Quantitative Evaluation of Carbon Emission Advantages of Hydrogen- based DRI



Our experience. Your growth.

A long journey

1861 — Registro Italiano Navale was established

1968 — RINA is a founding member of the International Association of Classification Societies (IACS) foundation

2000 — RINA S.p.A was born: 700 colleagues, 90 mln euro revenues

2011 — RINA enters the consulting engineering sector: acquisition of D'Appolonia

2013 — RINA expands its expertise in testing and laboratories: acquisition of Centro Sviluppo Materiali

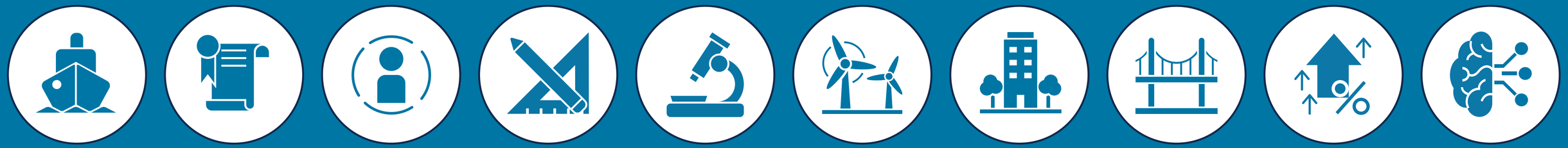
2016 — RINA expands into the UK market: acquisition of Edif

2018 — RINA grows into the Real Estate sector and African market: acquisition of RINA Prime and Comete

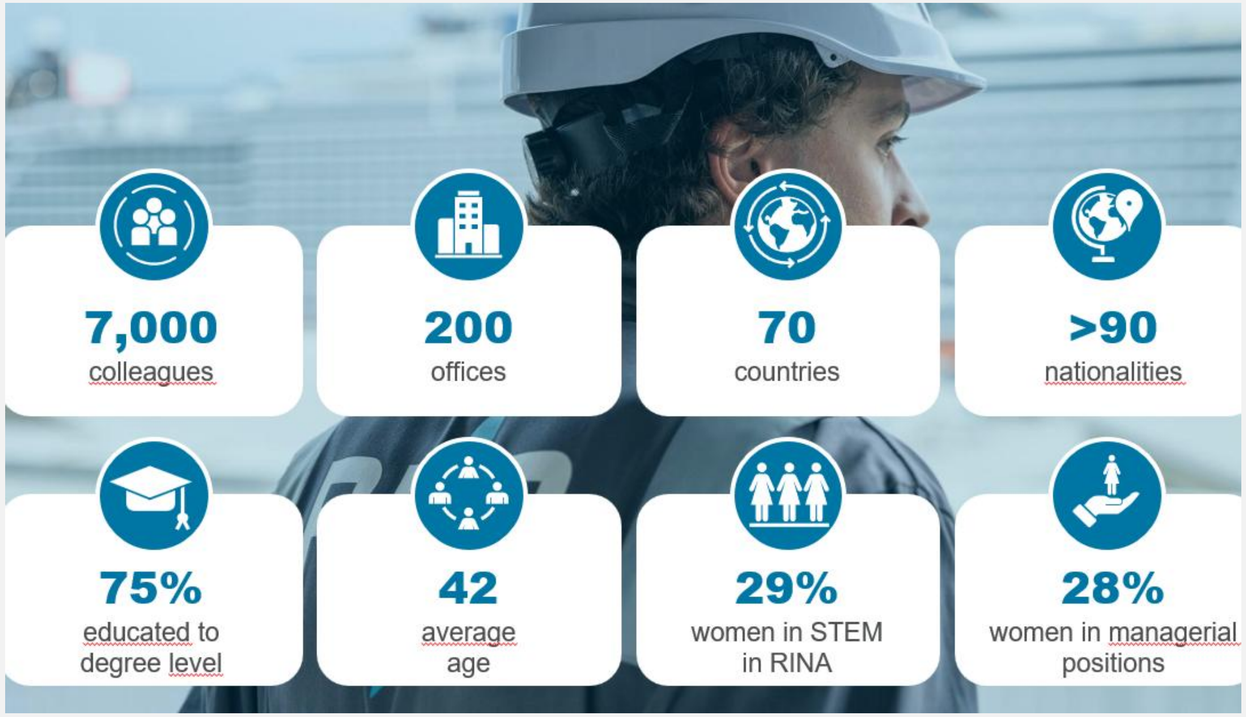
2021 — RINA consolidates its presence in the US market: acquisition of Patrick Engineering

2023 — Incorporation of the financial partner Fondo Italiano d'Investimento

2024 — RINA strengthens its positioning as a knowledge company



RINA Today





Our business unites

Energy

RINA's energy team offers global expertise in site characterization, advisory, engineering, inspections & supervision, supporting energy projects from development to decommissioning, ensuring safety and efficiency.

Industry

RINA's industry team provides highly qualified services, thank to its multidisciplinary approach and outstanding application expertise across all industrial sectors - including A&D, hard-to-abate industries, management consulting, and cybersecurity.

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Marine

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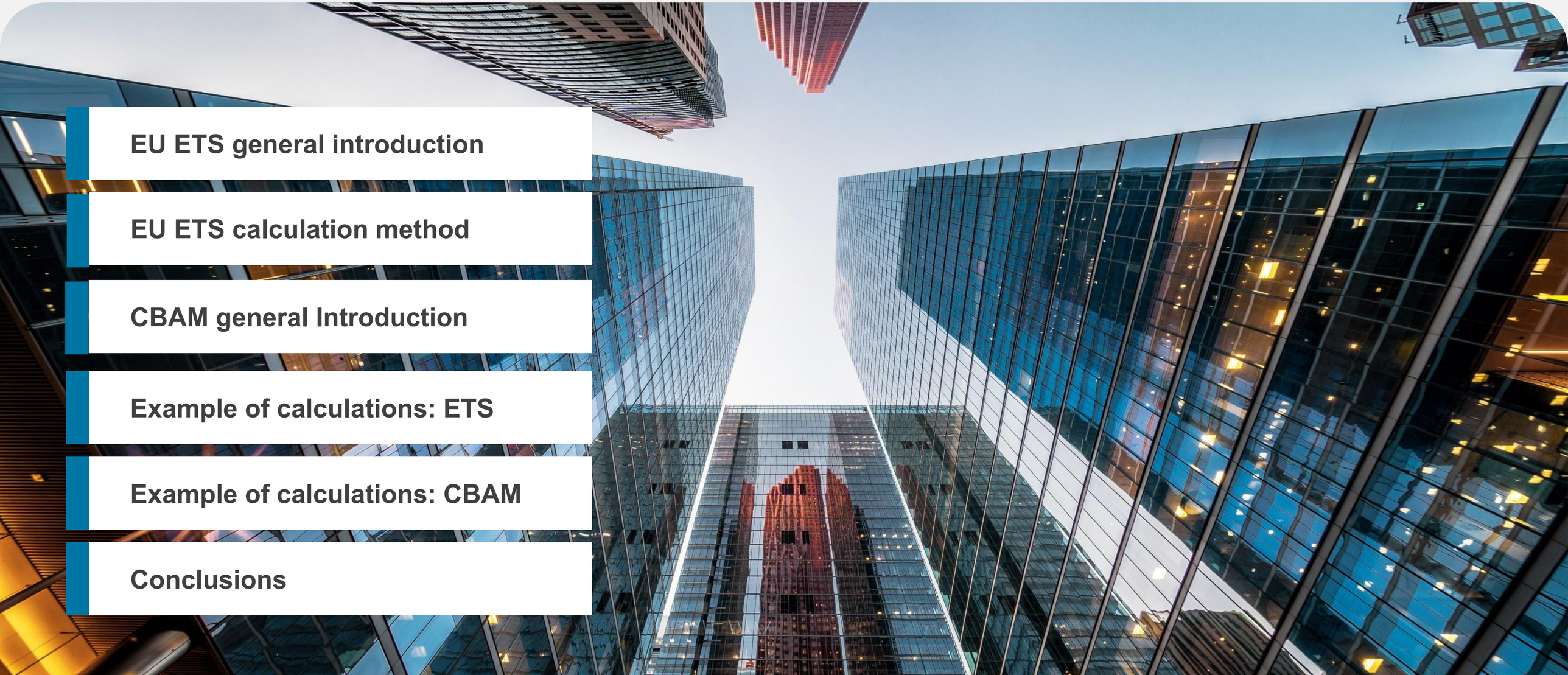
Certification

RINA's certification team guides companies on their journey toward continuous improvement and excellence, by certifying organizations' genuine dedication to best practices.

Real Estate

RINA's real estate team supports public and private market operators with innovative services aimed at protecting and enhancing real estate capital value at every stage of the investment.

Content of the presentation



- EU ETS general introduction
- EU ETS calculation method
- CBAM general Introduction
- Example of calculations: ETS
- Example of calculations: CBAM
- Conclusions

EU ETS: Introduction and Role

It is a Cap-and-Trade system that sets a maximum ceiling on emissions and creates a carbon market.

- **Scope of Application:** Covers energy-intensive industries, power generation, aviation, and, since 2024, maritime transport
- **2030 Objective:** A **62% emissions cut** compared to 2005 for covered sectors.
- **Towards 2040:** New EU target aligned with the 90% net greenhouse gas reduction goal.



CAP

EU-wide limit falls each year

ALLOCATE

Auctioning + targeted free allocation

EMIT

Operators monitor verified emissions

TRADE

Buy or sell EU allowances

SURRENDER

allowances submitted to cover the installation's verified emissions.

EU ETS

MONITORING, REPORTING & VERIFICATION COMPLIANCE CYCLE

Ensuring credible emissions data and environmental integrity

1 MONITORING OPERATOR

The installation operator monitors emissions in accordance with the approved monitoring plan and EU rules.



2 ANNUAL REPORT

The operator prepares an annual emissions report and submits it to the competent authority.



3 INDEPENDENT VERIFICATION

An accredited verifier independently verifies the report in accordance with EU standards and issues a verification opinion.



4 COMPETENT AUTHORITY REVIEW

The competent authority reviews the report and verification opinion and determines the verified emissions.



5 ALLOWANCE SURRENDER

The operator surrenders EU Allowances (EUAs) equal to the verified emissions in the EU Registry by the compliance deadline (30 April).



6 COMPLIANCE ACHIEVED

Emissions are covered by surrendered allowances. The cycle begins again.

THE EU ETS COMPLIANCE CYCLE

A continuous cycle ensuring accurate emissions accounting and compliance with EU ETS obligations

ENVIRONMENTAL INTEGRITY

Accurate data, independent checks, effective enforcement

EU-WIDE SYSTEM

Harmonised rules across the EU for a level playing field

CLIMATE ACTION

Driving emissions reductions cost-effectively

KEY BENEFITS

ACCURATE DATA

Reliable emissions data underpin effective policy

TRUST & TRANSPARENCY

Independent verification and oversight build confidence

FAIR COMPETITION

Common rules ensure a level playing field across the EU

LOW-CARBON FUTURE

Supports Europe's climate neutrality goals

COMPLIANCE DEADLINE
30 APRIL EACH YEAR

LEGAL BASIS
EU ETS Directive (2003/87/EC) and related Implementing Regulations

European Commission



EU ETS: Introduction and Role

ETS Evolution and "Cap" Reduction: the new trajectory of allowances from 2026 to 2040

- **Linear Reduction Factor (LRF):** Set at **4.3%** (2024-2027) and **4.4%** (2028-2030).
- **Post-2030:** Planned reduction drops to **3.7% annually** (2031-2035) and **1.7% annually** (2036-2040) to mitigate industrial costs.

Free Allocation and New System Entrants: Rules for receiving free CO_2 allowances are tightening and are now tied to real efficiency improvements (not yet approved by European Commission):

- **Extension to 2038:** The Commission reintroduced 15% of free allowances from 2028, delaying the full phase-out to **2038** (up from the original 2034 plan)
- **Conditionality Clauses:** From 2031, 80% of free allowances will require approved investment plans, and the remaining 20% will depend on actual emission reductions.

EU ETS: Calculation method

1 DEFINE THE SYSTEM

- Set installation boundaries
- Identify emission sources and source streams
- Select an approved monitoring approach

2 QUANTIFY EMISSIONS

- Collect activity data
- Determine calculation factors
- Apply tiers and uncertainty controls

3 REPORT AND VERIFY

- Aggregate annual emissions
- Apply data-flow controls
- Obtain independent verification and surrender allowances

Specific focus on quantification of emissions

EU ETS: Calculation method

Commonly used in hard to abate sectors

STANDARD METHOD	MASS BALANCE	CEMS	FALL-BACK
Activity data × emission factor × oxidation / conversion factor	Carbon entering minus carbon leaving the defined system	Measured GHG concentration × measured flue-gas flow	Approved non-tier method when tier 1 is not feasible or causes unreasonable cost

Integrated steelworks typically favour a carbon mass balance because carbon remains in products, by-products and exported process gases.

EU ETS: Calculation method

Em = amount of CO2 emitted

Standard method

Combustion emissions

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

FQ: fuel quantity NCV: net calorific value
EF: emission factor OF: oxidation factor

Process emissions

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

AD: activity data (quantity)
EF: emission factor CF: conversion factor

Mass balance method

$$Em = 3.664 \times \Sigma (f_i \times AD_i \times CC_i)$$

Em = 3.664 × (total carbon input – total carbon output)

SIGN CONVENTION

Inputs: $f_i = +1$
Outputs: $f_i = -1$
Stock changes must be allocated to the correct calendar year

CORE FACTORS

AD_i = mass of stream i [t]
CC_i = carbon content [t C/t]
3.664 = t CO_2 per t C

EU ETS example of calculation

Worked example: input data and assumptions for BF 1Mt of hot metal

Stream	Direction	Annual mass (t)	Carbon content	Carbon (t C)
Coke	Input	450,000	88.0%	396,000
Pulverized coal	Input	120,000	82.0%	98,400
Limestone carbon	Input	100,000	12.0%	12,000
Hot metal	Output	**1,000,000**	4.50%	45,000
Slag	Output	300,000	0.20%	600
Dust/sludge exported	Output	25,000	20.0%	5,000
Exported BF gas	Output	1,500,000	5.00%	75,000

EU ETS example of calculation

Worked example: input data and assumptions for BF 1Mt of hot metal

1 TOTAL CARBON INPUT

396,000 + 98,400 + 12,000

= 506,400 t C

2 TOTAL CARBON OUTPUT

45,000 + 600 + 5,000 + 75,000

= 125,600 t C

3 CARBON EMITTED

506,400 − 125,600

= 380,800 t C

CO_2 emissions = 3.664 x 380.800 t C × t CO_2/t C = 1.395.251 t CO_2

Specific direct emission: ~1.4 t CO_2 per tonne of hot metal

EU ETS example of calculation

Worked example: cokemaking

Input Stream	Annual Quantity (t)	Carbon Content (%)	Carbon (t C)
Coking coal	1.350.000	75	1.012.500
Additional coal additives	50.000	80	40,000

Out Stream	Carbon (t C)
Coke	880.000 (94%C)
Coke oven gas	100.000
Tar	36.000
Benzol	9.200
Dust/sludge	3.000
Total Carbon Output	1.028.200

EU ETS example of calculation

Worked example: cokemaking

1 TOTAL CARBON INPUT

1.012.500 + 40.000 = 1052500 tC

2 TOTAL CARBON OUTPUT

880000+100000+36000+9200+3000 = 1028200 t C

3 CARBON EMITTED

1052500 − 1028200 =

= 24300 t C = 89035 t CO2

Specific Emissions

$$\frac{89{,}035}{880.000} = 0.1\ tCO_2/t\ coke$$

Using 0,45t coke /t hot metal

0,045t CO2 / t Hot metal

EU ETS example of calculation

Worked example: sintering

Input / Carbon flow	Consumption	Annual mass flow	Carbon content	Carbon flow (t C/year)
Coke breeze	50 kg/t sinter	100,000 t/y	88% C	88,000
Limestone	100 kg/t sinter	200,000 t/y	10.8% C*	21,600
Dolomite	30 kg/t sinter	60,000 t/y	12.36% C*	7,414
Natural gas	0.15 GJ/t sinter	300,000 GJ/y		4590

EU ETS example of calculation

Worked example: sintering

1 TOTAL CARBON INPUT	2 TOTAL CARBON OUTPUT	3 CARBON EMITTED
88000+21600+7414+4590 = 121604	zero	121604 tC = = 445882 t CO2

Specific Emissions

For 2,000,000 t/y of sinter production:

$$\frac{445882}{2{,}000{,}000} = 0.22\ tCO_2/t\ sinter$$

Assuming 1,5t sinter per 1 ton of hot metal

Specific Emissions: 0,33 tCO2/t hot metal

EU ETS example of calculation

Worked example: EAF

$$C_{emitted} = C_{input} - C_{output}$$

Parameter	Amount per heat	Carbon content	Carbon input/output
Scrap charged	108 t	0.25% C	0.270 t C
Charge carbon	0.50 t	90% C	0.450 t C
Injected carbon	1.00 t	90% C	0.900 t C
Graphite electrodes consumed	0.20 t	99% C	0.198 t C
Natural gas	800 Nm³	calculated separately	0.429 t C
Total carbon input			**2.247 t C**
liquid steel	100 t	0.15% C	0.150 t C
Slag	10 t	0.5% C	0.050 t C
Dust	1.5 t	2% C	0.030 t C
Total carbon retained/exported			**0.230 t C**

$C_{emitted} = 2.247 - 0.230 = 2.017\ tC/heat$

$$CO_2 = C \times \frac{44}{12}$$

$CO_2 = 7.40\ tC\,O_2/heat$

$74\ kgC\,O_2/t_{LS}$

EU ETS example of calculation

Worked example: DRI natural gas operated

Basic assumptions for calculation

Parameter	Assumption
Natural gas consumption	280 Nm³/t DRI
CH_4 content in natural gas	95 vol.%
CH_4 density at reference conditions	0.716 kg/Nm³
DRI production	1.000 t
DRI carbon content	2.0 wt.% C
Carbon exported in other streams	neglected for this example
CO_2 captured	0

280×0.95=266 $Nm^3 CH_4$ = 190.5 $kgCH_4$
190.5× 12/ 16 =142.9 kgC

$$\boxed{C_{in} = 142.9\ kg\ C/t\ DRI}$$

$$C_{DRI} = 1{,}000 \times 0.020 = 20{,}0\ \text{kgC/tDRI}$$

$$\boldsymbol{C_{emitted} = 142.9 - 20.0}$$

$$\boxed{\boldsymbol{C_{emitted} = 122.9\ kg\ C/t\ DRI}} \quad \Rightarrow \quad \boxed{\boldsymbol{0.451\ tC\ O_2/t\ DRI}}$$

EU ETS example of calculation

Worked example: DRI Green Hydrogen operated

Basic assumptions for calculation

Parameter	Assumption
Green Hydrogen consumption	70 Nm³/t DRI
Natural gas consumption per process gas heater	60 Nm3/t DRI
CH_4 content in natural gas	95 vol.%
CH_4 density at reference conditions	0.716 kg/Nm³
DRI production	1.000 t
DRI carbon content	.0 wt.% C

60×0.95=57 Nm3CH4 = 41 kgCH4

41 × 12/ 16 =30,7 kgC

$$C_{in} = 30{,}7\ kg\ C/t\ DRI$$

$$C_{emitted} = 30,7\ \mathbf{kg}$$

$$C_{emitted} = 30,7\ kg\ C/t\ DRI \quad \Rightarrow \quad 0.11\ tC\ O_2/t\ DRI$$

Further CO2 decreasing with electrical process gas heater technology development

EU ETS example of calculation

Final comparison of direct emissions

BF 1.4 t CO_2 per tonne of hot metal

Coke 0,04 t CO_2 /t hot metal

sinter 0,33 t CO_2 /t hot metal

Direct emissions 1,77 t CO_2/t hot metal

DRP (NG) Direct emissions 0,451 t CO_2/t solid DRI

DRP (H2) 0,11 t CO_2/t

EAF Direct emissions 74 kg CO_2/t liquid steel

NG Overal Direct emissions 0,53 t CO_2/t liq. steel
H2 Overal Direct emissions 0,18 t CO_2/t liq. steel

CBAM: the border counterpart to the EU ETS

EU PRODUCER

Verified installation emissions

EU ETS carbon cost

Comparable carbon-price signal

NON-EU IMPORT

Embedded emissions in CBAM goods

CBAM certificates

Covered sectors

- Cement
- Iron & steel
- Aluminium
- Fertilisers
- Electricity
- Hydrogen

CBAM: the border counterpart to the EU ETS

CBAM is the EU Anti-Carbon Leakage Tool and it is a tool designed to prevent *Carbon Leakage* by putting a carbon price on goods imported from non-EU countries.

- **Definitive Phase:** On **January 1, 2026**, the transitional reporting-only period ended, and the financial compliance regime began.
- **Initial Sectors:** Iron and steel, aluminum, cement, fertilizers, electricity, and hydrogen.
- **Mandatory Status:** Importers above the de minimis threshold (50 tonnes annually) must register as *Authorized CBAM Declarants*.

2026 Compliance Year: Embedded emissions in goods imported during 2026 must be monitored and verified.

- Amount to be paid is on the basis of CO2 emissions and Free Allocation Adjustment (FAA), alligned with EU ETS
- **Certificate Sales Launch:** Postponed to February 1, 2027.
- **First Annual Declaration:** The deadline for CBAM certificates is set for **September 30, 2027** (instead of May).

CBAM: the border counterpart to the EU ETS

The CBAM Price Alignment Mechanism (2026-2034)

- **Price Calculation:** In 2026, the price is based on the quarterly average of EU ETS auctions; from 2027, it will shift to a **weekly average**.

- **The Phase-In Ramp:** The actual financial cost grows in parallel with the reduction of free allowances granted to EU manufacturers.

- **Financial Impact Evolution:** Starts low (2.5% in 2026), accelerates sharply between 2029 (22.5%) and 2030 (48.5%), reaching **100% by 2034** in line with the ETS update.

- The calculation is carried ouyt according to specific EU rules. Internal method are not accepted. If a Supplier is not able to monitor CO2 emission data, default values are to be used. They are based on the emission levels of the worst-performing facilities globally (the top 10% most polluting plants). Using them artificially inflates the number of CBAM certificates that need to be purchased, making the imported goods economically uncompetitive.

EXAMPLES OF CALCULATION

Practical CBAM Example: Italian company importing **10,000 tonnes of crude steel** from a non-EU producer (e.g., India or Turkey).

- **Imported quantity:** 10,000 tonnes of steel.
- **Emission intensity of the imported steel:** 2 tonnes of CO_2 for every tonne of steel produced (value based on the supplier's actual data).

CO_2 price on the EU ETS market: Let's assume **€80** per tonne.

- Total emissions =10,000 (t of steel) x 2(t of CO_2) = 20,000 t of CO_2
- Theoretical cost =20,000 x 80 = €1,600,000
- **Calculation of the actual financial impact in 2026 (2.5% Phase-In):** €1,600,000 x 0,25 = €40,000
- **In 2029** (22.5% phase-in ramp): The company will pay **€360,000**.
- **In 2030** (48.5% phase-in ramp): The company will pay **€776,000**.
- **After 2034):** The company will pay the full amount of **€1,600,000** for the same amount of steel.

CONCLUSIONS

- The net zero target is a general requirement for most of leading steel producing States and companies
- EU ETS system implemented in Europe sice 2005 (DIRECTIVE 2003/87/CE)
- EU ETS started its phase out phase in 2026

- Parallel mechanism CBAM is in place for materials imports in EU

- CBAM calculation method is based on ETS mechanism; CO2 emisison data are provided by exporting companies and verified by third parties

Thank you!



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