Steel decarbonization

The scale of the challenge

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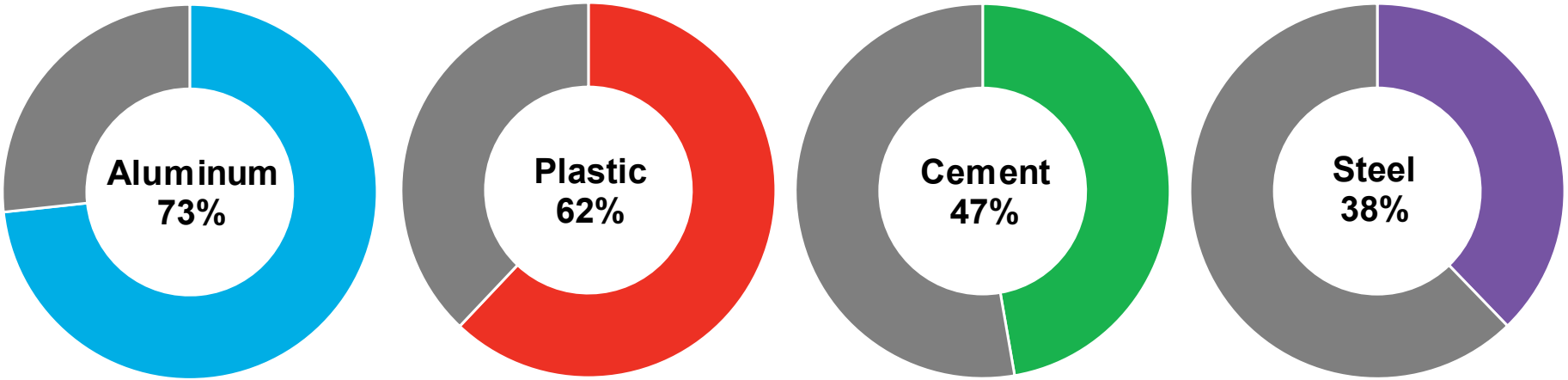
BloombergNEF

The state of the industry

Steel was an early mover in decarbonization, but others have now made major commitments

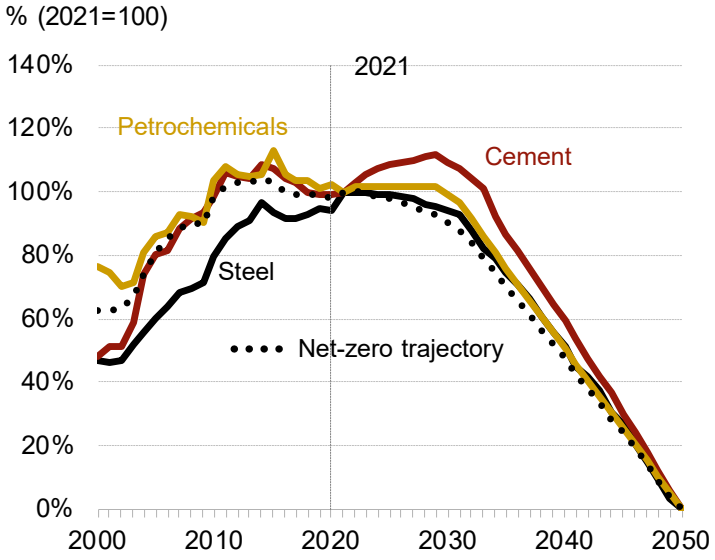
Tracked capacity covered by a corporate net-zero target, by material (Jan 2023)

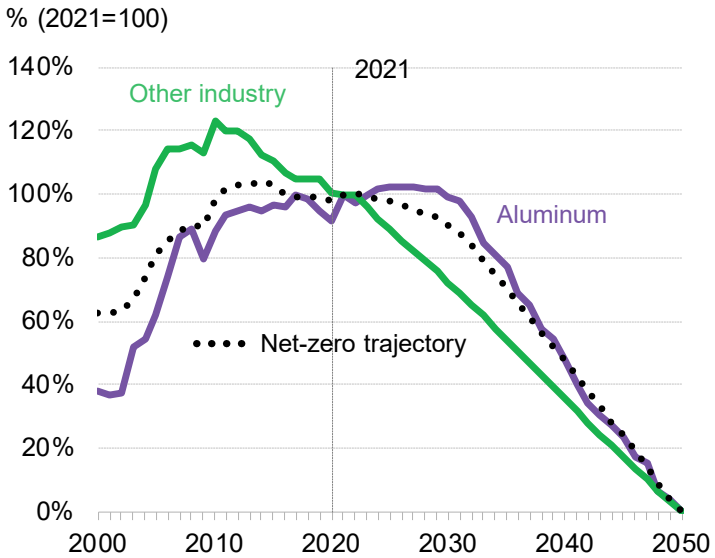


Source: BloombergNEF. Note: Plastics include polyolefins and PET.

Steel is still expected to decarbonize faster than its peers

Direct CO2 emissions by sector relative to 2021





Source: BloombergNEF

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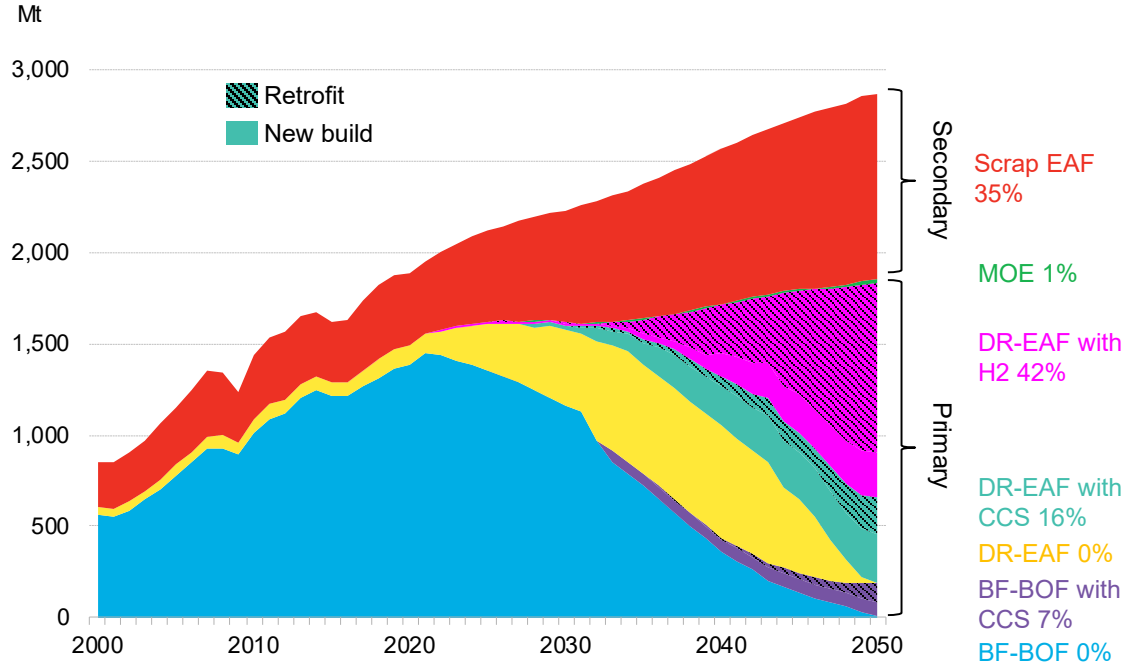
Steelmaking will shift to direct reduction and electrification

Global steel production for net-zero, by process



Source: BloombergNEF. Note: Mt is million tons, MOE is molten oxide electrolysis, DR-EAF is direct reduction paired with an electric arc furnace, BF-BOF is a blast furnace paired with a basic oxygen furnace. Percentages may not sum to 100% due to rounding.

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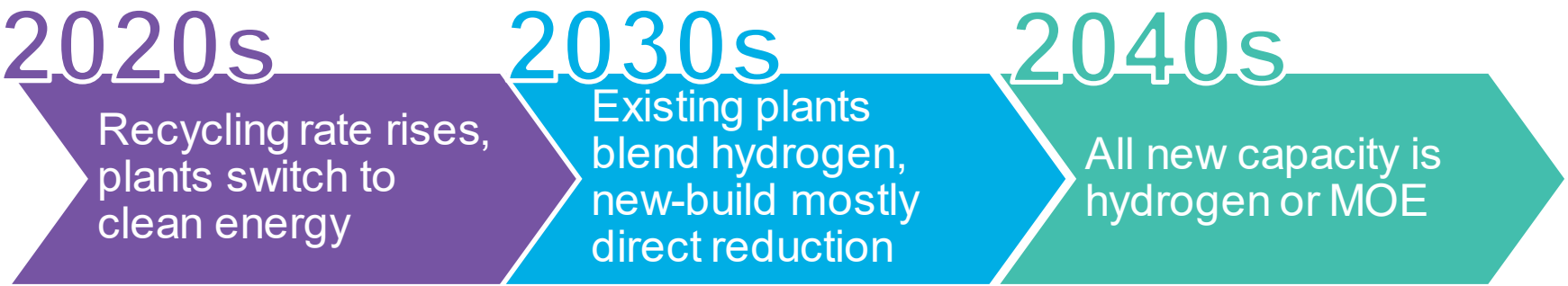
Changes need to happen right away

Transformation pathway for the steel sector

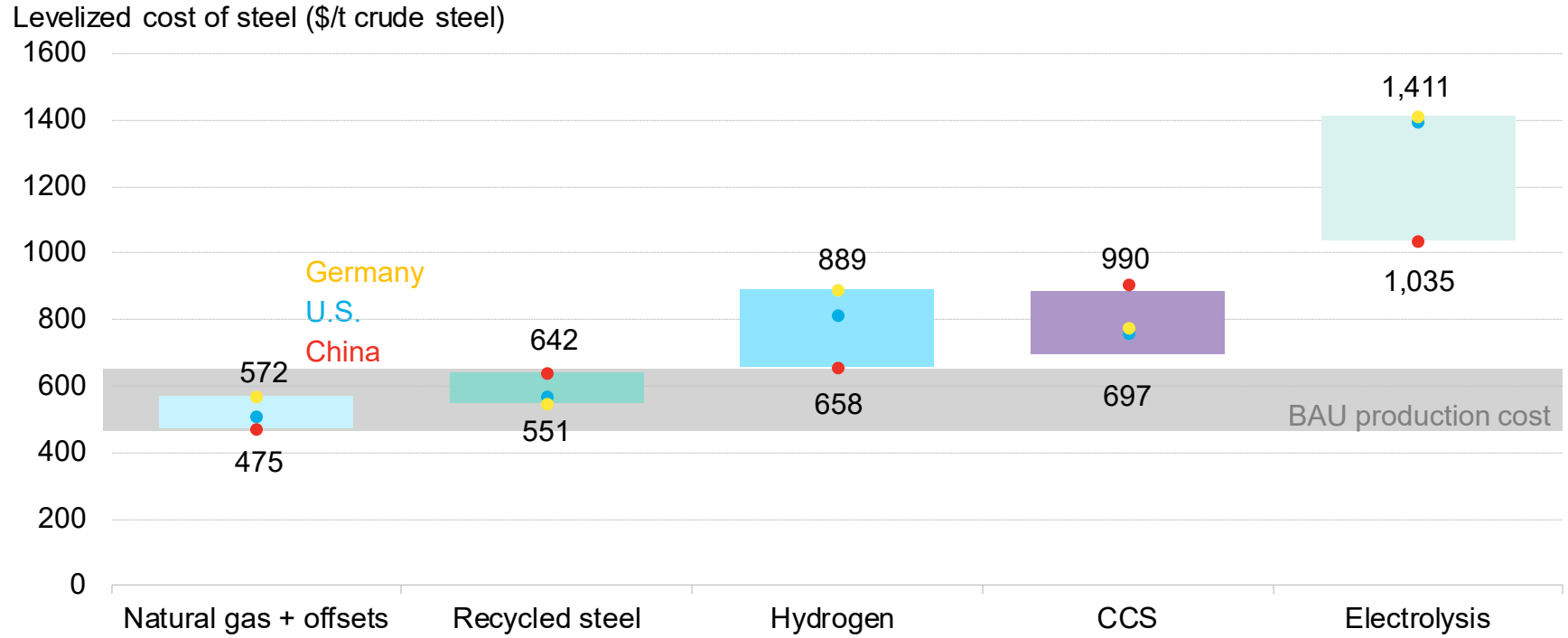


Source: BloombergNEF

Recycling and hydrogen lead the way

Net-zero steel costs are high for now

Cost of net-zero steel, by technology, 2021



Source: BloombergNEF

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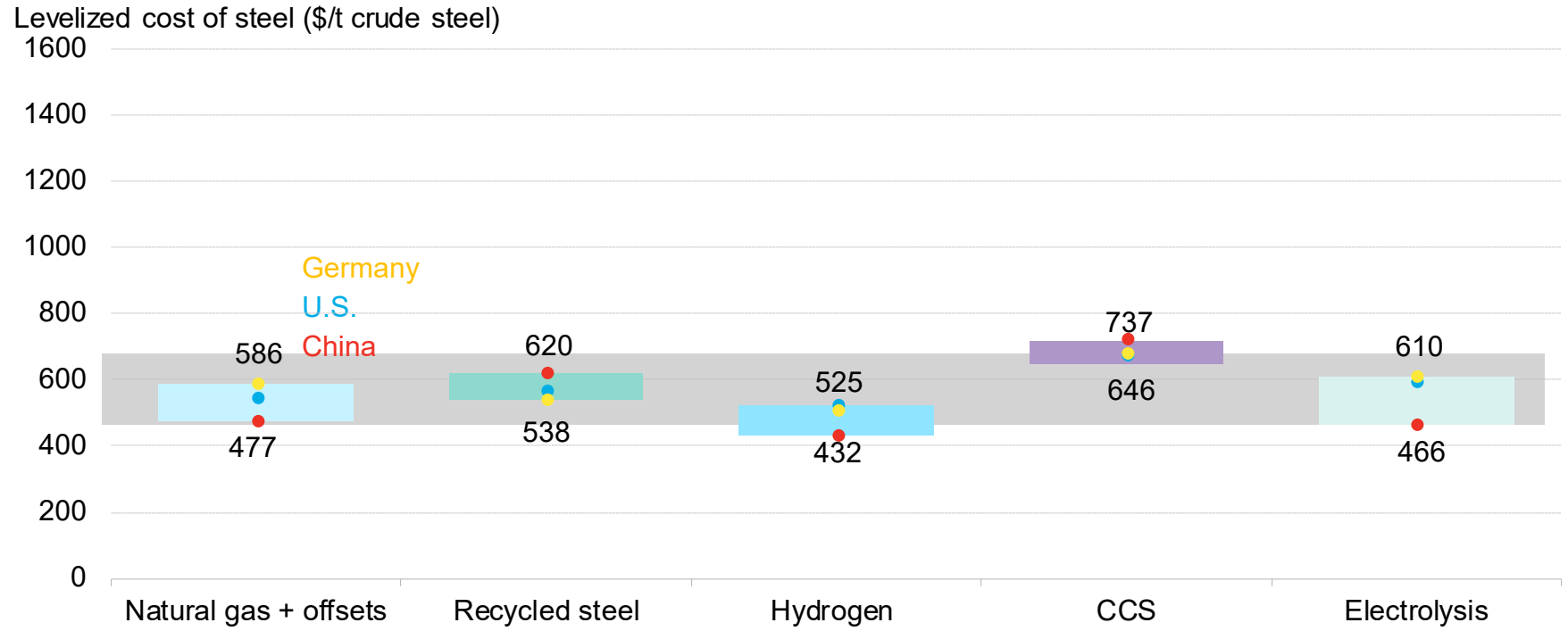
But could be competitive by 2050

Cost of net-zero steel, by technology, 2050



Source: BloombergNEF

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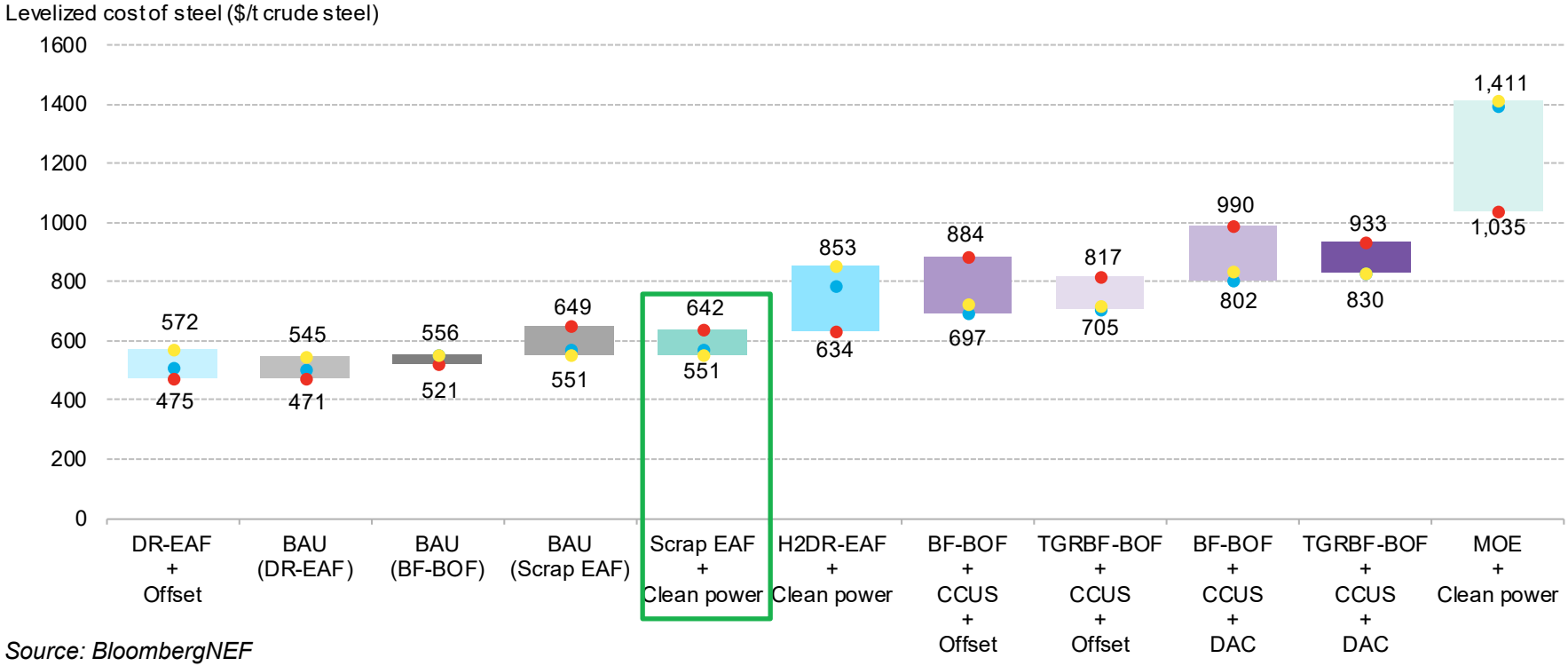
Net-zero production options

Levelized cost of steel, 2021

Recycling



Source: BloombergNEF

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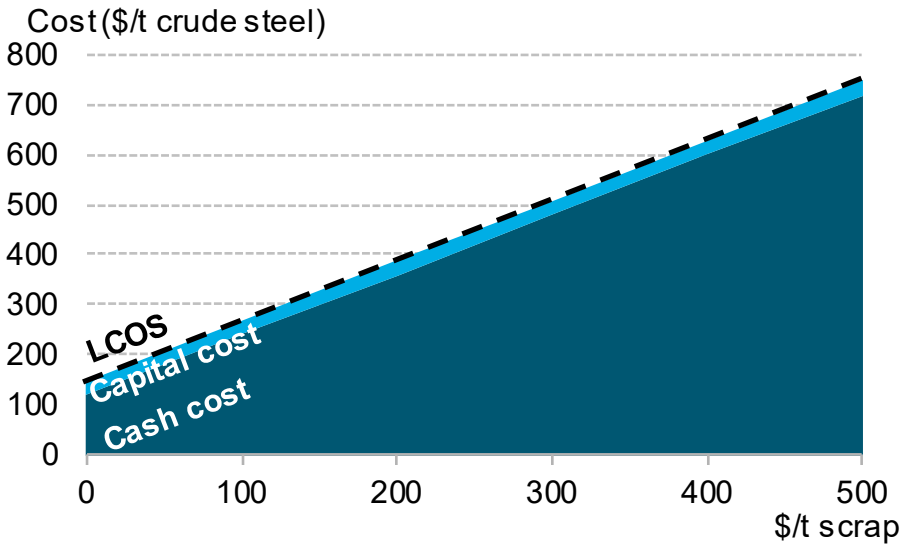
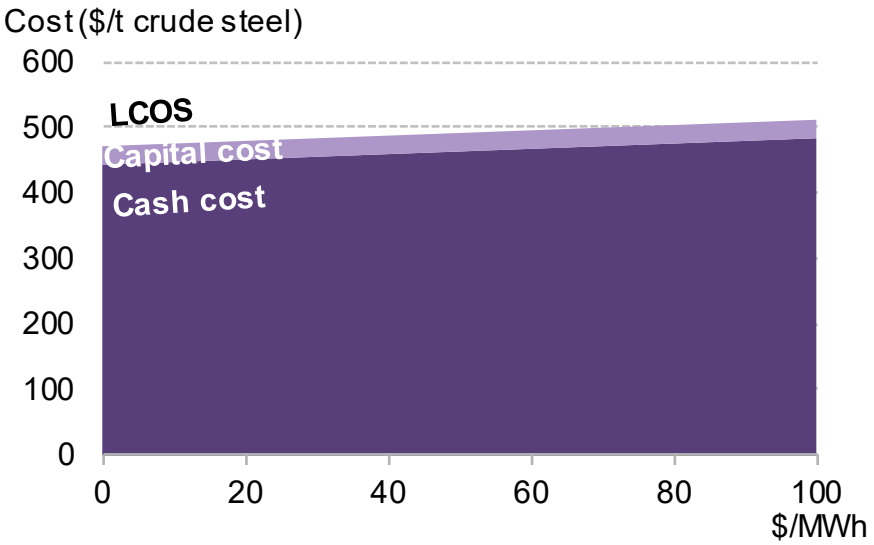
Scrap prices dictate recycled steel costs

LCOS of net-zero recycling over scrap prices, U.S. 2021



LCOS of net-zero recycling over renewable electricity prices, U.S. 2021



Source: BloombergNEF

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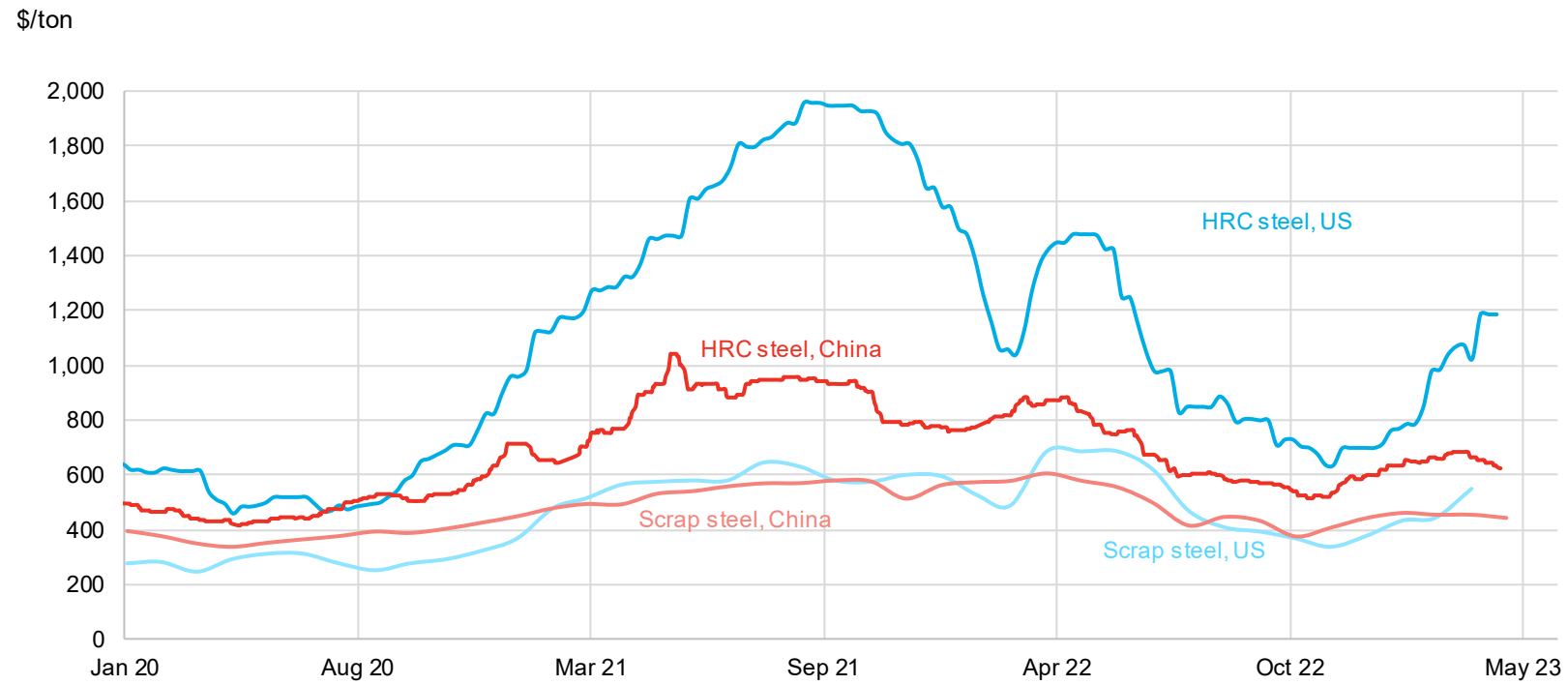
Steel scrap is following the super-cycle

Steel scrap and virgin price change since January 2020



Source: BloombergNEF, Kallanish, Scrap Monster, CU Steel

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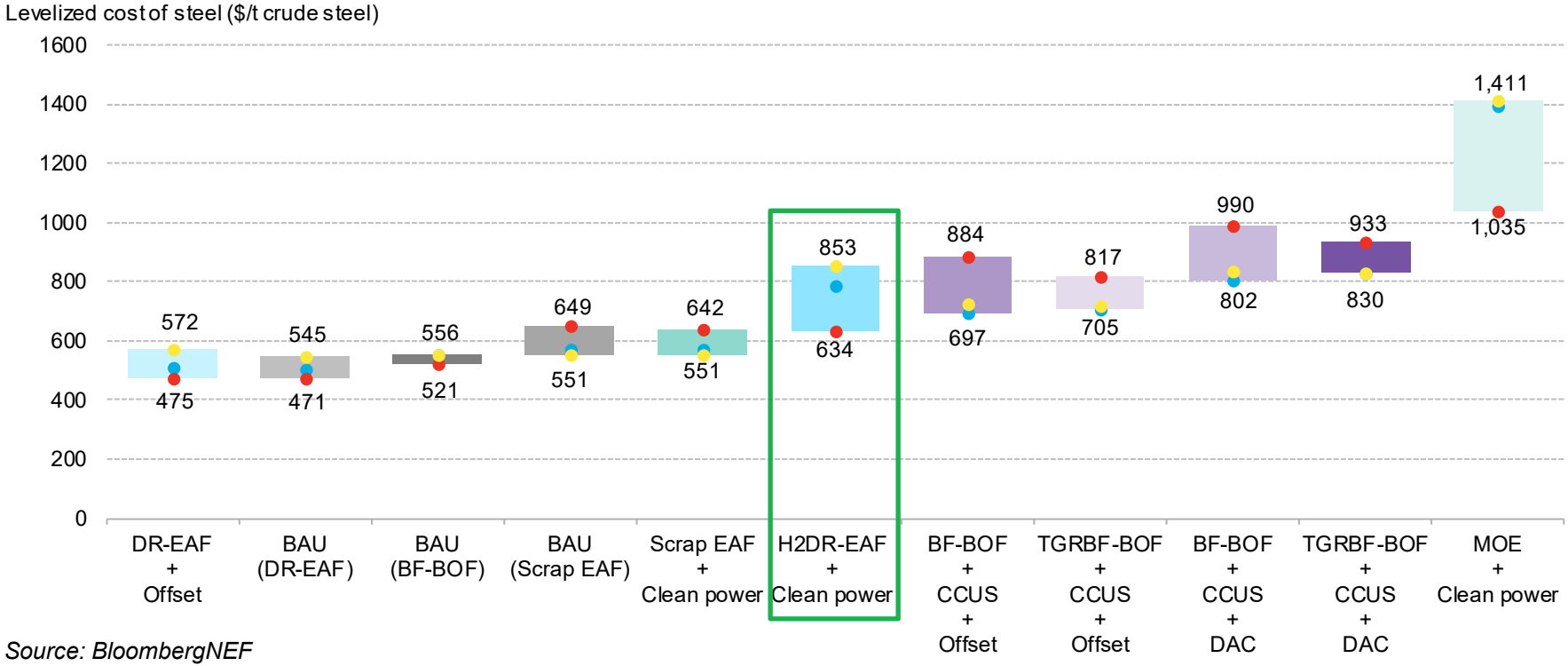
Net-zero production options

Levelized cost of steel, 2021

Hydrogen



Source: BloombergNEF

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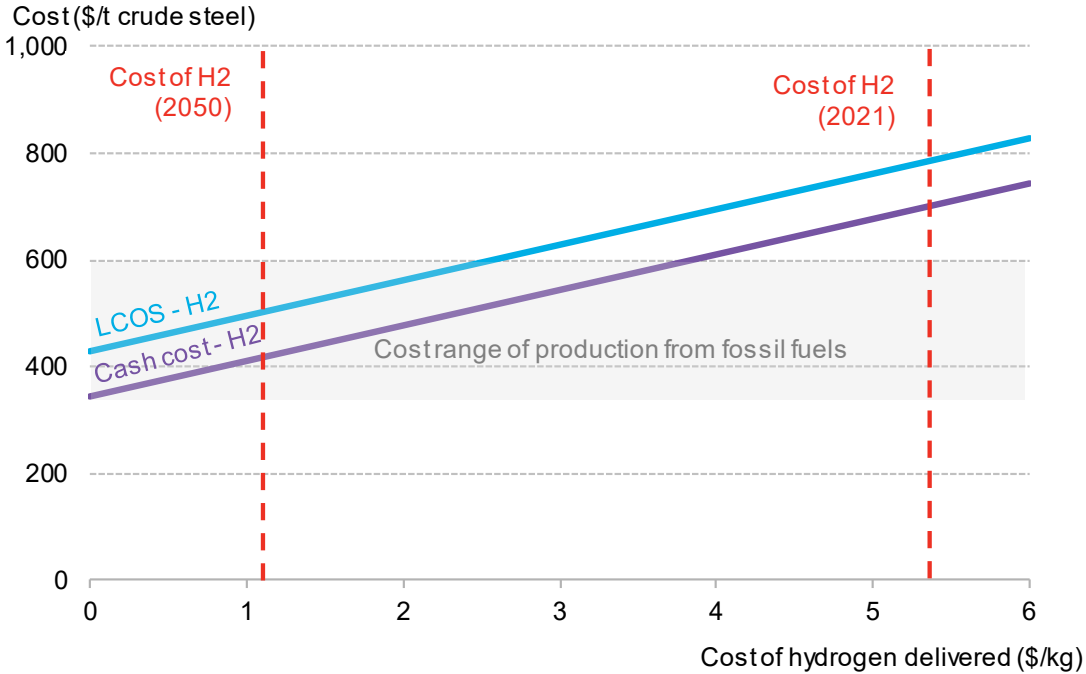
Hydrogen-made steel can compete

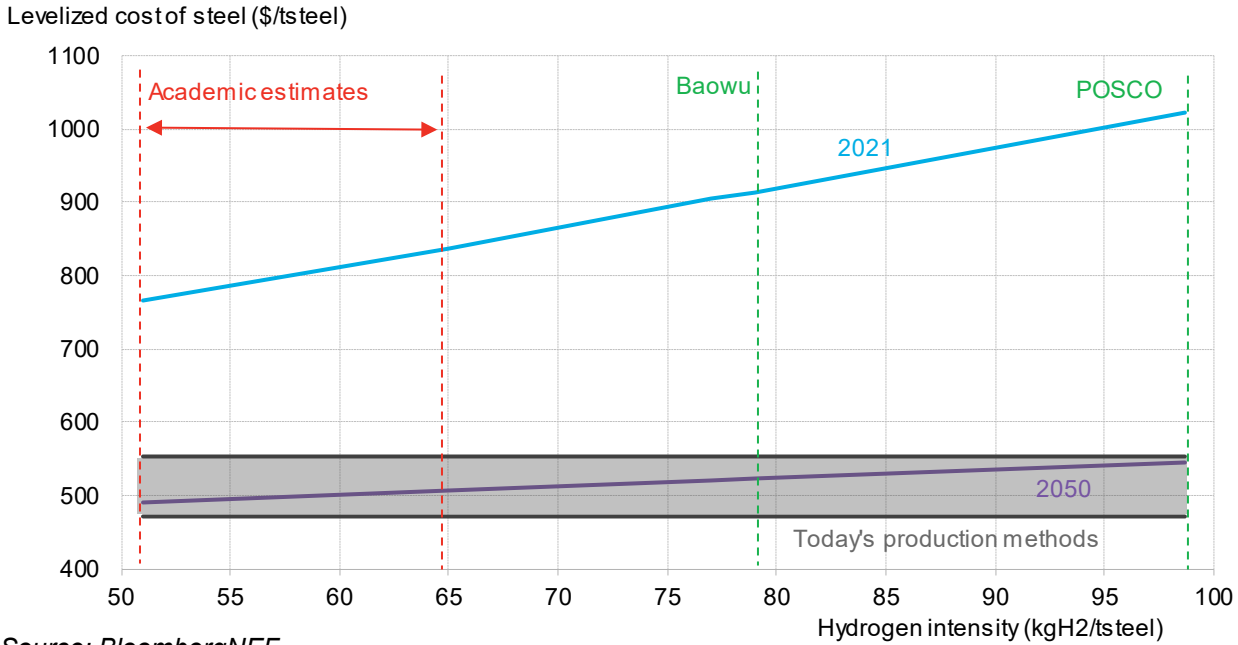
LCOS with hydrogen prices, 2050



Source: BloombergNEF. Note: H2 is hydrogen. Capex, opex and hydrogen price assumptions are based on Germany. For more on our assumptions for LCOS costs for CCUS, see Appendix B. The cost range of production from fossil fuels represents costs for new-build steel plants.

The amount of H2 needed to make steel is the greatest uncertainty

Hydrogen intensity's impact on green steel costs



Source: BloombergNEF

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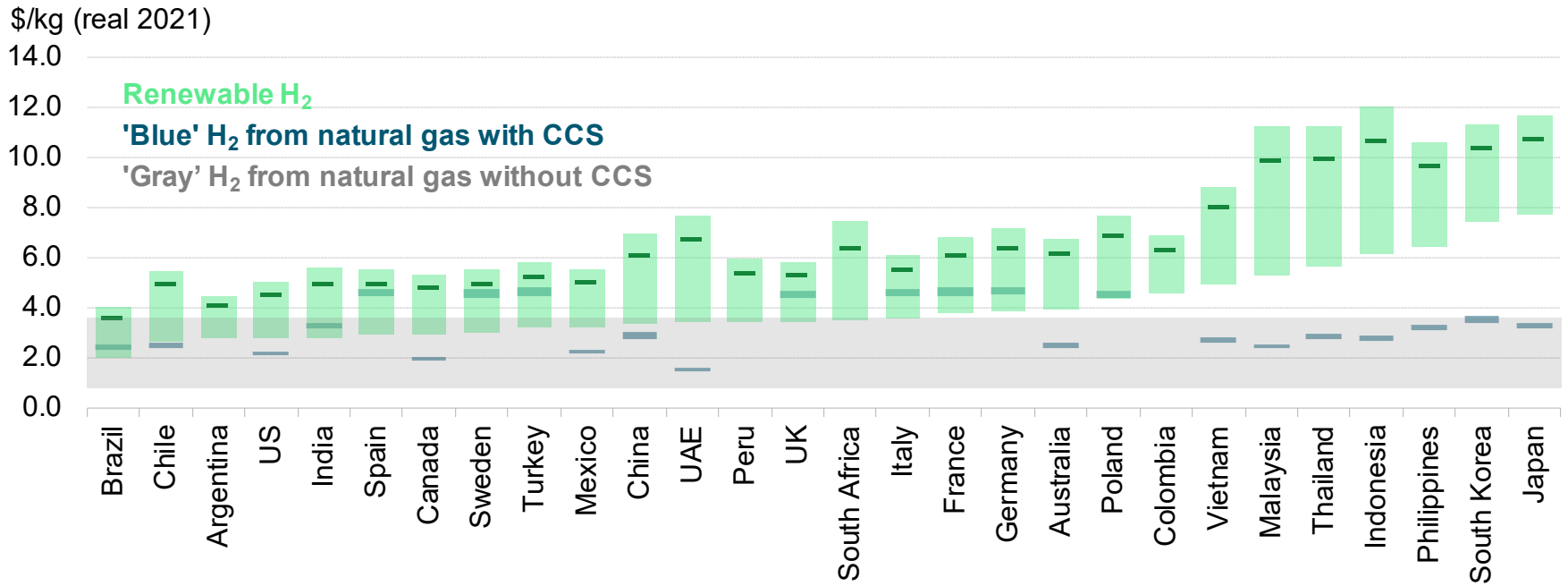
Blue and green are competing today

Global range of green and blue $LCOH_2$ in 25 countries, 2022

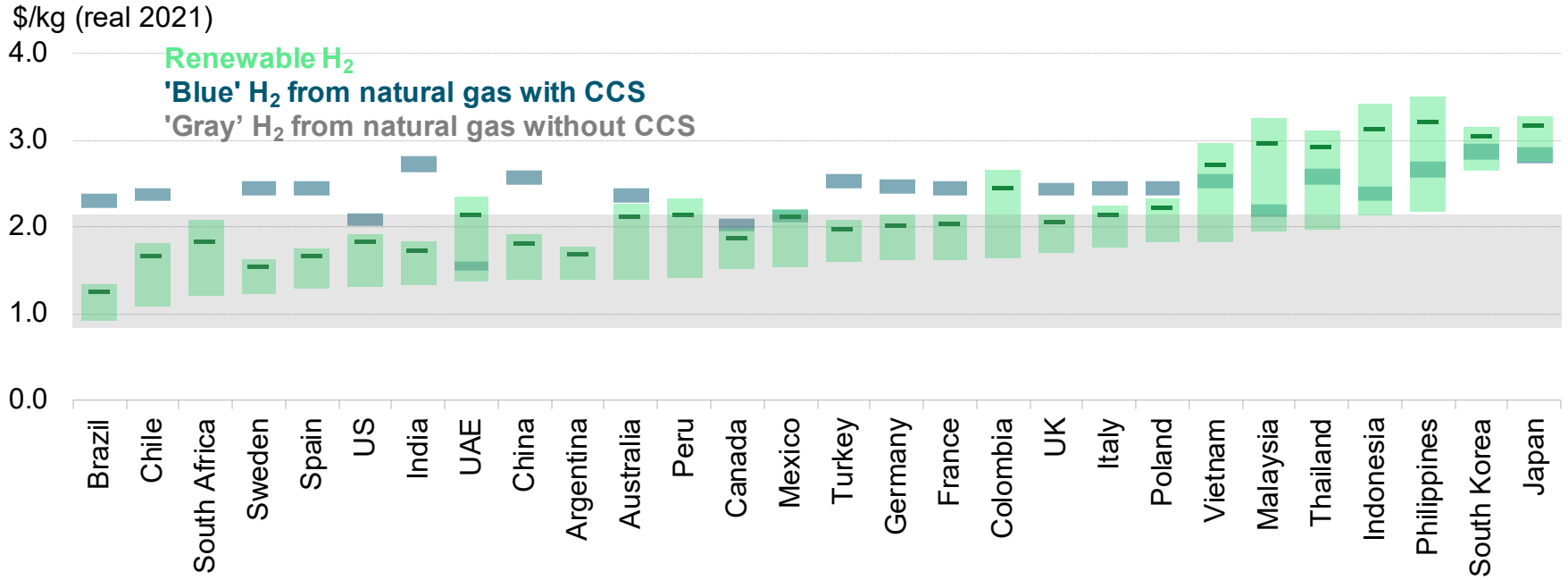


Source: BloombergNEF, NETL. Assumes our optimistic electrolyzer cost scenario. Renewable $LCOH_2$ range reflects a diversity of electrolyzer type, Chinese alkaline (low) to PEM (high). The electrolyzer's electricity is sourced from the cheaper renewable resource. Capital and operational costs for blue hydrogen are sourced from the National Energy Technology Laboratory. Gas prices derived from BloombergNEF's New Energy Outlook (web | terminal). Grid electricity prices assumed at $75 (real 2021) for all modeled markets.

Cost of production

Green overtakes blue by 2030

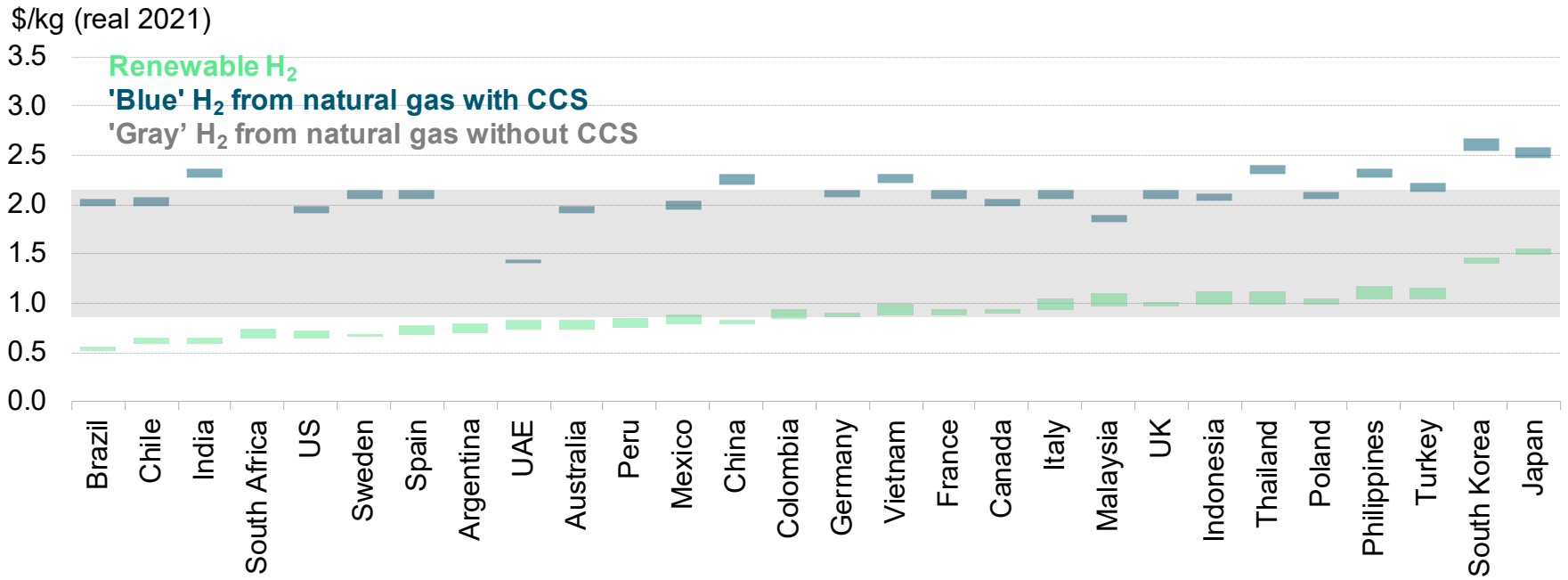
Global range of green and blue $LCOH_2$ in 25 countries, 2030



Source: BloombergNEF, NETL. Assumes our optimistic electrolyzer cost scenario. Renewable $LCOH_2$ range reflects a diversity of electrolyzer type, Chinese alkaline (low) to PEM (high). The electrolyzer's electricity is sourced from the cheaper renewable resource. Capital and operational costs for blue hydrogen are sourced from the National Energy Technology Laboratory. Gas prices derived from BloombergNEF's New Energy Outlook (web | terminal). Grid electricity prices assumed at $75 (real 2021) for all modeled markets.

Green is cheapest in the long run

Global range of green and blue $LCOH_2$ in 25 countries, 2050

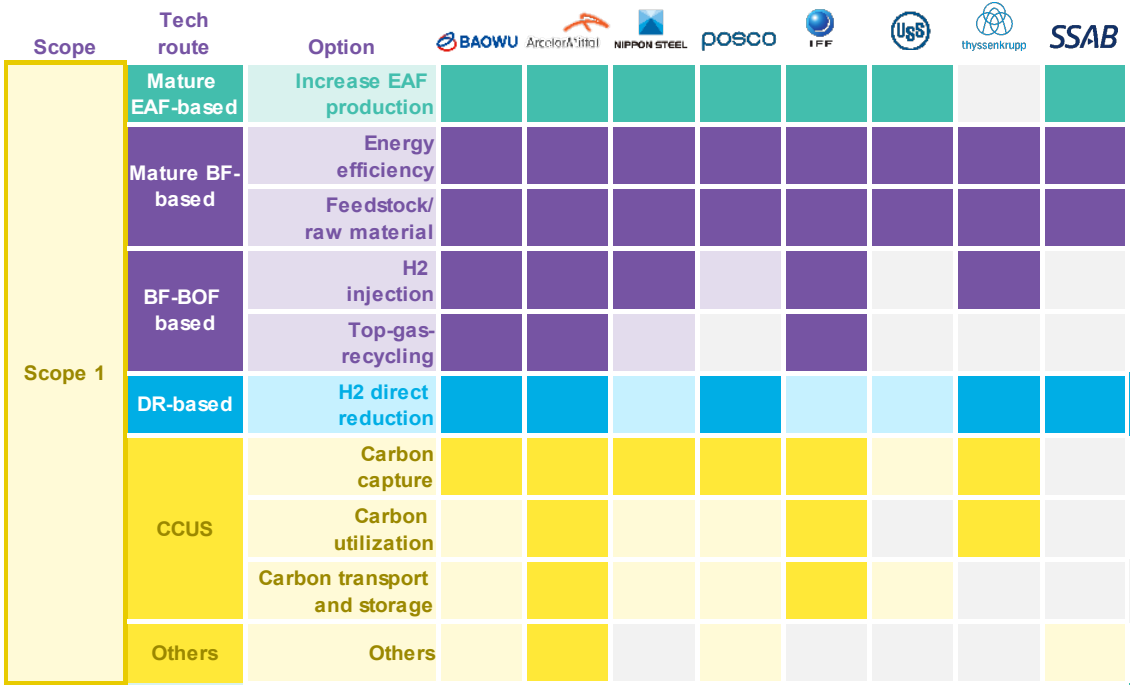


Source: BloombergNEF, NETL. Assumes our optimistic electrolyzer cost scenario. Renewable $LCOH_2$ range reflects a diversity of electrolyzer type, Chinese alkaline (low) to PEM (high). The electrolyzer's electricity is sourced from the cheaper renewable resource. Capital and operational costs for blue hydrogen are sourced from the National Energy Technology Laboratory. Gas prices derived from BloombergNEF's New Energy Outlook (web | terminal). Grid electricity prices assumed at $75 (real 2021) for all modeled markets.

Corporate commitments

There is no consensus on a net-zero technology route

Net-zero corporate strategies, by technology



Source: BloombergNEF

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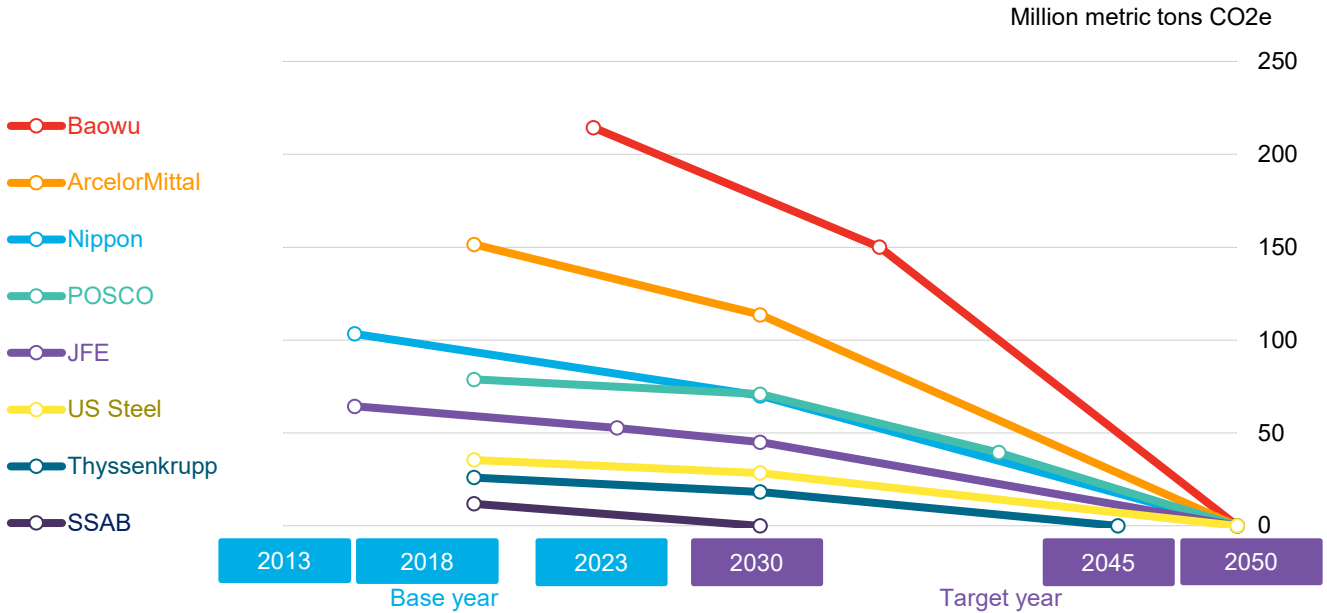
Most steelmakers are aiming for net-zero in 2050, with two exceptions

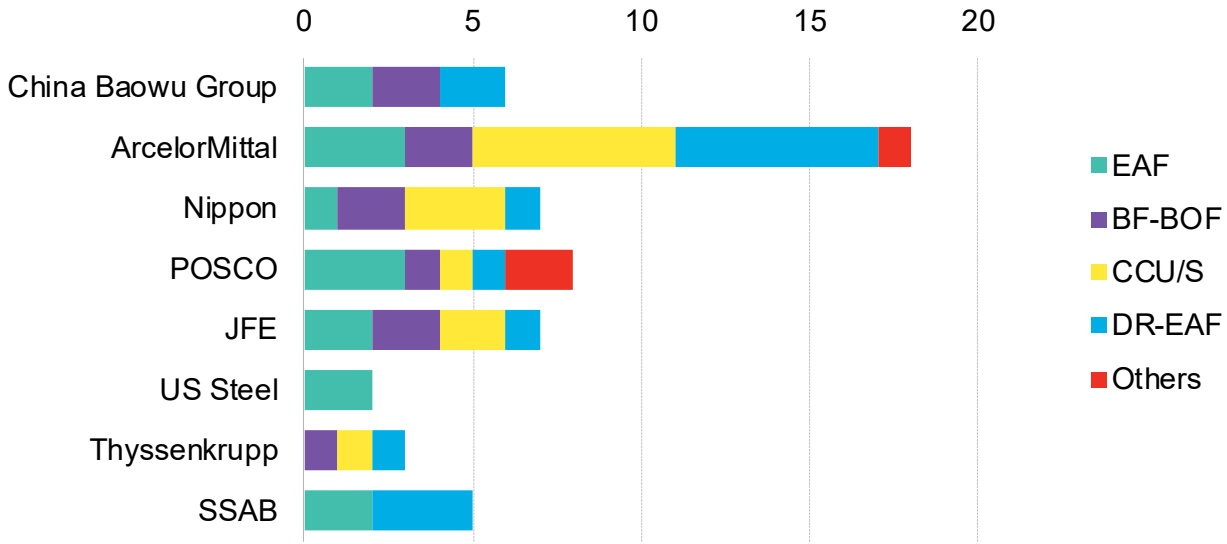
Net-zero pathway for select steelmakers, for absolute scope 1 &2 emissions reduction



Source: Company filings, BloombergNEF. Note: Emissions pathway begin with base year. The lines are illustrative only and do not necessarily indicate that corporates follow a linear emissions reduction pathway. For individual company assumption, see attached excel file.

ArcelorMittal leads in low-carbon project announcements

Low-carbon steel project count of steelmakers, by technology routes



Source: Company announcements, BloombergNEF. Note: EAF is building electric arc furnace. BF-BOF is emissions reduction based on blast furnace. CCU/S is carbon capture and utilization or storage. DR-EAF is hydrogen-based direct reduction. Others include electrolysis and FINEX. Projects include large demo and commercial projects.

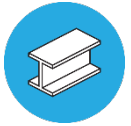
Customers and policy are pushing steelmakers to net-zero

1. Countries go towards net-zero

2. Carbon pricing kicks in

3. Investors demand ESG effort

4. Market demands green products



5. Industry competes to upgrade tech and product

Policy landscape for steel industry decarbonization in selected countries, by push and pull factors

Country/ region	Operating companies	Official target for industry	Carbon market / tax	Subsidies or grants for low-carbon steel	Support for hydrogen	Support for CCUS	Green public procurement	Access to low-cost clean energy
EU-27	ArcelorMittal, SSAB, thyssenkrupp, USS							
US	ArcelorMittal, SSAB, USS				Recent	Recent	Recent	
China	BAOWU							
Japan	JFE, NIPPON STEEL							
Korea	posco							

Source: BloombergNEF. Note: Access to low-cost clean energy only considers the high-level policies and may not reflect the regional reality most relevant to the current and planned operation sites of the steelmakers. The policies marked "Recent" were rolled out during the writing of this report, the effect of which may yet be shown on the analyzed steelmakers. Green= strong policy and clear; yellow= somewhat effective policy/policy pending, red=does not exist/ineffective.

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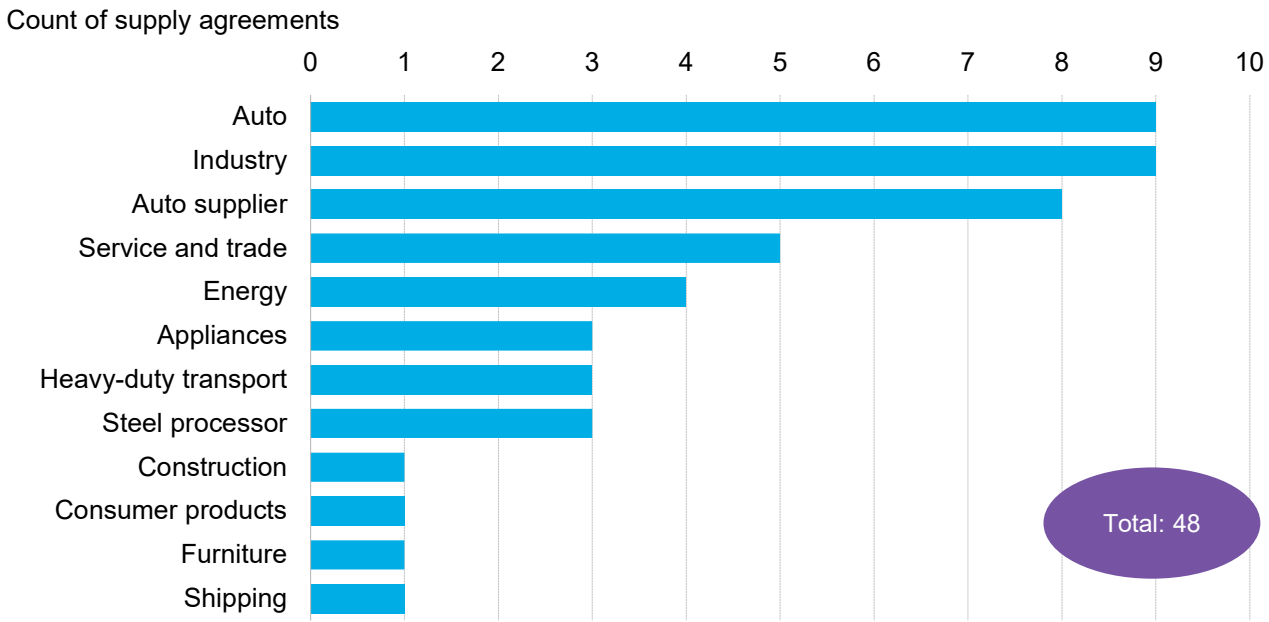
Customers are already signing contracts for green steel

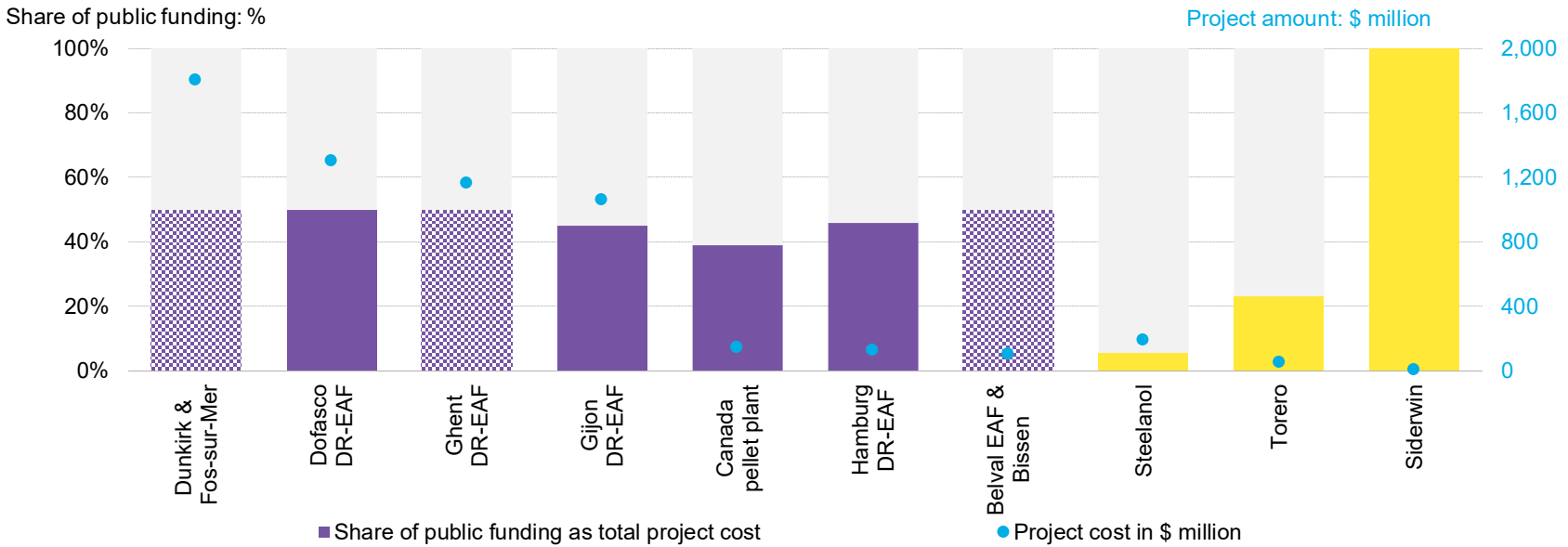
Count of supply agreements for green steel



Source: BloombergNEF, company announcements

Early green steel projects rely heavily on public funding

ArcelorMittal's steel projects with disclosed government support



Source: Company announcements, BloomebergNEF. Note:The shaded projects are supported by local government, but the exact amount of government funding was not disclosed. BNEF estimates these to be around 50% of project cost.

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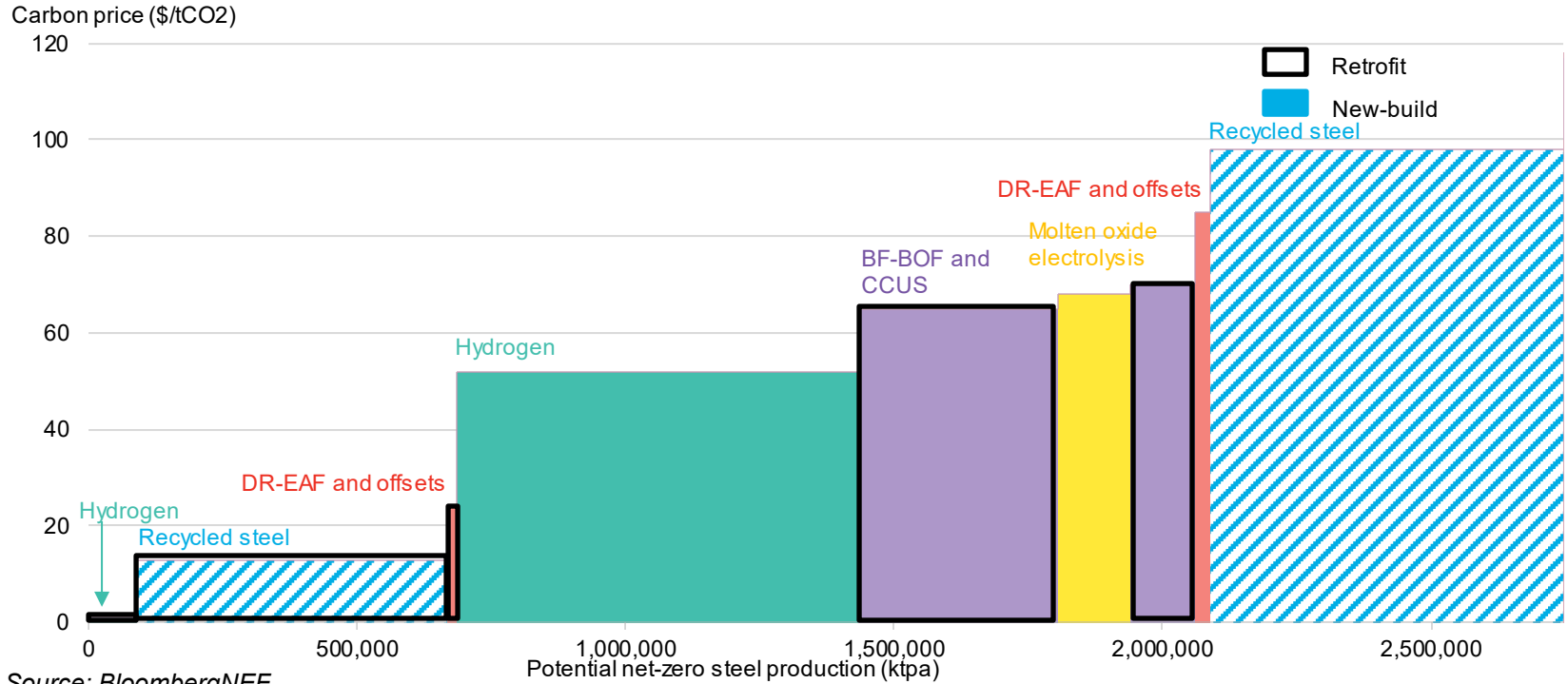
A helping hand from policymakers

Incentives needed for net-zero

Carbon prices required to support net-zero steel making (at NOAK costs)



Source: BloombergNEF

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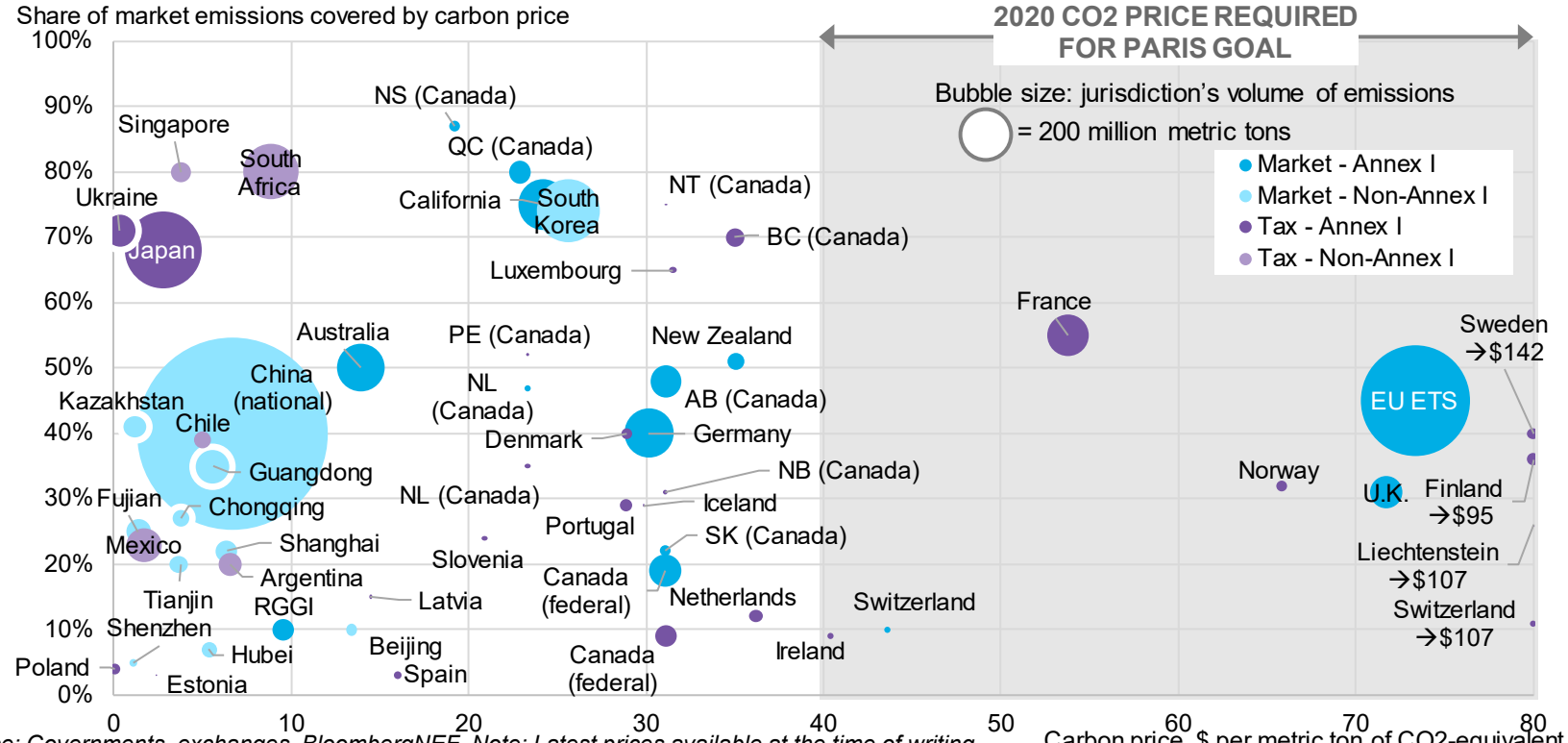
Carbon-pricing programs by price and emissions covered



Source: Governments, exchanges, BloombergNEF. Note: Latest prices available at the time of writing. Where tax rates vary across fuels, sectors and greenhouse gases, figure uses median.

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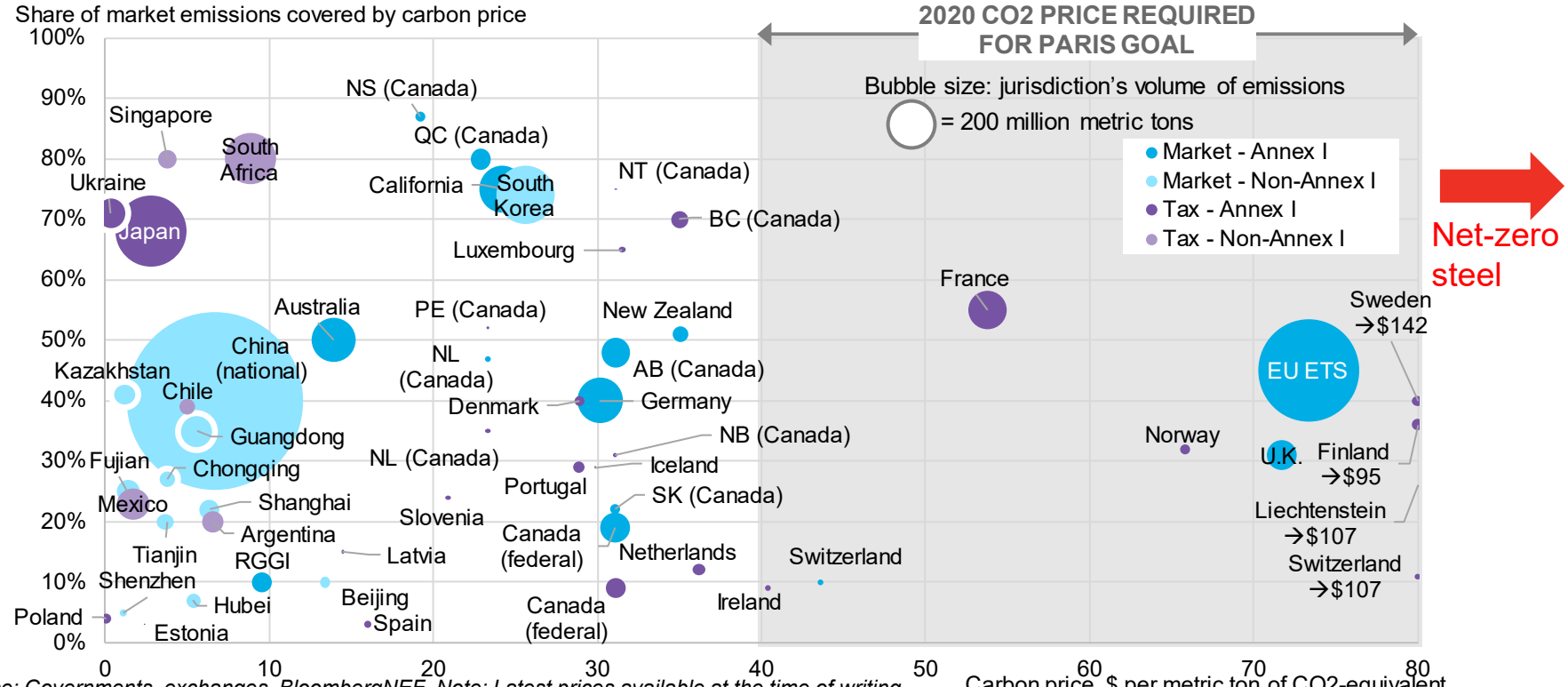
Carbon-pricing programs by price and emissions covered



Source: Governments, exchanges, BloombergNEF. Note: Latest prices available at the time of writing. Where tax rates vary across fuels, sectors and greenhouse gases, figure uses median.

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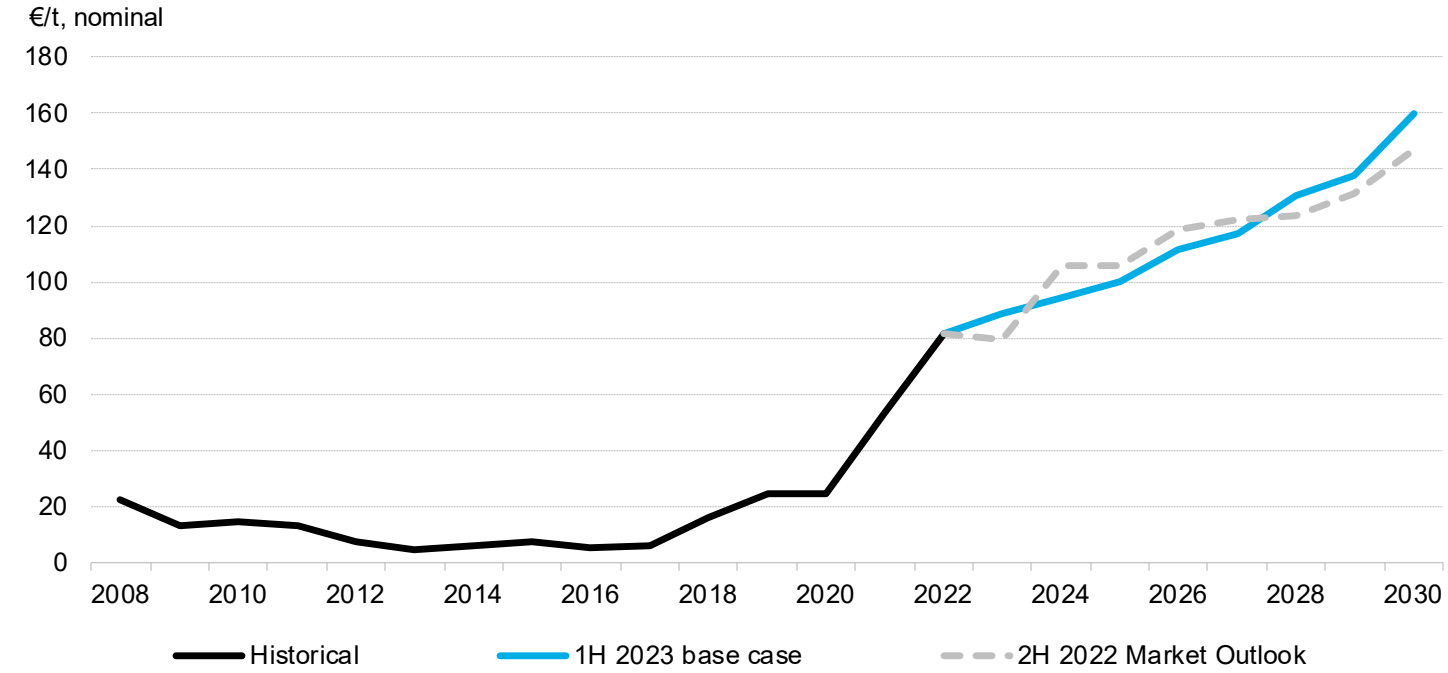
EU carbon prices are set to rise, but industry gets a pass

Historical and forecast EU emissions allowance price



Source: BloombergNEF

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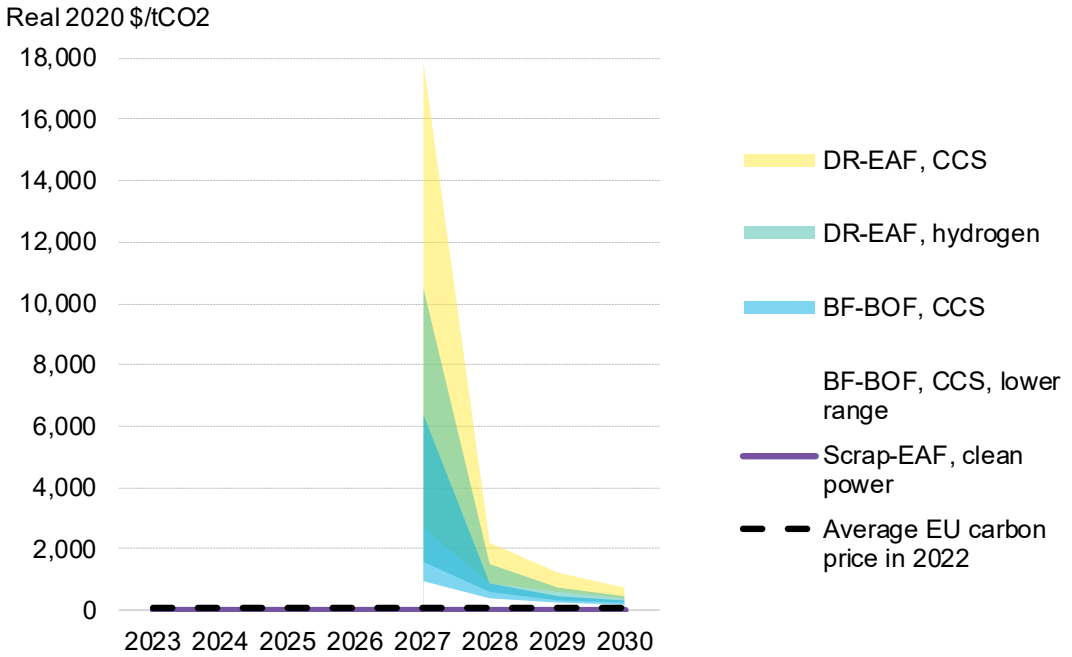
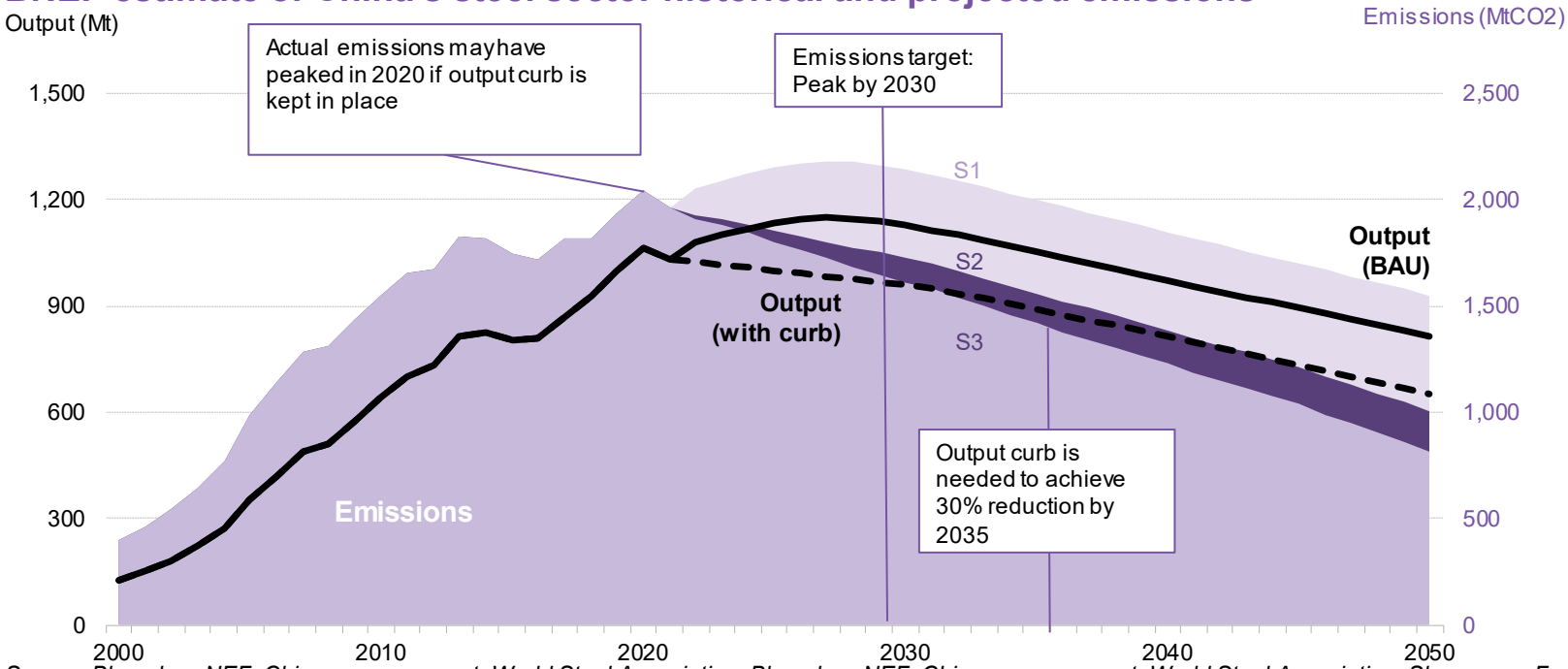
With free allowances in place, steel needs a price of thousands of dollars per ton



Source: BloombergNEF. Note: From 2026 to 2030, the upper range assumes a linear phase-out of free allocation from 2026 to 2032, while the lower range assumes a linear phase-out of free allocation from 2026 to 2036.

China’s emissions may already have peaked

BNEF estimate of China’s steel sector historical and projected emissions



Source: BloombergNEF, Chinese government, World Steel Association. BloombergNEF, Chinese government, World Steel Association, Shangguan,F, et al, Climate Change and decarbonization development of Steel Industry, 2021.

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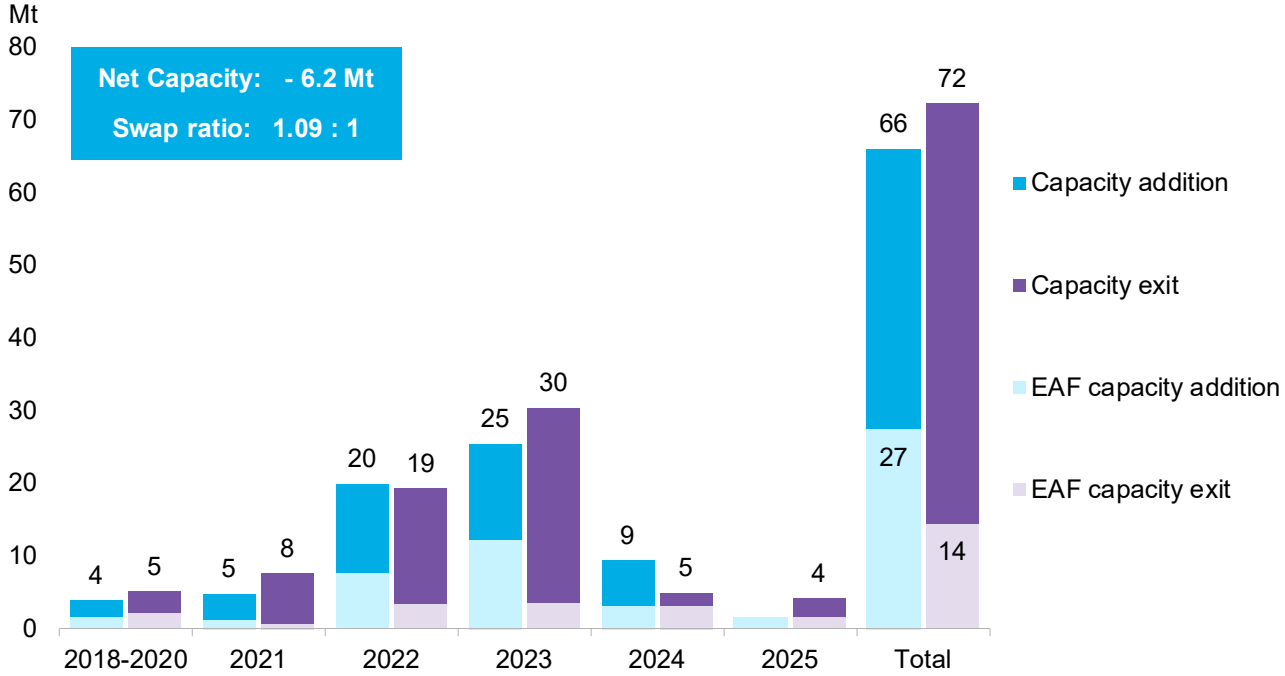
Capacity swapping makes EAFs more attractive

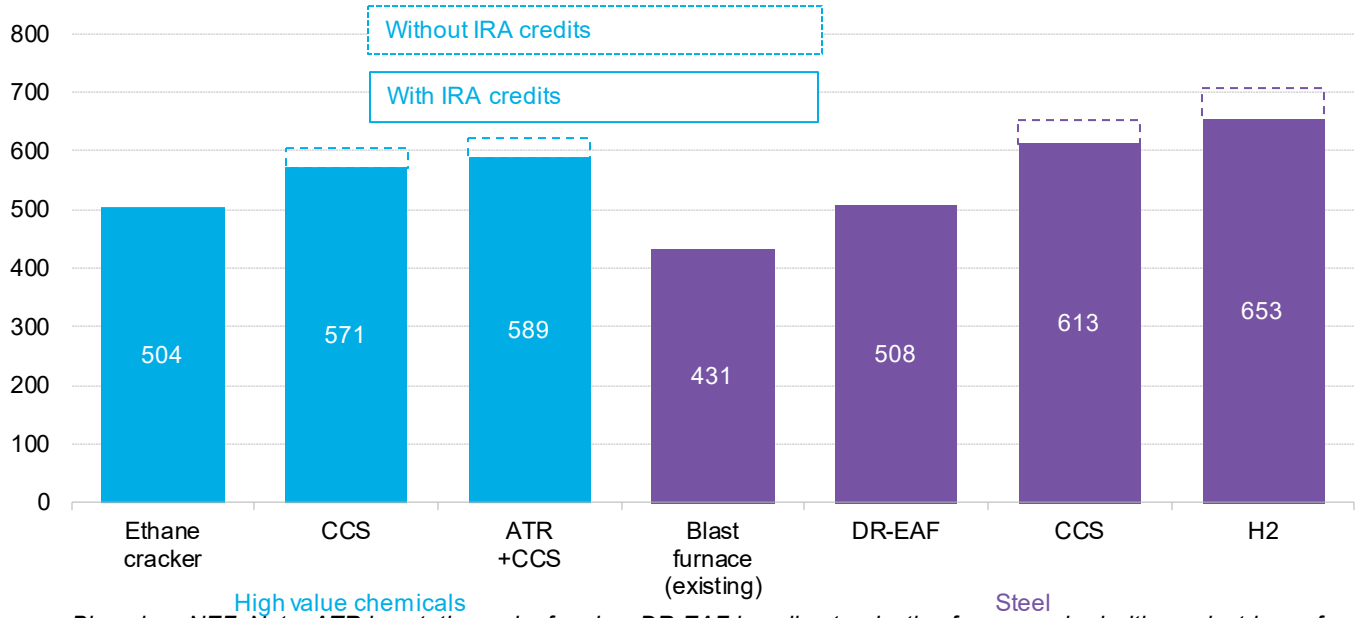


Source: BloombergNEF, Provincial government websites. Note: Data include only announcements made in 2021. The total amount includes plans without completion dates.

Green materials get a bit cheaper with the US's IRA subsidies

Reduction in green chemical and steel costs with 45Q and hydrogen subsidies

Levelized cost ($/t material)



Source: BloombergNEF. Note: ATR is autothermal reforming, DR-EAF is a direct reduction furnace paired with an electric arc furnace. H2 is hydrogen. Blast furnace cost is for an existing, coal-fired plant. Ethane cracker costs are for a new-build plant.

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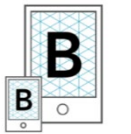

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