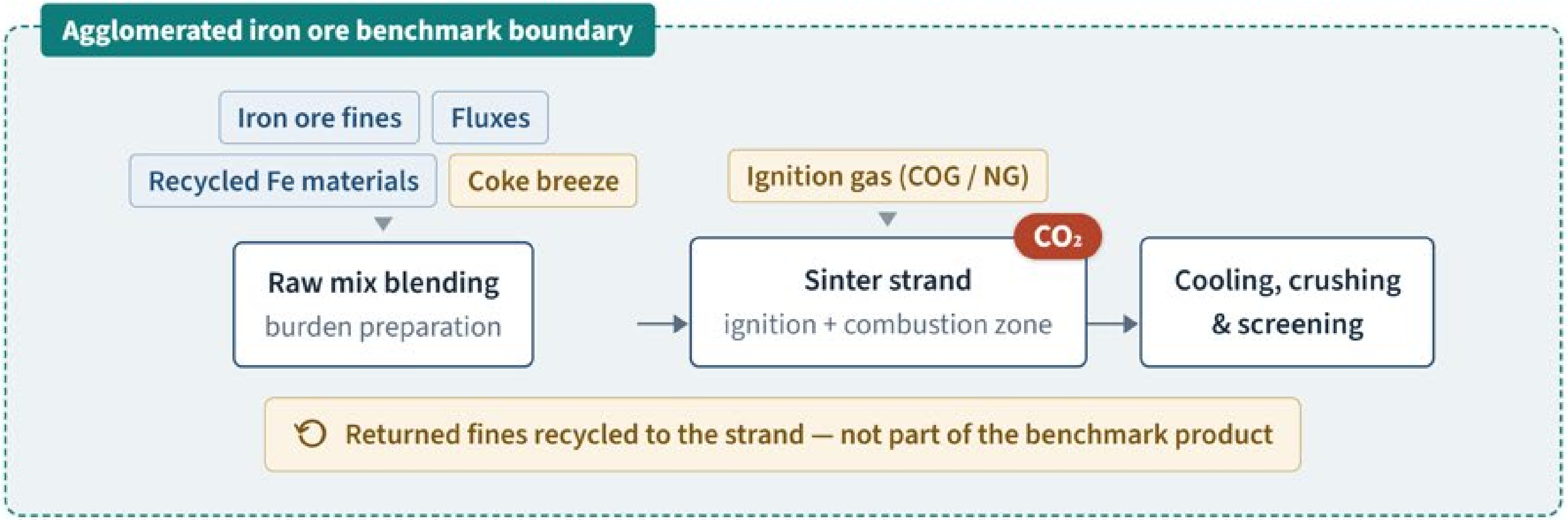
PRODUCTION ROUTES — TECHNICAL DETAIL

Sintered ore — Agglomerated iron ore



Sinter to blast furnace — measured leaving the plant, corrected for screening at the BF bunkers

Electricity (fans, drives) — indirect, excluded from the boundary

CO_2 sources inside the boundary: coke breeze and ignition gas combustion, calcination of carbonate fluxes, waste-gas de-dusting and treatment.

EU ETS benchmarks (2021–25): Sintered ore 0.157 · EU installations: 24

BM VALUE 2026–30

0.086

allowances / t agglomerated ore

Process: Iron ore fines are mixed with recycled fines, fluxes (such as limestone), and 3–5% coke breeze, then ignited with natural gas or coke oven gas. As the coke breeze burns, temperatures reach around 1,300°C, fusing the particles into porous sinter for the blast furnace. The main CO_2 emissions come from coke breeze combustion, with additional emissions from limestone calcination.

Boundary detail: blending beds, mixing, hot screening and sinter cooling are inside. Returned fines recirculated to the strand are not product — the activity level is agglomerated ore leaving the sub-installation, corrected for BF screening rejects.

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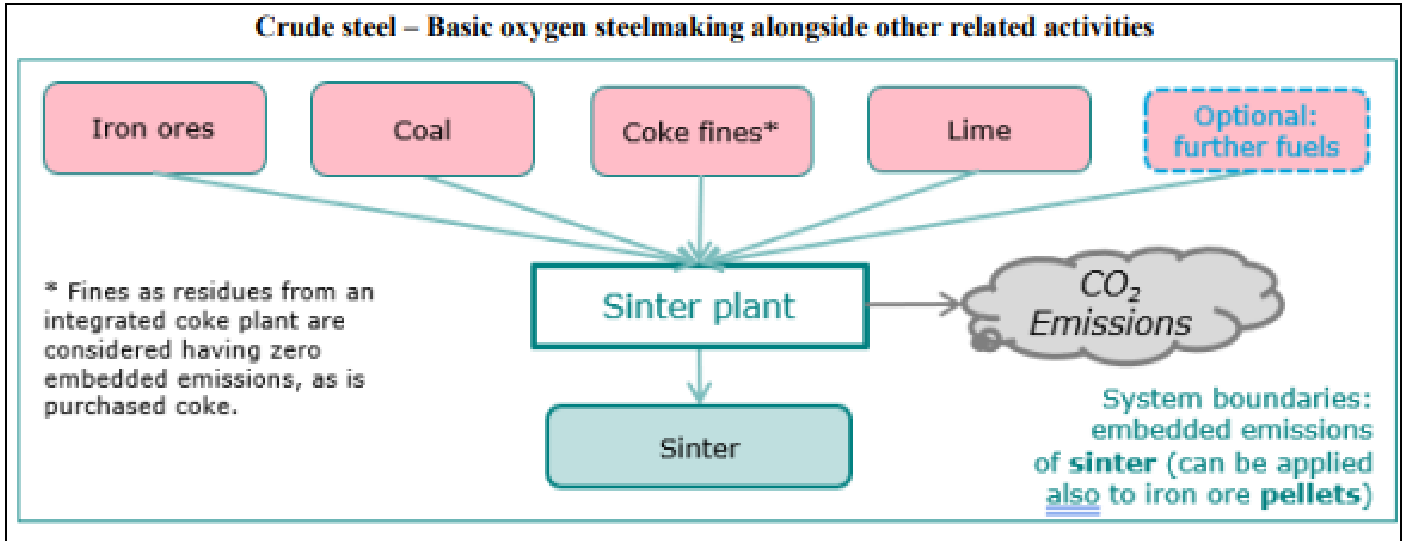
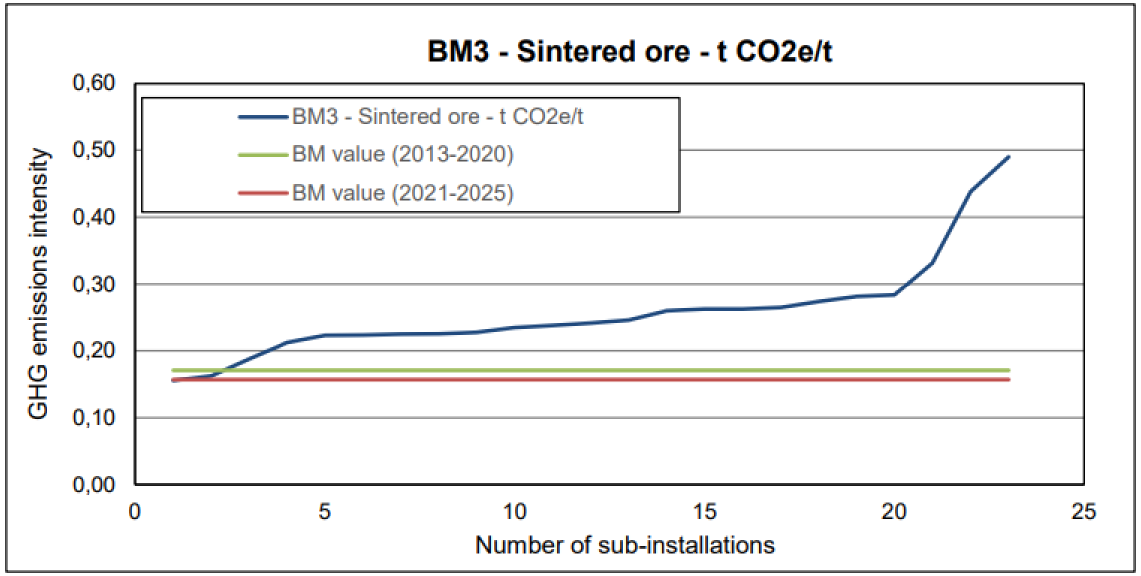
Sintered ore — Agglomerated iron ore





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PRODUCTION ROUTES — TECHNICAL DETAIL

Sintered ore — Agglomerated iron ore

What it is

- Agglomerated iron-bearing material (sinter/pellets) fed to reduction
- Unit: tonnes of agglomerated ore leaving the plant
- Returned (recycled) agglomerated ore is not counted as product
- Boundary: all processes directly/indirectly linked to agglomeration

Benchmark facts

Unit t agglomerated ore
CLEF 1 (100%)
CBAM scope yes
CN code 2601 12 00

ETS weighted average emission value
0,248 t CO_2e/t
EU ETS benchmark (2021–25)
0.157 t CO_2e/t · 24 EU installations
EU ETS benchmark (2026–30)
0.086 t CO_2e/t · 24 EU installations

CBAM default emission value (2026)
0,231 t CO_2e/t · CN 2601 12 00
CBAM Benchmark
0.086 t CO_2e/t · CN 2601 12 00

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Hot Metal – Blast furnace

Definition and explanation of products covered

According to the FAR this product benchmark covers:

"Iron produced from iron ores for primary steelmaking including

a) liquid iron saturated with carbon for further processing, considered as product of blast furnaces, and expressed in tonnes of liquid iron at the exit point of the blast furnace, excluding liquid iron produced from sponge iron under b),

b) sponge iron at the exit point of a direct reduced iron reactor, and expressed in tonnes of sponge iron at the exit point of the direct reduced iron reactor. Similar products such as ferroalloys are not covered by this product benchmark. Residual material and by-products are not to be considered as part of the product."

The liquid iron is considered to be the product of blast furnaces and sponge iron the product of direct reduced iron reactors. Within the given system boundaries, the benchmark also indirectly covers steel produced by the blast furnace route.

Similar products such as ferroalloys are not covered by this product benchmark.

This product benchmark refers to the hot metal in primary steel production rather than its end products. As such, there are no applicable PRODCOM codes for the benchmarked product. The broader PRODCOM codes for the steel sector do not differentiate between

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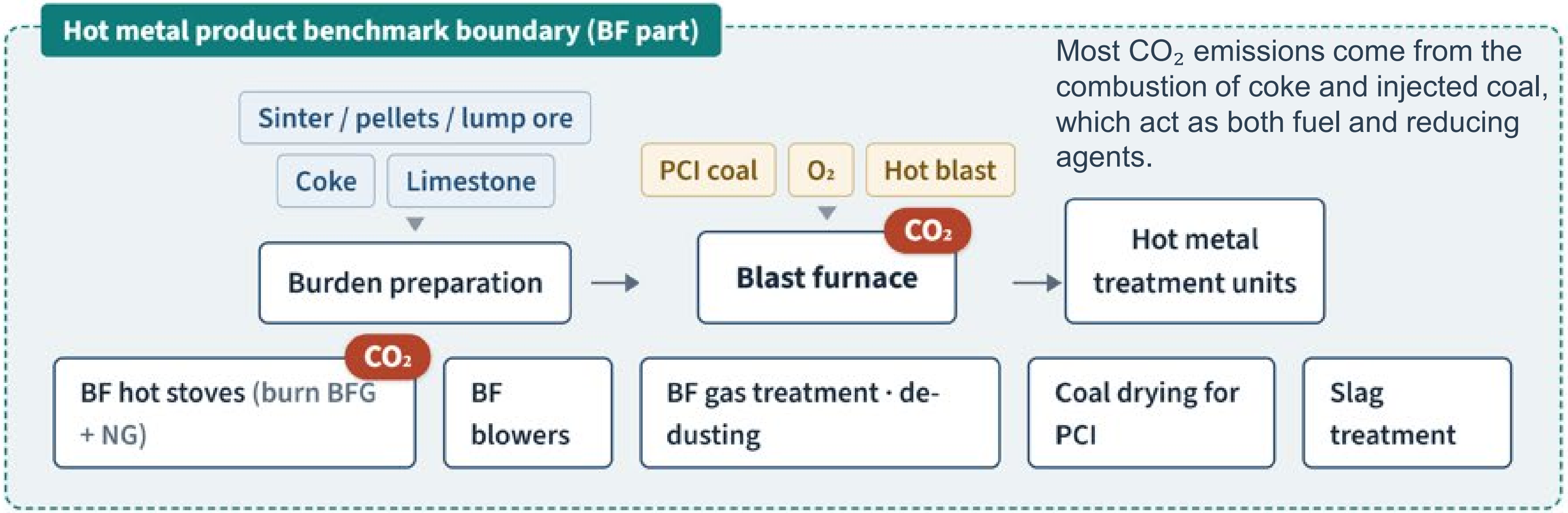
PRODUCTION ROUTES — TECHNICAL DETAIL

Hot Metal – Blast furnace



Liquid iron at BF exit — benchmark product (t hot metal); the boundary continues to BOF & casting

Surplus BF gas → on-site power plant: emissions attributed to electricity production, no free allocation (GD 8)

Ferroalloys and similar products are not covered. Emissions of consumed electricity are excluded.

Benchmark
2 · Coke
3 · Agglomerated iron ore
4 · Hot metal
5 · EAF carbon steel
6 · EAF high alloy steel
7 · Iron casting

Process: Iron ore (sinter, pellets, or lump ore) and coke are charged from the top of the blast furnace, while hot air is injected from the bottom. The coke and injected coal provide both the heat and the carbon needed to reduce the iron ore into molten iron. The process also produces slag and blast furnace gas, which is recovered and reused as a fuel.

Boundary detail: The system boundary includes the blast furnace and all downstream steelmaking steps, from oxygen blowing in the BOF to secondary metallurgy and continuous casting. Blast furnace gas emissions are accounted for where the gas is burned (e.g. in the stoves or power plant). Fuel used after casting is reported separately.

PRODUCTION ROUTES — TECHNICAL DETAIL

Hot Metal – Blast furnace

Definition and explanation of products covered

According to the FAR this product benchmark covers:

"Iron produced from iron ores for primary steelmaking including

a) liquid iron saturated with carbon for further processing, considered as product of blast furnaces, and expressed in tonnes of liquid iron at the exit point of the blast furnace, excluding liquid iron produced from sponge iron under b),

b) sponge iron at the exit point of a direct reduced iron reactor, and expressed in tonnes of sponge iron at the exit point of the direct reduced iron reactor. Similar products such as ferroalloys are not covered by this product benchmark. Residual material and by-products are not to be considered as part of the product."

The liquid iron is considered to be the product of blast furnaces and sponge iron the product of direct reduced iron reactors. Within the given system boundaries, the benchmark also indirectly covers steel produced by the blast furnace route.

Similar products such as ferroalloys are not covered by this product benchmark.

This product benchmark refers to the hot metal in primary steel production rather than its end products. As such, there are no applicable PRODCOM codes for the benchmarked product. The broader PRODCOM codes for the steel sector do not differentiate between

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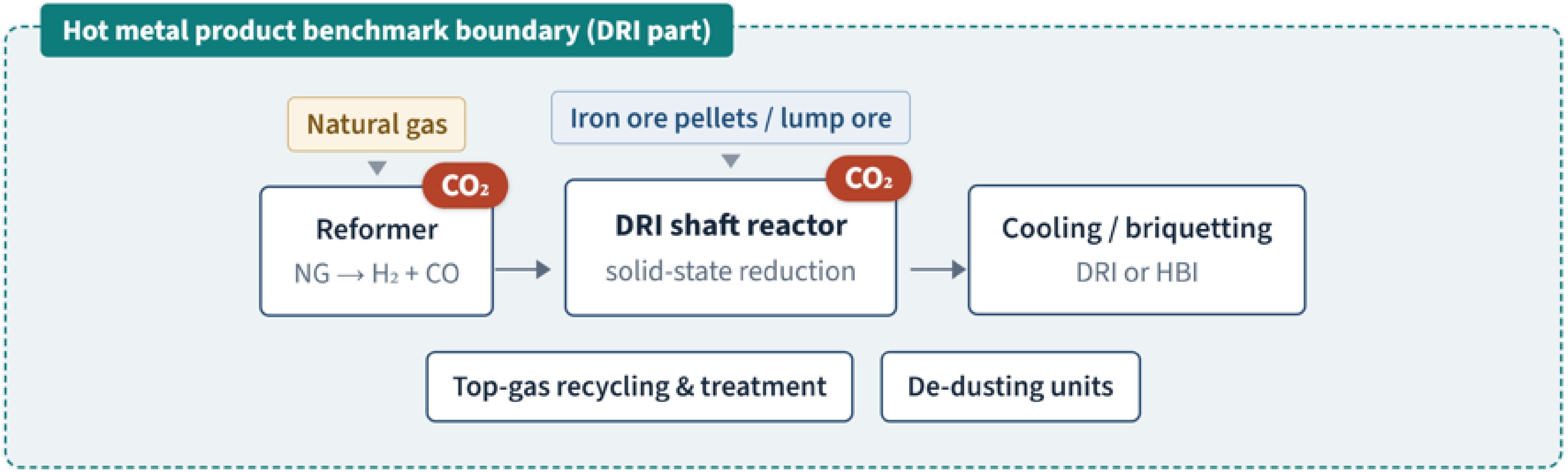
Hot Metal - DRI



Process: Natural gas is converted into a reducing gas (mainly hydrogen and carbon monoxide), which removes oxygen from iron ore pellets and lump ore inside a shaft furnace. The ore is reduced in the solid state at around 950°C, producing Direct Reduced Iron (DRI), which can be used directly or compacted into HBI. The top gas is recycled to improve energy efficiency.

Boundary detail: The boundary covers the reformer, shaft furnace and DRI processing units. Direct emissions come mainly from the reformer/heaters and carbon in the DRI, while electricity emissions are excluded. DRI allocated here must be deducted from EAF production to avoid double counting.

Sponge iron at reactor exit — benchmark product (t), same benchmark as BF hot metal

Electricity (compressors, drives) — indirect, excluded

Anti-double-counting: sponge iron allocated here must later be deducted from EAF steel activity levels (→ DRI/EAF slide).

New from 2026: in 2021–2025 DRI had no product benchmark (fallback: fuel BM / process emissions). Reg. (EU) 2024/873 added sponge iron to the hot metal BM for 2026–2030.

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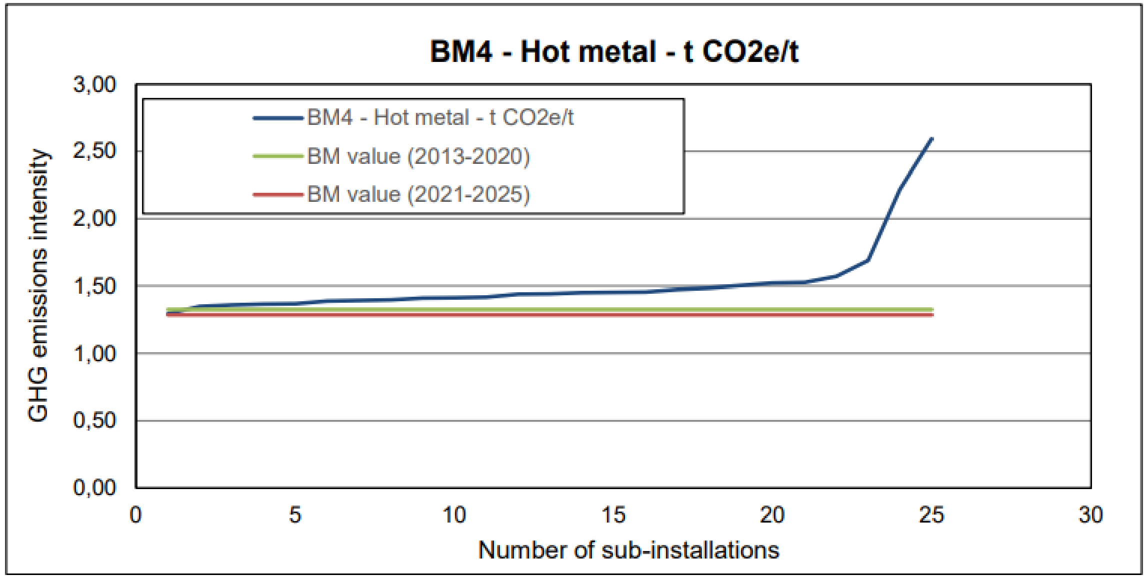
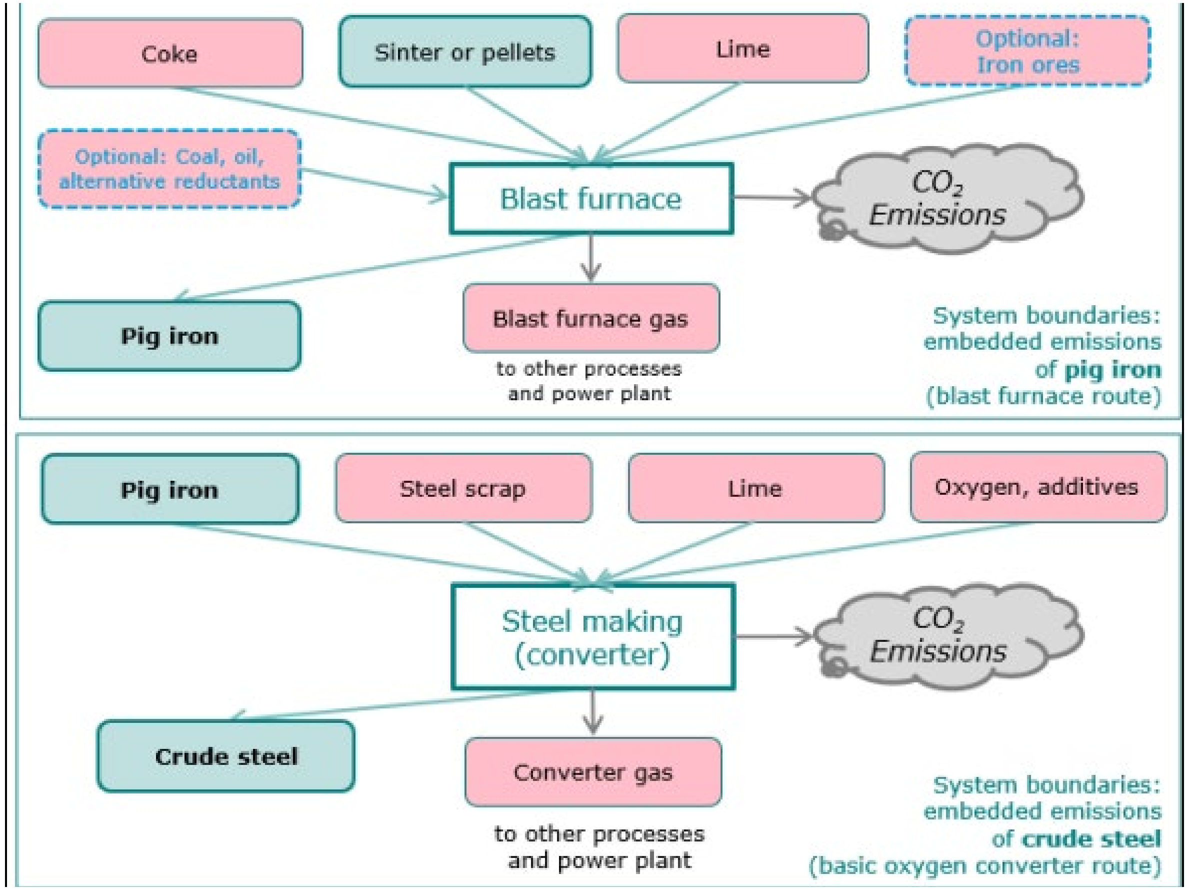
Hot Metal - DRI





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Hot metal — definition and system boundaries

Definition — two products

- (a) liquid iron at the exit of the blast furnace
- (b) sponge iron at the exit of the DRI reactor
- Indirectly covers steel made by the blast-furnace route
- Unit: tonnes of liquid iron; ferro-alloys excluded

Inside the boundary

- BF, hot stoves, blowers
- DRI reactor; EAF for sponge iron
- BOF; secondary metallurgy
- Casting, slag/gas treatment, dedusting
- Electricity emissions excluded

ETS weighted average emission value

1,495 t CO_2e/t

EU ETS benchmark (2021–25)

1,288 t CO_2e/t · 28 EU installations

CBAM default emission value (2026)

2,079 t CO_2e/t · CN 7205

CBAM Benchmark

1,288 t CO_2e/t · CN 7205

Key: hot metal bundles the BF route AND DRI / sponge iron — there is no separate crude-steel benchmark.

Sources: FAR 2019/331 Annex I 'Hot metal' + GD9 §4; benchmark-curve factsheet. [ETS/]

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PRODUCTION ROUTES — TECHNICAL DETAIL

EAF route

Lime, electrodes and other fuels
Non CBAM good

Alloy components
CBAM good

DRI
CBAM good

Pig Iron
NOT a CBAM good

Steel scrap
NOT a CBAM good

→ **EAF**
Optional AOD / VOD

→ **Crude steel**
Or crude alloy steel

Benchmark
2 · Coke
3 · Agglomerated iron ore
4 · Hot metal
5 · EAF carbon steel
6 · EAF high alloy steel
7 · Iron casting

Inputs that ARE CBAM goods / indirect

- DRI
- Pig iron
- Ferro-alloys — 7202 (FeMn, FeCr, FeNi)
- Electricity — a CBAM good, counted as indirect (dominant)

Inputs NOT under CBAM

- Steel scrap — zero embedded emissions in CBAM
- Lime / fluxes
- Graphite electrodes

EU ETS benchmarks (2021–25):

- EAF carbon steel: 0,215 · EU installations: 76
- EAF high alloy steel: 0,268 · EU installations: 82

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EAF carbon vs EAF high alloy steel — how to tell them apart

EAF high alloy steel

- >= 8% metallic alloying elements, OR
- High surface quality / processability
- Adds slow-cooling pit to the boundary
- Excludes FeCr converter & cryogenic gas storage

EAF carbon steel

- < 8% alloying elements, and
- None of the high-quality criteria met
- E.g. concrete reinforcing bar

Quality criteria assessed per cast (or per steel grade if not possible at cast level) and aggregated annually.

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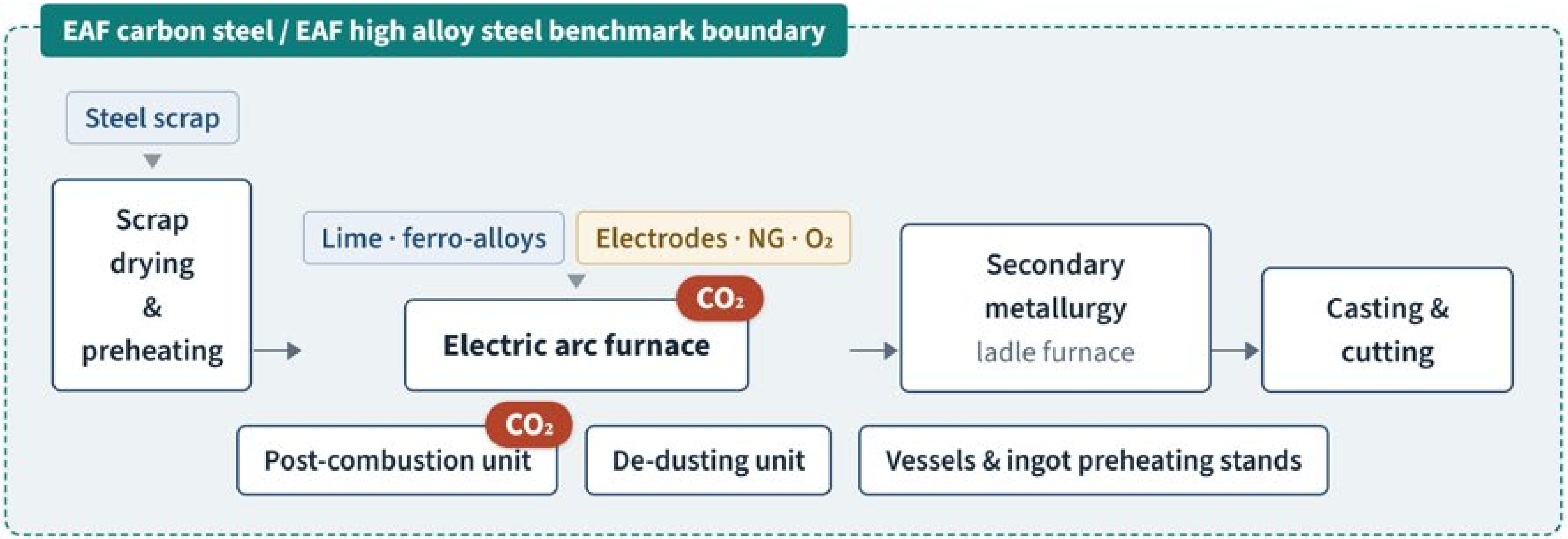
PRODUCTION ROUTES — TECHNICAL DETAIL

Scrap based EAF



Crude secondary steel ex-caster — benchmark product

Electricity (arc power) — indirect, excluded; total electricity consumption is still collected as data

Carbon vs. high alloy: ≥ 8% metallic alloying elements, or GD9 surface-quality / processability criteria met → EAF high alloy steel benchmark; otherwise EAF carbon steel. FeCr converter and cryogenic gas storage: not included.

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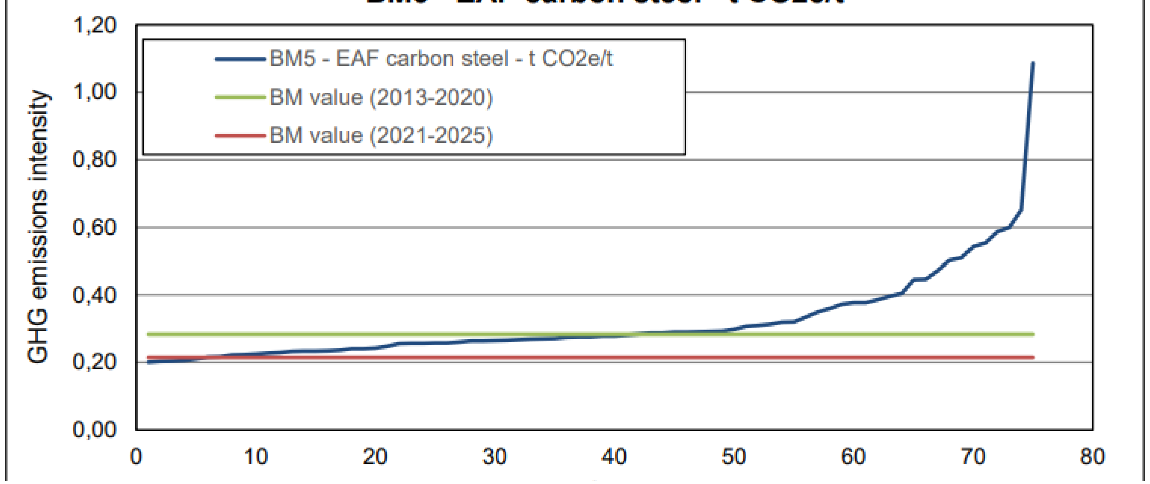
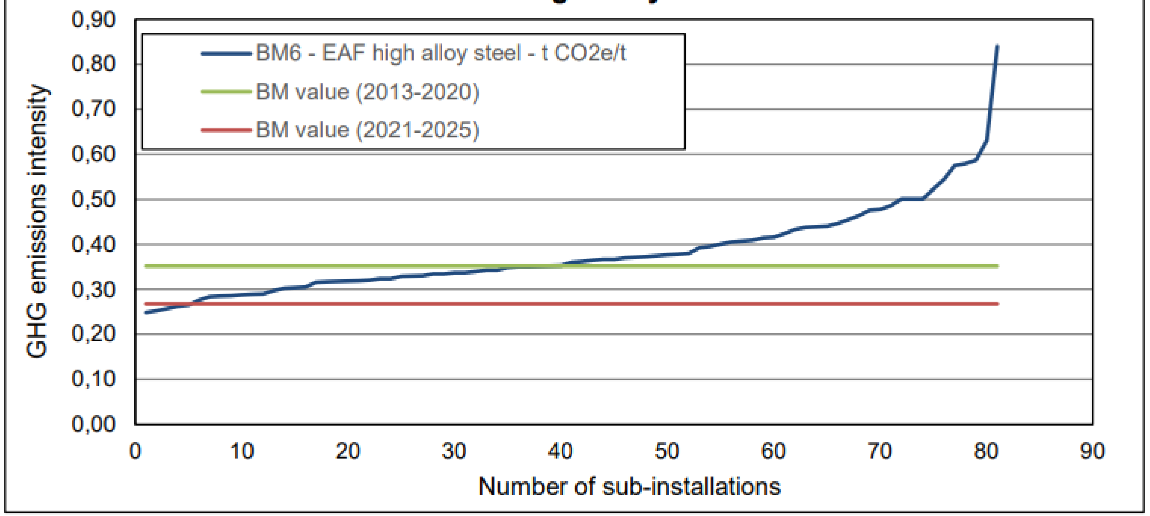
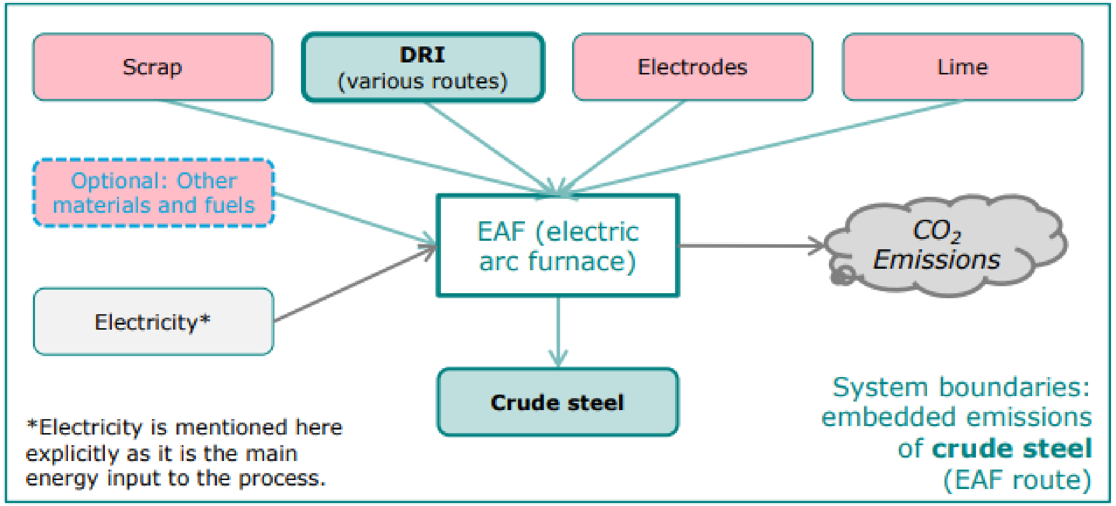
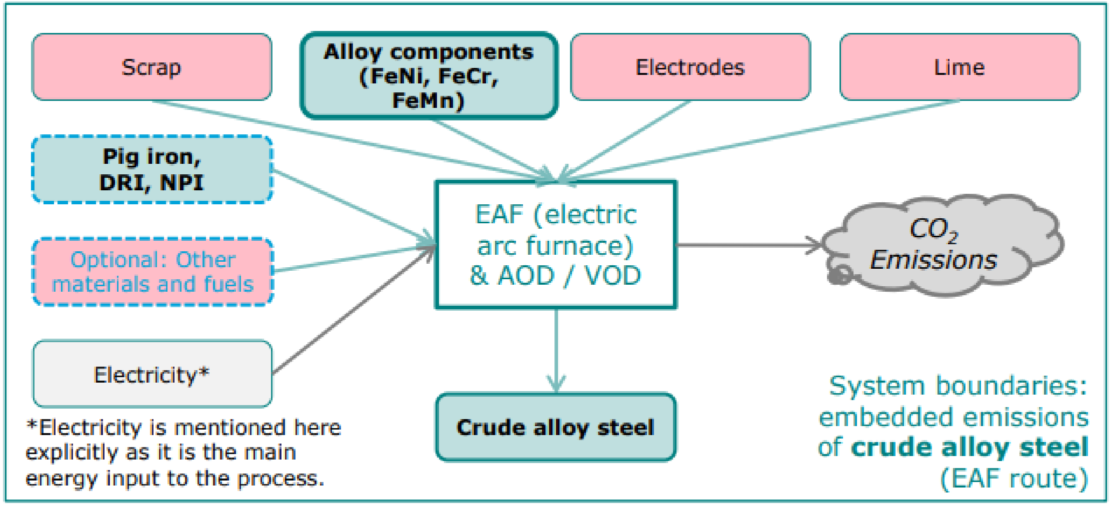




Crude steel – EAF alloy and non-alloy steel production route





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EAF route

EAF Carbon steel

CBAM default emission value (2026)

2,541 t CO_2e/t · CN 7207 11 11 (C): BF/BOF - as an example

CBAM Benchmark

1,364 t CO_2e/t · CN 7207 11 11 (C): BF/BOF

CBAM Benchmark

0,475 t CO_2e/t · CN 7207 11 11 (D) → Carbon steel produced using the DRI/EAF route

EAF high alloy steel

CBAM default emission value (2026)

7,645 t CO_2e/t · CN 7224 10 (F): BF/BOF

CBAM Benchmark

1,807 t CO_2e/t · CN 7224 10 (F): BF/BOF

CBAM Benchmark

1,180 t CO_2e/t · CN 7224 10 (J): High-alloy steel (produced using the EAF route)

EAF Carbon steel

ETS weighted average emission value

0,255 t CeO_2e/t

EU ETS benchmark (2021–25)

0,215 t CO_2e/t · 76 EU installations

EU ETS benchmark (2021–25)

0,142 t CO_2e/t ·

Concrete reinforcing bars

EAF high alloy steel

ETS weighted average emission value

0,323 t CeO_2e/t

EU ETS benchmark (2021–25)

0,268 t CO_2e/t · 76 EU installations

EU ETS benchmark (2021–25)

0,176 t CO_2e/t ·

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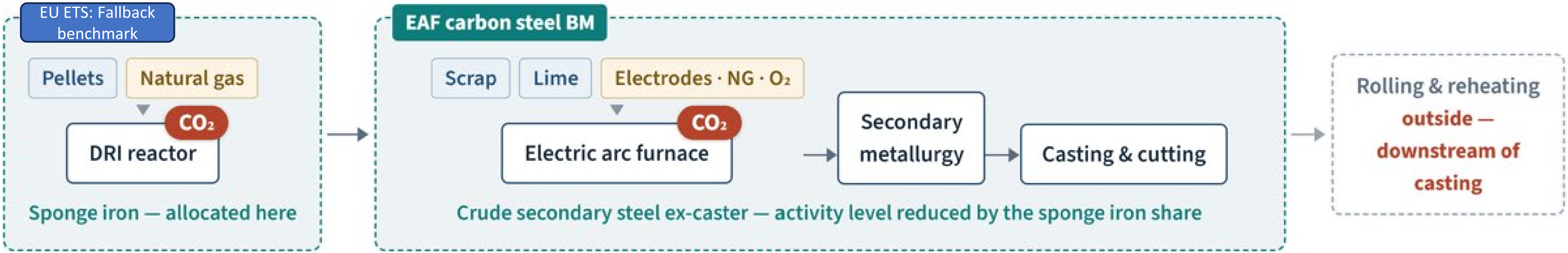
PRODUCTION ROUTES — TECHNICAL DETAIL

DRI – EAF combination



BM VALUES 2026–30

Hot metal 1.248

EAF carbon 0.142

allowances / t · C(2026) 4372

Process chain: The route is split into two benchmark sub-installations: DRI production and EAF steelmaking. The DRI transferred to the EAF is the measurement point separating the two benchmarks.

Sponge-iron deduction (GD9 §5): Steel produced from DRI already covered by the hot metal benchmark is excluded from the EAF benchmark. Only the scrap-based share remains, avoiding double counting.

Two plants in europe:

- **ArcelorMittal Hamburg (Germany):** Uses natural gas as fuel. It receives ~0.5 t CO_2 per tonne of DRI produced under the fall-back approach.
- **Höganäs (Sweden):** Uses coal gasification. Its emissions are significantly higher, reaching aprox 0.79 t CO_2 per tonne of product.

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PRODUCTION ROUTES — TECHNICAL DETAIL

Scrap/EAF route (secondary)

Steel scrap
NOT a CBAM good

→

EAF
+ electricity, lime

→

Crude steel
CBAM 7206/07

Inputs that ARE CBAM goods / indirect

- Ferro-alloys — 7202 (FeMn, FeCr, FeNi)
- Electricity — a CBAM good, counted as indirect (dominant)

Inputs NOT under CBAM

- Steel scrap — zero embedded emissions in CBAM
- Lime / fluxes
- Graphite electrodes

EU ETS benchmarks (2021–25): Iron casting 0,282 · EU installations: 32

Process: high-current electric arcs melt the scrap (~400–600 kWh/t); little chemical reduction, so the lowest direct CO_2. CBAM exposure is mainly indirect (electricity) plus the alloy precursors.

Sources: JRC EUR 31653 (2023); CBAM iron & steel sector presentation; CBAM benchmark Annex (ferro-alloys 7202). [reasearch material/ · CBAM/]

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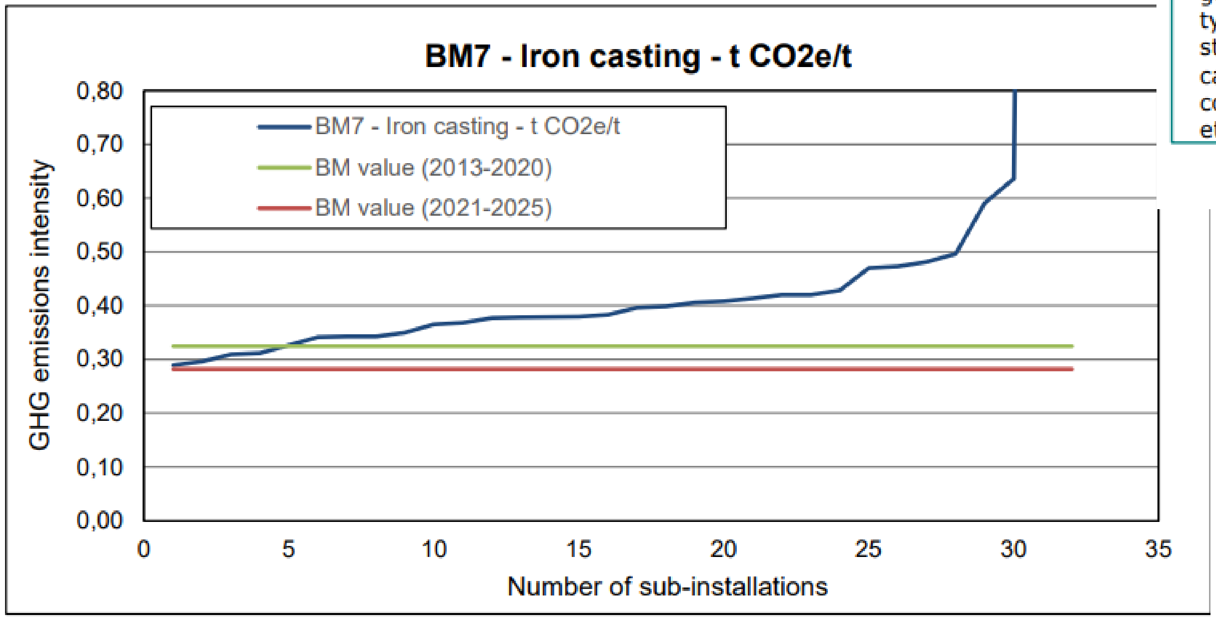
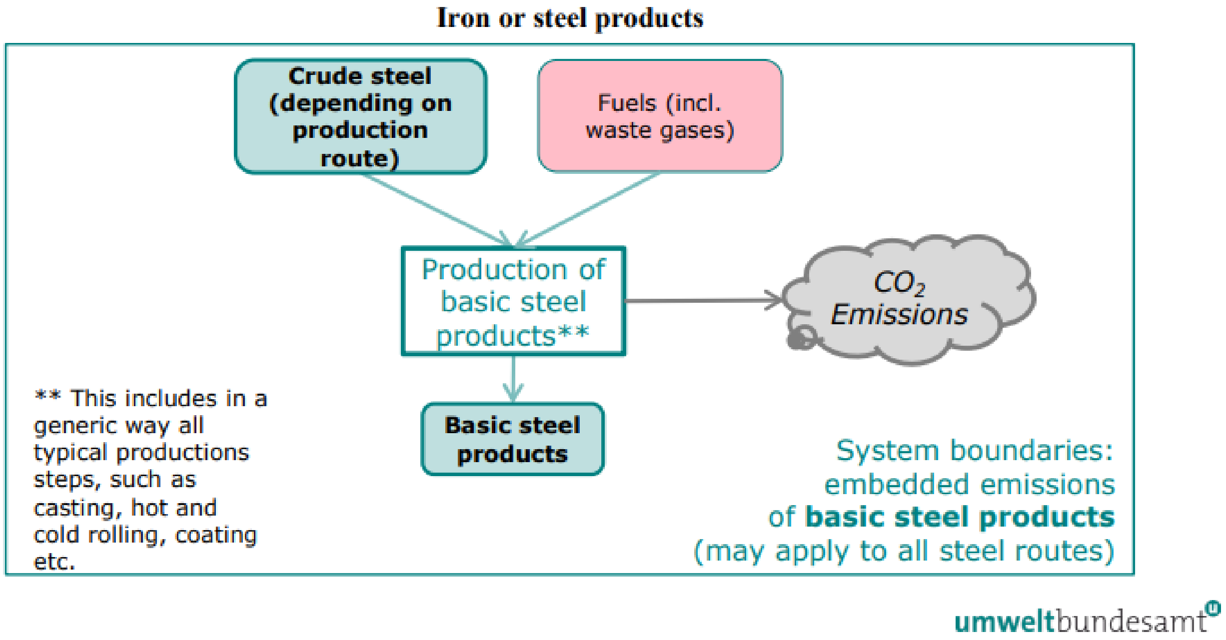
PRODUCTION ROUTES — TECHNICAL DETAIL

Scrap/EAF route (secondary)





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RECAP

What we covered — emissions counting & the production routes

Production routes

Coke, iron ore, Hot metal, EAF and iron casting

CBAM precursors

Sintered ore (2601 12 00), pig iron (7201), DRI (7203), ferro-alloys (7202) are CBAM goods; coke, scrap and lime are not

How to count

Calculation (combustion / process) or mass balance (C in − C out) × 3.664; integrated works → mass balance

Intensity by route

BF/BOF ≈ 1.85 vs DRI-EAF ≈ 0.79 vs scrap-EAF ≈ 0.15 t CO_2/t — the spread the benchmarks reflect

Next: the EU ETS product benchmarks and how they meet CBAM.

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DAY 2

Agenda for the day

1. Introduction: Routes and benchmark map (EU ETS ↔ CBAM)
2. How emissions are counted (MRV & mass balance)
3. The production routes in technical detail & the benchmark curve
4. System boundaries and relation between EU ETS benchmarks and CBAM
5. Full worked calculation EAF – high alloy steel (Emissions + allocation + CBAM factor)
6. Example of a full integrated plant (Emissions + allocation) - *overview*
7. Q&A

Detailed sector: Iron&steel (items 3–4)

Case study: Iron&steel (items 5–6)

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Sub-installation logic — product benchmarks + fallbacks

- Each product benchmark = one product-benchmark sub-installation
- An integrated works has several (sinter, hot metal, EAF...)
- Residual scope goes to fallbacks: heat, fuel, process-emissions sub-installations
- Waste gases (COG, BF gas, BOF gas) need special treatment
- No emission may be counted under two sub-installations

Attribution hierarchy

1. **Product benchmarks**
2. Heat benchmark
3. Fuel benchmark
4. Process emissions

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ALLOCATION RULES

Cross-cutting allocation rules

Sub-installation hierarchy

Product benchmark first; only then heat benchmark, fuel benchmark and process emissions sub-installations for what remains outside product boundaries.

No double counting

Processes inside a product benchmark never receive additional allocation via fall-back approaches. Safety flaring is always covered by the product benchmark.

Electricity excluded

Emissions from production of consumed electricity are outside every boundary shown. For EAF benchmarks, total electricity consumption is still reported as data.

Measurable heat

Heat export is not covered by these product benchmarks — export to non-ETS consumers may form separate heat benchmark / district heating sub-installations (GD 6). Heat imported from non-ETS production is deducted (FAR Art. 21).

Sponge iron deduction

Sponge iron allocated under the hot metal benchmark is netted out of downstream EAF steel activity levels, in proportion to its share of total iron input.

Waste gas flaring — from 2026

Non-safety flaring of waste gases not used for heat or electricity reduces the product benchmark allocation by the historical flaring emissions (FAR Art. 16(5), GD 8).

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SYSTEM BOUNDARIES

Avoiding double counting — sponge iron fed to an EAF

- Sponge iron already received allocation under the Hot metal benchmark
- When melted in an EAF, reduce the EAF activity level accordingly
- Reduction = share of iron from sponge iron × iron content of the steel

Worked example (GD9 §5)

1. Sponge iron = 10% of the iron input to the EAF
2. Crude steel total iron content = 25,000 t
3. Reduction = 25,000 × 10% = 2,500 t
4. → subtract 2,500 t from the EAF activity level

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EU ETS

Product benchmarks for iron & steel

EU ETS product benchmark	Unit	2026 - 2030	2021- 2025	Ph-3 ref.	# EU inst.
Coke	t dry coke	0.143	0.217	0.286	33
Agglomerated iron ore (sintered ore)	t aggl. ore	0.086	0.157	0.171	24
Hot metal	t liquid iron	1.248	1.288	1.328	28
EAF carbon steel	t crude steel	0.142	0.215	0.283	76
EAF high alloy steel	t crude steel	0.176	0.268	0.352	82
Iron casting	t liquid iron	0.163	0.282	0.325	32

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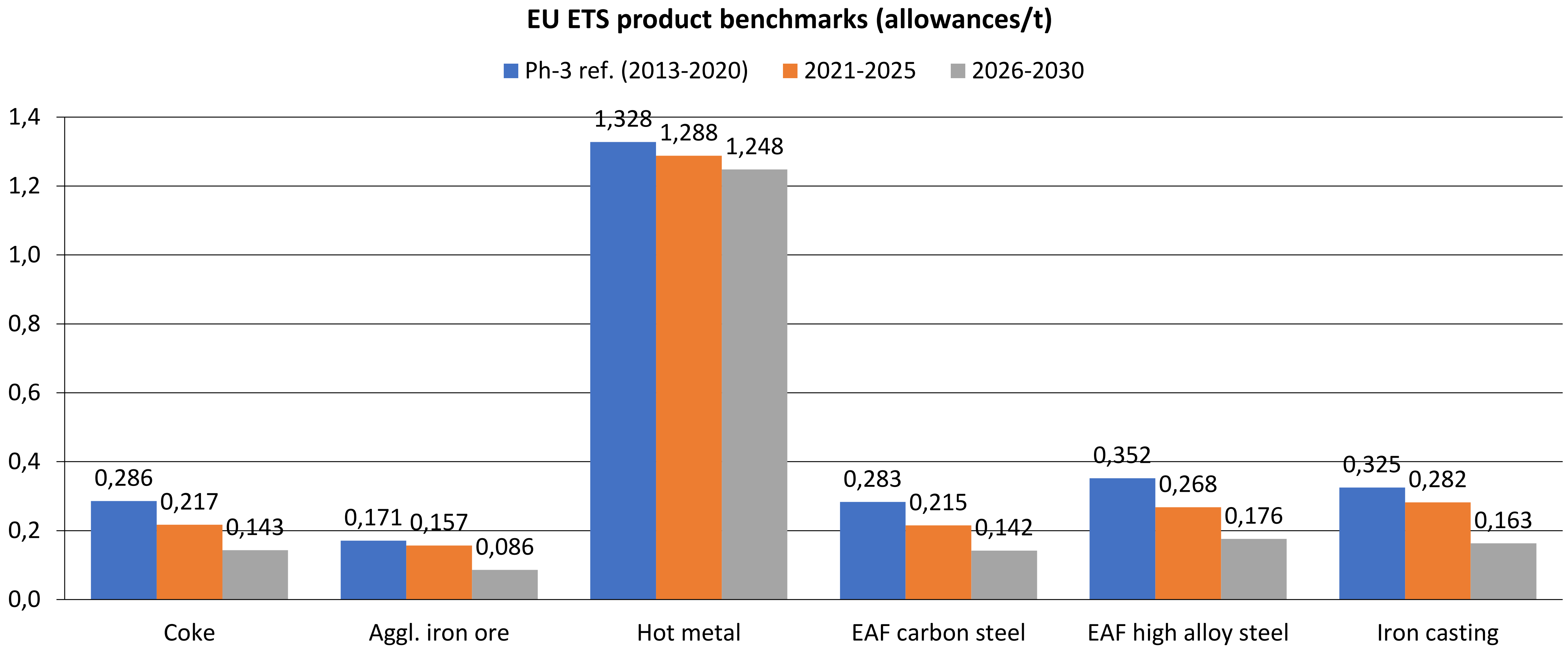
Iron & steel benchmarks: evolution across trading periods



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Crude steel — production routes Reg. 2025 / 2621

Production route	How the EU ETS covers the crude steel	CBAM code
BF/BOF	Hot metal benchmark — covers the integrated BF route up to crude steel	C
DRI/EAF	Sponge iron under Hot metal + EAF benchmark on melting; sponge-iron deduction avoids double counting	D
Scrap/EAF	EAF carbon steel / EAF high alloy steel benchmark	E

Key point: the EU ETS has no single "crude steel" benchmark — coverage depends on the route. CBAM instead splits crude steel into route codes C/D/E (benchmark values on the CBAM-side slide).

Sources: FAR 2019/331 Annex I (Hot metal, EAF benchmarks) + GD9 §4–6; CBAM benchmark Annex, Reg (EU) 2025/2620 (codes C/D/E). [ETS/ · CBAM/]

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DRI (natural-gas based) — EU ETS vs new CBAM benchmark

EU ETS

- Sponge iron (DRI) is covered by the Hot metal benchmark — part (b); no separate ETS value
- Free allocation applies the polluter-pays principle (Art. 191(2) TFEU; Del. Reg. (EU) 2019/331)
- In the first CBAM years, the hot-metal adjustment would exceed the embedded emissions of natural-gas DRI → no CBAM certificates due

CBAM

- Dedicated CBAM benchmark for natural-gas based DRI (CN 7203 10 00 & 7203 90 00)
- Values: 0.295 (col. A) / 0.397 (col. B)
- Level set so DRI obligations fall below primary BF steel but above secondary (scrap-EAF) steel
- Preserves CBAM environmental integrity and shields EU secondary steel from carbon leakage

Polluter pays in practice: without differentiation, higher-carbon gas-based DRI imports would owe no CBAM certificates while cleaner secondary steel would — Recital 16, Implementing Regulation (EU) 2025/2620.

PRODUCTION ROUTES — TECHNICAL DETAIL

What each route needs: inputs and CBAM precursors

Route	Main material inputs	CBAM goods among the inputs (precursors)
BF/BOF (integrated primary)	Iron ore, sinter/pellets, coke, limestone, oxygen, scrap (in BOF)	Sintered ore 2601 12 00 → pig iron 7201
DRI/EAF (gas-based primary)	DR-grade pellets, natural gas, electricity, ferro-alloys, scrap	Sintered ore 2601 12 00, DRI 7203, ferro-alloys 7202
DRI + steel products (pig iron) EAF (gas-based primary)	Pig iron, natural gas, electricity, ferro-alloys, scrap	Pig iron 12 00, DRI 7203, ferro-alloys 7202
Scrap /EAF (secondary)	Steel scrap, electricity, ferro-alloys, lime, graphite electrodes	Ferro-alloys 7202

CBAM precursor = a CBAM good consumed to make another CBAM good; its embedded emissions are carried into the final good. **Not CBAM:** coke, scrap, limestone, natural gas, electrodes. Electricity is itself a CBAM good but is counted as indirect emissions.

Sources: JRC Technical Report EUR 31653 (2023); CBAM iron & steel sector presentation (CN codes); CBAM benchmark Annex, Reg (EU) 2025/2620. [reasearch material/ · CBAM/]

Interactive Q&A

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Electric Arc Furnace — High-Alloy Steel Plant

Monitoring Emissions & Calculating Free Allocation

A complete, worked methodology — from source streams and the mass-balance method through to product- and fuel-benchmark free allocation.

26
monitored source streams

2
benchmark sub-installations

≈236 kt
CO_2 reported per year

≈179 k
free allowances per year

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THE INSTALLATION

A high-alloy steel plant at a glance

The site produces **special (high-alloy) steel** through a fully electric route. Steel scrap, purchased pig iron, direct-reduced iron and ferroalloys are melted in electric arc furnaces, refined, cast into semi-finished shapes, then reheated and rolled, forged and heat-treated.

Because there is no iron-making, carbon enters mainly with **charge carbon, graphite electrodes and ferroalloys** — and leaves in the steel, slag and dust. That balance is the heart of the emissions calculation.

2 × 100 t
electric arc furnaces

≈1.15 Mt
crude steel / year

NACE 24.10
basic iron & steel

MELT SHOP

2 electric arc furnaces (AC + DC) · 3 ladle refining furnaces · 3 continuous casters

ROLLING & FORGING

3 rolling mills · reheating (walking-beam) furnaces · forging line — all natural-gas fired

HEAT TREATMENT

quench & temper, annealing and normalising furnaces · ladle & tundish heaters — natural gas

ANCILLARY

emergency diesel gensets & fire motor-pumps · civil heating boilers

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PROCESS MAP

Block flow diagram of the installation

● CO_2 emission point ■ Carbon-bearing output

Scrap | Pig iron / HBI | Ferroalloys | Charge carbon | Electrodes | Lime

Natural gas ▸ furnaces

Melt shop ●
2 electric arc furnaces + 3 ladle furnaces
mass balance

→

Continuous casting
3 casters → billets, blooms, ingots
crude steel

→

Reheat & roll ●
3 rolling mills + reheating furnaces
combustion

→

Heat treatment ●
quench, temper, anneal + forging
combustion

→

Finished products

Slag ↓ | Filter dust ↓ | Mill scale ↓

PRODUCT BENCHMARK SUB-INSTALLATION — high-alloy steel

FUEL BENCHMARK SUB-INSTALLATION — natural gas

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SCOPE

Drawing the EU ETS system boundary

Annex I activities covered by the permit

01 Production of pig iron or steel, incl. continuous casting

02 Processing of ferrous metals — rolling mills, reheaters & heat-treatment furnaces

03 Combustion of fuels in units > 20 MW total rated thermal input

✓ **INSIDE THE BOUNDARY**

All fuel combustion · process carbon in the mass balance · emergency gensets & motor-pumps · on-site civil heating

✕ **NOT IN DIRECT EMISSIONS**

Imported grid electricity (indirect) · biogenic CO_2 fraction (monitored but zero-rated)

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WHAT WE MONITOR

Source streams & emission sources

Mass-balance streams

22 streams

Carbon-bearing inputs & outputs of the melt shop

Anthracite | Coke | Pet coke | Electrodes | Lime | Scrap

Pig iron | HBI / DRI | Ferroalloys (8) | Polymers

outputs (subtracted): Crude steel | Slag | Dust | Scale

Carbon content of each is set by **laboratory analysis**.

Combustion streams

4 streams

Fuels burned purely for heat / power

Natural gas | Diesel | LPG | Civil-line gas

EMISSION SOURCES (physical units)

100+ units, e.g. 2 arc furnaces, ladle furnaces, reheating & heat-treatment furnaces, ladle / tundish heaters, diesel gensets and fire motor-pumps.

We report on **streams** ; each source is mapped to the stream that feeds it.

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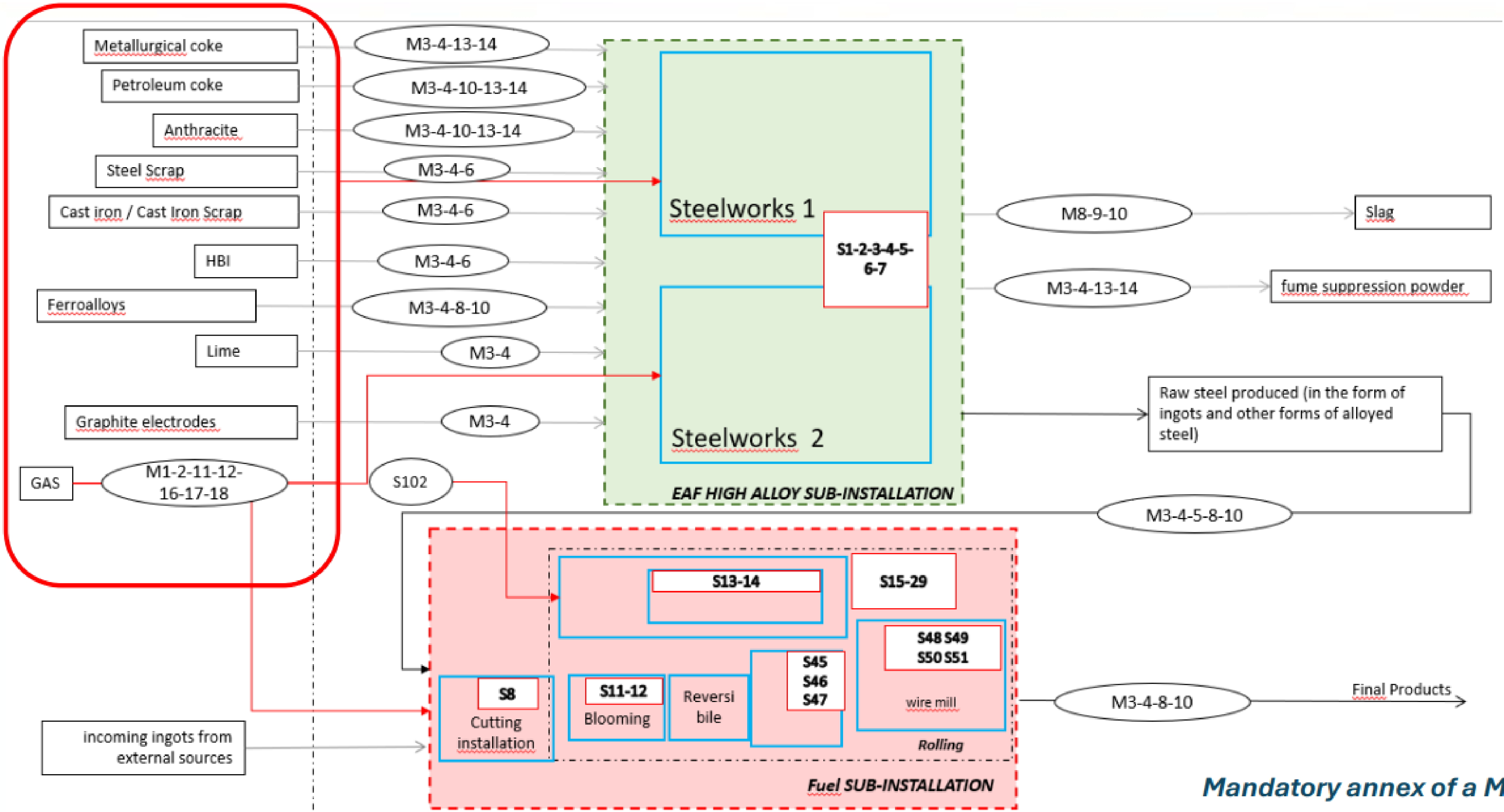
WORKED EXAMPLE · EAF high alloy steel plant

Layout



Mandatory annex of a MMP

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Two calculation methodologies

Mass balance

Melt shop — track carbon in vs. carbon out

$$CO_2 = \Sigma(AD_i \times C_i) \times {}^{44}/_{12}$$

AD_i mass of each stream (t)

C_i carbon content (t C / t) — lab

44/12 = 3.664, CO_2-to-carbon ratio

Inputs count **positive**, products & by-products **negative** . The residual carbon left the process as CO_2.

Standard combustion

Gas-fired furnaces & engines — burn for heat

$$CO_2 = AD \times NCV \times EF \times OF$$

AD fuel consumed (t or 1000 Nm^3)

NCV net calorific value (GJ/unit)

EF emission factor (t CO_2/TJ)

OF oxidation factor (≈ 1)

Fuel quantity × its energy content × how much CO_2 per unit of energy.

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DATA QUALITY

Activity data, calculation factors & monitoring

ACTIVITY DATA

How much?

Weighbridges — accuracy class III, calibrated annually; all solids & materials

Fiscal gas meters — turbine meters with P/T volumetric correction at custody transfer

CALCULATION FACTORS

How carbon-rich?

Lab analysis — carbon content of each material, on a documented sampling plan

NCV & EF for fuels — analysis or approved default values

Accredited laboratories — results traceable in the monitoring plan

TIERS & UNCERTAINTY

How accurate?

Each stream meets a minimum **MRR tier**

Backed by a simplified **uncertainty assessment**

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Sub-installations & avoiding double counting

PRODUCT BENCHMARK

High-alloy steel from EAF

The melt shop: arc furnaces, ladle refining, continuous casting. Covers the process emissions (mass balance) and its own fuel use.

activity → tonnes of steel

FUEL BENCHMARK (fallback)

Downstream gas-fired heat

Rolling mills, reheating & heat-treatment furnaces. No product benchmark applies — allocation follows the fuel actually burned.

activity → TJ of fuel

THE RULE

No stream counted twice

Each source stream, unit of heat and tonne of output is assigned to **exactly one** sub-installation.

The FAR system boundaries are mutually exclusive — the benchmark **hierarchy** decides ties: product ▸ heat ▸ fuel ▸ process.

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WORKED EXAMPLE · PART 1 OF 2

Emissions accounting for the year

rounded & anonymised

① MASS BALANCE — melt shop

stream	t	C	t CO_2
Anthracite	13,100	0.79	37,800
Pig iron	122,100	0.041	18,300
Coke + pet coke	5,900	0.89	19,000
Electrodes	2,800	1.00	10,300
Polymers	9,400	0.77	23,800
Scrap + HBI + alloys	1,213,000	—	15,400
– Crude steel	1,147,000	0.003	−13,300
– Slag, dust, scale	218,000	—	−3,000

Net (× 44/12) **≈ 108,300 t**

② COMBUSTION — natural gas

60,700 k·Nm^3 × 37.6 GJ = 2,283 TJ × 56.0 t/TJ = **127,900 t CO_2**

+ diesel, LPG & civil gas ≈ 240 t → ≈ **128,100 t**

TOTAL REPORTED

≈236,400 t CO_2 / yr

108,300 (process) + 128,100 (combustion). Biogenic ≈ 2,500 t monitored but **zero-rated**.

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How free allowances are calculated

Allocation = HAL × Benchmark value × CLEF × (CSCF)

HAL

Historical activity

Median output over the baseline period — fixes the volume.

BENCHMARK

EU efficiency yardstick

Allowances per tonne of product, or per TJ of fuel / heat.

CLEF

Carbon-leakage factor

= 1 for exposed sectors like steel; lower otherwise.

HIERARCHY

Which benchmark?

product ▸ heat ▸ fuel ▸ process

Fallbacks only where no product benchmark fits.

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THE NUMBERS THAT APPLY

The two benchmarks applied here

PRODUCT BENCHMARK

High-alloy steel from EAF

0.268 EUA / t steel

Activity = tonnes of qualifying high-alloy steel. Electricity ↔ fuel interchangeability applies, so an **exchangeability factor** scales the result.

FUEL BENCHMARK (fallback)

Downstream gas-fired heat

42.6 EUA / TJ fuel

Activity = net energy of fuel burned (TJ). A single EU-wide value applied to all fuel with no product benchmark of its own.

KEEPING ALLOCATION CURRENT

HAL, ALC & the annual adjustment

HAL
Historical activity level
Baseline median. Sets the preliminary allocation.

→

ALC
Annual level of activity
Reported each year. Two-year rolling average compared to HAL.

→

ADJUST?
Both thresholds together
relative change > 15% AND absolute ≥ 100 EUA

THIS PLANT — LATEST YEAR
No adjustment triggered

Steel activity vs HAL
≈ +4%
under the 15% band

Fuel activity vs HAL
≈ +10%
under the 15% band

Allocation
unchanged
stays at HAL basis

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Preliminary free allocation

rounded & anonymised

① PRODUCT BENCHMARK

HAL 1,154,600 t × BM 0.268 = 309,400 × ElExch 0.313 × CLEF 1.0

≈ **96,997 EUA**

② FUEL BENCHMARK

HAL 1,924 TJ × BM 42.6 × CLEF 1.0 (fallback benchmark)

≈ **81,962 EUA**

TOTAL PRELIMINARY ALLOCATION

178,959

free allowances / year

96,997 (product) + 81,962 (fuel) . Adjusted yearly against the ALC.

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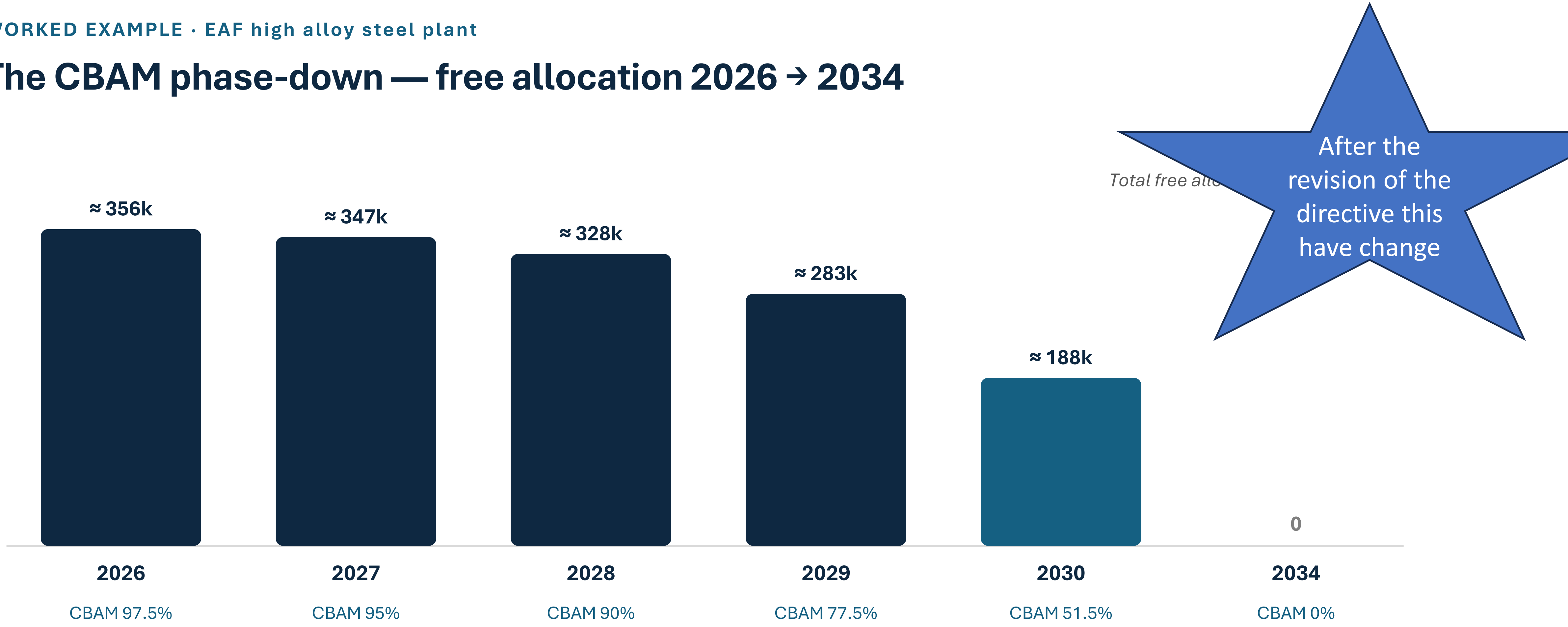
WORKED EXAMPLE · EAF high alloy steel plant

The CBAM phase-down — free allocation 2026 → 2034



The CBAM factor is the share of free allocation still granted — it reaches 0% in 2034, when CBAM fully replaces free allocation. As free allocation falls, the import-side CBAM obligation rises by the mirror amount.

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WORKED EXAMPLE · EAF high alloy steel plant

Emissions vs. free allocation — the 2025 gap

≈ 236,000

t CO_2e — verified emissions (to surrender)

≈ 179,000

EUA — free allocation (≈ 76% of emissions)

≈ 57,000 allowances to purchase — the gap the operator must cover on the market.

- Free allocation covers ≈ 76% of this plant's emissions; the balance must be bought.
- From 2026 the CBAM factor phases down free allocation for CBAM goods — the gap widens (see earlier slides).
- One dataset — emissions, activity levels, sub-installations — feeds both surrender and free allocation.

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How CBAM certificates are calculated

Specific emissions covered by free allocation [t CO_2/t goods]

Specific emissions already paid for under a carbon price [t CO_2/t goods]

Number of certificates

(Actual specific embedded emissions [t CO_2/t goods] − (CBAM benchmark [t CO_2/t goods] × CBAM factor [%] 97.5% in 2026) − ((Carbon price already paid [EUR/t CO_2] × Actual specific embedded emissions [t CO_2/t goods]) ÷ CBAM certificate price [EUR/t CO_2])) × Amount of goods [t goods] = Number of certificates

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The CBAM side, by route — CN 7224 10 (alloy-steel ingots)

Türkiye

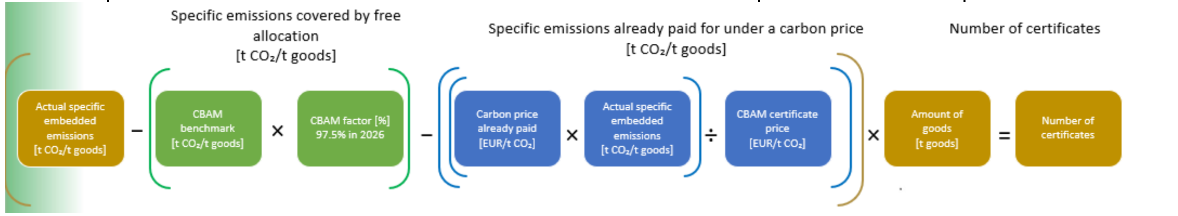
Product CN Code	Description	Default Value (direct emissions)	Default Value (indirect emissions)	Default Value (total emissions)	2026 Default Value (including mark-up)	2027 Default Value (including mark-up)	2028 and onwards Default Value (including mark-up)	Underlying production route determining CBAM BM
7224 10	Steel, alloy, other than stainless, in ingots or other primary forms (excl. waste and scrap in ingot form, and products obtained by continuous casting)	6,950	N/A	6,950	7,645	8,340	9,035	(F)

(F) Low alloy Steel based on BF/BOF

CN code	CN Description	Column A BMg* [tCO_2e/t]	Column B BMg [tCO_2e/t]
7224 10 90	Steel, alloy, other than stainless, in ingots or other primary forms (excl. of tool steel, waste and scrap in ingot form and products obtained by continuous casting)	0,453 (F) 0,330 (G) 0,330 (H) 0,358 (J)	1,807 (F)(1) 0,982 (G)(1) 0,640 (H)(1) 1,180 (J)(1) 1,640 (F)(2) 0,969 (G)(2) 0,628 (H)(2) 1,148 (J)(2)

CBAM cost per tonne for this product (2026):

[7.645 − (1.807 × 0.975) − emissions already paid under a carbon price] × €75.36 ≈ €443 / t



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WORKED EXAMPLE · EAF high alloy steel plant

The CBAM side, by route — CN 7224 10 (alloy-steel ingots)

- When emissions are properly calculated, the applicable benchmark is lower; however, in most cases, the reported emissions are also correspondingly lower.
- Where an ETS is in place in the country of origin, it will also influence the CBAM-adjusted border price. A key advantage is that the carbon cost remains within the country of origin, rather than being fully transferred abroad.

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DAY 2

Agenda for the day

1. Introduction: Routes and benchmark map (EU ETS ↔ CBAM)
2. How emissions are counted (MRV & mass balance)
3. The production routes in technical detail & the benchmark curve
4. System boundaries and relation between EU ETS benchmarks and CBAM
5. Full worked calculation EAF – high alloy steel (Emissions + allocation + CBAM factor)
6. Example of a full integrated plant (Emissions + allocation) - *overview*
7. Q&A

Detailed sector: Iron&steel (items 3–4)

Case study: Iron&steel (items 5–6)

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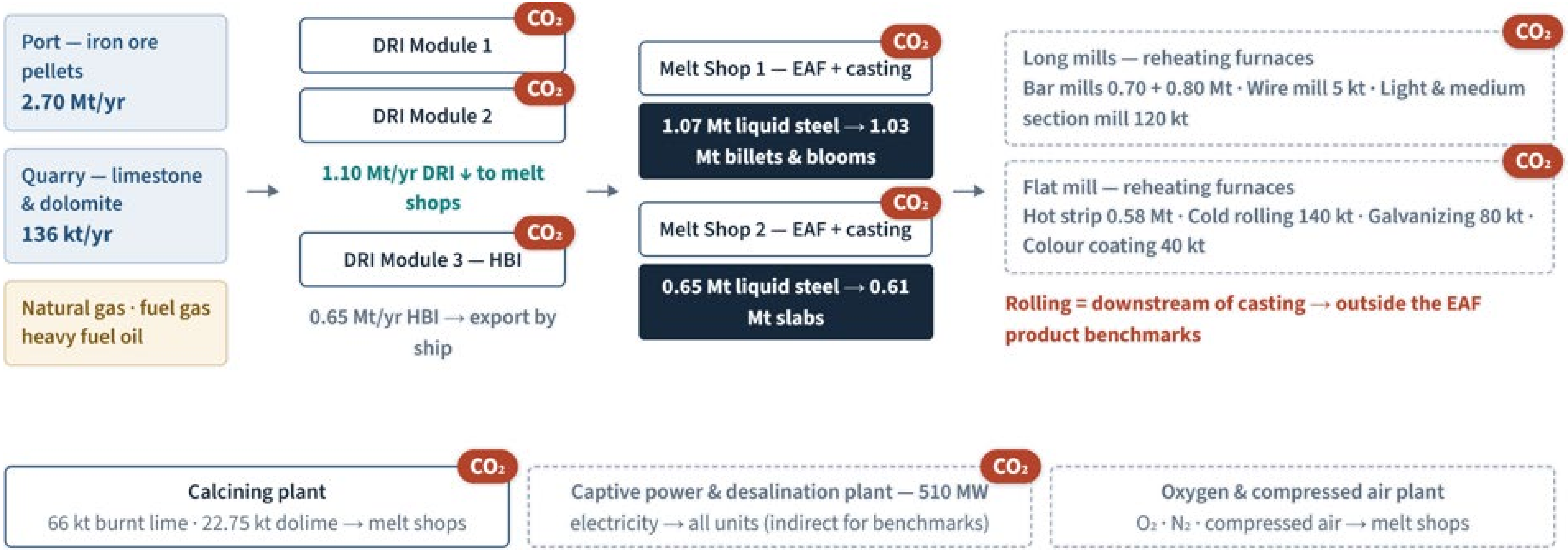
CASE STUDY · INTEGRATED DRI–EAF

Example



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CASE STUDY · INTEGRATED DRI–EAF

First steps to

9 goods

one 2025 annual report — separate SEE per good

6 processes

defined for attributing emissions to goods

DRI → EAF → casting → rolling — plus captive power, calcining and oxygen plants; fuels: natural gas & heavy fuel oil.

- Precursors: iron ore supplier data is partial — actual values used where available, EU default values elsewhere; alloy additions (FeMn, SiMn) on defaults;

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CASE STUDY · INTEGRATED DRI–EAF

An integrated DRI–EAF works — the natural-gas route

- **Precursors arrive from prot**— natural-gas reduces into DRI on shaft furnaces (≈ 1.10 Mt DRI + 0.65 Mt HBI/yr) feeding two EAF melt shops (≈ 1.72 Mt liquid steel/yr).
- **Products:** billets & blooms (≈ 1.03 Mt), slabs (≈ 0.61 Mt), rolled long products, hot-rolled coils — plus HBI shipped for export.
- **Inside the boundary:** captive power plant (≈ 500 MW), calcining plant (burnt lime & dolime), oxygen plant, own quarry — fuels: natural gas & heavy fuel oil.
- **Why it matters:** gas-based DRI sits between BF/BOF and scrap-EAF — the case the dedicated CBAM DRI benchmark targets.

≈ 1.75 Mt

DRI + HBI produced per year (CN 7203 10 00)

9

CBAM goods in scope — monitoring year 2025

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CASE STUDY · INTEGRATED DRI–EAF

Mapping the works — production processes, goods, CN codes

Production process	Output / CBAM good	CN code
DRI plants — two shaft-furnace modules	DRI — ≈ 1.10 Mt/yr	**7203 10 00**
HBI plant — one module	HBI — ≈ 0.65 Mt/yr, largely exported	**7203 10 00**
EAF melt shops 1 & 2 (crude steel)	Billets & blooms ≈ 1.03 Mt · slabs ≈ 0.61 Mt	**7207 11 11 · 7207 12 10**
Rolling mills (reheating furnaces)	Bars · wire rod · sections · hot-rolled coils	**7214 20 00 · 7213 10 00 7216 10 00 · 7208 10 00**
Auxiliaries	Captive power plant, calcining (burnt lime & dolime), oxygen plant	**inputs — not CBAM goods**

KEY LINK — the plant's DRI and HBI fall under CN 7203 10 00 — exactly the code carrying the new dedicated CBAM benchmark for natural-gas DRI (0.295 col. A / 0.397 col. B, Reg. (EU) 2025/2620). Precursors declared: iron ore, FeMn, SiMn, scrap.

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CASE STUDY · INTEGRATED DRI–EAF

BF/BOF vs DRI–EAF vs scrap-EAF — what the route means

Per tonne of crude steel	Integrated BF/BOF	NG DRI–EAF (this case)	Scrap-EAF
Direct emission intensity	≈ 1.83 t CO_2/t	≈ 0.7–1.0 t CO_2/t	≈ 0.21 t CO_2/t
EU ETS benchmark applied	Hot metal — 1.288 EUA/t	Hot metal (DRI included — no separate ETS value)	EAF high-alloy — 0.268 EUA/t
Covered by free allocation (2025)	≈ 77%	— (non-EU exporter: CBAM side)	≈ 76%
CBAM default benchmark (col. B)	≈ 1.288 (BF/BOF)	0.397 — dedicated DRI benchmark	≈ 0.027 (scrap/EAF)

TAKEAWAY — route, not output, drives the carbon cost. Our anonymised case sits in the middle: the dedicated CBAM DRI benchmark (slide on Reg. 2025/2620) keeps its obligations below BF/BOF steel but above scrap-EAF. Türkiye makes ≈ 70% of its steel via scrap-EAF → among the lowest CBAM exposure; gas-based DRI exporters face a moderate, growing obligation as free allocation phases out.

Sources: JRC 2023 (Türkiye); applied 2021–25 EU benchmarks; Reg. (EU) 2025/2620 Annex (col. B). Anonymised pre-verification data, 2025. [ETS+CBAM/]

DAY 2

Agenda for the day

1	Introduction: Routes and benchmark map (EU ETS ↔ CBAM)	
2	How emissions are counted (MRV & mass balance)	
3	The production routes in technical detail & the benchmark curve	Detailed sector: Iron&steel
4	System boundaries and relation between EU ETS benchmarks and CBAM	
5	Full worked calculation EAF – high alloy steel (Emissions + allocation + CBAM factor)	Case study: Iron&steel
6	Example of a full integrated plant (Emissions + allocation) - *overview*	
7	Q&A	

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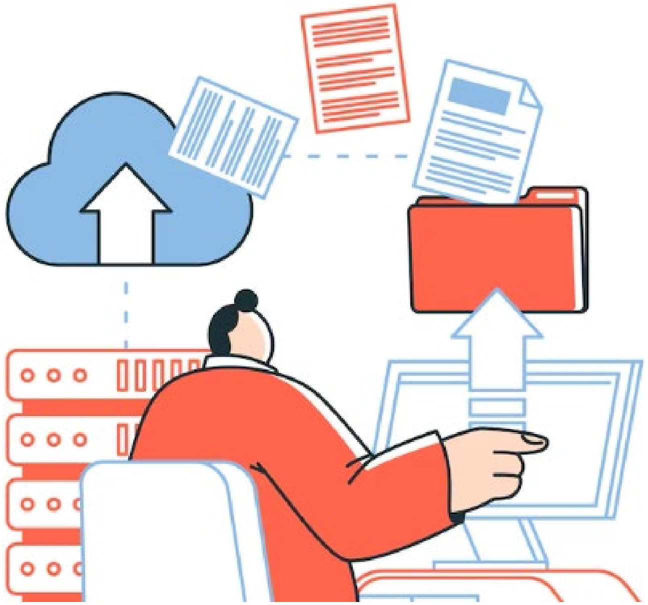
CLOSE

Iron and steel – Day 2

Questions and discussion · Next: Day 3 — cement, lime and aluminium

Primary sources cited in this storyboard

- EU ETS Directive 2003/87/EC (consolidated 01.03.2024) — Art. 10a [ETS/]
- Free Allocation Regulation (EU) 2019/331 (cons. 01.01.2024) — Annex I, Annex IV [ETS/]
- Free Allocation Guidance GD9 — sector-specific guidance, iron & steel §2-7 [ETS/]
- Supporting guidance: GD3, GD4, GD5, GD6, GD8 [ETS/]
- CBAM Implementing Reg (EU) 2025/2620 — benchmark Annex (codes C-J; DRI; pig iron; iron ore) [CBAM/]
- CBAM Reg (EU) 2023/956 and 2025/2621 (default values) [CBAM/]
- Accreditation & Verification Reg (EU) 2018/2067 (AVR) [MRV/]
- Continuity reference: Presentations 2024 / Day 2

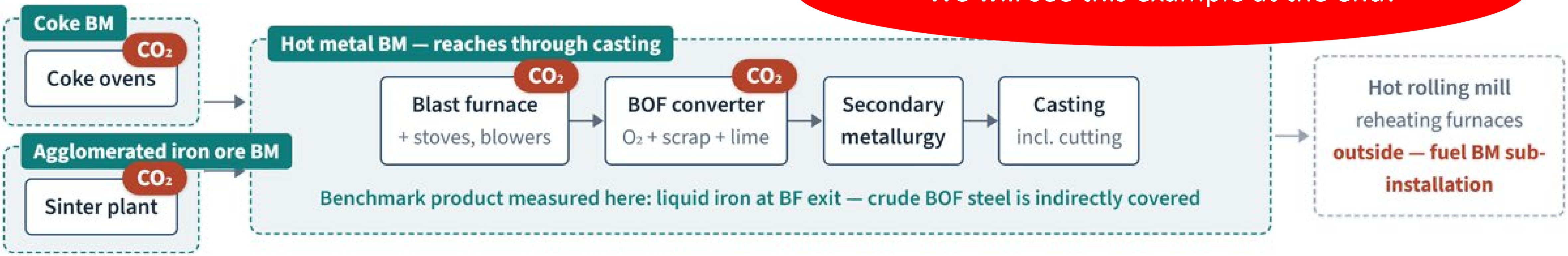


Back-up slides

PRODUCTION ROUTES — TECHNICAL DETAIL

Integrated plant

We will see this example at the end!



COG · BFG · BOFG Waste gases → on-site power plant: combustion emissions attributed to electricity production, excluded from free allocation (GD 8)

WORKED EXAMPLE illustrative figures

Given: the coke plant discharges 800 kt dry coke: 740 kt charged to the blast furnace, 60 kt coke breeze consumed at the sinter strand.

Rule & result: allocation for coke production = BM_{coke} × **800 kt** (full production). In emissions monitoring, the 740 kt is a source stream of the **hot metal** sub-installation and the 60 kt of the **sinter** sub-installation — consumption follows the consuming boundary.

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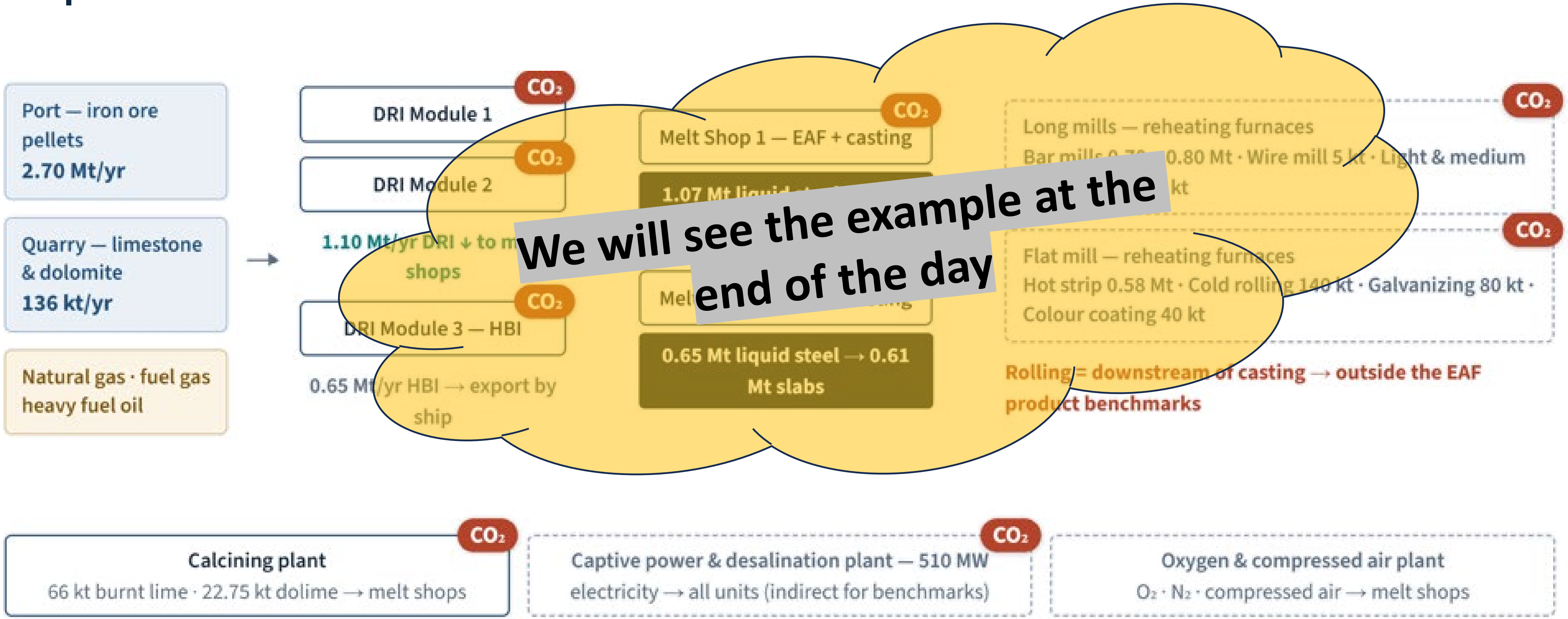
PRODUCTION ROUTES — TECHNICAL DETAIL

Example



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Promoting Enhanced EU ETS Alignment in Türkiye's Emerging ETS

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

Cement sector

Fabio Romani and Matias Franke

July 24th 2026

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MODULE 2 — CBAM-RELEVANT PRODUCT BENCHMARKS BY SECTOR

Online Day 3 — Cement: Clinker & Lime

Grey clinker · white clinker · lime — benchmarks, system boundaries, BDR & a worked calculation

Grey clinker 0.693 t CO_2e/t

White clinker 0.957 t CO_2e/t

Lime 0.725 t CO_2e/t (not CBAM)

Experts: F. Romani / M. Franke · DRAFT — pending GIZ approval

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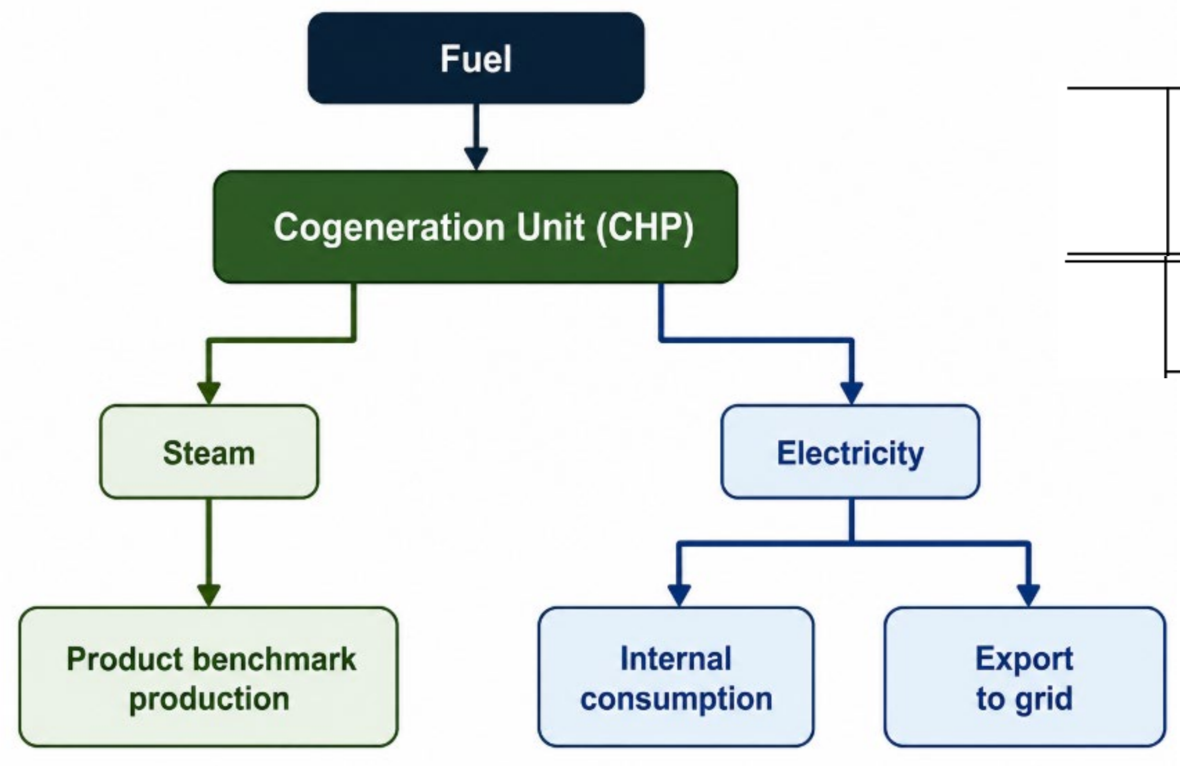
How should fuel consumption and emissions from a cogeneration unit (CHP) be allocated between product, heat and electricity sub-installations under the Turkish ETS?



Category	Energy source	Year of construction		
		Before 2016	2016–2023	From 2024
G10	Natural gas, LPG, LNG and biomethane	52,5	53,0	53,0

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I have one follow-up question regarding the evidence required forCBAM.

- For electricity imported from Turkey into Bulgaria, whatdocuments would the European Commission or the customsauthority actually accept as proof of the hourly import and theassociated embedded emissions?
- Would market operator data (e.g. EPİAŞ in Turkey and IBEX/ADEXin Bulgaria) be sufficient, or would the evidence have to comefrom the Transmission System Operators (TEIAŞ and ESO), such ashourly nominations and capacity allocations?
- In other words, which data source is considered the officialevidence for CBAM compliance?

Regulation 2025/2547

For electricity imports, the European Commission requires proof of physical hourly flow, not just commercial trading. The officially accepted evidence comes from the Transmission System Operators (TSOs)—TEİAŞ for Turkey and ESO for Bulgaria—not from market operators like EPİAŞ or IBEX, which only confirm financial transactions but not physical delivery. Specifically, to use actual emissions, you must provide written TSO documentation demonstrating that there was no physical congestion on the interconnector at the time of export, and formal confirmation that the corresponding capacity was explicitly designated for that specific hour. These TSO-issued documents, combined with the generator's verified emission report (proving below 550 g CO_2/kWh) and smart meter data from both production and consumption sites, form the complete and auditable evidence chain. Without these official TSO records, customs authorities will not accept actual emission values and will default to the higher predefined emission factors, significantly increasing your carbon costs.

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DAY 3

Agenda for the day

1. **Introduction: cement & lime in the EU ETS and CBAM**
2. The process & how emissions are counted (MRV)
3. EU ETS benchmarks & the benchmark curve (clinker · white clinker · lime)
4. System boundaries, emission calculation and monitoring plan - Clinker plant example
5. Lime plat example: Monitoring emissions and free allocation

Case study

6. Conclusions and last considerations

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CONTINUITY WITH DAY 2

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

Same framework as Day 2

- Product benchmarks = average of the 10% best EU installations
- Free allocation = BM × HAL × CLEF × CBAM factor
- Carbon-leakage list → CLEF = 1 (100%)
- Sub-installations, BDR data, verified MRV

What is different for cement

- ~2/3 of the CO_2 is process (calcination), not fuel
- CBAM default ≈ EU ETS benchmark (little spread)
- Lime is on the leakage list but NOT a CBAM good
- Cement is far more CBAM-exposed than steel

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CONTEXT — RESEARCH MATERIAL (OECD study, continued from Day 2)

Cement is the CBAM sector the border levy protects least

−1.44%

EU value added — the worst-hit CBAM sector

The steepest value-added fall of any CBAM good, even with the border levy in place (Full Policy Mix).

up to −2.8%

when free allowances are removed

Loss for sectors whose free allocation covered >85% of emissions — cement and basic metals — before any CBAM cushion.

−3% → −1%

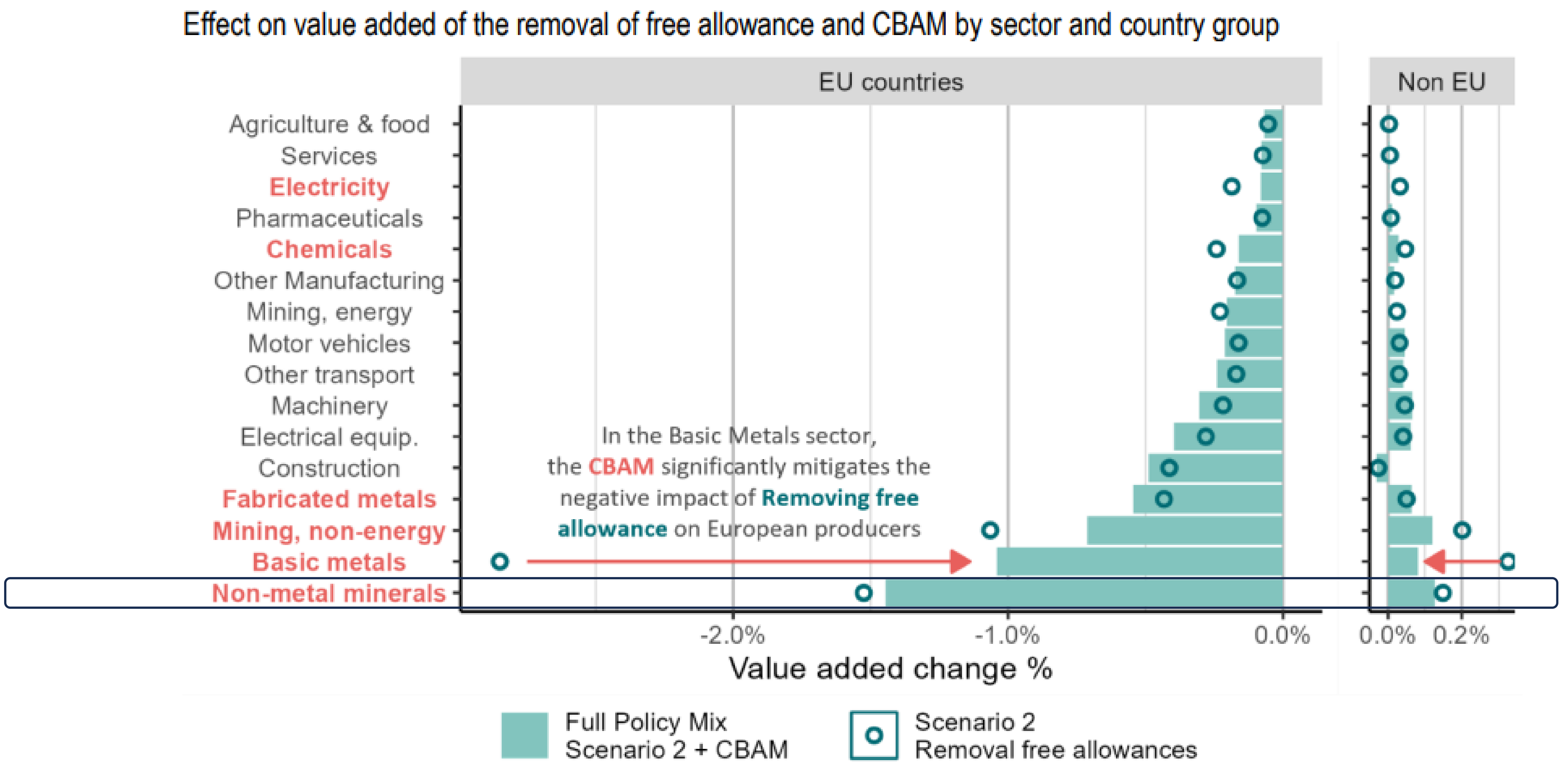
steel is rescued, cement is not

CBAM lifts basic metals back to about −1%; cement stays near its full loss because fewer of its products are covered.

Why cement fares worst: its downstream products (concrete, mortar, articles) sit outside CBAM, so the border levy covers only part of the value chain — and cement carried the second-largest free allocation. Less cover plus more to lose gives the deepest value-added hit.

Source: OECD (2025) — The potential effects of the EU CBAM along the supply chain, Figs. 11–12 & Executive summary. [reasearch material/]

CONTEXT — RESEARCH MATERIAL (OECD study, continued from Day 2)



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CONTEXT — RESEARCH MATERIAL (OECD study, continued from Day 2)

What the CBAM means for cement specifically

Why the border levy under-protects cement

- Limited product coverage: only clinker and cements are CBAM goods; concrete, mortar and cement articles stay outside
- Scope 2 counts: cement is one of only two sectors (with fertilisers) where electricity emissions are included
- Imported cement also carries its clinker emissions — clinker is itself a CBAM precursor (Scope 3)
- Cost pass-through is wide and uncertain — 20–100% for cement (vs 60–100% for steel)

What it means for Türkiye

- The study's small positive result for Türkiye comes from low-carbon recycled steel (EAF) — not from cement
- Read it as a caveat, not relief: cement stays Türkiye's most CBAM-exposed product
- No measurable EU ETS leakage in cement or steel so far (Branger, Quirion & Chevallier, 2016)...
- ...but removing free allowances and adding CBAM shifts that balance for the 2026 pilot

Source: OECD (2025) — The potential effects of the EU CBAM along the supply chain, §2 & Box 3; Branger, Quirion & Chevallier (2016). [reasearch material/]

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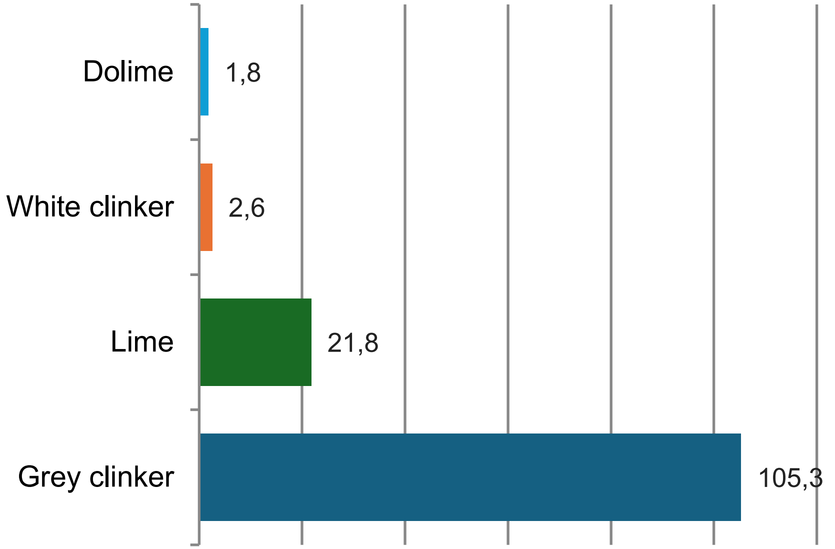
Why cement matters: a top emitter with the most installations

- Grey clinker ≈ 105 Mt CO_2 (2016/17) — among the EU ETS's largest single sources
- 191 installations for grey clinker — the most of any benchmark
- Lime adds ≈ 22 Mt CO_2 across 171 installations
- Emissions are structural: ~2/3 come from calcining limestone
- All on the carbon-leakage list (CLEF = 1); clinker also within CBAM scope

EU emissions covered by benchmark (Mt CO_2)



Source: EU benchmark-curve factsheet (12 Oct 2021), attributed 2016/17 emissions. [reasearch material/]

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DAY 3

Agenda for the day

1. Introduction: cement & lime in the EU ETS and CBAM
2. **The process & how emissions are counted (MRV)**
3. EU ETS benchmarks & the benchmark curve (clinker · white clinker · lime)
4. System boundaries, emission calculation and monitoring plan - Clinker plant example
5. Lime plat example: Monitoring emissions and free allocation

Case study

6. Conclusions and last considerations

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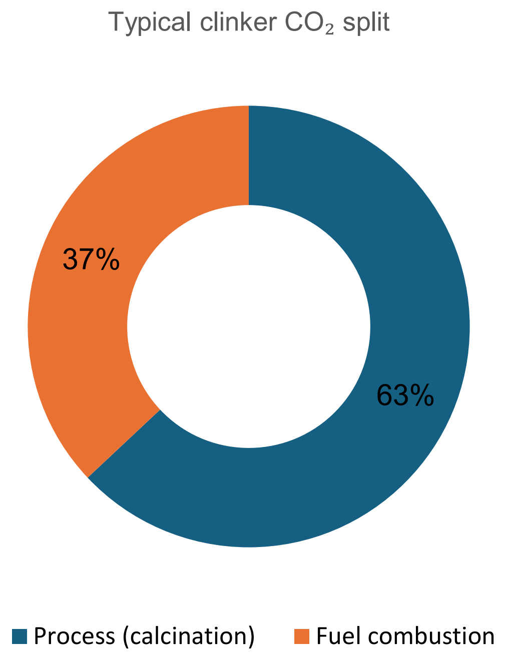
Where the CO_2 comes from — and the levers



- Process emissions (~2/3): unavoidable by fuel switching — they come from the limestone itself
- Fuel emissions (~1/3): lever via alternative fuels (waste, tyre-derived) and biomass (zero-rated)
- White clinker is higher (0.957): low-iron raw meal needs a hotter kiln → more fuel CO_2
- Biggest product-level lever — clinker substitution — sits outside the clinker benchmark

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THE CEMENT PROCESS

How clinker and cement are made

Raw meal limestone + clay/sand → **Preheater / precalciner** → **Rotary kiln** ~1450 °C → **Clinker** (CBAM good) → **+ gypsum / SCMs** → Cement

Calcination (in the kiln): $CaCO_3 \rightarrow CaO + CO_2$ — limestone releases CO_2 as it turns into lime; this is the bulk of cement's emissions.

- Clinker is the CO_2-intensive intermediate; cement = clinker + gypsum + supplementary cementitious materials (SCMs)
- The EU ETS benchmark is set per tonne of CLINKER, not per tonne of cement
- Lowering the clinker content of cement (clinker substitution) cuts emissions at the cement-product level

Sources: FAR 2019/331 Annex I; GD9 §10. Process per standard cement chemistry.

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EMISSIONS ACCOUNTING (MRV)

How cement emissions are counted

Process emissions (calcination)

- Method A — carbonate input: t carbonate × emission factor
- Method B — oxide output: t CaO/MgO in clinker × EF
- Correct for cement kiln dust (CKD) & bypass dust

Fuel & other

- Combustion: fuel × NCV × EF × OF (incl. alternative fuels)
- Biomass fraction is zero-rated for CO_2
- Or measurement-based (CEMS) in the stack

- All emissions of the clinker process — calcination, fuel, CKD/bypass dust — are attributed to the clinker sub-installation
- Electricity emissions are outside the benchmark boundary (handled via indirect-cost support, not free allocation)
- For a national ETS, the carbonate data and the biomass/alternative-fuel split are the parameters needing most care

Sources: MRR (EU) 2018/2066 (Arts. 24–25); GD9 §10. [ETS/ · ETS/training material/]

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Two methods to calculate process emissions: Lime (EU Regulation 2018/2066)

Method A: Input-based approach

Starting point:
- Raw material consumption
- $CaCO_3$ and $MgCO_3$ content
- Moisture and gangue correction

Raw materials
↓
Carbonate content
↓
Stoichiometric conversion
↓
Process CO_2 emissions

Best suited when
- Raw material composition is well characterised

Method B: Output-based approach

Starting point
- Lime production
- CaO, MgO and residual CO_2 analyses
- Residual carbonates correction

Lime production
↓
Chemical composition
↓
Actual calcined oxides
↓
Process CO_2 emissions

Best suited when
Product quality is continuously monitored

Both methods are based on the same stoichiometric principles and should lead to equivalent annual process emissions when properly applied.
.

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Two methods to calculate process emissions: Cement clinker (EU Regulation 2018/2066)

Method A: Input-based approach

Starting point:

- Raw meal consumption
- $CaCO_3$ and $MgCO_3$ content
- Moisture and non-carbonate correction

Raw meal
↓
Carbonate content
↓
Stoichiometric conversion
↓
Process CO_2 emissions

Best suited when
- Raw meal composition is well characterised

Method B: Output-based approach

Starting point

- Clinker production
- Clinker chemical composition (CaO, MgO)
- CKD and bypass dust (where applicable)

Clinker production
↓
Chemical composition
↓
Actual calcined oxides
↓
Process CO_2 emissions

Best suited when
Clinker production and quality are continuously monitored

Both methods are based on the same stoichiometric principles and should lead to equivalent annual process emissions when properly applied.
.

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RECAP

What we covered — the cement process & emissions accounting

Make clinker, then cement

Raw meal → kiln (~1450 °C) → clinker → + gypsum/SCMs → cement; benchmark is per tonne clinker

Calcination dominates

$CaCO_3$ → CaO + CO_2; ~2/3 of clinker CO_2 is process, ~1/3 fuel

Levers

Alternative fuels & biomass (fuel side); clinker substitution at product level

How it's counted

Process via carbonate input (A) or oxide output (B); fuel by combustion; CKD corrected

Next: the EU ETS cement benchmarks and the benchmark curve.

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Cement & lime product benchmarks

Product benchmark	Unit	2026 - 2030	2021 - 2025	Ph-3 ref.	# EU inst.	CBAM?
Grey cement clinker	t clinker	0,656	0.693	0.766	191	Yes (0.666)
White cement clinker	t clinker	0,890	0.957	0.987	12	Yes (0.859)
Lime	t standard lime	0,693	0.725	0.954	171	No
Dolime	t standard dolime	0,792	0.815	1.072	36	No
Sintered dolime	t sintered dolime	1,162	1.406	1.449	6	No

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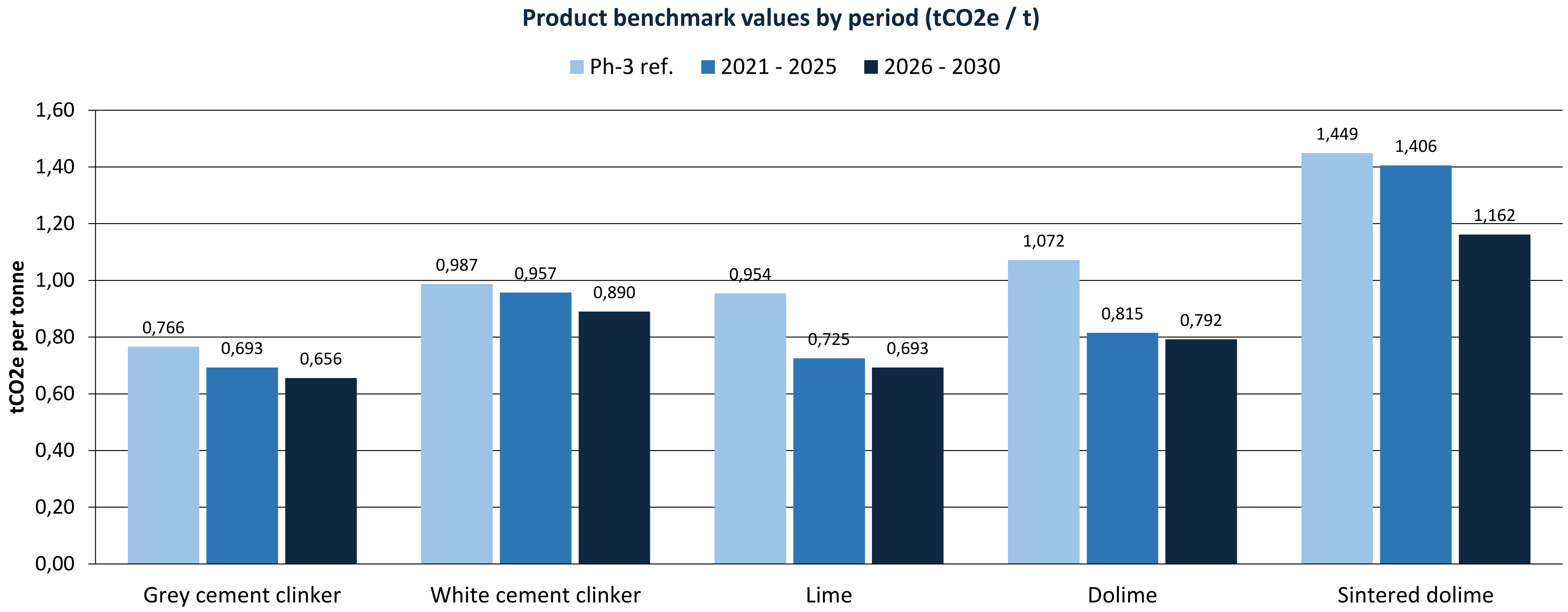
EU ETS

Benchmark tightening over time



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INTERFACE — KEY SLIDE

Crosswalk: EU ETS cement benchmarks ↔ CBAM

EU ETS benchmark	CBAM good?	CBAM benchmark (Reg 2025/2620)	Free allocation phase-out?
Grey cement clinker	Yes — clinker (CN 2523 10 00)	0.666 (grey, col A & B equal)	Yes — CBAM factor to 0% by 2034
White cement clinker	Yes — clinker (CN 2523 10 00)	0.859 (white)	Yes — CBAM factor
Lime	**No — not a CBAM good**	—	**No — CBAM factor = 1 (keeps free allocation)**

Key: clinker (and cement, via its clinker content) is in CBAM scope and loses free allocation from 2026; lime stays outside CBAM and keeps full free allocation. For clinker the CBAM default ≈ the EU ETS benchmark.

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CBAM - Default Values

Regulation (EU) 2025/2621

		Türkiye			
Product CN Code	Description	Default Value (direct emissions)	Default Value (indirect emissions)	Default Value (total emissions)	2026 Default Value (including mark-up)
Cement					**10% mark-up**
2507 00 80	Calcined clay	–	–	–	–
2523 10 00	White clinker	–	–	–	–
2523 10 00	Grey clinker	–	–	–	–
2523 21 00	White Portland cement	–	–	–	–
2523 29 00	Grey Portland cement	–	–	–	–
2523 90 00	White hydraulic cements	–	–	–	–
2523 90 00	Grey hydraulic cements	–	–	–	–
2523 30 00	Aluminous cement	1,820	0,140	1,950	2,145

		Other Countries and Territories			
Product CN Code	Description	Default Value (direct emissions)	Default Value (indirect emissions)	Default Value (total emissions)	2026 Default Value (including mark-up)
Cement					**10% mark-up**
2507 00 80	Calcined clay	0,210	0,070	0,280	0,308
2523 10 00	White clinker	1,320	0,060	1,370	1,507
2523 10 00	Grey clinker	1,370	0,050	1,410	1,551
2523 21 00	White Portland cement	1,300	0,140	1,450	1,595
2523 29 00	Grey Portland cement	1,360	0,080	1,440	1,584
2523 90 00	White hydraulic cements	1,310	0,180	1,490	1,639
2523 90 00	Grey hydraulic cements	1,280	0,090	1,370	1,507

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How to face high carbon price

Installation emission verification

Regulation (EU) 2025/2547 on methods for the calculation of emissions embedded in goods

Or

National ETS

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Grey cement clinker

What it is

- Grey cement clinker (or alternative hydraulic binders) for cement
- Unit: tonnes of grey clinker (as total hydraulic binder produced)
- Boundary: all processes linked to clinker — calcination + fuel
- By-pass / kiln dust attributed to the clinker sub-installation

Benchmark facts

Unit t grey clinker
CLEF 1 (100%)
CBAM scope yes
CN code 2523 10 00

ETS weighted average emission value
0.810 t CO_2e/t
EU ETS benchmark (2021–25)
0.693 t CO_2e/t · 191 EU installations

CBAM default emission value
1,551 t CO_2e/t · CN 2523 10 00
CBAM Benchmark
0,66 t CO_2e/t · CN 2523 10 00

Sources: FAR 2019/331 Annex I; GD9 §10; benchmark-curve factsheet; CBAM Reg 2025/2620. [ETS/ · CBAM/]

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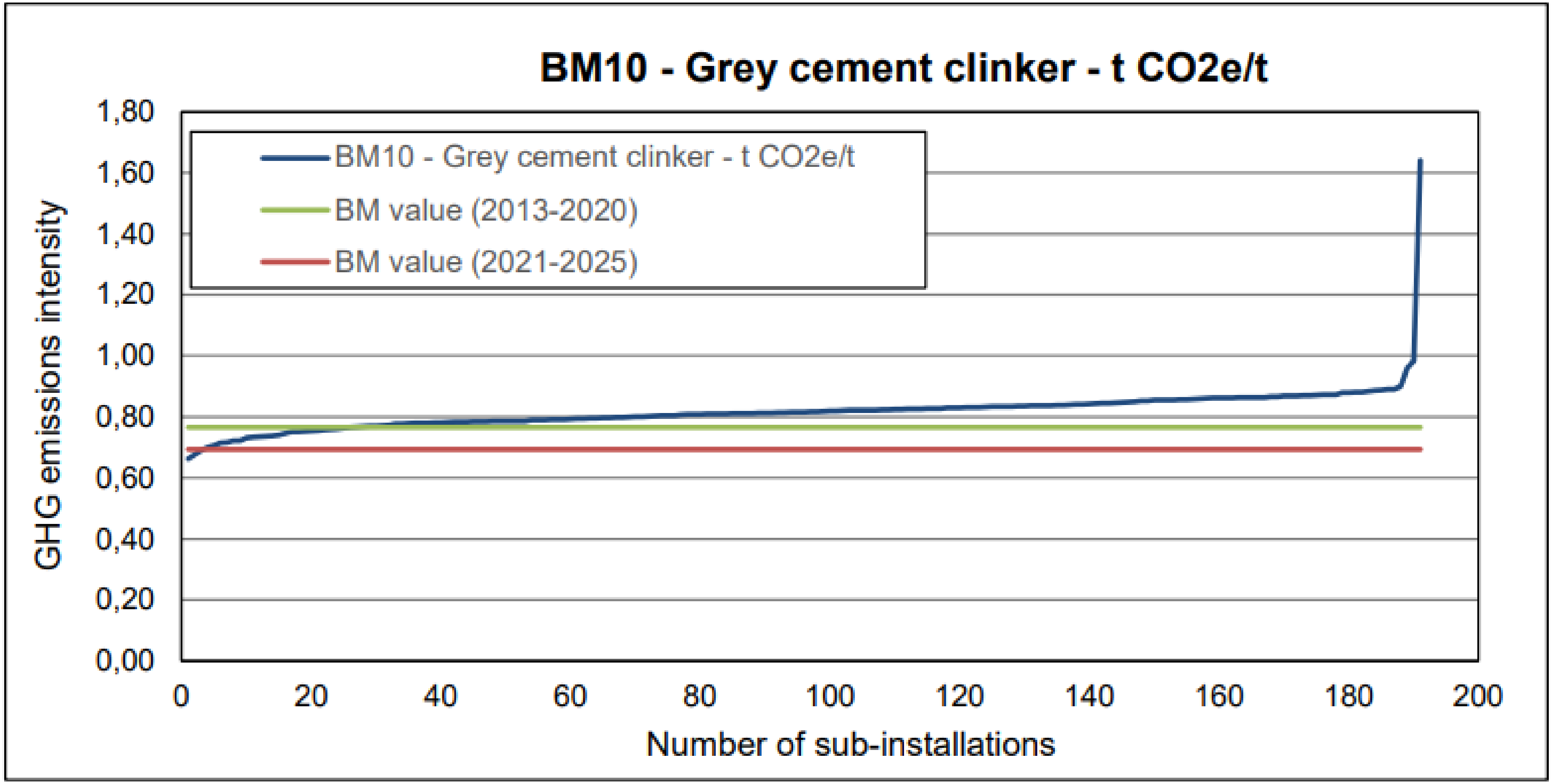
Grey cement clinker



Weighted average GHG emissions intensity of all installations in 2016/2017	0,810	t CO_2e/t

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White cement clinker

What it is — and why it's higher

- White clinker for white cement (decorative, architectural use)
- Made from low-iron / low-manganese raw materials
- Needs a hotter kiln + sometimes bleaching → more fuel CO_2
- Same calcination chemistry, but higher fuel intensity

Benchmark facts

Unit t white clinker
CLEF 1 (100%)
CBAM scope yes
EU inst. 12 (rare)

ETS weighted average emission value

1.114 t CO_2e/t

EU ETS benchmark (2021–25)

0.957 t CO_2e/t · ≈ 38% above grey clinker

CBAM default emission value

1,507 t CO_2e/t · CN 2523 10 00

CBAM benchmark (default)

0.859 t CO_2e/t · CN 2523 10 00 (white)

Sources: FAR 2019/331 Annex I; GD9 §11; benchmark-curve factsheet; CBAM Reg 2025/2620. [ETS/ · CBAM/]

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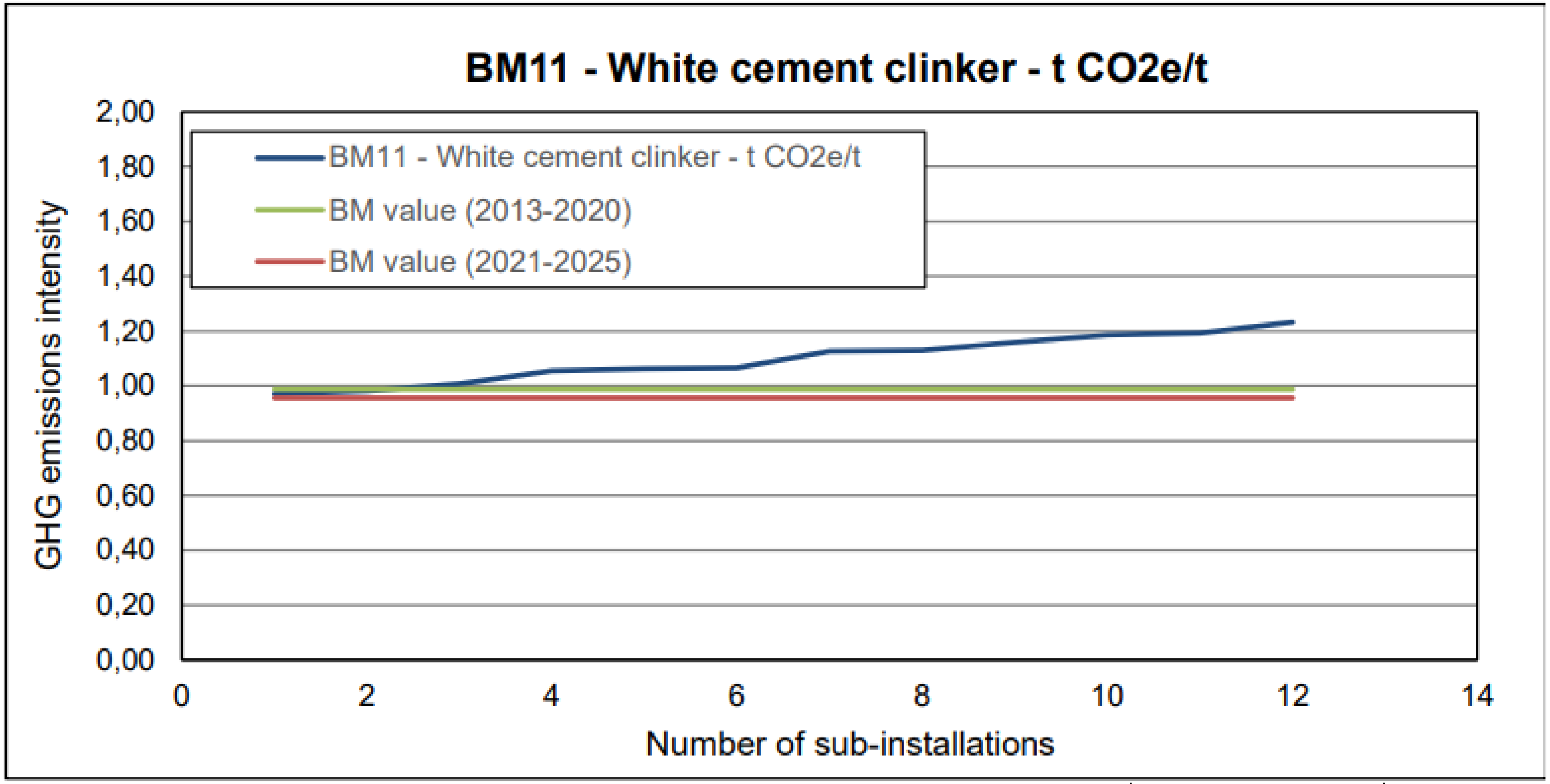
White cement clinker



Weighted average GHG emissions intensity of all installations in 2016/2017	1,114	t CO_2e/t

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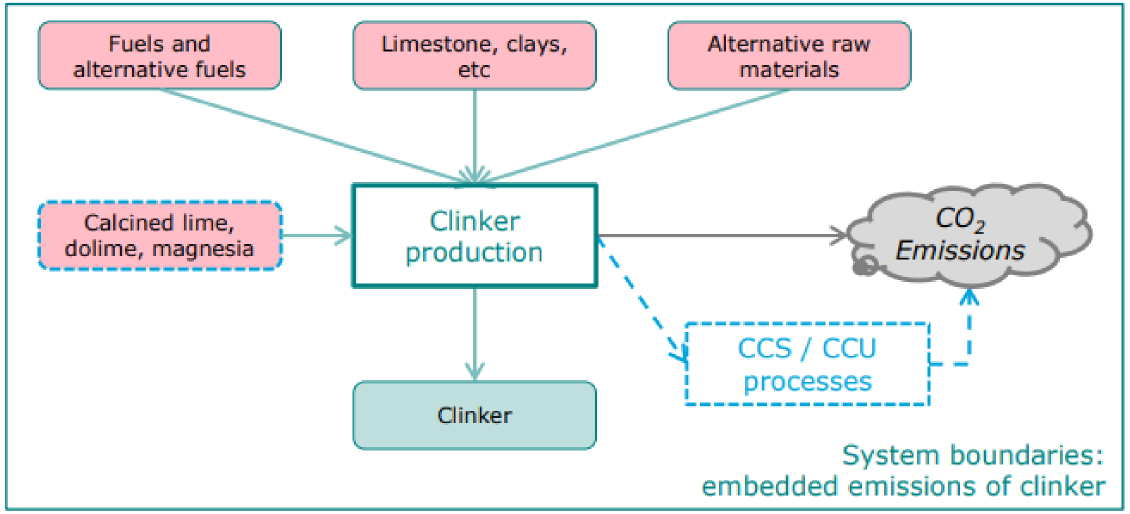
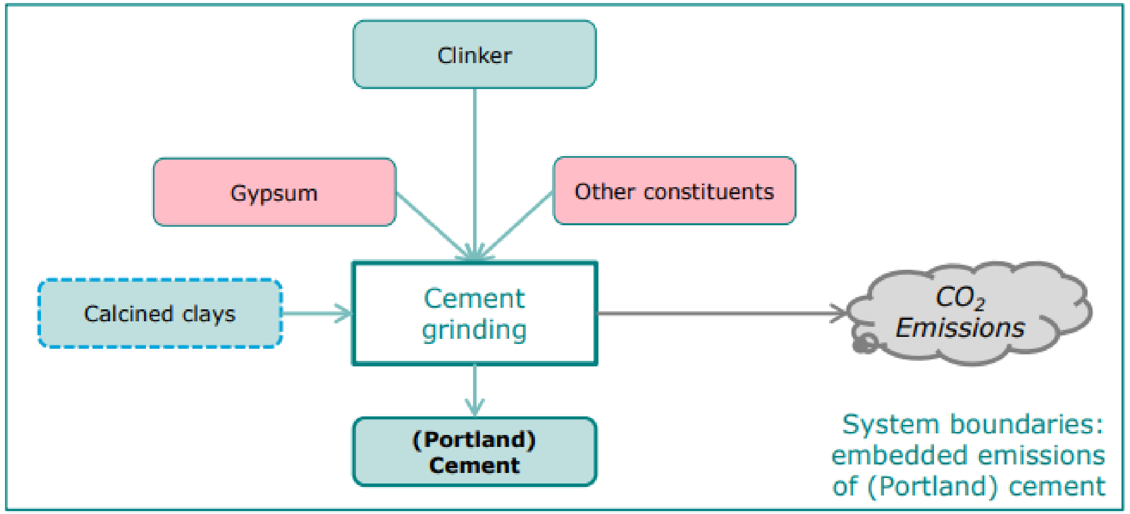
Emission calculations

Cement clinker and cement production processes

Cement clinker and cement production processes





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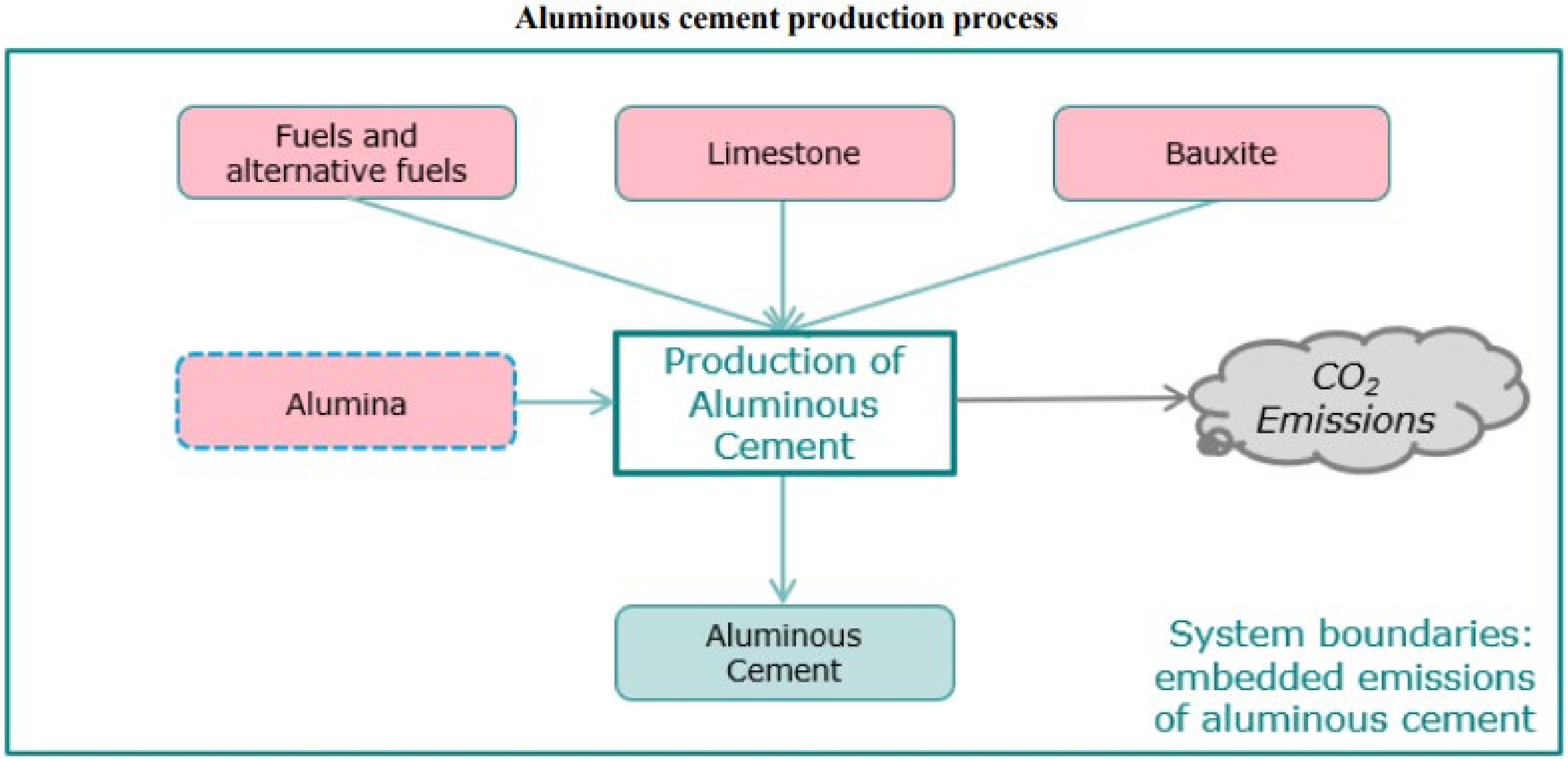
Emission calculations

CAC: Aluminous cement production processes



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Lime — on the leakage list, but NOT a CBAM good

What it is

- Quicklime: CaO from decarbonation of limestone ($CaCO_3$)
- Unit: tonnes of 'standard pure' lime (94.5% free CaO)
- Boundary: all processes linked to lime production
- Mostly process emissions — same calcination as clinker

Benchmark facts

Unit t standard pure lime

CLEF 1 (100%)

CBAM scope NO

EU inst. 171

Consequence: lime 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 0.725 t CO_2e/t across 171 installations.

Sources: FAR 2019/331 Annex I; GD9 §12 ('Under the CBAM scope: No'). [ETS/]

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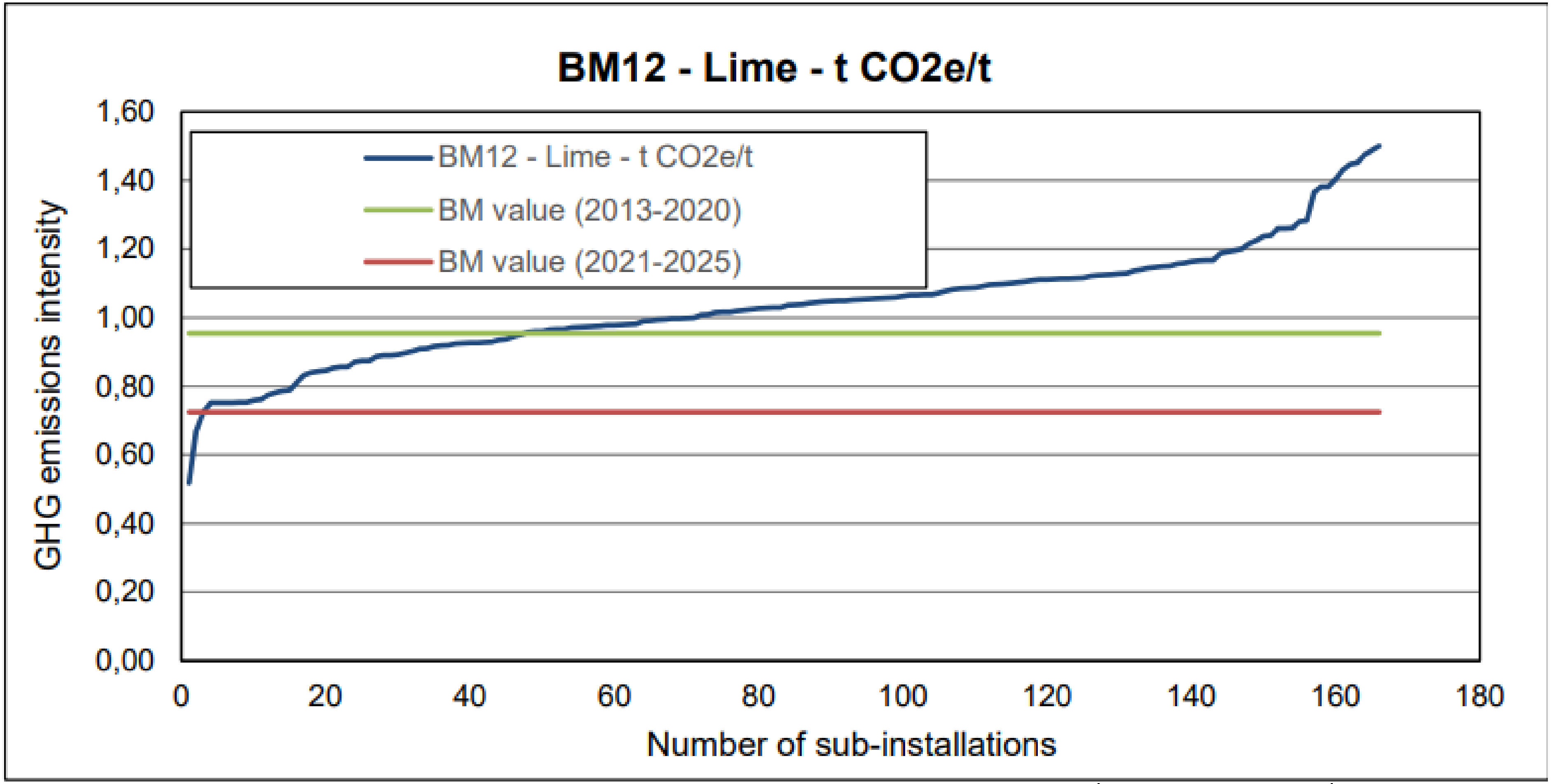
Lime



Weighted average GHG emissions intensity of all installations in 2016/2017	1,059	t CO_2e/t

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Dolime — on the leakage list, but NOT a CBAM good

What it is

- Dolime: CaO+MgO from decarbonating dolomite ($CaCO_3 \cdot MgCO_3$)
- Unit: t 'standard pure' dolime (57.4% CaO; 38.0% MgO)
- Boundary: fuel prep, calcination/sintering & flue-gas treatment
- Definition: residual CO_2 >0.25%; free MgO 25–40%; density <3.05 g/cm^3

Benchmark facts

Unit t standard pure dolime

CLEF 1 (100%)

CBAM scope NO

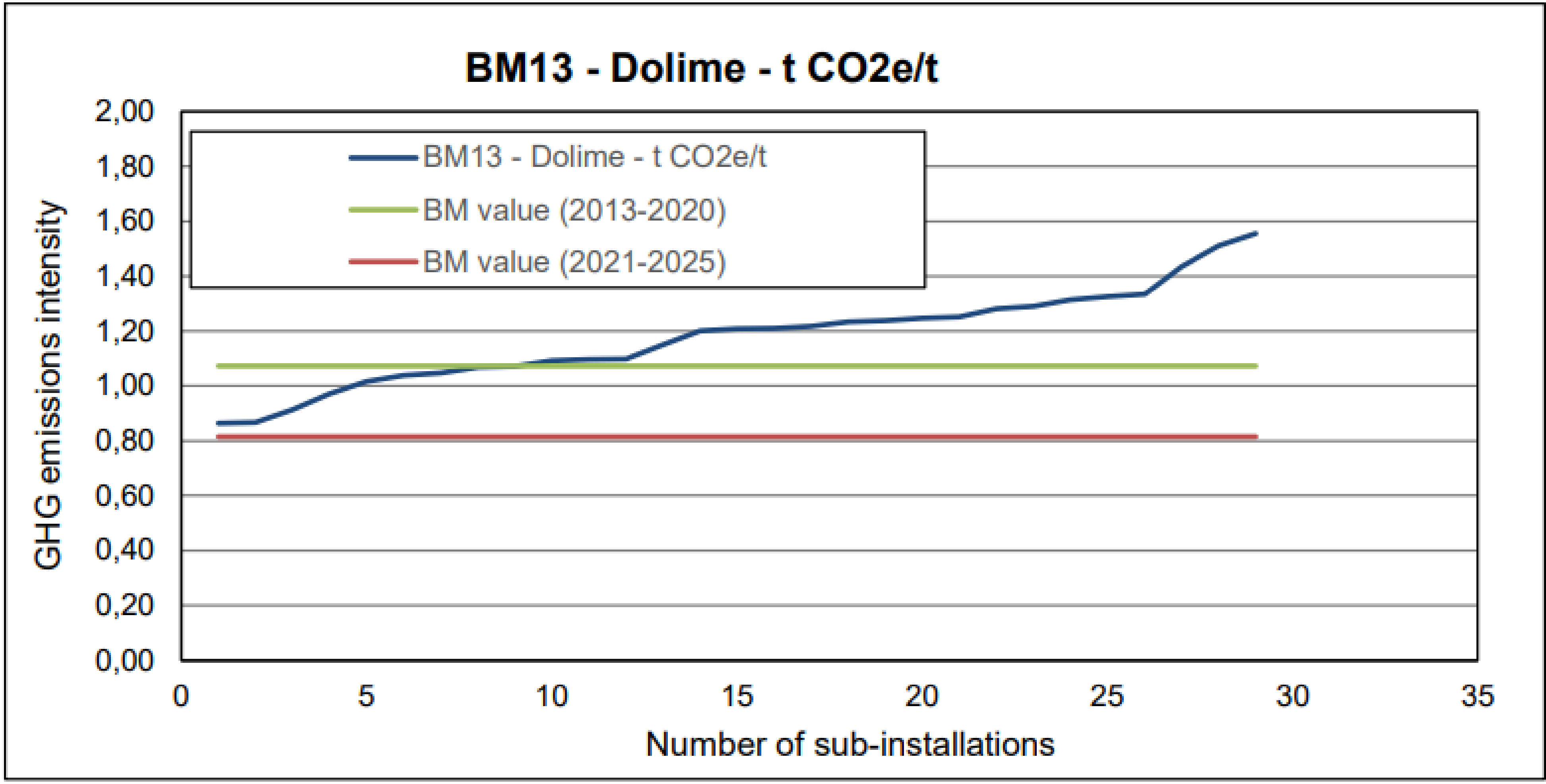
EU inst. 36

Consequence: dolime is on the carbon-leakage list (CLEF = 1) but is not a CBAM good — CBAM factor = 1, so free allocation does not phase out. EU ETS benchmark 0.815 t CO_2e/t across 36 installations; HAL is corrected using free CaO/MgO content.

Sources: FAR 2019/331 Annex I/III; GD9 §13 (Dolime; CBAM scope: No). [ETS/]

BENCHMARK 4 OF 4

Dolime



Weighted average GHG emissions intensity of all installations in 2016/2017	1,214	t CO_2e/t

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RECAP

What we covered — EU ETS cement benchmarks & the benchmark curve

Three benchmarks

Grey clinker 0.693, white clinker 0.957, lime 0.725 (t CO_2e/t)

The curve

Benchmark = 10% best; clinker intensities cluster tightly (process-driven)

CBAM ≈ EU ETS

For clinker the CBAM default (0.666) ≈ the EU ETS benchmark — little spread

Lime is special

On the leakage list but not a CBAM good → keeps full free allocation

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

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DAY 3

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SYSTEM BOUNDARIES

Sub-installations for a cement / lime plant

- Clinker sub-installation = one product-benchmark sub-installation (grey or white)
- Calcination, fuel, and CKD/bypass-dust emissions all attributed here
- Lime is its own product-benchmark sub-installation
- Residual scope → fallback sub-installations: heat, fuel, process emissions
- No emission counted under two sub-installations (no double counting)

Attribution hierarchy

1. **Product benchmarks**
2. Heat benchmark
3. Fuel benchmark
4. Process emissions

Sources: FAR 2019/331 (sub-installation attribution); GD9 §10–12.

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SYSTEM BOUNDARIES

Summary — what is inside each benchmark

Benchmark	Unit	Key processes inside the boundary
Grey cement clinker	t clinker	Raw-meal prep, calcination, kiln fuel, clinker cooling; CKD/bypass dust included
White cement clinker	t clinker	As grey clinker; higher kiln temperature / fuel for low-iron raw materials
Lime	t standard lime	Calcination of limestone in lime kilns; fuel; mostly process emissions
(Dolime / sintered dolime)	t product	Calcination of dolomite/magnesite — specialised lime products

Across all: electricity emissions are excluded from the boundary; biomass CO_2 is zero-rated; measurable heat handled separately.

Sources: FAR 2019/331 Annex I; GD9 §10–14.

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EU ETS · MONITORING, REPORTING & VERIFICATION

Accounting the CO_2 emissions of a cement plant

Source streams, methodologies, tiers and reporting — a complete walkthrough of one real installation.

Cement Plant

Integrated dry-process plant · anonymized

≈ 543,000 t CO_2

Fossil emissions, reporting year 2024

7 sources · 8 streams

Emission sources F1–F7 · source streams CM1–CM8

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The accounting framework

1

Define the boundary

List every emission source (F) and every source stream (CM) inside the permit — down to the fire-pump diesel.

2

Choose the methodology

Calculation-based standard methodology: combustion formula for fuels, process formula for carbonates.

3

Apply tiers

The bigger the stream, the stricter the accuracy requirements on activity data and calculation factors.

4

Report and verify

Annual emissions report, independently verified, based on an approved monitoring plan.

COMBUSTION EMISSIONS

$$E = AD \times NCV \times EF \times OF$$

PROCESS EMISSIONS

$$E = AD \times EF \times CF$$

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02 · THE INSTALLATION

Cement Plant X at a glance

1
rotary kiln
dry process, with preheater

661 kt
clinker produced
from ≈ 1,023 kt of raw meal

4
fuel families co-fired
pet coke, tyres, plastics, natural gas

543 kt
CO_2 per year
fossil, rounded · + 11 kt biomass CO_2 rated zero

A fully integrated plant: raw materials are ground into **raw meal**, burned into **clinker** in kiln F1, then ground with additives into **cement** for bagging and dispatch. Auxiliary boilers heat offices and buildings; emergency devices stand by on diesel.

Every unit emits CO_2 — and **every single one is inside the accounting boundary** , from the kiln's 540,000 tonnes to the fire pump's 9.

NOTE ON THE DATA

Installation anonymized. All quantities rounded. Reporting year: 2024.

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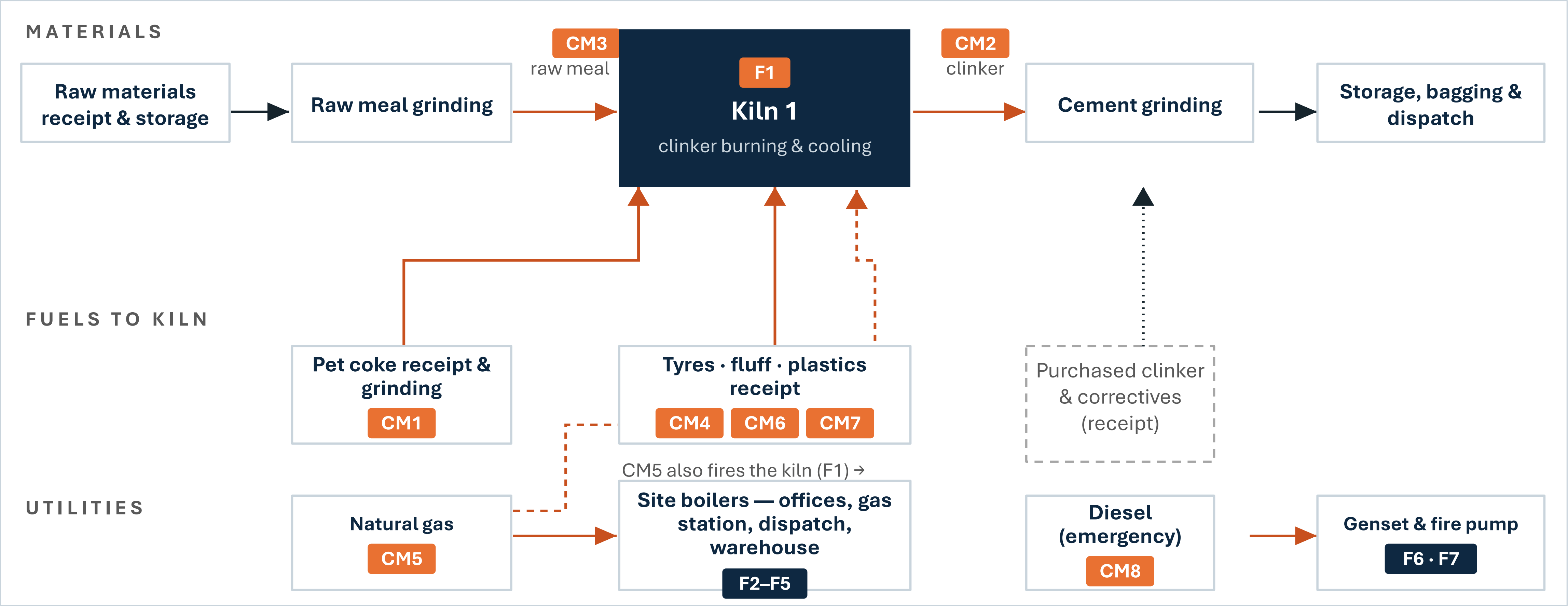
03 · SOURCE-STREAM DIAGRAM

Process flow and source streams

CM source stream (measured) F emission source (emits)



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04 · WHERE CO_2 LEAVES THE PLANT

Emission sources F1–F7

F1

The clinker kiln

Decarbonation of raw meal + combustion of fossil and alternative fuels, including biomass fractions.

99.8% of the plant's CO_2

F2
Office boiler
natural gas

F3
Gas-decompression boiler
natural gas

F4
Dispatch boiler
natural gas

F5
Warehouse boiler
natural gas

F6
Emergency genset
diesel

F7
Fire-fighting pump
diesel

Completeness rule Every combustion or process unit inside the permit boundary is a source — even the fire pump that emitted 9 tonnes. Nothing is left out; small sources just get lighter requirements.

05 · WHAT GETS MEASURED

Source streams CM1–CM8

Stream	Description	Method	CO_2 2024 (t, rounded)	Class
CM1	Petroleum coke (main kiln fuel)	Combustion	**174,000**	**Major**
CM2	Clinker — carbonate decarbonation	Process	**340,000**	**Major**
CM3	Raw meal — non-carbonate carbon (TOC)	Process	4,300	Minor
CM4	Used tyres (31% biomass)	Combustion	23,500 + 10,800 bio	**Major**
CM5	Natural gas (kiln + boilers)	Combustion	700	De-minimis
CM6	Fluff (not used this year)	Combustion	0	De-minimis
CM7	Plastics & rubber (31% biomass)	Combustion	260 + 120 bio	De-minimis
CM8	Diesel — emergency devices	Combustion	9	De-minimis

Major: everything not minor or de-minimis **Minor:** < 5,000 t CO_2/yr or < 10% of total **De-minimis:** < 1,000 t CO_2/yr or < 2% of total

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06 · FORMULA I

Combustion emissions

$$E = AD \times NCV \times EF \times OF$$

Activity data

Tonnes of fuel consumed in the year.

From calibrated weighbridges and belt scales, reconciled with stock changes.

Pet coke: **58,800 t**

Net calorific value

Energy content per tonne (GJ/t).

Laboratory analysis of representative samples, per an approved sampling plan.

Pet coke: **31.5 GJ/t**

Emission factor

t CO_2 per TJ of energy.

Lab-derived for major streams; standard national factors allowed for small ones.

Pet coke: **93.9 t CO_2/TJ**

Oxidation factor

Share of carbon actually oxidised.

Conservatively set to 100% — unburned carbon is not deducted.

All fuels: **100%**

Applies to CM1, CM4, CM5, CM6, CM7, CM8 — expressing consumption on an energy basis (AD × NCV) is the preferred MRR approach.

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07 · FORMULA II

Process emissions

$$E = \text{Clinker output} \times EF_{cli} \times CF$$

CM2

Clinker decarbonation — Method B (output)

$CaCO_3$ and $MgCO_3$ in the raw meal release CO_2 when burned. Instead of weighing every carbonate input, measure the **clinker produced** and apply an emission factor derived from its CaO / MgO content.

661,000 t
clinker (weighed)

0.545
t CO_2 / t clinker (lab)

≈ 340,000 t
CO_2 after conversion factor

CM3

Non-carbonate carbon in raw meal

Organic carbon (TOC) in the raw meal also burns: 1,023,000 t of meal × 0.0042 t CO_2/t ≈ **4,300 t CO_2**.

≈ 63%

of the plant's CO_2 is process emissions — released by chemistry, not by fuel choice.

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Biomass in alternative fuels

Used tyres (CM4) — 11,800 t burned, 34,300 t CO_2 released at the stack

biomass fraction: 31% (natural rubber, by analysis)

23,500 t CO_2 — fossil

counted in full, allowances surrendered

10,800 t CO_2 — biomass

reported, rated zero

Prove the fraction

The biomass share must come from laboratory analysis. EN 15440 offers three methods for determining the biomass fraction of a mixed material: 1. The selective dissolution method; 2. The manual sorting method; 3. The 14C method.

Or approved standard values — never assumed.

Report both fractions

Biomass CO_2 appears in the annual report as a memo item with emission factor zero — transparency without cost.

Why it matters

≈ 11,000 t of zero-rated CO_2 per year is a direct financial incentive to substitute fossil fuels with waste-derived ones.

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08 · ZERO-RATED CARBON

Biomass in alternative fuels — the rules behind the zero rating

ZERO-RATING IS CONDITIONAL — MRR ART. 38(5)

Biomass counts at emission factor zero only if it meets the RED II sustainability and GHG-saving criteria.

Evidence: a Proof of Sustainability from a RED II certification scheme, or the purchase and cancellation recorded in the Union Database.

Criteria not met → the preliminary emission factor becomes final: the CO_2 counts as fossil, in full.

Waste-derived fuels — tyres, fluff, plastics mixes

Not agricultural or forestry biomass → only the GHG-saving criterion applies, and only where biomass use started after 1 Jan 2021.

Prove the biomass fraction — Art. 39

Laboratory analysis (e.g. EN 15440). An estimation method needs CA approval, plus proof that analysis is technically infeasible or unreasonably costly.

No reliable data? Use conservative values

High preliminary EF, low biomass fraction. Tyres: typically 20–30% biogenic; Annex VI default EF 85.0 t CO_2/TJ, with a consistent NCV.

Why it matters

Zero-rated CO_2 means no allowances to surrender — and because free allocation follows the product benchmark, not the fuel, a substitution to compliant biomass cuts the carbon bill while the allocation stays. The evidence trail (analyses, PoS, UDB records) is exactly what the verifier re-checks.

Source: GD3 — Biomass and other zero-rating under the EU ETS MRR (26 Sep 2025); MRR Arts. 38–39 & Annex VI.

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09 · ACCURACY REQUIREMENTS

Tiers and uncertainty

MAJOR STREAMS

CM1 · CM2 · CM4

— Highest tiers required

— Activity data: ± 1.5–2.5% max uncertainty

— NCV, EF, biomass fraction: plant-specific, from accredited lab analyses

— Formal sampling plan per material

MINOR STREAMS

CM3

— Lower tiers acceptable

— Activity data: ± 5–7.5%

— Standard or literature factors allowed

— Less frequent analyses

DE-MINIMIS STREAMS

CM5 · CM6 · CM7 · CM8

— No minimum tier

— Conservative estimates permitted

— Supplier invoices as activity data

— National standard factors

The principle

Measurement effort is proportional to the tonnes at stake: 94% of this plant's CO_2 sits in two streams, and that is where the strictest accuracy applies. Dropping a tier requires proof of unreasonable cost or technical unfeasibility.

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Uncertainty assessment in practice — four routes to prove a tier

A tier is a maximum permissible uncertainty for the year's activity data (95% confidence). The monitoring plan must show, with evidence, how each tier is met — GD4 allows four routes.

ROUTE CO-1

Instrument under national legal metrological control (NLMC): the maximum permissible error in service counts as the uncertainty — no further evidence.

ROUTE CO-2a

No NLMC, but the instrument is installed and checked to comparable requirements: the MPES for that instrument class may still be used.

ROUTE CO-2b

Use the expanded uncertainty from calibration, multiplied by a conservative adjustment factor for in-service conditions.

ROUTE CO-3

Full instrument-specific uncertainty assessment — always allowed; required when the simplified routes cannot show compliance.

THE OPERATOR

Keeps instruments calibrated and maintained exactly as the monitoring plan says, and includes stock changes in the assessment.

If a tier still cannot be met: corrective action — or evidence of technical infeasibility or unreasonable costs, and the next lower tier.

THE VERIFIER

Confirms the validity of the uncertainty information (AVR): calibration certificates, NLMC evidence, the calculation itself.

Expert judgement can be acceptable for minor and de-minimis streams and low-emitting installations.

Cement Plant X: the pet-coke dosing scales (±1.5% tier) are verified under national metrological control — Route CO-1, no extra uncertainty study needed.

Source: GD4 — Guidance on uncertainty assessment (2021); Commission training material on uncertainty (2019); MRR Art. 12 & Annex II.

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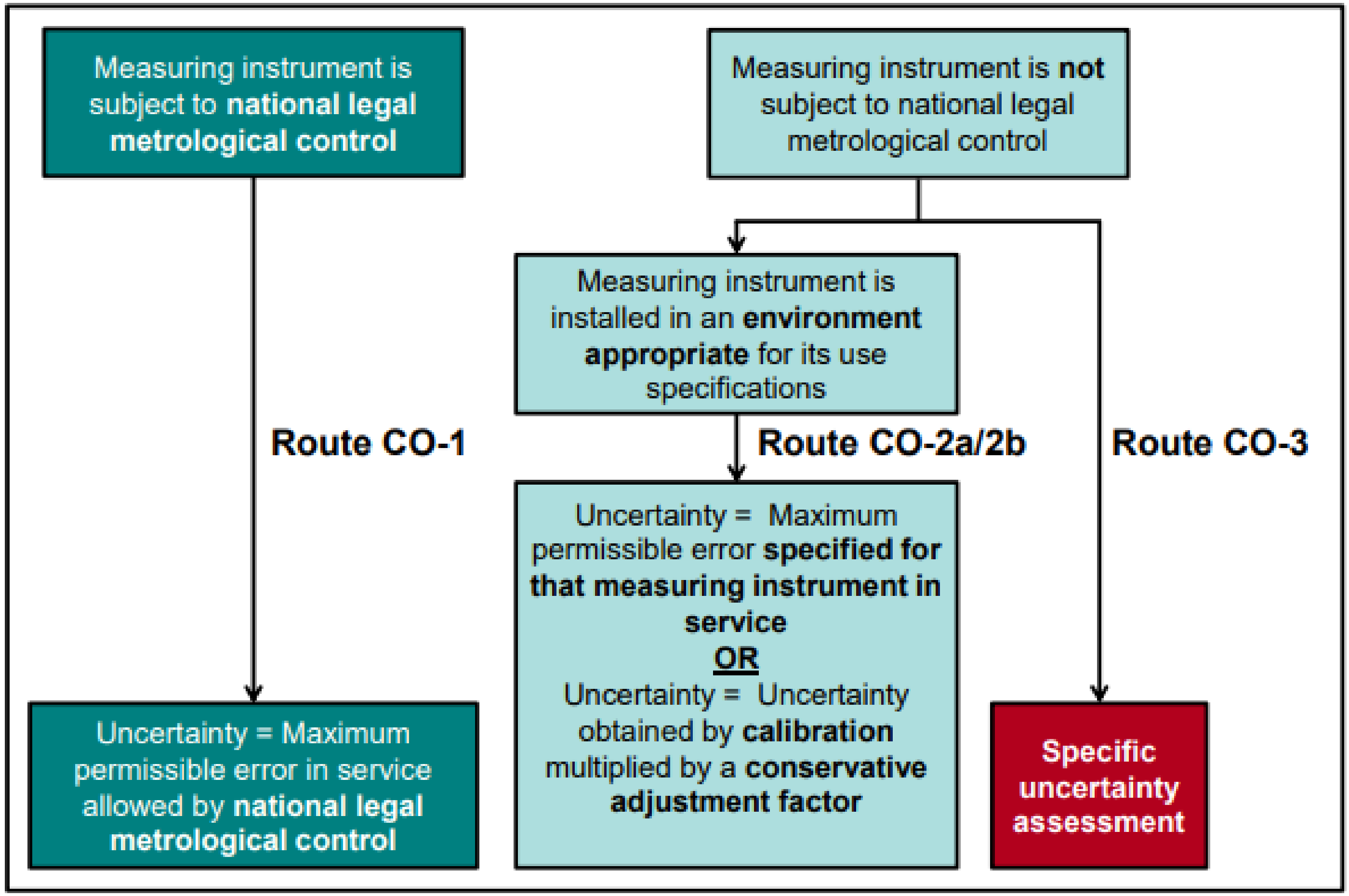
Uncertainty assessment in practice — four routes to prove a tier



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What the monitoring plan defines

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

Per source stream, the MP fixes:

- Monitoring approach — calculation-based
- Activity data: weighbridge / metering (tonnes, TJ)
- Emission factor, NCV, biomass fraction — and the TIER for each
- Clinker process emissions: Method B (output-based)
- Process/combustion split and the biomass treatment

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: an approved plan per installation

Source: plant monitoring plan (anonymised real example); MRR (EU) 2018/2066; GD9 §10. [uploaded example]

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Unreasonable costs — when may an operator settle for less accuracy?

THE TEST — MRR ART. 18

Costs are unreasonable where they exceed the benefit of the improvement.

An objective calculation, not a negotiation: the operator shows the numbers, the competent authority evaluates them.

WHAT COUNTS ON EACH SIDE

Costs: the annuity of the investment (economic lifetime, interest), O&M and external analyses — only additional costs, clearly attributable to the improvement.

Benefit = 20 €/t CO_2 × emissions of the stream × improvement factor.

Improvement factor: for activity data, the gap between achieved and required uncertainty; 1% for all other improvements.

WORKED CHECK — MAJOR FUEL STREAM

Current uncertainty 2.8% · tier requires 1.5% · stream emits 760,000 t CO_2/yr

Benefit = 20 × 760,000 × 1.3% ≈ €197,600 / yr

Any upgrade costing less than that is reasonable — the operator must carry it out.

WHAT IT DOES — AND DOES NOT — DO

Justifies the next lower tier or an approved estimation method — never a gap in monitoring.

Improvements up to €2,000/yr (€500 for low emitters) are never unreasonable.

The claim is re-examined through the regular improvement reports — it is a postponement, not an exemption.

Where even tier 1 is out of reach, a fall-back approach (Art. 22) with an overall uncertainty threshold remains the last resort.

Source: Commission training material on unreasonable costs (2019); MRR Arts. 18 & 22; GD4.

Laboratory analyses behind the numbers

ACCREDIA
L'ENTE ITALIANO DI ACCREDITAMENTO

Stream (sample)	Key laboratory values	Feeds in the AER
Petroleum coke (CM1)	EF 93.5 tCO_2/TJ · NCV ≈ 30.8 GJ/t	fossil combustion CO_2
Used tyres / PFU (CM4)	EF 89 tCO_2/TJ · NCV ≈ 32 GJ/t · biogenic fraction zero-rated	alternative-fuel CO_2 + biomass
Raw meal / farina (CM3)	CO_2 33.7% · TOC (organic C) 0.13% · CaO 43%	process check + non-carbonate carbon
Clinker (CM2)	CaO 65.5% · MgO 1.27% → calcination ≈ 0.53 t CO_2/t	process emissions (Method B)

Return to primary source: every emission factor in the AER traces to a dated, signed lab certificate — exactly what the verifier re-checks. Tyres carry a biogenic fraction, so part of their CO_2 is zero-rated.

Combustibile come Ricevuto (ar)

Biomassa (Bar)	%	**28,68**

EN 15440:2011 (Annex A) / AC:2011 + EN ISO 16993:2015

10 · INSTRUMENTATION

Metering points S1–S35

S1 · S2

Weighbridges

All incoming solids: pet coke, tyres, plastics, raw materials, diesel deliveries.

S3 – S26

Cement & dispatch scales

Finished-product weighing at bagging and shipping — closes the mass balance.

S27 – S30

Fuel dosing scales

Belt scales at solid-fuel grinding — the direct measurement behind CM1's 58,800 t.

S31 – S35

Gas meters

Fiscal-grade natural gas metering for kiln, boilers, offices and laboratory.

Traceability rule Every tonne in the report traces back to a named instrument in the monitoring plan — calibrated, maintained, with a documented fallback if it fails.

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Worked example — petroleum coke (CM1)

1	Fuel weighed on dosing scales S27–S30 over the year	58,800 t
2	× net calorific value from laboratory analysis (31.5 GJ/t)	= 1,853 TJ
3	× emission factor from laboratory analysis (93.9 t CO_2/TJ)	= 174,000 t CO_2
4	× oxidation factor 100% · biomass fraction 0% → reported emissions	≈ 174,000 t CO_2

Every combustion stream — tyres, plastics, gas, diesel — follows exactly these four steps, with its own measured values.

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12 · REPORTING YEAR 2024

Annual emissions summary

CM2 · Clinker (process)	340,000
CM1 · Pet coke	174,000
CM4 · Tyres (fossil share)	23,500
CM3 · Raw meal TOC	4,300
CM5 + CM7 + CM8 · Gas, plastics, diesel	1,000

≈ 543,000 t CO_2 total fossil — allowances to surrender

≈ 10,900 t CO_2 biomass — reported, rated zero

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13 · CLOSING THE LOOP

Reporting and verification

BEFORE THE YEAR

Monitoring plan

Sources, streams, formulas, tiers, instruments and procedures — approved by the competent authority. The diagram on slide 4 is part of it.

ALL YEAR

Data collection

Weighing, sampling, lab analyses, meter readings — with data-flow and control procedures, and records kept for 10 years.

BY 31 MARCH

Verified report

The annual emissions report is checked by an accredited independent verifier before submission.

BY 30 SEPTEMBER

Surrender

One allowance per verified tonne — ≈ 543,000 for Cement Plant X — surrendered in the Union Registry.

Beyond the EU The same building blocks — boundary, streams, tiers, verification — are the template for any emissions trading system, from monitoring plan to surrendered allowance.

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DAY 3

Agenda for the day

1 Introduction: cement & lime in the EU ETS and CBAM

2 The process & how emissions are counted (MRV)

3 EU ETS benchmarks & the benchmark curve (clinker · white clinker · lime)

4 System boundaries, emission calculation and monitoring plan - Clinker plant example

5 **Lime plat example: Monitoring emissions and free allocation**

Case study

6 Conclusions and last considerations

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EU ETS · CASE STUDY FOR TR ETS CAPACITY BUILDING

Monitoring emissions and free allocation in lime production

How a real EU lime installation accounts for its CO_2 under the Monitoring & Reporting Regulation — and how its free allocation is calculated under the Free Allocation Rules.

“LimeCo” — anonymised installation

All values rounded

MRR 2018/2066 · FAR 2019/331

CASE STUDY (LIME) · THE INSTALLATION

A lime plant at a glance

$CaCO_3$ + heat → CaO + CO_2

$CaCO_3 \cdot MgCO_3$ + heat → $CaO \cdot MgO$ + 2 CO_2

≈ 0.79 t CO_2 per t CaO from the stone alone

EU ETS INSTALLATION BOUNDARY — "PRODUCTION OF LIME" · CAPACITY ≈ 1,100 T/DAY

Limestone & dolomite
from quarry · weighbridge S1

Biomass wood dust · CM3
main kiln fuel · weighbridge S1

Natural gas · CM2
pre-heat burners · gas meter S2

→

CO_2 ↑ stacks EP1–EP3 (process + combustion)

3 vertical shaft kilns
emission sources F1 · F2 · F3 — ≈ 56 MWth
calcination at ≈ 900–1,100 °C

Minor on-site sources: emergency diesel genset F5 (CM4) · office boiler F7

→

Quicklime (CaO) · CM1
silos S5 · weighbridges S7/S8

Dolime (CaO·MgO) · CM5
same instruments

Dispatch to customers
steel · construction · chemicals

OUTSIDE the boundary — 2 gas CHP engines (F4/F6)
operated by another company — their fuel and CO_2 are monitored by that operator, never by LimeCo

OUTSIDE the EU ETS — premixed-mortar plant on the same site
consumes lime and CHP heat, but is not an Annex I activity

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Monitoring & reporting emissions

Regulation (EU) 2018/2066 — the Monitoring & Reporting Regulation (MRR): the compliance cycle seen from the operator's side.

Boundaries & sources → Source streams & tiers → Process CO_2 → Combustion CO_2 → Worked example

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CASE STUDY (LIME) · PART 1 — MRR

System boundaries and emission sources

The installation

Annex I activity "production of lime, or calcination of dolomite/magnesite" (> 50 t/day), plus all directly associated on-site activities — monitored under an approved monitoring plan.

Category B installation — Art. 19(2)

Average verified emissions 50,000–500,000 t CO_2e/yr (LimeCo ≈ 199,000 t). The category drives the minimum tiers required.

One source, one operator

Each emission source is monitored inside exactly one installation boundary. That rule — not any later correction — is what prevents double counting.

SOURCE	EMISSION POINT	STATUS
F1–F3 Calcination kilns	EP1–EP3 kiln stacks	**Included — the plant's emissions**
F5 Emergency diesel genset	EP4 genset stack	Included — de minimis
F7 Office-heating boiler	shared gas metering	Included — de minimis
Premixed-mortar plant	—	**Excluded — not an Annex I activity**

Source: anonymised real EU lime plant; MRR (EU) 2018/2066 Arts. 19–20; GD1 §4.

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CASE STUDY (LIME) · PART 1 — MRR

Source streams and monitoring approaches

Calculation-based methodology throughout (Art. 21) — no continuous measurement. Every fuel and material that causes emissions is a source stream with its own tiers.

STREAM	METHOD (ART. 24)	CATEGORY (ART. 19(3))	ACTIVITY DATA	CALCULATION FACTORS
CM1 Quicklime	Process — Method B (oxide output)	**Major**	Tier 2 ±2.5% required · ±0.1% achieved (weighbridges)	EF: monthly lab analyses of free CaO/MgO · CF = 1
CM5 Dolime	Process — Method B (oxide output)	**Major**	Tier 2 ±2.5% required · same instruments	EF: monthly lab analyses · CF = 1
CM3 Biomass wood dust	Combustion — standard method	**Zero-rated (100% biomass)**	Weighbridge, no tier obligation	Type I standard values · RED II sustainability evidence
CM2 Natural gas	Combustion — standard method	De minimis	Turbine meter + volume converter · conservative estimate allowed	NCV/EF Type II values from national GHG inventory
CM4 Diesel (genset)	Combustion — standard method	De minimis	Invoices / delivery records	Commercial standard-fuel values

Categories scale the effort: minor streams < 5,000 t CO_2/yr (or < 10% up to 100,000 t) · de minimis < 1,000 t CO_2/yr (or < 2% up to 20,000 t) — both may use lower tiers and estimation methods outside the tier system.

Source: monitoring plan (anonymised real EU lime plant); MRR Arts. 19, 21, 24.

CASE STUDY (LIME) · DOC 2 — MONITORING PLAN

What the monitoring plan fixes for each source stream

Per source stream, the MP fixes:

- Monitoring approach — calculation-based
- Activity data: bridge weigher (S1/S7/S8), gas meter (S2/S6), silo level (S5)
- Emission factor, NCV, biomass fraction — and the TIER for each
- Lime process: Method B (oxide output), EF from lab analysis
- Wood biomass: biomass fraction 99% → CO_2 zero-rated

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: an approved plan per installation

Source: monitoring plan (anonymised real EU lime plant); MRR (EU) 2018/2066; GD9 §12.

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Process emissions from calcination

METHOD B — ART. 24(2), ANNEX IV §9

$$Em = AD \times EF \times CF$$

AD — tonnes of oxide produced (quicklime or dolime)
EF — stoichiometric factor from the product's composition
CF — conversion factor = 1 (all oxide assumed from carbonate)

EXAMPLE — ONE MONTH OF QUICKLIME

m CaO = 84.0% · m MgO = 0.8%

EF = 0.785×0.840 + 1.092×0.008

EF ≈ 0.67 t CO_2 / t lime

EMISSION FACTOR — ANNEX II §4

$EF = 0.785 \times m(CaO) + 1.092 \times m(MgO)$ [t CO_2/t]

The ratios 44/56.1 and 44/40.3 are the molar masses of CO_2 over CaO and MgO.

Free CaO and MgO contents come from monthly laboratory analyses — Arts. 32–35: EN standards, accredited laboratory, approved sampling plan.

WHY METHOD B, NOT METHOD A?

Method A weighs the carbonate input; Method B weighs the oxide output.

LimeCo already weighs every tonne of product for sale — the ±2.5% tier is met with ±0.1%.

Variable stone quality makes input-side carbonate analysis harder, and kiln dust would need a separate correction under Method A.

Source: MRR Art. 24(2), Annex II §4 & Annex IV §9; monthly laboratory certificates (anonymised).

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CASE STUDY (LIME) · PART 1 — MRR

Combustion emissions from kiln fuels

STANDARD METHOD — ART. 24(1)

$$Em = FQ \times NCV \times EF \times OF$$

fuel quantity × net calorific value × emission factor × oxidation factor

NATURAL GAS CM2 — PRE-HEAT BURNERS

FQ (turbine meter)	200 × 1000 Nm^3
NCV (Type II, national inventory)	36.6 GJ / 1000 Nm^3
EF (Type II)	56.8 t CO_2 / TJ
OF	100%
Emissions	**≈ 420 t CO_2**

BIOMASS WOOD DUST CM3 — MAIN KILN FUEL

FQ (weighbridge)	62,000 t
NCV	15.6 GJ/t → ≈ 970 TJ
Biomass fraction (Arts. 38–39)	99%
Biogenic CO_2 (memo item)	≈ 108,000 t
Emissions counted	**1,080 t CO_2**

Zero-rating is conditional: the biomass must meet the RED II sustainability and GHG-saving criteria, with evidence kept for verification — otherwise the preliminary EF (≈ 112 t CO_2/TJ for wood) applies in full.

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Worked example — annual emissions

SOURCE STREAM	ACTIVITY DATA	CALCULATION	FOSSIL CO_2 [t]
CM1 Quicklime (process)	230,000 t	× 0.67 t CO_2/t × 1	**154,100**
CM5 Dolime (process)	55,000 t	× 0.81 t CO_2/t × 1	**44,550**
CM2 Natural gas (combustion)	200 kNm^3	× 36.6 GJ/kNm^3 × 56.8 t/TJ	420
CM4 Diesel (combustion)	< 1 t	standard values	≈ 0
CM3 Biomass wood dust	62,000 t	99% biomass → zero-rated	1,080 (106,920 is biogenic)
Total reportable emissions			**≈ 200,080**

99.8% of fossil CO_2 is process CO_2

Because the kilns burn biomass, virtually all counted emissions come from the stone — a lime-sector signature.

Verified report by 31 March

Annual emissions report checked by an accredited verifier; allowances surrendered by 30 September.

Source: annual emissions report (anonymised real EU lime plant), values rounded; MRR 2018/2066; AVR 2018/2067.

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Free allocation

Delegated Regulation (EU) 2019/331 (FAR) · benchmark values Reg. 2021/447 · activity-level changes Reg. 2019/1842.

Sub-installations & benchmark → Historical activity level → Preliminary allocation → Annual adjustments → Worked example

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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 · HAL = median historical activity level (t clinker or t lime)
- CLEF = 1 (100%) for cement & lime — both on the carbon-leakage list
- CBAM factor: clinker phases out (97.5% in 2026 … 0% in 2034)
- CBAM factor for LIME = 1 (not a CBAM good) → lime free allocation does NOT phase out

Sources: GD9 free-allocation section; Directive 2003/87/EC Art. 10a; GD9 §10–12 (CBAM scope).

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CASE STUDY (LIME) · PART 2 — FAR

Sub-installations and the lime product benchmark

Sub-installation 1 — product benchmark "lime"

Kilns' share for quicklime: process CO_2, all kiln fuels, ancillaries. Carbon-leakage exposed.

Sub-installation 2 — product benchmark "dolime"

Kilns' share for dolime, split by campaign production records. Carbon-leakage exposed.

No fallback sub-installations

A product benchmark covers all direct emissions inside its boundary ("all processes directly or indirectly linked") — so no heat or fuel benchmark may overlap it. FAR Art. 10: the sub-installations' sum must never exceed the installation's totals.

BENCHMARK VALUES — EUA / T STANDARD PURE

	Lime	Dolime
2013 starting point (Annex I)	0.954	1.072
2021–2025 (Reg. 2021/447, max −24%)	0.725	0.815
2026–2030 (proposed May 2026)	0.693	0.792

"STANDARD PURE" PRODUCT — FAR ANNEX I

Lime: tonnes with free CaO content of 94.5%.

Dolime: tonnes with 57.4% CaO + 38.0% MgO.

Real production is converted to this quality — plants making lower-purity lime are not over-allocated per raw tonne.

Source: FAR (EU) 2019/331 Arts. 10–11 & Annex I; Reg. (EU) 2021/447; GD9 §12.

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Historical activity level and standard purity

HAL — FAR ART. 15(3)

The median annual activity level over the baseline period — 2014–2018 for the 2021–2025 allocation, 2019–2023 for 2026–2030 — reported in the verified baseline data report (NIMs).

CONVERSION TO STANDARD PURE — ANNEX III §2

HAL std = HAL uncorr × (0.7848·m CaO + 1.0920·m MgO) / 75.28

m CaO, m MgO in mass-% per baseline year · dolime uses the same form with denominator 86.55. The plant's tonnes are re-expressed at the CO_2 intensity of the standard product.

No composition data? Conservative defaults apply — lime ≤ 85% CaO / 0.5% MgO; dolime ≤ 52% CaO / 33% MgO — always to the operator's disadvantage.

EXAMPLE — LIMECO QUICKLIME

HAL uncorr = 225,000 t

m CaO = 84% · m MgO = 1%

factor = (0.7848×84 + 1.092×1) / 75.28 = 0.890

HAL std ≈ 200,000 t standard pure lime

225,000 physical tonnes count as 200,000 benchmark tonnes — the plant's lime is less pure than the 94.5% reference.

One measurement system, two regimes

Composition comes from the same monthly lab analyses already used for the MRR emission factor.

Source: FAR (EU) 2019/331 Art. 15(3), Annex III §2; GD2 §6; GD9 §12.

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CASE STUDY (LIME) · PART 2 — FAR

Preliminary allocation

F prelim = BM × HAL × CLEF

per sub-installation, per year (FAR Art. 16) · CLEF = carbon-leakage exposure factor: 1.00 for CL-exposed products like lime and dolime; 30% → 0% during 2026–2030 for others

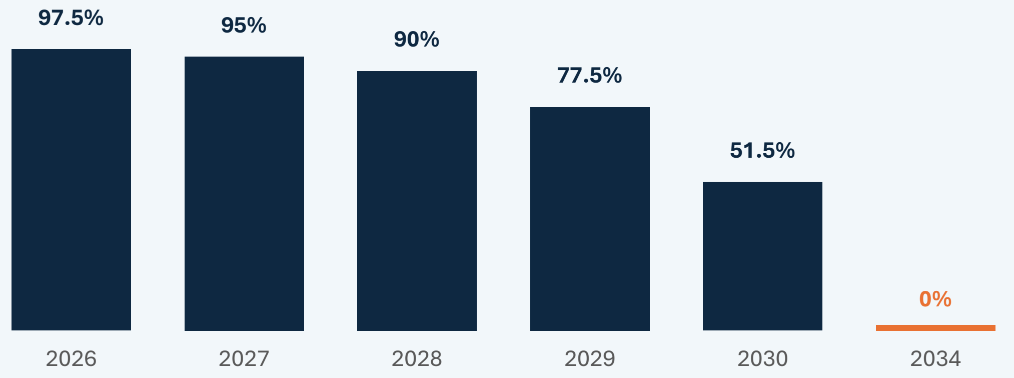
FROM PRELIMINARY TO FINAL

All EU sub-installations are summed; if the total exceeds the free-allocation cap, a cross-sectoral correction factor scales everything down (not triggered in 2021–2025).

Deductions apply for measurable heat imported from non-ETS suppliers (FAR Art. 21).

Full conditionality: energy-audit recommendations must be implemented, or allocation is cut by 20% (from 2024).

CBAM GOODS PHASE OUT — LIME DOES NOT



The CBAM factor multiplies the allocation of CBAM goods (clinker, cement). Lime is not in CBAM Annex I — its factor stays 1, so lime allocation does not phase out.

Source: FAR Art. 16; Directive 2003/87/EC Art. 10a(1a); CBAM Reg. (EU) 2023/956 Annex I; GD9 §12.

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CASE STUDY (LIME) · PART 2 — ALC, REG. 2019/1842

Annual activity levels and adjustments

1 · Report every year

Verified activity-level report (ALC) for each sub-installation, submitted with the annual cycle (typically by 31 March).

2 · Compare the 2-year average with HAL

Average activity of the two preceding years vs. the sub-installation's HAL. Within ±15%: allocation unchanged.

3 · Beyond ±15%: recalculate

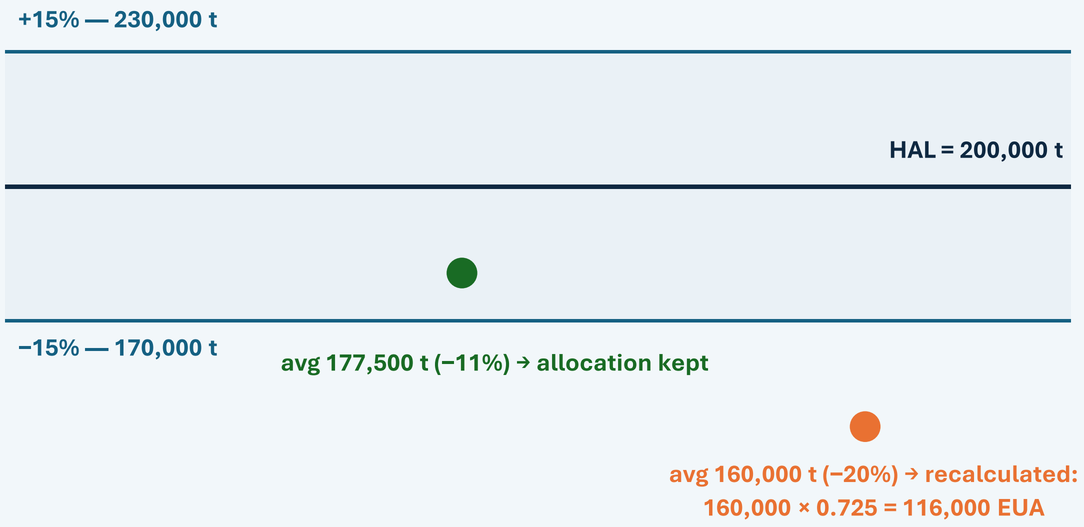
Allocation is recalculated with the average activity level in place of HAL — upwards or downwards, symmetrically. Each further move of 5% triggers a new adjustment.

Why it matters

No windfall profits when production falls, no penalty for growth — allocation tracks reality with a stability band.

Source: Implementing Reg. (EU) 2019/1842 Arts. 3–5; FAR Art. 16; GD2 §7.

LIMECO LIME SUB-INSTALLATION — HAL STD = 200,000 T



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CASE STUDY (LIME) · PART 2 — FAR

Worked example — free allocation

SUB-INSTALLATION	HAL UNCORRECTED	AVG. COMPOSITION	HAL STANDARD PURE	BM 2021–25	PRELIMINARY EUA / YR
Lime (CL-exposed)	225,000 t	84% CaO · 1% MgO	200,000 t	0.725	**145,000**
Dolime (CL-exposed)	55,000 t	55% CaO · 36% MgO	52,400 t	0.815	**42,700**
Total preliminary allocation (CLEF = 1.00)					**≈ 187,700**

Coverage ≈ 94%

187,700 EUA against ≈ 199,000 t of verified fossil CO_2. The gap (≈ 11,000 EUA/yr) must be bought — the price signal survives even with full carbon-leakage protection.

Outlook 2026–2030

New baseline (2019–2023) and the proposed lime BM 0.693: 200,000 × 0.693 ≈ 138,600 EUA/yr. No CBAM factor applies — lime is not a CBAM good.

Biomass is not rewarded twice

Allocation follows the product, not the fuel. LimeCo's biomass switch lowers its emissions, so more of its allocation is surplus — that is the incentive working.

Source: anonymised real EU lime plant; FAR 2019/331; Reg. 2021/447; GD9 §12.

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CASE STUDY (LIME) — WHAT THE EXAMPLE SHOWS

Five takeaways from the lime worked example

- One verified chain: Schema → Monitoring Plan → AER → ALC — primary data to allocation
- Lime is ≈ 99.6% process (calcination) — because of biomass used on the plant
- Kilns fired mostly on wood biomass → only ≈ 650 t fossil combustion
- Lime EF ≈ 0.72 t CO_2/t — essentially at the 0.725 (2019 – 2005) benchmark (near the 10% best)
- Lime keeps full free allocation (not a CBAM good) — unlike clinker's phase-out

For a national / Türkiye ETS: lime needs the same product-benchmark and verified-data approach, but sits outside CBAM — design its allocation separately from CBAM goods.

Source: anonymised real EU lime plant; FAR 2019/331; GD9 §12; MRR 2018/2066; AVR 2018/2067.

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DAY 3

Agenda for the day

1. Introduction: cement & lime in the EU ETS and CBAM
2. The process & how emissions are counted (MRV)
3. EU ETS benchmarks & the benchmark curve (clinker · white clinker · lime)
4. System boundaries, emission calculation and monitoring plan - Clinker plant example
5. Lime plat example: Monitoring emissions and free allocation

Case study

6. **Conclusions and last considerations**

CASE STUDY (LIME) · SUMMARY

Key points for ETS design

1 **Capture process CO_2**

Lime CO_2 is mostly process CO_2 from the stone — monitoring rules must cover carbonates and oxides (Methods A/B), not only fuels.

2 **Scale the effort with tiers**

Tight uncertainty and lab analyses for major streams; simplifications for minor and de-minimis ones.

3 **Draw boundaries once, cleanly**

One source, one operator; sub-metering settles shared sites; product benchmarks cover all direct emissions, so fallbacks cannot overlap.

4 **Benchmark the product, corrected for quality**

The “standard pure” conversion makes one EUA/t value fair across plants of different purity.

5 **Keep allocation dynamic**

Annual activity-level reports with a ±15% band and 5% steps track reality without constant recalculation — and one measurement system (weighbridges + monthly analyses) feeds both emissions monitoring and allocation.

Source: anonymised real EU lime plant; MRR 2018/2066; FAR 2019/331; AVR 2018/2067; GD9 §12.

WORKED CALCULATION

Allocation and the CBAM factor — clinker vs lime

Sub-installation	2025 (CBAM 100%)	2026 (×97.5%)	2030 (×51.5%)
Grey clinker (×0.693)	485,100	472,973	249,827
Lime (×0.725) — not CBAM	217,500	217,500	217,500
Total	**702,600**	**690,473**	**467,327**

Read it: clinker free allocation roughly halves by 2030 and ends in 2034; lime stays flat at 217,500 EUA because its CBAM factor is 1. The plant's CBAM exposure is entirely on the clinker.

CBAM factor: Directive 2003/87/EC Art. 10a. Lime out of CBAM scope: GD9 §12. Arithmetic by the trainer.

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WORKED CALCULATION

The CBAM side — clinker default values

CBAM good	CN code	CBAM benchmark (col A & B)
Grey cement clinker	2523 10 00 (grey)	0.666 t CO_2e/t
White cement clinker	2523 10 00 (white)	0.859 t CO_2e/t
Cement (grey)	2523 29 00	via clinker content (precursor)
Lime	—	not a CBAM good

Note: for clinker the CBAM column A (free-allocation) and column B (default) values are equal — intensities are uniform. Finished cement carries the embedded emissions of its clinker content. The importer's CBAM bill ≈ embedded intensity × EU ETS price, net of the (declining) free-allocation factor.

Source: CBAM Reg 2025/2620 Annex (cement: 2507 00 80, 2523 ...). [CBAM/]

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WORKED CALCULATION

Results & the read-across to Türkiye

On the EU side

- Clinker free allocation could halve by 2030
- Lime keeps full free allocation (not a CBAM good)
- CBAM default ≈ EU ETS benchmark for clinker

For Türkiye (imports)

- Cement is the most CBAM-exposed sector (≈ 4.1% of export value)
- Little room to beat the benchmark — process emissions are structural
- A domestic carbon price would keep revenue at home

Because clinker intensities are uniform and mostly process-based, importers have limited ability to undercut the benchmark — so CBAM cost is hard to avoid without a domestic carbon price or clinker substitution.

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CLOSE

Cement and lime – Day 3

Questions and discussion · Next: Day 4 — aluminium

Primary sources cited in this storyboard

- EU ETS Directive 2003/87/EC (consolidated 01.03.2024) — Art. 10a [ETS/]
- Free Allocation Regulation (EU) 2019/331 (cons. 01.01.2024) — Annex I, Annex IV [ETS/]
- Free Allocation Guidance GD9 — sector-specific guidance, iron & steel §2-7 [ETS/]
- Supporting guidance: GD3, GD4, GD5, GD6, GD8 [ETS/]
- CBAM Implementing Reg (EU) 2025/2620 — benchmark Annex (codes C-J; DRI; pig iron; iron ore) [CBAM/]
- CBAM Reg (EU) 2023/956 and 2025/2621 (default values) [CBAM/]
- Accreditation & Verification Reg (EU) 2018/2067 (AVR) [MRV/]
- Continuity reference: Presentations 2024 / Day 3

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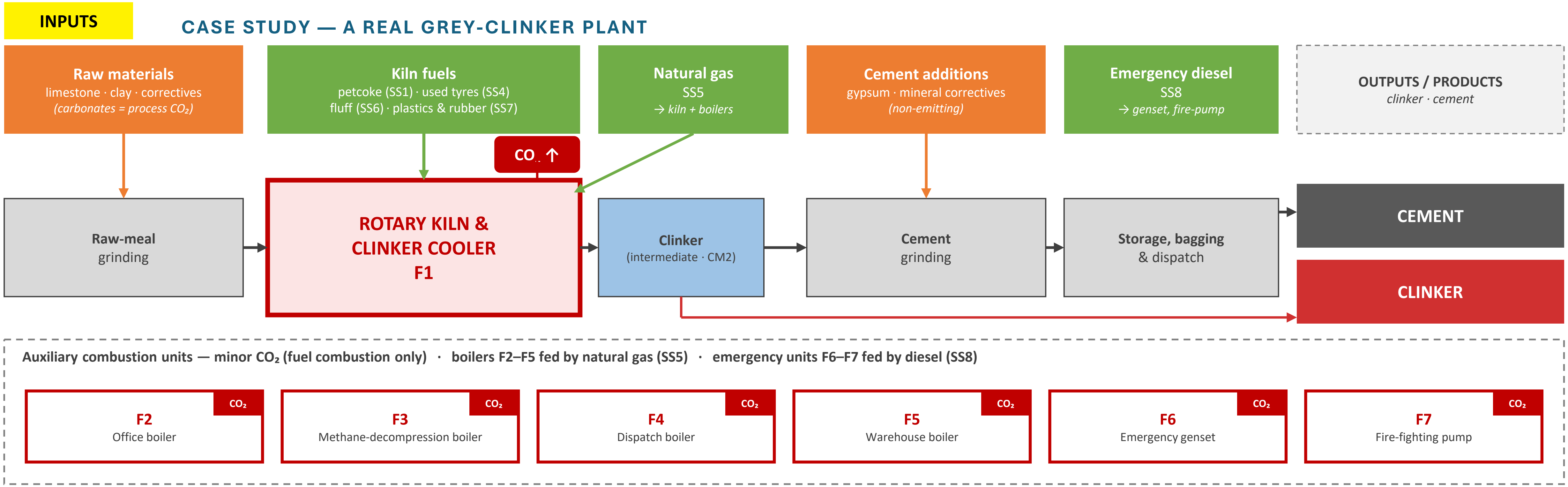
CASE STUDY — A REAL GREY-CLINKER PLANT



Where is CO_2 released?

Rotary kiln (F1) — the main source:

- Process CO_2 — decarbonation of raw meal ($CaCO_3 \rightarrow CaO + CO_2$)
- Combustion of fossil & alternative fuels (petcoke, tyres, fluff, plastics, gas)
- Biomass fraction of alternative fuels — monitored, zero-rated under ETS

Boilers F2–F5 & emergency units F6–F7 — minor CO_2 from fuel combustion only.

Legend

Source streams (SSx): CM1 petcoke · SS2 clinker/cement · SS3 raw meal (non-carbonate C) · SS4 tyres
SS5 natural gas · SS6 fluff · SS7 plastics & rubber · SS8 emergency diesel

- red box = ETS emission source (CO_2 released here)
- green = fuel / combustion stream · orange = raw material
- grey = process step · blue = intermediate · → flow

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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

July 29th 2026

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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

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DAY 4

Agenda for the day

1. **Introduction: aluminium in the EU ETS and CBAM**
2. The two routes & how the CO_2 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

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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 × HAL × CLEF × CBAM factor
- Carbon-leakage list → 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 → indirect (electricity) emissions matter
- Primary emits PFCs (CF_4, C_2F_6) — not just CO_2
- Secondary has NO product benchmark → 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.

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

Primary aluminium EU ETS benchmark

1.464 t CO_2e/t

25 EU (sub-) installations · electrolysis

Pre-bake anode EU ETS benchmark

0.312 t CO_2e/t

15 EU (sub-)installations · not CBAM

Secondary aluminium

≈ 5–20× lower CO_2

scrap remelting vs primary — no electrolysis

No product Benchmark

The headline

- Primary aluminium is one of the most CO_2- and electricity-intensive EU ETS products — most of its footprint is the electricity used in electrolysis, plus direct anode CO_2 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 [reasearch material/]; GD9 §8–9. The 5–20× range is indicative (order-of-magnitude).

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CONTEXT — WHY THIS MATTERS FOR TÜRKIYE

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

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CONTEXT — TÜRKIYE

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. [reasearch material/]

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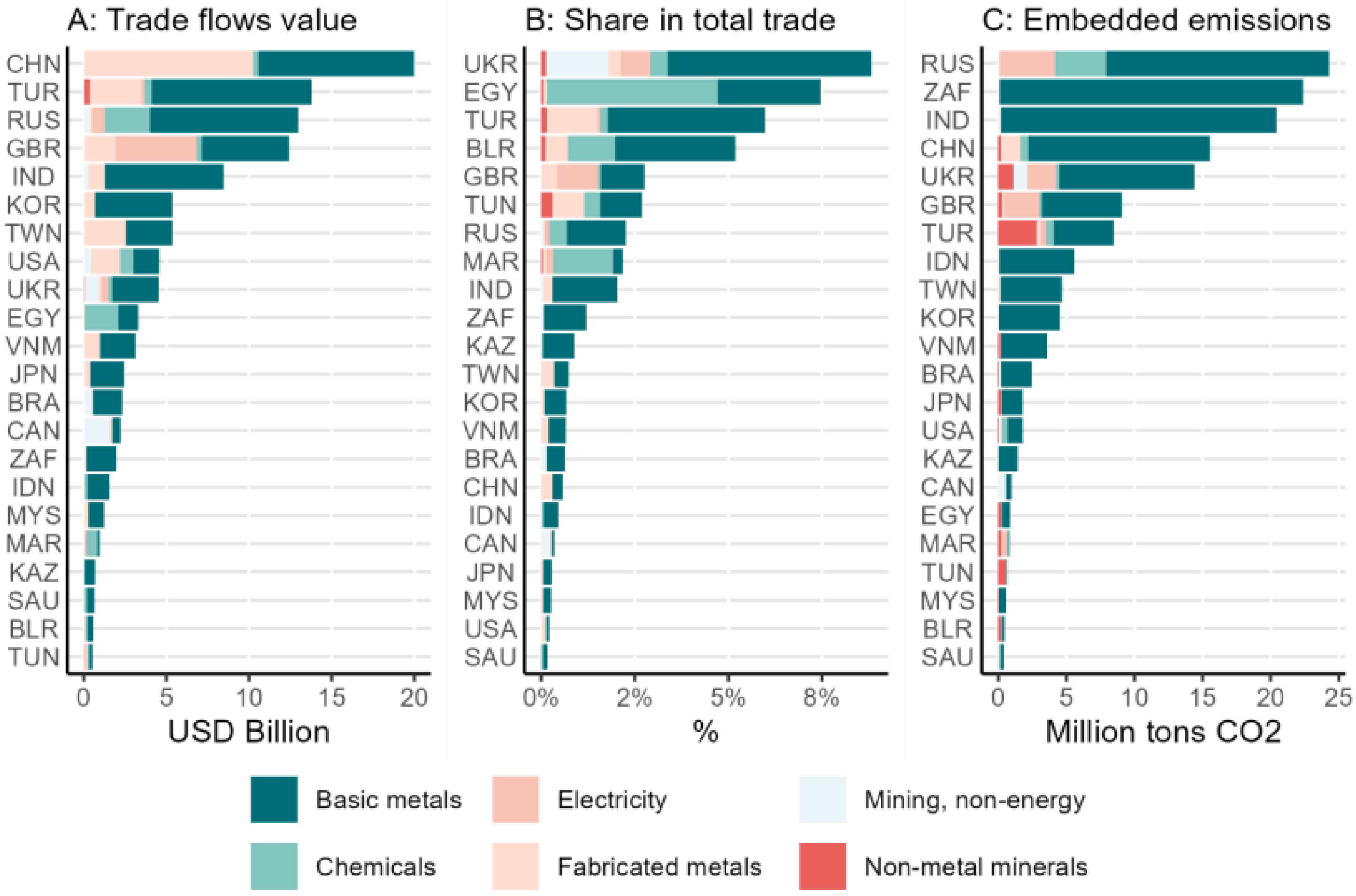
CONTEXT — TÜRKIYE

CBAM impact



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DAY 4

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Case study

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Two technologies to unwrought aluminium

PRIMARY — electrolysis

Alumina (Al_2O_3) → Electrolysis cell (~960 °C) → Liquid aluminium → Casting → ingots/billets

Carbon anode + O_2 → CO_2

Plus PFCs (CF_4, C_2F_6) during 'anode effects'. Electricity for electrolysis is the dominant footprint (excluded from the EU ETS direct boundary).

SECONDARY — scrap remelting

Aluminium scrap → Melting furnace (gas) → Liquid aluminium → Casting → billets

No electrolysis → no anode CO_2, no PFCs

Direct emissions are essentially fuel combustion (natural gas) to melt the scrap, plus minor non-combustion process CO_2.

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).

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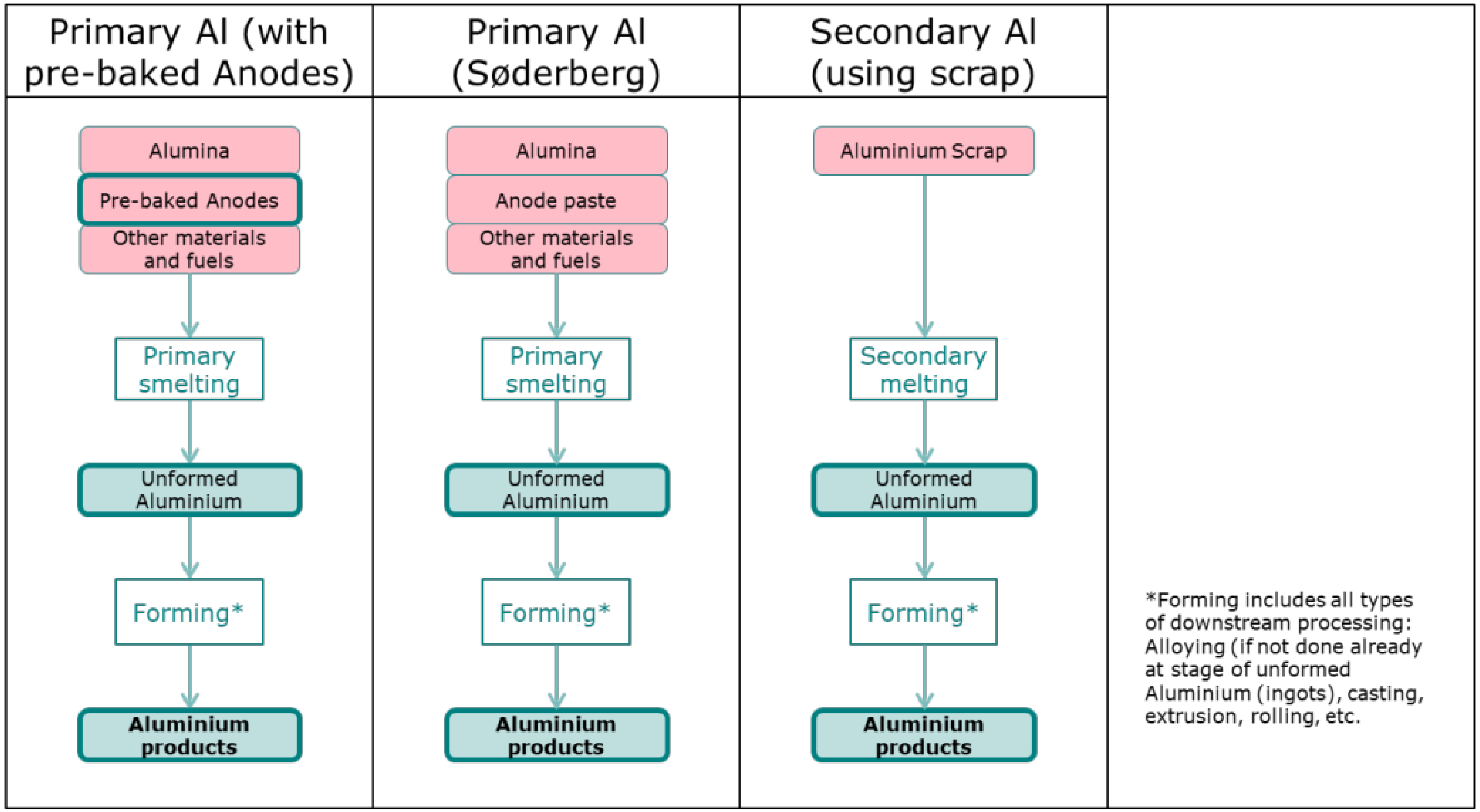
Routes to unwrought aluminium

System boundaries and value chain for aluminium products



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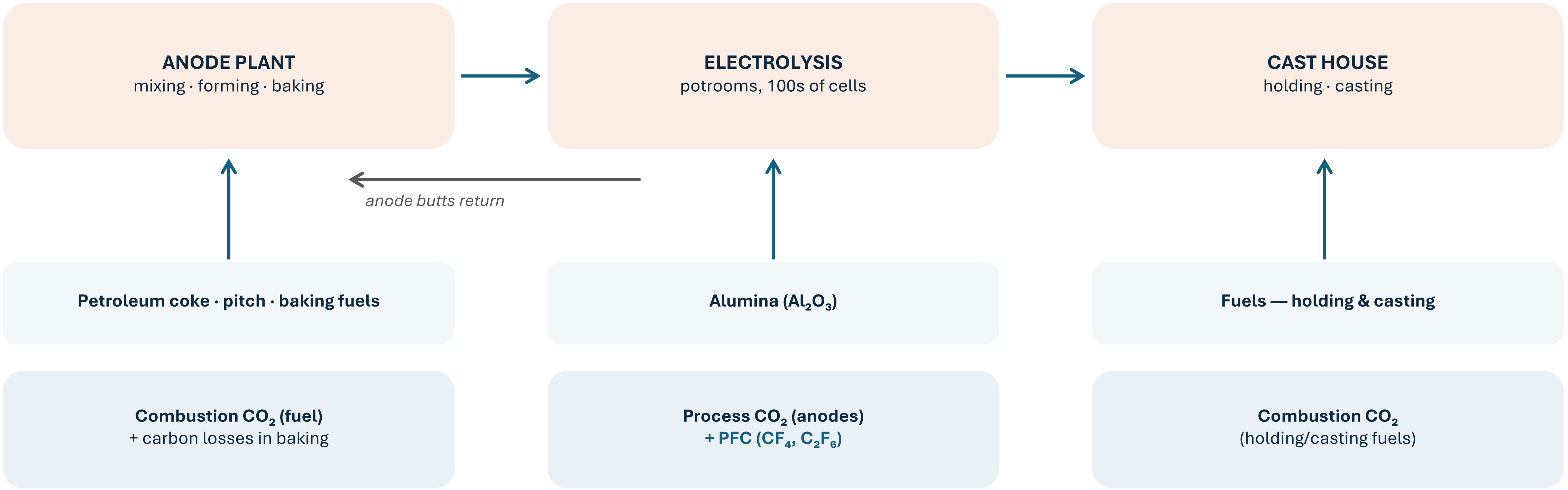
Source streams and emission sources of a primary smelter



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 CO_2 sources); GD9 §§8–9 (boundaries). [MRV/ · ETS/]

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How aluminium emissions are counted — primary vs secondary

Primary (electrolysis)

- **Process CO_2 — carbon anodes consumed in the cells:** mass balance (Art. 25, Annex IV §7) — mandatory
- **PFCs (CF_4, C_2F_6) from anode effects:** slope or overvoltage method (Annex IV §8), reported as CO_2e
- **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 CO_2** (carbon-bearing additives / fluxes) — a separate source stream
- **No electrolysis** → no anode CO_2, 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 CO_2) & §8 (PFC). [MRV/]

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The regulatory map — where each requirement sits in the MRR

MONITORING PLAN
Arts. 11–12 — approved by the competent authority.
Defines source streams, methods, tiers, instruments, procedures and QA/QC.

→

Process CO_2 → MASS BALANCE
Art. 25 + Annex II §3 · Annex IV §7 (mandatory)

Combustion CO_2 → STANDARD METHOD
Art. 24 · or included in the mass balance

PFC (CF_4, C_2F_6) → SLOPE / OVERVOLTAGE
Annex IV §8 · incl. fugitives via collection efficiency

→

ANNUAL EMISSIONS REPORT
Annex X — process CO_2, combustion CO_2 and PFC CO_2e reported separately.
GWPs: Annex VI, Table 6.
Verified per AVR 2018/2067.

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.

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PROCESS CHEMISTRY — PRIMARY

Hall-Héroult electrolysis — why the carbon anode becomes CO_2

$$2\,Al_2O_3 + 3\,C \rightarrow 4\,Al + 3\,CO_2$$

(any CO formed is assumed fully converted to CO_2)

Inside the cell

- Alumina (Al_2O_3) dissolved in molten cryolite (Na_3AlF_6) at ≈ 960 °C
- DC current (300–600 kA) reduces Al^{3+} 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, CO_2 reactivity, current efficiency (EAA: ≈ 428 kg anode/paste per t)
- **Result:** ≈ 1.5 t CO_2/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→CO_2 convention, system boundary); bm study aluminium (Ecofys/Fraunhofer 2009), Table 3 & §2. [ETS/]

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The anode effect — where CF_4 and C_2F_6 come from

What happens in the cell

- Dissolved alumina falls below ≈ 1–2 % → normal electrolysis starves
- Cell voltage jumps from ≈ 4 V to 8–40 V (the 'anode effect')
- The fluoride electrolyte itself is electrolysed at the anode
- Anode carbon reacts with fluorine → CF_4 and C_2F_6

$$4\ Na_3AlF_6 + 3\ C \rightarrow 4\ Al + 12\ NaF + 3\ CF_4$$

$$2\ Na_3AlF_6 + 2\ C \rightarrow 2\ Al + 6\ NaF + C_2F_6$$

Why PFCs dominate the risk register

- **GWP (MRR Annex VI, Table 6):** CF_4 = 6 630, C_2F_6 = 11 100 t CO_2e/t
- **Chemically inert,** atmospheric lifetime of thousands of years — no end-of-pipe abatement exists
- **Emitted only during process upsets** → 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/]

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Choosing the method — what Annex IV §7 prescribes

The rule: mass balance is mandatory

- **Scope:** CO_2 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 CO_2 — 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/]

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The mass-balance equation — every variable explained

$$Em\ [t\ CO_2] = \Sigma_k\ AD_k \times CC_k \times 3.664$$

(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 (± stock change)
- Carbon in the metal: negligible — aluminium is ≥ 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/]

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Tiers, categories and uncertainty — data quality rules

Classify first (Art. 19)

- **Installation categories:** A ≤ 50 kt · B 50–500 kt · C > 500 kt CO_2e/yr — most primary smelters are B or C
- **Major source streams:** everything that is not minor or de-minimis
- **Minor:** jointly < 5 kt CO_2/yr or < 10 % (cap 100 kt)
- **De-minimis:** jointly < 1 kt CO_2/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.

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COMBUSTION — MRR ART. 24

Combustion emissions — the standard methodology

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

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/]

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PFC monitoring framework — ducts, fugitives, two methods

PFC (total) = PFC (duct) ÷ 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 CF_4/C_2F_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/]

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Method A — anode-effect minutes per cell-day

CF_4 [t] = AEM × ($SEF(CF_4)$/1 000) × Pr(Al) C_2F_6 [t] = CF_4 × $F(C_2F_6)$ AEM = frequency × duration

Variable	Unit	Source
AEM — anode-effect minutes	AE-min / cell-day	Cell control system logs
$SEF(CF_4)$ — slope emission factor	(kg CF_4/t Al)/(AE-min/cell-day)	Tier 1 default or Tier 2 measured
Pr(Al) — annual primary Al production	t	Production records
$F(C_2F_6)$ — weight fraction	t C_2F_6 / t CF_4	Tier 1 default or Tier 2 measured

Tier 1 (Table 1)	$SEF(CF_4)$	$F(C_2F_6)$
CWPB (prebake)	0.143	0.121
VSS (Søderberg)	0.092	0.053

Tier 2: installation-specific factors from field campaigns, max ±15 % uncertainty, redetermined ≥ every 3 years or after significant cell-control changes.

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/]

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Method B — anode-effect overvoltage

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

Variable	Unit	Source
OVC — overvoltage coefficient	(kg CF_4/t Al) / mV	Tier 1 default or Tier 2 measured
AEO — anode-effect overvoltage	mV	∫(time × voltage above target) ÷ data-collection time — cell controller
CE — average current efficiency	%	Production vs. theoretical (Faraday) output
Pr(Al) — annual production	t	Production records; ×0.001 converts kg → t

Tier 1 (Table 2)	OVC	$F(C_2F_6)$
CWPB (prebake)	1.16	0.121
VSS (Søderberg)	n.a.	0.053

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).

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/]

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Source streams and emission sources of a primary smelter

ANODE PLANT
mixing · forming · baking

→

ELECTROLYSIS
potrooms, 100s of cells

→

CAST HOUSE
holding · casting

← *anode butts return*

Petroleum coke · pitch · baking fuels	Alumina (Al_2O_3)	Fuels — holding & casting
Combustion CO_2 (fuel) + carbon losses in baking	**Process CO_2 (anodes)** **+ PFC (CF_4, C_2F_6)**	**Combustion CO_2** (holding/casting fuels)

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 CO_2 sources); GD9 §§8–9 (boundaries). [MRV/ · ETS/]

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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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DAY 4

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2. The two routes & how the CO_2 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

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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.

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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. [reasearch material/ · CBAM/]

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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 CO_2e/t

CLEF 1 (100%)

CBAM scope yes (CN 7601)

PFCs included (CF_4, C_2F_6)

EU ETS benchmark (2021–25)

1.464 t CO_2e/t

weighted avg of all EU inst. 1.641 · 25 installations

CBAM benchmark — primary (K)

1.423 t CO_2e/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/]

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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 CO_2 (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/]

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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 CO_2e/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 CO_2e/t across 15 installations.

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

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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 CO_2 × 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/]

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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_2F_6)	Yes — from the anode effect	No
Electricity footprint	Very high (mostly indirect)	Low
EU ETS product benchmark	Yes — 1.464 t CO_2e/t	None → fallback (fuel + process)
Allocation basis	Product BM × HAL	Fuel BM × HAL + process × 0.97
CBAM benchmark (CN 7601)	1.423 t CO_2e/t (K)	0.091 t CO_2e/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/]

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RECAP

What we covered — benchmarks & boundaries

Primary aluminium	Product benchmark 1.464 t CO_2e/t; electrolysis only; CBAM good; PFCs included
Pre-bake anode	Product benchmark 0.312 t CO_2e/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.

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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 CO_2 (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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Case study

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CBAM INTERFACE

From billet to sheet — how embedded emissions add up

Unwrought precursor
(e.g. billets, 7601)
embedded emissions

+

Fabrication step
casting · rolling
extrusion · foil

=

Embedded emissions
of the finished good

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. [reasearch material/ · CBAM/]

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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/]

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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:** CO_2 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

- CO_2 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).

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

Identical equations: Method A (slope, Eqs. 21–23) · Method B (overvoltage, Eqs. 24–25) · collection efficiency for fugitives (Eq. 20) · same GWPs: CF_4 6 630, C_2F_6 11 100 (section G)

Slope defaults (Table 2)	SEF(CF_4)	F(C_2F_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
- **Overvoltage 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/]

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From installation totals to the production process (Annex III)

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

Term	Meaning (period totals, t CO_2e)
DirEm*	Direct emissions of the production process (Annex II, section B)
Em(H,imp/exp)	Emissions embodied in measurable heat imported / exported (Q × EF(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 CO_2e 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 §§A.1–A.3 (Eqs. 41–42, 52, 55, 57); Annex II §F; Art. 7 (reference period).

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Complex goods — adding the precursors (Annex III B)

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

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/]

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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_2e per installation-year (AER)	SEE — t CO_2e 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/]

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SYNTHESIS

The whole day in one view

Aluminium matters	Two routes: primary (electrolysis, intensive) and secondary (scrap, low-carbon)
Count the CO_2 (MRV)	Primary: anode CO_2 + PFCs + electricity; secondary: fuel combustion
Benchmarks	Primary 1.464, pre-bake anode 0.312 t CO_2e/t; secondary has NO product benchmark
Secondary = fallback	Fuel-benchmark + process-emissions sub-installations (CL | CBAM)
Allocation × CBAM	F = BM × HAL × CLEF × CBAM factor → phases to 0 by 2034 for CBAM goods
CBAM exposure	Billets: secondary 0.091 vs primary 1.423 t CO_2e/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.

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DAY 4

Agenda for the day

1. Introduction: aluminium in the EU ETS and CBAM
2. The two routes & how the CO_2 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

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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 t C × 3.664 = 150 800 t CO_2

→ 1.51 t CO_2 / 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 t/t × 0.98 × 3.664 ≈ 1.5 t CO_2/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).

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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_2F_6)	0.143 · 0.121	Annex IV Table 1

CF_4 = 0.075 × 0.143/1 000 × 100 000 = 1.07 t
C_2F_6 = 1.07 × 0.121 = 0.13 t

Convert to CO_2e (Annex VI, Table 6)

1.07 t CF_4 × 6 630 = 7 110 t CO_2e

0.13 t C_2F_6 × 11 100 = 1 440 t CO_2e

Total ≈ 8 550 t CO_2e → 0.086 t CO_2e/t Al

Context: well-controlled modern cells run ≈ 0.02–0.1 t CO_2e/t; poorly controlled or Søderberg 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.

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REPORTING — EU ETS

From three calculations to one verified annual report

Process CO_2 (mass balance)
150 800 t CO_2

Combustion CO_2 (Art. 24)
5 050 t CO_2 (90 TJ gas × 56.1)

PFC CO_2e (Annex IV §8)
8 550 t CO_2e

TOTAL ≈ 164 400 t CO_2e
≈ 1.64 t CO_2e / t Al

The AER for aluminium (Annex X)

- Process CO_2, combustion CO_2 and PFC CO_2e 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.

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WORKED CALCULATION

Free-allocation formula and the CBAM factor

$$F_{p,k} = \mathbf{BM}_p \times \mathbf{HAL}_p \times \mathbf{CLEF}_{p,k} \times \mathbf{CBAM}_{p,k}$$

- **BM** = benchmark value. For a fuel sub-installation = the fuel benchmark (allowances/TJ); for a process sub-installation = historical process CO_2 × 0.97.
- **HAL** = median historical activity level (TJ of fuel, or t CO_2 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/]

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WORKED CALCULATION

Primary aluminium — illustrative product-benchmark allocation

Sub-installation	Benchmark (2021–25)	Annual production (HAL)
Primary aluminium (electrolysis)	Aluminium — 1.464 t CO_2e/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 CO_2e/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.

DAY 4

Agenda for the day

1. Introduction: aluminium in the EU ETS and CBAM
2. The two routes & how the CO_2 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

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 ≈ 45 MW
- Main fuel: natural gas, fired in melting, casting & homogenising furnaces
- Started operation mid-2020 → 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) ≈ 99% of emissions
  - Process-emissions sub-installation (non-combustion CO_2) < 1%
- Product: unwrought aluminium billets, CN 7601 20 40 → 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]

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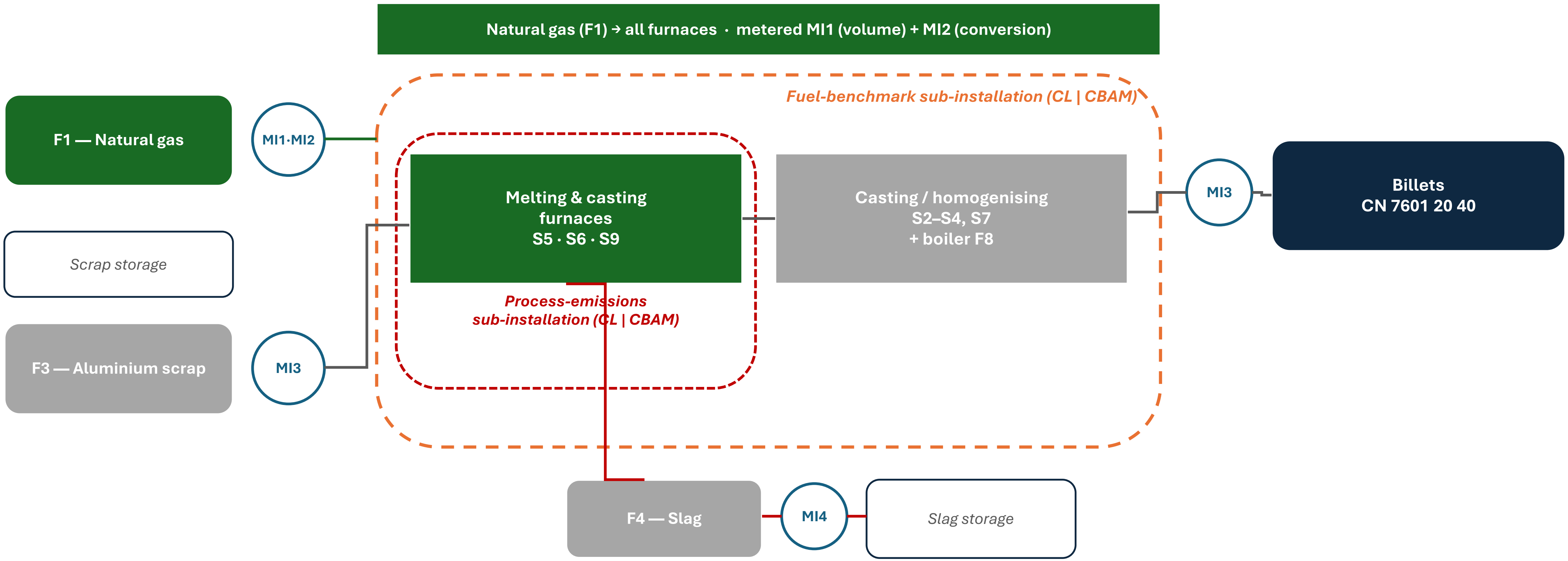
CASE STUDY · secondary aluminium plant - Annual emission report

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]

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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]

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CASE STUDY · secondary aluminium plant - Annual emission report

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 (Nm^3)
- 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 CO_2: 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]

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How the CO_2 is computed — combustion of natural gas

$$E_{CO_2} = \Sigma\,(\text{Activity data}_{[Nm^3 \rightarrow TJ\ \text{via NCV}]} \times EF \times OF)$$

Natural-gas parameters

- Activity data: gas volume (Nm^3) → energy (TJ) via net calorific value (NCV)
- Emission factor (EF) ≈ 56.1 t CO_2/TJ (effective value derived from the data ≈ 56)
- Oxidation factor (OF) = 1; biomass fraction = 0
- Plus a small non-combustion process CO_2 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 CO_2/TJ — consistent with the natural-gas default. Combustion is ≈ 99% of the total; process CO_2 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]

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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 CO_2
- Process CO_2 < 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]

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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]

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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)
- ≈ 99% of the installation's CO_2
- Allocation = fuel benchmark × HAL × CLEF × 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) × 0.97 × CLEF × CBAM factor

Both are on the carbon-leakage list → CLEF = 1. Both produce a CBAM good (billets) → 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]

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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_2e

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 CO_2e.

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

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CASE STUDY · secondary aluminium plant – Free allocation

The worked free-allocation calculation

The two sub-installation formulas

- Fuel sub-installation: F = Fuel BM (28.05 allow./TJ) × 305 TJ × CLEF (1) × CBAM factor → base ≈ 8,600 EUA
- Process sub-installation: F = 150 t × 0.97 × CLEF (1) × CBAM factor → base ≈ 150 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.

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CASE STUDY · secondary aluminium plant

The squeeze: free allocation shrinks, emissions don't

Actual emissions (avg 2021–23)

≈ 17,000 t CO_2/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 CO_2/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.

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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_2e/t	0.091 t CO_2e/t
Unwrought aluminium (general)	7601	1.423 t CO_2e/t	0.091 t CO_2e/t

Secondary route (this plant)

0.091 t CO_2e/t

CBAM benchmark, indicator (L) — recycled

Primary route (for comparison)

1.423 t CO_2e/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/]

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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 [reasearch 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]

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Promoting Enhanced EU ETS Alignment in Türkiye's Emerging ETS

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

Fertilizers sector

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MODULE 2 — CBAM-RELEVANT PRODUCT BENCHMARKS BY SECTOR

Online Day 5 — Fertilizers

Production of fertilizers — CO2 accountability, EU ETS benchmarks, system boundaries, urea & mixed fertilizers, and CBAM

Nitric acid
Adipic acid

Ammonia

Soda ash

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

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CONTINUITY WITH DAYS 2–3

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

Same framework as before

- Product benchmarks = average of the 10% best EU installations
- Free allocation = BM × HAL × CLEF × CBAM factor

BM = benchmark · HAL = historical activity level · CLEF = carbon-leakage exposure factor

- Carbon-leakage list → CLEF = 1 (100%)
- Sub-installations, baseline data reports (BDR), verified MRV — the same chain

What is different for Fertilizers

- Process emissions dominate: CO_2 from feedstock & carbonates, N_2O from HNO_3 / adipic acid
- Carbon leaves in products (urea, soda ash) → mass-balance MRV
- N_2O requires continuous emission measurement (CEMS)
- Four product benchmarks — but only NH_3 & HNO_3 are CBAM goods
- CO_2 is also a feedstock: transferred-CO_2 rules (Art. 48–49a MRR)

DAY 5

Agenda for the day

1. **Introduction: Fertilizers in the EU ETS and CBAM**
2. How the CO_2 is counted (MRV)
3. EU ETS benchmarks — ammonia, nitric acid, adipic acid and soda ash
4. System boundaries & sub-installations
5. Worked example: Integrated fertilizer complex sub-installation map
6. Urea & mixed fertilizers: production, CO_2 and monitoring
7. CBAM and fertilizers

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Fertilizer production in the EU ETS — activities, gases, products

Annex I activity (Dir. 2003/87/EC)	Threshold	GHG covered	Typical products
Production of ammonia	None	CO_2	NH_3 (merchant or for urea / AN)
Production of nitric acid	None	CO_2 + N_2O	HNO_3 30–70 %+ (for AN, CAN, NPK)
Production of adipic acid	None	CO_2 + N_2O	Purified adipic acid (nylon 6,6)
Production of soda ash / sodium bicarbonate	None	CO_2	Na_2CO_3, $NaHCO_3$ (Solvay process)
Combustion of fuels in installations	> 20 MW total rated thermal input	CO_2	Steam / heat for granulation, drying, prilling
Bulk organic chemicals (cracking, reforming, oxidation)	> 100 t/day	CO_2	Urea via NH_3 + CO_2 (if not in NH_3 permit)

No capacity threshold: ammonia, nitric acid, adipic acid and soda ash production are in the EU ETS at any size — unlike combustion (> 20 MW). Fertilizer finishing plants (granulation, blending) without these activities enter only via the combustion activity.

Aggregation rule: where several activities are carried out in the same installation, the permit and the monitoring plan cover them all; capacities of the same activity are added (gd0 §3).

Directive 2003/87/EC Annex I · gd0 Guidance on Interpretation of Annex I (2024), §4 and Annex I table

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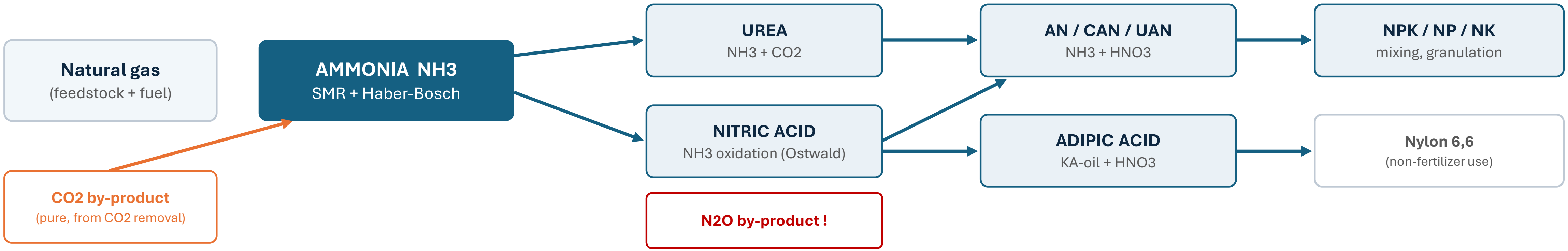
Main production routes — one carbon and nitrogen value chain



Process descriptions: GD9 §§39–41, 52 · CBAM Guidance for Importers §5.5.3 (value-chain overview)

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SECTION 1 · CHEMISTRY

The reactions behind the value chain — and where the gases arise

Process step / reaction	What happens	GHG consequence
Reforming: $CH_4 + H_2O \rightarrow CO + 3 H_2$	natural gas + steam → hydrogen (endothermic, gas-fired)	combustion CO_2 in the reformer flue gas; process CO_2 appears after the shift and CO_2 removal.
Shift: $CO + H_2O \rightarrow CO_2 + H_2$	more H_2; ALL feed carbon ends up as CO_2	process CO_2 — removed as a nearly pure stream
Haber-Bosch: $N_2 + 3 H_2 \rightarrow 2 NH_3$	ammonia synthesis at ~200 bar over Fe catalyst	no CO_2 from the reaction itself — energy use only
Ostwald: $4 NH_3 + 5 O_2 \rightarrow 4 NO + 6 H_2O$	$NO \rightarrow NO_2$, absorbed in water → HNO_3 (exothermic)	N_2O by-product over the Pt/Rh gauze — unwanted, unavoidable
Urea: $2 NH_3 + CO_2 \rightarrow CO(NH_2)_2 + H_2O$	via ammonium carbamate; CONSUMES CO_2	binds 0.733 t CO_2 / t urea — re-released later in the field
Neutralisation: $NH_3 + HNO_3 \rightarrow NH_4NO_3$	ammonium nitrate for AN / CAN / NPK finishing	no CO_2; the N_2O legacy sits in the HNO_3 precursor

Read the last column top to bottom: the same molecules keep reappearing — the CO_2 made by reforming is consumed by urea; the NH_3 from Haber-Bosch feeds both nitric acid and urea. This internal recycling is exactly why CO_2 attribution rules and system boundaries dominate the rest of this day.

Process chemistry: GD9 §§39–41 · CBAM Guidance for Importers §5.5.3 · MRR (EU) 2018/2066 Annex VI

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SECTION 1 · CONTEXT — OECD STUDY

CBAM along the supply chain — the view for fertilizers and Türkiye

What the OECD (2025) simulation finds

- CBAM covers 3 % of EU imports — metals, fertilizers, cement dominate
- Türkiye among the 3 most exposed exporters: ≈ USD 13.8 bn covered (2022)
- No CBAM → ≈ 19 % carbon leakage; CBAM largely reverses it
- EU demand reroutes to carbon-efficient producers
- Own carbon price = lower border bill

What this means for fertilizer exports to the EU

- **Fertilizers are fully in scope:** direct CO2 and N2O plus indirect (electricity) emissions all count for fertilizer goods
- **The ammonia route decides the bill:** gas-based plants with modern N2O abatement face far lower CBAM costs than coal-based routes
- **A domestic carbon price is deductible:** a functioning Turkish ETS reduces the CBAM certificates its exporters must buy (Art. 9)
- **Efficient plants keep their EU market:** the model shows demand rerouting rewards low-emission producers — verified MRV data is the entry ticket
- **Bottom line:** proving actual embedded emissions is the sector's main competitive asset under CBAM

Scope note: the paper's general findings were presented in earlier sessions — today we keep only the fertilizer and Türkiye angle as context for the allocation and CBAM arithmetic of Sections 5 and 7.

OECD STI Working Paper 2025/02 — Dechezleprêtre et al., "Carbon Border Adjustments: The potential effects of the EU CBAM along the supply chain"

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DAY 5

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1. Introduction: Fertilizers in the EU ETS and CBAM
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SECTION

2

How CO2 is counted — Monitoring, Reporting, Verification

Regulation (EU) 2018/2066 (MRR) applied to fertilizer installations: source streams, calculation factors, mass balances, N2O measurement

In this section

- The CO2 map: where CO2 is generated, captured, reused — and where it leaves
- Calculation-based vs measurement-based methodologies — and when each is mandatory
- Mass balance and stoichiometry — counting carbon, not fuel
- Continuous N2O measurement for nitric and adipic acid
- Hydrogen production routes and how they shape the emission profile
- Worked numerical examples on a carbon flow diagram

Primary legal sources

- Regulation (EU) 2018/2066 (MRR), consolidated 2025
- MRR Annex I (monitoring plan), Annex II (tiers), Annex IV §§16, 17, 20, Annex VI (factors)
- Regulation (EU) 2018/2067 (AVR) for verification

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Where CO2 is generated, captured, reused — and where it leaves

Where in the plant	What happens to the CO2	How the MRR sees it
Reformer & boiler stacks (fired heaters)	dilute combustion CO2 leaves with the flue gas — not captured	emission of the installation — inside the mass balance
CO2-removal unit (after the shift reactor)	process CO2 captured as a nearly pure stream (~99 %)	not yet an emission — its downstream fate decides
Urea synthesis (on site)	captured CO2 reused: bound into CO(NH2)2 at 0.733 t/t	still counted as emitted by the NH3 plant (Annex IV §17)
Merchant CO2 — food & beverage, greenhouses	CO2 leaves by truck/pipeline for short-lived uses	counted as emitted — no deduction (not Art. 49/49a)
CCS pipeline / permanently binding CCU	CO2 leaves for geological storage or mineralisation	deductible from reported emissions (Art. 49, 49a)
Nitric acid tail-gas stack	no CO2 here — but the N2O leaves at this point	measured continuously by CEMS (Annex IV §16)

One design principle: every fossil carbon atom is priced exactly once — the rules only decide WHERE it is counted. Follow the pure CO2 stream: vented = emitted; to urea = emitted here (the field re-releases it); to CCS = deducted. That single principle explains the whole monitoring design for fertilizers.

Regulation (EU) 2018/2066, Annex IV §§16, 17, 20 · Art. 48–49a

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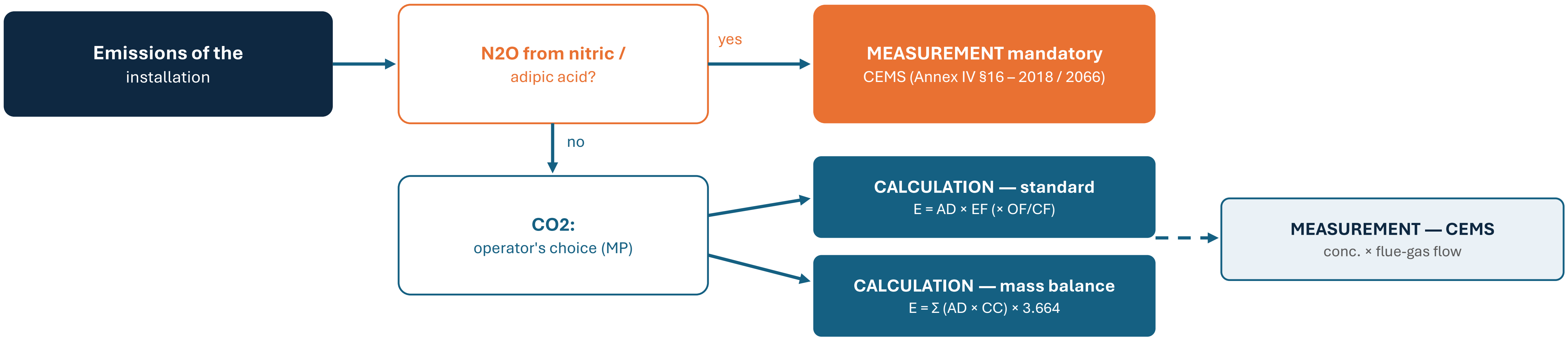
SECTION 2 · METHODOLOGY CHOICE

Calculation-based vs measurement-based — Art. 21 decision logic

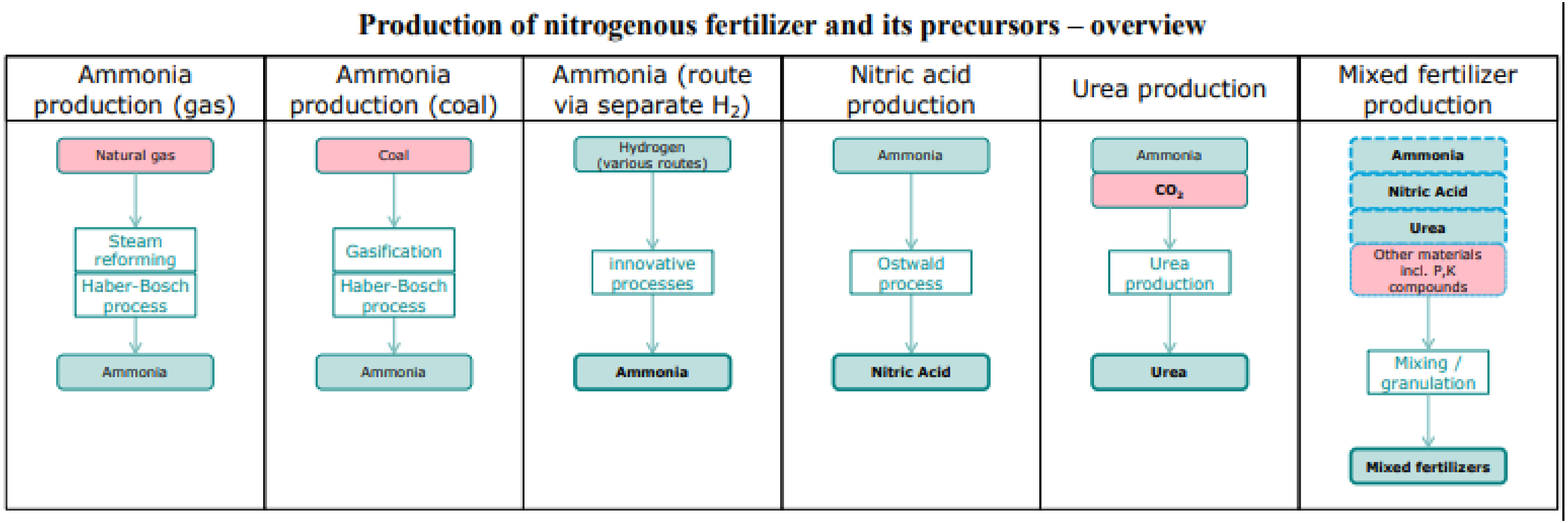


- **Combining is normal (Art. 21(1)):** one installation may use standard methodology for boilers, mass balance for the integrated NH_3–urea complex, CEMS for N_2O — provided no gaps and no double counting.
- **Switching hierarchy (Art. 21(2)–(3)):** measurement may be used for CO_2 if the operator demonstrates required tiers are met; corroborating calculation is required for CO_2 CEMS.
- **Fall-back (Art. 22):** methodology without tiers only where all tiers are technically infeasible / unreasonable cost — must quantify overall uncertainty (< 7.5 % cat. C).

Regulation (EU) 2018/2066, Art. 21–22, 24–25, 40–46; Annex IV §16

SECTION 2 · PRODUCTION ROUTES

Production routes for nitrogenous fertilizers — overview



SECTION 2 · CALCULATION — MASS BALANCE

Mass balance (Art. 25): count the carbon, not the fuel

$$Em\ CO_2 = \sum_{inputs/outputs} (AD \times CC) \times 3.664$$

AD counts positive for inputs, negative for outputs (products, exports); CC = carbon content [t C / t]; 3.664 = 44.010/12.011 t CO_2 per t C

IN: natural gas (feed+fuel)

IN: coke, limestone, other C

IN: CO_2 received (Art. 48)

MASS BALANCE
BOUNDARY
(installation or part)

OUT: carbon in products (urea, Na_2CO_3)

OUT: CO_2 transferred (Art. 49) / exports

REST = EMITTED × 3.664

Use it when...

- carbon leaves in products or wastes
- inputs are chemically converted, not burnt
- streams are too interlinked to attribute per unit

Carbon balance discipline: every carbon atom that enters must appear once — as product carbon, transferred CO_2 or emission. Tier for CC follows Annex II §3; AD tiers as for standard methodology; biomass carbon per Art. 39.

Regulation (EU) 2018/2066, Art. 25, Art. 39, Annex II §§1.4, 3 · Annex IV §17, §20 (fertilizer applications)

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Stoichiometric anchors for fertilizer MRV

Reaction / relationship	Factor	Use in MRV
$CaCO_3 \rightarrow CaO + CO_2$ (lime kiln)	0.440 t CO_2 / t $CaCO_3$	Method A carbonate input (Annex VI table 2)
Na_2CO_3 carbon content	0.415 t CO_2-equiv. / t Na_2CO_3	Output term in soda ash mass balance
$NaHCO_3$ carbon content	0.524 t CO_2-equiv. / t $NaHCO_3$	Output term (bicarbonate co-product)
$CO_2 + 2\ NH_3 \rightarrow CO(NH_2)_2 + H_2O$ (urea)	0.733 t CO_2 bound / t urea	CO_2 chemically bound in urea (60.06/44.01)
CH_4 combustion / reforming	56.1 t CO_2 / TJ NCV	Natural gas default EF (Annex VI table 1)
N_2O global warming potential	265 t CO_2(e) / t N_2O	Convert measured N_2O to CO_2(e) (Annex VI §3)

Method A vs Method B for carbonate process emissions (Annex II §4): A = input-based (t carbonate charged × stoichiometric EF, CF for residual carbonate in products); B = output-based (t oxide produced × EF). For Solvay lime kilns Method A on limestone is standard; combine with the CO_2 re-absorption logic of Annex IV §20.

Regulation (EU) 2018/2066, Annex II §4, Annex VI tables 1–2 and §3

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N2O from nitric & adipic acid: continuous measurement is the law

Annex VIII equations

$$GHG\ emissions\ [t] = \Sigma_h \left(conc._h\ [g/Nm^3] \times flow_h\ [Nm^3/h] \right) / 10^6$$

$$V_{flue\ gas} = V_{air} \times (1 - O_{2,air}) / (1 - O_{2,flue})$$ (Art. 43(5)(a) preferred for HNO_3)

$$CO_2(e)\ [t] = N_2O\ [t] \times 265$$

Measure at a representative point AFTER the abatement unit; instruments must cover abated AND unabated conditions; dry-gas basis.

Regime by activity (Annex IV §16 B.1)

- **Nitric acid:** continuous emission measurement — no alternative.
- **Adipic acid:** measurement for abated emissions + mass-balance calculation for temporary unabated events (bypass, abatement trips).
- **QA:** EN 14181 (QAL1–3, AST), EN 14789 for O_2; substitution data for missing hours per Annex VIII §5 (conservative averages).

Tier (Annex VIII §1)	1	2	3	4
Max. uncertainty, annual hourly-average based emissions	±10 %	±7.5 %	±5 %	±2.5 %

Highest tier required for major emission sources (category C nitric acid plants routinely must justify ±2.5 %). Uncertainty rises during unabated events — include in the uncertainty assessment.

Regulation (EU) 2018/2066, Art. 40–46, Annex IV §16, Annex VIII · GWP: Annex VI §3

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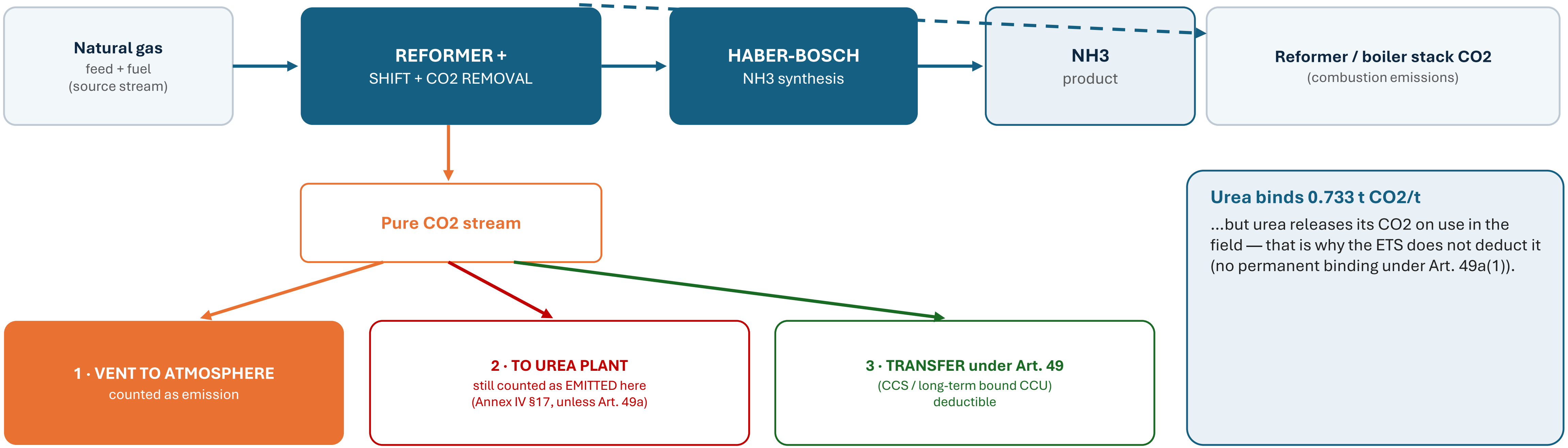
Where carbon enters and leaves an ammonia–urea installation



Urea binds 0.733 t CO_2/t

...but urea releases its CO_2 on use in the field — that is why the ETS does not deduct it (no permanent binding under Art. 49a(1)).

Regulation (EU) 2018/2066, Annex IV §17 (M5), Art. 48–49a · GD values: Annex VI

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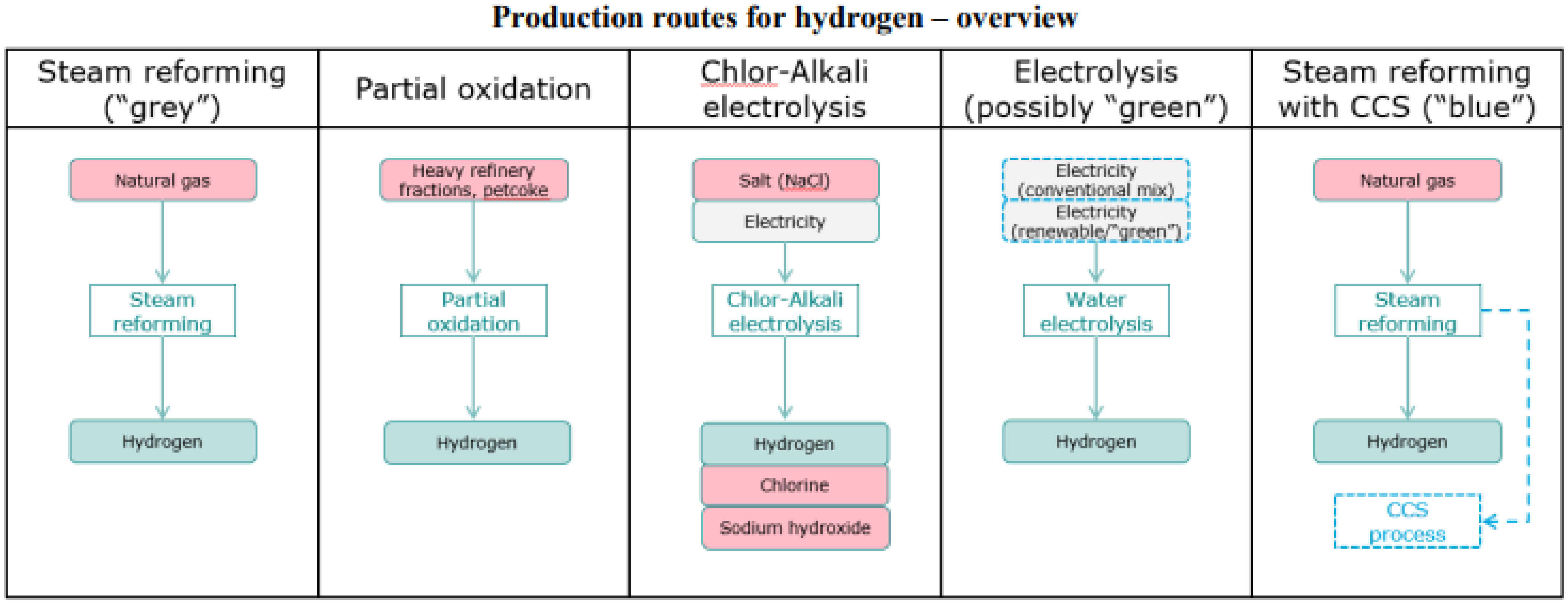
Hydrogen production routes — five system boundaries



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How the hydrogen route drives the emission profile

H2 route	How it works	Direct CO2	Indirect (electricity)	Ammonia benchmark?	CBAM view	Typical role
Steam reforming (“grey”)	CH_4 + steam → H_2 + CO_2	high (process + combustion)	moderate	inside BM 41	CCS variant deducts stored CO_2	dominant in EU / Türkiye
Partial oxidation / gasification	coal / heavy oil → syngas → H_2	very high (≈ 2× gas route)	moderate	inside BM 41	largest embedded emissions	China, legacy plants
Water electrolysis (“green”)	electricity splits H_2O	near zero	very high (grid factor)	in BM 41 (2026–30)	SEE (specific embedded emissions) ≈ indirect only	growing (PPAs)
Chlor-alkali by-product H2	by-product of brine electrolysis	low (cell process)	high	EXCLUDED from BM 41	separate precursor, own SEE	niche NH_3 feed

Why this figure matters: the H_2 route fixes most of ammonia’s emission profile — and urea, AN and NPK inherit it via the precursor rules.

Watch the boundary: H_2 made inside an NH_3 plant is part of BM 41 — the hydrogen benchmark (BM 50) is for merchant H_2 plants only.

CBAM Guidance for Importers §5.4.3 (Fig. 5-3) · GD9 benchmarks 41 & 50 · FAR Annex I as amended (Del. Reg. (EU) 2024/873)

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SECTION

3

EU ETS benchmarks — ammonia, nitric acid, adipic acid, soda ash

Product benchmark logic, system boundaries, values and eligibility for the four fertilizer-chain benchmarks

In this section

- What a benchmark is in practice — and the formula it feeds: BM × HAL × CLEF × CBAM factor
- The four benchmarks: units, boundaries, inclusions and exclusions
- Treatment of heat, steam, electricity at each boundary
- Carbon leakage status, CBAM status and historical activity levels

Primary legal sources

- Delegated Reg. (EU) 2019/331 (FAR), Annex I — definitions & starting points
- Impl. Reg. (EU) 2021/447 — values 2021–2025
- Impl. Reg. (EU) 2026/1412 — values 2026–2030
- GD9 sector guidance (2024): §§39–41, 52

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Fertilizer-chain product benchmarks at a glance

Benchmark (FAR Annex I no.)	Unit of production	Gases in boundary	2021–25 value [all./t]	2026–30 value [all./t]	Carbon leakage	CBAM good
Nitric acid (39)	t HNO_3, 100 % purity	CO_2 + N_2O	0.230	0.151	Yes → CLEF 1	Yes
Adipic acid (40)	t dry purified adipic acid	CO_2 + N_2O	2.12	1.40	Yes → CLEF 1	No
Ammonia (41)	t NH_3, saleable net, 100 %	CO_2	1.570	1.522	Yes → CLEF 1	Yes
Soda ash (52)	t Na_2CO_3, total gross prod.	CO_2	0.753	1.122	Yes → CLEF 1	No

2026–2030: values per Impl. Reg. (EU) 2026/1412 (C(2026) 4372, 26.6.2026; data 2021–22). Heat benchmark: 31.2 · fuel benchmark: 28.1 allowances/TJ. Soda ash reflects the amended FAR Annex I definitions (Del. Reg. (EU) 2024/873) — always read a value together with its definition and period.

Read the CBAM column carefully: ammonia and nitric acid lose free allocation via the CBAM factor from 2026; adipic acid and soda ash keep CBAM factor = 1 (full benchmark allocation, subject to CLEF).

FAR (EU) 2019/331 Annex I · Impl. Reg. (EU) 2021/447 · Impl. Reg. (EU) 2026/1412 · GD9 §§39–41, 52 · Del. Dec. (EU) 2019/708

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Which product belongs to which benchmark?

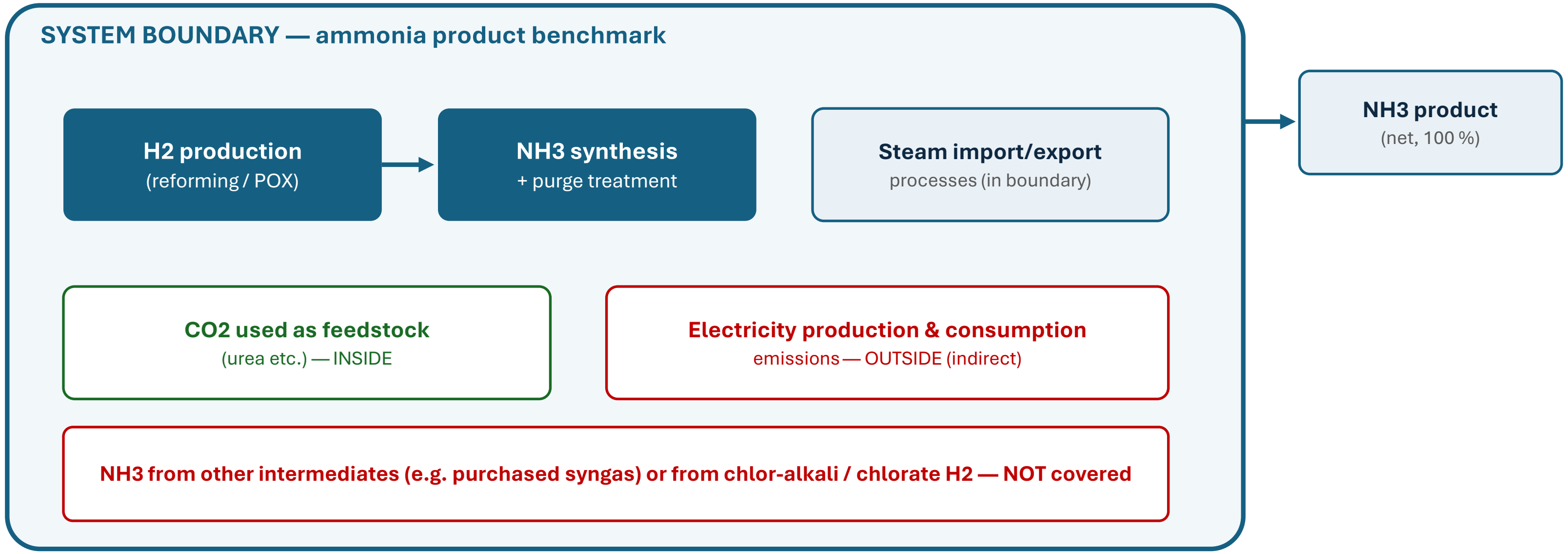
Product	Made by	Allocation basis	BM no.	Unit of production	CL list	CBAM good
Ammonia (incl. its H_2)	SMR / gasification + Haber-Bosch	Product benchmark	41	t net saleable NH_3 (100 %)	Yes	Yes
Nitric acid (incl. N_2O abatement)	Ostwald process	Product benchmark	39	t HNO_3 at 100 %	Yes	Yes
Urea, AN, CAN, UAN, NPK / NP / NK	NH_3 (+ HNO_3 / CO_2) + finishing	NO product BM → heat + fuel fallback	—	TJ of heat / fuel consumed (CL)	Yes	Yes (urea, mixed fert.)
Merchant hydrogen / syngas	stand-alone H_2 or syngas plants	Product benchmark (own)	50 / 51	t H_2 (100 %) / t syngas (47 % H_2)	Yes	H_2: partly

The rule of thumb: a product benchmark exists only where EU-wide comparable products exist. Fertilizer FINISHING (granulation, prilling, blending) is deliberately not benchmarked — it receives fallback allocation that follows the heat and fuel it consumes. Adipic acid (BM 40) and soda ash (BM 52) complete the family — both non-CBAM (factor 1).

Consequence for the BDR: an integrated complex reports one product-benchmark sub-installation per benchmarked product, plus fallback sub-installations for everything downstream — Section 4 shows how to cut them.

FAR (EU) 2019/331 Annex I · GD9 §§39–41, 50–52 · Reg. (EU) 2023/956 Annex I

Ammonia benchmark — boundaries and special features



Key facts

- Unit: t saleable NH_3 (100 %)
- Value: 1.570 (2021–25) · 1.522 (2026–30) all./t
- CO_2 as feedstock counted inside boundary (consistent with MRR Annex IV §17)
- Heat export → possible separate heat-BM sub-installation of the consumer
- CBAM good (CN 2814): CBAM factor applies from 2026

Boundary quote (FAR Annex I): *"All processes directly or indirectly linked to the production of the ammonia and the intermediate product hydrogen are included... For the purpose of data collection, the total electricity consumption within the system boundaries shall be considered."*

FAR (EU) 2019/331 Annex I (benchmark 41) · GD9 §41 · Impl. Reg. (EU) 2021/447; 2026–30: Impl. Reg. (EU) 2026/1412

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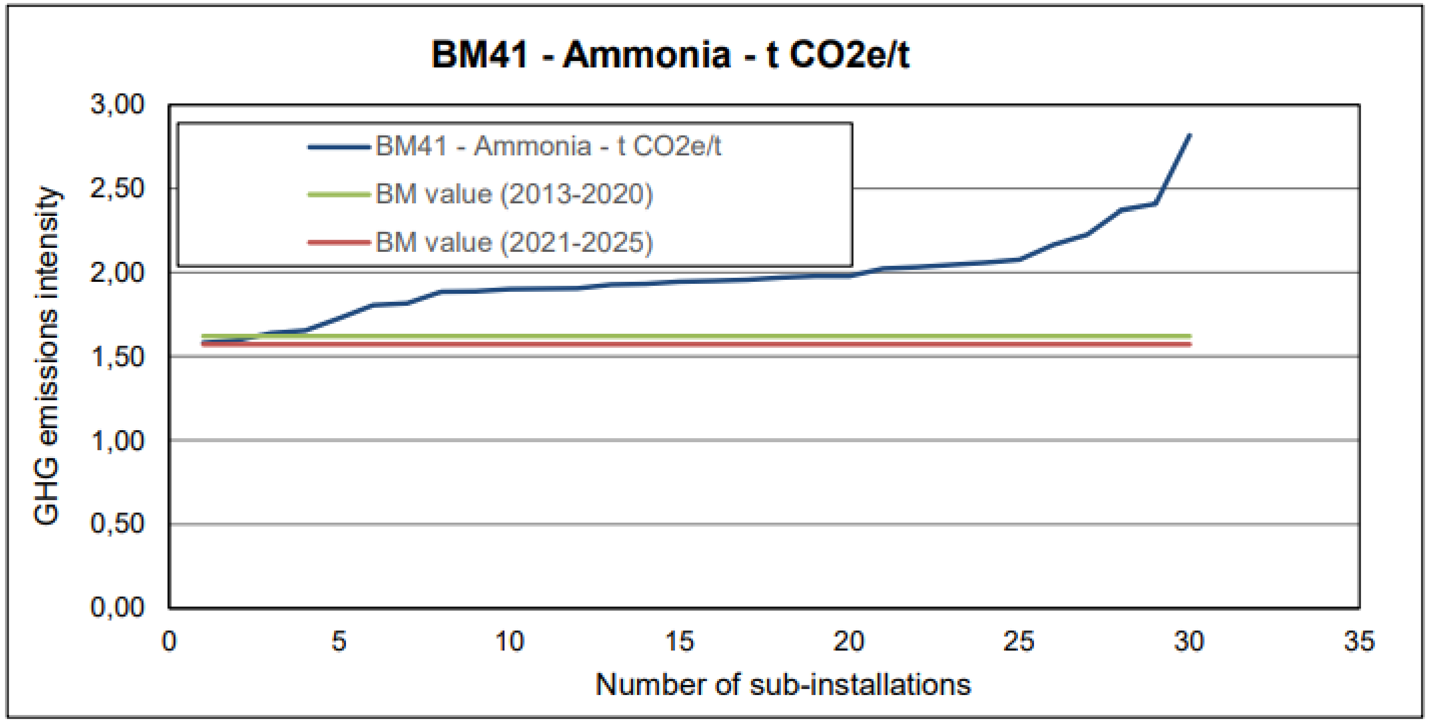
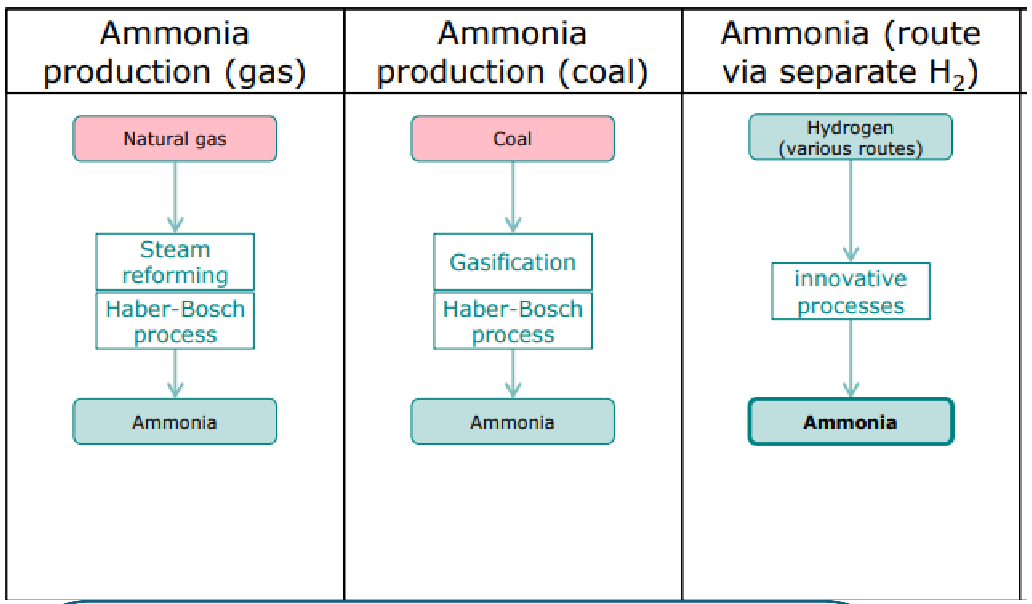
Ammonia — reading the benchmark curve





HOW TO READ THIS CURVE

- Each point = one ammonia sub-installation, ranked by GHG intensity (t CO2e/t NH3, boundary emissions incl. feedstock CO2)
- Average of the 10 % most efficient (flat left tail) sets the value: 1.570 for 2021–25 (phase 3: 1.619)
- A FLAT curve: steam reforming is mature — 35 EU sub-installations cluster near the thermodynamic optimum; median 1.948
- Plant at the median buys ≈ 0.4 EUA/t at market — and from 2026 the CBAM factor cuts the free share further

Route figure (top right): the H2 route decides where a plant lands on this curve.

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Nitric acid benchmark — N2O inside, ammonia outside, heat penalised

SYSTEM BOUNDARY — nitric acid product benchmark

NH3 oxidation
(Ostwald, Pt/Rh)

→

Absorption
HNO3 30–70 %+

N2O destruction /
abatement — INSIDE

Production of ammonia
— OUTSIDE (own BM)

Electricity consumed — OUTSIDE
(indirect emissions)

Heat from HNO3 production exported to other sub-installations: NO extra allocation — and the receiver's heat allocation is REDUCED (FAR Art. 16(5))

Key facts

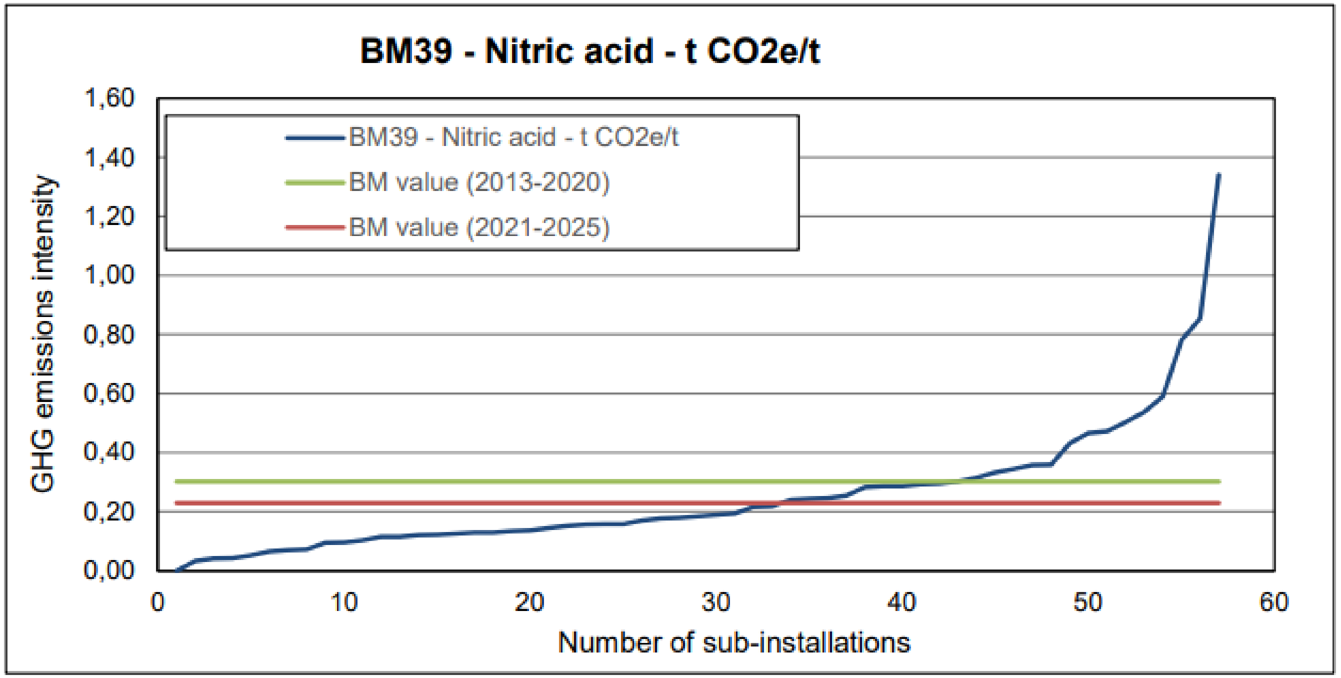
- Unit: t HNO3 at 100 % (divide by concentration!)
- Value: 0.230 (2021–25) · 0.151 (2026–30) all./t
- Covers CO2 + N2O (CEMS data feed HAL-period emissions)
- CBAM good (CN 2808 00 00)
- Special provision: exported measurable heat non-eligible

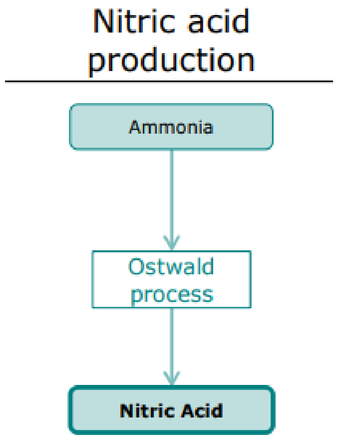
Art. 16(5) FAR mechanics: Reduction of receiver's preliminary allocation = BM_heat × HAL_heat-from-nitric-acid. Rationale: the N2O-heavy benchmark already remunerates the whole process including its exothermic heat; paying the heat again at the receiving sub-installation would double-fund it.

FAR (EU) 2019/331 Annex I (benchmark 39), Art. 16(5) · GD9 §39 · Impl. Reg. (EU) 2021/447; 2026–30: Impl. Reg. (EU) 2026/1412

SECTION 3 · BENCHMARK 39 — THE CURVE

Nitric acid — the abatement cliff in one picture





HOW TO READ THIS CURVE

- 57 sub-installations ranked by t CO2e/t HNO3 (CO2 + N2O)
- Value 0.230 (2021–25) = average of the 10 % best; phase 3: 0.302
- Median (0.184) is BELOW the benchmark — most plants now run modern N2O abatement
- The steep right tail = lines with weak or no tertiary abatement, up to ≈ 1.4 t CO2e/t
- Clearest EU example of benchmark-driven abatement investment — falls further to 0.151 for 2026–30

SECTION 3 · BENCHMARK 40

Adipic acid benchmark — the N_2O heavyweight (not a CBAM good)

SYSTEM BOUNDARY — adipic acid product benchmark

- **Oxidation of KA-oil** with HNO_3 → **Crystallisation, drying,** storage, packaging
- **N_2O abatement** unit — INSIDE
- **Net steam consumption** (import − recovery) — INSIDE
- **KA-oil & nitric acid production** — OUTSIDE · electricity — OUTSIDE
- **Side products glutaric & succinic acid: processing/handling emissions INSIDE · salts & esters of adipic acid NOT covered by the unit**

Key facts

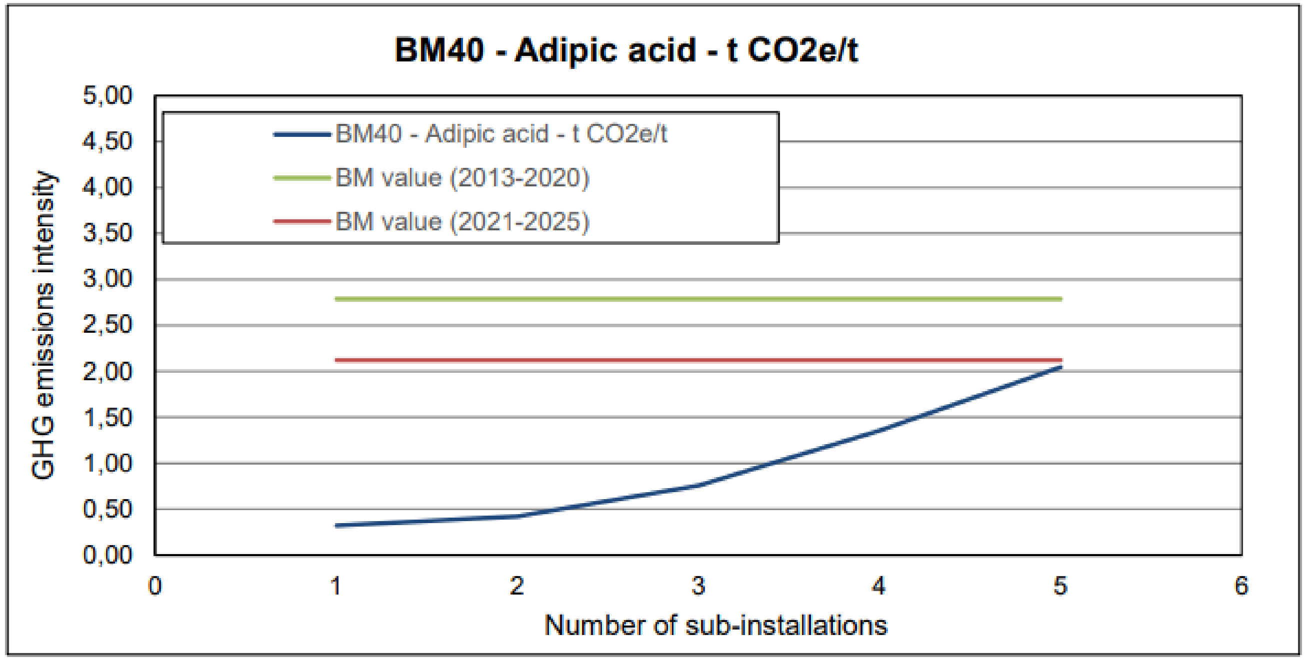
- Unit: t dry purified adipic acid (silos / big-bags)
- Value: 2.12 (2021–25) · 1.40 (2026–30) all./t
- CO_2 + N_2O in boundary; hybrid MRV regime (CEMS + mass balance)
- NOT a CBAM good → CBAM factor = 1
- Heat export eligible under heat BM (GD6 rules)

Why the highest benchmark of the four: stoichiometric N_2O co-production (~0.3 t N_2O/t before abatement ≈ 80–90 t CO_2e/t unabated at GWP 265) means even the best abated plants carry material residual N_2O — hence 2.12 allowances per tonne.

FAR (EU) 2019/331 Annex I (benchmark 40) · GD9 §40 (incl. Figure 6 emission map) · Impl. Reg. (EU) 2021/447; 2026–30: Impl. Reg. (EU) 2026/1412

SECTION 3 · BENCHMARK 40 — THE CURVE

Adipic acid — five installations, one N2O story



HOW TO READ THIS CURVE

- Only 5 EU sub-installations use this benchmark — the smallest population of the four (confidentiality limits published detail)
- Value 2.12 (2021–25) = average of the 10 % best; phase 3: 2.79 — the calculated update rate (−9.84 %/yr) hit the −1.6 %/yr cap
- Median of all plants: 0.76 t CO2e/t — abated plants sit far below the value; unabated events dominate the right end
- Residual N2O after abatement keeps this the highest of the four fertilizer-chain benchmarks
- Not a CBAM good: allocation continues at CLEF 1 — value falls to 1.40 for 2026–30

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Soda ash benchmark — nine process units, one boundary

Brine purification	Limestone calcination & milk of lime	CO_2 reactors (carbonation)
NH_3 absorption	$NaHCO_3$ precipitation	Filtration / separation of $NaHCO_3$
$NaHCO_3$ → Na_2CO_3 decomposition	Ammonia recovery	Densification / dense soda ash

Key facts

- Unit: t soda ash, TOTAL GROSS production
- Excluded: dense soda ash by-product of caprolactam networks
- Value: 0.753 (2021–25) · 1.122 (2026–30, revised definition) all./t
- CO_2 only · electricity emissions outside
- NOT a CBAM good → CBAM factor = 1
- Annex I activity: production of soda ash and $NaHCO_3$

Boundary formula (FAR Annex I): *“all processes directly or indirectly linked to the process units” listed above are included*. Emissions of consumed electricity are excluded; exported measurable heat is not covered but may be eligible under heat-benchmark rules (GD6).

Sub-installation practice: the CHP / boiler house serving the Solvay units belongs INSIDE the product benchmark to the extent its heat feeds the nine units — only heat to other consumers forms a separate sub-installation.

FAR (EU) 2019/331 Annex I (benchmark 52) · GD9 §52 · Impl. Reg. (EU) 2021/447; 2026–30: Impl. Reg. (EU) 2026/1412

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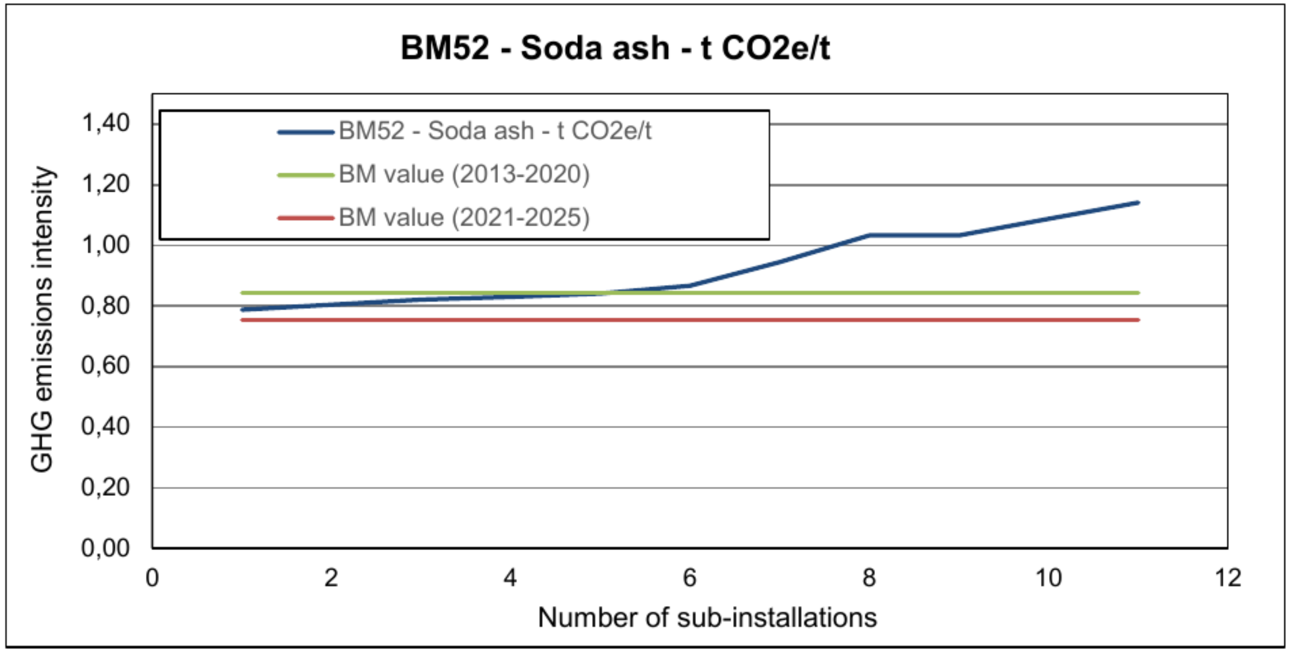
Soda ash — a tight curve about to be redefined



HOW TO READ THIS CURVE

- 12 sub-installations ranked by t CO_2e/t soda ash (gross production)
- Value 0.753 (2021–25) = average of the 10 % best; phase 3: 0.843; median 0.866 — a tight band, Solvay technology is mature
- Our case study plant (≈ 0.8 t CO_2/t) sits mid-curve — free allocation covers ≈ 94 % of its attributed emissions
- For 2026–30 the value RISES to 1.122 — the amended Annex I definition (Del. Reg. (EU) 2024/873) adds the CO_2 bound in the product to the benchmark scope, not worse performance
- Never read a benchmark value without its definition and period

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DAY 5

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1. Introduction: Fertilizers in the EU ETS and CBAM
2. How the CO_2 is counted (MRV)
3. EU ETS benchmarks — ammonia, nitric acid, adipic acid and soda ash
4. **System boundaries & sub-installations**
5. Worked example: Integrated fertilizer complex sub-installation map
6. Urea & mixed fertilizers: production, CO_2 and monitoring
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SECTION

4

System boundaries & sub-installations

How an installation is cut into sub-installations, and how emissions and energy flows are attributed between products

In this section

- Installation boundary vs sub-installation vs benchmark boundary
- The strict hierarchy: product benchmark → heat → fuel → process emissions
- Included and excluded processes at each benchmark boundary
- Interactions between sub-installations: heat, CO_2, intermediate products
- Graphical boundary examples for an integrated fertilizer complex

Primary legal sources

- Delegated Reg. (EU) 2019/331 (FAR), Art. 2–10, Annex I–IV, VI–VII
- Impl. Reg. (EU) 2019/1842 (ALC)
- GD9 (2024) + GD2 (installation guidance), GD3 (data collection)

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Sub-installation hierarchy — strictly in this order (FAR Art. 10)

1 · PRODUCT BENCHMARK

Everything inside a FAR Annex I product boundary (ammonia, nitric acid, adipic acid, soda ash...)

2 · HEAT BENCHMARK

Measurable heat consumed / exported to non-ETS, not covered by 1 · split CL / non-CL / district heating

3 · FUEL BENCHMARK

Non-measurable heat: direct fuel use (drying, prilling, flares except safety flaring), not covered by 1–2

4 · PROCESS EMISSIONS

Residual process emissions (Art. 2(10) types), allocation = 0.97 × historical emissions

Golden rules

- Mutually exclusive, jointly exhaustive — every emission in exactly one sub-installation
- Physical units can be shared: one boiler may serve several sub-installations (attribute by measured heat)
- CL status split: separate heat/fuel sub-installations for carbon-leakage vs non-CL products
- Electricity: never allocated via these sub-installations (indirect; national compensation only)
- Safety flaring → heat benchmark treatment excluded; process flaring → fuel benchmark

FAR (EU) 2019/331 Art. 2(10), Art. 10, Annex I · GD2/GD3 · process emissions factor 0.97: FAR Art. 24 practice

Installation boundary vs sub-installation vs benchmark boundary

Installation boundary — the MRV world

- Set by the GHG permit: all Annex I activities plus directly associated activities
- Answers: what does the site EMIT? — verified every year in the AER
- One boundary; transferred CO_2 crosses it only under Art. 48–49a rules
- Same boundary for category, tiers and verification duties
- Source: Directive Annex I + MRR

Sub-installations & benchmark boundaries — the FAR world

- **Sub-installations cut the installation into allocation units:** product benchmark parts first, then heat, fuel, process emissions — mutually exclusive, jointly exhaustive
- **Each product benchmark has a FIXED system boundary (FAR Annex I):** "all processes directly or indirectly linked to production" — the same list for every plant in Europe
- **Included at ammonia:** reforming, shift, CO_2 removal, synthesis, purge treatment, own steam systems — and the H_2 intermediate
- **Excluded everywhere:** electricity-related (indirect) emissions; inputs with their own benchmark (NH_3 into HNO_3); downstream products (urea is outside BM 41)
- **Why fixed boundaries:** comparability — ranking installations only makes sense if every plant counts exactly the same processes

One site, two worlds: **the MRV boundary decides what is reported and surrendered;** the FAR boundaries decide what is allocated for free. **They meet in the Monitoring Methodology Plan (MMP),** which maps every tonne of CO_2 and every TJ of heat to exactly one sub-installation.

FAR (EU) 2019/331 Art. 2, 10, Annex I · MRR (EU) 2018/2066 · GD2 · GD9 §§39–41, 52

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SECTION

5

Worked calculation

In this section

- Integrated fertilizer complex — sub-installation map
- Old world vs new world — what the producer must now buy

Primary legal sources

- FAR (EU) 2019/331 Art. 16 · Directive 2003/87/EC Art. 10a(1a), 10a(5)
- Impl. Reg. (EU) 2021/447 (BM values used here)
- Impl. Reg. (EU) 2026/1412 (insert 2026–30 values in live work)

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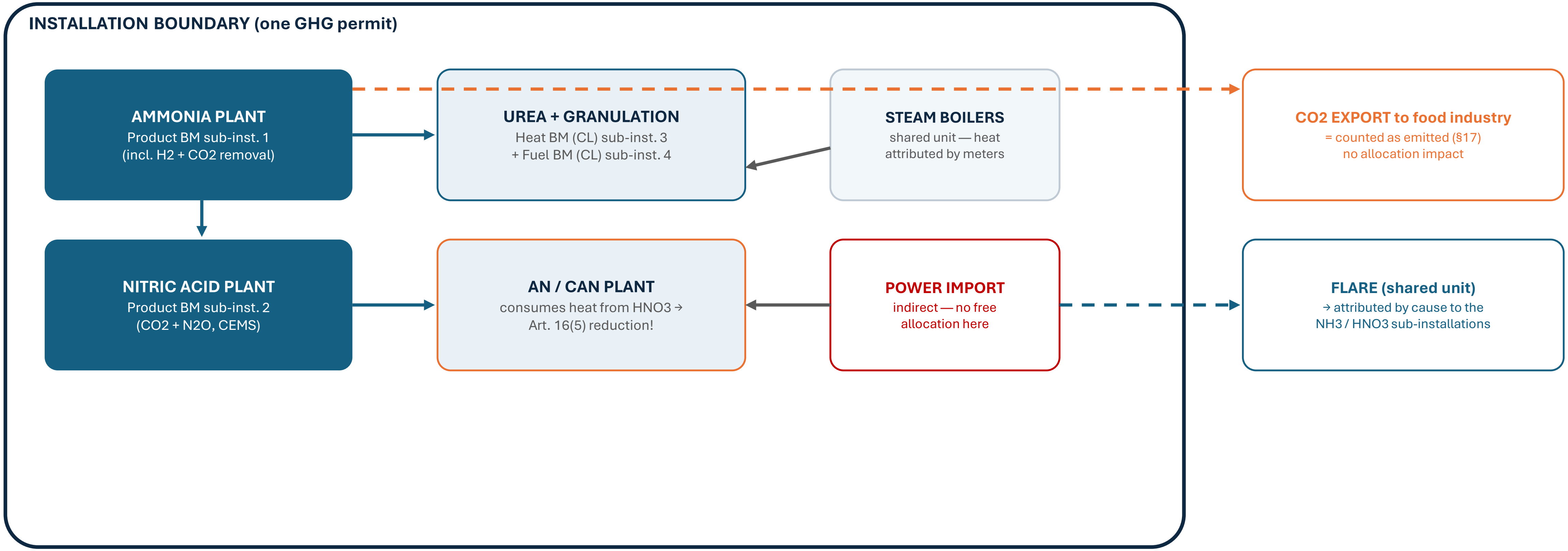
SECTION 4 · WORKED BOUNDARY MAP

Integrated fertilizer complex — sub-installation map



One installation → 4 sub-installations: 2 product BM (NH_3, HNO_3) · 1 heat BM (CL) · 1 fuel BM (CL) — plus the Art. 16(5) correction on the heat flowing from HNO_3 to AN.

FAR (EU) 2019/331 Art. 10, 16(5), 21 · GD2 §Installation splitting · GD6 (cross-boundary heat)

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Flows between sub-installations — and who gets the allocation

Flow between units	Rule that applies	Allocation consequence
Steam: nitric acid → AN / finishing units	FAR Art. 16(5) — this heat is already paid inside BM 39	receiver's heat allocation REDUCED by heat-BM × that heat
Steam: shared boilers → several consumers	attribute by steam metering per the MMP (FAR Annex VII)	each consuming sub-installation claims only its measured share
CO_2: ammonia plant → urea plant	MRR Annex IV §17 — counted as emitted at the NH_3 plant	no allocation effect; the urea unit gets heat/fuel fallback only
NH_3: ammonia plant → nitric acid plant	NH_3 is outside the BM 39 boundary (it has its own benchmark)	no double allocation — each product is paid once, in its own BM
Heat imported from a non-ETS supplier	FAR Art. 21 special rules for cross-boundary heat	allocation possible at the consumer, with corrections
Carbonate additives / residual process chemistry	process emissions sub-installation (FAR Art. 2(10))	0.97 × historical process emissions

The attribution principle: every tonne of CO_2 and every TJ of heat must land in exactly ONE sub-installation. Where a physical unit serves several (boilers, flares), metering plus MMP attribution rules divide it — nothing is counted twice, nothing is lost. Getting these interactions right is where allocation projects are won or lost.

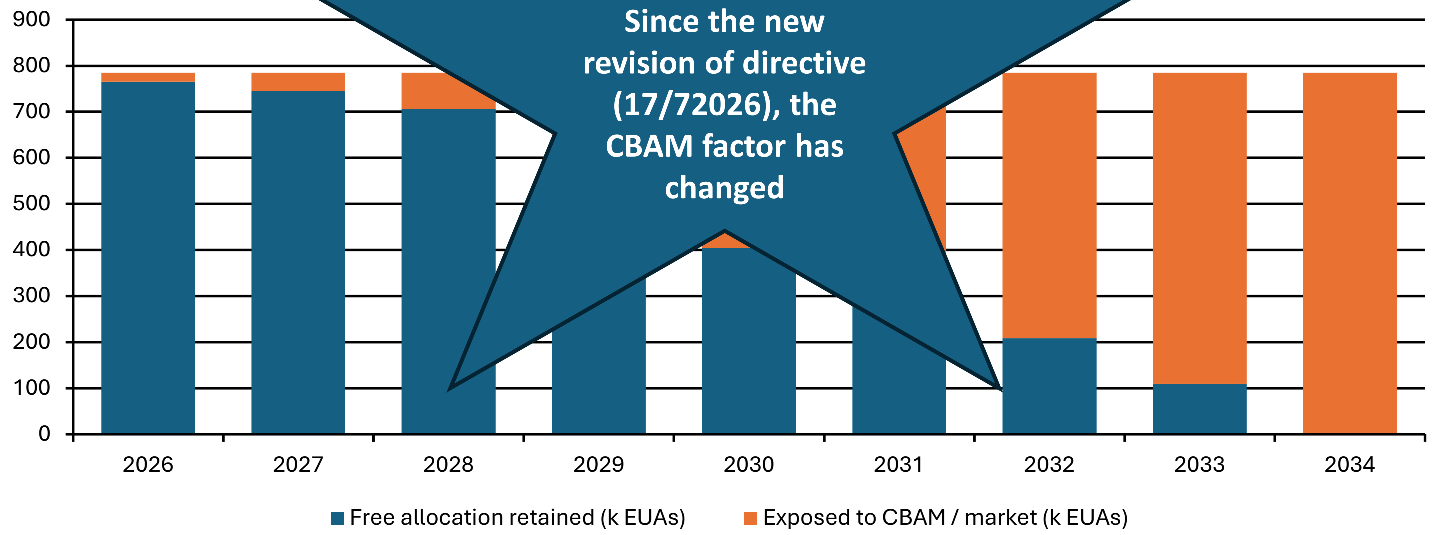
FAR (EU) 2019/331 Art. 10, 16(5), 21, Annex VII · GD6 (cross-boundary heat) · MRR Annex IV §17

SECTION 5 · STEP 4 — THE CBAM FACTOR

CBAM goods lose free allocation on a fixed schedule

Year	2026	20[illegible]	2028	2029	2030	2031	2032	2033	2034
CBAM factor	97.5 %	[illegible]	90 %	77.5 %	51.5 %	39 %	26.5 %	14 %	0 %
Allocation (k EUAs)	765	[illegible]	707	608	404	306	208	110	0

Since the new revision of directive (17/72026), the CBAM factor has changed



Read the cliff

- Gentle start (−2.5 pp/yr to 2028), steep middle (−26 pp in 2030), zero in 2034
- Mirror image: importers surrender CBAM certificates for the SAME phased-in share
- Applies only to CBAM goods: ammonia & nitric acid here — NOT soda ash / adipic acid
- Formula: Final = BM × HAL × CLEF × CBAM factor

Directive 2003/87/EC Art. 10a(1a) (schedule) · Reg. (EU) 2023/956 Art. 31 · FAR Art. 16a (as amended by Del. Reg. 2024/873)

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SECTION

6

Urea & mixed fertilizers — the downstream chain

How NH3, CO2 and HNO3 become urea, AN, CAN, UAN and NPK — and how the EU ETS and CBAM each see the downstream steps

In this section

- Urea synthesis: chemistry, process flow and CO_2 consumption
- Mixed fertilizers: AN, CAN, UAN and NPK routes and their emissions
- Monitoring considerations for finishing plants: dryers, heat, additives
- The downstream asymmetry: fallback allocation in the ETS — full goods under CBAM

Primary legal sources

- MRR (EU) 2018/2066, Annex IV §17 · FAR fallback allocation rules
- CBAM Guidance for Importers §5.5.3 · IR (EU) 2025/2547 Annex II §§3.9–3.10
- Reg. (EU) 2023/956 Annex I (urea and mixed fertilizers)

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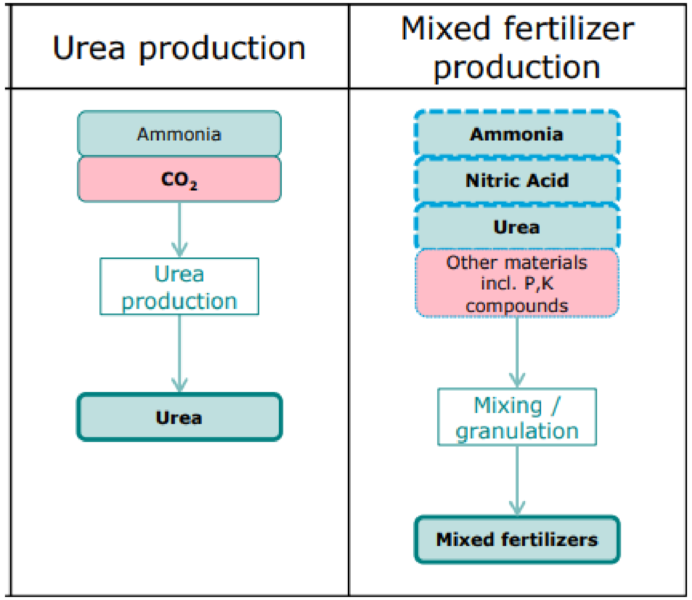
Urea and mixed fertilizers — the production systems CBAM sees



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Urea — chemistry, process flow and CO_2 balance

Step	Chemistry / operation	CO_2 & monitoring view
1 · CO_2 supply from the NH_3 plant's removal unit	pure CO_2 compressed to ~150 bar	counted at the NH_3 plant (Annex IV §17)
2 · Carbamate formation (exothermic)	$2\,NH_3 + CO_2 \rightarrow NH_2COONH_4$	consumes 0.733 t CO_2 / t urea
3 · Dehydration to urea (endothermic)	$NH_2COONH_4 \rightarrow CO(NH_2)_2 + H_2O$	steam → heat-BM sub-installation (CL)
4 · Recycle of unconverted NH_3 / CO_2	stripping and carbamate recycle loops	internal loop — no source stream
5 · Evaporation + prilling / granulation	melt concentrated, shaped, dried	fired dryers → fuel-BM sub-installation (CL)
6 · Product leaves the site (urea, 46 % N)	CO_2 is re-released on use in the field	ETS: no deduction · CBAM: CO_2 → urea's SEE

Numbers to remember: 1 t urea binds 0.733 t CO_2 and needs ~0.57 t NH_3. A 600 kt/yr urea line consumes ≈ 440 kt CO_2/yr — roughly the process-CO_2 output of its ammonia plant. ETS and CBAM treat this CO_2 differently: the ETS counts it at the NH_3 plant (Annex IV §17); CBAM carries it into urea's embedded emissions (IR 2025/2547 Annex II §3.9). Never mix the two logics.

MRR (EU) 2018/2066 Annex IV §17 · IR (EU) 2025/2547 Annex II §3.9 · CBAM Guidance for Importers §5.5.3.3

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AN, CAN, UAN, NPK — routes, emissions, monitoring

Product / route	Process	Emissions & monitoring view
AN — ammonium nitrate	$NH_3 + HNO_3 \rightarrow NH_4NO_3$, evaporation, prilling	no process CO_2; dryer fuel CO_2; N_2O sits upstream in HNO_3
CAN — calcium ammonium nitrate	AN melt + ground limestone / dolomite filler	filler NOT calcined → normally no carbonate CO_2
UAN solution (32 % N)	urea + AN dissolved together ~1:1	inherits urea's CO_2 and AN's HNO_3-N_2O via precursors
NPK — mixed-acid or nitrophosphate route	phosphate rock + acids + NH_3; K salts; granulation	dryer fuel CO_2; possible carbonate CO_2 from the rock
Blending / bulk mixing only	physical mixing of finished fertilizers	outside the ETS unless combustion > 20 MW
CBAM view of all of the above	CN 3102 / 3105, KNO_3 — kg-N unit from 2026	embedded = own fuel + electricity + precursor SEE

The downstream asymmetry — say it twice: these products have NO product benchmark (fallback heat/fuel allocation, CL via NACE 20.15) — yet they ARE CBAM goods. The finishing plant's own emissions are small; the carbon story of an NPK is written almost entirely in its precursors: the ammonia route and the nitric acid N_2O abatement.

CBAM Guidance for Importers §5.5.3.4 · IR (EU) 2025/2547 Annex II §3.10 · FAR (EU) 2019/331 fallback rules

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SECTION

7

CBAM and fertilizers

Embedded emissions, calculation methods, default values, and the importer's obligations in the definitive period

In this section

- Which fertilizer goods are covered (CN codes) — and which are not
- Embedded emissions: direct, indirect, precursors; the new functional unit
- Actual values vs default values — the definitive-period rulebook
- Complete reporting example: NPK 15-15-15
- Interaction with EU ETS free allocation and the 2026–2034 phase-out

Primary legal sources

- Reg. (EU) 2023/956 (CBAM), as amended by Reg. (EU) 2025/2083
- Impl. Reg. (EU) 2025/2547 (definitive-period calculation methods)
- CBAM Guidance for Importers (transitional-period concepts)

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Which fertilizer goods are CBAM goods (Annex I, Reg. 2023/956)

Aggregated goods category	CN codes	Notes	Relevant GHG
Nitric acid	2808 00 00	incl. sulphonitric acids	$CO_2 + N_2O$
Urea	3102 10	whether or not in aqueous solution	CO_2
Ammonia	2814	anhydrous or aqueous solution	CO_2
Mixed fertilizers	2834 21 00 · 3102 (excl. 3102 10) · 3105 (excl. 3105 60 00)	K-nitrates, N-fertilizers, NPK/NP/NK	$CO_2 + N_2O$
NOT covered	3105 60 00 (PK), 3104 (potassic), phosphates 3103	no significant N-related embedded emissions	—

Remember the asymmetry: urea, AN, CAN, NPK are CBAM goods but have NO EU ETS product benchmark (fallback allocation only); adipic acid and soda ash are ETS-benchmarked but NOT CBAM goods. **De-minimis (2025 amendment):** importers of ≤ 50 t/year of covered goods (cumulative mass, all CBAM goods except electricity & hydrogen) are exempt — removing ~90 % of importers, keeping ~99 % of emissions.

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SECTION 7 · CONCEPT

Embedded emissions — direct + indirect + precursors

PRODUCTION PROCESS SYSTEM BOUNDARY (third-country installation)

DIRECT
fuel + process CO2 (+ N2O)
incl. heating/cooling

INDIRECT
electricity consumed
(MWh × EF grid or actual)

PRECURSORS
embedded emissions of
NH3 / HNO3 / urea inputs

SEE = (attributed direct + indirect + precursor emissions) ÷ activity level (functional unit)

Functional unit (definitive period)

- **CN 2808, 2814, 3105:** kg of NITROGEN contained (IR 2025/2547 Art. 4(4))
- **Urea & other CN:** CN supplementary units
- N content recorded by form: ammonium (NH4+), nitrate (NO3−), urea, other (per Reg. 2019/1009)

EU ETS mirror by design: monitoring at installation level → attribution to production processes → division by output (IR 2025/2547 Art. 4–8, Annex II–III) — methodologically the MRR transplanted. Complex goods = simple goods + precursor embedded emissions (Art. 15–16: actual or default precursor values).

Reg. (EU) 2023/956 Annex IV · Impl. Reg. (EU) 2025/2547 Art. 4–8, 15–16, Annex II §§3.7–3.10, Annex III

Actual values vs default values

ACTUAL values (preferred)

- Installation-level monitoring per IR 2025/2547 Annex II — EU ETS methodology (calculation / measurement)
- Reporting period: typically the calendar year preceding import; data via the CBAM Registry (operator portal)
- Verified by accredited verifier; declarant uses verified SEE per installation & goods category
- Precursors: actual SEE from the precursor's installation, or default

DEFAULT values (fallback)

- Set per third country + goods category where reliable data exist; otherwise: average of the X % worst-performing EU ETS installations, with mark-up
- Indirect: default grid emission factor of the origin country (or actual under PPA/direct-line conditions)
- No verification needed — but deliberately conservative: paying the default is usually MORE expensive than proving actuals
- Alternative defaults possible if formally adopted and published by the Commission

Consulting play: helping third-country fertilizer plants build EU-ETS-grade MRV to replace defaults with actuals is the single largest CBAM value lever.

Reg. (EU) 2023/956 Annex IV §§4–5 · Impl. Reg. (EU) 2025/2547 Art. 15–16, recitals 19–22, Annex II

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Interactive Q&A

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CLOSE

Fertilizers – Day 5

Primary sources cited in this storyboard

- EU ETS Directive 2003/87/EC (consolidated 01.03.2024)
- Free Allocation Regulation (EU) 2019/331 (cons. 01.01.2024) — Annex I, Annex IV [ETS/]
- Free Allocation Guidance GD9 — sector-specific guidance, Fertilizers
- Supporting guidance: GD3, GD4, GD5, GD6, GD8 [ETS/]
- CBAM Implementing Reg (EU) 2025/2620
- CBAM Reg (EU) 2023/956 and 2025/2621 (default values) [CBAM/]
- Accreditation & Verification Reg (EU) 2018/2067 (AVR) [MRV/]