Green iron trade

Unlocking opportunities for Brazil

November 2025

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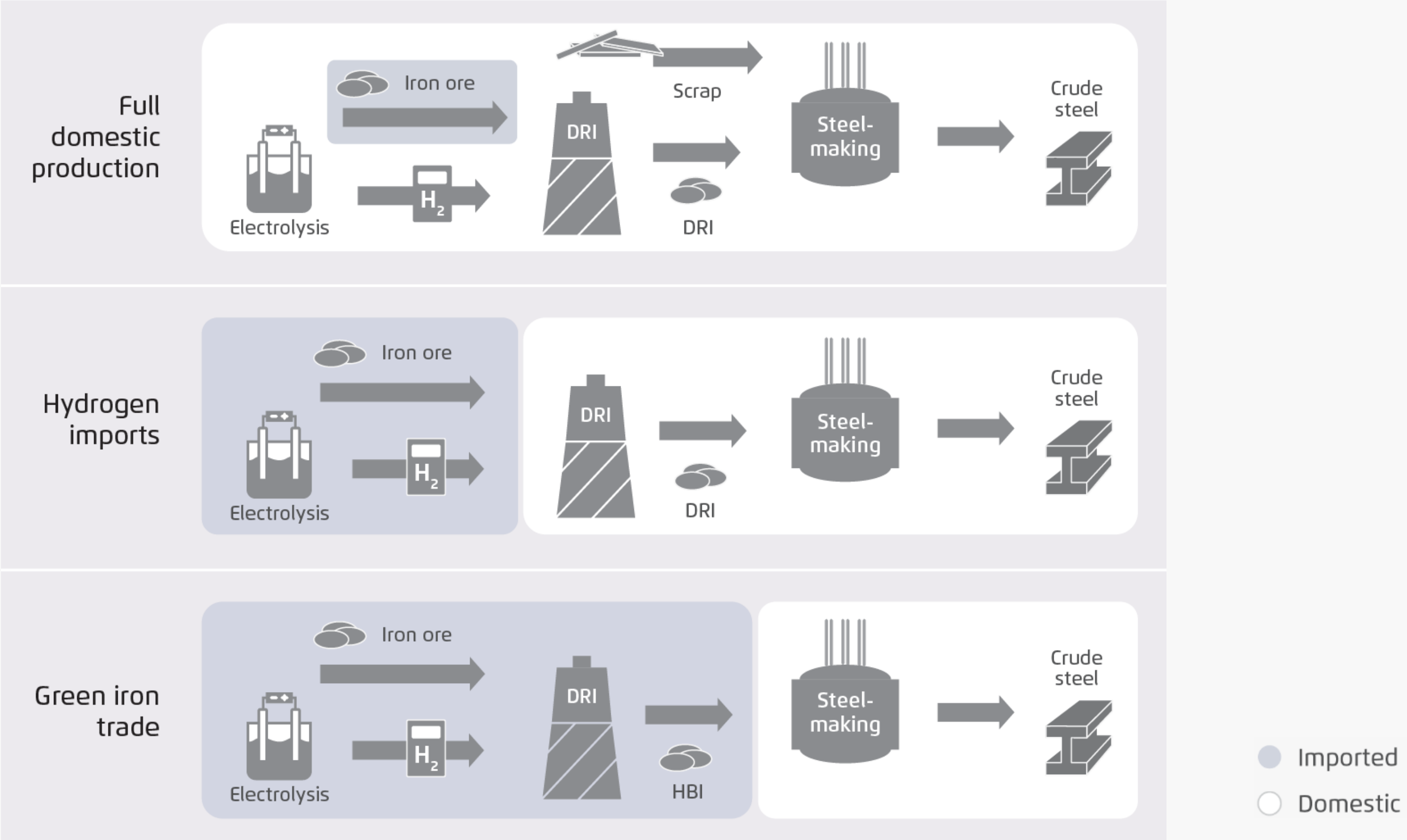
Key findings

1. **Brazil's abundant renewable resources, high-grade iron ore and established industrial base provide a unique foundation for large-scale green iron production.** With its ideal combination of solar and wind potential, locally available direct reduction (DR)-grade ore and relatively low labour costs, Brazil can become one of the world's most cost-effective green iron producers if capital costs are de-risked and DR-grade iron ore capacity and logistics are scaled up.
2. **Green iron trade offers a win-win opportunity for Brazil and its partners.** If Brazil produced 10 million tonnes (Mt) of green iron by 2040, it could avoid 12.8 Mt of carbon dioxide, create around 35,500 jobs and more than double current export revenues compared to iron ore. For countries such as Germany, South Korea and Japan, sourcing green iron from Brazil could lower steelmaking costs by 12 to 15 percent by 2040 while safeguarding higher-value steel production sites and downstream value chains.[1]
3. **Strategic international partnerships are essential to unlock this potential for Brazil.** Partnerships between green iron exporters and importers can align climate, industrial and trade goals while ensuring fair benefits for all sides. For Brazil, these partnerships can attract finance, enable technology transfer and help build a resilient green iron market. Existing mechanisms, such as the German-Brazilian Partnership for a Socially Just and Ecological Transformation offer a solid foundation.
4. **Targeted finance and policy coordination are necessary to mobilising investment.** Brazil's high cost of capital remains a key barrier to large-scale projects. Concessional finance, guarantees and blended de-risking mechanisms can improve bankability. Coordinated action on standards, certification and financing can catalyse investment and position Brazil as a cornerstone of the global green iron market.

[1] All quantitative results reflect scenario modelling for 2040. Jobs include annualised temporary and permanent positions across manufacturing, construction, operations and maintenance and decommissioning. HBI price/cost assumptions, WACC and de-risking instruments are detailed in the Appendix. Results are indicative and contingent on certification, offtake and infrastructure delivery.

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.

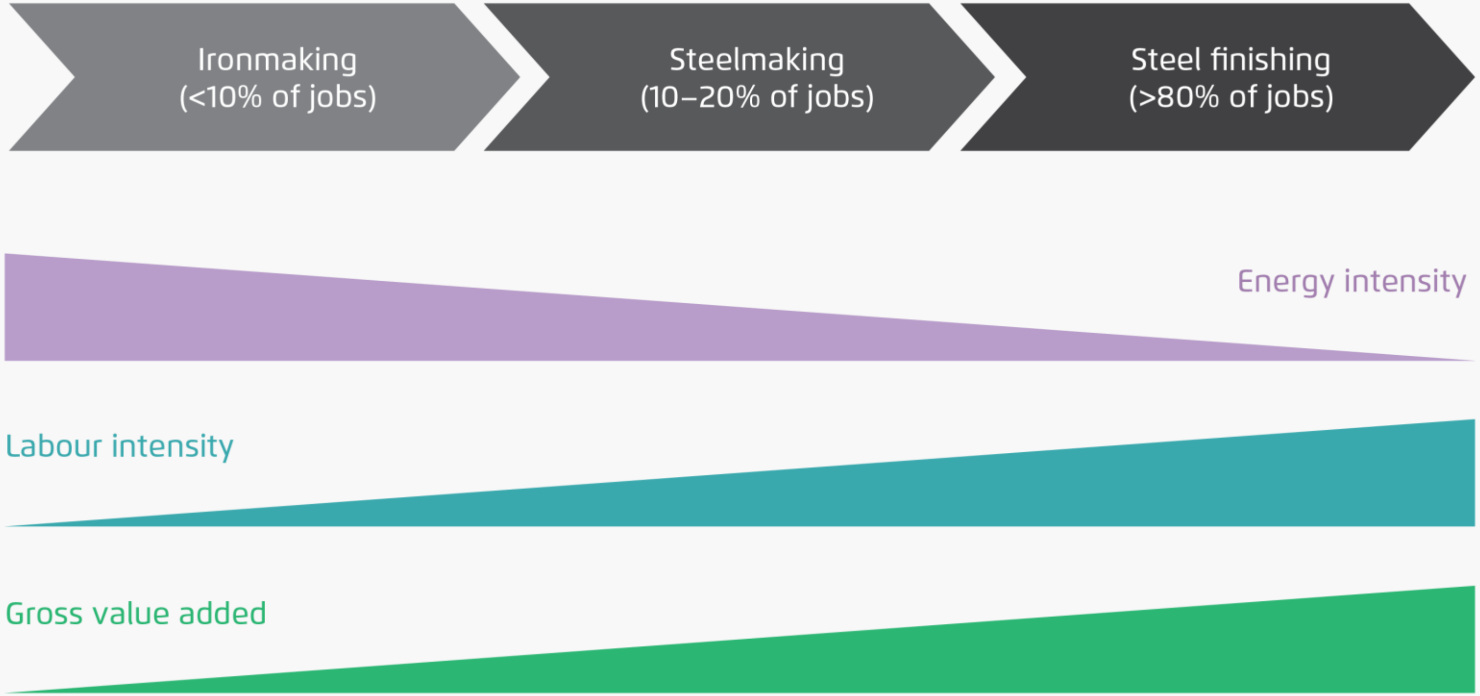
→ Green iron can be shipped as HBI, complementing domestically sourced metallic inputs (iron and steel scrap), thereby providing steelmakers some flexibility in their raw material inputs compared to the integrated coal-based BF-BOF route.

→ 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

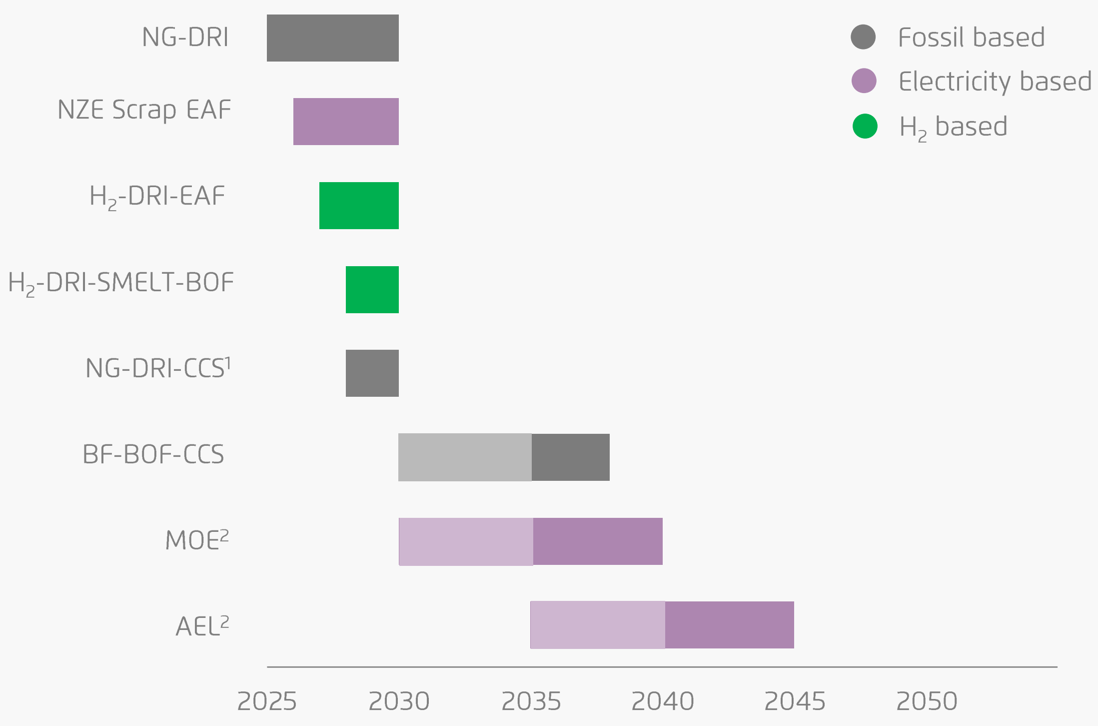


[1] Steel sector and downstream steel finishing share of employment calculated based on WV Stahl (2025), Statistisches Jahrbuch der Stahlindustrie 2024/2025.

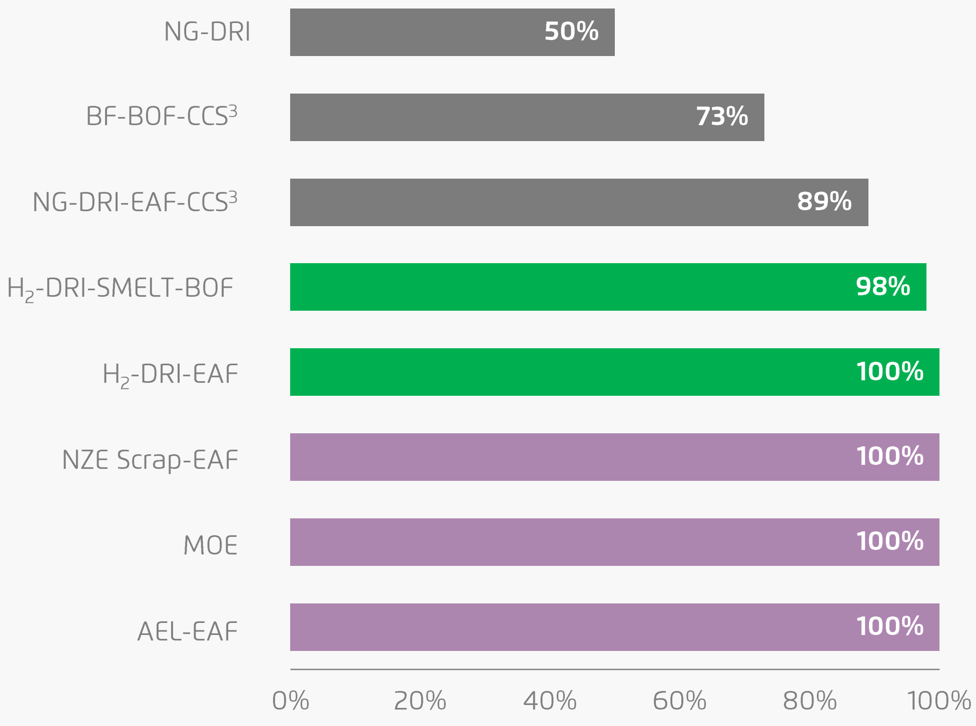
Next generation steelmaking

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

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

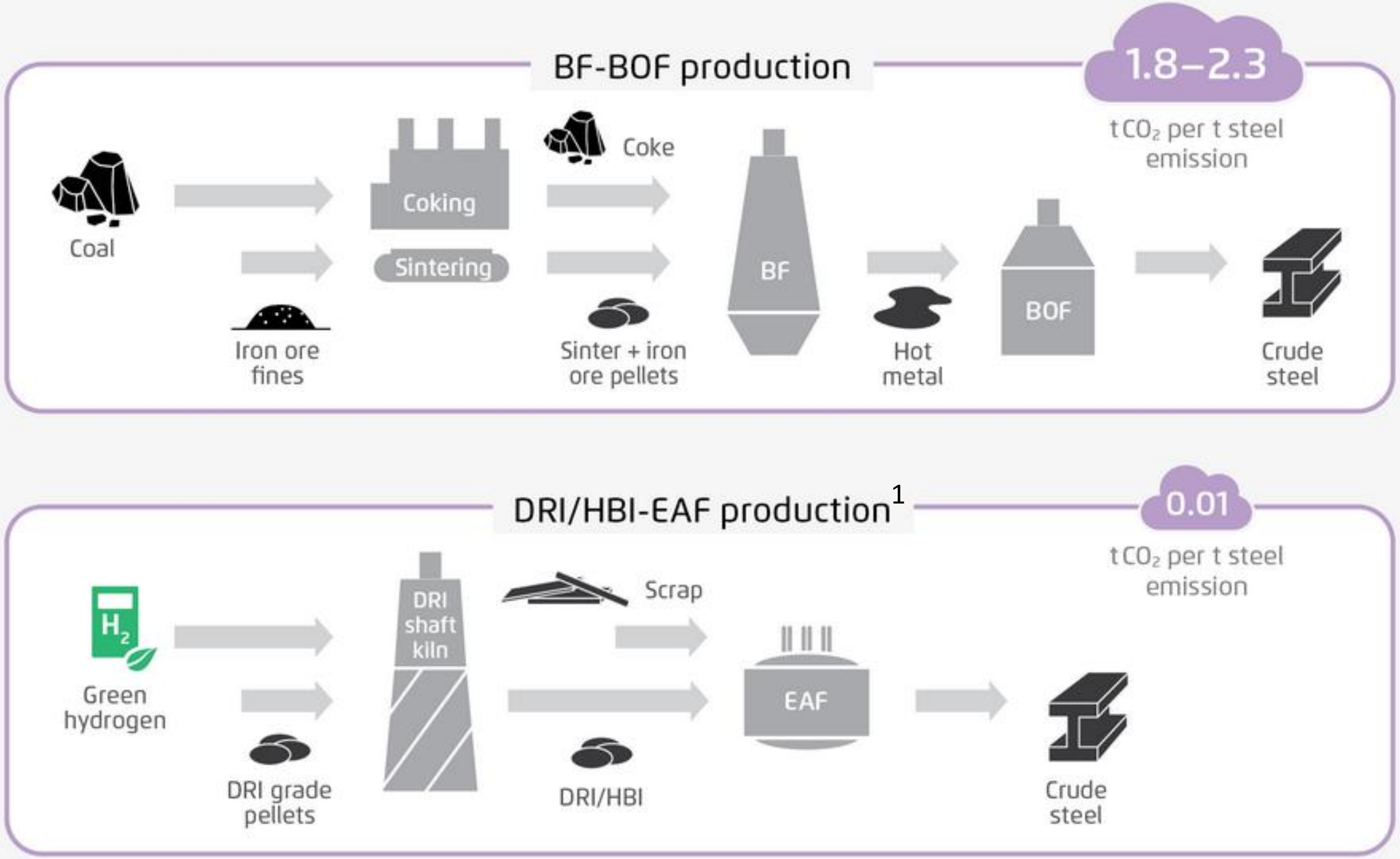


CO_2 abatement potential of different technologies compared to the integrated blast furnace route (BF-BOF)[3]



Agora Industry and Wuppertal Institute (2022, 2023). [1] Current commercial NG-DRI-CCS projects are not considered breakthrough technologies, as they do not achieve substantial CO_2 emission reductions.
[2] Due to their low TRL at the time of modelling, MOE was not expected 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] This implies that TRL 9 is reached, transitioning from small commercial trials to full market deployment. Technology deployment will depend on the availability of renewable electricity and hydrogen.

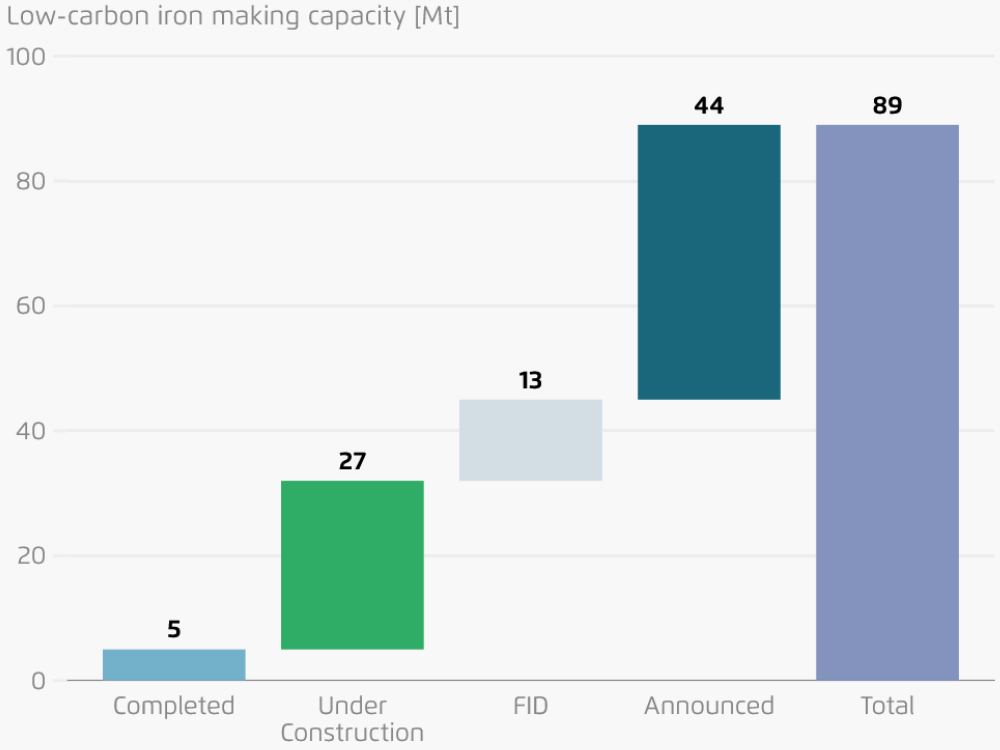
Steelmaking via the green hydrogen-DRI/HBI-EAF route can eliminate the vast majority of carbon emissions compared to the coal-based BF-BOF route



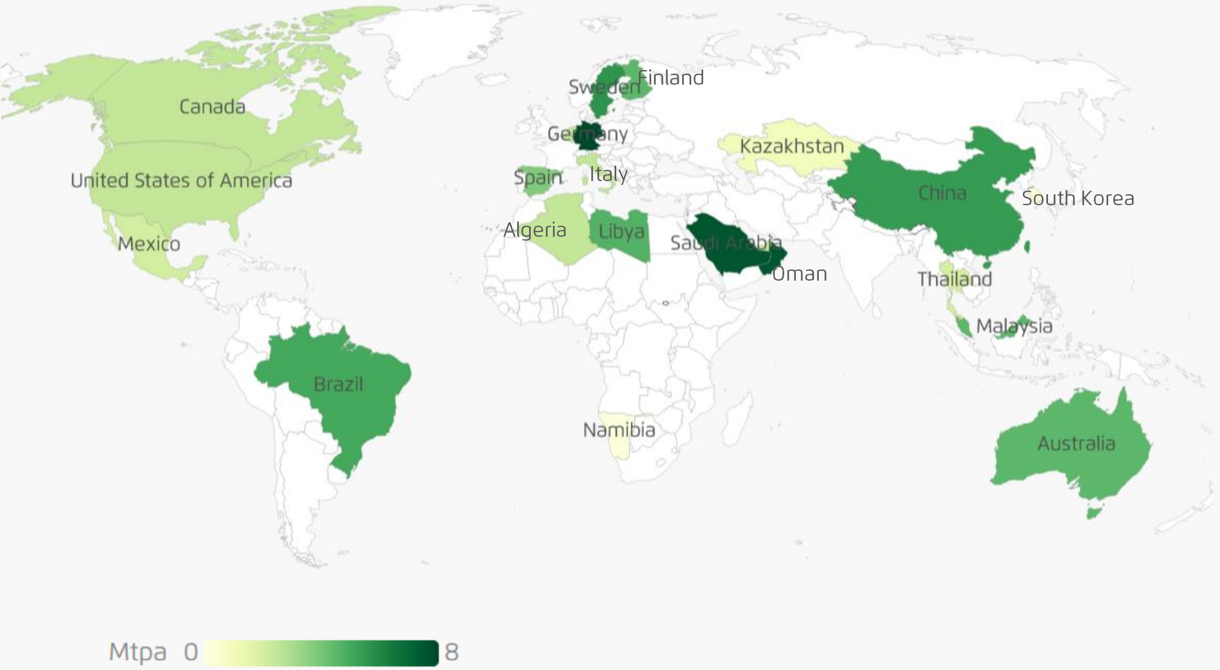
 | [1] The DRI-SMELT-BOF route (not pictured here) is another viable route for green iron trade, which is described further in Agora Industry and Wuppertal Institute (2023).

The transition to green steel is gaining momentum, with the EU and MENA region emerging as front-runners in the shift to hydrogen-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.

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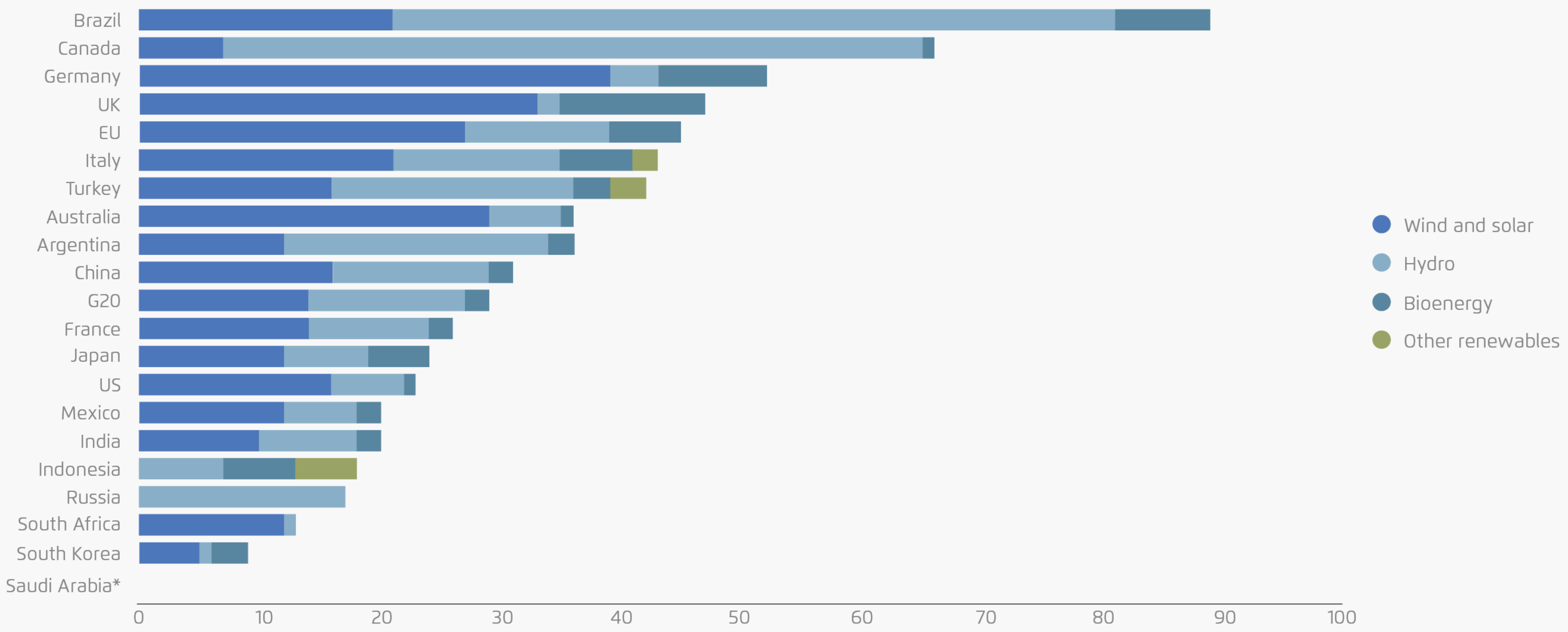
Opportunities of green iron trade: the case of Brazil

Brazil is the world's renewable energy powerhouse, enabling competitive production of renewable hydrogen and green iron

Renewable share of electricity generation, 2023 rankings [%]

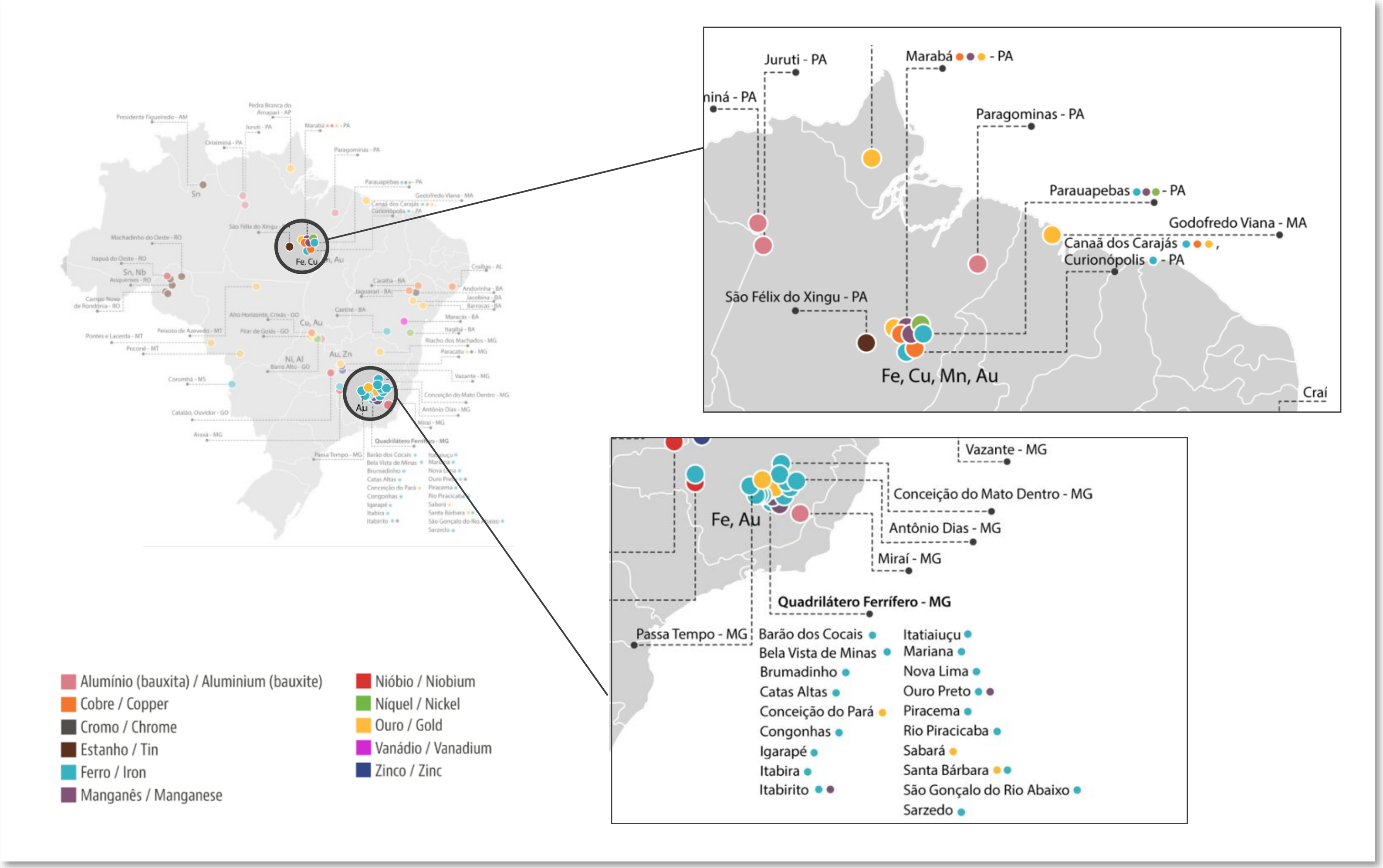


 | Ember. * Saudi Arabia displays data for 2022, the latest available data.

Brazil holds some of the world's highest-grade iron ore reserves. Scaling DR-grade iron ore quality, capacity and logistics in Carajás and the South-East is key to enable HBI exports

Mining sites with production
> 1 Mt per year

- → Iron ore production in Brazil in 2023:[1] **582 Mt**
  - Minas Gerais: **392 Mt** (~62% iron)
  - Pará: **175 Mt** (~65% iron)
- → Second largest iron ore exporter (378 Mt in 2023)[2]
  - Only 10-15% of Brazil's iron ore is used domestically, while 85-90% is exported, with China receiving 65-70% of these exports.
- → Value of iron ore exports in 2023: **USD 30.6 billion**
- → Value of iron ore exports from Pará: **> USD 10 billion per year**



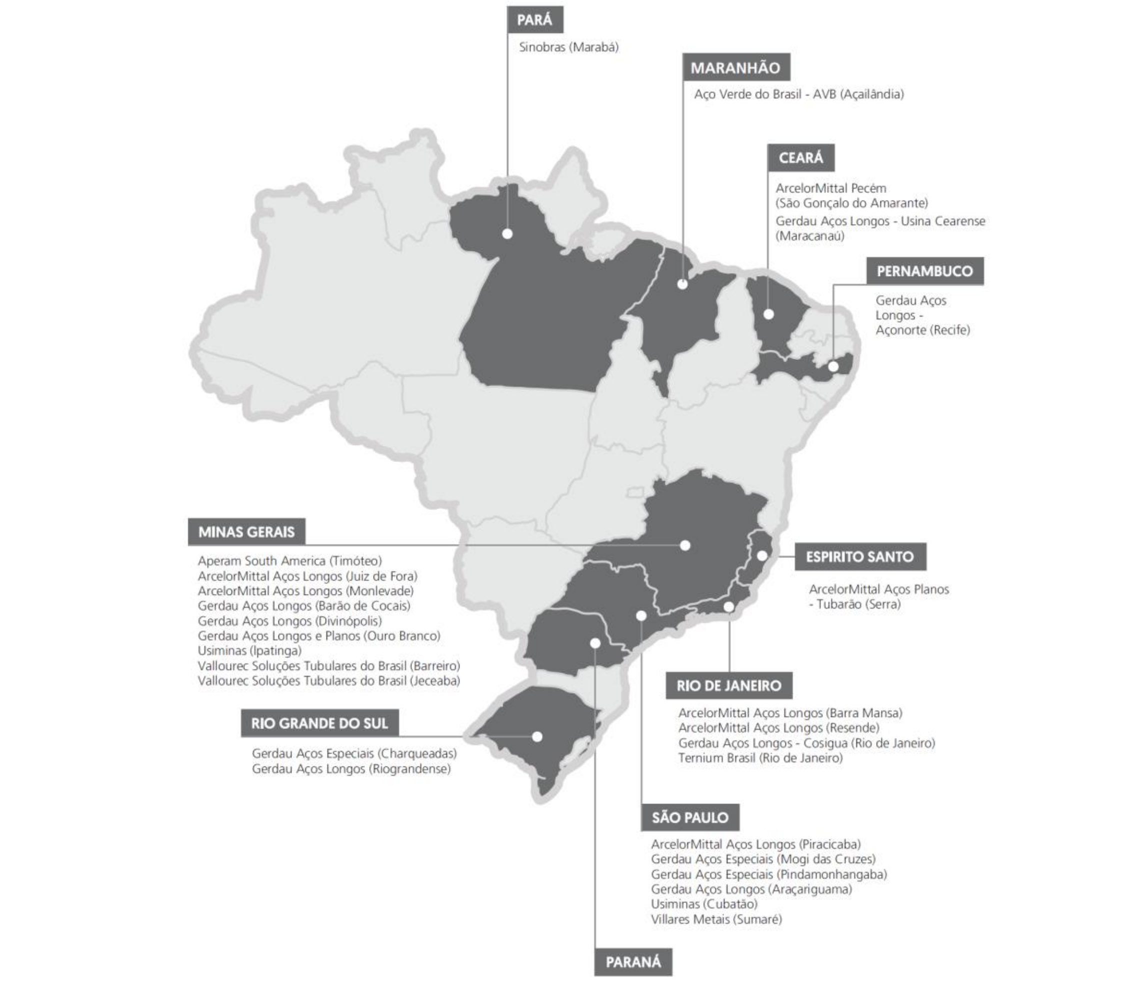
Visualisation: Agencia Nacional de Mineracao (2022) – Anuario Mineral Brasileiro. [1] Agencia Nacional de Mineracao (2024); [2] IBRAM (2024)

Brazil's strong industrial base and high-tech steel companies are well-positioned to lead the global shift towards green steel production

→ **Crude steel production sites in Brazil in 2023**:[1]
- Overall steel production in Brazil: **32 Mt**
- **South-East region 85%** of production (State of Minas Gerais: 9.3 Mt per year)
- **North region 1.5%** of production (State of Pará: 0.47 Mt per year)

→ Crude steel production represented 3.8% of Brazil's industrial GDP and 1% of Brazil's total GDP in 2023.

→ Total crude steel consumption: **26.1 Mt per year**
- Crude steel consumption from domestic production: **23.9 Mt per year**
- Crude steel imports: **4.5 Mt per year**
- Crude steel exports: **2.3 Mt per year**



 | Visualisation: Instituto Aco Brasil (2024) – Anuario Estatistico. [1] Instituto Aco Brasil (2024) – Anuario Estatistico

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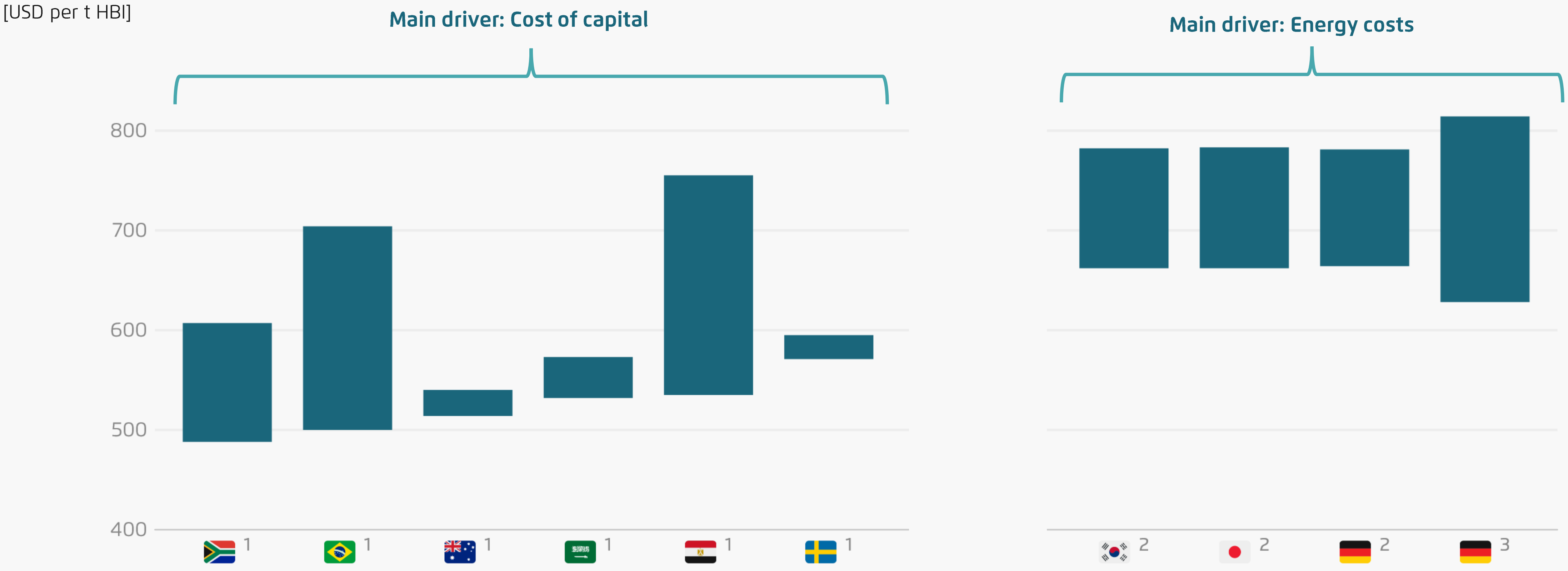
Green HBI production costs are mainly driven by cost of capital in potential exporting countries and by hydrogen costs from high energy costs in potential importing countries

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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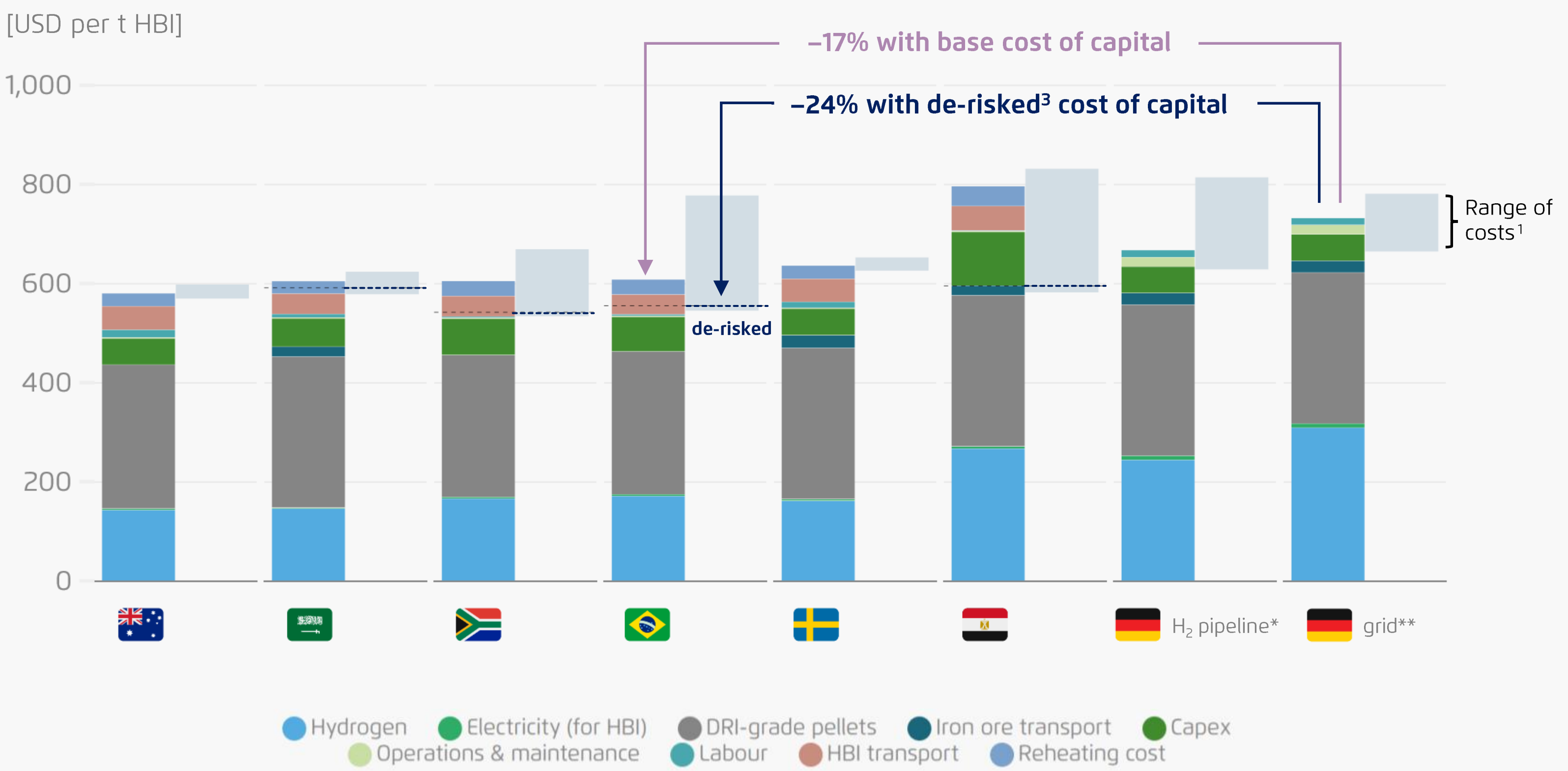
Unlocking production in regions with high renewables potential could create significant opportunities to reduce steelmaking costs

HBI production and import[2] costs in 2040 based on medium cost scenario



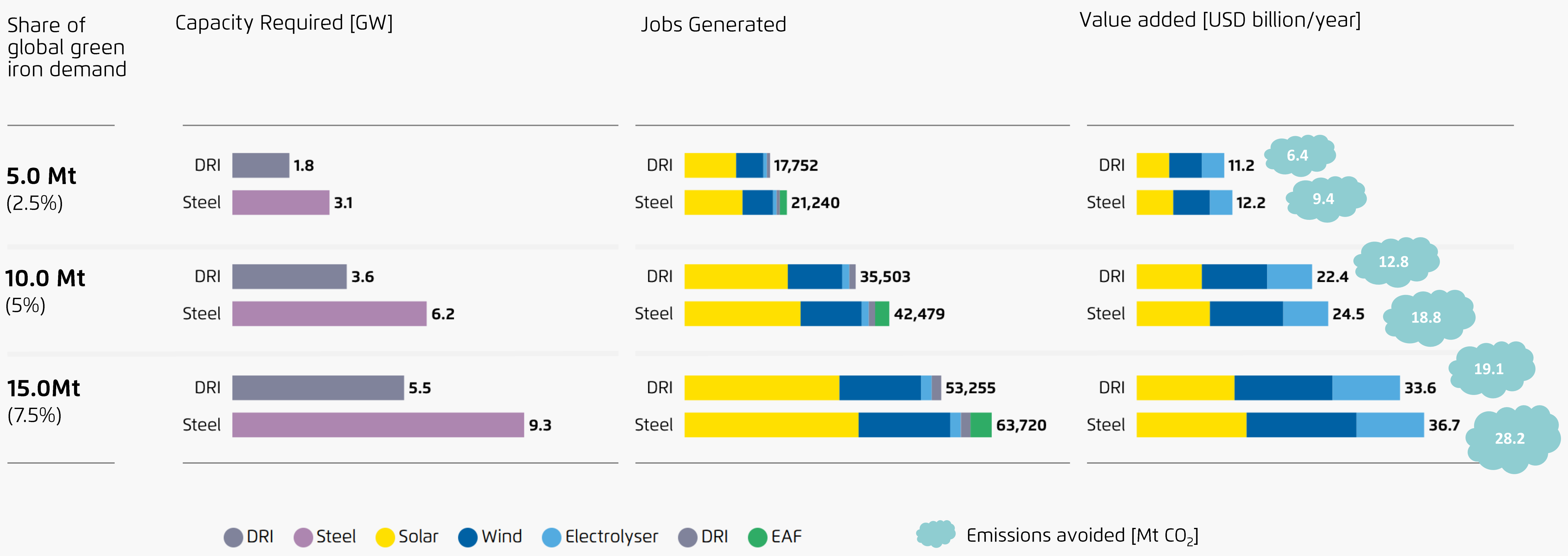
→ Projects in many exporting countries will need supporting de-risking[4] measures.

→ 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 24% lower production costs can reduce the cost of overall steelmaking in Germany by up to 15%.

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 transportation and 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.

Supplying 5% of global green iron demand[1] by 2040 could create around 35,500 green jobs for Brazil and more than double current iron ore export revenues



[1] 2.5% (5 Mt), 5.0% (10 Mt) and 7.5% (15 Mt) represents shares of projected global iron demand in 2040, based on estimates from Bataille, Stiebert and Li (2024), "Facility-Level Global Net-Zero Pathways Under Varying Trade and Geopolitical Scenarios". CO_2 emissions avoided assuming 1 tonne HBI is equivalent to 1 tonne crude iron. Jobs generation include temporary and permanent direct jobs. Temporary jobs were annualised to the lifespan of the project (20 years).

Brazil's gains from green iron exports by 2040

Gross revenues from iron ore exports today

2.9

USD billion per year

1.3

USD billion per year

Investment

Gross revenues from green iron exports from 2040

6.6

USD billion per year

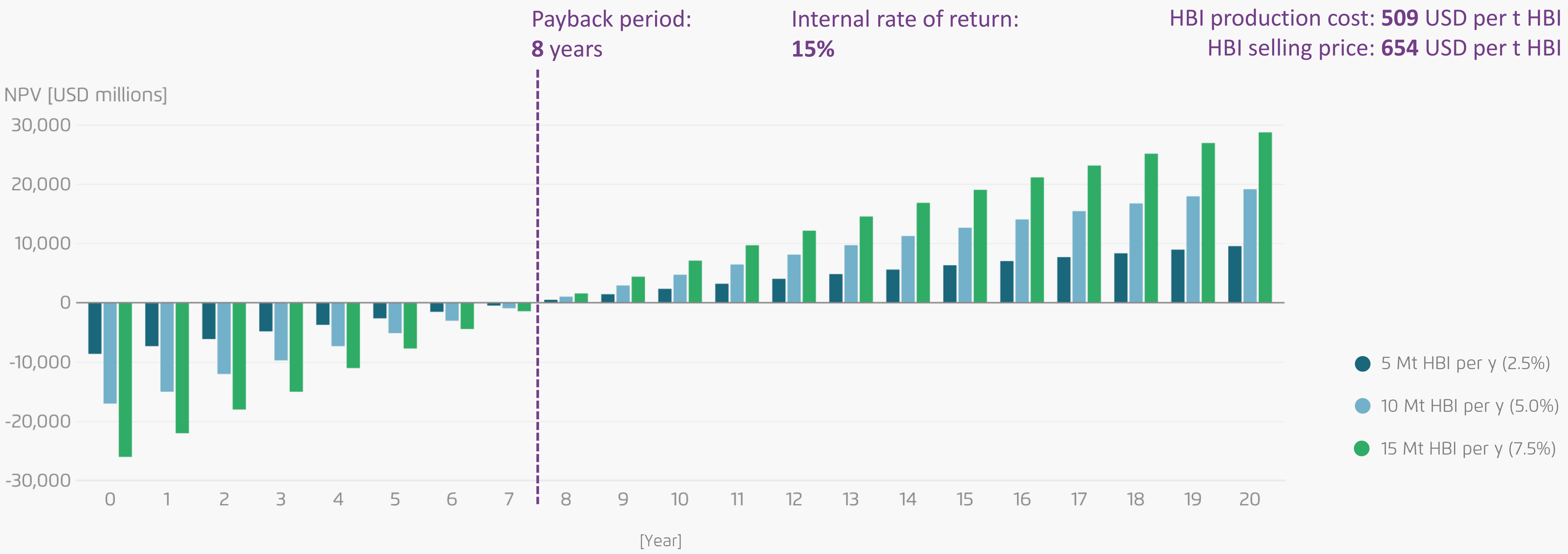
And also:

12.8 Mt CO_2 avoided and 35,500 jobs generated

Values based on 10 Mt DRI exports per year. Investment annualised considering 20 years of project lifespan and 4.3% discount rate.
Including temporary and permanent jobs during manufacturing, installation, operation and maintenance, and decommissioning phases.

Investing in the value chain of green iron in Brazil could achieve a payback period of 8 years with a 15% internal rate of return

Net Present Value (NPV) for domestic production of HBI in 2040



 | Agora Industry (2025). Note: 2.5% (5 Mt), 5.0% (10 Mt) and 7.5% (15 Mt) refer to the percentage of global iron demand (200 Mt) in 2050

Brazil 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: strengthening national enablers for green industrial transformation in Brazil

1. **Scale renewable energy and hydrogen infrastructure**
   - Coordinate and de-risk the expansion of renewable power, grids and hydrogen infrastructure
   - Use the Hydrogen Act to attract investment and ensure affordable renewable hydrogen supply for green iron production

2. **Create lead markets for green iron**
   - Establish a national certification system aligned with international standards to secure market access
   - Use public procurement, private incentives and targeted finance to drive early demand and improve competitiveness
   - Integrate green iron and steel goals into industrial and climate strategies to build a coherent domestic market

3. **Incentivise new industrial projects**
   - Strengthen investor confidence through clear policy alignment across hydrogen, energy and industry
   - Expand enabling infrastructure via public-private partnerships and streamlined permitting
   - Promote industrial clusters and coherent incentives on carbon pricing and finance to scale up green iron and steel production

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

1. **Develop strategic international partnerships**
   - Leverage existing frameworks such as the Brazil-Germany Partnership for an Ecologically and Socially Just Transition, the German-Brazilian Energy Partnership, and the EU Clean Trade and Investment Partnerships-CTIPs to anchor green iron in clean industrial supply chains and trade agreements
   - Use harmonised green product criteria, trade agreements and CBAM to align energy, industrial and climate policies

2. **Establish offtake mechanisms and supply security**
   - Engage with international demand-side platforms and procurement coalitions to aggregate early demand
   - Include green iron in international market-maker schemes (such as H2Global) to develop cross-border offtake agreements

3. **Enable financing for green iron projects and value chains**
   - Deploy de-risking instruments and blended-finance tools through public banks and multilateral institutions to lower capital costs
   - Expand international trade and investment cooperation to attract private capital and improve market access for green iron exports

4. **Set global standards and support technology transfer**
   - Work through bilateral and multilateral platforms to harmonise standards for green steel, hydrogen and carbon accounting
   - Promote technology cooperation and local capacity building to accelerate the global diffusion of clean industrial solutions

Appendix

List of abbreviations

AEL: Alkaline iron electrolysis

BF: Blast furnace

BOF: Basic oxygen furnace

Capex: Capital expenditures

CBAM: Carbon Border Adjustment Mechanism

CCS: Carbon capture and storage

DRI: Direct reduced iron

EAF: Electric arc furnace

Fe: Iron

FLH: Full Load Hours

GHG: Greenhouse gase

H_2: Hydrogen

HBI: Hot briquetted iron

MOE: Molten oxide electrolysis

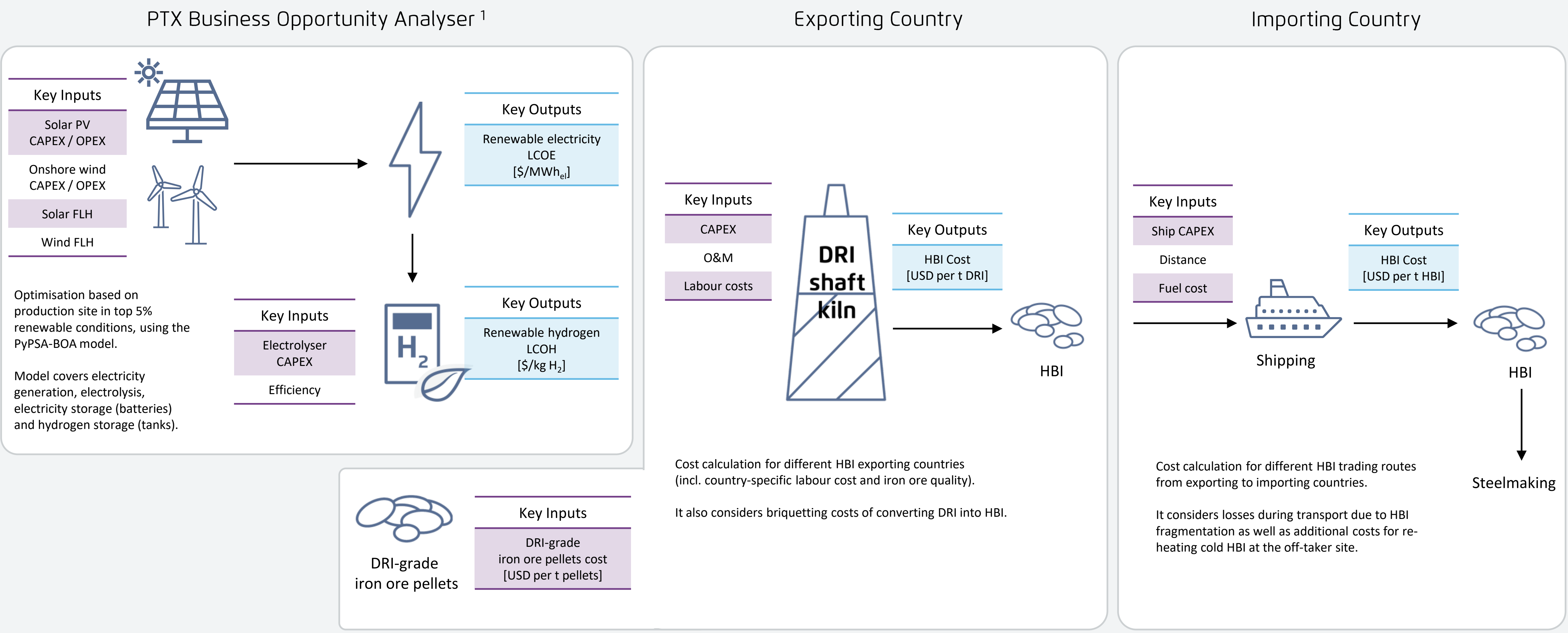
NZE-scrap-EAF: Near-zero emissions scrap electric arc furnace

Opex: Operating expenditures

TRL: Technology Readiness Level

WACC: Weighted average cost of capital

HBI production cost – calculation methodology



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

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.

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	-

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.

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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
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.

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