Towards Greener Steel

Steering the Transition

Building a better working world

Foreword

Steel is critical to continued economic development and is the backbone of global sustainable initiatives, including energy transition. It is also one of the world's most sustainable materials — permanent, forever reusable and the most recycled material on the planet. Therefore, building more sustainable steel products through an environmentally friendly process is a long-term investment that will yield enormous environmental benefits over the full life cycle of steel.

Today, the steel industry is one of the world's most energy intensive and accounts for around 8%-9% of global carbon dioxide emissions. For steelmakers, reducing emissions and specific energy consumption is critical as the global decarbonization agenda speeds up. Steelmakers that move now on a journey to improve the sustainability of operations can get ahead of developing carbon regulations and capitalize on environmental, social and governance (ESG) metrics to gain a competitive edge.

There has been a consistent improvement in metrics of sustainability over the last few years for the steel industry. However, the intensity of environmental impact of this industry needs an execution of a compelling and a well thought out action plan. Depending on the region and the existing asset base of steel production, we discuss the reasons for which such an action plan will be unique for each steel maker. The quantum and timing of investments will depend on the choice of pathway and the urgency of complying with sustainability targets.

We also present our point of view on the options available to steelmakers to meet the long-term targets of carbon neutrality. As a first step, a well-planned, stage gated roadmap/pathways will be critical for a successful set up. All such pathways will represent an informed choice of clean technologies while balancing business risk, quality of end product and capital cost while improving sustainability metrics across the steel value chain. Stakeholders like governments, the UN, academia, communities and steel associations are likely to play an important role in supporting the implementation strategies of steelmakers. Other than carbon pricing mechanisms, governments will need to provide support for R&D and finances to encourage and catalyze change.

Reducing the carbon emissions and energy consumed in steel production can boost the long-term commercial and societal value of one of the world's most sustainable materials like steel. There are several pathways of getting there. The choice of the user specific journey with its intended consequences should be made now.

Saurabh Bhatnagar

Partner
Mining and Metals, EY

Steel is one of the most critical materials for continued economic development, and the backbone of global sustainable initiatives including energy transition. Reducing the energy intensity of its production process will be critical to achieving this potential and accelerating global decarbonization goals. Transitioning to more sustainable steelmaking will require a multi-pronged, collaborative approach that will create a more efficient, competitive and sustainable industry.

The steel industry is one of the world's most energy intensive, accounting for around 8% of global carbon dioxide emissions.[1] For every tonne of steel produced, an average of 1.85 tonnes of carbon dioxide are emitted into the atmosphere.[2]

China's and India's steelmaking sector are the world's first and the second biggest,[3] both stoked by the rapid economic growth of these countries. As production grows, the carbon dioxide emission from their steel sector is expected to triple by 2050.[4] Decarbonizing the sector will be a priority for both India and China and other steelmaking countries, as meeting more ambitious carbon goals becomes urgent. At the Climate Action Summit 2019, more than 60 countries, including the EU and the UK, committed to full carbon neutrality by 2050. China plans to reduce the emissions intensity of its GDP by over 65% by 2030 (from 2005 levels) and become carbon-neutral by 2060[5,6]. India intends to reduce the emissions intensity of its GDP by 33%–35% during the same timeframe[7]. Reducing the energy intensity of steelmaking will be integral to achieving this goal.

> "Climate change is an overwhelming societal priority. At ArcelorMittal, we have an important role to play in helping society deliver the objectives of the Paris Agreement and are determined to lead our industry's transition to carbon neutral steel. We have the scale, resources and technological prowess to make a significant impact, and have already identified the routes to carbon neutral steelmaking through our Smart Carbon and Innovative DRI pathways.[8]"
>
> ***Aditya Mittal, CEO, ArcelorMittal***

[1] IRENA

[2, 3] World Steel Association

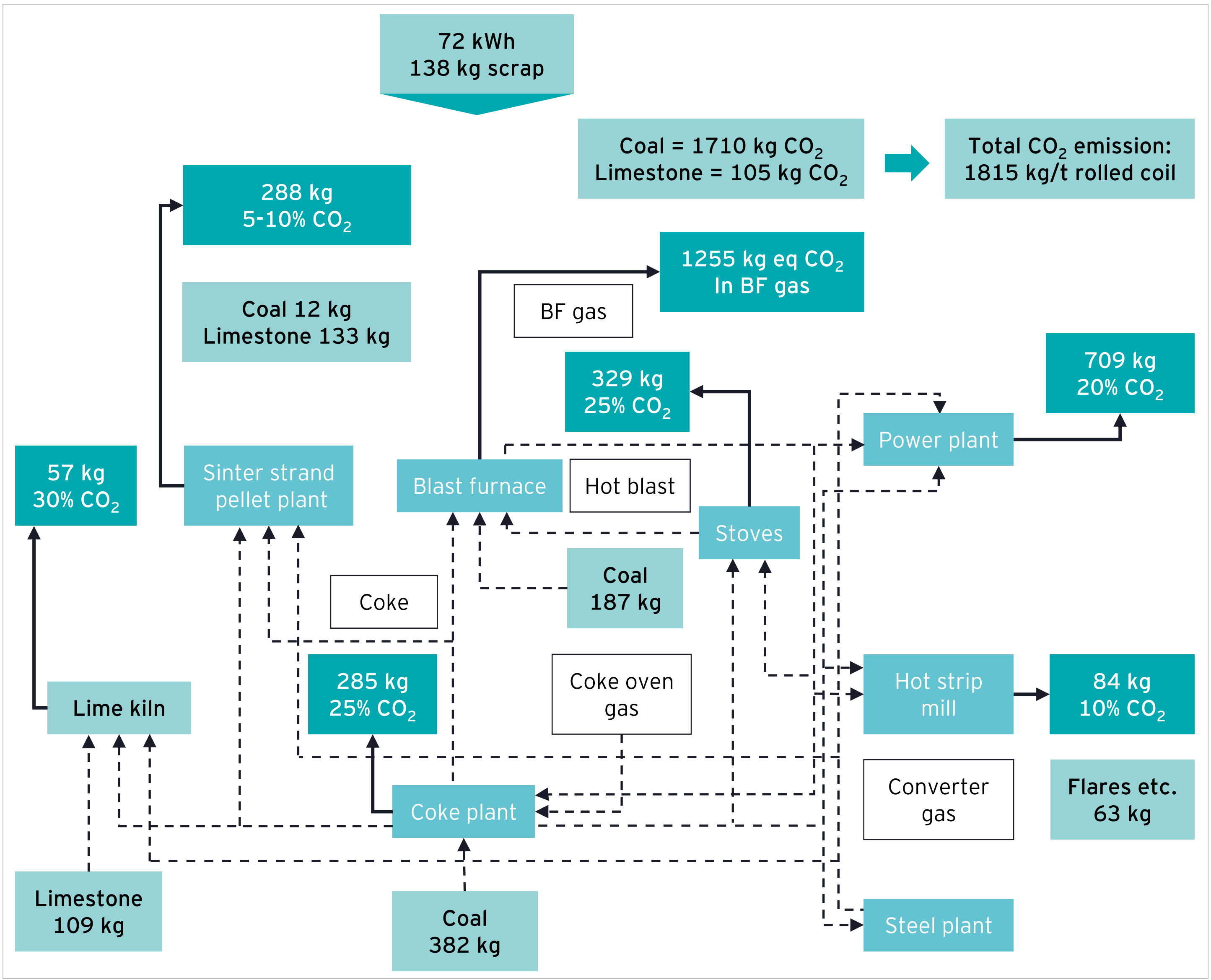
[4] "Carbon emissions by India's steel sector to triple by 2050", The Economic Times, https://economictimes.indiatimes.com/industry/indl-goods/svs/steel/carbon-emissions-by-indias-steel-sector-to-triple-by-2050/articleshow/73927391.cms?from=mdr, accessed in January 2021

[5] "China's Xi targets steeper cut in carbon intensity by 2030", Reuters, https://www.reuters.com/article/climate-change-un-china-idUSL1N2IS0DY, accessed in January 2021

[6] "Climate change: China aims for 'carbon neutrality by 2060' ", BBC, https://www.bbc.com/news/science-environment-54256826, accessed in January 2021

[7] Ministry of Environment, Forest and Climate Change, GoI

[8] https://corporate.arcelormittal.com/media/press-releases/arcelormittal-launches-xcarb-signalling-its-commitment-to-producing-carbon-neutral-steel



Flowsheet of an integrated steel mill, showing carbon-bearing material input, CO_2 emissions, expressed in volume (kg/t of hot-rolled coil) and concentration in flue gas (volume %)

Source: Carbon dioxide (CO_2) capture and storage technology in the iron and steel industry, Woodhead Publishing Limited

Of course, the quest to build a more sustainable steelmaking sector is not new. Over the past 50 years, advances in technology and a move towards the electric-arc furnace (EAF) have reduced energy use in steel production by 60%, with steelmakers reducing consumption by 0.35%-0.40% year-on-year for the past decade. The continued move to EAF will help drive down emissions further but the reality is that the industry will need to consider broader measures, if they are to create a genuinely sustainable industry that can maintain quality standards and competitiveness while meeting higher community and investor expectations around environmental, social and governance (ESG) measures.

The WEF (World Economic Forum) has proposed a set of universal ESG metrics, developed with leading CEOs and firms including EY, to measure how companies are creating and reporting on long-term value beyond the bottom line.

And investors are increasingly aligning themselves with organizations that perform well against ESG measures, believing them to be less risky, better positioned for the long term and better prepared for uncertainty.

For steelmakers, an accelerating decarbonization agenda and the growing importance of ESG performance represent both a challenge and an opportunity. Certainly, reducing the energy intensity and environmental impact of the industry will require a significant effort across the lifecycle of steel. Players will need to commit to deploying energy-efficient measures, adopting and investing in circular economy principles, improving material efficiency and waste management and investing in low-carbon emission technologies for steel production. To improve on these parameters, the usage of high-quality iron ore and coal will increase to achieve higher efficiency.

Decarbonization is a critical challenge in the steel industry

The world's steelmaking industry is in transition, adopting new technologies, different ways of working and rethinking old problems to lay the foundation for genuinely green steel. Steelmakers have long prioritized energy efficiency and more recently have made a concerted effort to adopt circular economy principles. The major challenge that remains in the face of more stringent emissions targets is to significantly reduce emissions in the steelmaking process.

An analysis of the key metrics of the top global steelmakers reflects that while some companies are continuously improving, others are still at the early stages of development. For our analysis, we divided steel companies into three broad ranges of emissions and energy intensity: low, medium and high. In the best-case scenario (low), production facilities may attain energy needs 0.1x of global average and emissions may be 0.2x of the global average. Companies in the high range were the ones largely using Blast Furnaces (BF). As most BF processes are already technologically mature, CO_2 abatement is not possible without significant investments in radical technologies such as carbon capture and top gas recycling.

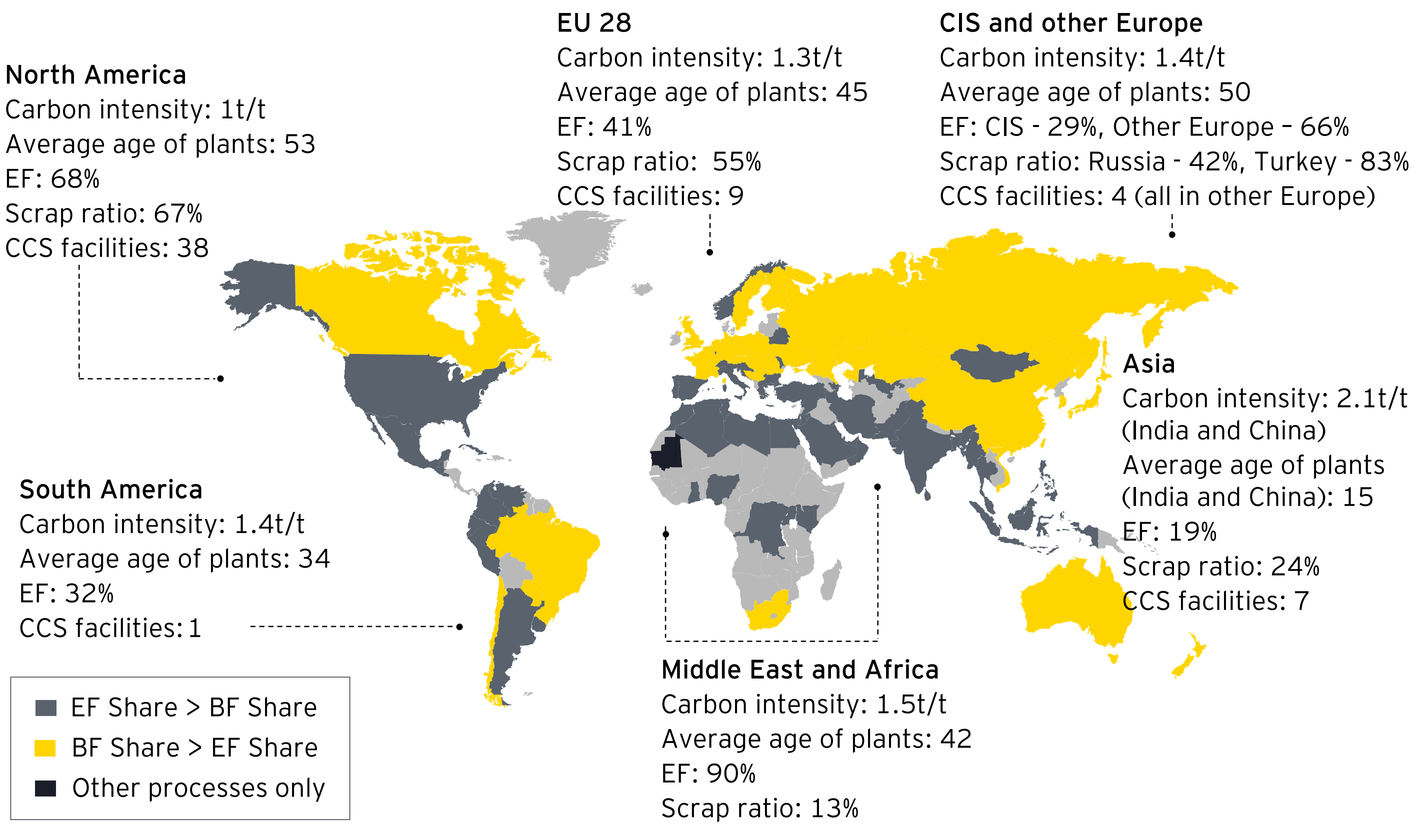
Specific Emissions and Energy Intensity: Range for Steel Manufacturing

	Low (4)	Medium (7)	High (5)
Energy intensity (GJ/t)	2-15	15-25	25+
GHG emission intensity (t/t)	0.5-1	1-2	2+
NOx emission intensity (kg/t)	0.05-1	1-2	2+
SOx emission intensity (kg/t)	0.1-1	1-2	2+

Note:
Upper limit included in lower range
The number besides Low, Medium and High denotes the number of companies falling in those ranges respectively.
Gj/t- gigajoules/tonne, t/t- tonne/tonne, kg/t- kilogram/tonne
Sources[9]: Company reports, EY analysis

[9] For the steel scoring:
- The datapoints are considered from 2016-2019, not consistently available for all companies
- Specific datapoints from steel business considered where reported separately, else group values considered
- For analysis, Scope 1 and 2 CO_2 equivalent and CO_2 emissions considered under GHG emissions
- Plants have different production technologies in use
- For approximation, value per cast steel and crude steel production considered as same

Carbon intensity and age of steel plants by region



*South America: 1.3% other processes
CIS: 6.4% other processes
Scrap ratio is defined as scrap consumption/crude steel production
Asia: Scrap ratio calculated for China, Japan and Korea Republic
North America: Scrap ratio calculated for Canada and the US
Middle East and Africa: Scrap ratio determined by assuming 100% scrap used in EAF production
CCS: Values for commercial CCS facilities; facilities are not specific to iron and steel industry only

> We understand that raw material processing technology is extremely important in the research and development towards carbon neutrality. We have a long history working closely together with BHP collaborating to study raw material utilization technology and mine development. It is very significant for us to be able to work together with BHP towards reduction of CO_2 emissions, which is an extremely important agenda for the steel making sector.[10]
>
> ***Yoshihisa Kitano, President and Chief Executive Officer, JFE***

[10] BHP press release, https://www.bhp.com/media-and-insights/news-releases/2021/02/bhp-partners-with-jfe-to-address-decarbonisation-in-the-steel-industry/

A comparison of BRIC and non-BRIC steelmaking

To get an understanding of the progress of global steelmakers in reducing emissions, we compared the initiatives of key steel players in BRIC (Brazil, Russia, India and China) and non-BRIC nations.

Non-BRIC

Understandably, some nations and regions, such as the US and the EU, are better positioned to invest in sustainable steelmaking, with other non-BRIC nations also making great strides towards green steel. The US steel sector is now 70% EAF, compared to a global figure of 30%.[11] BF production is still dominant in Japan and South Korea, but both countries are making significant investments in R&D to explore how to reduce emissions from production. For example, JFE Steel is currently testing ferro coke production that can reduce energy consumption and CO_2 emissions in ironmaking process by approximately 10%.[12] Nippon steel is exploring the deployment of inputting hydrogen/gas based DRI and 100% scrap into large scale EAFs with power sourced from renewable sources for making high grade steel[13].

Of all steel producing regions, the EU has the most stringent decarbonization policies, which has significantly reduced the industries' use of carbon over the past few years. Carbon pricing and a push for more renewables have increased costs for EU steelmakers and reduced their global competitiveness, but sustainability initiatives have also spurred increased investment in R&D – this should lead to lower production costs, continue to improve the decarbonization of processes and, over time, improve competitiveness.

For example, steelworks in the Dutch port of Ijmuiden have developed a new technology called HIsarna which is more efficient, reduces energy use by 20% and cuts CO_2 emissions by removing numerous pre-processing steps. HIsarna produces almost pure CO_2, which can be used in carbon capture for storage or use, potentially achieving CO_2 savings of 80% throughout the steel production process.[14]

In another breakthrough, SSAB, LKAB and Vattenfall plan to industrialize fossil-free steelmaking technology developed through HYBRIT (Hydrogen Breakthrough Ironmaking Technology). HYBRIT can reduce Sweden's CO_2 emissions by 10% and Finland's by 7% if implemented at full-scale. Companies plan to start the world's first demonstration plant for producing 1.3mt fossil-free sponge iron by 2026 in Sweden.[15]

The EU also has a strong policy framework for green hydrogen deployment. The EU Hydrogen Strategy aims to build large-scale green hydrogen capacities by 2050, paving the way for region's steelmakers to transition more easily to hydrogen-based production.

BRIC

Among BRIC nations, especially Russia, China and India, the trajectory of carbon reduction is likely to be more gradual than the one seen in the West. Many of the region's BFs are less than 15 years old, making replacement uneconomical at this time. Moreover, sector consolidation in China and India, the world's two largest steel producing countries, is below global average, with many small capacity enterprises operating with less efficiency, more pollutants and a lack of investment in new technologies. China intends to increase its EAF share in overall steelmaking to reach 15-20% by 2025 from 10% in 2019.[16]

All BRIC countries are committed to significantly reducing the carbon emissions of their steelmaking industries, but a credible roadmap is urgently needed to make it a reality through more consolidation, a greater move to EAF production and investment in a robust recycled steel supply for steelmaking.

As demand for green steel increases, countries with more sustainable steelmaking industries are likely to reap a competitive advantage. As origin of steel becomes a bigger part of trade negotiations between steel producers and OEMs, we are likely to see BRIC nations accelerate their adoption of sustainable alternatives to retain competitiveness in the long run.

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[11] World Steel Association

[12] https://www.jfe-steel.co.jp/en/release/2020/201012.html

[13] "Nippon Steel Zero Carbon Initiative" report released 30th March 2021 by Nippon Steel

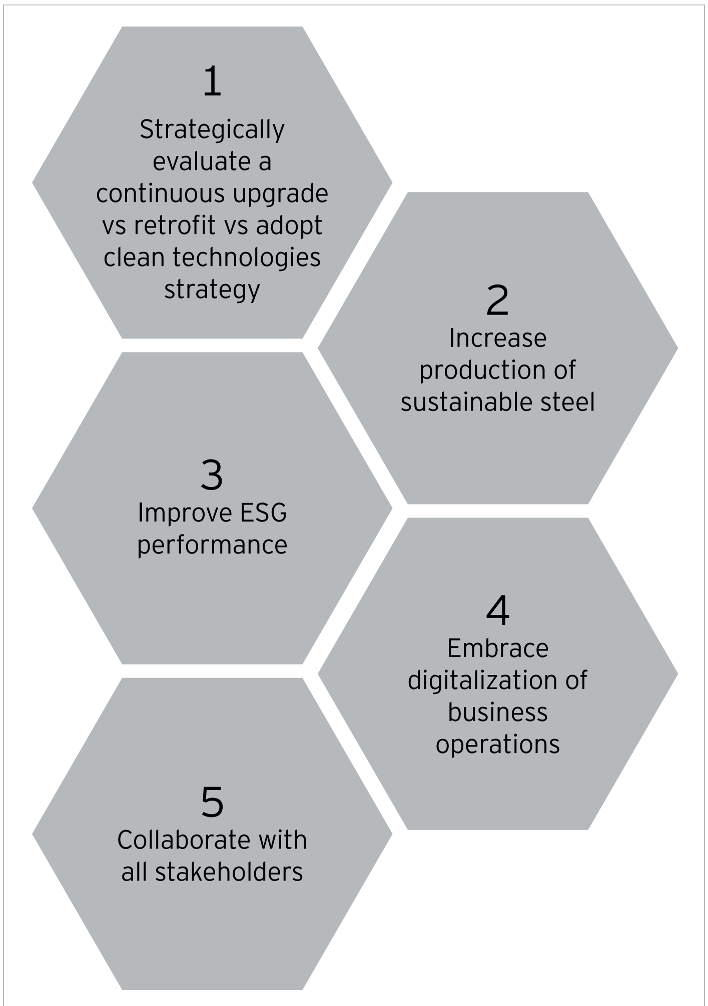
[14] https://www.tatasteeleurope.com/ts/sites/default/files/TS%20Factsheet%20Hisarna%20ENG%20jan2020%20Vfinal03%204%20pag%20digital.pdf

[15] https://www.ssab.com/company/sustainability/sustainable-operations/hybrit

[16] "China steel mills plan around 2030 carbon peak", Hellenic Shipping News, https://www.hellenicshippingnews.com/china-steel-mills-plan-around-2030-carbon-peak/, accessed in May 2021

How should steelmakers steer the transition?

Achieving sustainability will require steelmakers to roll out strategies across the entire value chain, with five steps critical to success:



1 Assess and adopt clean technologies ensuring a balance of risk, capital cost and quality

Steelmakers need to take a pragmatic approach to implementing cleaner alternatives. Ensuring overall production capacity remains in line with demand to maintain profitability and competitiveness will require companies to balance risk, cost, quality and their chosen trajectory to decarbonize steel production.

That said, controlling emissions will be the central challenge of steelmakers over the decades to come, and those that find the capital to invest in greener production will ultimately emerge as winners. All new steel production should adopt greener alternatives, although companies will need to make judicious choices around when and where to adopt clean technologies. For example, around 18% of new steel projects over the next decade will be in the Middle East where an affordable supply of natural gas makes EAFs a natural choice.[17] In comparison, Indian steelmakers have struggled to gain approval to expand greenfield capacity – brownfield expansions will likely make up most of India's new production coming online. Aligning investments with cyclical gains can mitigate financial risks as higher initial capital costs are likely to be offset by the long-term benefits of more sustainable operations and improved ESG performance.

A key consideration for integrated steel mills currently in production will be the need to factor in the costs of relining blast furnaces. A plant with capital costs of US$1b/mtpa and a remaining life of 40 years will need to be relined twice over its lifetime. This accounts for around a quarter of the mill's capital cost.[18] As each relining period approaches, steelmakers should perform a cost-benefit analysis of extracting the full life compared with moving to alternative technologies.

Steelmakers will need to forge a path that combines retiring assets and replacing them with new, cleaner technologies and improving the sustainability of existing assets – all while ensuring that commitments around reducing greenhouse gases (GHG) and achieving carbon neutrality are met within the agreed time frame.

[17] OECD

[18] "Pathways to decarbonisation episode two: steelmaking technology", BHP, https://www.bhp.com/media-and-insights/prospects/2020/11/pathways-to-decarbonisation-episode-two-steelmaking-technology/, accessed in January 2021

Initiatives to improve the sustainability of existing steelmaking assets:

Existing Commercial Technologies	Energy efficiency
BF/BOF	▶ Substitution of coal injection in blast furnace by biomass ▶ Optimization of back pressure turbine and hot blast temperature control system for BF ▶ Optimal design of plantwide fan systems: ASDs, flow and pressure control ▶ Deployment of CDQ (Coke dry quenching) and heat recovery from sintering
COREX with O_2 converter	▶ Maximize PCI injection in melter gasifier ▶ Direct and automatic use of export gas for power generation
Non coking coal-based DRI/EAF	▶ Optimizing metallization rates ▶ Advanced analytics for C/Fe ratio ▶ Improving waste heat recovery ▶ Use of advanced control technologies for power generation and usage
NG-DRI/EAF	▶ Optimizing metallization rates ▶ Advanced analytics for Gas/Fe ratio ▶ Improving waste heat recovery in recovery boilers ▶ Control of syn-gas quality to ensure thermal efficiency of EAF
Scrap-EAF	▶ Use of analytics for optimizing and reducing variation in batch cycle times ▶ Real time synchronicity of grid power usage ▶ Ladle scheduling Tap to power ON time optimization for multi furnace operations ▶ Use of advanced control technologies for power

Source: EY analysis

> “At JSW Steel, we aren't only responsibly addressing the environmental impact of our operations, but also want our sustainable products to safeguard the environment and conserve resources. We are relentlessly driving initiatives to benchmark our operations with the best in the world on the Environment, Social and Governance parameters to deliver value to all our stakeholders.”
>
> ***Dr Vinod Nowal, Deputy MD JSW***

Decarbonization	Circular Economy	Utility efficiency
▸ Exploitation of synergies of plantwide installation and integration of sensor data for carbon emissions ▸ Optimization of balance of CO/CO_2 generation in real time ▸ Replacement of coke with natural gas injection for reduction ▸ Deploy electric vehicles for intra-mine logistics	▸ Setting up a inbound supply chain for scrap sourcing, storage, handling and monitoring ▸ Maximization of usage of scrap in SMS ▸ Efficient systems of minimization formation and recycling scale	▸ Rain water harvesting both on the surface as well as recharging the aquifers as additional sources ▸ Digitally enabled plantwide steam management system with a real time "Pinch control system" ▸ Automation and control of cyclone separations and ESPs
▸ Use of high quality non-coking coal for carbon generation ▸ Re-use of gas from convertors into reduction furnace ▸ Deploy electric vehicles for logistics	▸ Digitalized maintenance of scrubbers and fines separation units and gas scrubbers for melter gasifiers	
▸ Use of bio mass/solid waste/ non-fossil in kilns ▸ Deploy electric vehicles for logistics	▸ Setting up a inbound supply chain for scrap sourcing storage, handling and monitoring ▸ Maximization of usage of scrap in SMS	
▸ Use of bio mass/solid waste/ non fossil in gas generators ▸ Control of yield of gas through digital automatic control ▸ Deploy electric vehicles for logistics		

> In the current state of technological evolution, supply demand gap of steel, BF BOF route will continue to be most economical and relevant for all steel makers for the next 10 years. The solution for reducing the carbon loading by industry at large lies in embracing a unique combination of judicious use of carbon Tax, economical availability of scrap, selective raw material sourcing and scaling up of technologies for replacement of Carbon with H_2, Methane and Coke Oven gas as a primary reducing agent.

Uttam Singh, VP. Iron Making, Tata Steel

Emerging technologies that help integrated steelmakers reduce emissions

Carbon capture

Top gas recycling combined with carbon capture storage and/or utilization (CCUS) technology may offer a solution to significantly reducing emissions. Top gas recycling can recycle up to 90% of the exhaust gas from BFs, reusing it for combustion with the remaining highly concentrated CO_2 stored and/or used.[19]

Determining whether carbon capture is suitable may depend on overall operating costs. Technology costs are still high at this relatively early stage of development, though they should come down over the next few years. Steelmakers will also need to invest in transport and storage if they are to scale up operations. Finding storage capacity may be difficult, with potential sites having to undergo site characterization to ensure suitability to safely store CO_2, in compliance with regulations.

CO_2 captured in steelmaking can be reused as fuels in other industrial production, though we see only limited examples of its large-scale commercial utilization at this stage. One is an Abu Dhabi project where CO_2 captured from flue gas within an Emirates Steel plant is used in enhanced oil recovery (EOR) at the Abu Dhabi National Oil Company.[20]

Innovations in product mix

Other strategies center around innovations in the product mix, including using higher quality inputs or changing the mix. We see steelmakers injecting pulverized coal or biofuel to reap cost, efficiency and emission benefits. As plants near their end of life, companies will need to evaluate all alternatives while bearing in mind the long-term sustainability agenda.

For integrated steel players considering a transition to scrap-based EAF production, the affordability and availability of scrap and the quality of the end product will be important determinants of the strategy and technological choice between:

1. Fully scrap based EAF
2. Primary steel through DRI with natural gas as the primary reductant followed by EAF (NG-DRI/EAF)
3. Primary steel through DRI with green hydrogen as the primary reductant followed by EAF (H2-DRI/EAF)

Maintaining the quality of certain high grades of steel will limit the quantity of scrap that can be recycled through EAF.

[19] ULCOS top gas recycling blast furnace process (ULCOS TGRBF), European Commission

[20] Carbon Sequestration Leadership Forum

A comparison of emerging and new technology production methods for greener steel

Emerging Commercial Technologies	Incremental prod. costs	Potential CO_2 reduction	Commercial horizon	Benefits	Challenges
Scrap-EAF	-	80%	Commercial	High potential of CO_2 reduction; technology readily available; useful in case of low supply of high quality coal	High scrap supply required; energy needs of EAF can add to emissions
Smelting reduction	-	4-20%	Commercial	Lower operating cost; Possible elimination of sinter/pellet and coke plants	High calorific value export gas generated; Lower economic scale of operations
BF/BOF with biofuel	-	20-50%	Commercial	Easier to implement by altering the input mix in blast furnace	High quantity of biofuel required; Increased storage and transportation cost; High moisture content of biofuels
BF/BOF with carbon capture	+30-50%	30%	5-10 years	Can easily be integrated to BF-BOF; Advantage from R&D going on since long time	Large infrastructure investment for storage and transport; Difficult to capture all CO_2 emissions
BF/BOF with hydrogen	-	-	~ 10 years	Potential to reduce emissions both in coke plant (reduced amount of coal required) and blast furnace	Difficult to replace reducing agent by hydrogen beyond a point to maintain operations
Natural gas DRI (NG-DRI/EAF)	-	40%	Commercial	High energy and emissions savings	Adequate and afford-able supply of natural gas critical to determine profitability
Blue hydrogen DRI (H2-DRI/EAF)	+35-55%	-	10-20 years	Flexibility; scalability of producing blue hydrogen in some areas	Production cost of blue hydrogen: ~US$2/kg compared to black hydrogen: ~US$1.7/kg; Does not address emissions from pellets
Green hydrogen DRI (H2-DRI/EAF)	+60-90%	80-95%	10-20 years	Increased flexibility as hydrogen and HBI can be stored	High green hydrogen costs: ~US$5/kg compared to black hydrogen costs of ~US$1.7/kg
Iron electrolysis	Not determined	~90%	20-30 years	Largest potential in CO_2 reduction	Still at an early stage of development, only been tried at a lab scale

Note: Potential CO_2 reduction for scrap-based EAF, smelting reduction process considered as compared to blast furnace

Estimates majorly for transition to low-emissions steelmaking in Europe

Incremental production costs (OPEX and CAPEX) compared with average annual net income of steel industry

Values compared for crude steel production

Hydrogen

In the medium to long term, replacing coal or natural gas with hydrogen can substantially reduce GHG emissions. Based on the most recent research, use of green hydrogen (generated by renewables) with DRI/EAF is likely to be the cleanest alternative for steelmakers in the future.[21] Residual emissions may still arise in EAFs due to the consumption of graphite electrodes and use of lime and natural gas, but tackling these is likely to be far easier than the challenge of lowering the emissions of BFs run on coking coal. However, it will be some time before hydrogen is economically feasible and scalable.

Alternative smelting reduction processes

Other commercialized smelting reduction processes, such as COREX, FINEX and HIsarna can offer better emission control, compared with integrated plants. However, the economic viability of these processes depends on the effective utilization of export gases and overall power consumption. The low rate of adoption thus far of these designs also undermines their emission benefits, and we see only limited use of these processes in certain regions.

2 Increase production of sustainable steel to capitalize on growing demand

As companies and industries face more pressure to measure, report and reduce scope 3 emissions, demand for low carbon supplies, including steel, is growing. The push to decarbonize the automotive sector, which accounts for 12% of the world's total steel use, is prompting automakers to seek cleaner inputs.[22] Government incentives are stoking demand further; the US support for carbon-neutral construction materials and electric vehicle (EV) infrastructure is likely to further increase the appeal of greener steel.[23]

For steelmakers, meeting demand requires altering their product mix to ensure a greater share of green products. We already see some dominant players, such as ArcelorMittal, offering certified green steel products with more set to follow.

3 Improve ESG performance to meet stakeholder expectations

Many investors are seeking more sustainable portfolios, demanding greater ESG compliance and performance from potential investment targets. Between 2016-18, the value of assets in sustainable investment portfolios in the major markets of Europe, the US, Japan, Canada, Australia and New Zealand grew by 34% to reach about US$31t, with Europe and the US accounting for 85% of this total.[24]

At the same time, many governments are enforcing carbon abatement strategies, including carbon tax regimes and the Emission Trading Systems (ETS) seen in the EU and in countries including Canada and Mexico.

Improving ESG metrics will reap benefits for steelmakers beyond compliance with regulations and stakeholder expectations. Companies with a better ESG performance will secure project financing at a lower cost, enhance how they manage resources, reduce operational risk and be more resilient against economic shocks and any changes to a government's environmental regulations.

We see some steelmakers taking a proactive approach to the ESG agenda, for example including the impact of carbon emissions in assessing the profitability of capital investments - JSW Steel has adopted a shadow internal carbon price of US$20/t CO_2, while Tata Steel has marked US$15/t CO_2.[25] This helps firms to identify sustainability inefficiencies that may be increasing overall costs and the potential impact of a low carbon economy on costs. Internal carbon pricing also encourages firms to earmark funds for future low-carbon efforts.

For steelmakers yet to integrate non-financial frameworks into investment decisions, four steps can help guide the process:

1. Assess current ESG maturity against the key metrics of the Taskforce for Climate-related Financial Disclosures (TCFD), including those of business governance and people.
2. Build a specific short- to medium-term roadmap for the organization to improve performance around key metrics including decarbonization, climate change, land use/ecological sensitivity and water usage.
3. Commit the necessary resources i.e., budgets, people, technology/digital and external partnerships, to execute the roadmap at speed, and with the right data-driven
4. Real-time coordination of compliance (measure, monitor, disclose), value creation (strategize, goal setting, execution) and compliance for perpetuity.

4 Digitalization to unlock value

In many ways, steelmakers are already leaders in the use of digital solutions, with many using technology to improve defect recognition, process safety and quality

[21] BNP Paribas

[22] Statista

[23] https://corporate.arcelormittal.com/sustainability/xcarb/xcarb-green-steel-certificates

[24] Global Sustainable Investment Review 2018, Global Sustainable Investment Alliance

[25] https://www.jsw.in/groups/sustainability-framework-measuring-success-climate-change; https://www.tatasteel.com/tata-steel-brochure/sustainability.html

assurance. We see some organizations exploring integrated architectures of technologies including IoT, big data analytics, cloud computing and AI at various points in the value chain, including e.g., digital twins and variable process prediction.

But there's potential to make greater use of digitalization to improve sustainability metrics and unlock greater long-term value. Data can help steelmakers quantify, monitor, record and assess processes to enhance performance and ensure reporting requirements are met.

Digitalization can also help in improving productivity of operations by optimizing energy consumption, minimizing waste generation and controlling emissions. For example, digital solutions can support enthalpy and the carbon balancing of gas networks of varying composition and calorific value generated at various flow stages of steel manufacturing. Real-time dynamic routing and allocation of gases used in heating stoves, power plants, sinter, pellet, coke oven plants and rolling mills can help minimize flare burning in Integrated Steel Plants (ISP) and, where relevant, even be used in DRI-based EAFs. Digital solutions can optimize the logistics for inbound and outbound materials flows to maximize material throughput in a multi-modal transport world and ensure the least fuel burnt per ton of material moved.

Blockchain can verify the sustainability quotient of steel value chains, giving end users reliable data to assess their net carbon impact. It also helps create more agile supply chains, with cloud computing allows for central command and control centers to oversee geographically dispersed mine to metal value-chains. As steelmakers further their sustainability agenda, the adoption of more digital solutions will be a critical step, to ensure organizations can collect and monitor the high-quality, timely data required for actionable insights.

5 Collaborate with all stakeholders

Decisions made around sustainability initiatives cannot be based purely on financial costs to the business. Instead, steelmakers must act with all stakeholders in mind, and be prepared to make a balanced trade-off between industry, end consumers and the environment.

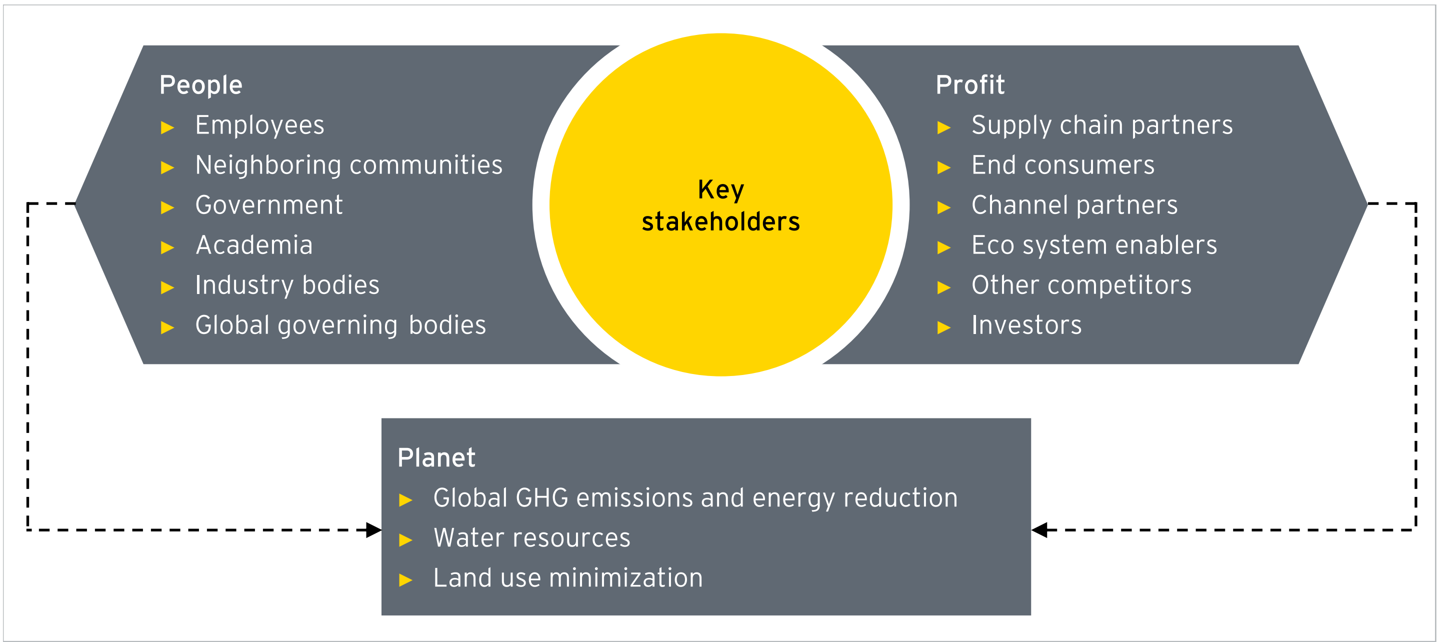
Aligning stakeholders around the changes that must be made will be critical to quicken the pace of the structural shift required. Collaboration is needed to co-develop feasible solutions to complex sustainability challenges. In the EU, we see many examples of partnerships between steelmakers, raw material providers, OEMs and renewable energy providers that have accelerated the development of sustainable alternatives to traditional methods. These efforts are not just advancing the sustainability agenda – they are creating a competitive advantage for the region's steelmakers and their ecosystem of partners.

As newer methods mature towards implementation readiness, steelmakers may need to integrate their use with more established methods to maintain profitability. This will require working in tandem with supply chain partners.

Collaborating with communities can ensure that the impact of new technologies on local land use and other resources is minimized to ensure sustained production in regions.

Regulatory bodies and governments can act as catalysts to incentivize both production and demand for greener steel. Aligning policies with steelmakers' initiatives requires efforts from both sides. Organizations will need to ensure that actions taken are relevant to their region of operation, to better advance their sustainability agenda.

Source: EY Analysis



Building the future of green steel

The steel industry's transition to greener steel will not be uniform across regions. Steel producers in western regions and those countries already investing in improving sustainability are likely to see a more rapid adoption of newer low carbon technologies compared with steel producers in China and India where the combination of newer capital assets and cost pressures will force a more gradual transition. Even in regions and countries where progress will be slower, steelmakers should continue to make incremental investments in process improvements to decrease energy intensity, reduce carbon emissions, increase material efficiency and promote the circular economy.

For all steelmakers, the journey to green steel will be an individual one, where capex costs, quality of production and business risk are well considered and balanced. Businesses will need to meet local legislation, retrofitting assets when necessary, and making investments that fit their own business strategy, existing asset base and capacity to take risks with emerging technology. Given the relatively large carbon footprint of steel production, even small steps will make a big difference in reducing its impact on the environment, and moving the industry closer to carbon neutrality. As the global agenda to combat the climate crisis, through regulatory changes and carbon taxes, accelerates, steelmakers that proactively shift to sustainable processes will reap a competitive advantage.

Making this shift will require a staged digital roadmap to realize the full potential of new technologies to achieve economies of scale while improving sustainability across the steel value chain. Early experimentation and consequent adoption will enable both better assessment and improvement of sustainability matrix. This will be critical in developing cost-efficient, integrated solutions across plant operations.

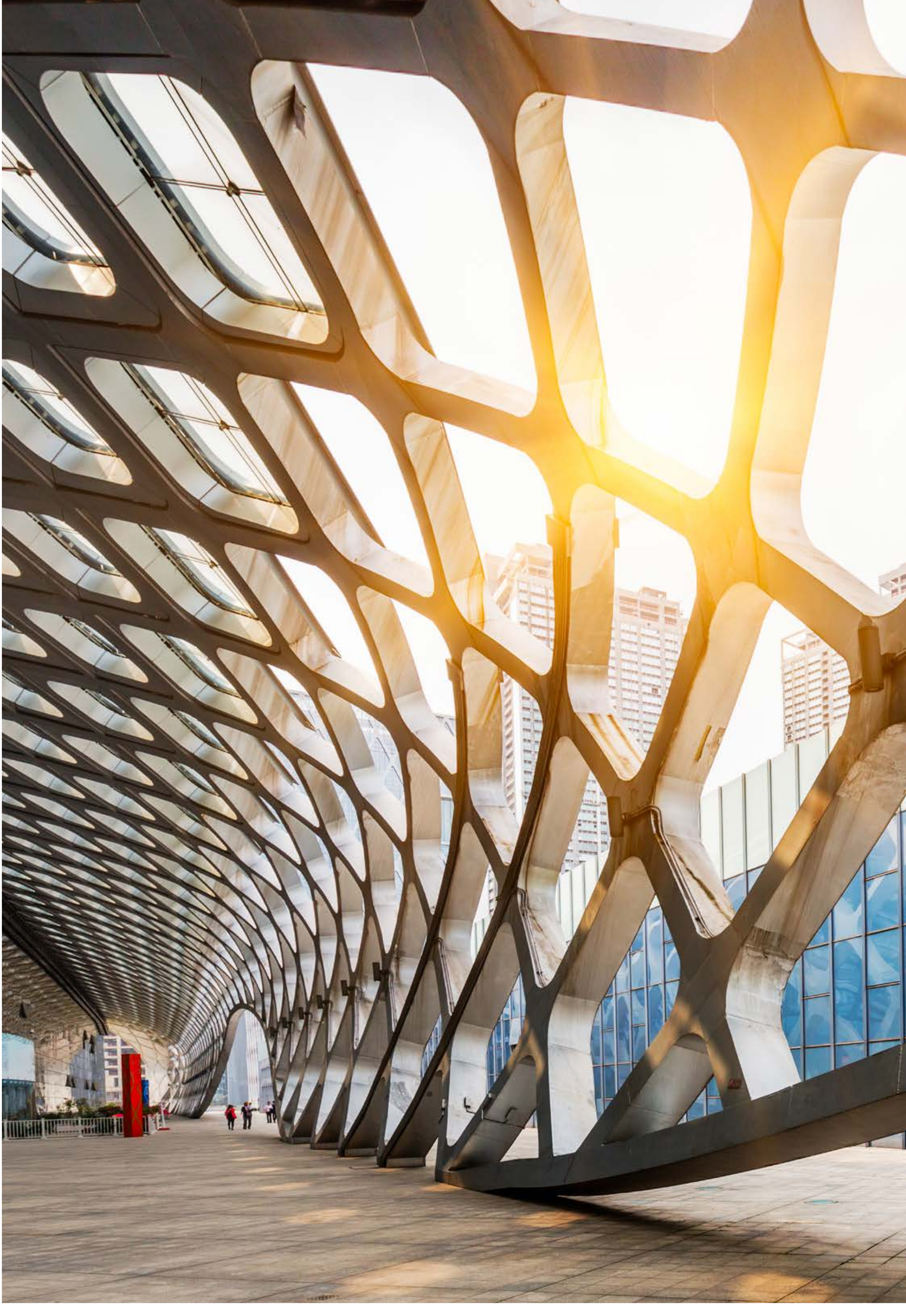
Other stakeholders, including governments, the UN, academia, communities and the World Steel Association also have an important role to play in building a greener steel industry. Governments are likely to impose more carbon pricing mechanisms, but more direct financial support and investment in research and development is also needed to incentivize positive changes. There is an urgent requirement to launch a framework of global standards and sustainability yardsticks that can help steel producers work with end consumers to design sustainable products, with the overall life cycle cost in mind. Creating demand-side incentives can boost the market for value-added steels, which governments should support in the early years to ensure stability.

Already we see encouraging signs of progress towards more sustainable steelmaking. Integrated European steelmakers are leading the way by implementing hydrogen-based pilot initiatives which have the potential to drastically shift the industry's reliance on coal. While the cost of sourcing and transporting green hydrogen to existing steel locations will need financial support, in the meantime, use of DRI-based EAFs is expected to increase, contributing 50% of total crude steel production by 2030. We expect the continued adoption of new technologies to shift the raw materials mix towards the use of more recycled scrap. Within new steelmaking, we'll see a growing shift towards natural gas/ hydrogen based DRI/ HBI production. And all of these changes will take place as calls grow from end consumers, particularly the automotive sector, for transparency around steel's country of origin as efforts to minimize value chain emissions increase.

Steel is one of the world's most sustainable materials. Essential to modern society, steel is permanent, forever reusable and the most recycled material on the planet. Building a more sustainable steel production process is a long-term investment that will yield enormous environmental benefits over the full life cycle of green steel.

> Hydrogen is the key to turning the big lever we have in reducing CO_2 emissions in the steel industry," explains Dr. Arnd Köfler, Executive Board Member for Production at Thyssenkrupp Steel. By using climate-neutral hydrogen, thyssenkrupp can avoid 20 million tons of CO_2 a year in steel in the long term.[26]
>
> ***Dr. Arnd Köfler, Executive Board Member Thyssenkrupp Steel***

[26] Thyssenkrupp press release, https://engineered.thyssenkrupp.com/en/green-hydrogen-for-green-steel/



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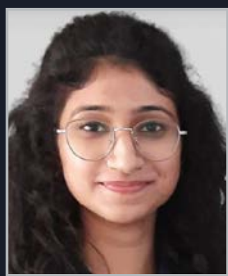

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