Agora
Industry

Green iron trade

Unlocking opportunities for Europe

Version 1.0, September 2025

Key findings

1. **The steel industry produces about five percent of the EU's carbon emissions, yet it is vital to Europe's economic sovereignty, security and climate neutrality.** Investing into green steelmaking is both a necessity and a strategic opportunity to secure jobs, strengthen industrial competitiveness and safeguard Europe's resilience in the materials critical for its future. Smart policy and international cooperation can unlock this potential and help build a global market for green iron.
2. **To ensure long-term competitiveness and safeguard jobs, Europe needs to develop a robust transition strategy for the steel sector.** For primary steel production, this could entail a three-phase strategy: supporting domestic green iron projects in Europe, leveraging the EU single market and ultimately complementing this with green iron imports. Central to this pathway is ensuring sufficient expansion of renewable power and affordable electricity prices – essential for the electrification of steelmaking.
3. **By complementing domestic production with green iron imports from regions rich in iron ore and renewables potential, countries like Germany could cut steelmaking costs by 12–15 percent by 2040.** The partial decoupling of energy-intensive iron production from steelmaking and downstream processes could facilitate the cost-competitive transformation of the EU's steel sector, while also contributing to the global transition through the development of international green iron supply chains.
4. **Looking forward, mutually beneficial strategic international partnerships are key to building resilience and contributing to sustainable global economy.** For example, the EU's proposed bilateral Clean Trade and Investment Partnerships will integrate industrial, climate and trade policies. Backed by tools such as financial guarantees, offtake agreements and concessional finance, they can help unlock investments into climate-neutral industries and foster new markets for green products.

 [1] Steel sector and downstream steel finishing share of employment calculated based on WV Stahl (2025), Statistisches Jahrbuch der Stahlindustrie 2024/2025.

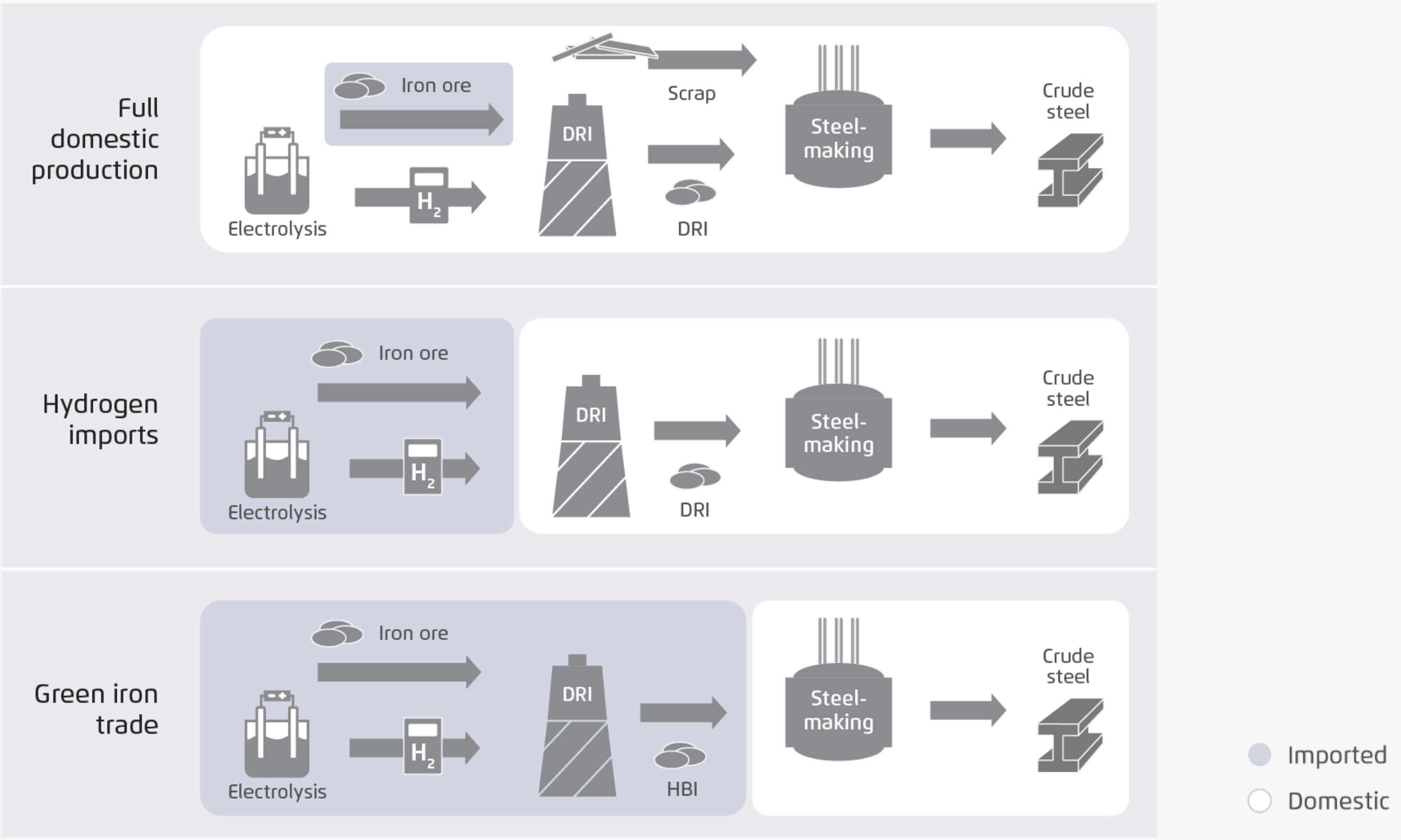
Introduction

- The steel industry produces around 5–6% of Europe's total emissions.[1] Transforming the industry is thus essential for the EU to be climate neutral by mid-century. Instead of CO_2-intensive coal-based blast furnaces, primary green steel can be made using hydrogen to produce Direct Reduced Iron (DRI), which is fed into downstream steelmaking processes (EAFs or BOFs)[2] to produce steel.
- Europe produces around 70 Mt[3] a year of pig iron through the blast furnace route. In the coming decades, recycled scrap-based steel production in EAFs is projected to play an increasingly important role, potentially accounting for over 50% of total steel production (compared to 45% today). However, a significant share of steel will still need to be made from virgin iron ore, requiring an estimated 50-60 Mt of iron (depending on future steel demand).
- European steel companies have announced plans to build up to 34 Mt capacity of H_2-DRI by 2030. However, projects have struggled to reach FID in recent years, with only 12 Mt capacity at FID or under construction, while several large projects have recently been postponed or cancelled. Fully realising this pipeline would cover roughly half of the EU's projected low-carbon iron demand, but doing so will require the EU and its Member States to ensure that industry has access to cheap and abundant renewable energy.
- Complementing domestic production with imports of green iron from renewable energy rich regions can be an additional important piece of the puzzle, providing EU steelmakers with a cost-competitive low-carbon intermediary material. Unlocking these value chains through strategic industrial partnerships – initiated by European Commission and backed by Member States – with regions capable of producing green iron at scale will be essential for safeguarding the competitiveness of the EU's green steel sector.

[1] JRC Raw Materials Information System, Report, 2025.
[2] EAF - Electric Arc Furnace; BOF - Basic Oxygen Furnace. If DRI-grade iron ore is not available for DRI, the EAF step can be replaced by a smelt-BOF process, which can accommodate lower-grade iron ore.
[3] Worldsteel, World Steel in Figures, 2025

Green steel supply chains: a diversified approach

The value chain shifts for exporters and importers from iron ore to green iron

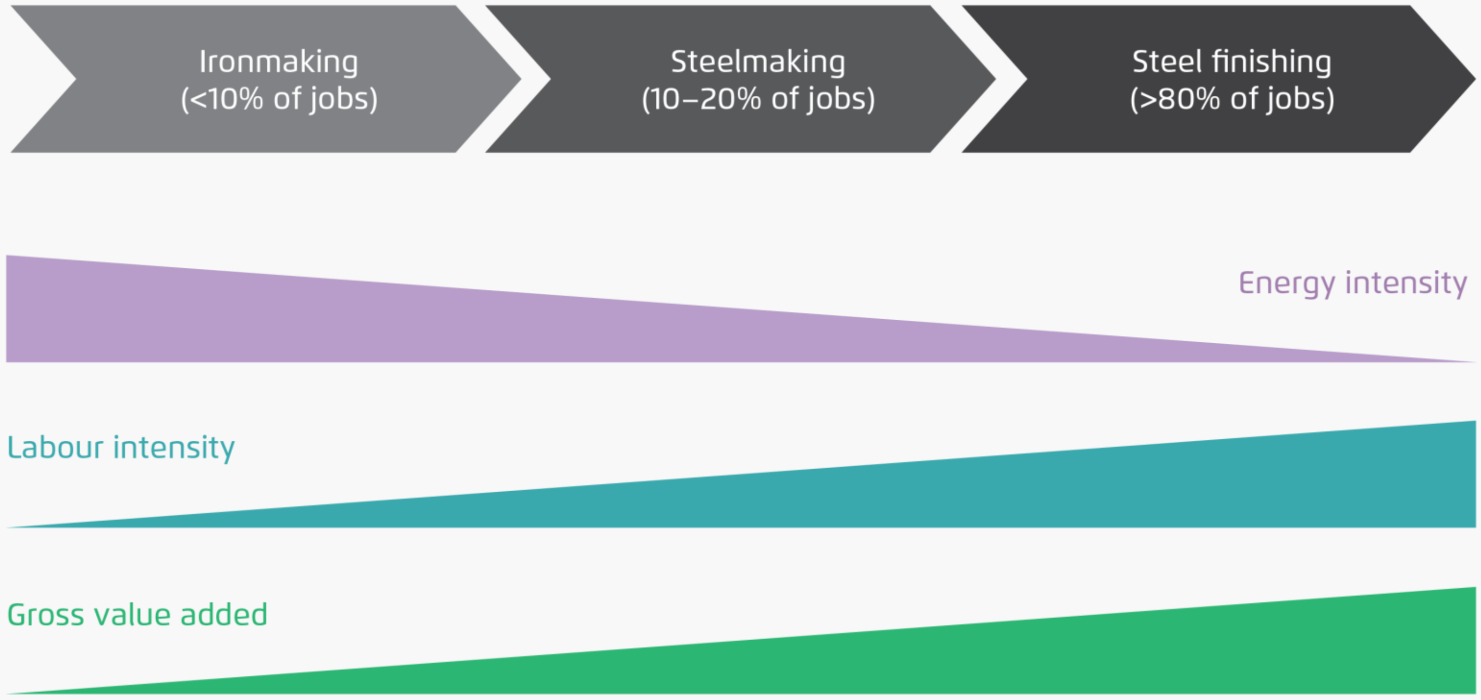


- → Producing green steel via DRI shifts the energy inputs from coal to clean electricity and H_2.
- → Green iron can be shipped as HBI, complementing domestically sourced metallic inputs (iron and steel scrap) and thereby providing steelmakers some flexibility in their raw material inputs compared to the integrated BF-BOF route.
- → This reduces the demand for domestic or imported H_2 and associated renewable energy and infrastructure.

Adapted from Verpoort et al. (2023).
Steelmaking refers to either the EAF process when DRI uses DRI-grade (high-grade) iron ore, or to the Smelt-BOF process if lower-grade iron ore is used for DRI production.
For more information on low-carbon iron production, refer to Agora Industry (2024).

Around 90 percent of jobs in the steel sector are in the more labour-intensive steelmaking and steel finishing sectors

Downstream steelmaking is also less energy-intensive and delivers higher gross value added



[1] Steel sector and downstream steel finishing share of employment calculated based on WV Stahl (2025), Statistisches Jahrbuch der Stahlindustrie 2024/2025.

A three-phase strategy strengthening domestic EU production and green iron imports can support a resilient and cost-effective transformation towards climate neutrality

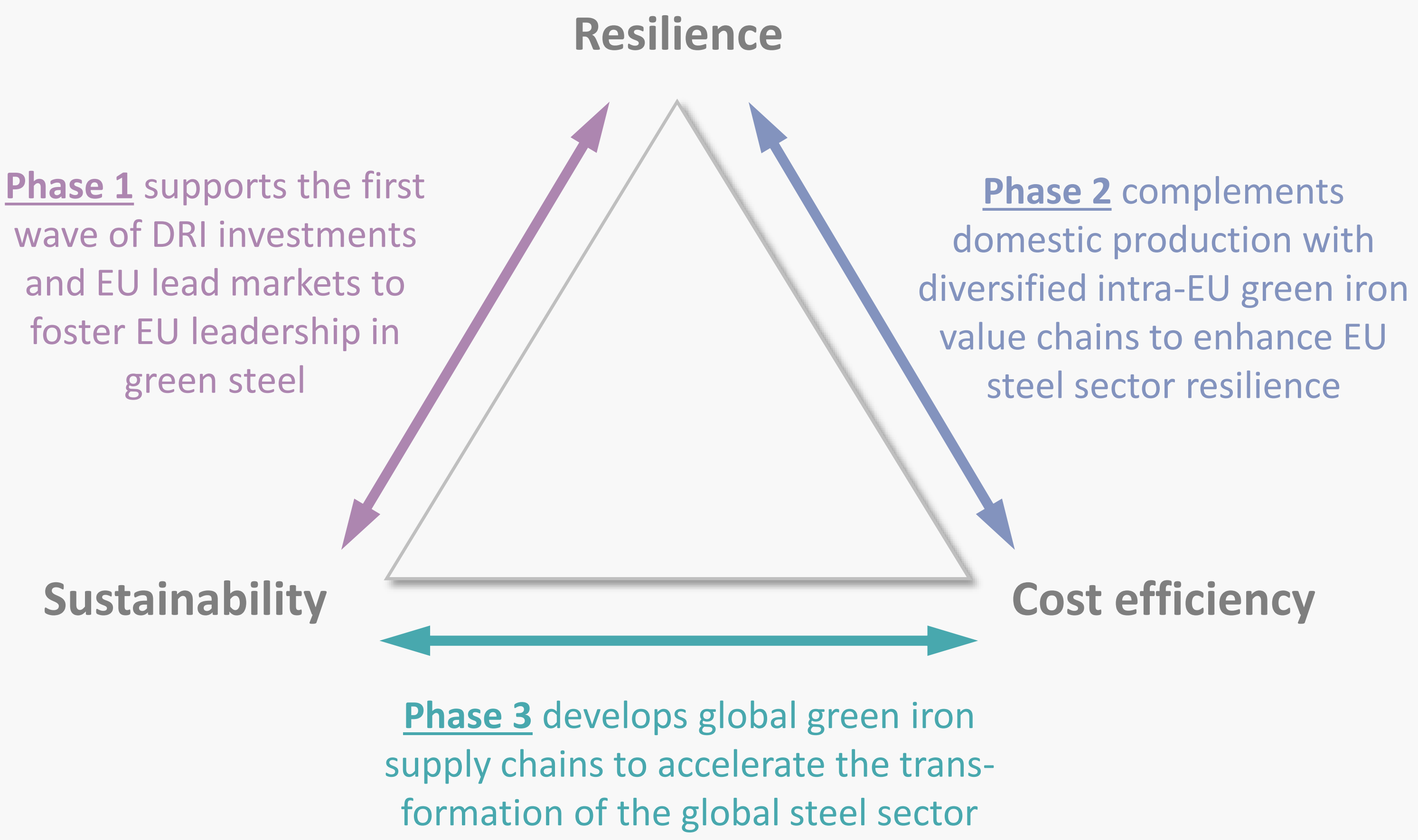
Phase 1 A **first wave of DRI plants** replacing blast furnaces is critical to ensure resilience of local production, accelerate technology deployment and kickstart a market for green steel. Policy measures along the value chain are needed to **unlock investments** and **scale the hydrogen ramp-up** for these projects.

Phase 2 A common European industrial vision should **strengthen the EU Single Market** and develop value chains that leverage regional strengths and competitive advantages, firmly establishing European steel production as a **cornerstone of resilience and security**.

Phase 3 **Strategic industrial partnerships** can enhance the cost-competitiveness of European steelmaking by diversifying supply chains and importing green iron as an intermediary material from renewable energy-rich regions.

→ A future-orientated industrial strategy that strikes the right balance between robust domestic support and future green iron imports can lower the cost of producing green steel while safeguarding higher-value steel production sites and downstream value chains.

A smart and balanced industrial policy that incorporates resilience, sustainability and cost efficiency

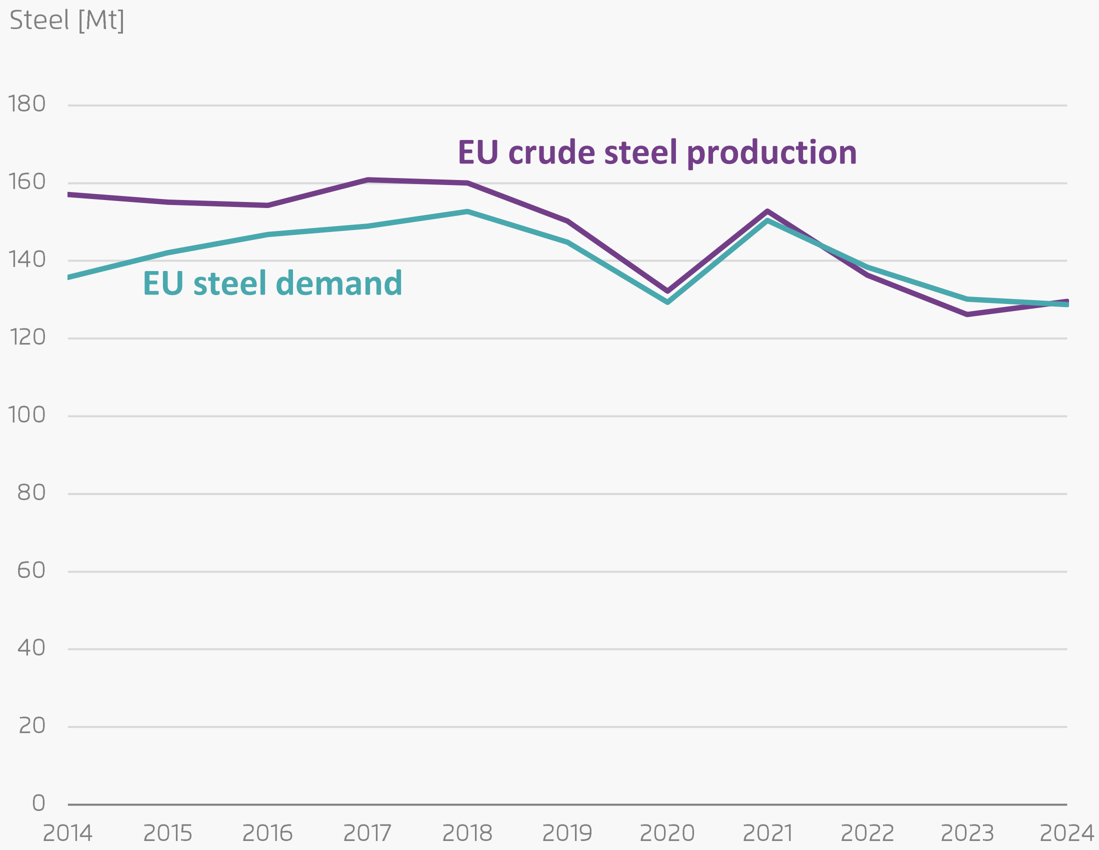


→ Targeted support for domestic green iron and steel production strengthens **supply chain resilience** and **reduces dependencies**, while promoting **green technology leadership**.

→ Complemented by first intra-EU green iron trade, and then global imports, the **steel sector's competitiveness** and a **large proportion of jobs** can be secured in the long term.

Next generation steelmaking

The European Union is the world's third largest steelmaker, but production has significantly declined over the last decade



- → 130 Mt of crude steel production in 2024 (behind only China and India), with Germany as the largest steel producer in the EU
- → Steel industry accounts for ~5% of EU emissions and over 25% of all industrial emissions
- → Production routes: 55% primary steel (BF-BOF) and 45% secondary steel (EAF)
- → Average blast furnace age of 50 years, with 32 BFs having announced retirement dates[1]
- → **Trade (finished steel products, in 2024):**
  - Direct exports 17 Mt
  - Direct imports 27 Mt

Eurofer (2025), Steel in Figures.
[1] The State of the European Steel Transition (2025), E3G, CAN Europe, BFF et al.

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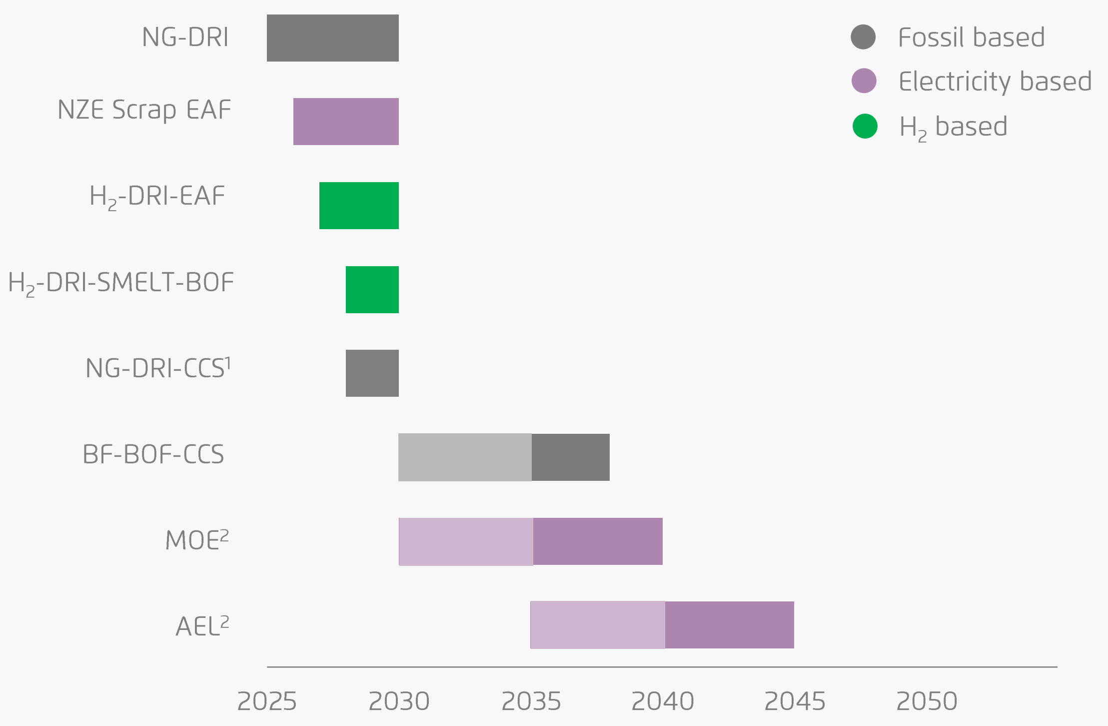
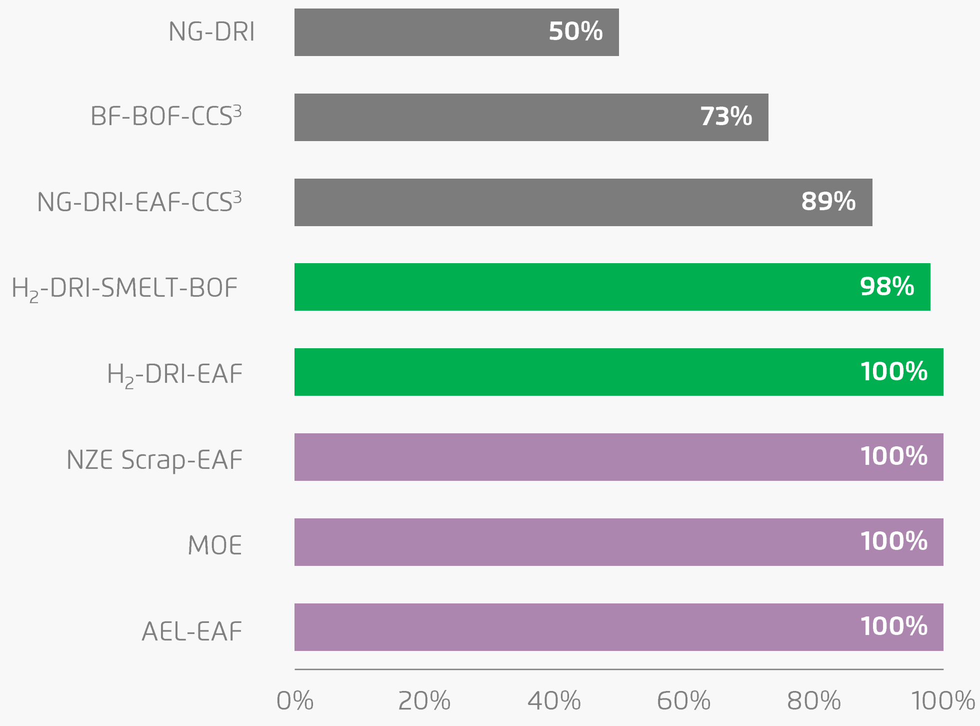
By 2030, mature technologies like scrap-based EAF and H_2-based DRI routes will drive the decarbonisation of the steel sector

Expected market readiness[4] of different breakthrough technologies for steelmaking

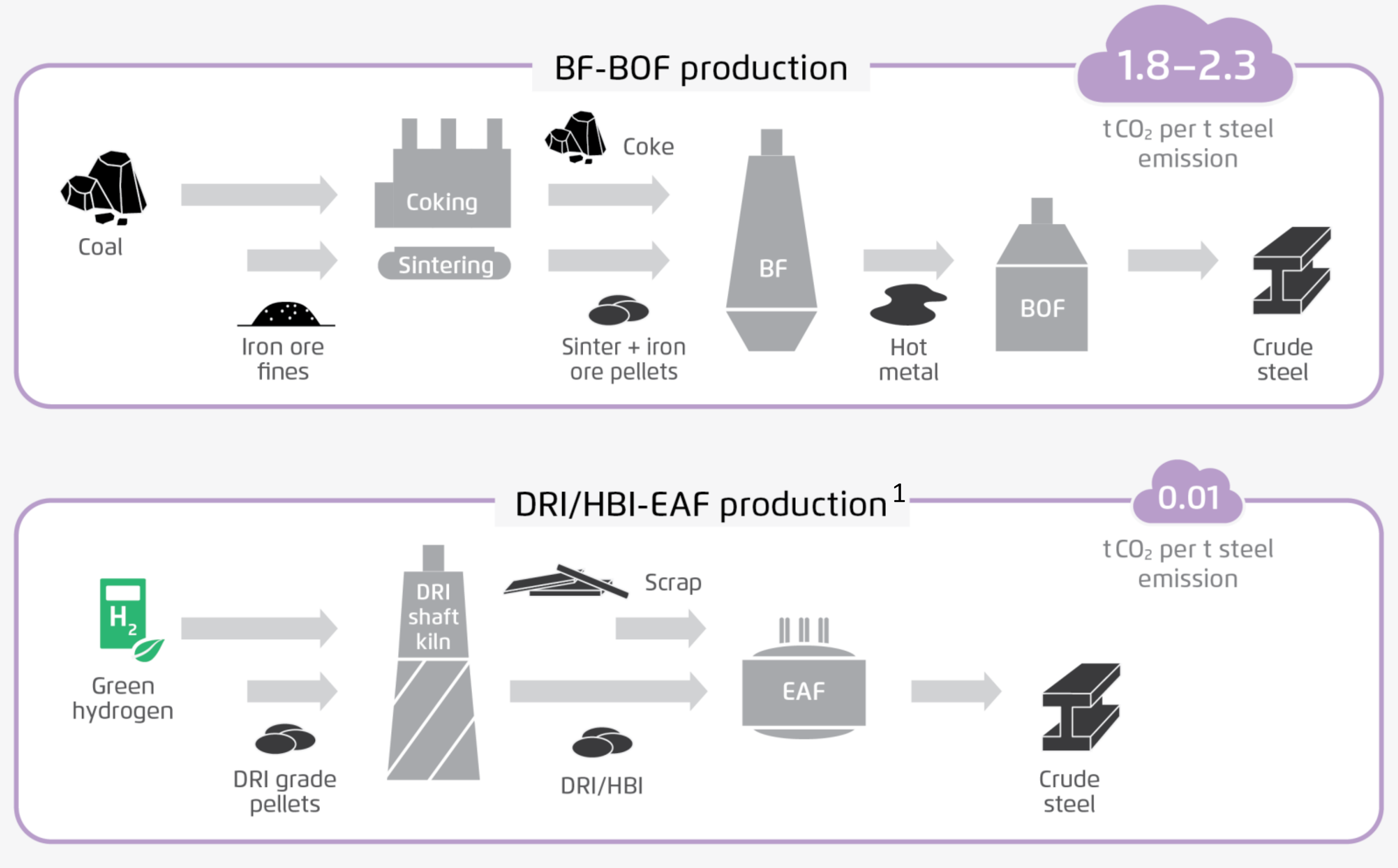


CO_2 abatement potential of different technologies compared to the integrated blast furnace route (BF-BOF)[3]



Agora Industry and Wuppertal Institute (2022, 2023). [1] Current commercial NG-DRI-CCS projects are not considered breakthrough technologies since they do not achieve large CO_2 emissions reduction rates.
[2] Due to their low TRL at the time of modelling, MOE was not foreseen to reach market readiness before 2035 and AEL before 2040. [3] CCS calculations are based on ambitious assumptions. Achieving high CO_2 capture rates at a BF-BOF plant is technically and economically challenging due to the many CO_2 point sources at the site. Note that upstream methane emissions (out of scope of this analysis) can substantially increase the full carbon footprint of steel, both for BF-BOF and NG-DRI with CCS. 4 Implies that TRL 9 is reached, and then you go from small commercial trials to full market deployment.

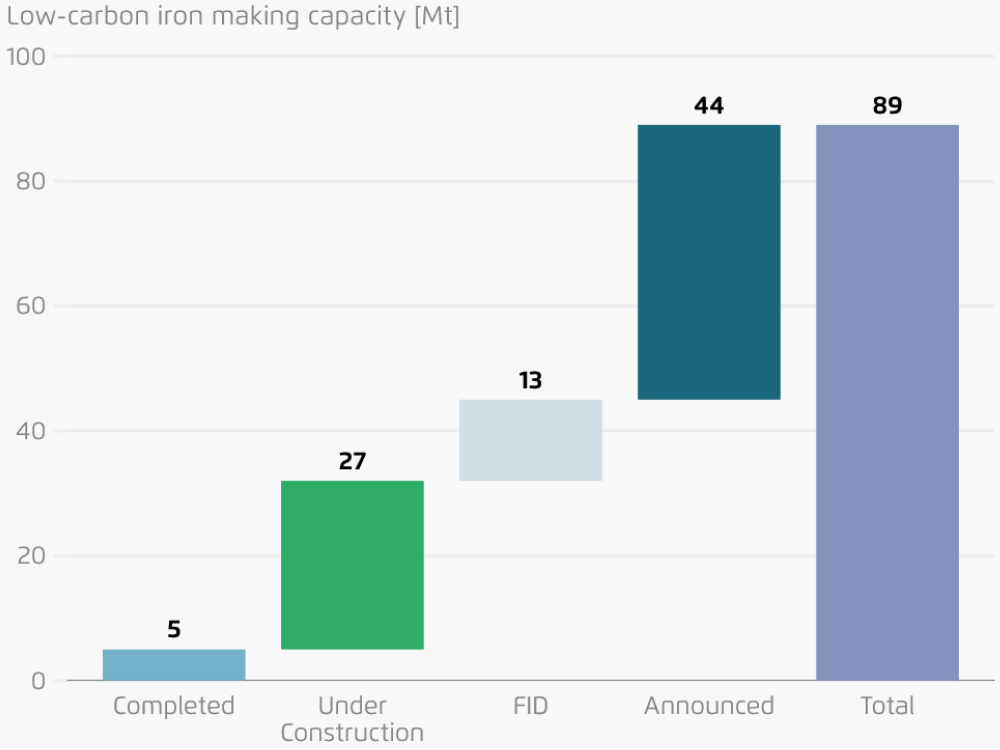
Steelmaking via the H_2-DRI/HBI-EAF route can eliminate the vast majority of carbon emissions compared to the BF-BOF route



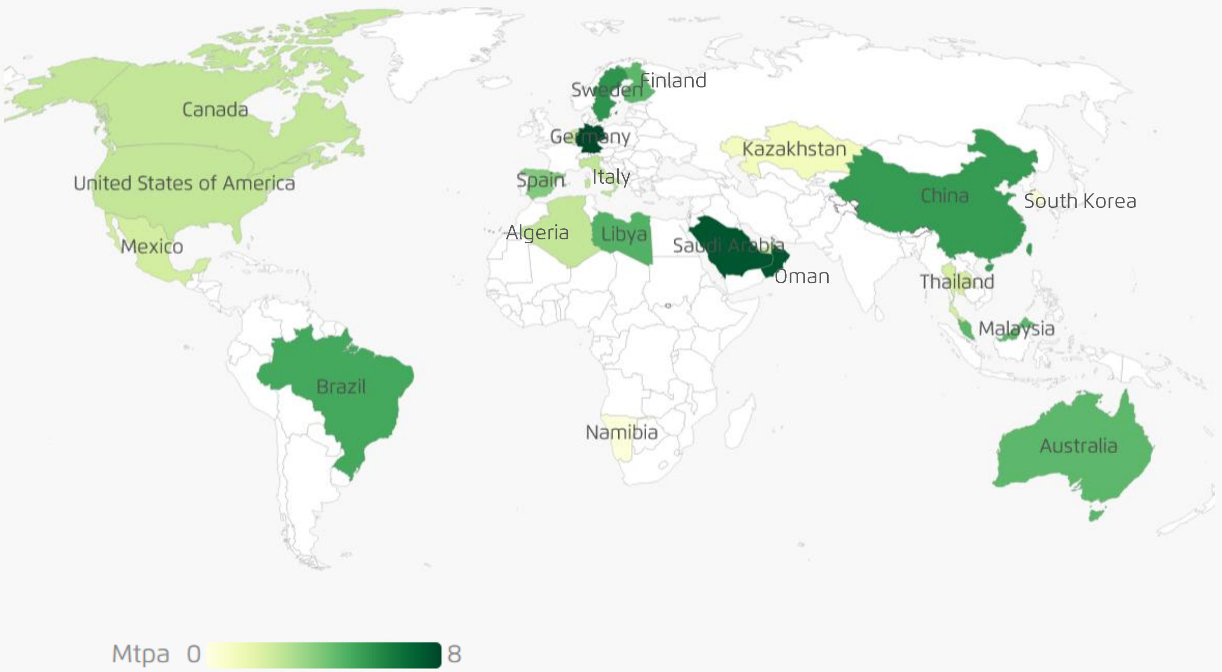
[1] The DRI-SMELT-BOF route (not pictured here) is another viable route for green steel production, which is described further in Agora Industry and Wuppertal Institute (2023)

The transition to green steel is gaining momentum, with the EU and MENA region emerging as front-runners in the shift to H_2-DRI by 2030

2030 low-carbon steel announcement pipeline by project status



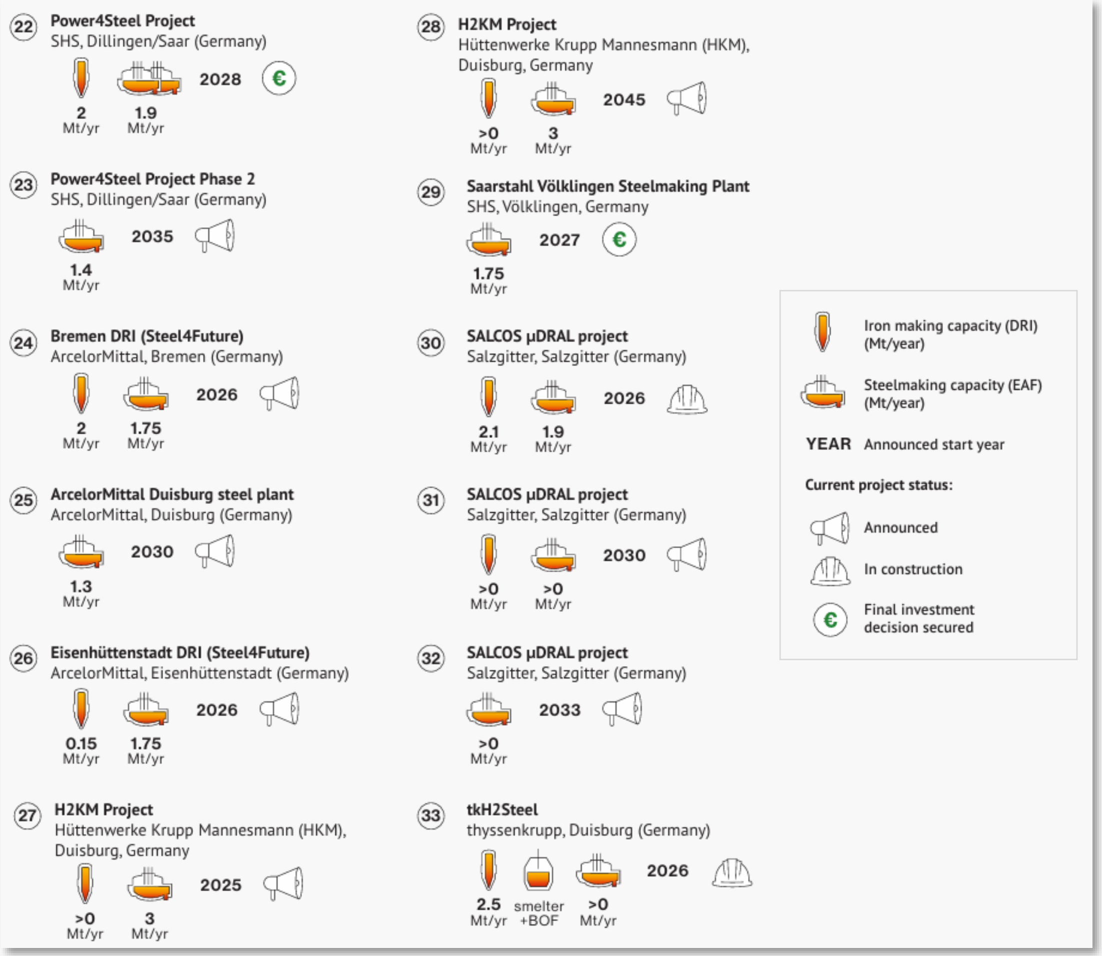
2030 low-carbon steel announcement pipeline by country



 Agora Industry (2025) Low-Carbon also includes announced projects that are initially based on fossil gas. The large majority of the projects have plans to switch to renewables based H_2 in the future but many have unspecified timelines on when that switch to H_2 will occur.

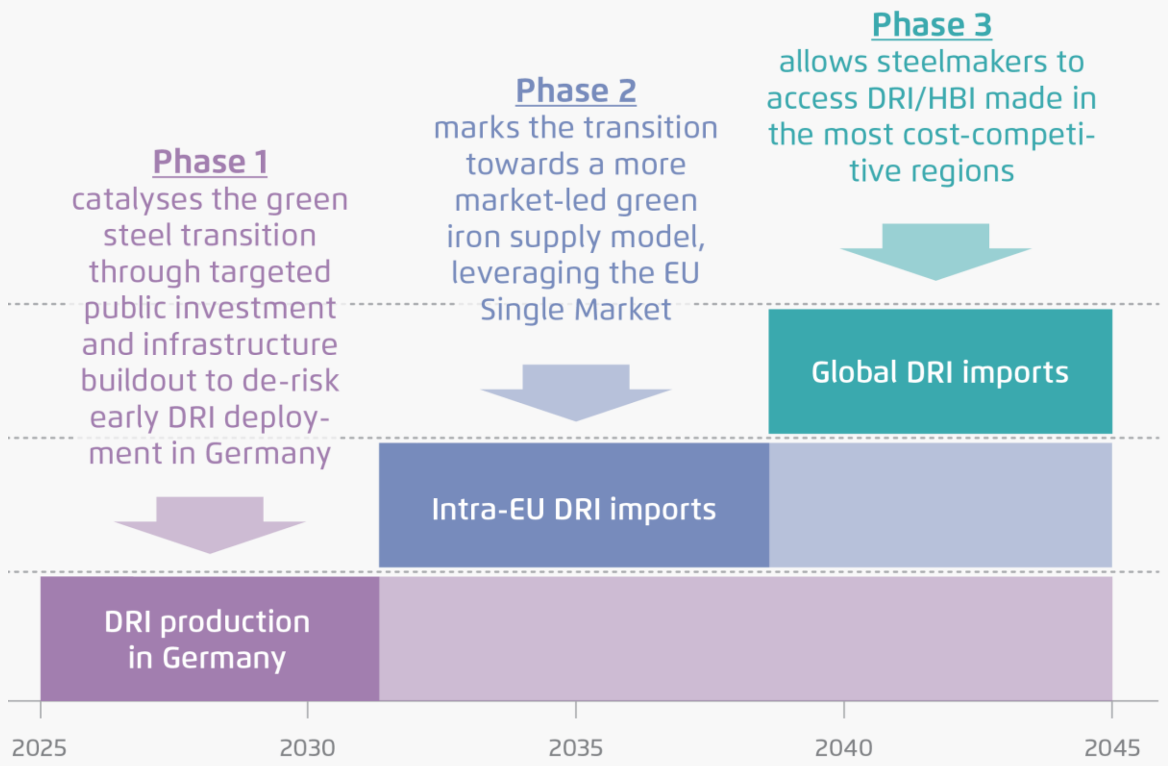
Opportunities of green iron trade: the case of Germany

Germany has agreed to fund the transition of its integrated steelworks with 7.3 billion euros of state aid to fund seven site transformation projects



- Access to affordable hydrogen has been a major bottleneck for many of these projects to move from announcement to Final Investment Decision.
- The DRI project pipeline has gone through recent changes due to one steel maker cancelling two of the decarbonisation projects in Germany, citing challenging energy and market conditions.
- Several projects are under construction; however, they still need to secure competitively priced renewable hydrogen to work.
- These first wave projects are crucial for technological innovation and kick-starting a market for green steel and will be needed to ensure a resilient domestic iron and steel sector.

German case study: applying the three-phase approach to unlocking climate-neutral primary steel production



Phase 1

Launch of Germany's first commercial DRI plants

- **Requires**: Robust investment support policies for new plants and derisking instruments to enable H_2 ramp-up
- **Benefit**: Maintaining domestic iron and steel production supports broader industrial value chains

Phase 2

Develop intra-EU green iron value chains

- **Requires**: Derisking instruments, lead markets for clean, EU-made products
- **Benefit:** Hedge against domestic H_2 cost inflation while improving strategic resilience

Phase 3

Establish global green iron trade

- **Requires:** Trade or offtake agreements and domestic support for downstream steelmaking value chain
- **Benefit**: Access to lowest-cost ironmaking regions

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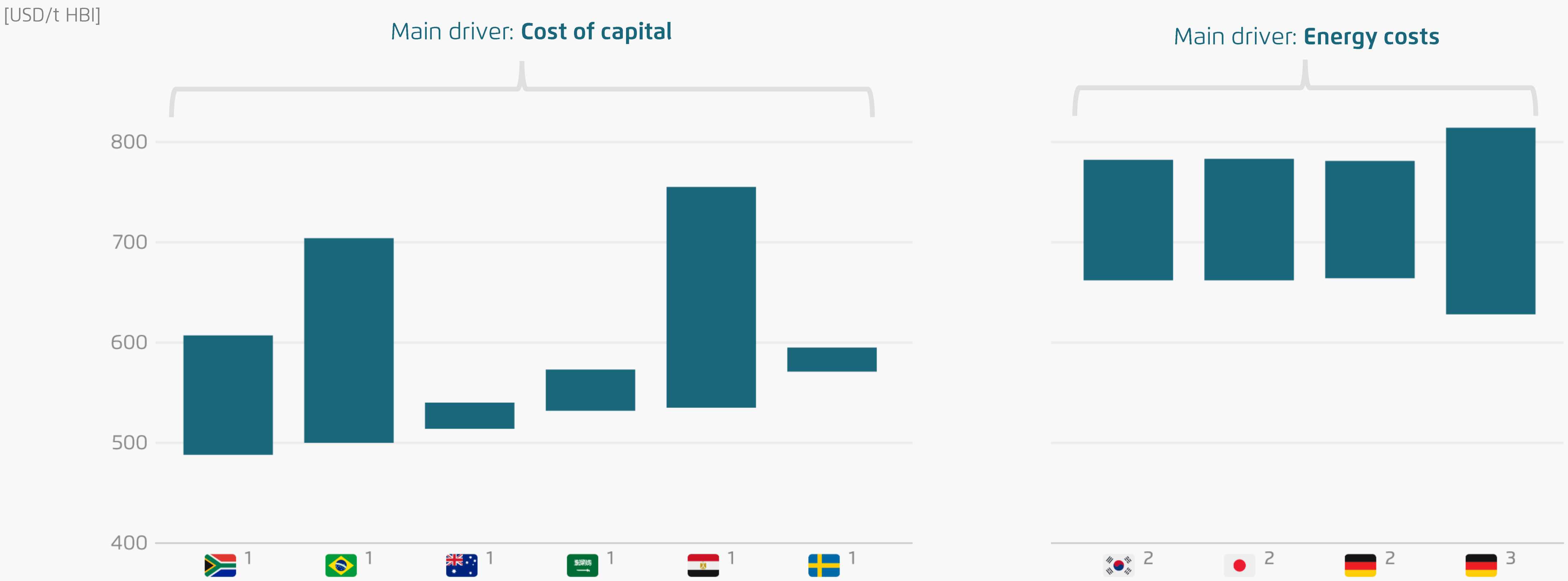
Green HBI production costs are mainly driven by cost of capital in potential exporting countries and by hydrogen costs from high energy costs in potential importing countries

Range of HBI production costs in 2040



Agora Industry (2025). [1] driven by variable renewable energy; [2] grid-based electricity procurement; [3] hydrogen imports via pipeline from Tunisia (upper bound) and Denmark (lower bound). HBI production costs based on Oeko-Institut, Agora Energiewende and Agora Industry (2024): PtX Business Opportunity Analyser, version 2.0. For detailed information on the scenarios assessed, see slides in the Appendix.

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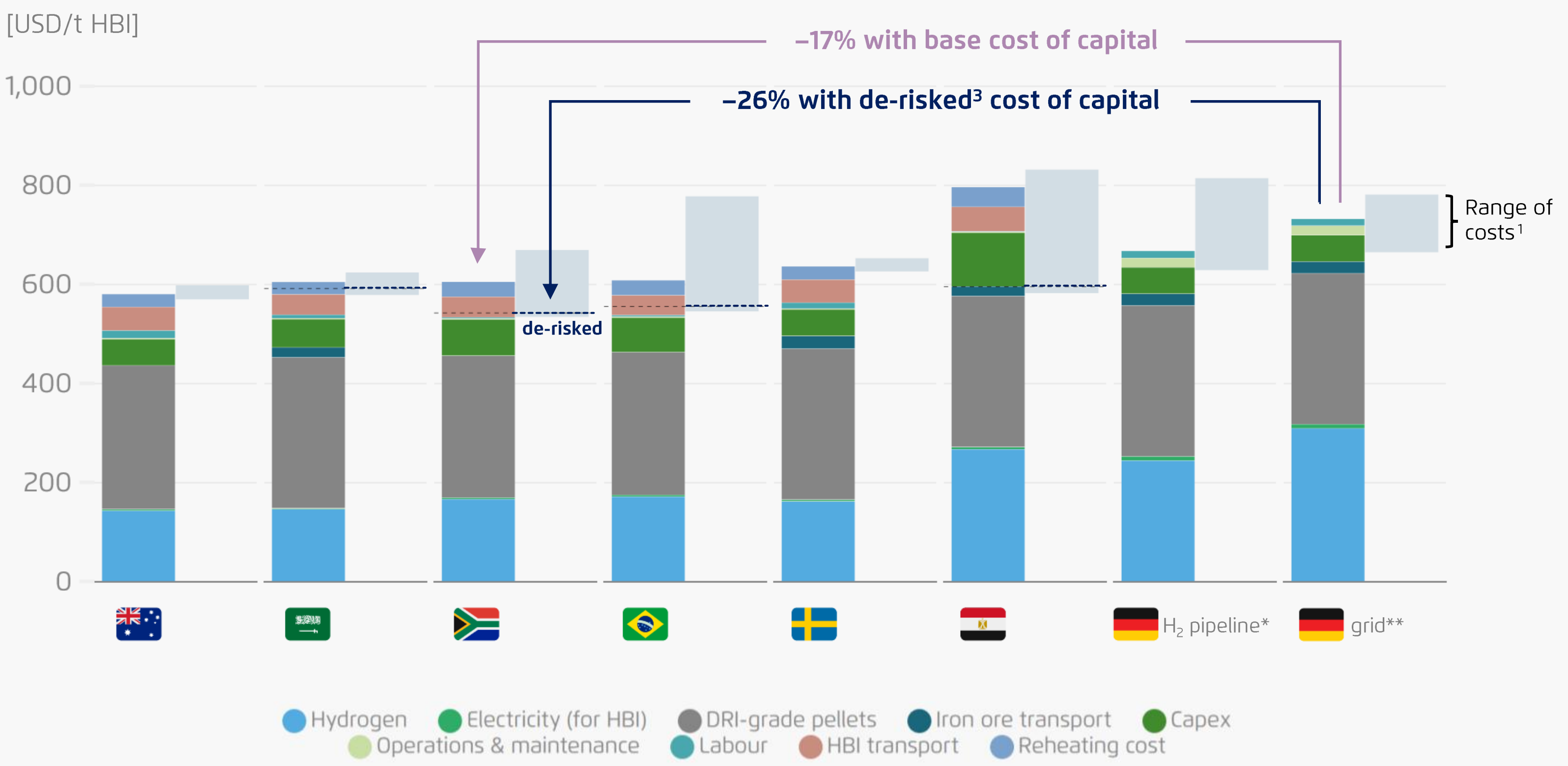
Unlocking production in regions with high renewables potential could create significant cost-reduction opportunities

Germany case study: HBI production and import[2] costs in 2040 based on medium cost scenario



→ Projects in many exporting countries will need supporting derisking[4] measures to be developed.

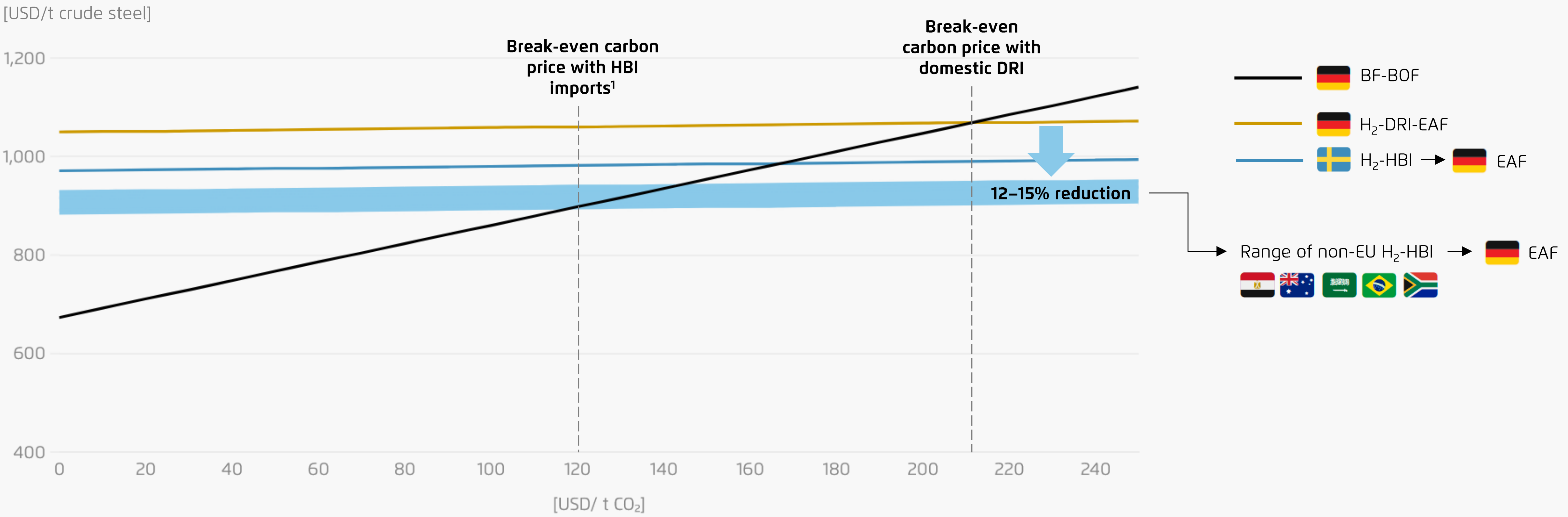
→ As a global green iron market develops, access to cost-competitive HBI imports would enable more cost-effective steel production.

→ Using imported green HBI with up to 26% lower production costs can lead to a cost reduction of 15% of overall steelmaking in Germany.

Agora Industry (2025). * H_2 pipeline in Europe considering imports from Spain (medium cost scenario); **HBI production costs based on grid-based electricity procurement.
[1] The light grey columns indicate the range of HBI production costs across low, medium, and high cost scenarios. [2] import costs include re-heating cold HBI; [3] de-risked cost of capital assumed to be 4.3%.
[4] De-risking includes measures such as concessional finance and offtake contracts that result in lowering the cost of capital for investments in HBI production. For detailed information on the scenarios assessed, see slides in the Appendix.

Importing green HBI imports from regions rich in iron ore and renewables could nearly halve the break-even CO_2 price needed for green steel to compete with BF-BOF in Germany

Germany case study: crude steel production costs in 2040 using imported (de-risked*) and domestic HBI/DRI.
Importing HBI could cut 12–15% of steel production costs.



Agora Industry (2025). *de-risked cost of capital: 4.3%; production costs of green steel include: shipping costs of iron pellets and HBI, losses during transportation, cost of re-heating cold HBI as well as costs associated with higher tap to tap time by using cold HBI. For detailed information on the scenarios assessed, see slides in the Appendix.

Transformation: turning risk into opportunity for Germany's steel sector

→ Germany's steel sector is navigating a sluggish economy, persistent global overcapacities and geopolitical uncertainties. However, this challenging environment also presents a pivotal **opportunity for Germany to regain competitiveness and future-proof its industry** through innovation and leadership in green steel production. By supporting the transformation of its steel sector – the largest in the EU – Germany can reinforce its position as a global green industry and technological innovator.

→ To achieve climate neutrality, it is crucial for Germany to decarbonise its steel industry, which is currently responsible for around 7% of national greenhouse gas emissions, and one third of industrial emissions. **Coordinated climate and industrial policy are needed to achieve competitiveness, resilience and sustainability**.

→ A **clear strategy along its industrial value chains** is needed to preserve this strategically important sector. This means combining policy measures that unlock investments in domestic green iron and steel production with a deliberate approach to diversifying supply chains.

→ **Green HBI imports can hedge against high H_2 import costs**, enhancing the cost-efficiency of high-value German steelmaking. This could lower green steel production costs by 12–15% – a meaningful reduction in a highly competitive, margin-sensitive industry.

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EU policy recommendations

Key players must come together to create the enabling environment required to enable H_2-DRI project implementation

- → National government and regulators
- → Multilateral organisations and platforms (World Bank, UN bodies, Climate Club, etc.)
- → Think tanks and researchers
- → Certification bodies (standards, MRV)

- → Iron ore miners
- → Green iron and steel producers
- → Renewables and hydrogen developers
- → Infrastructure developers (grids, pipelines, storage)
- → Technology providers (electrolyser, DRI, EAF)
- → Green iron & steel offtakers
- → Project developers (EPC, plant design)

- → Local communities
- → Labour and trade organisations
- → Environmental and community NGOs

- → Equity investors (project consortium)
- → Commercial debt providers (commercial banks)
- → Concessional finance (PPPs, DFIs, MDBs, JETPs)
- → Export credit agencies

1) Domestic industrial policy: unlocking the first and second waves of green primary steel production

1. **Support domestic lighthouse projects**
   - Support first movers through EU funding to de-risk green iron and steel projects and improve project bankability (e.g., via the Industrial Decarbonisation Bank, EU-wide carbon contracts for difference [CCfDs] and auction schemes of the EU Innovation Fund)
   - De-risk projects by leveraging national support via State Aid (e.g., via CCfDs investment support)

2. **Scale renewable energy and hydrogen production and infrastructure**
   - Co-ordinate, de-risk and accelerate build-out of renewable electricity and hydrogen infrastructure (grids, pipelines, storage)
   - Secure IPCEI funding for electrolyser projects
   - Leverage the European Hydrogen Bank to finance hydrogen availability at scale and targeted at no-regret sectors – green iron and steel, in particular

3. **Create a single market for green iron and steel**
   - Introduce harmonised EU standards for green steel, including a credible label
   - Establish lead markets via private and public procurement; focus on end-use sectors such as automotive, construction and machinery and set content requirements for green steel made in Europe

2) International collaboration: leveraging trade to drive investments into green supply chains

1. **Develop strategic international partnerships**
   - Expand frameworks like the EU-South Africa Strategic Partnership and the Global Gateway programme and initiate Clean Trade and Investment Partnerships (CTIPs) with a focus on clean industrial supply chains
   - Integrate green iron into trade agreements, strengthen CBAM and align it with global climate goals
   - For green iron value chains, prioritise engagement with key suppliers like Australia, Brazil, Canada and South Africa

2. **Establish offtake mechanisms and long-term security of supply**
   - Broaden the H_2Global double-auctioning mechanism to support the international production and import of green hydrogen derivatives (e.g., green iron)
   - Consider defining green HBI as a strategic raw material under the Critical Raw Materials Act (CRMA)

3. **Lower the capital cost of green iron projects and value chain**
   - Reduce investment and projects risks with de-risking instruments (e.g., guarantees on counterparty credit or political risk via export credit agencies, insurance firms, National and Multilateral Development Banks)
   - Provide blended finance (e.g., concessional capital, low-interest loans) to reduce financing barriers for international JVs and enable long-term offtake agreements

4. **Set global standards and support technology transfer**
   - Work with developing markets to harmonise green steel and hydrogen standards
   - Support technology cooperation, local capacity building and efficiency improvements

Appendix

List of abbreviations

AEL: Alkaline iron electrolysis

BF: Blast furnace

BOF: Basic oxygen furnace

Capex: Capital expenditures

CCS: Carbon capture and storage

DRI: Direct reduced iron

EAF: Electric arc furnace

EU ETS: EU emissions trading system

Fe: Iron

FID: Final investment decision

GHG: Greenhouse gas

H_2: Hydrogen

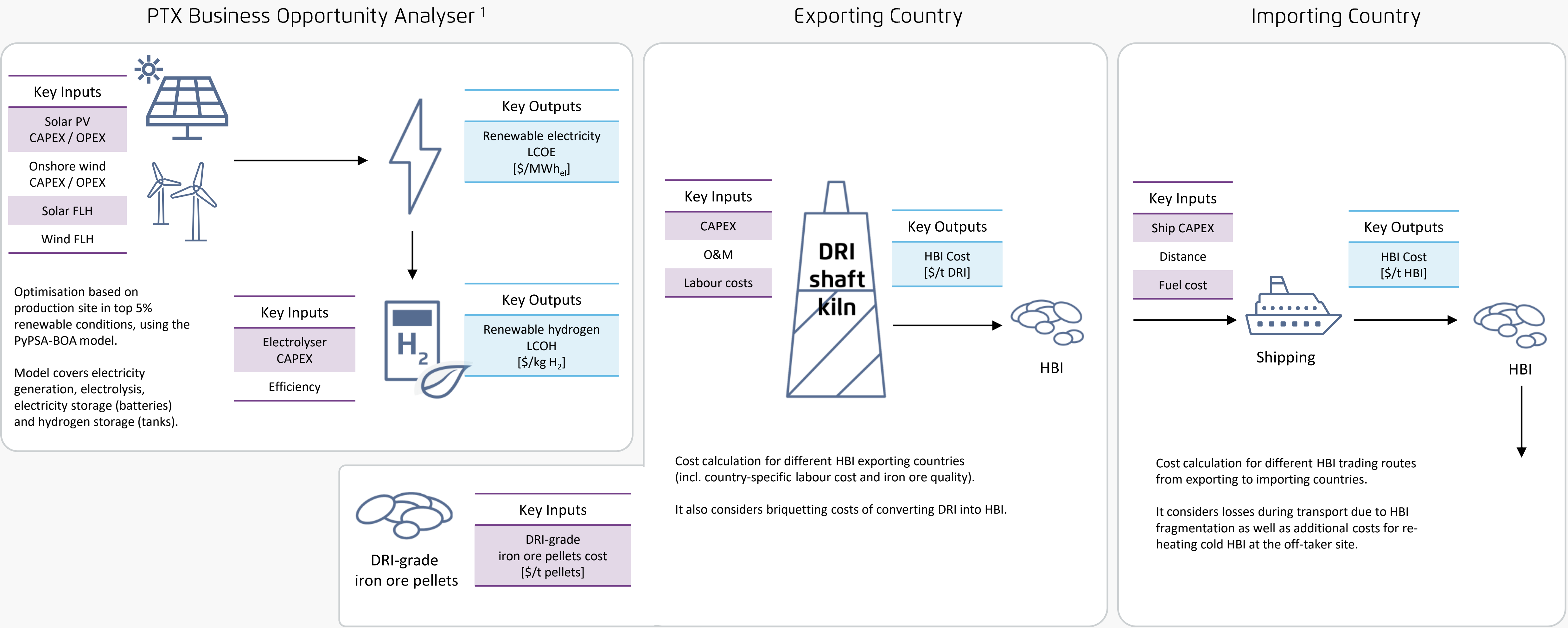
HBI: Hot briquetted iron

MOE: Molten oxide electrolysis

NZE-scrap-EAF: Near-zero emissions scrap electric arc furnace

Opex: Operating expenditures

Appendix – calculation methodology



[1] Oeko-Institut, Agora Energiewende & Agora Industry (2024): PTX Business Opportunity Analyser, Version 2.0

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Appendix – key assumptions

Overall values

Parameters		Value	Reference	Comment
Amortisation time (years)		20	Own assumption	-
Capacity utilisation (%)		90	Own assumption	72% for EAF charged with cold HBI[1]
DR grade iron pellets (USD_{2024} / tonne)		207	1, 2	Price for countries without DR grade iron ore. Countries with DR grade iron ore can produce pellets with lower costs.
DRI plant	CAPEX (USD_{2024} / tonne DRI per year)	633	2	-
	Fixed OPEX (% of CAPEX per year)	3	2, 4	-
	Electricity consumption (kWh / tonne DRI)	93	2, 3	Including DRI briquetting
	Hydrogen consumption (kg H_2 / tonne DRI)	69	2, 4	Including H_2 pre-heating
EAF plant	CAPEX (USD_{2024} / tonne CS per year)	468	2,	-
	Fixed OPEX (% of CAPEX per year)	3	2, 4	-
	Electricity consumption (kWh / tonne HBI)	651	2, 4, 5	Including re-heating of cold HBI (150 kWh / tonne HBI)

Note: [1] The capacity factor of the EAF was adjusted to account for lower productivity when charged with cold HBI compared with hot HBI due to a higher tap-to-tap time.

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Appendix – key assumptions

Overall values

Parameters		Value	Reference	Comment
BF-BOF plant	CAPEX (USD_{2024} / tonne CS per year)	326	10	-
	Fixed OPEX (% of CAPEX per year)	3	10	-
	Coking coal (USD_{2024} / tonne)	257	2	-
Alkaline electrolyser	CAPEX (USD_{2024} / kW_{el})	657	8	-
	Fixed OPEX (USD_{2024} / kW_{el}-year)	13	8	-
	Efficiency	71.5%	8	-

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Appendix – key assumptions

Country-specific values

Parameters	Case	Australia	Brazil	Egypt	South Africa	Saudi Arabia	Germany*	Germany**	Japan	South Korea	References
Discount rate*** (%)	High	4.3	14.6	14.3	10.8	5.1	4.3	4.3	5.3	4.9	6,7
	Medium (default)	4.3	7.7	14.3	8.3	5.1	4.3	4.3	5.3	4.9	6
	Low	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	6
CAPEX of wind onshore (USD_{2024} / kW)	High	1,176	910	1269	868	1,482	1,456	-	-	-	8
	Medium (default)	1,037	802	1,119	765	1,307	1,624	-	-	-	8
	Low	977	756	792	721	1,232	1,531	-	-	-	8
CAPEX of solar PV (USD_{2024} / kW)	High	698	564	628	515	977	1,042	-	-	-	8
	Medium (default)	528	426	475	389	357	434	-	-	-	8
	Low	411	332	370	303	278	505	-	-	-	8

* H_2 pipeline for Germany is based on H_2 production in Tunisia (high case), Spain (medium case) and Denmark (low case). ** grid-based electricity for Germany; *** country-specific equity risk premiums (ERP) and government bond yields are used as simplified approach in levelised cost calculations, since a more detailed weighted average cost of capital (WACC) is intrinsic to each individual project; All costs refer to 2040 technological scenario.

Appendix – key assumptions

Country-specific values

Parameters	Case	Australia	Brazil	Egypt	South Africa	Saudi Arabia	Germany*	Germany**	Japan	South Korea	References
Cost of renewable energy (USD_{2024} / MWh)	High	37	64	77	70	26	55	105	105	105	8,9
	Medium (default)	32	38	55	29	21	39	90	90	90	8,9
	Low	29	27	22	21	16	45	70	70	70	8,9
Cost of renewable hydrogen (USD_{2024} / kg)	High	2.3	4.0	4.3	4.5	2.4	4.6	5.2	5.2	5.2	8,9
	Medium (default)	2.1	2.5	3.9	2.5	2.1	2.9	4.5	4.5	4.5	8,9
	Low	1.9	1.9	2.0	2.0	1.8	2.8	3.5	3.5	3.5	8,9

* H_2 pipeline for Germany is based on H_2 production in Tunisia (high case), Spain (medium case) and Denmark (low case); ** grid-based electricity for Germany; All costs refer to 2040 technological scenario.

Imprint

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