WE MEAN BUSINESS COALITION

CORPORATE CLIMATE STOCKTAKE: STEEL SECTOR

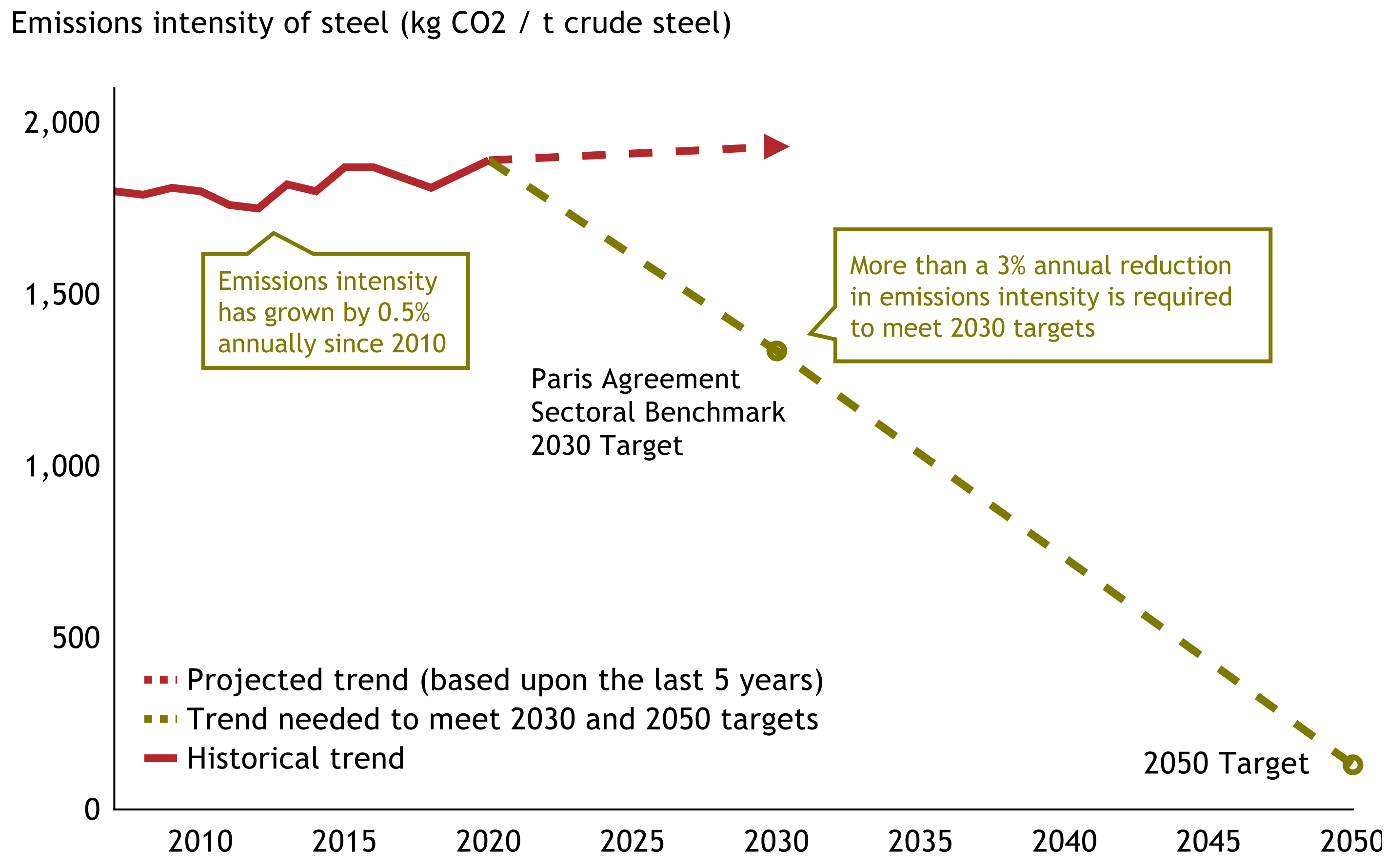
October 2023

Steel: Table of Contents

Steel: Table of Contents

Steel production has been growing steadily in the last decade - a rapid turnaround in emission intensity would be required to stop emission growth

Recent increases in emissions intensity are expanding the gap to 2030 targets



Commentary

- **Steel production grew by 20% in the last decade,** from 1,547 Mt in 2012 to 1,885 Mt in 2022
- **Hydrogen and natural gas technologies** for direct reduction of iron and electric arc furnace, **cut emissions intensity by 70-95%,** compared to traditional blast furnaces
- Despite their potential, **high costs and limited offtake commitments** limit the deployment of such technologies to the U.S. and EU, with **emerging markets still expanding blast furnaces capacity**

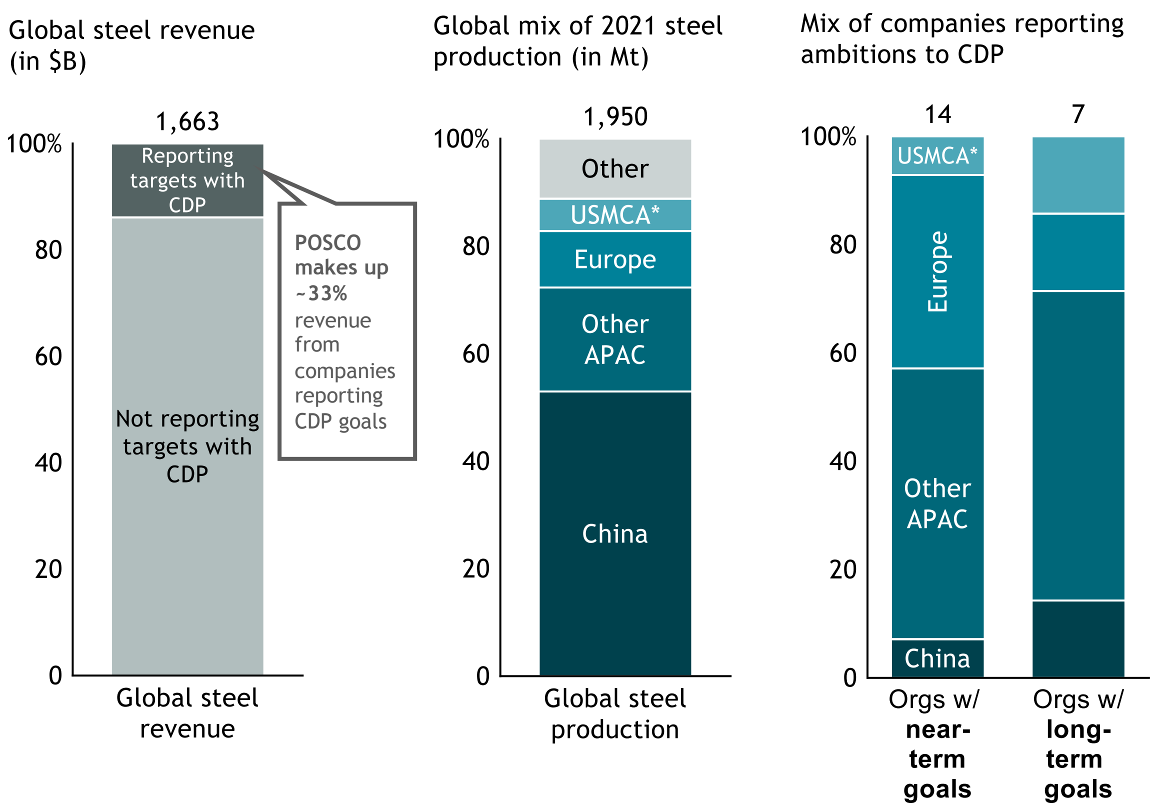
Source: Systems Change Lab; World Steel Association – Environmental Sustainability Indicators; Climate Action Tracker – Paris Agreement Compatible Sectoral Benchmarks

Less than15% of global steel market is reports in line with CDP. Of those reporting, nearly half are on track to exceed Breakthrough targets

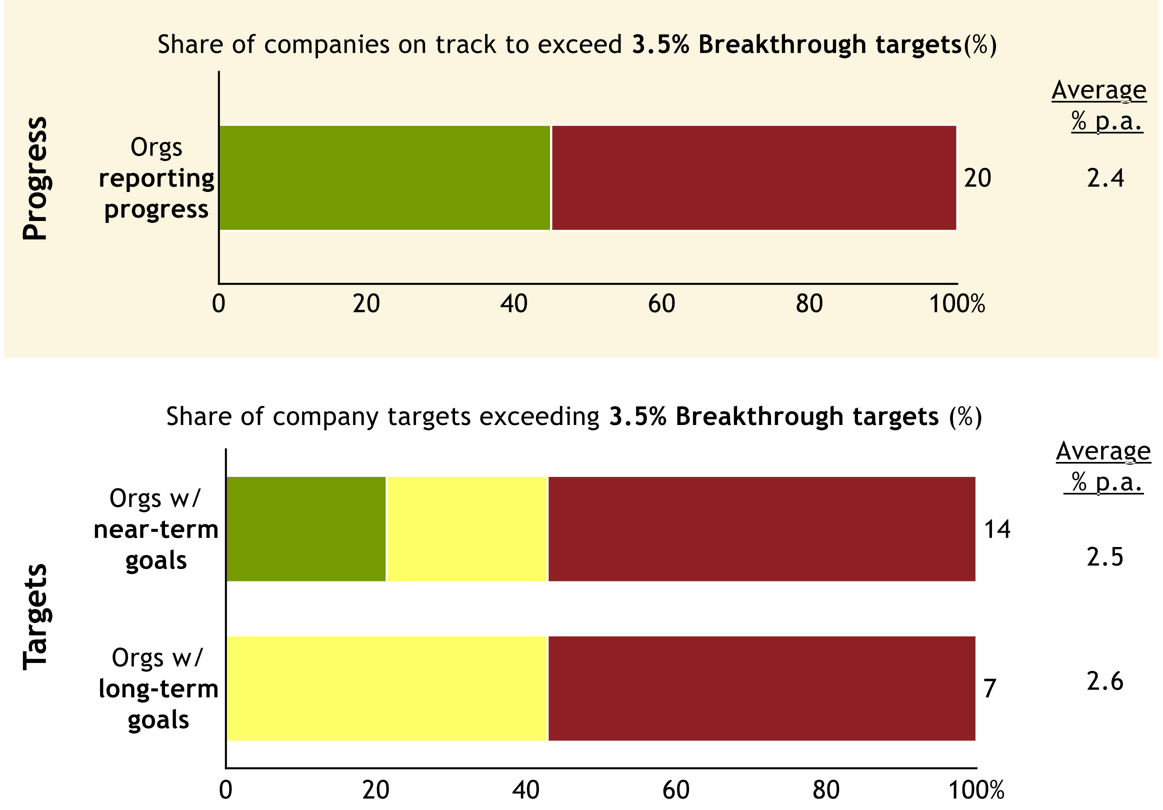
STEEL OVERVIEW

Legend — Company performance vs. Breakthrough: Missed target (<80%) | Near miss (80-100%) | Hit target (+100%)

<15% of global steel market is covered by emissions targets



45% of steel companies are on track w/ Breakthrough guidance



Note: (*) US, Mexico, and Canada; Annual reduction ambition shows the % reduction a company will need per year in order to reach their target from the base year (includes underway, new, or revised targets); near-term defined as target year before 2030; Priority countries selected based upon highest emission countries from 2022 Global Carbon Project Data; % reduction refers to an annual percentage and does not take into account compounding; Breakthrough Agenda goals account for Scopes 1+2 only

Source: 2022 CDP Climate Questionnaire Data; 2022 Global Carbon Project; World Steel Organization

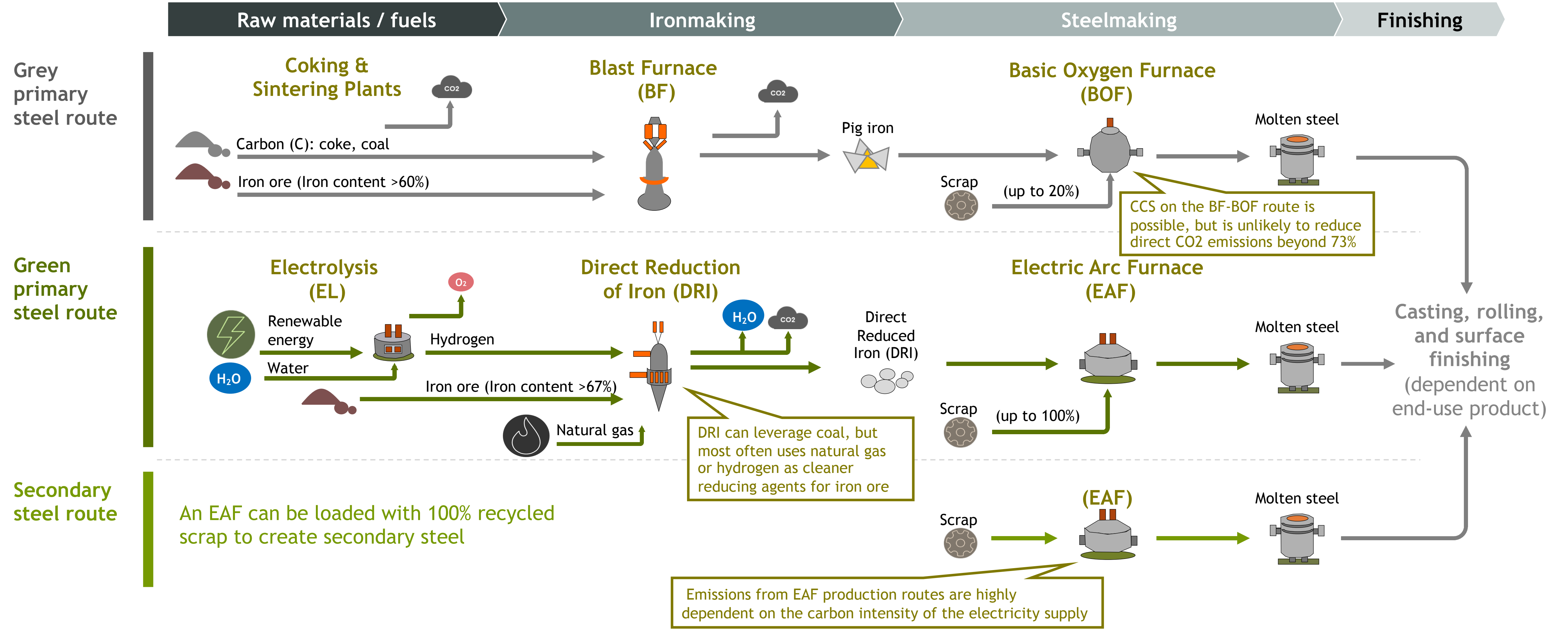
There are three mainstream methods used to produce steel – each varying in operating procedures, required inputs and equipment, and emissions intensity

	Blast Furnace – Basic Oxygen Furnace (BF-BOF)	Direct Reduced Iron – Electric Arc Furnace (DRI-EAF)	Scrap – Electric Arc Furnace (Scrap-EAF)
Emissions intensity	• **~2.1 (t CO_2 / t crude steel)**	• **~0.1-1.2 (t CO_2 / t crude steel)** *(from Hydrogen and Natural Gas respectively)*	• **~0.1-0.5 (t CO_2 / t crude steel)** *(dependent on electricity supply)*
Key inputs	• **Coking coal** • **Iron ore** (Iron content 56-66%) • **Steel scrap** (up to 50%) • **Limestone** (or other calcium-rich material)	• **Natural gas / Hydrogen** • **Electricity** • **Iron ore** (Iron content 66-68%) • **Steel scrap** (up to 100%) • **Limestone** (or other calcium-rich material)	• **Electricity** • **Steel scrap** (up to 100%)
Production process: Material pre-processing	• **Coking plant:** Metallurgical coal is processed and heated to 1200°C for use as reducing agent • **Sintering plant:** Iron ore fines (iron content of 56-66%) are mixed with limestone, dolomite, and heated to form larger ore pieces	• **Pelletizing plant:** Iron ore fines are mixed with limestone and dolomite, moistened, then rolled into small pellets for direct reduction processes	• **Scrap recovery:** Steel scrap is collected, inspected, and separated based on purity before it can be used in steel production
Production process: Ironmaking	• The blast furnace heats to ~1600°C, activating coke to remove oxygen from iron ore, producing high-impurity pig iron and slag waste	• Direct reduction of iron (DRI) uses gaseous agents to remove oxygen from iron ore at ~1000°C, producing impure sponge iron and slag waste	• Ironmaking is not required when converting scrap into secondary steel
Production process: Steelmaking	• Pig iron is sent to a basic oxygen furnace, heated to ~1600°C with scrap and limestone, producing primary crude steel and slag waste	• An electric arc heats a mixture to ~1800°C, melting DRI and scrap together, producing primary crude steel and slag waste	• An electric arc heats the mixture to ~1800°C, melting recycled steel scrap into secondary steel and slag waste

Notes: The emissions intensity values are global averages. They can vary by geography- high volumes of scrap have driven growth in EAF capacity in North America; Europe and China primarily use BF-BOF steel production route and locations with abundant and low-cost natural gas, such as the Middle East, see DRI-EAF technology play a larger role; lower limit of the emission intensity values assume renewable energy use

Source: World Steel Association, Mission Possible Partnership

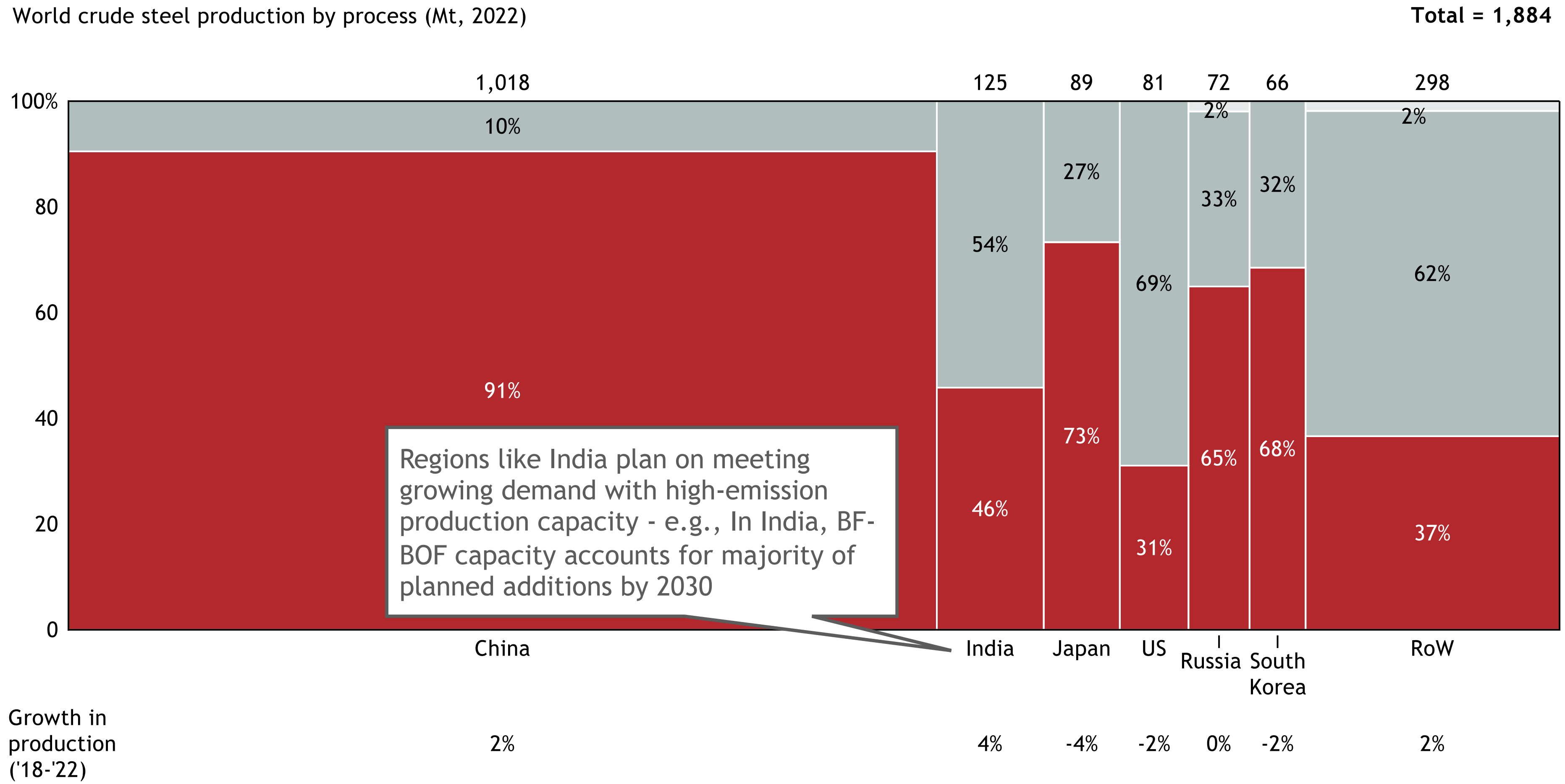
Hydrogen and natural gas can replace coal/coke via new processes for end-to-end steel production, which can result in up to 95% reduction in emissions intensity



Note: Carbon emission figures are not inclusive of coal mine methane leakage
Source: Mission Possible Partnership – Making Net Zero Steel Possible

Over 70% of global steel is produced using basic oxygen furnaces, with high demand regions like India expected to further add high-emission production capacity

World crude steel production by process (Mt, 2022)



Legend	Share of production (2022)
Basic Oxygen Furnace	71.5%
Electric Arc Furnace	28%
Open Hearth Furnace	0.5%

Older process where impurities are burnt out of pig iron in a large oven, surpassed by other technologies ~1950s

Note: Global production includes both primary and secondary steel production volumes
Source: World Steel Association, World Steel in Figures 2023

Executive Summary: The State of the Transition in Steel

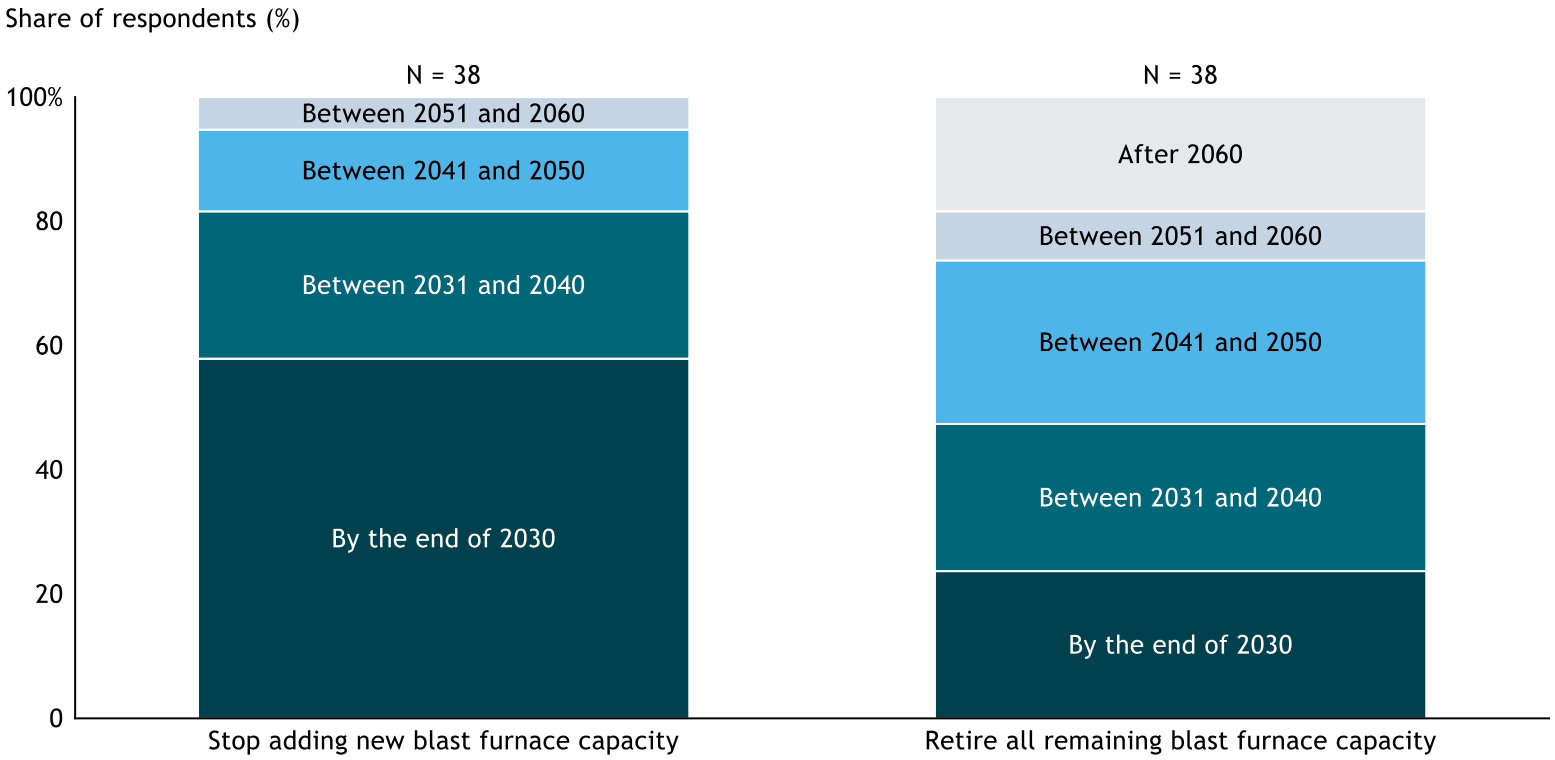
Dimension of sector	Deploy near-zero emission tech	Ensure access to key inputs	Abate high-emission capacity
Future decarbonization scenario	Near-zero emission production capacity will emerge as a viable solution to satisfy demand sustainably	Increased availability of key inputs that support the transition to near-zero emission steel production	Advancing CCS and other abatement technologies de-risks future investments in emerging markets
Indicators of progress towards accelerating decarbonization	Investment in **near-zero emissions capacity is accelerating** to enable a shift from blast furnace into electric arc furnace production by 2050 While H2-DRI production **costs remain >20% higher** than conventional production (depending on the grade of iron ore pellets), they're **expected to come down** as green hydrogen technology scales **European governments are incentivizing** green steel, but the focus of decarbonization needs to be on the new capacity emerging in countries from the Middle East, North Africa and Asia	**Major steel consuming nations** are **promoting scrap utilization** - e.g., China's scrap supply is expected to double by 2030, supporting expansion of its electric arc furnace capacity For DRI, **limited supply and high costs of green hydrogen and renewables** is a key constraint, but costs are expected to decline and innovative solutions (e.g., using alternative inputs) are underway In the longer term, **availability of high-grade iron will be key** to ensure scaled deployment of DRI, which is particularly challenged in some growing markets like India	Given the ~30-year lifespan of steel plants, **early retirement of new blast furnace lines will be challenging** given the risk of stranded costs A **portfolio of technology solutions (e.g., DRI-Smelt, CCS etc.)** is under development to achieve decarbonization in the longer term, especially in U.S. and EU Deploying CCS technology in emerging markets with growing demand will need **financial support, CCS infrastructure** and **adequate regulation**

Steel: Table of Contents

~75% of business leaders from the U.S., Canada, and Europe believe that the firms can completely shift away from blast furnace production by 2050

In what year do you expect your company will stop adding new blast furnace production capacity?

In what year do you expect your company will retire all remaining blast furnace production capacity?



Commentary

- The majority of steel producers in the US, Canada, and EU responded they will **stop adding new BF capacity by the end of 2030**
- Although it may take some time, steel producers in these regions believe that they **will be able to retire all remaining blast furnace capacity**

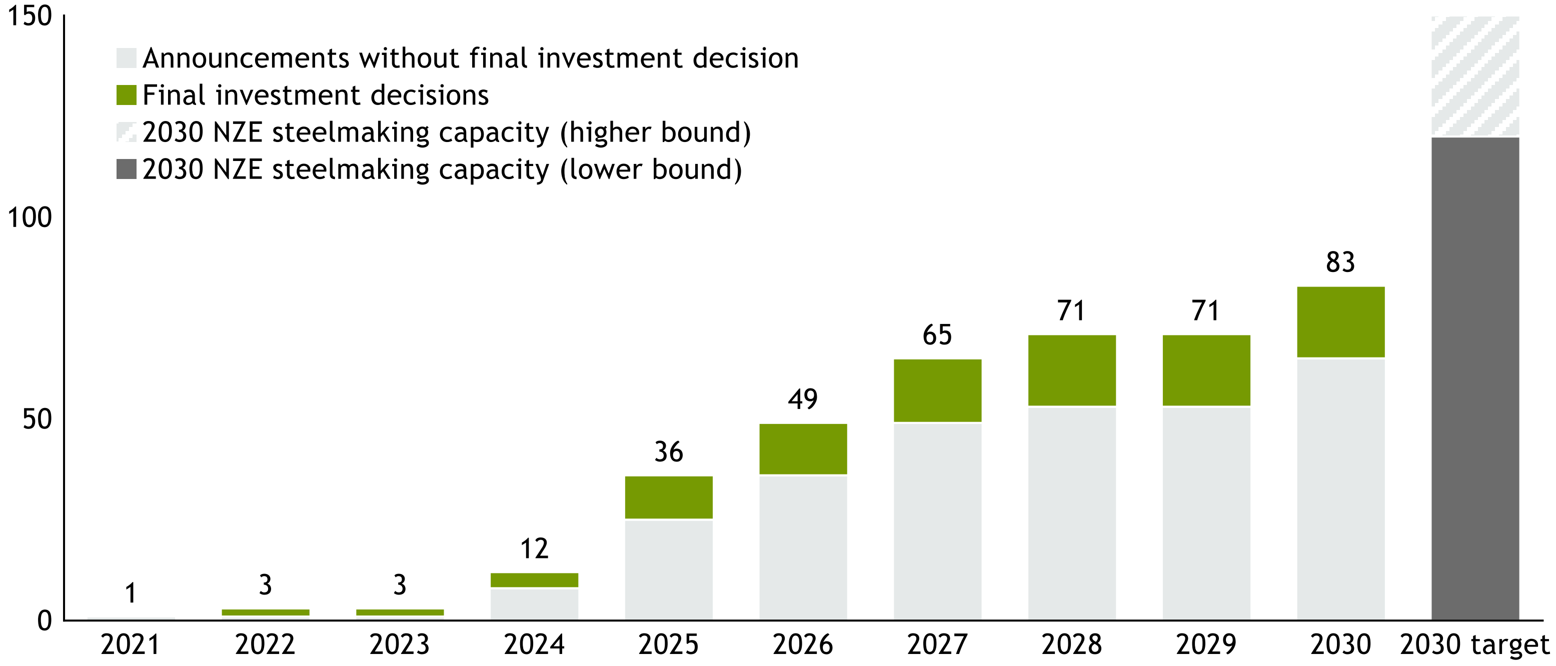
Note: Chart includes responses from respondents with expertise in the steel sector from the U.S., Canada, and Europe (N = 38) – respondents had the opportunity to answer each question across regions where they had expertise; The survey findings and emerging insights are based on the views of a subset of these companies and thus do not represent a universal view on the steel industry transition

Source: Bain / WMBC Global Stocktake Survey (N = 215)

"Steel mills are making huge investment to change their technologies to produce low carbon steel - it's the only way to produce decarbonized steel"

Investment decisions and announcements show an increased uptake in near-zero emission steel production, but still fall short of 2030 target

Global near-zero emission primary steelmaking capacity (Million tonnes p.a.)



Commentary

- Announcements total **83 Mt of H2 ready DRI capacity by 2030**
- DRI projects recently surged, averaging **33 Mt / year in 2021 and 2022**
- **High cost of green hydrogen production** may cause announced capacity to rely on blue hydrogen
- Estimated capacity from **engineering and construction firms stands at 70 Mt** by 2030, suggesting a bottleneck

"There is no question that there is early demand, but there are ***very few projects available that have investment decisions*** *and a timeline to come online soon and are green enough."*

Manager of Climate Action, Auto manufacturer #1

Note: Title quote from Environment Manager, Auto manufacturer #2; The 2030 targets refer to the near-zero emissions primary steelmaking capacity that would be needed to be on a 1.5C compatible pathway based on IEA, IRENA, UN 2022, and Agora Industry scenarios

Source: Agora Industry (2023); Global Steel Transformation Tracker (2023)

Investments are being driven towards building large-scale green steel plants

H2 green steel — **Case Study: H2 green steel**

Overview

- **Description:** Innovative steel manufacturer that is deploying a giga-scale electrolyzer to create green hydrogen to be used in primary steel production
- **Founded:** 2020
- **Headquarters:** Stockholm, Sweden
- **Ownership:** Private
- **Series C Funding Round (2023):** ~$1.64B
- **Technology deployed:** H-DRI-EAF primary steel production powered by renewable energy

Targets

2025
- Aim to build the world's first operational large-scale green steel plant

2026
- Increase near-zero emission production to 2.5M metric tons of steel

2030
- Achieve maximum operating capacity of 5M metric tons of green steel

Activities

Becoming an industry leader in green steel production

- Partnership with Thyssenkrupp Nucera to create a **700 MW electrolyzer facility** using highly efficient 20 MW modules
- H_2 Green Steel plans to **produce green hydrogen leveraging onsite hydro and wind electricity** and use it for steel production in the Boden plant
  - Boden steel plant expects to produce up to **95% lower carbon emissions** than standard blast furnace routes
- **Integrating Midrex direct reduction ironmaking (DRI) technology** to leverage 100% green hydrogen at launch

Leveraging green hydrogen production capabilities to serve other sectors

- H_2 Green Steel is continuing to **sign customers to purchase commitments in key markets** like automobile manufacturing and shipping
  - Agreements in 2023 alone include industry leaders such as **Cargill, Anglo American, Mercedes-Benz, and Scania**
- Outside of green steel production, **H_2 Green Steel plans to provide green hydrogen to other hard to abate industries like shipping**
  - Gotland Company has agreed to use green hydrogen provided by H_2 Green Steel in their Horizon fleet's gas turbines by 2030 at the latest

Source: H_2 Green Steel company website and press releases, Thyssenkrupp press releases; Pitchbook

Efforts to develop innovative solutions to drive down emissions further are also underway

SSAB **Case Study: SSAB**

Overview

- **Description:** Global steel manufacturer that is fully transforming its traditional blast furnace steel-making to brand new fossil-free DRI-EAF production
- **Founded:** 1978
- **Headquarters:** Stockholm
- **Ownership:** Public
- **Founding:** Debt free since 2021
- **Technology deployed:**
  - EAF scrap based production with fossil-free energy inputs (in the US)
  - Fossil-free hydrogen DRI-EAF based production with fossil-free inputs (in the Nordics)

Targets

2021 *(Completed)*
- Become the first steel company to delivery fossil-free steel to its customers

2022 (Completed)
- Launch of SSAB Zero - made from recycled scrap, 0.0 kg Co2e emissions per kg steel

2026
- Launch HYBRIT demo plant (DRI) and a brand new EAF for large scale fossil-free steel production
- Fully transform Nordic system with two brand new state of the art mini-mills

Activities

Fine-tune fossil-free steel

- SSAB **fine-tuned its proprietary fossil-free steel** made from hybrit sponge iron
  - Carbon emissions include purchased energy and iron ore (scope 1-2 and iron ore of scope-3 upstream)
- Hybrit technology **proven for direct reduction of iron ore** with 100% fossil-free hydrogen at **pilot scale**
  - Launched in 2016 with initial volumes produced in 2021 to Volvo
  - Hybrit R&D project co-owned by SSAB, LKAB and Vattenfall
  - Results through value chain: fossil-free pellets, fossil-free sponge iron, pilot scale underground storage for H2, delivered first fossil-free steel
- **Produced and delivered** fossil-free steel to selected customers and applications (500 tons in 2022)

Large scale fossil-free production utilizing HYBRIT technology

- Plans to **replace blast-furnace in Oxelösund and demonstration plant** for Hybrit technology (2026) and build two state of the art mini-mills based on Hybrit DRI-EAF (by around 2030)
- **Targeted partnerships** with strategic fossil-free steel partners, e.g. Volvo group, Mercedes-Benz, Polestar, Autoliv, Volvo cars, Epiroc, PEAB, etc.

Source: H_2 Green Steel company website and press releases, Thyssenkrupp press releases; Pitchbook

But DRI plant engineering and construction capabilities are highly concentrated, creating a potential constraint to the pace of global deployment

	MIDREX	ENERGIRON HYL	PRIMETALS TECHNOLOGIES, posco, Metso
DRI technology	• **Midrex Flex** (using natural gas) • **Midrex H_2** (using up to 100% hydrogen) • **MX COL** (using coal)	• **ENERGIRON ZR** (primarily using natural gas with modifications enabling a high ratio of H_2)	• Companies are working to deploy novel H_2-based DRI plants leveraging **fluidised bed reactors** (commercially ready by 2030)
Share of construction additions (since 2011)	80%	17%	<3%
Business model	• **Relies on a licensing model** with companies like SMS Group and Primetals to implement DRI technology into steel plants	• **Designs and constructs** ENERGIRON direct reduction plants for major steel manufacturers	• Innovative manufacturers are researching **low-emission smelting technology** to leverage conventional grades of iron ore
Current pilot projects	• Thyssenkrupp steel is integrating MIDREX Flex technology at its Duisburg, Germany site to use **50% H_2 for reduction by 2026** until sufficient H_2 supply is available	• Baosteel Zhanjiang steel plant in the Guangdong province will be the **largest hydrogen-based DRI plant in China** expecting to begin production as early as 2024 using ENERGIRON ZR technology	• Metso's DRI smelting furnace is **capable of handling BF-grade iron ore** by enabling high slag volumes

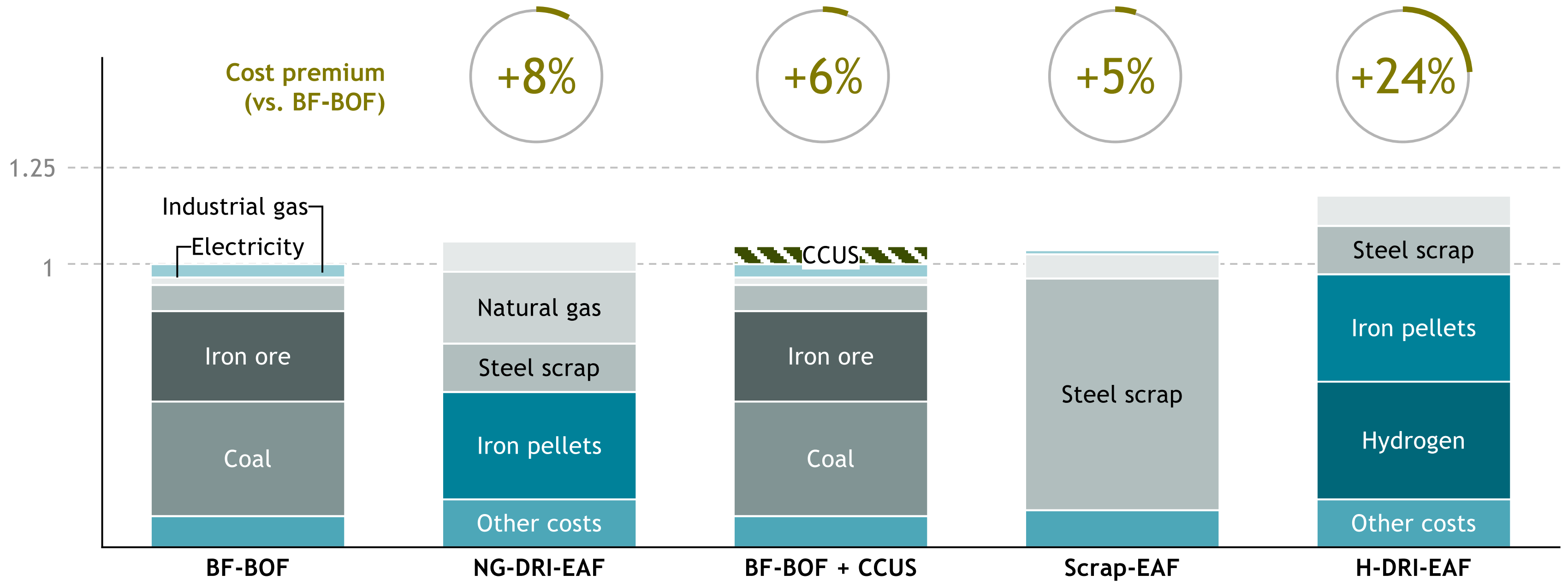
Total combined DRI construction capacity of ~70 Mt by 2030, suggests that additional solutions will be required to realize announced capacity in the pipeline

Source: H2 Green Steel company website and press releases, Thyssenkrupp press releases; Pitchbook

"It will be difficult for companies to fully commit to green steel without some intervention to push cost parity"

Low-emission production methods currently carry a premium to the traditional BF-BOF process

Levelized cost of steel production (2023, USD/metric ton of liquid steel; indexed)



	BF-BOF	NG-DRI-EAF	BF-BOF + CCUS	Scrap-EAF	H-DRI-EAF
Average CO2 emissions (metric tons)	2.1	1.2	0.6	0.5	0.1

Commentary

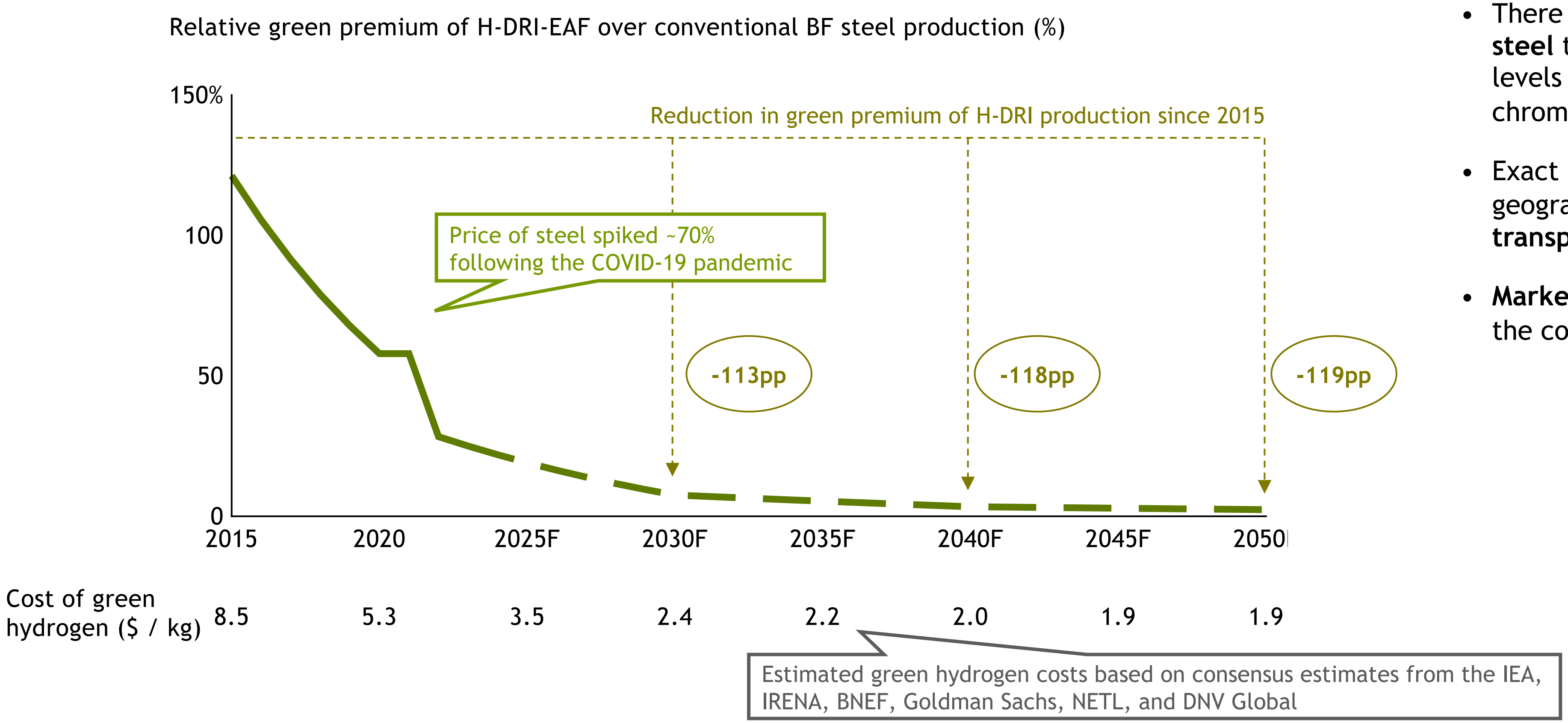
- **BF-BOF** is the **lowest cost method** of production
- **Lower-emission technologies will become cheaper** as input costs (renewable electricity and green hydrogen) decline
- **Fossil-dependent production technologies** (e.g., BF-BOF, NG-DRI) **may increase** with broader adoption of carbon pricing

"Decarbonisation of steel is a ***cost issue*** *– in both Capex and Opex terms. There isn't really a technical barrier, though clearly innovation can bring costs down. Reality is that* ***low emission steel is going to be more expensive*** *– except for very rare exceptions"* - Head of Strategic Projects & CO2 strategy, Steel manufacturer #3

Note: Title quote from Manager of Climate Action, Auto manufacturer #1; 'Other costs' include costs associated with labor, CAPEX, and other raw materials; 'Natural gas' costs are inclusive of other industrial furnace gasses used in the process; CCS cost per ton of CO2 based on a 90% capture rate system for retrofitting an average 2.5Mt capacity BF-BOF facility; Average carbon emissions for H-DRI-EAF production route assumes access to a supply of renewable electricity and green hydrogen
Source: World Steel Association; Mission Possible Partnership – Steeling Demand Report; Morgan Stanley – Green Steel 2.0; Steel on the Net – EAF/BOF Cost Structure Summary; St. Louis Fed – Natural Gas and Iron Ore prices; Primetals – Outline of MIDREX DRI process; National Energy Technology Lab (DOE) – Cost of Capturing CO2 from Industrial Sources

"The cost premium will come down as we scale, get more efficient and share cost more effectively. HDRI will become cost competitive with blast furnace"

The cost of low-emission steel production is expected to approach BF-BOF over time



Commentary

- There are **over 3,500 different grades of steel** that manufacturers create using varying levels of alloying elements (e.g., nickel, chrome, etc.)
- Exact steel production costs can vary across geographies due to **material, energy, transport, and labor costs**
- **Market conditions can have major impacts** on the cost of production and the price of steel

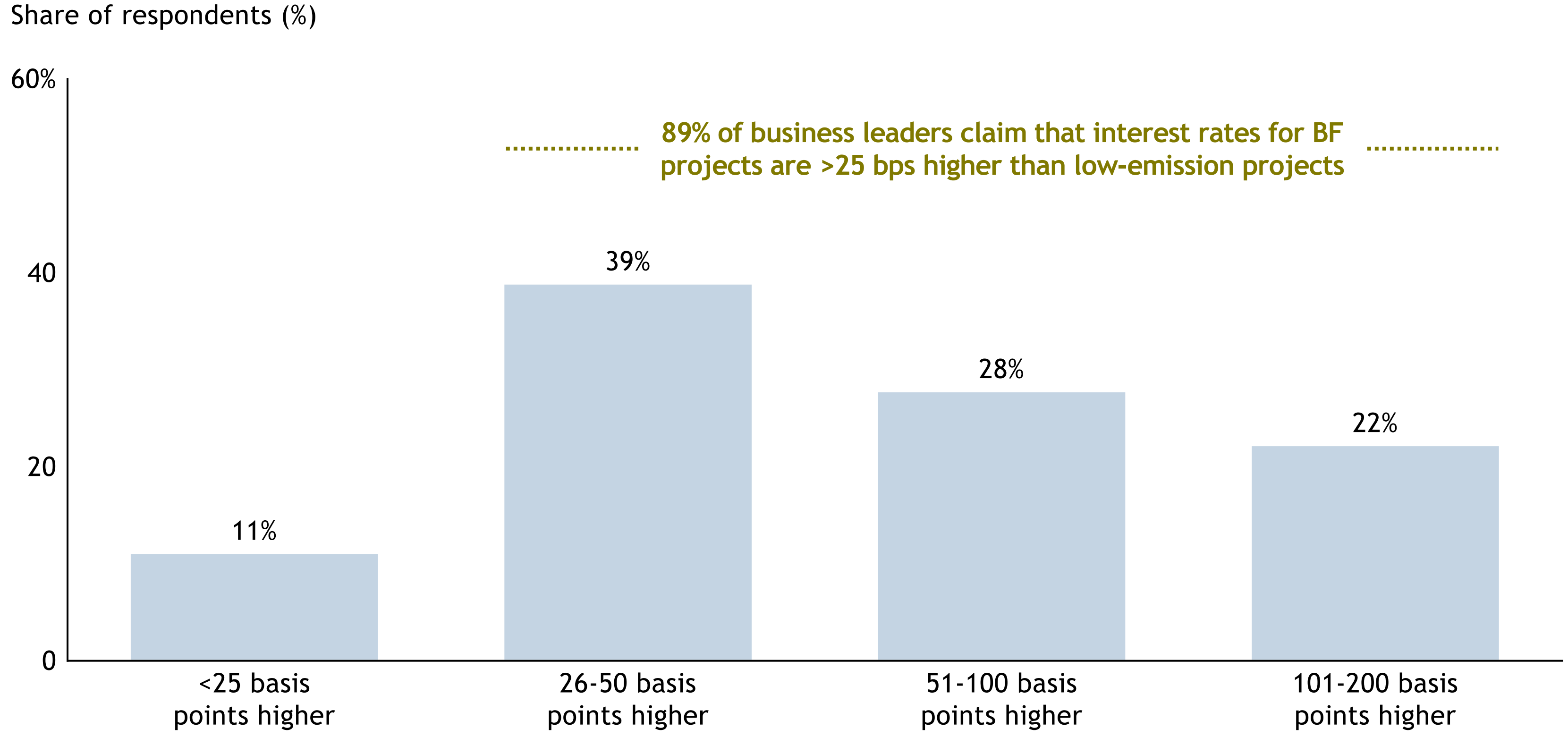
Note: Title quote from Chief Technology Officer, Resource provider #2; Assuming the cost of BF-BOF will not change over time; Green premium is defined as the cost premium of H-DRI-EAF production over BF-BOF; Price of steel based on historical hot rolled steel indexed back to 1/1/2015 using annual averages

Source: World Steel Association; Mission Possible Partnership; Energy Transmissions Commission; Morgan Stanley; Bain Commodity Dashboard; St. Louis Fed Commodity Tracker; IEA; IRENA; BNEF; Goldman Sachs; NETL; DNV Global

Across North America and Europe, business leaders report that debt financing interest rates for BF-based projects are higher than low-emission alternatives

01 | **02 ZERO-EMISSION TECH** | 03 | 04

On average across the Steel sector, debt financing ***interest rates for new high-emission production projects (e.g., BF-BOF) are ___ than debt financing interest rates for new low-emission production projects*** *(e.g., H-DRI-EAF)?*



Commentary

- Rising interest rates for high-emission production projects, indicating that Lenders view new **blast furnace capacity as higher risk**
- Despite competitive interest rates, **high operational costs** of near-zero plants hinder capacity deployment
- Despite lower financing costs, **steel producers need green steel offtake agreements** to justify the investment
  - **Roughly 40% of business leaders** surveyed believe that they need **>25% of production** to be covered by offtake agreements to invest in H-DRI capacity

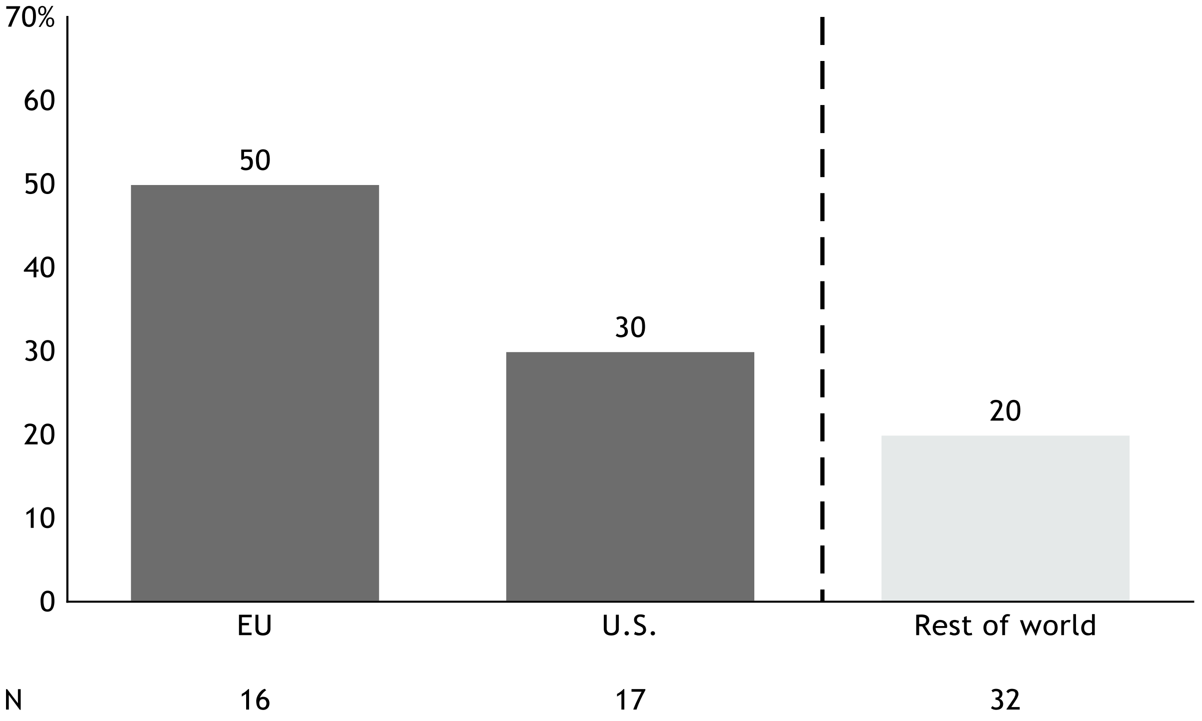
*"The investment that has been sunk in blast furnaces…is obviously really significant. And we're talking about…**young investment that is well short of its payback.**"*
Manager of Sustainability, Resource provider #1

Note: Chart includes responses from directors, vice presidents, and C-level executives with from steel companies in the U.S., Canada, and Europe (N = 18); Chart excludes 9 participants that responded "I don't know" to this survey question; The survey findings and emerging insights are based on the views of a subset of these companies and thus do not represent a universal view on the steel industry transition
Source: Bain / WMBC Global Stocktake Survey (N = 215)

Most business leaders in the U.S. and EU steel sectors expect to leverage green hydrogen for steel production by 2030

***What share of your company's total steel production do you expect to leverage green hydrogen** by 2030 in each of the following regions?*

Share of total steel production leveraging green hydrogen (%)



Commentary

- Producers across regions anticipate **green hydrogen** to become a significant **input to production** by 2030
- Developed markets (EU and U.S.) aim for higher share of inputs than rest of world
- The Middle East, which has a high share of DRI production may more easily transition to using hydrogen
- **China,** world's top steel producer, expects the **lowest share of production with green Hydrogen** by 2030

*"In steel, we have **various option to decarbonise** - we can use green electricity either via green hydrogen through direct reduction, or in the future, we may be able to make steel through the direct electrolysis of iron as we do with aluminium today. But in the **next 10-15 years**, it **will be through green hydrogen**"* - Head of Strategic Projects & CO2 strategy, Steel manufacturer #3

*"One of the challenge is the likely **costs for DRI.** One of the big issues is going to be the ramp-up rates, [..] and how you compress that timeframe is a key question"* - Manager of Sustainability, Resource provider #1

Note: Regional figures were calculated using the median response for each country; Rest of world includes China (N=7), India (N=9), Southeast Asia (N=4), Africa (N=2), Middle East (N=4), Oceania (N=1), Other Europe (N=1), Other North America (N=4); The survey findings and emerging insights are based on the views of a subset of these companies and thus do not represent a universal view on the steel industry transition
Source: Bain / WMBC Global Stocktake Survey (N = 215)

"The voluntary demand route is a red herring. In term of total impact, policy will be what moves the needle - through pricing, subsidies, or a combination"

The EU Emissions Trading System (ETS) will increase the cost of BF production

- ETS applies the 'cap and trade' principle, setting a total GHG emission limit, divided into **tradeable allowances for steel producers**
- Producers must **buy extra allowances** if emissions surpass the annual benchmark
- As this benchmark lowers, **continuing BF operations becomes costlier** – alternatively producers can invest in low-emission capacity to stay below the limit
- The Carbon Border Adjustment Mechanism (CBAM) offers an alternative, **fostering a market for decarbonized steel** and incentivizing investment in low-emission capacity

EU funding and subsidies for green H_2 increases the supply for steelmakers

Direct Funding

- **€10.6B of funding under IPCEI Hy2Use[3] and Hy2Tech[4]** for 76 green H_2 industrial projects
- Several European countries are establishing funding and specific targets to facilitate industry adoption

Subsidies

- The European Commission introduced the EU Hydrogen Bank, allocating **€3B in subsidies for green H2 producers**
- Launched in December 2022, Germany's **H2 Global[2] provides €900M in subsidies** to support the production and import of H_2 from countries outside EU

Funds supporting the CAPEX of novel tech have accelerated deployment

Important Projects of Common European Interest (IPCEI)

- **IPCEI funding covers the construction** of hydrogen production facilities, transportation infrastructure, and the development of near-zero emission technologies for the steel sector
  - **ArcelorMittal** has received nearly $800M in financial support for deploying 3 demonstration projects for H-DRI production across Europe[5]

EU Innovation Fund

- Funded by the EU ETS, the aim is to introduce cost-competitive net-zero technologies for transitioning the energy and industrial sectors
  - **HYBRIT-initiative[6]**, driven by SSAB, LKAB and Vattenfall, has received **€143M from Innovation Fund** in April'22 for demonstration of a complete **value chain for H_2 based steelmaking, replacing BF with DRI**

The EU is also providing funding to support OPEX of novel production routes

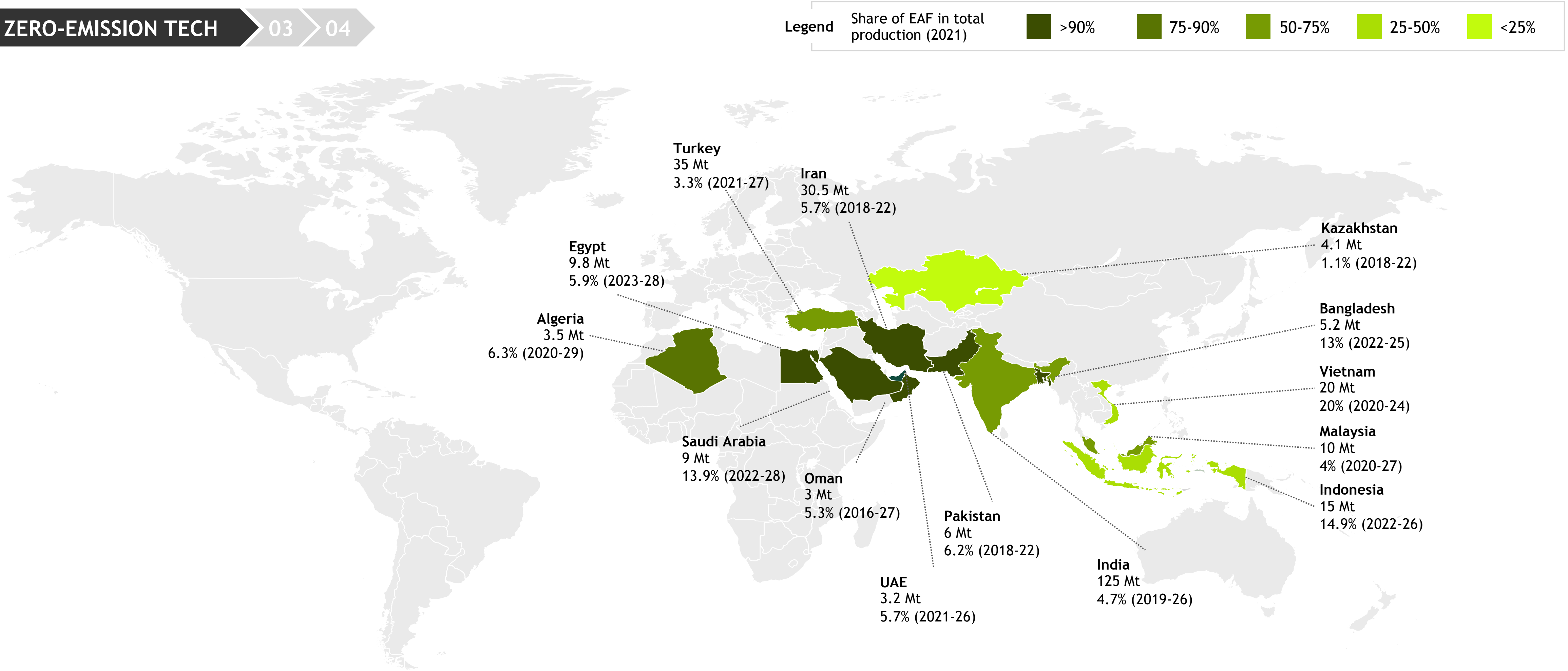
Germany's Carbon Contract for Difference (CCfD)[8]

- Offers €50B of **funding to make climate-friendly production processes competitive** in energy-intensive industries (e.g., steel, cement, chemicals) to offset differences in the cost of green technologies over conventional energy sources
- **CCfD can accelerate the transition** from natural gas-based DRI to green H_2 based DRI by covering a portion of the cost premium associated with near-zero emission steel production

Note: Title quote from Head of Strategic Projects & CO2 strategy, Steel manufacturer #3

Source: 1) European Hydrogen Bank; 2) H2 Global Subsidies; 3) IPCEI Hy2Use; IPCEI Hy2Tech; 5) Arcelor Mittal Projects: Spain, Germany, Belgium; 6) HYBRIT Initiative; 7) Research Fund for Coal and Steel 8) German carbon CfD

Additional capacity will emerge in the Middle East, North Africa, and Asia, as some regions are poised to adopt lower emission technologies



Notes: 1) Countries with annual production >2Mn MT in 2022 selected for the analysis (~1% of global production of 1,900Mn MT in 2022); 2) Countries planning to cut or not planning to expand steel production have been eliminated from the analysis; 3) Different ranges for CAGR have been used for various countries based on availability of market reports; 4) Growth forecasts for Iran are not available but production is expected to expand: Iran; 5) Share of EAF in total production is for 2021 except for UAE, Pakistan, and Oman for which the data is for 2018 – however government statements and news article do not indicate any BF/BOF expansion

Sources: 1) Steel Statistical Yearbook, 2019; World Steel Annual Production Data, 2022; Lit search

Algeria and Egypt have expanded DRI steel production due to abundant natural gas; efforts towards green H2 expansion could enable shift to H2-DRI capacity

Algeria

With world's third lowest natural gas prices, large iron ore reserves, and incentives for FDI and private investment, Algeria is growing NG-DRI-based EAF production

Production & capacity

3.5M	Steel production (Mt, 2022)
↑ 15%	Growth rate (2018-2022 production CAGR)
5M	NG-DRI capacity[3] (Mt, 2022)
1.5M	Blast Furnace capacity (Mt, 2022)
2.5M	Announced NG-DRI capacity (Mt)

Supporting policies

- Algeria has created investment incentive policy providing benefits that could be applied to support regional steel projects including:
  - Partial or total refund of expenditure relating to infrastructure works under the zone exemption arrangements
  - Concession of land under forward contract, over periods of 33 years
  - 5-year exemptions from corporate income tax
  - 3% interest rate subsidies boosting FDI and private investment[1]
- While initiatives to scale hydrogen production will enable emergence of H2-DRI, Algeria has the intent to export H_2
  - Algeria is targeting 25GW of domestic power from green and blue hydrogen by 2050

Egypt

Leveraging abundant, low-cost natural gas, Egypt is expanding DRI capacity using tax incentives in dedicated industrial zones

Production & capacity

9.8M	Steel production (Mt, 2022)
↑ 5.9%	Growth rate (2018-2022 production CAGR)
8M	NG-DRI capacity (Mt, 2022)
0.5M	Blast Furnace capacity (Mt, 2022)
4M	Announced EAF capacity[4] (Mt)

Supporting policies

- Incentives for the Ain Sokhna Industrial Zone covering heavy industry projects may attract foreign investment into new steel production capacity
  - Similar incentives exist for RE manufacturing in Suez Canal Economic Zone[7]
  - Policy provides a favorable location for international trade
  - Financial incentives such as 0% Customs Tax and VAT, and up to 50% of investment amount from net profits for taxation purposes
- Proposed tax credit of up to 55% on revenues made from production of green H_2 can potentially enable scaled H-DRI
  - Other incentives for green H2 include VAT exemption on equipment, waiver on land related charges, and credit facilities and mortgages; ambition to cut average thermal energy consumption in steel by 10%

Source: 1) Algeria Invest, 2) World Steel Association Production Data, 2022; 3) North Africa – Focus on DRI Steel Making; 4) OECD: Latest developments in steelmaking capacity; 5) Algeria Green H2 Policies; 6) Egypt's Green H2 Policies; 7) SCZone Benefits

Reducing the cost premiums associated with green steel requires demand commitments to unlock investment in **zero-carbon primary production technologies**

Commercial viability

- **Direct Reduction of Iron (DRI) using green H_2 has been proven to result in ~95% lower emissions**
- **But DRI steel is currently ~25-40% more expensive** than conventional blast furnace ironmaking methods, creating cost-competitiveness issues in a commoditized market
- **Early-stage demand through green steel procurement commitments** is allowing steel producers to de-risk investments in zero-emission technology. Scaling near-zero-emission production capacity will be challenging within the existing market context

"It will be difficult for companies to fully commit to green steel without some intervention to push cost parity."
Head of Climate Action,
Auto manufacturer #1

Deployment of capacity

- Engineering companies developing DRI technology are **limited by the pace at which they can build and install new ironmaking equipment**, potentially delaying final investment decisions for near-zero emission projects
- **H-DRI-EAF primary steel production capacity is currently in the demonstration stage**, with commercial scale plants planned for 2030
- Absent more **rapid deployment of electrolyzer capacity** to scale green H_2 production and bring it down the cost curve, producers will rely on natural gas / coal to ensure commercially viable ironmaking

"There is no question that there is early demand, but there are very few [production] projects available that have investment decisions and a timeline to come online soon and are green enough."
Head of Climate Action,
Auto manufacturer #1

Procurement policies, pricing mechanisms, and international coordination will help the industry overcome capacity deployment challenges as it climbs down the learning curve

Expanding niche demand for green steel

- Creating niche demand for green steel is critical for **enabling early stage H2-DRI** to be further developed, as well as reduce costs and technology risks
- Early-stage adoption of net zero steel production can be kickstarted through **carbon contracts for difference**, **public procurement initiatives** (such as through the Green Public Procurement Pledge), sector specific **green steel mandates,** and **private sector procurement**

Enabling broader adoption

- As DRI technology comes down the learning curve and green hydrogen becomes more readily available, **pricing and subsidy mechanisms** can create a level playing field for green steel
- Policy options include incentives such as **tax reliefs or grants to manufacturers**, or **carbon pricing mechanisms** like the Emissions Trading System (ETS)
- Transition at scale will require **much stronger international policy coordination,** given the inherent challenges of such a competitive and strategic sector

International coordination

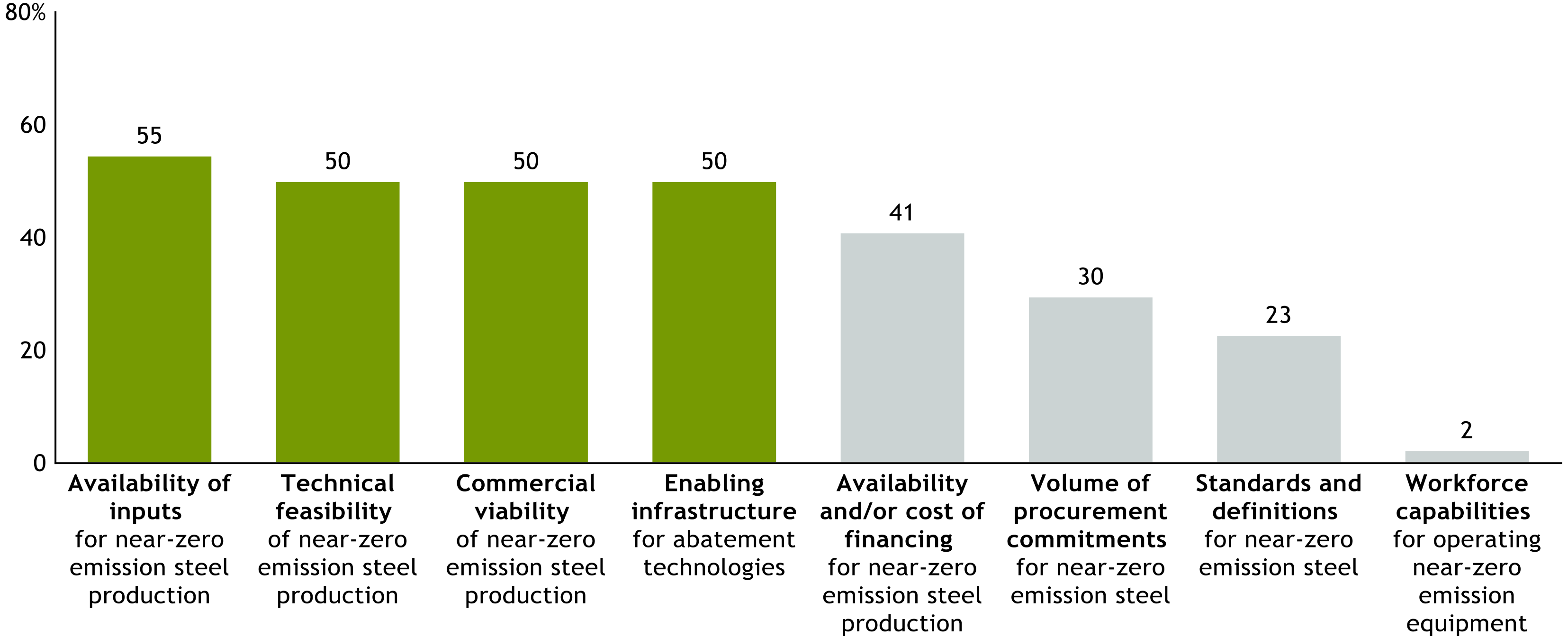
- Decisive action across developed, emerging, and developing markets will be needed to ensure the next series of capacity additions and replacement for steel is low-carbon
- Ideally, this transition would involve the **alignment of regulation and standards of steel production**, **technology transfer mechanisms**, and **international support** for the adoption of lower carbon production methods
- Absent this scenario, coordinated measures by a coalition of willing actors may be the next best approach, which could include **coordinated carbon border adjustments** or broader trade policy approaches

Steel: Table of Contents

Sector leaders identify inputs availability as the key barrier to decarbonizing along with technical feasibility, commercial viability, and infrastructure

*Which of the following do you view as the **steel sector's largest barriers towards accelerating decarbonization?** Please select the top 3 most impactful barriers.*

Share of survey respondents selecting barrier in the top 3 (%)



Commentary

- Steel producers are concerned with ensuring a consistent **supply of steel scrap** and the **high-grade iron ore, green H_2, and renewable energy** necessary to produce direct-reduced iron and operate an electric arc furnace
- **Developing sufficient transport and storage infrastructure** will be a key enabler for producers to deploy carbon capture technology
- Two players – Midrex and EnergIron – lead **production of direct reduction technologies,** limiting speed to scaled deployment
- **Commercial viability and high costs associated with financing** near-zero emission production are both linked to the sufficient offtake for greener products

Note: Chart includes data from respondents with expertise in the steel sector (N=44); The survey findings and emerging insights are based on the views of a subset of these companies and thus do not represent a universal view on the steel industry transition; About half of the responses represent the EU and US, one-third represent India and China, and the rest of the responses represent the rest of the world. A respondent is tagged to a region based on the region they are responsible for overseeing (represents at least 30% of their time). One respondent can thus answer for multiple regions.
Source: Bain / WMBC Global Stocktake Survey (N = 215)

"Governments are pushing towards scrap steel production [..] It's the quickest way of decreasing emissions across the product portfolio"

The **European Union** is Increasing domestic scrap availability through export restrictions, standards and funding for scrap recycling

- **Circular Economy Package:** Enables usage and recovery of scrap via Extended Producer Responsibility (EPR) and increased recycling targets
- **Waste Shipment Regulation[1]:** Ensures availability of high-grade scrap within the EU, by **restricting exports of EU-origin scrap to countries that don't have EU waste treatment standards**
- **Steel Action Concept of Germany[2]:** Prescribes that "sustainable" products should include recycled materials and increased usage of steel scrap
- **Clean Steel Partnership[3]:** Provides **€700M in funding from the EU Commission over 10 years** to increase the share of low-quality scrap recycling to 50% in '27

The **United States** is indirectly incentivizing scrap collection by promoting domestic production, which is 70% EAF

- **Build America, Buy America Act[4]:** Set of domestic preference laws requiring that 55% of steel used in federally funded projects should be domestically manufactured as of 2022
  - Increases to 75% requirement in 2029
- **Buy Clean Initiative[5]:** Covers **98% of government purchases** to prioritize products with **lower emissions**
  - Expected to increase use of low-emission construction materials including steel made with higher scrap percentage

In addition, the EU Commission is providing €700M in **direct funding** over 10 years for lowering steel energy intensity by 10% and increasing the share of low-quality input scrap recycling to 50% by 2027 by progressively increase the uptake of post-consumer scrap grades

China is promoting expansion of domestic EAF production capacity and restricting the quality of scrap imports

- **Capacity Replacement Program[6]:** Favors new EAF capacity by allowing a **1:1 replacement ratio for scrap-based EAFs** while replacement ratio for **other technologies is 1.5:1**
  - China's 14th Five Year Plan roadmap set a target for EAFs to reach 25% share of production by '25
- **Higher quality scrap import norms:** In 2021, the government **revised quality standards for ferrous scrap imports**
  - Specified impurity levels to be below 0.3%, 0.8%, 1% for 3 different grades, impacting the use of imported scrap due to limited availability of compliant material in global markets
- **Substitution of iron-ore by scrap:** China's 14th Five Year Plan roadmap set a target to **achieve 30% crude steel output from scrap by 2025**

India is directly promoting scrap collection through standards and guidelines

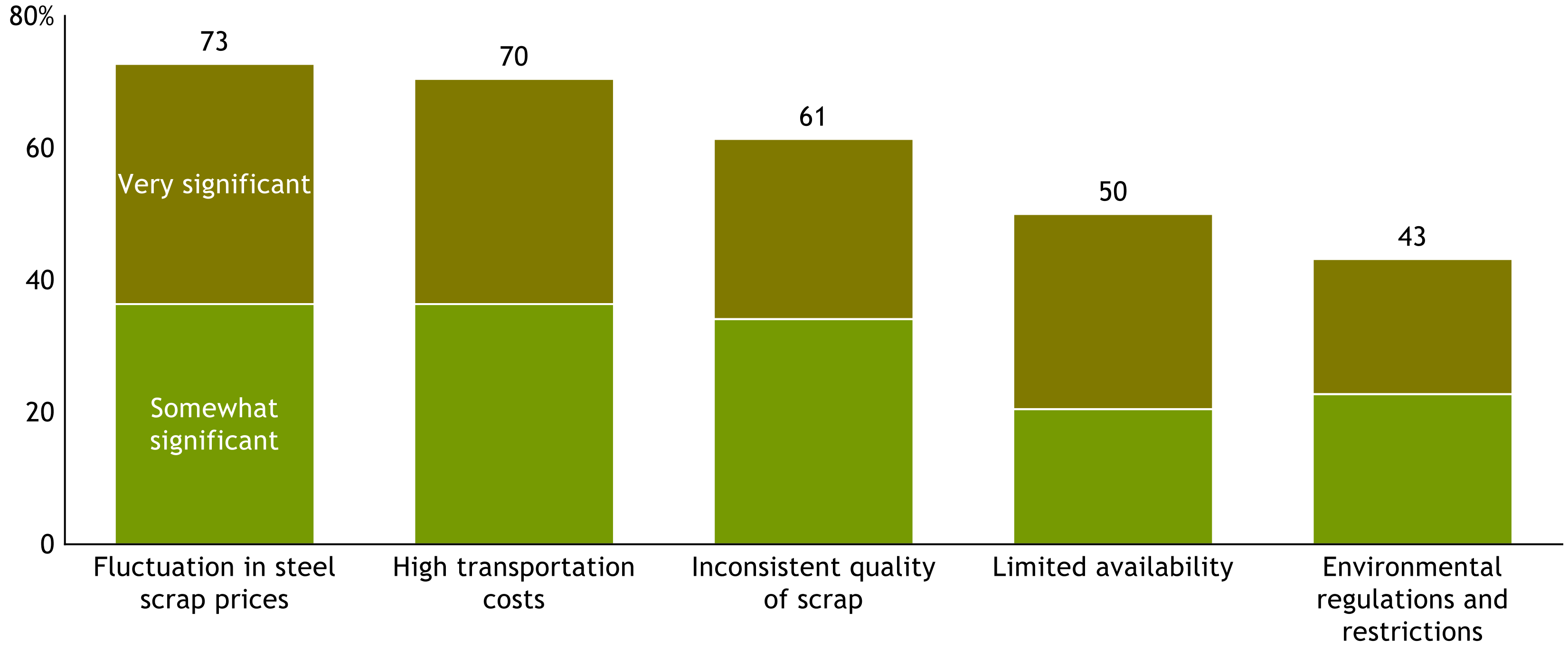
- **Steel Scrap Recycling Policy[7]:** Ministry of Steel's policy focused on **enhancing the availability of domestically generated scrap,** providing guidelines for collection, dismantling and shredding activities in an organized, safe and environmentally sound manner
  - **Automobile Fitness Certification Policy** to prevent plying of unfit and polluting vehicles
  - **Extended Producer Responsibility** requires vehicle manufacturers to incentivize scrapping of unfit vehicles in exchange for price discounts for purchase of new vehicles
  - New manufacturing companies and scrapping centers can pay income-tax at 15% (a subsidy of 15% and avoids requirement to pay the Minimum Alternate Tax)

Source: 1) Waste Shipment Regulation; 2) Steel Action Concept, Germany; 3) Clean Steel Partnership; 4) Build America, Buy America Act; 5) Buy Clean Initiative; 6) China's Capacity Replacement Program; 7) Steel Scrap Recycling Policy, 2019 ; Title quote from Sr. VP, Business Development, Technology provider #2

~70% of business leaders in the steel sector believe that transportation costs and inconsistent quality are significant barriers to maximizing supply of scrap

*On a scale from 1 to 5 – where 1 is not at all significant and 5 is very significant – **how significant are these barriers for steel producers when procuring sufficient steel scrap supply** for their production needs?*

Share of respondents ranking barrier as somewhat or very significant (%)



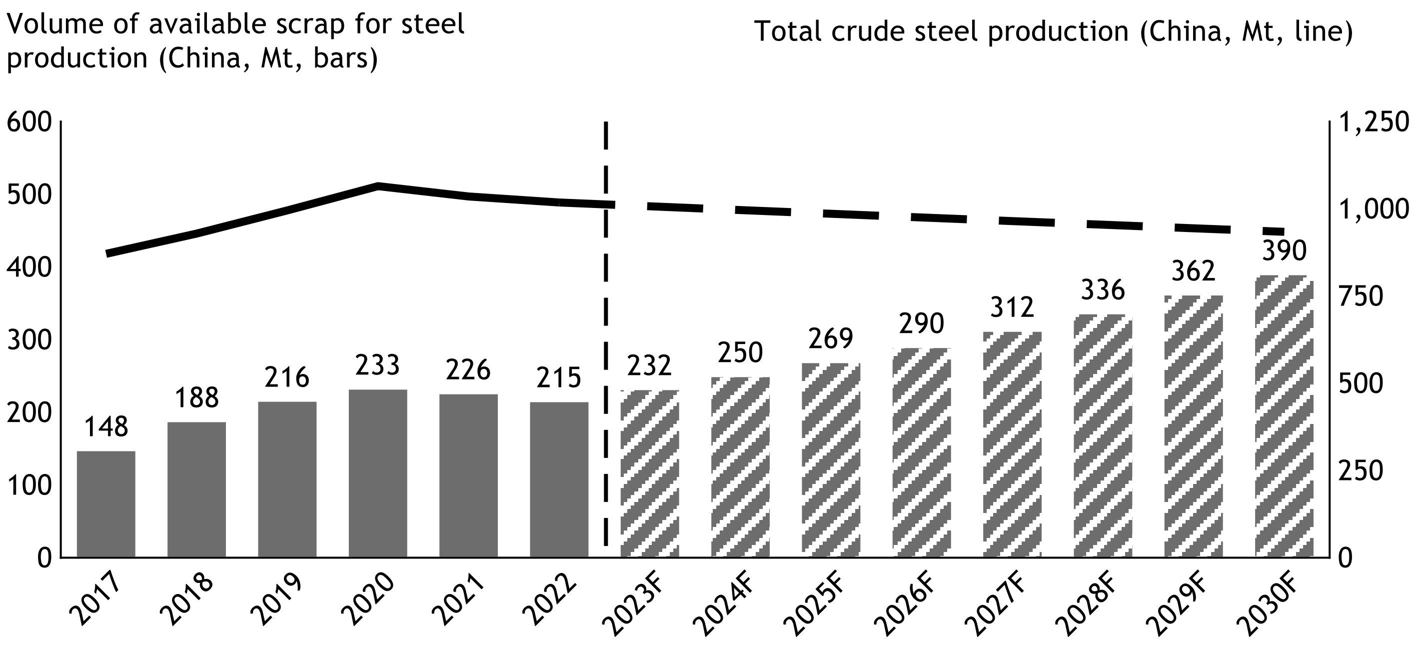
Commentary

- High transportation costs **limit the amount of scrap that steel producers can move to production facilities** or import from international sellers
- Additional costs associated with purifying contaminated scrap can be a significant **barrier to maximizing recovery rates**
- Growing dependence on scrap for emerging EAF production combined with policies limiting the export of scrap may **exacerbate these barriers in the future**

Note: Chart includes data from respondents with expertise in the steel sector (N = 44); The survey findings and emerging insights are based on the views of a subset of these companies and thus do not represent a universal view on the steel industry transition; About half of the responses represent the EU and US, one-third represent India and China, and the rest of the responses represent the rest of the world. A respondent is tagged to a region based on the region they are responsible for overseeing (represents at least 30% of their time). One respondent can thus answer for multiple regions.
Source: WMBC Sector Survey (N = 215)

Leveraging growth in domestic scrap, China - world's leading steel producer - will transition production toward low-emission electric arc furnaces

China will benefit from increasing scrap availability over the next decade



Share of EAF prod. (%)	9%	12%	10%	9%	11%	10%

China's government aims to increase the share of EAF production to 15% by 2025

Commentary

- In regions with low-carbon grids, the EAF method is the least emissions-intensive for producing secondary steel from scrap
- China produces ~53% of the world's steel but only ~10% through EAF (vs. 28% of global production)
- China expects a ~70% by 2030 in scrap supply based on historical production, steel lifecycles, and enhanced recycling
- China's Capacity Replacement Program encourages new EAF capacity to replace old blast furnace capacity
  - By 2030, more than 70% of China's BF-BOF capacity will be due for relining
  - It also incentivizes replacement with larger, more efficient blast furnaces

Note: Growth in scrap supply was averaged across 2023-2030 at a CAGR of 7.7%; Decrease in steel production was averaged across 2023-2030 at a CAGR for demand of -1%; Growth in share of EAF was taken between '22-'25 and averaged across 2025-2030 to model growth

Source: World Steel Association – Maximizing Scrap Use Helps Reduce CO2 Emissions; RMI – Pursuing Zero Carbon Steel in China; Bureau of International Recycling – Ferrous Division; China's Association of Metalscrap Utilization (CAMU); World Steel Association – World Steel in Figures 2017-2022; China Metallurgical Industry Planning and Research Institute; Agora – Chinese BOF Reinvestment Requirements; China's Ministry of Industry and Information Technology, National Development and Reform Commission, Ministry of Ecology and Environment – Joint Report January 2022; Eurofer (2013) A steel roadmap for a low carbon Europe 2050

China's Capacity Replacement Program favors new EAF capacity, while also supporting larger BFs to increase productivity

Recent policy will drive the transition of…

- Aligned with China's 14th 5-year plan (2021-2025), the Chinese Ministry of Industry and IT (CMIIT) announced that **EAF would make over 15% of steel production in 2025** and 20% in 2030
- China's **Capacity Replacement Program** sets stricter requirements for new capacity, **consolidating smaller BF plants and encouraging EAF additions**
- **China's ETS system,** launched in 2021, **could increase the cost of BF operation if steel is covered in future phases**
- The Action Plan for Carbon Peaking outlines the **ambition to increase the supply of scrap metals** to be used for low-emission secondary steel production

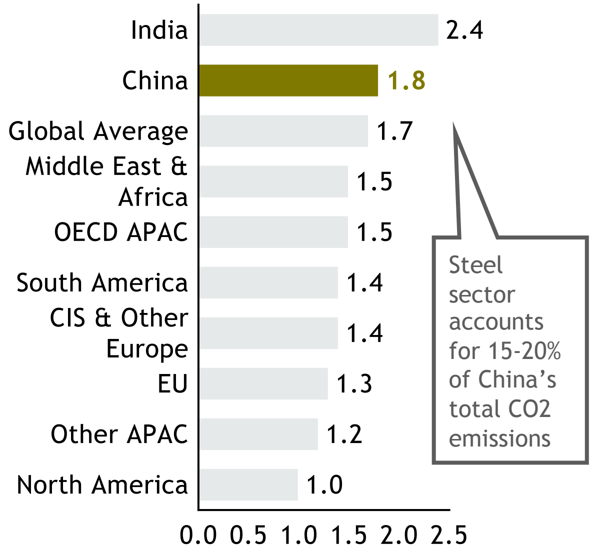
…a fragmented, blast furnace-oriented sector…

- Smaller, privately-owned mills quickly expanded lowering utilization rates and undermining steel margins
- Larger blast furnaces have lower coke usage, lower emissions of waste gas, limit the production of slag, and require lower inputs of energy sources (e.g., coal, electricity) per tonne of hot metal produced
- Incentives to replace BF/BOFs with EAFs will allow China to leverage its growing domestic scrap supply

CMIIT 2025 target: top 5 mills to account for ~40% of China's steel capacity

…that is highly carbon intensive…

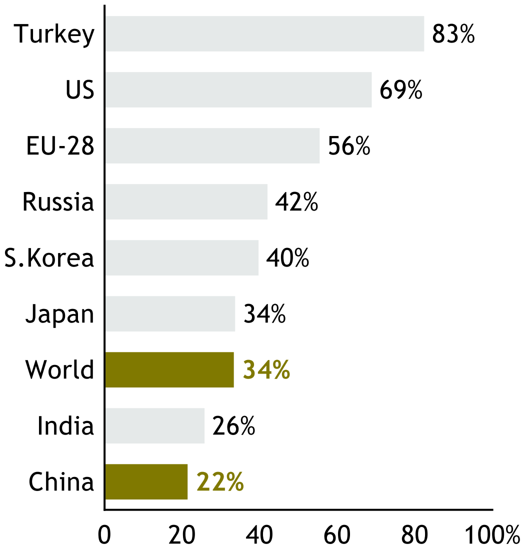
Steel sector emissions intensity by region (t CO2 / t steel)



Chinese Ministry of Ecology and Environment set 2025 emissions targets for 80% of capacity

…and uses a relatively low share of scrap

Scrap ratio, 2019
(scrap usage as % of crude steel production



CMIIT mandate to lift scrap usage in domestic steel production from 22% in 2019 to 30% by 2025

Source: Energy Transitions Commission; Lit. search

National approaches to restricting scrap exports could end up slowing the decarbonization of the global steel sector

Scrap export restrictions…

- 43 countries – largely in Africa, Middle East, and Asia – set scrap export restrictions to promote local recycling
- By 2024, the EU will modify its Waste Shipment Regulations, to promote domestic scrap utilization and monitor sales to non-OECD countries
  - Expected to impact most heavily China, India, Bangladesh, and Pakistan
  - With EU's new rules, the number of countries with such restrictions might rise to ~70
- Other top scrap exporters (US, UK, Canada, Japan) have refrained from such measures

…risk distorting markets for scrap collection and deployment of clean production

Reduce total scrap collection

- Export restrictions will lower scrap prices for domestic consumers, undermining price incentive driving recovery efforts[3]
- Export restrictions hinder efficient scrap distribution to high-demand regions

Disincentivize new clean capacity

- Export restrictions will prevent export of scrap to non-OECD countries
- A shortage of scrap in these countries will limit their ability to expand DRI-EAF production and further incentivize BF-BOF production

Inhibits equitable development

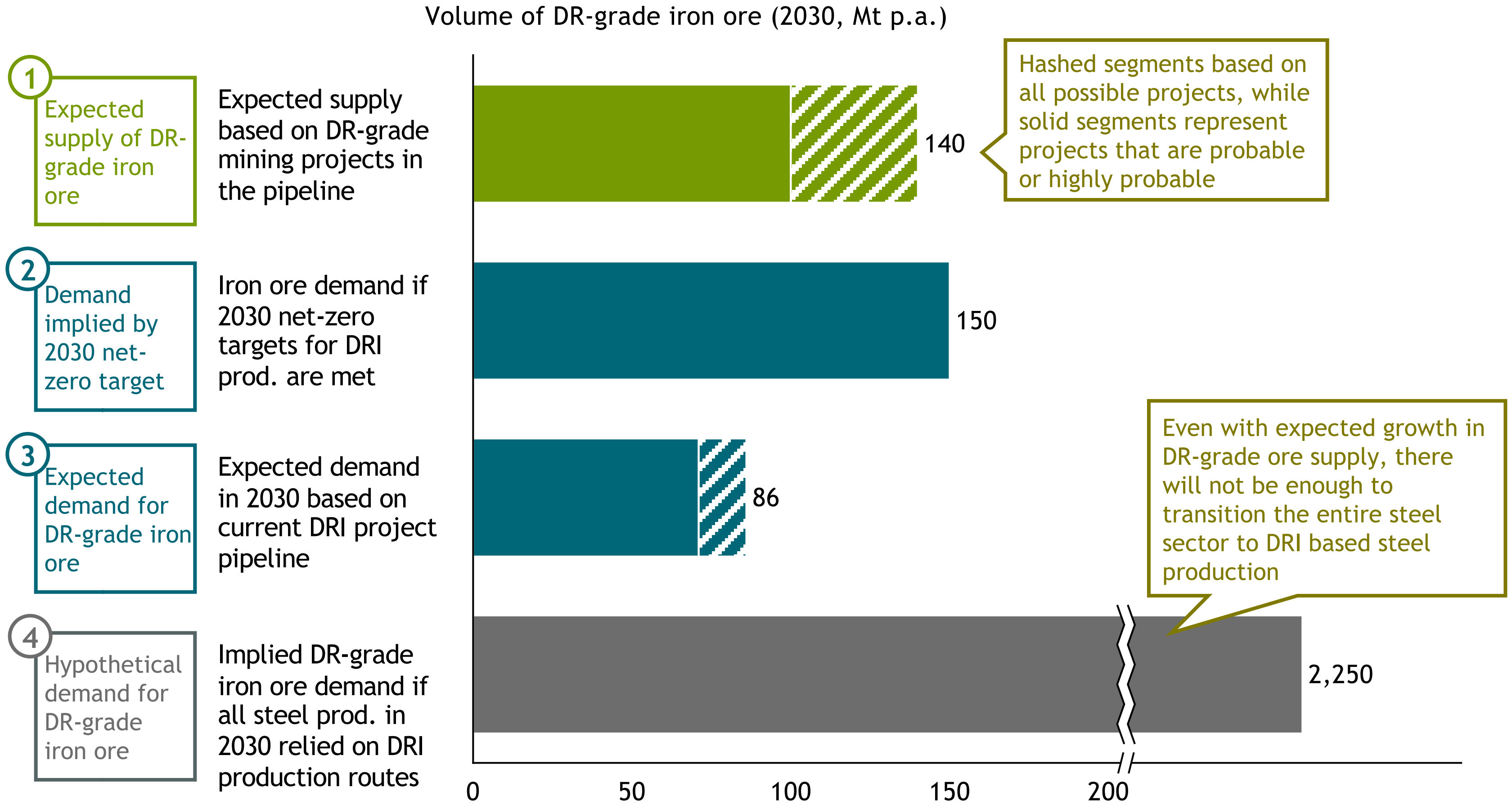
- Scrap export restrictions risk sharper trade diversion and more trade among developed countries
- Only developed countries would have sustainable waste treatment processes in line with EU standards

Downcycling of high-quality scrap

- Scrap export restrictions may cause high-quality scrap to be downcycled and used in end-products that do not require it
- A lack of high-quality scrap in regions where it is required may lead to an increased reliance on primary steel production routes resulting in higher carbon emissions

Sources: 1) 43 countries globally have restricted the export of ferrous scrap; 2) EU avoids scrap export ban, monitors non-OECD exports ; 3) EU scrap metal export curbs would be backwards step in global decarbonization

“Iron ore grades are one of the constraints to the deployment of DRI that often gets overlooked”



Multiple things must occur in parallel for ore supply to meet scaled DRI-based steel production

Mining companies and steel producers may be able to address this shortage by:

- **Developing new deposits** of high-grade iron ore (with >66% iron content)
  - Conventional blast furnace production currently uses iron ore with iron content as low as 58%
  - Only ~3% of iron ore shipped today is of a suitable grade to be used in DRI-EAF steelmaking
- **Advancing and expanding iron ore beneficiation** to improve the quality of low-grade ore and meet DR-grade iron ore demand
  - **Expanding pelletizing capacity** to convert high-grade ore and pre-processed low-grade ore into DRI-suitable pellets
- **Developing new melter technologies (e.g., DRI-Smelt-EAF)** that enable lower-grade ores to be utilized in DRI-based steelmaking
- Even considering actions to expand DR-grade ore supply, **CCS technology will be necessary** to abate remaining BF capacity

Note: Title quote from Manager of Sustainability, Resource provider #1; Net-zero target based on 1.5C compatible target for 2030 as stated in the Breakthrough Agenda 2022; Expected demand based on current DRI-EAF project pipeline; Lower bound of expected supply is based on high-grade iron ore mining projects for which realization by 2030 is highly probable or probable, whereas the hashed upper bound estimate reflects the IIMA projection if all possible projects were built; The survey findings and emerging insights are based on the views of a subset of these companies and thus do not represent a universal view on the steel industry transition

Source: Agora Industry; Wuppertal Institute; IEEFA; Wood MacKenzie; IIMA

In India, the sourcing of iron ore compatible with DRI operations is challenging, and would significantly drive-up costs for transitioning to DRI

*"The issue is not that there is no iron ore for DRI pellets in India, but that the **operational efficiency of DRI goes down a lot without high grade iron ore** – so either you need to **spend money improving the iron ore grade** or **ensure that the DRI process is adapted** to lower operating parameters*

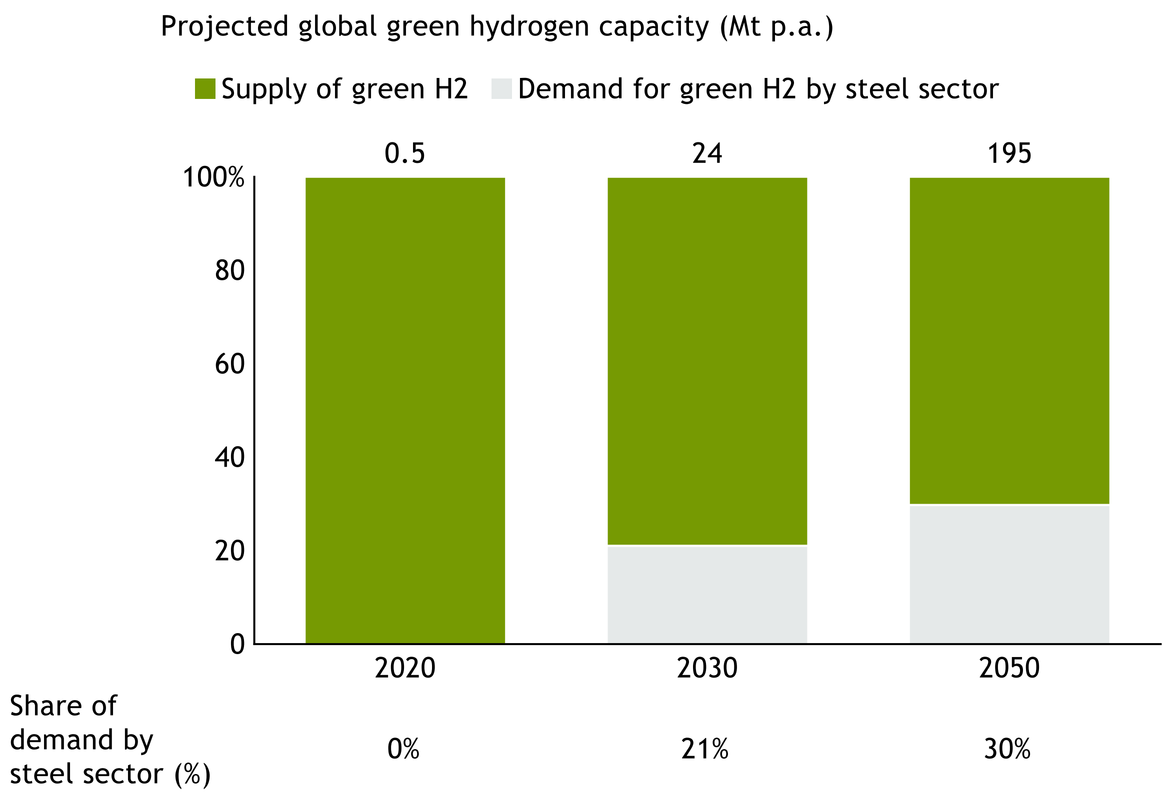
*The question is can you get the **regulatory environment and policy incentives** to make this shift – the cost is 80$ more per tonne. I will be out of business in a week if I have to take this on as a producer. This is the broader decarbonisation question – in the end, **somebody has to pay"***

Head of Strategic Projects & CO2 strategy, Steel manufacturer #3

Source: Corporate interviews

"The renewable and hydrogen demand that the steel sector will drive is not going to other sectors where it may be more efficiently and productively used"

Green steel is forecasted to use up to 30% of global supply for green hydrogen



Commentary

- **Global supply of green hydrogen is expected to grow to ~200Mt p.a.** by 2050
- **Global demand for green hydrogen** for steel production is expected to reach **~60Mt p.a.in 2050** assuming net-zero steel targets are met
  - **EU policy** like the Renewable Energy Directive 3 is **driving hydrogen demand across sectors**, increasing the need for sufficient supply
- To meet projected demand in the steel sector, and ensure a sufficient supply for other major sectors, hydrogen producers may be able to address this shortage by expanding:
  - **Renewable energy and electrolyzer capacity** to produce green hydrogen
  - **Transport infrastructure** to move hydrogen to demand centers

"There is also a ***scalability challenge.*** *Even if we made a decision tomorrow to shift to green hydrogen, the* ***scale of green hydrogen required would be massive****"*
- Head of Strategic Projects & CO2 strategy, Steel manufacturer #3`

Note: Title quote from Manager of Sustainability, Resource provider #1; Green hydrogen supply figures based on consensus estimate from DNV, Goldman Sachs, Credit Suisse, IEA, and Ember; Supply figures exclude hydrogen produced as a process by-product, Demand figures for 2030 and 2050 based on 1.5C compatible steel decarbonization scenarios from Agora Industry and the IEA
Source: DNV Global, Goldman Sachs, Credit Suisse, IEA, Ember, Agora Industry – Global Green Iron Scenario

Alternative steel production technology solutions are being developed that don’t rely on hydrogen or high-grade iron ore

BOSTON METAL **Case Study: H2 green steel**

Overview

- **Description:** Global metal technology company intended to commercialize molten oxide electrolysis for high-volume steel production
- **Founded:** 2013
- **Headquarters:** Massachusetts, USA
- **Ownership:** Private
- **Funding:** Raised $240M as of May 2023
- **Technology deployed:** Molten Oxide Electrolysis (MOE) ironmaking powered by renewable energy

Targets

2025
- Launch demonstration plant capacity showcasing the molten oxide electrolysis process

2030
- Deploy first commercial-scale MOE steel production plants

Activities

Developing zero-emission production

- Molten Oxide Electrolysis (MOE) replaces fossil fuels with renewable electricity to **convert low- and mid-grade iron ore fines directly into high-purity molten iron**
- **MOE eliminates multiple steps in the conventional steelmaking process** like coke production, iron ore sintering and pelletizing, blast furnace reduction, and basic oxygen furnace refinement

Enabling affordable, modular production capacity

- Boston Metal’s modular **MOE cells can be scaled up** to meet production capacity targets **from thousands to millions of tons** of steel output
  - Roughly the size of a school bus, MOE cells contain an electrolyte solution that is heated to excite electrons that split the bonds in the iron ore
- MOE production process can **reduce capital expenditure** needed to construct new production capacity by eliminating the need for coke ovens and sintering plants that would otherwise be required for blast furnace facilities

Source: Boston Metal company website and press releases

Limited availability of raw inputs restrict companies' ability to advance low-emission production

Steel scrap

- **Steel producers are dependent on scrap** for cost-effective and low-emission steel production which in turn decreases the need for raw materials such as coke and iron ore
- Purifying steel scrap can be **labor-intensive and may require specialized equipment** to properly separate impurities, contaminants, and non-ferrous material before it can be used
- **Existing infrastructure and a region's historical manufacturing rates** directly drive the pool of available scrap as steel products reach the end of their life

~70% of business leaders consider transportation costs to be a barrier to securing a sufficient supply of scrap

Energy inputs

- Steelmakers require access to **renewable energy to power EAF capacity and produce green H_2** to use as a reducing gas in low-emission ironmaking (e.g., DRI), but the volume of renewable capacity and high-voltage distribution infrastructure varies between regions
- **Leveraging green H_2 in the DRI process can enable up to a 95% reduction in carbon emissions** compared to conventional blast furnace routes, but many steel producers opt for fossil dependent fuel sources due to lower costs and wider availability

~60% of business leaders consider availability of inputs to be a top barrier to the decarbonization of the steel sector

High-grade iron ore

- Until now, ore with >66% iron content has not been specifically needed in steel production which has deterred mining companies from pursuing new deposits or purifying low-grade ore, further **limiting the supply of inputs required for low-emission DRI processes**
- While there is enough high-grade iron ore to serve near-term DRI capacity additions, **other low-emission methods of ironmaking (e.g., HI-smelt) that leverage conventional grades of iron ore** will need further development to replace BF capacity

"Iron ore grades are one of the constraints to the deployment of [DRI] that often gets overlooked… You get a significant shortfall if there's rapid expansion of hydrogen based DRI."

Mngr. of Sustainability, Resource provider #1

Increasing the availability of raw inputs is key in advancing low-emission production

Promote Circular Economy for Scrap Steel

- **Champion recycling and collection of scrap steel**, by allocating funds to recycling initiatives for scrap following examples like the EU's Clean Steel Partnership, or by adopting standards such as those highlighted in India's Steel Scrap Recycling Policy
- Impose **recycling standards for steel production**, through mandates on the percentage of raw materials to be sourced from recycled steel
- Provide **support to enterprises investing in cutting-edge recycling technologies**, such as tax credits, to encourage innovation and efficient recycling practices

Invest in green hydrogen infrastructure

- Lower cost green hydrogen production is critical for the development of greener steel
- **Alongside supply-side policy**, which enables the development of the broader hydrogen industry, **industry-specific demand-side policy** can also help increase investor certainty, with options such as industry-specific mandates for the adoption of green hydrogen, or more technology-neutral approaches such as carbon standards

Promote international cooperation on critical inputs

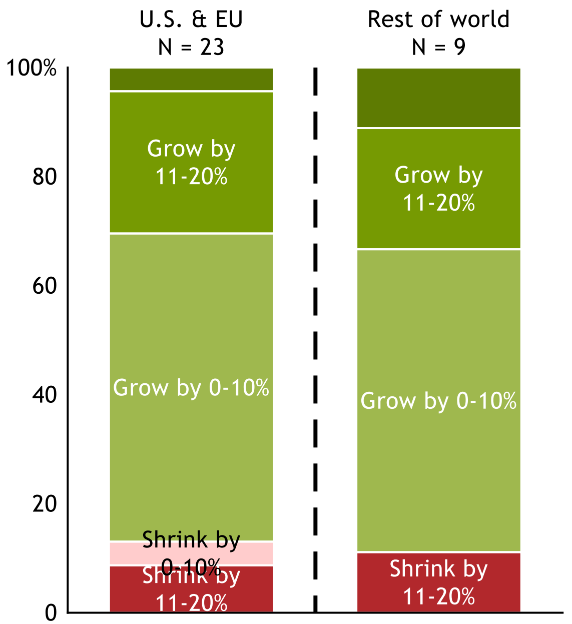
- Greater coordination across major economies will be needed to ensure efficient access to essential inputs like **high-grade iron ore and scrap steel** and mitigate recent policies banning scrap metal exports

Steel: Table of Contents

Business leaders expect to increase R&D spend on CCS technology, and drive deployment of the technology by 2030, particularly in the U.S. and EU

I would expect my company's total R&D spend directed toward CCS technology for blast furnace production to ___ from now until 2030

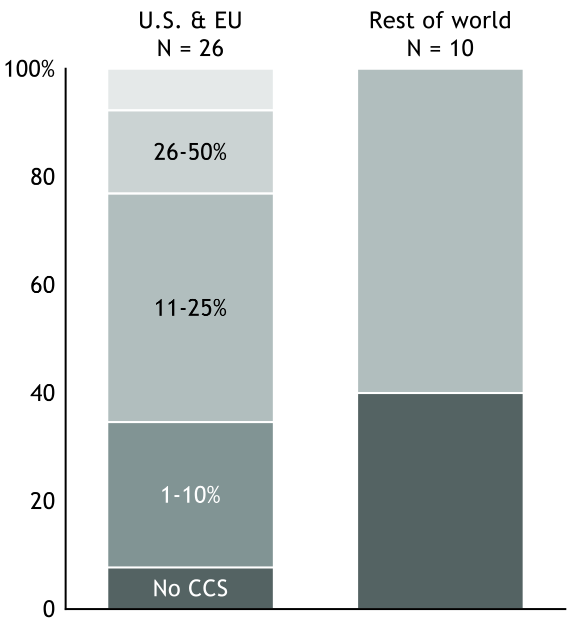
Share of respondents (%)



Change in R&D spend on CCS technology by 2030

What proportion of your company's blast furnace capacity do you anticipate being abated using CCS technology by 2030?

Share of respondents (%)



Share of blast furnace capacity with CCS by 2030

Commentary

- **Steel producers are confident they will increase their R&D investments** to fast-track the commercial viability of Carbon Capture and Storage (CCS) technology
- **Producers in the U.S. and EU believe this technology can be leveraged** within existing blast furnace capacities to curtail carbon emissions by 2030
- **Commercially viable CCS technology will be particularly impactful in emerging markets** where rapidly increasing demand is being met with new blast furnace capacity
- Steel producers are partnering with mining companies in China to **finance the deployment of CCS projects**

"***CCUS is the most cost effective in terms of scalability.*** *Seems like a good option, but it depends on the specific economics of each region"* - Head of Strategic Projects & CO2 strategy, Steel manufacturer #3

*"It's **difficult to expect** that **China will adopt CCS** in their production facilities.* - Chief Technology Officer, Resource provider #2

*"Pragmatic view is to ensure that **technologies that a region like India** adopt are **as clean as possible,** and they **can be converted to carbon neutral in the future.** This might mean ensuring they're compatible with **future deployment of CCUS.** In our view, this is likely to remain the **most cost-effective option**"* - Head of Strategic Projects & CO2 strategy, Steel manufacturer #3

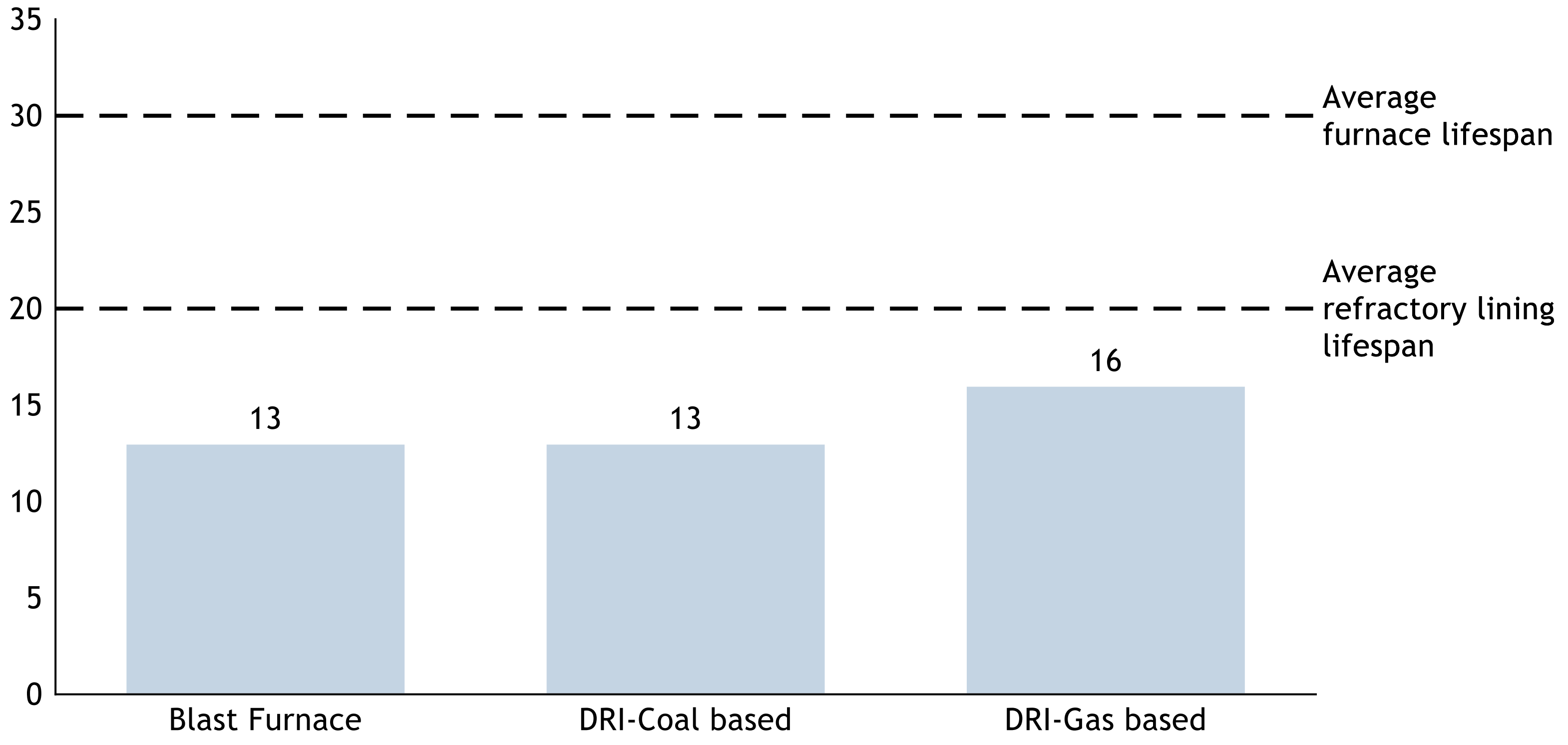
Note: Chart includes data from energy consumers with expertise in the steel sector (N = 36) and excludes 3 "I don't know" responses from the U.S. & EU, and 1 from the rest of world; The survey findings and emerging insights are based on the views of a subset of these companies and thus do not represent a universal view on the steel industry transition

Source: WMBC Sector Survey (N = 215)

“The investments sunk in blast furnaces is really significant [..] also a young investment well short of its payback”

Most iron and steel plants are relatively young

Average age of steel plants by technology in years, 2020



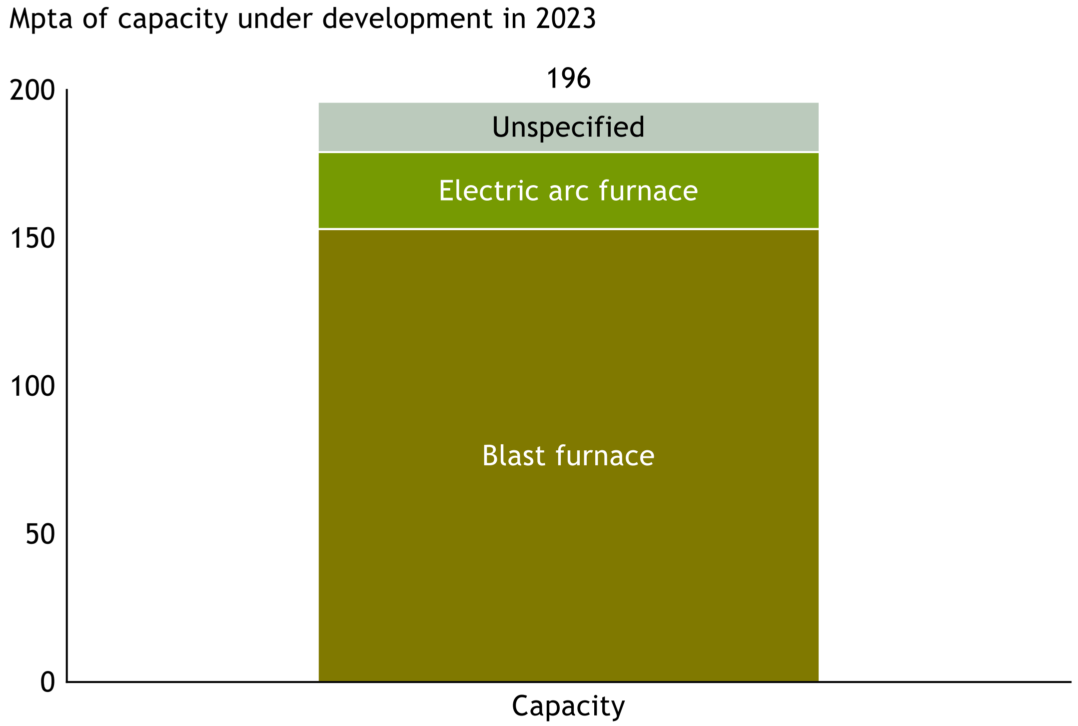
Commentary

- Given the ~30-year lifespan of steel plants, early retirement of blast furnace capacity would impose **stranded cost burdens** on producers
- However, **~70% of global blast furnace capacity will need relining** before 2030 according to world steel association, presenting a window to retire high-emission capacity in areas with decreasing demand
- ~50% of the current equipment inventory is in China; India accounts for an additional 5%

Notes: Title quote from Manager of Sustainability, Resource provider #1
Source: IEA: Iron and steel technology roadmap; World steel association

“India is a high growth market and they’re planning on building coal integrated BF plants [..] green technology is just not ready for the capacity they need”

Growing steel demand in India requires 162 Mt of capacity additions by 2030



Commentary

- **By 2030, India’s steel making capacity is expected to triple**, surpassing 300 Mt as they aim to become a net steel exporter
- India currently stands as the globe's premier developer of coal-driven steel capacity, **commanding 40% (153 mtpa) of the global BF-BOF** steelmaking projects underway
- Given the ongoing projects, India appears poised to **maintain high-emission steel production for about the next three decades** until these facilities are phased out
- China, once at the forefront, now closely follows India, accounting for 39% (147 mtpa), with both nations contributing to **over 75% of global BF-BOF development**
- India is also a leader in the development of coal-based DRI-EAF production with 9.1% of total (26 mtpa), laying the groundwork for a potential shift to more eco-friendly H-DRI-EAF ironmaking, sans CCUS

Source: Global energy monitor petal to the metal 2023; Title quote from Sr. VP, Business Development, Technology provider #2

India is promoting BF/BOF expansion to achieve its ambition of being a net steel exporter

India is currently world's leading producer of direct-reduced iron

- India produces **30% of global direct reduced iron (DRI)**, with 39 million tons of steel output from DRI in 2021[2]
- Currently, **~80% of India's DRI capacity is coal-based**
- A transition toward H-DRI has the potential to cut India's DRI emissions from ~2.8-3.2 tCO_2/ton steel (via current coal-fired DRI) to ~0.4-0.5 tCO_2/ton steel

While India has put in place recent policies to promote H_2 production…

- **India's 2022 National Green Hydrogen Mission aims to make India a leading producer and supplier of green hydrogen globally**
  - ~$2.4B announced for the development of cost-competitive green H_2 at <$1 per kg with the aim to produce 5M tons of green H_2 by 2030
  - Of the proposed outlay, ~$2.1B is directed towards Production-linked Incentives (PLI)[3] for green H_2 production (75% of fund) and electrolyzer manufacturing (25% of fund)
- While India has set targets to increase adoption of green H_2 across sectors (e.g., fertilizer, oil refineries, gas distribution networks), it **has not set any specifications for steel to drive near-zero emission production**

…India is advancing BF/BOF production to create a self-sustaining steel industry

India's National Steel Policy 2017[1]:

- Explicitly expects the **BF-BOF route to contribute 60-65% of the crude steel capacity and production** in 2030-31
  - Remaining 35 – 40% to come via EAF & IF route
- Aims to **increase domestic steel output to ~300Mt by 2030**
  - An ~$0.8M production-linked incentive for Specialty Steel is expected to drive additional ~$5B investment and add 25 MT of steelmaking capacity
  - Plans to generate demand for steel via infrastructure development projects and the National Rail Plan 2030
  - Expecting this demand to spur investment, India has set aside ~3M hectares of land for steel plants
  - 100% FDI allowed in steel, infrastructure, rail and automotive sectors
- Establishes India's **ambition to become a net steel exporter** by 2025-26
- Promotes **usage of low-grade iron ore** at captive mine sites conducive to BF/BOF production in conjunction with the Ministry of Mines

Notes: BF/BOF – Blast Furnace/ Blast Oxygen Furnace, DRI – Direct Reduction of Iron,
Source: 1) National Steel Policy, 2017; 2) India's DRI Production; 3) India's PLI schemes under the Green Hydrogen ecosystem;4) World's second-largest producer of Crude Steel

"I could not justify investment in anything like CCS. There's no market premium for the product. There's no regulatory push"

NON-EXHAUSTIVE

There a few commercial-scale CCS projects planned

	Partners	Project type	Announcement	Operation	Project Status	Announced capacity (Mt CO2/ yr)	Fate of carbon
France	ArcelorMittal, IFP, Axens, Uetikon, Grassco, brevik, TotalEnergies	Capture	2019	2025	Planned ▲	1	N/A
France	Arcelor Mittal, Air Liquide	Capture	2020	2030	Planned ▲	1 - 2.85	Dedicated storage
Norway	Statkraft, Carbon Recycling International	CCU	2017	-	Planned ▲	0.3	Use
United States	Dastur International Inc., ON Clean Energy, Inc., University of Texas	Capture	2020	-	Planned ▲	2	N/A
United States	Board of Trustees of the University of Illinois, Voestalpine, Air Liquide	Full chain	2022	-	Planned ▲		Dedicated storage
United Arab Emirates	ADNOC, Masdar	Full chain	2007	2016	Operational ★	0.8	EOR

Notes: Title quote from Manager of Sustainability, Resource provider #1; EOR - Enhanced Oil Recovery
Sources: Materials Processing Institute, Agora EnergieWende, Bain analysis

Commentary

- **Adding CCS on a blast furnace** is a possible pathway to abating existing emissions, with up to **~70% direct CO2 emissions reduction**
- Multiple **cross-industry collaborations have been announced** leveraging CCU/CCUS technology in BF/BOF
- However, **2030 pipeline for commercial-scale CS on the BF-BOF is slim,** with **other alternatives** gaining more traction
  - Production of 1 Mt for CS projects vs 84 Mt for H2-ready direct reduced iron (DRI) plants in 2023
- Key barriers include preference for **other alternatives, inability to address upstream emissions** (e.g., coal mine methane leakage) and **high CAPEX costs**
  - £400-£500m CAPEX for 1mt of steel estimated as investment costs in the UK

"There's a lot of ***discussion on CCUS but the project announcements have been limited****"*
- Sr. VP, Business Development, Technology Provider #2

“We are increasingly engaging with our customers on technology development pathways [..] CCS, CCUS is something we’ve been looking into recently”

HBIS GROUP

Case Study: HBIS Group

Overview

- **Description:** HBIS Steel is the sixth largest steelmaker in the world, producing ~41M metric tons annually
- **Founded:**1943
- **Headquarters:** Shijiazhuange City, China
- **Ownership:** State owned enterprise
- **Revenue (2022):** $21.3B
- **Technology deployed:** Trial carbon capture, utilisation, and storage (CCUS) technologies at conventional steel facilities

Targets

2022	• Peak carbon emissions from steel production
2025	• Cut carbon emissions from steel production by 10% from the peak
2030	• Cut carbon emissions from steel production by 30% relative to the peak
2050	• Achieve carbon neutral steel production across the entire business

Activities

Leveraging partnerships to develop CCUS technology

- Invested in the **development of carbon capture and utilization technology** to enable integration into steel production processes and reduce CO_2 emissions
  - Using an alternative form of carbon capture in vacuum pressure swing adsorption (VPSA)
  - Two utilization technologies constituting slag mineralization and biological conversion to protein to sequester CO_2
- **Formed partnership with global mining company BHP** to develop and implement absorptive desulphurization at the HBIS demonstration project in Xuanhua, Hebei
  - Absorptive desulphurization will allow HBIS to use nearly 60K metric tons of capture CO2 per year in the food and industrial sectors
  - The **Hebei province accounts for ~20% of China’s reported steel production** emphasizing the need for more CCUS initiatives

Source: HBIS and BHP press releases; title quote from Manager of Sustainability, Resource provider #1

Industry stakeholders call for a global carbon price to ensure the long-term viability of green steel

Source: Corporate interviews

*"The EU ETS helps to justify the green premium for carbon-zero steel, but **this framework does not exist in other markets and makes green steel demand hard to aggregate**"*

Chief Technology Officer, Resource provider #2

*"Ultimately, we need government intervention **to create a level playing field**. In the short term we have launched an internal carbon price to deal with this"*

Stina Klingvall, Manager of Climate Action, Volvo Cars

*"Steel accounts for 9% of global emission and the cost for the global economy to get rid of CO2 emissions is peanuts. But putting it all on steel makers makes it impossible – it's a **question of effort distribution.** If **we had decided to put a CO2 tax** on the global steel industry **some years ago**, our collective **investment plans would have been set** by now"*

Head of Strategic Projects & CO2 strategy, Steel manufacturer #3

Emissions from existing blast furnaces must be minimized, but carbon capture tech is expensive and in early development

Retire BF-BOF capacity

- Given the ~30-year lifespan of steel plants, early retirement of blast furnace capacity would impose **stranded cost burdens on producers**
- **Roughly 70% of global blast furnace capacity will need relining before 2030,** presenting a window to retire high-emission capacity in areas with decreasing demand

"The investment that has been sunk in blast furnaces…is obviously really significant. And we're talking about… young investment that is well short of its payback."
Mngr. of Sustainability, Resource provider #1

Mature CCS technology

- **Insufficient infrastructure** to enable transport and storage of carbon **constrains the short-term commercial viability of CCS** by limiting a producer's ability to remove captured carbon from their facility
- **Producing steel from CCS-abated BF-BOF is ~5-20% more expensive than unabated BF-BOF production**, making the technology unattractive to steel producers until there is a regulatory push from governments or if it can reduce its cost premium

~80% of business leaders believe that their companies will accelerate R&D investment into CCS technology by 2030

Abate existing BF-BOF capacity

- Growing steel demand in emerging economies like India has driven steel producers to continue investment in new fossil-dependent blast furnace capacity primarily to **develop infrastructure, become self-sufficient, and leverage low-cost coal reserves**
- CCS on the blast furnace production route is possible, and would **achieve a ~73% direct CO2 emissions reduction using existing tech**

"I could not justify investment in anything like CCS. There's no market premium for the product. There's no regulatory push."
Mngr. of Sustainability, Resource provider #1

Government support is needed to modernize steel capacity, and ensure international cooperation for a level playing field

Provide financial support to retire or upgrade blast furnace

- In developed markets, the construction, retrofitting, and upgrading of existing blast furnaces can be enabled through a range of policy measures including standards, tax incentives, and carbon pricing
- Developing countries will likely need support if the world is to move towards lower carbon production - whether that's the move towards **DRI plants** or the **upgrading** of existing blast furnaces to CCUS; in either case, the early retirement or upgrading of high-emitting blast furnaces should be a **priority for international finance initiatives** in the coming decade

Support CCS technology

- At a minimum, all major steel-producing economies should aim to ensure that **any new or upgraded blast furnace facilities are as clean as possible** and are **compatible with future deployment of CCUS**, even if policy support is not possible today
- Established international standards would support the development of CCUS over the medium-term – including **unified carbon sequestration regulations**, **on- and off-shore storage standards**, and **diverse transport method guidelines**
- Ultimately, businesses will need **significant incentives to deploy CCUS** at scale - whether that's for R&D, infrastructure, or subsidies for operational facilities

Ensure international coordination on green steel

- **Harmonized international standards** and **greater transparency** can support the development of international trade in green steel: a unified and standardized methodology for quantifying and reporting greenhouse gas emissions and better labelling can enable stakeholders to validate sustainability claims, reinforcing consumer confidence
- That said, CCUS at scale will be extremely challenging to achieve through voluntary demand or national approaches
- Ultimately, the technologies for lower carbon steel are known - whether DRI or carbon capture makes more economic sense may vary by context; in either case, a **giant leap forward in international governance** will be required to enable the decarbonization of the steel sector, which may be through coordinated carbon pricing across major producer economies or common approaches to production standards

WE MEAN BUSINESS COALITION

wemeanbusinesscoalition.org

linkedin.com/company/wemeanbusines

twitter.com/WMBtweets

WE MEAN BUSINESS COALITION | BSR | CDP DISCLOSURE INSIGHT ACTION | Ceres Sustainability is the bottom line. | CLG Europe | THE B TEAM | CLIMATE GROUP | wbcsd