

ESTEP SPRING DISSEMINATION EVENT

17-18 FEBRUARY 2026 - BRUSSELS (BELGIUM)

Transformation of the Iron and Steel Industry:

a general overview of R&D&I-requirements
for technology-gap-closing



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Current situation and estimation for steel production and CO₂-emissions:

National targets for CO₂-emissions:

China: - until 2060 CO₂-neutral & until 2030 reach peak-emissions – China is today's world's largest emitter (>33% in 2025)

US: - until 2050 CO₂-neutral & until 2030 reduce Green House Gas (GHG)-emissions by 50% (Basis 2005)

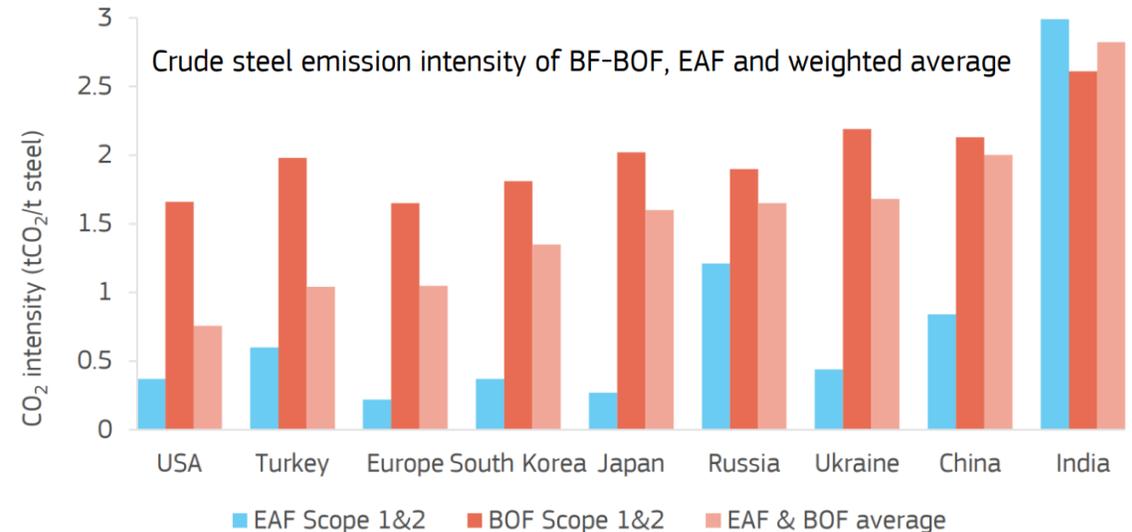
EU (27): - until 2050 CO₂-neutral & until 2030 reduce Green House Gas (GHG)-emissions by 55% (Basis 1990)

Iron and Steel industries varying share of CO₂-emissions:

Global: ~ 7% EU (27): ~ 5%

EAF: ~ 350kgCO₂/t_{steel} (scrap & nuclear power)
~ 1600kgCO₂/t_{steel} (scrap + DRI & coal-fired power)

BF-BOF: ~ 1500kgCO₂/t_{steel} (low-C-process)
~ 2700kgCO₂/t_{steel} (high-C-process)



Source: Somers, J., Technologies to decarbonise the EU steel industry, EUR 30982 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-47147-9 (online), doi:10.2760/069150 (online), JRC127468

Political framework in the EU / Green Deal

- Reduce CO₂-emissions by 55% until 2030 & climate neutrality until 2050

Steel industry approach

- **Replace Carbon-based sinter-BF-BOF-route** by Direct Reduction (DR) with H₂ and Electric Arc Furnace (EAF)

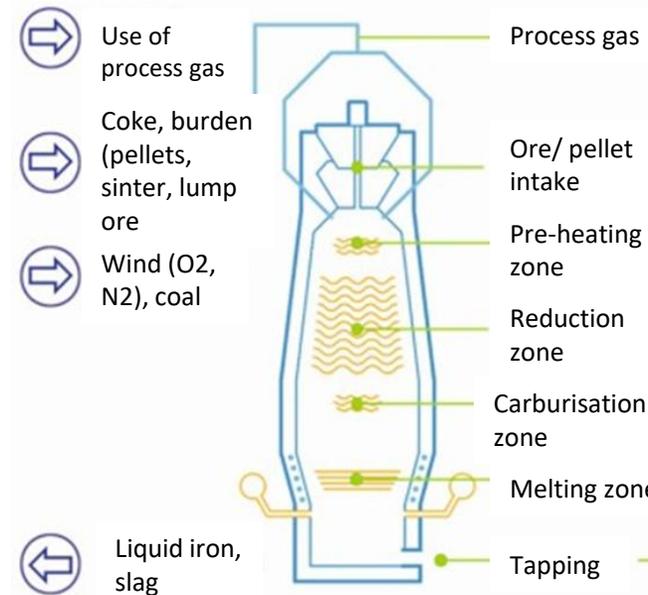
Impacts (here - focus: raw materials/by-products/residuals)

- Increased demand for high-quality ore-pellets
- Increased demand for scrap (including high-quality)
- Emerging of new by-products/residuals (unknown composition/quantity/..)

- **Cut-off of existing internal recycling and reuse for 6 Mio t/a (EU27) due to replacement of sinter-BF-BOF-route**
- **R&D&I required for new recycling technologies adjusted to requirements of low-CO₂-steel production-routes**

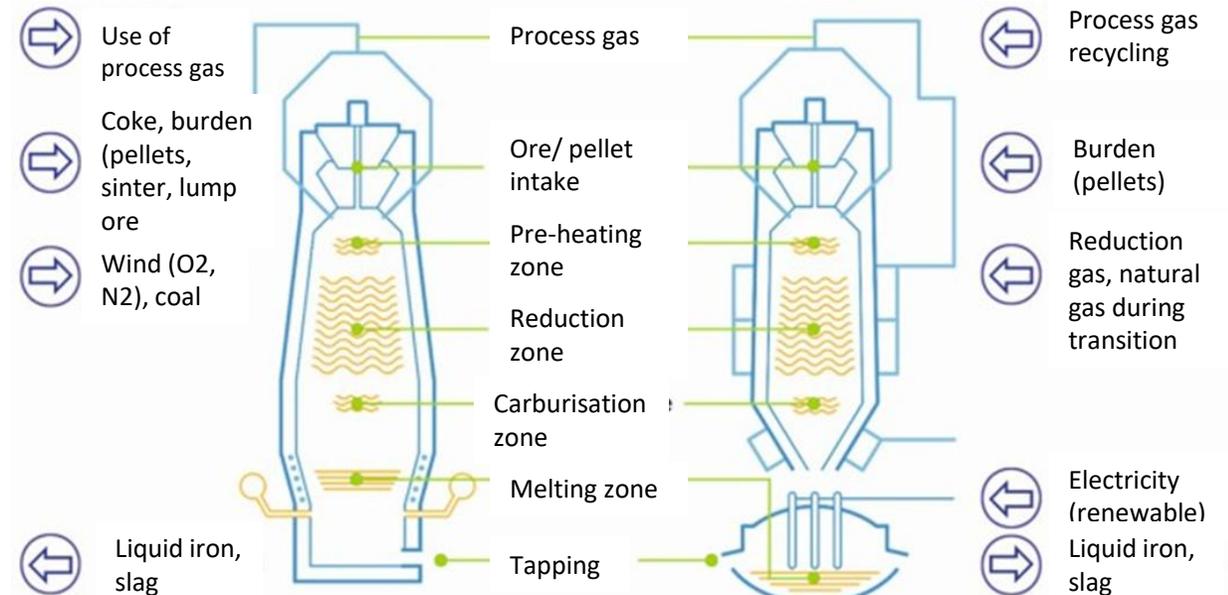
Blast Furnace (BF)

Carbon as reduction agent and energy carrier

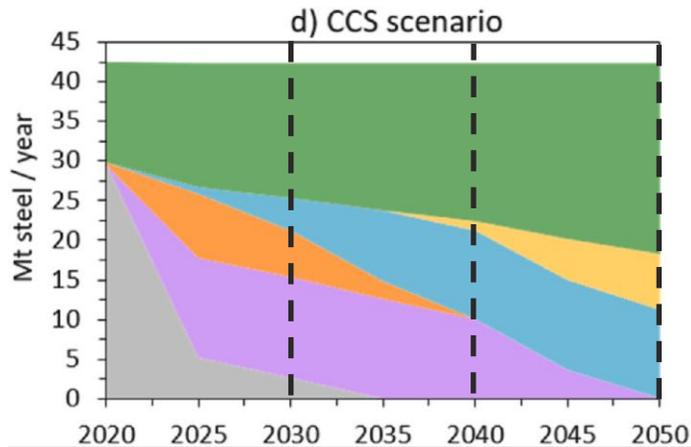
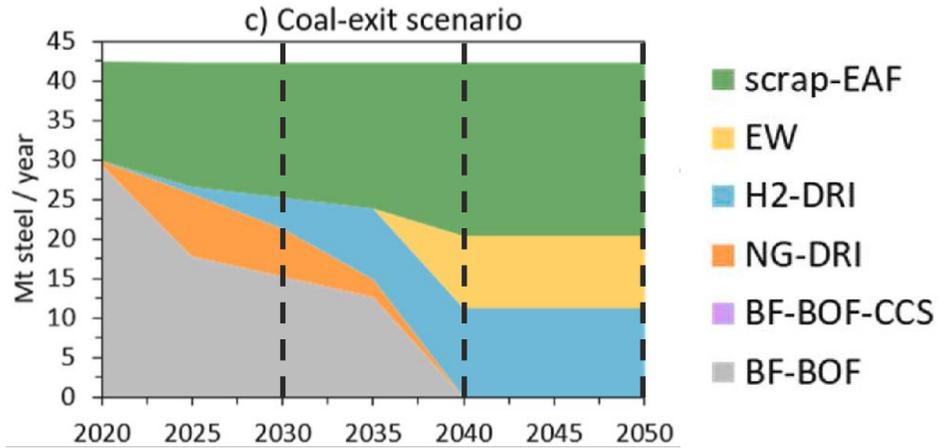


Direct Reduction (DR) & EAF

Hydrogen as reduction agent in DR plant
Green electricity as energy carrier in smelter



Scenarios of process-route shares in steel production with / without transformation of steel industry



source: Decarbonization scenarios for the iron and steel industry in context of a sectoral carbon budget: Germany as a case study, 2022

Steel production 2030

- › 40% scrap-based Electric Arc Furnace (EAF)
- › 40% Blast Furnace-Blast Oxygen Furnace (BF-BOF)
- › 16% Electrowinning (EW)
- › 14% Direct Reduction (H₂-DR)

Steel production 2040

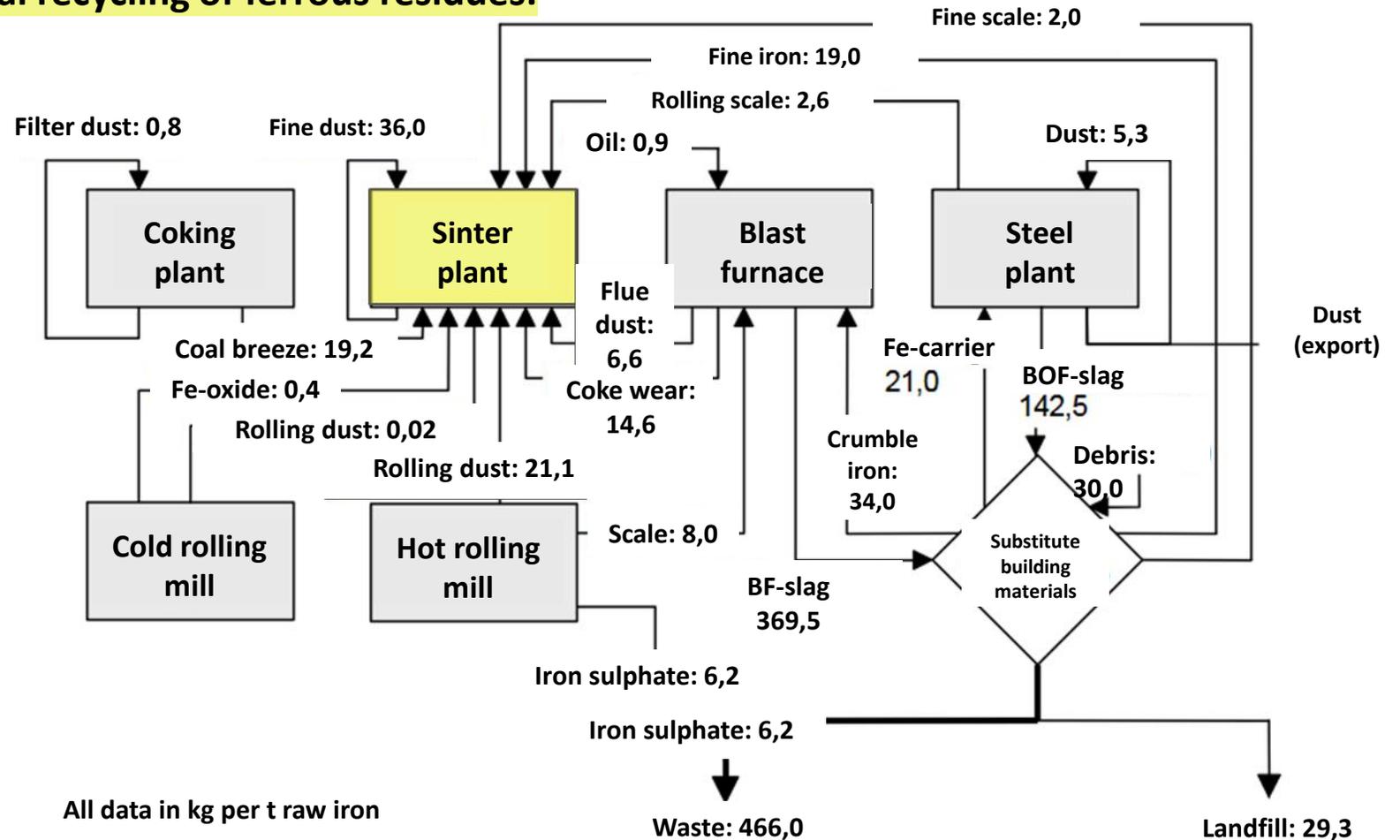
- Complete/major conversion from BF-BOF to DR-route
- Complete/major shut-down of sinter plant recycling

Steel production 2050

- › 50% Electric Arc Furnace (EAF)
- › 30% Direct Reduction (H₂-DR)
- › 20% Electrowinning (EW)
- Complete shut-down of sinter plant recycling

Importance of the sintering plant for internal recycling of ferrous residues:

- › **Closed network** of sinter plant with all production processes regarding by-product-/waste-treatment
- › **Cut-off by BF-BOF replacement**
- **R&D&I of new technologies for recycling and reuse required**
- **aim: recycling to products for reuse adjusted to requirements of**
 - Direct Reduction (DR) and
 - Electric Arc Furnace (EAF)
- **Avoid additional landfill & Minimize current amount of landfill**



Composition of exemplary ferrous residues of **current recycling and reuse**:

By-products/ residuals	Collection point	Current treatment	Main components	Critical components
Coarse scale	Continuous casting hot rolling	Blast Furnace (BF) Sinter plant → reuse	Fe-Oxides	
Fine scale		Sinter plant → reuse	Fe-Oxides	
Oily fine scale (> 0,3 wt-% oil)		External treatment & landfill	Fe-Oxides	oil
Pellet sieve fines	Pre-treatment	Sinter plant → reuse		
Dust	Electric Arc Furnace (dust extraction system)	External treatment & landfill	Fe-Oxides	e.g. Zinc
Sludge	Gas scrubber	landfill	Fe-Oxides	e.g. Zinc

➤ **Shut-down of sinter plant & BF-BOF-process = shut-down of current recycling & reuse → increase landfill
→ diminish reuse as raw material**

Requirements for internal recycling and reuse:

➤ for current BF-BOF-route:

plant	Limit values	Material properties
Sinter plant BF	<ul style="list-style-type: none"> Fe: > 30% Zinc in sinter feed: 70-200 g/t Zink in BF: 100 - 250g/t hot metal or new BF: < 150g/t hot metal Different limit values for e.g. Cu, Pb, Cr, Si (depending on product) Oil: < 0.1/0.2 wt.%) 	<ul style="list-style-type: none"> Pellets or bulk material > 0,5 mm
DK-process	<ul style="list-style-type: none"> Zinc: >10 wt.% or 38 kg / t hot metal 	<ul style="list-style-type: none"> see above
BOF	<ul style="list-style-type: none"> Zink: < 0.1 - 0.3 wt.%) Fe: > 60% Oil: < 0.1 wt.%) 	<ul style="list-style-type: none"> Briquettes Partial reuse of iron-rich slag

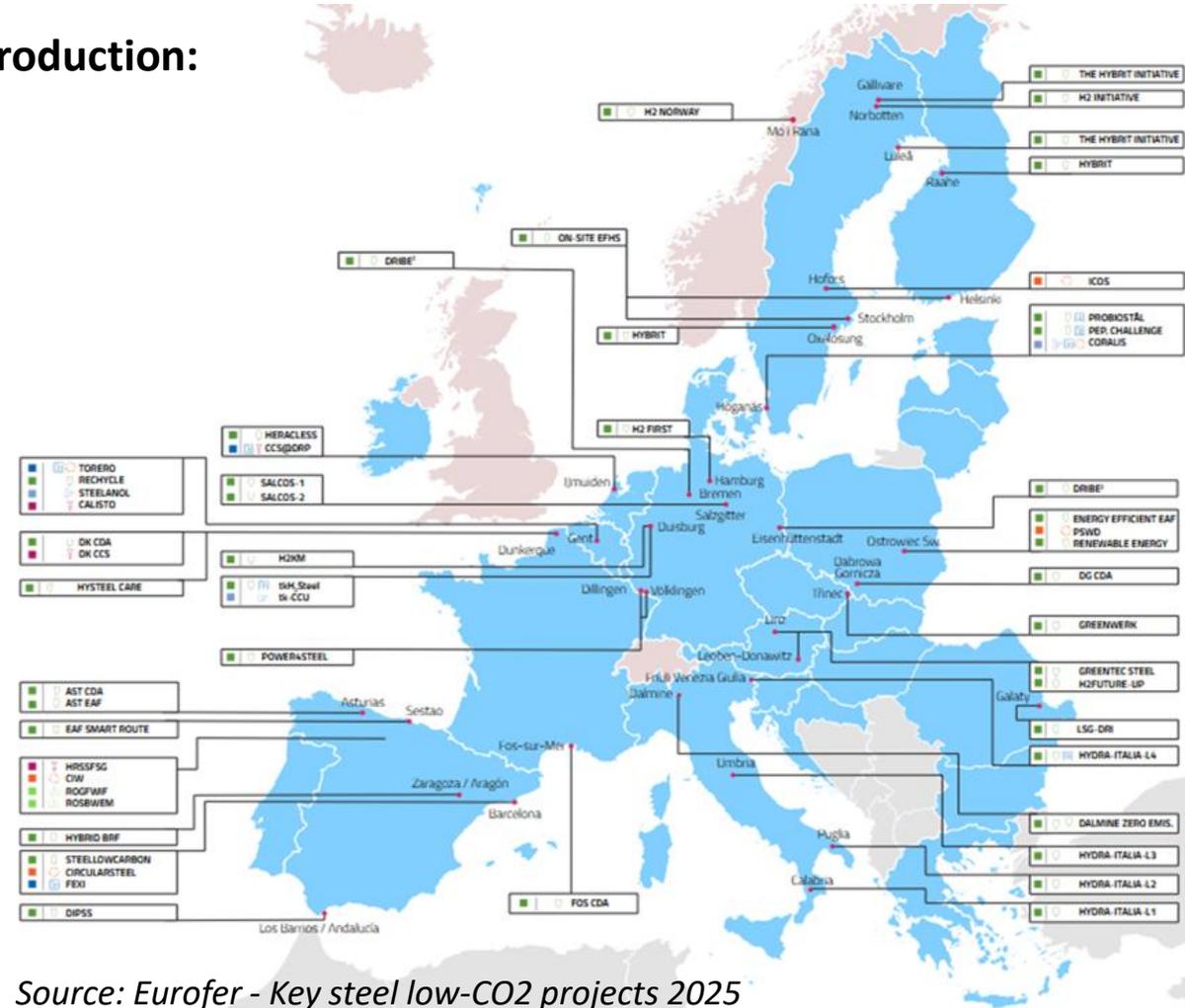
➤ Current scrap-based-EAF- & future DR-route:

Anlagen	Limit values	Material properties
Direct Reduction (MIDREX)	<ul style="list-style-type: none"> Fe: 67 % Gangue: 3-4 % (especially Si, Al) 	<ul style="list-style-type: none"> Pellets Cold compression strength > 35 MPa Abrasion resistance R30 (100) > 85 % Iron ore/oxide
Direct Reduction (HYL)	<ul style="list-style-type: none"> Fe: 65 - 69 % Gangue 1.4-7.0 % 	<ul style="list-style-type: none"> Pellets Iron ore/-oxides
EAF	<ul style="list-style-type: none"> Fe total: 89.2-94 % Fe metallic: 79-89 % C: 0.3-4 % (optimum: 2.5 %) Gangue CaO, MgO, SiO₂, Al₂O₃) 	<ul style="list-style-type: none"> Briquette (fine iron dust) DRI-Pellets: 4–18 mm HBI: < 100x50x25 mm Porosity > 30 %

➤ **EAF- and Direct Reduction route requires higher iron-content and lower residual elements/components than sinter- & BF-BOF-processes**

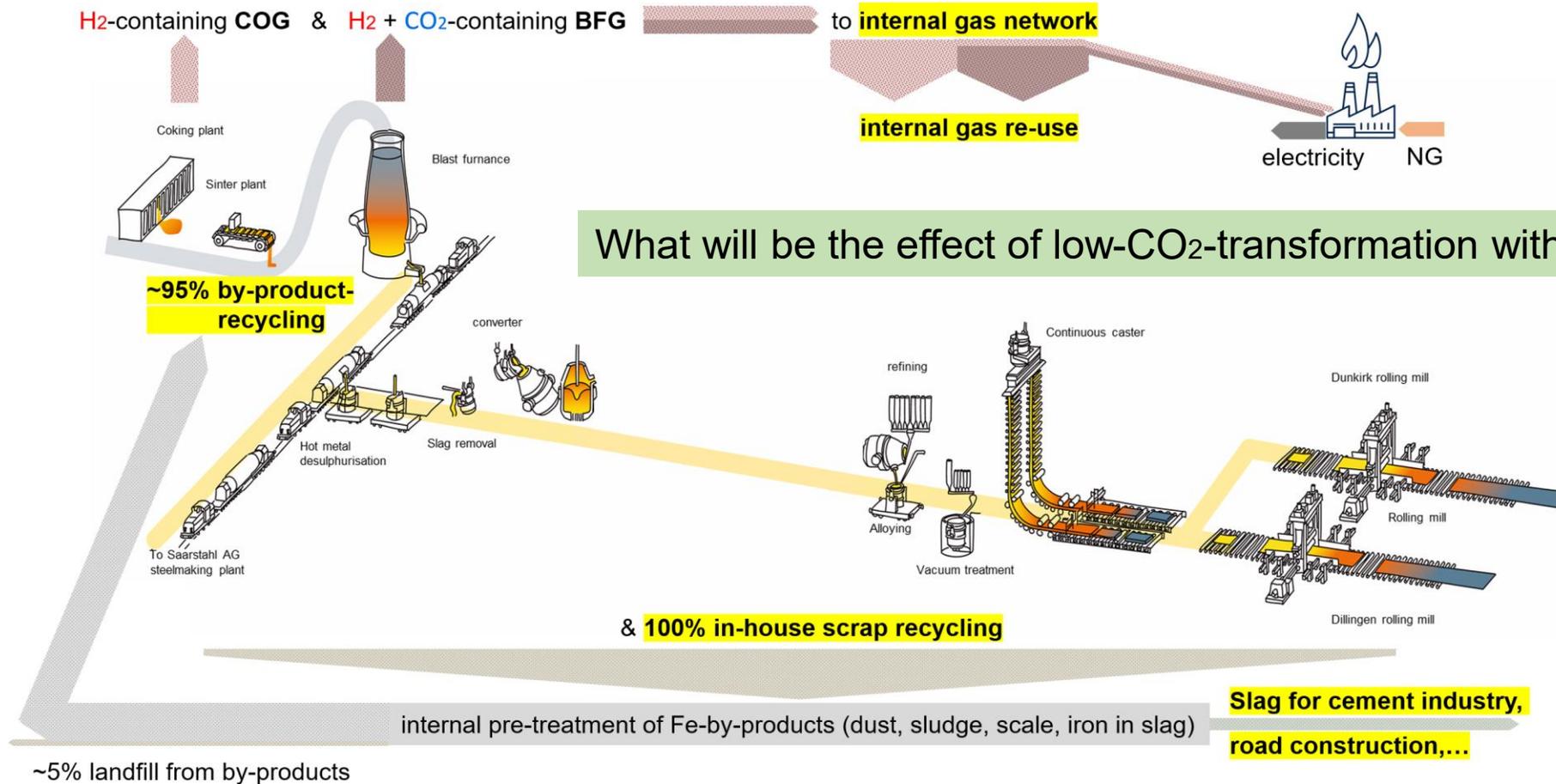
European R&D&I- & transformation-projects for low-CO₂ steel production: (energy, raw materials, circular economy, ...)

- Complexity of process-route-transformation requires
→ intensified R&D&I and
→ filling know-how and technology-gaps in all areas
- Shown with the example of Power4Steel at Dillinger ...

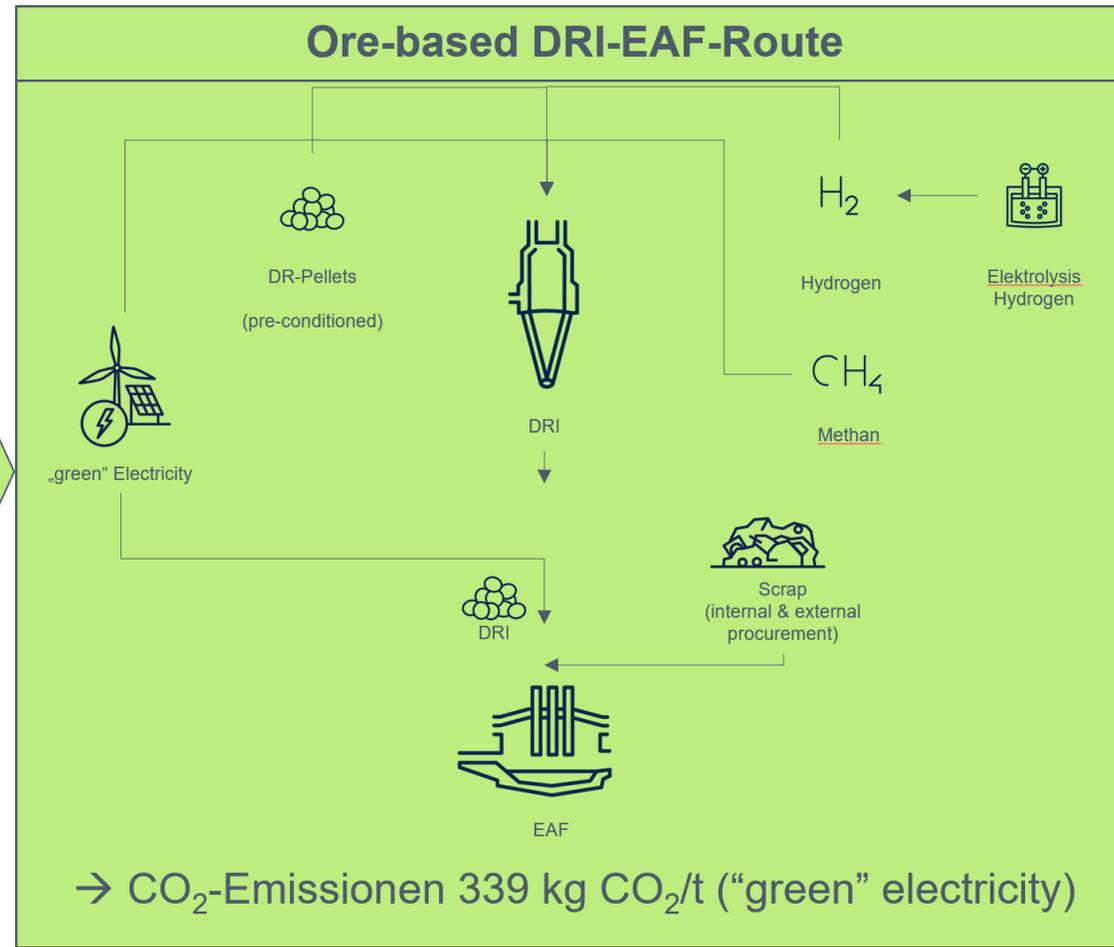
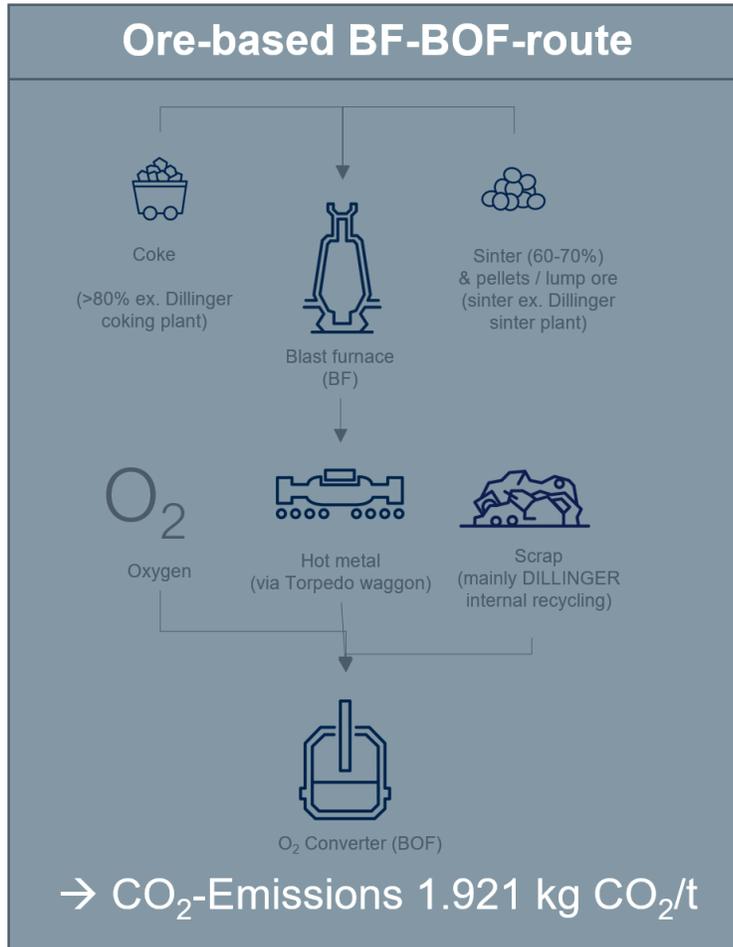


Source: Eurofer - Key steel low-CO₂ projects 2025

Today's conventional BF-BOF-steel production at Dillinger with efficient internal gas & energy & media & material reuse



Steel production from „conventional“ to „green“ (= low CO₂) with Power4Steel

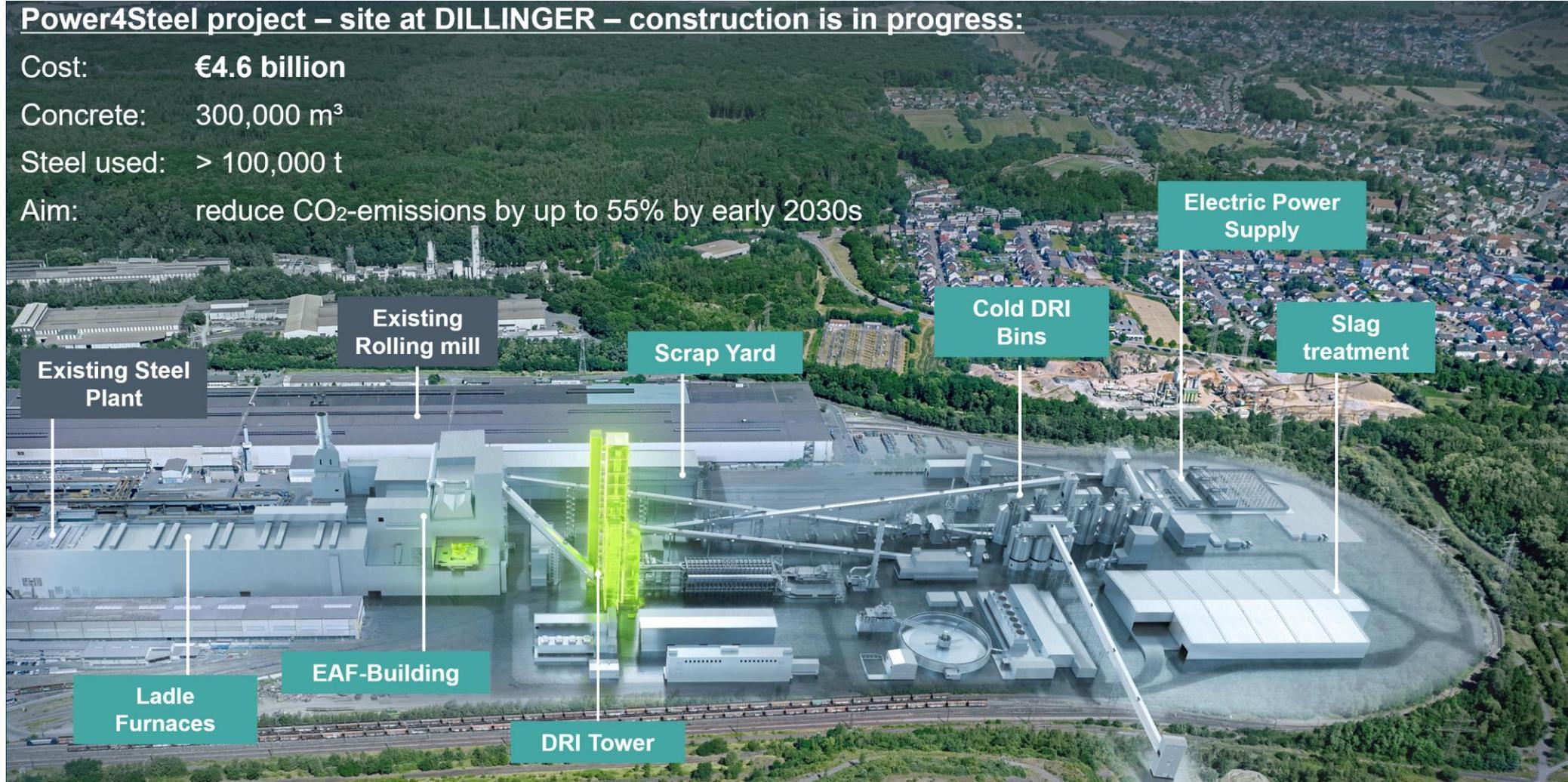


Power4Steel

Transformation of iron & steel industry: a general overview of R&D&I-requirements for technology-gap-closing – an example

Power4Steel project – site at DILLINGER – construction is in progress:

- Cost: €4.6 billion
- Concrete: 300,000 m³
- Steel used: > 100,000 t
- Aim: reduce CO₂-emissions by up to 55% by early 2030s

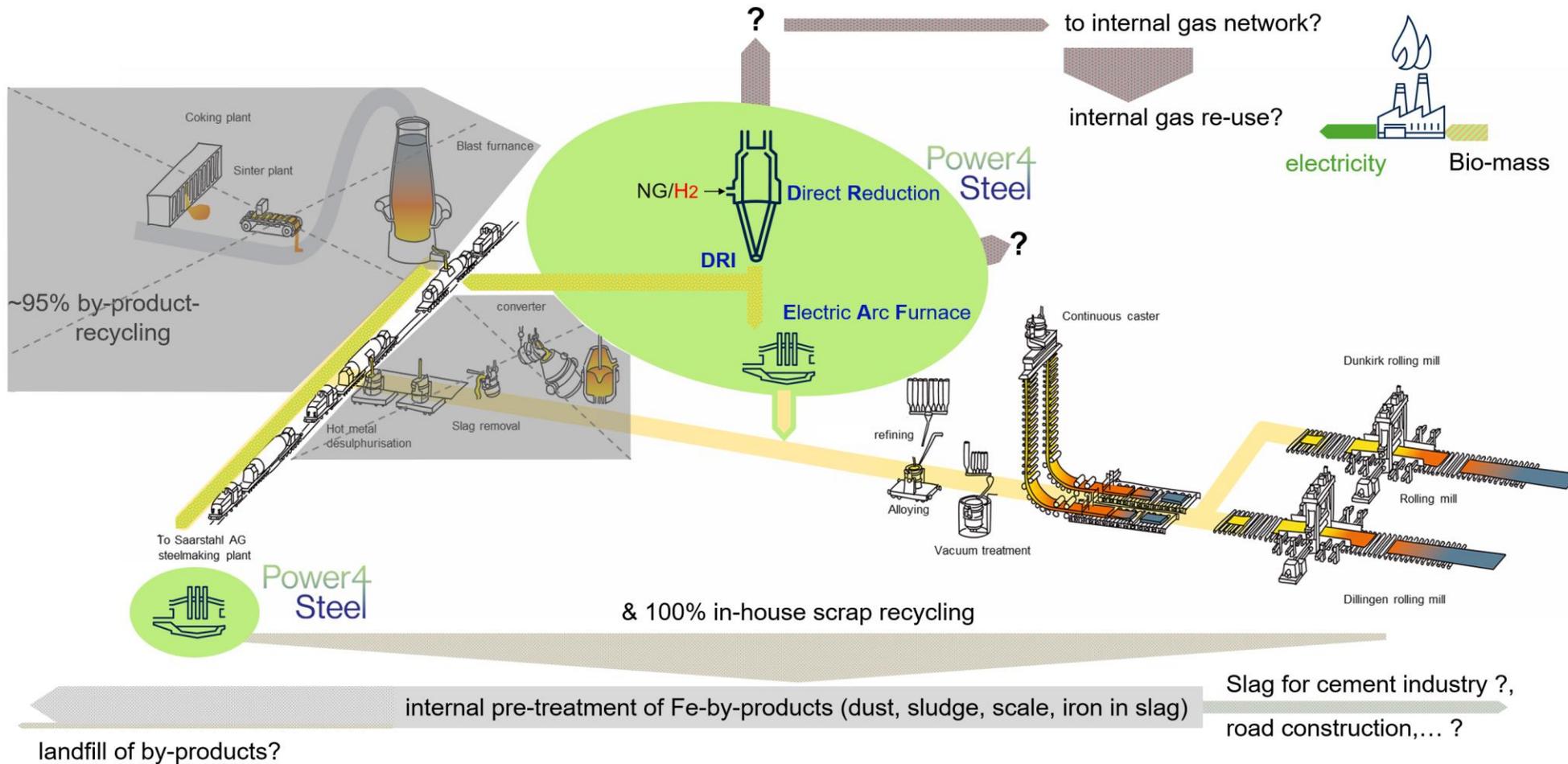


Power4Steel

Power4Steel supported by:



Power4Steel with final step → cut-off of internal recycling- and reuse-loops ? → R&D&I required



Power4 Steel

Power4Steel supported by:



Requirements for innovative recycling processes to ensure metallurgical reuse of current and future by-products and residuals:

Technical aspects

- Preferably single-stage process / process with easy handling
- Preferably autonomous operation with low maintenance and personnel effort

Ecological aspects

- Low CO₂-emissions, preferably CO₂-free
- Low energy consumption

Economical aspects

- Return of Investment (< 3 years) – take into account: disposal and landfill cost without recycling
- Low investment (CAPEX) and operating cost (OPEX) as well as low personnel cost

Possible obstacles

- Material recovery with high cost for disposal or high technical and economic costs of the overall process

Source: EUROFER - Key steel low-CO2 projects 2025

➤ Complexity of low-CO₂-transformation requires **intensified R&D&I** and know-how- and **technology-gaps-closing** until 2040!

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