The decarbonisation challenge in steel – Actions in Europe, what next for China and possible implications for the SE Asian steel industry.

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Decarbonisation trends and challenges: Europe

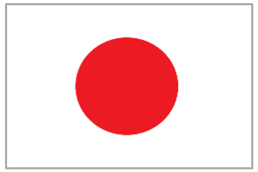
Governments are committing to emissions reduction from around the world…

Key GHG announcements and targets, selected countries

- **≥ 55% reduction by 2030[1]**
- **Net zero by 2050**

- **Peak emissions before 2030**
- **Net zero before 2060**

- **Rejoining Paris Agreement**
- **Net zero by 2050?**



- **26% reduction by 2030[2]**
- **Net zero by 2050**

- **26-28% reduction by 2030[3]**

- **33-35% reduction by 2030[4]**

Notes: (1) Compared to 1990 levels; (2) Compared to 2013 levels; (3) Compared to 2005 levels; (4) Reduction in emissions intensity, compared to 2005 levels.

The EU Green Deal signals tougher emissions cuts ahead in Europe

2020	2030	2040	2050
Scaling up of ambition: **Green Deal approved** Plans, benchmarks, and strategies being created.	Rapid initial action: **55% reduction of emissions**. Enforcement of regulations, and end of initial investment programmes.	Uncertainty: **Current targets TBD**, likely subject to review based on previous decade's experience.	Final objective: **A carbon neutral continent**, competitive, circular economy, and 'no one left behind'

Industrial decarbonisation

Reducing carbon intensity of European industry while maintaining competitiveness. Key measures include a focus on **carbon pricing** through further **reforming the EU ETS** and introducing **Carbon Border Adjustment** on imports.

Technology and innovation

1 Trillion EUR investment in the Green Deal, including significant public outlay and by InvestEU. At least 150B investment through **Just Transition Fund** between 2021-27. At least 10B funding toward **helping industries producers** to **innovate**

Clean energy

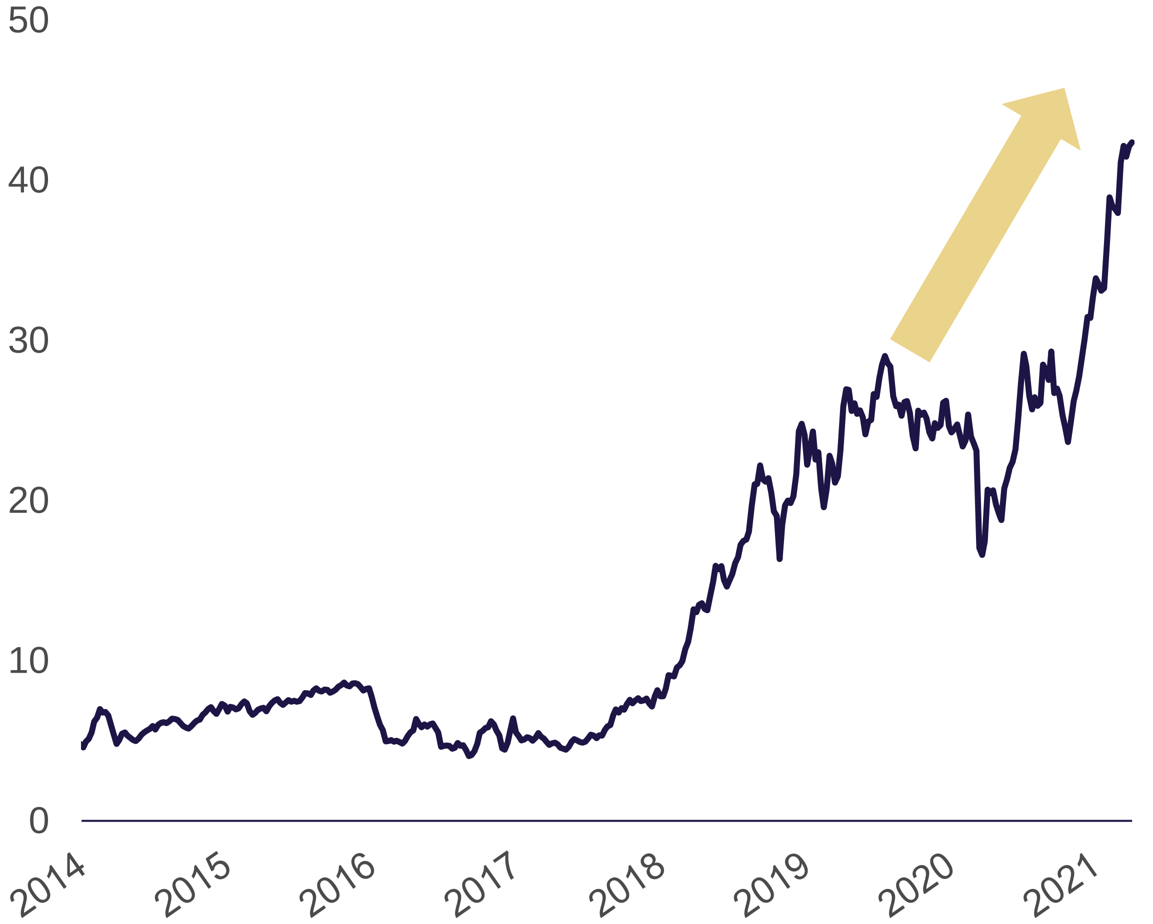
Fully integrate European energy market, largely based on renewables. Member states update **national energy and climate plans** by 2023. **Investment in low carbon fuel** to support energy intensive industries and transport.

Circular Economy

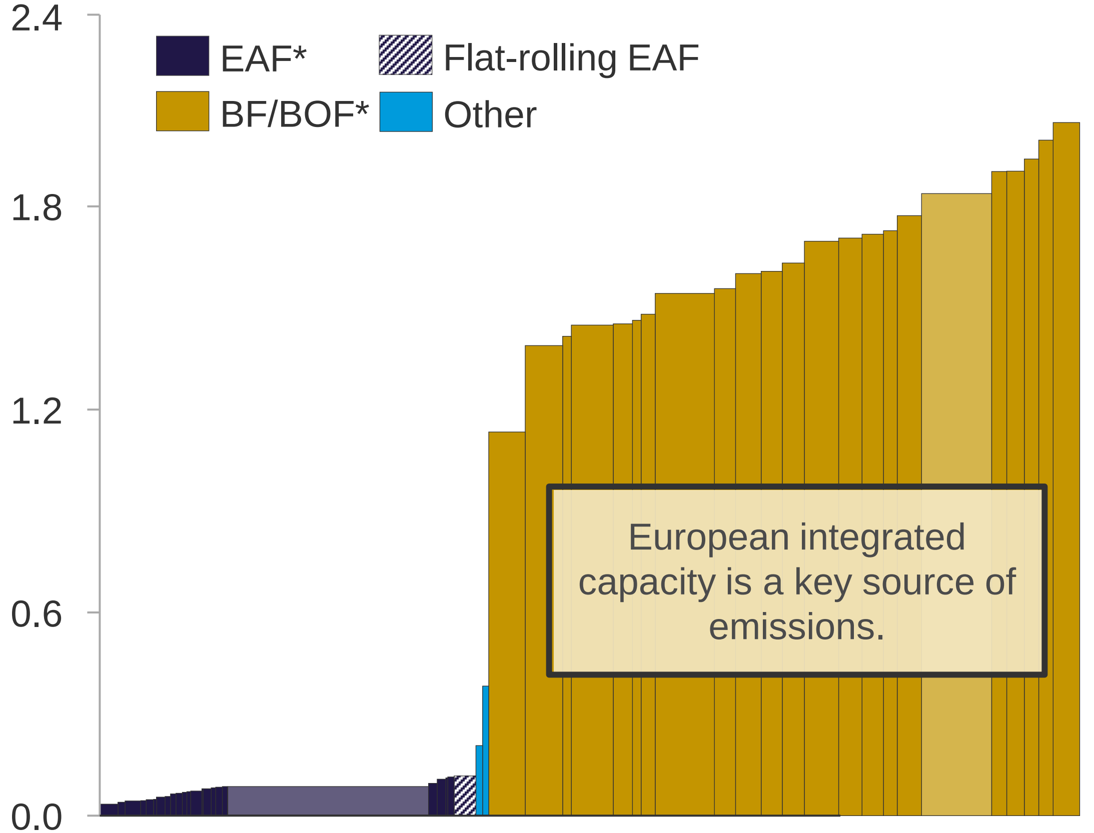
Decreasing dependence on new raw materials through reusing and recycling, particularly in construction, electronics, plastics, and textiles. Reuse & recycling requirements and regulation on packaging by 2030.

ETS reform is already increasing costs for CO_2 emissions

EU Emissions Trading Scheme Carbon price, €/t-CO_2



Carbon emissions intensity of European steelmaking by production process[1], t-CO_2/t-crude steel



DATA: CRU, Sandbag

NOTE: (1) transparent bars highlight production and CO_2 intensity of European steel production not covered by the Steel Cost Model.

Pressure from steel consumers increases the urgency to act

Automotive

BMW	Reduce CO_2 emissions in supplier network by 20% by 2030
Volvo	Reduce CO_2 emissions in supplier network by 25% by 2030
GM	50% sustainable content in vehicles by 2030
VW	30% reduction in lifecycle GHG emissions by 2025

Renewables

Ørsted	Reduce Scope 3 GHG emissions by 50% by 2032
Vattenfall	Reduce Scope 3 GHG emissions from use of sold products by 20% by 2030
Vestas	Reduce supply chain emissions by 45% per MWh by 2030
Iberdrola	Reduce scope 3 GHG emissions by 43% by 2030

Construction

Skanska	Net zero by 2045, across whole value chain
Mace	To transition 100% of its steel requirement to net zero by 2040
Acciona	Reduce scope 3 GHG emissions by 47% by 2025
AECOM	Reduce scope 3 GHG emissions from purchased & capital goods by 10% by 2025

Consequently, Europe plans to transform its supply chains

BF/BOF + EAF → By ~2030s → **DRI/HBI** + EAF → By ~2040s → **H_2-fuelled DRI/HBI** + EAF

Use CO_2 productively or make current processes **more efficient**

Incrementally lower CO_2

Bridge technology: Replace BF with DRI/HBI fuelled by **natural gas** and partly **H_2**

-30%

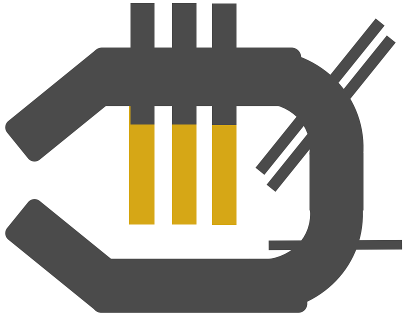
New base technology: DRI/HBI fuelled by by **sustainably produced H_2**

-95%

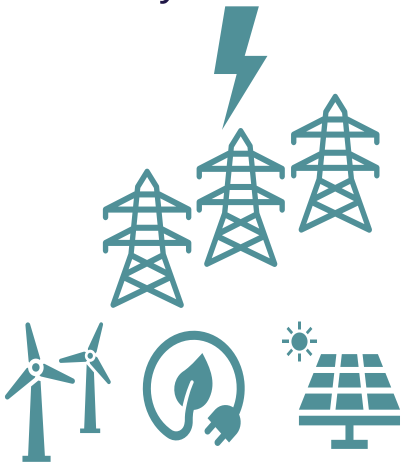
DATA: CRU

However, the industry faces multiple challenges in achieving this

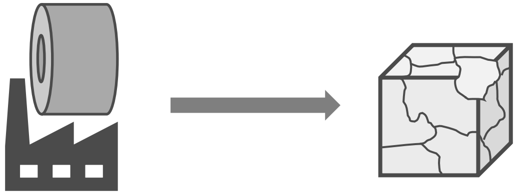
1 **DR-grade pellet supply:** is small and there are limitation in the use of lower material

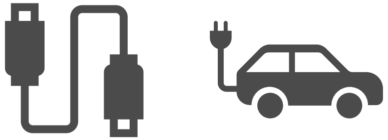


3 **Energy infrastructure is insufficient:** Europe is already net short energy and carbon neutral sources are in their infancy.



2 **Prime scrap supply:** is not expected to grow with demand, particular as increasing alloy content makes recycling more difficult

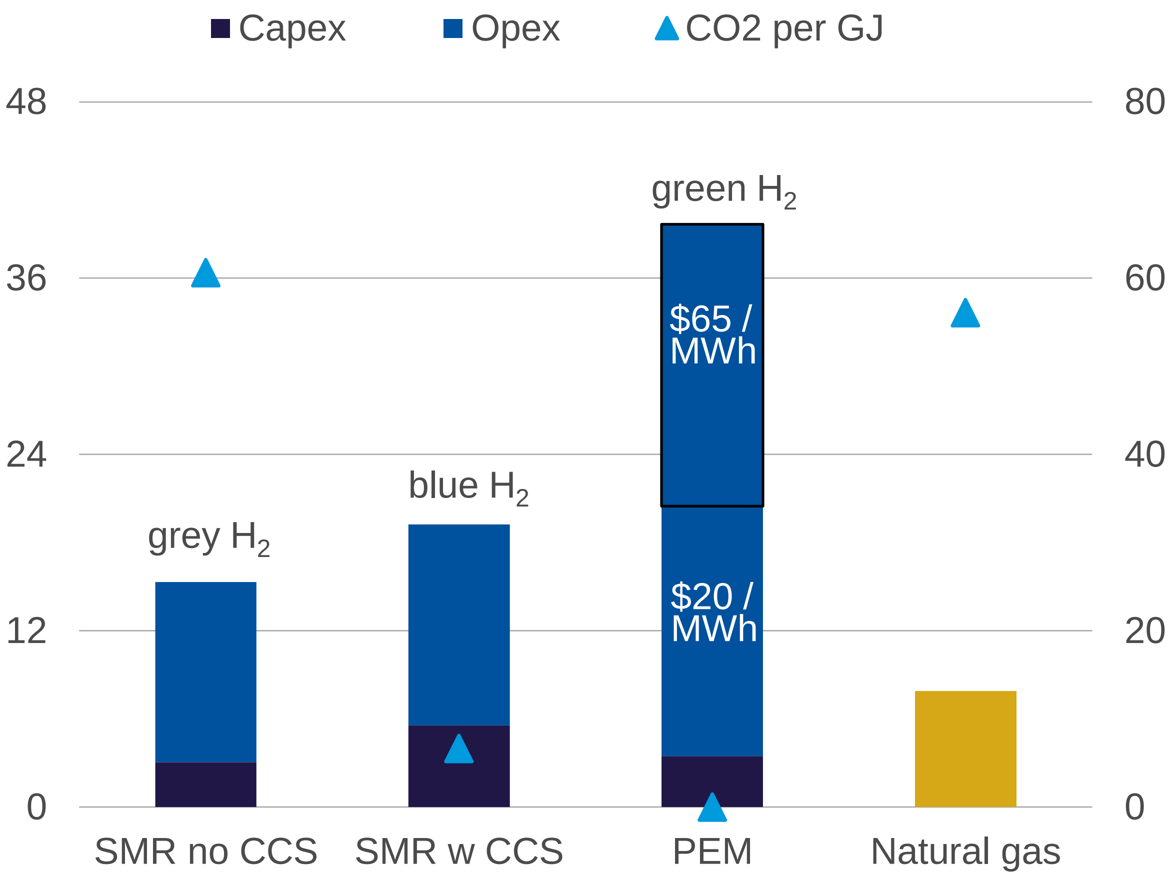




Other demand for energy: such as EV will compete for electricity supply.

Green hydrogen is a very high-cost reductant relative to natural gas

LHS: EU levelised cost of H_2 and natural gas price, real 2019$, $/GJ
RHS: CO_2 intensity of fuel, kg-CO_2/GJ (▲)



- The lowest cost route for producing hydrogen is currently 'grey' hydrogen, utilising natural gas, or coal gas, with no carbon capture and storage. If steel was produced using 'grey' hydrogen, there would be little difference in the finished steel in terms of emission intensity.
- Operating costs are the largest cost driver in the production of hydrogen.
- The generation of 'green' hydrogen is achieved via electrolyzing water with renewable electricity. In 'green' electrolysis processes, such a Proton Exchange Membrane (PEM), the electricity price drives the operating costs and in 'grey/blue' – Steam Methane Reforming (SMR) – natural gas prices drive the operating costs.
- 'Green' hydrogen is currently more than double the cost of 'grey' hydrogen.

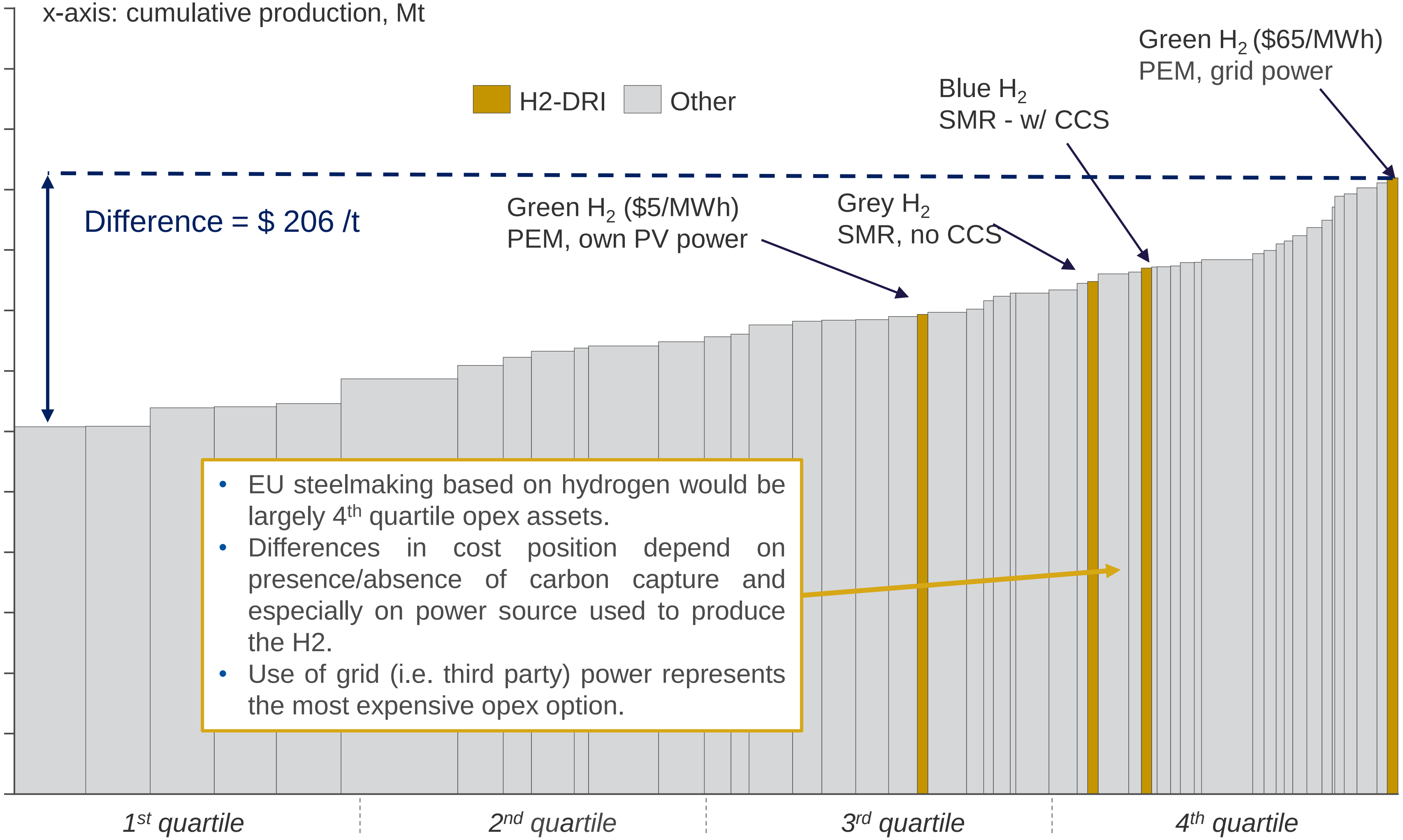
DATA: CRU. Note: CCS capex. and opex. for blue H_2 represents flue gas amine scrubbing. PEM capex includes electrolyser only and opex. assumes renewable power supply at $20 /MWh and $65 /MWh for comparison.

European hydrogen steelmaking projected to be largely 4th quartile

European steelmakers cost curve (2025)

y-axis: EU liquid steel costs (CO_2 costs removed), 2025, $/t

x-axis: cumulative production, Mt



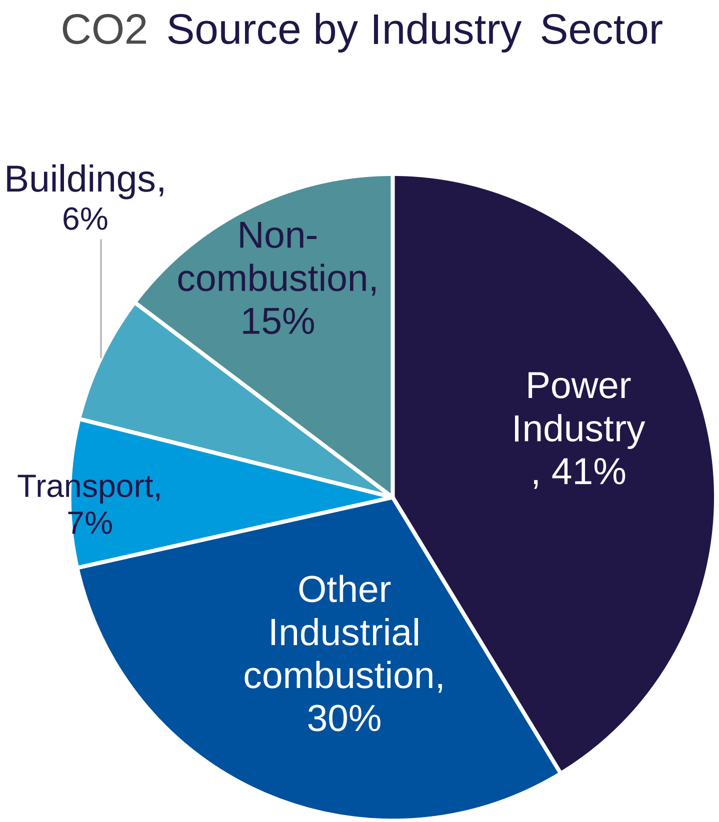
- EU steelmaking based on hydrogen would be largely 4th quartile opex assets.
- Differences in cost position depend on presence/absence of carbon capture and especially on power source used to produce the H2.
- Use of grid (i.e. third party) power represents the most expensive opex option.

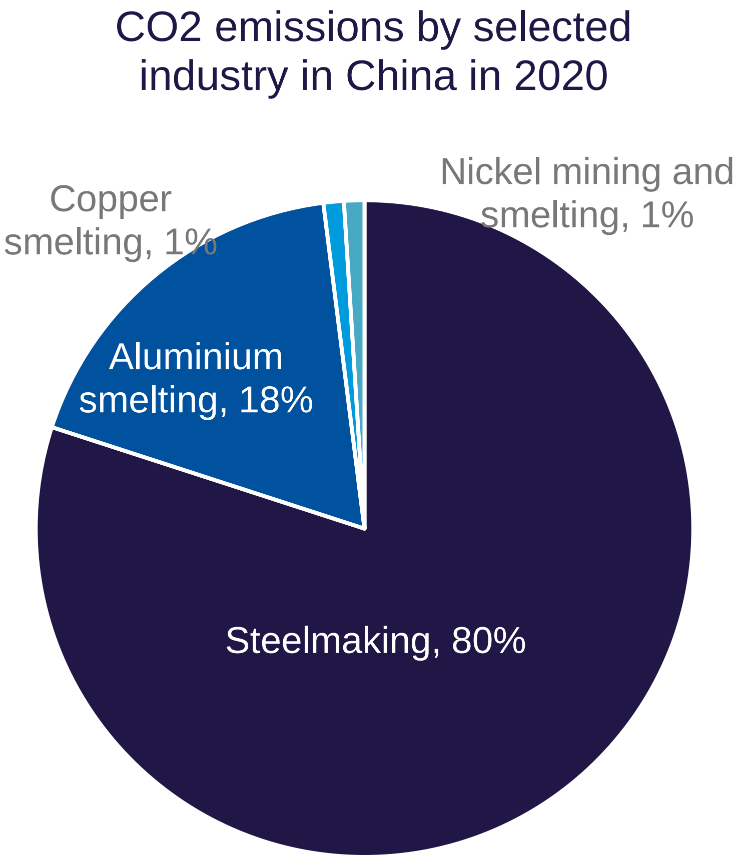
- **European H-DRI plants are forecast to sit largely in the 4th quartile** of the cost curve in the medium-term.
- **Cheap power** could enable more **competitive operating costs** of hydrogen-based technology, however this would most likely indicate that the power is **captive**. There are **associated capex implications** with owning the power source.
- For a steel producer sitting in the bottom of the 1st quartile of the cost curve, they will require an **incentive** to lift their operating cost by ~$200/t to invest in carbon reducing breakthrough technology operating in the 3rd or 4th quartile.
- Supportive policies such as carbon tariffs, low renewable power costs and access to funding will be key to encourage the adoption of green hydrogen.

DATA: CRU Steel Cost Model

China net zero

Xi's big announcement implies challenge for coal, power & industrials





SOURCE: CRU, CO_2 Emissions Worldometer, Global Carbon Project, figures shown are for 2016 unless stated

Net Zero commitment marks a step change in Chinese energy policy…

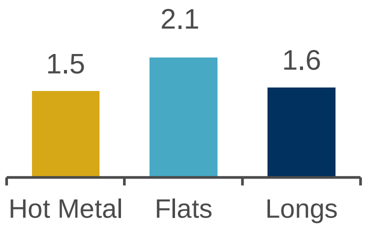
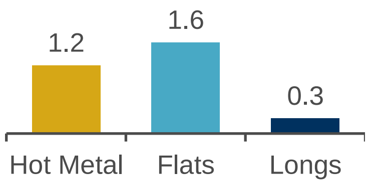
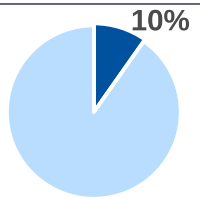
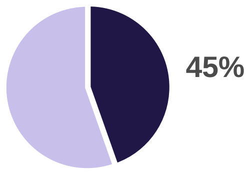
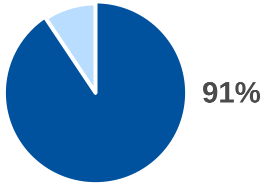
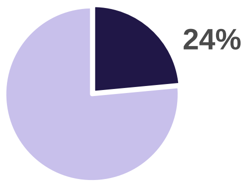
China's Five-Year Plans	Ambitions	Results	Enablers
11th Five-Year Plan 2006-2010	**20%** ↓ energy intensity	**19.1%** ↓ energy intensity	- **Top-1,000 / Top-200 programme** - **10 "key projects" subsidies** - **Capacity retirement programme**
12th Five-Year Plan 2011-2015	**17%** ↓ in carbon intensity **16%** ↓ in energy intensity **11.4%** non-fossil energy share	**20%** ↓ carbon intensity **18%** ↓ energy intensity **12.1%** non-fossil share	- **Top-10,000 programme** - **Capacity retirement programme** - **Energy Conservation Technology Fund**
13th Five-Year Plan 2016-2020	**18%** ↓ in carbon intensity **15%** ↓ in energy intensity **15%** non-fossil energy share	**18.2%** ↓ in carbon intensity by **2019** **15%** ↓ energy intensity by **2019** **15.3%** non-fossil share in **2019**	- **Top-10,000 programme** - Restructuring of coal fired power - Flexible gas capacity & infrastructure build out - Renewable offtake guarantees - Nuclear/ hydro build out - **ETS pilots**
14th Five-Year Plan 2021-2025	**18%** ↓ in carbon intensity **13.5%** ↓ in energy intensity **20%** non-fossil energy share		- **Energy structure adjustment (renewable uptake)** - **National ETS + ETS pilots** - **NEV + Recycling + CCUS**

…but China has generally overachieved previous energy and climate goals

Key: Exceed/Just missing/ miss target

Significant differences in challenges faced by China vs Europe

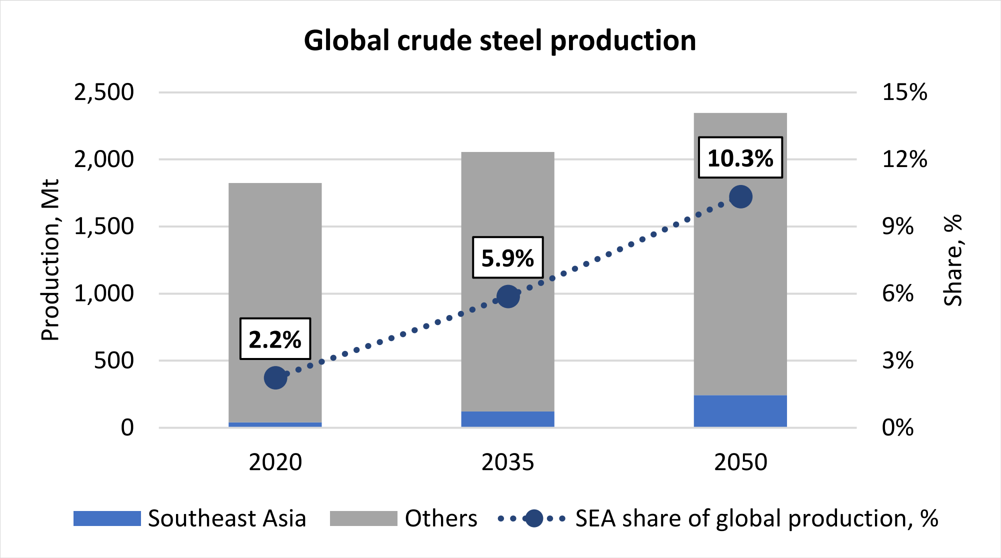
- The average CO_2 intensity of Chinese steel is far above European levels, due to the dominance of BOF steelmaking, less efficient blast furnaces and low BOF scrap rates.
- Large emissions reductions can be achieved through China's ongoing shift to higher BF productivity and scrap-EAF steelmaking, though these changes will not be sufficient to achieve long-term net zero goals.

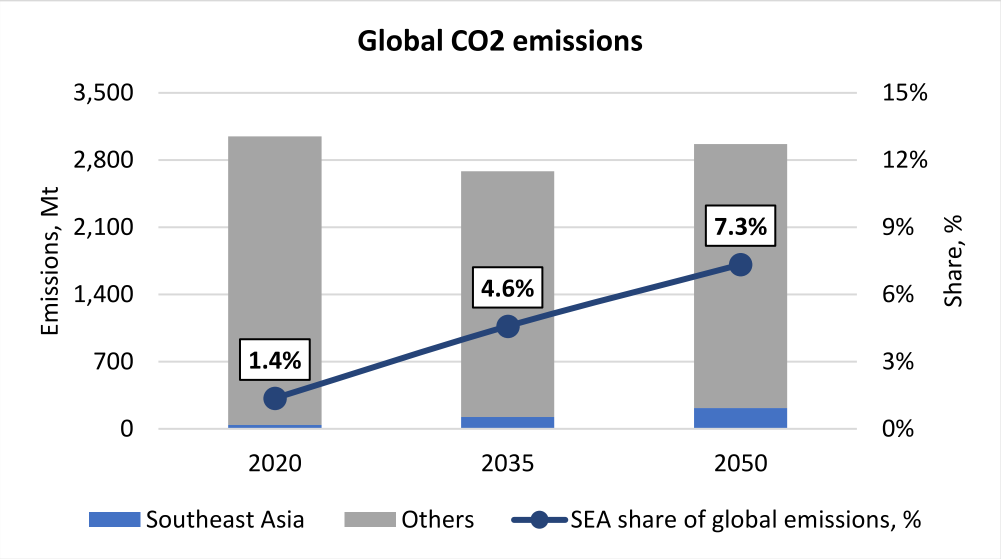
2020 status	China	Europe	Impact
Steel CO_2 emissions intensity, tCO_2/t			• Significant CO_2 reductions can be achieved if China adopts current Best in Class operating parameters with existing BF fleet, e.g. by improving iron ore burden and reducing coke rates. • In Europe, many plants are near technical limits for efficiency, meaning new technology has to be adopted to achieve significant emission reductions.
EAF share, %			• Initial shift to EAF in China will be driven by long products production which can rely on lower quality iron units (scrap); adoption of ore-based metallics (pig iron, DRI) for EAF flat products production likely to occur later than in Europe.
Met. coal self sufficiency, %			• China's large domestic coal sector means there will be greater pressure to retain some coal-based steelmaking, either through BOF+CCS or coal gasification. • In Europe, anti-coal sentiment has stifled CCS projects.

So what for SE Asian steel industry?

SE Asia will account for 24% of growth in steel production outside China by 2050….

- Increase in SE Asian crude steel production of 202mt by 2050 (vs 522mt net growth globally)
- Increase in annual CO_2 emissions of 177mt over the period (vs net *reduction* of 80mt globally)



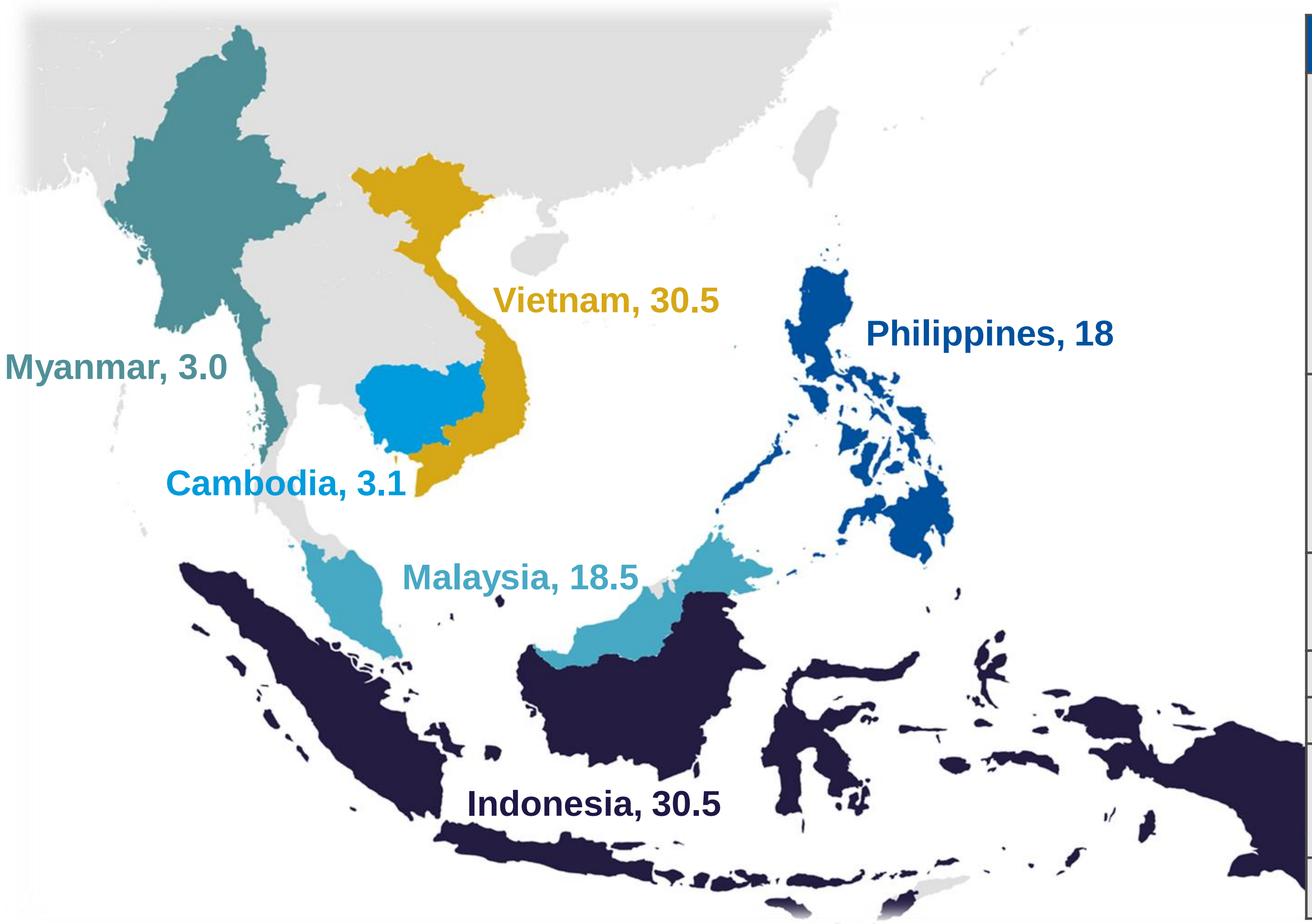


…with 18% of growth in CO_2 emissions (outside of China) to come from SE Asia by 2050

DATA: **CRU Consulting Crude Steel and Emissions Model**

Steel mills in SE Asia largely funded by China…

Proposed, committed and operational mills in Southeast Asia, **~67 Mt of which are Chinese-funded**



Country	Capacity (Mt)	Operator	China funded
Indonesia	1.5	Hebei Bazhou Xinya Steel	
	1.0	Gunung Group	
	3.0	Shenwu Steel	
	3.5	Dexin Steel	
	6.0	Hebei Bishi	
	5.0	Krakatau Steel/POSCO	
	10.5	Shanxi Industrial Complex	
Malaysia	2.0	Eastern Steel/ Shougang	
	3.0	Megasteel	
	3.5	Alliance Steel	
	10.0	Xin Wu'an/Wenan Steel	
Philippines	8.0	HBIS	
	10.0	Panhua Group	
Cambodia	3.1	Baowu Steel	
Myanmar	3.0	Kunming Steel	
Vietnam	1.5	Pomina Steel	
	7.0	Hoa Phat - Dung Quat	
	22.0	Formosa Ha Tinh	
Total	**104**	**(65% China-owned)**	

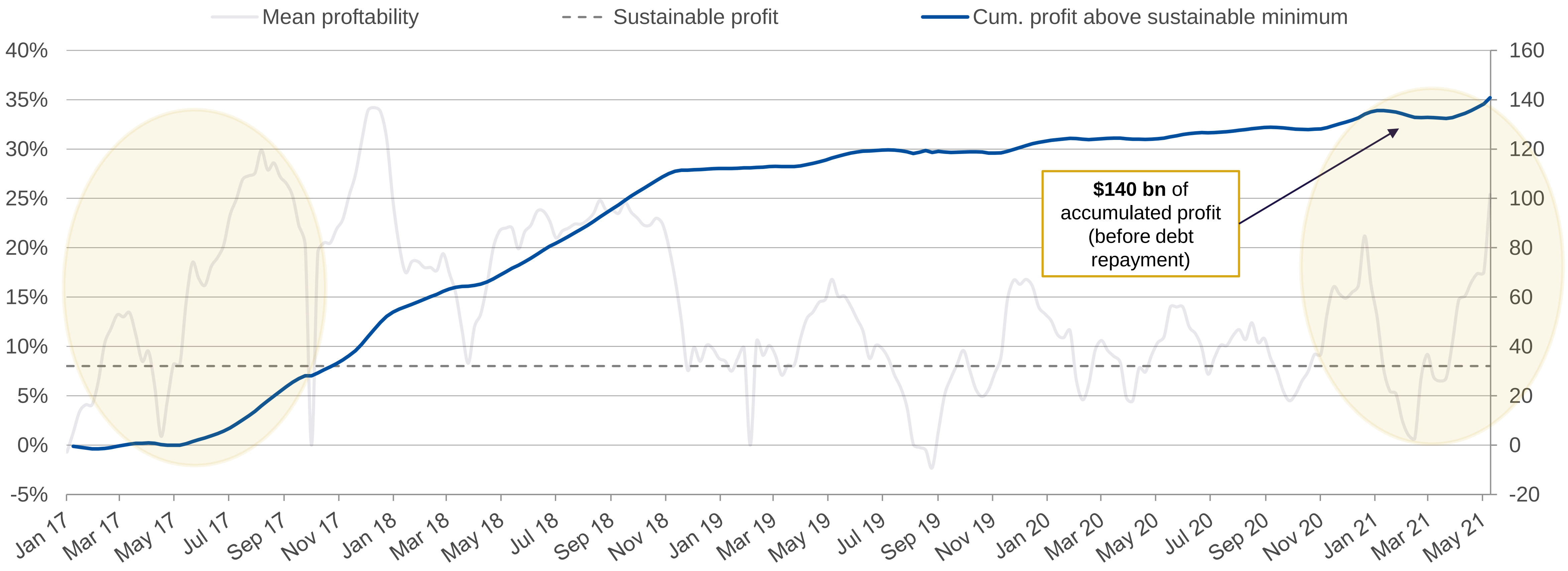
DATA: **CRU Steel Capacity Database**

Supply-side reform has allowed Chinese steel sector profitability to lift

China steel has accumulated up to $65 bn after debt payment of $75 bn, but cannot spend domestically

Cumulative profits above sustainable minimum have reached $140 bn (before debt repayment)

LHS: EBITDA profitability; RHS: accumulated profit above sustainable minimum, $ bn

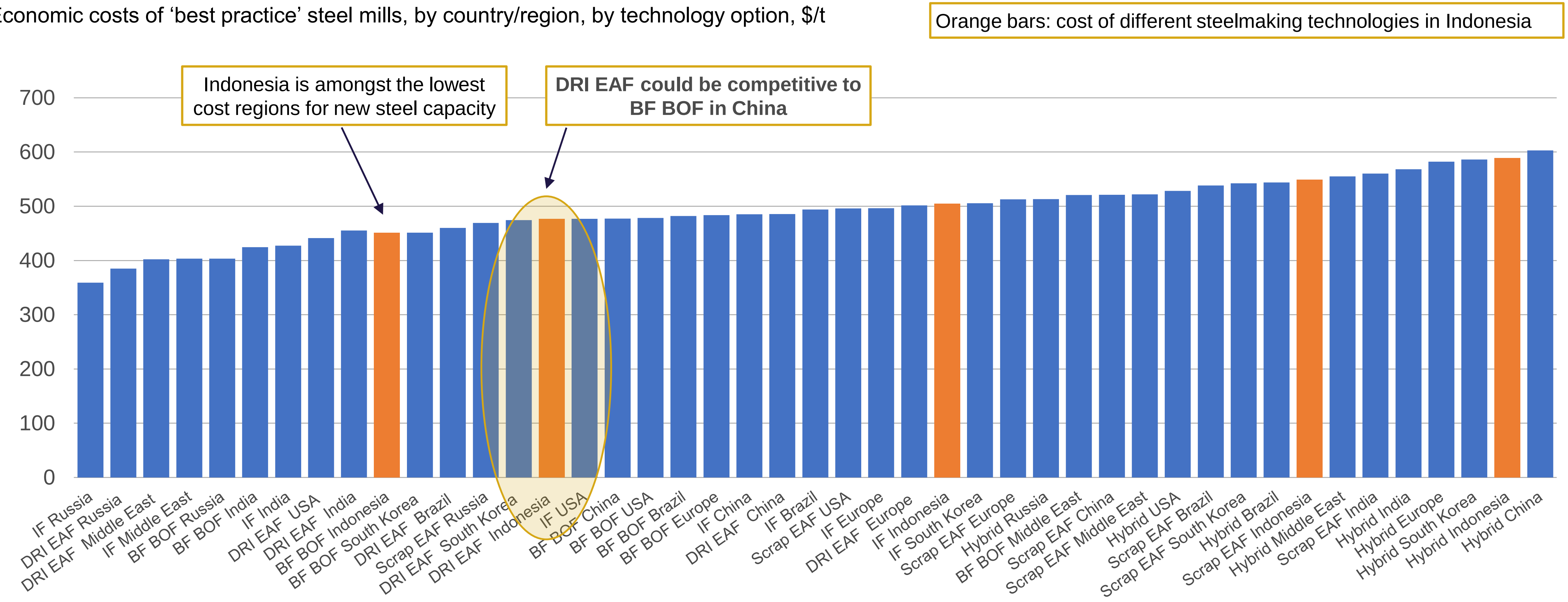


DATA: **CRU Steel Cost Review**

Indonesia, and SE Asia in general, is a low-cost area to build steel mills

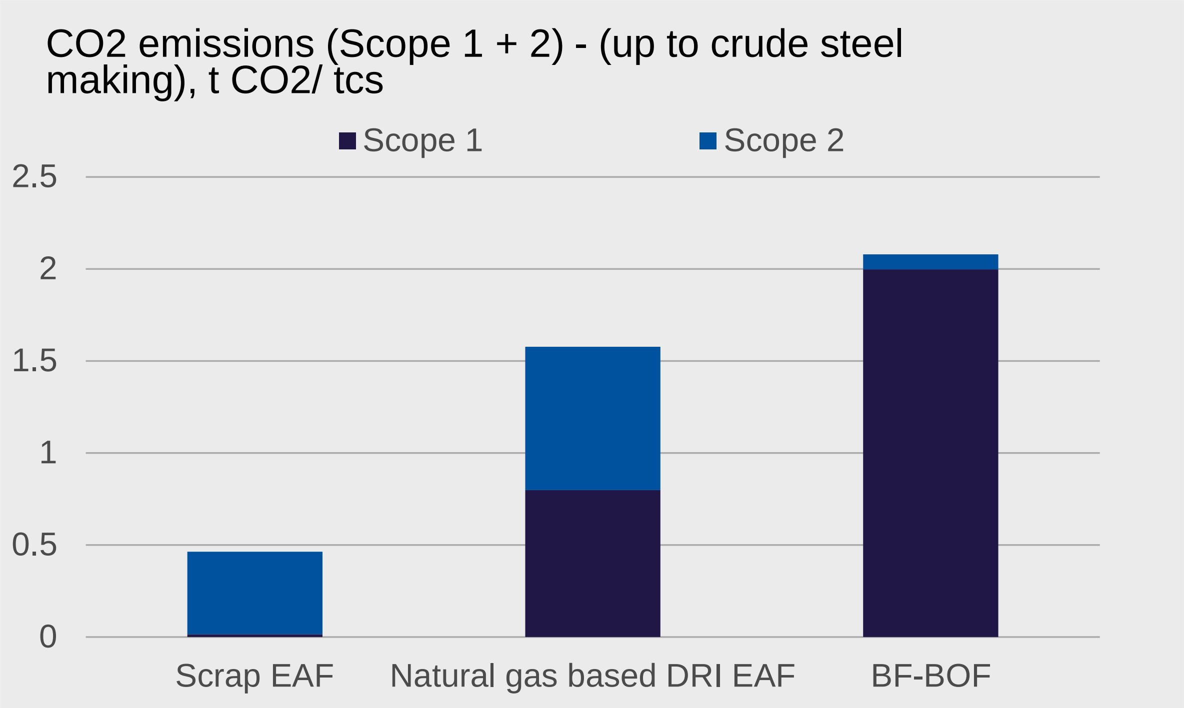
For projects yet to be committed to there are technology choices to be made

Economic costs of 'best practice' steel mills, by country/region, by technology option, $/t



DATA: **CRU Steel Cost Model**

Adoption of DRI/EAF technology could save up to 99mt of future CO_2 emissions from the region…



- Natural gas based DRI EAF offers opportunity to reduce emissions by 0.5t CO_2 per tcs (24% reduction).
- EAF powered by 100% renewable energy offers opportunity to reduce emissions by a further 0.78t CO_2 per tcs (62% reduction overall).
- Pathway to near carbon free steel production with switch to hydrogen reduction in future.

…a 56% reduction vs CRU 'base case'.

Summary – Europe and China

- Decarbonisation is here to stay – targets announced in most of the key steelmaking regions across the world, including China.

- Policy instruments most advanced in Europe – carbon pricing, EU Emissions Trading Scheme and pending Carbon Border Adjustment. EU Green Deal signals tougher emissions cuts ahead.

- Increasing pressure and interest from steel consumers.

- Pathways to significantly reduce or eliminate carbon from steel making do exist BUT…
  - Significant challenge with respect to scale (of legacy assets) and transition costs (capex)
  - As yet not fully proven technology at commercial scale
  - Pressures on other parts of the value chain eg DR grade pellet supply, availability of prime scrap etc.
  - Dependency on adjacent industries undergoing their own transition eg Power generation, hydrogen infrastructure.

- Current estimates suggest carbon price in Europe needs to be c.$200/t to make hydrogen steel making economic, all other things being equal.

- Challenge in China different to those is Europe with significant opportunity to increase scrap based EAF share of steel make

Summary – SE Asia

- SE Asia set to increase CO_2 emissions by 177mtpa by 2050. Most new capacity planned / committed to be BF/BOF.

- For projects planned but not yet started, there is an opportunity to ‘design out’ emissions by considering alternative steelmaking technology to BF/BOF.

- Adoption of DRI EAF (with renewables) could reduce CO_2 emissions by c.99mtpa – a 56% reduction vs CRU’s base case.

- Sponsors of new capacity in the region perhaps have an obligation to minimise the increase in CO_2 emissions in the region – not just a ‘moral’ obligation but also out of self interest? Other regions / countries that make significant steps to decarbonise their steel industries (eg China) will also protect against carbon leakage through border adjustments / taxes.

- SE Asia is set to be a net exporting steel producing region in the long term. Its future competitiveness will be a function of both production costs and CO_2 emissions.

- Acting now could save transition costs down the line.

Thank You!

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