WHITE PAPER

The Green Pricing Opportunity for European Steelmakers

June 2023

By Nicole Voigt, Diana Dimitrova, Marie-Luise Meyer, Alexander Klueber, Felix Schmitz, François-David Martino, Tim Milde

European steelmakers face a significant green pricing opportunity that will arise due to an impending supply shortage in green steel. This shortage is implied today and likely to last for several years into the 2030s as the market for green steel evolves. By the end of this decade, demand could exceed domestic supply by 15 to 20 million tons (Mt) based on what we know today. This paper focuses on the European market but is also relevant to the development of green steel in other regions worldwide. We already see other markets following Europe's lead, starting with more mature economies such as Japan and those in North America.

Why we need green steel

Steel production causes about 7% of global greenhouse gas emissions. Consequently, it is one of the highest emitting industries worldwide. The reason: steel is an essential component in a range of everyday products, such as cars and washing machines, making it a particularly important to abate sector in discussions around "hard-to-abate sectors". As a result, reducing emissions along the steel value chain – and especially from traditional steelmaking (which as of today is a highly carbon-intensive process) – has become a key climate change mitigation priority. Governments and a growing number of steelmakers are seeking ways to decarbonize steel production. This would enable steel-procuring companies to meet decarbonization targets as the material constitutes a significant share of their supply chain emissions. If successful, this 7% would turn from a burden into a compelling opportunity.

What is green steel?

Green steel (made using low-carbon production techniques) is lauded as the solution to this decarbonization challenge. But because of differences in production methods and types of steel products, there is no consensus around defining green steel.

The value of green steel production to customers stems from the reduction in carbon dioxide equivalent (CO_2e) emissions it offers compared with traditional production routes. Therefore, we believe a definition of green steel should solely be based on the physical CO_2e footprint of steel products. We then define green steel along different categories, which are based on cradle-to-gate emissions intensity thresholds and measured in kg of CO_2e per ton of product. These thresholds allow transitionary factors to be considered and steel can become greener over time if the producer makes meaningful steps to abatement.

There are three advantages to our definition:

- It includes the emissions of all value chain steps from extracting raw materials to the steelmaking process itself (providing a cradle-to-gate assessment). This allows for comparisons between other products and materials.

- It is rooted in the physical CO_2e-reduction activities involved in producing a ton of physical steel (unlike so-called 'balanced' definitions which allow CO_2e savings to be virtually allocated to just a predefined fraction of total production).

- It does not involve the use of carbon offsets and credits to reduce steelmakers' emissions or include associated emission reductions from other industries (e.g., carbon reductions achieved in the cement industry due to the use of blast furnace slag, a byproduct from steel production).

The International Organization for Standardization (ISO) and the Greenhouse Gas Protocol provide the most widely recognized guidance for calculating the CO_2e footprint of products. For the customer, emissions calculated following our definition and their guidance result in data that is manageable, auditable, and comparable.

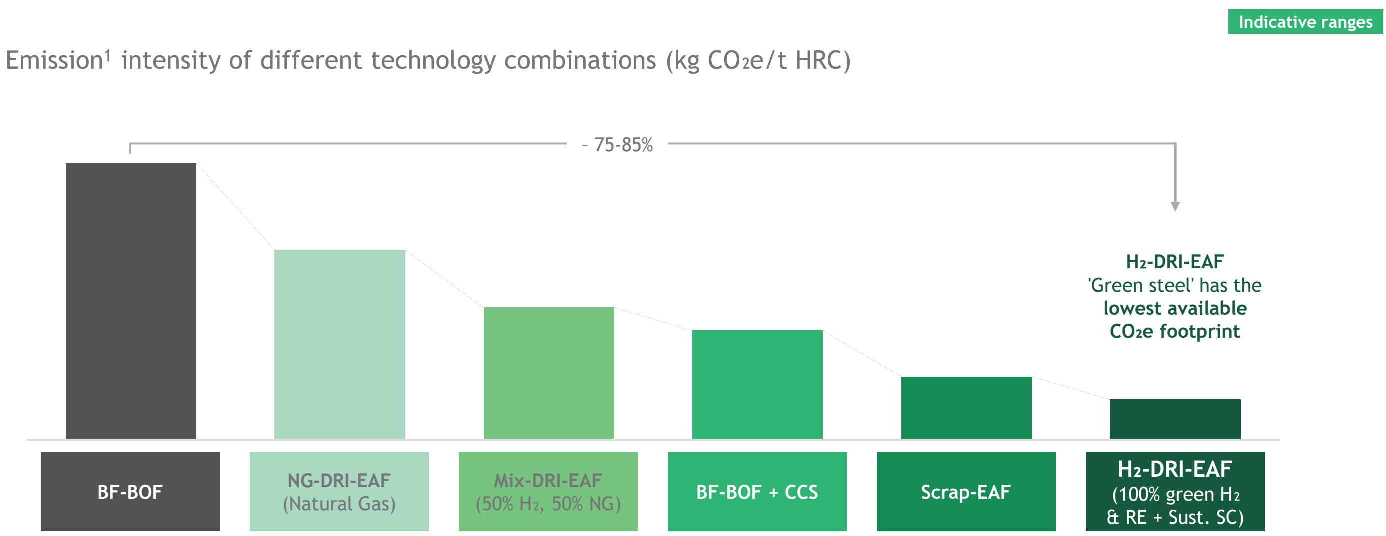
The CO_2e footprint of steel products is determined by a few key production-related decisions, such as how companies mine and transport raw materials. But the production route itself is the main determinant. We have identified different categories of green steel based on production routes that are available or under development today. (See Exhibit 1.) Each production route results in different emission levels, which we have estimated for hot rolled coil (HRC).

In terms of the magnitude of transformation required, we must also differentiate between flat and long steel production. In Europe, most long steel products are made from scrap steel using electric arc furnaces (EAFs). Operating these furnaces using renewable power rather than power from the grid yields only a small reduction in emissions. Consequently, reducing CO_2e emissions from long steel products is a step change but not a transformation for the steel industry.

The transformational challenge for the European and also the global steel industry, lies in particular in flat steel production (which is why flat steel will be the focus for the remainder of this paper). Due to quality requirements and limited scrap supply, most European flat steel is produced from virgin iron in blast furnaces and basic oxygen furnaces (BF-BOFs). This production method is highly carbon-intensive as emissions occur during the removal of oxygen from iron ore and due to heat generation. The BF-BOF process uses coking coal both as a reducing agent and as fuel. Most of this coal needs to be imported to Europe, creating additional emissions from transportation.

To reduce emissions from flat steel production, entirely new plants that use direct-reduced iron in electric arc furnaces (DRI–EAFs) are required. These plants rely on natural gas to reduce the iron ore. Eventually, green hydrogen (H_2) and potentially other reduction agents will replace the role of natural gas, further reducing these plants' emissions. To lower emissions even further, they can also use renewable power to generate heat for steel production. At the same time, the CO_2e emissions associated with the extraction and transportation of coking coal disappear entirely. When all these factors are combined, they add up to a substantial reduction in the carbon emissions per ton of steel. Future efforts to reduce the

Exhibit 1 - Different Shades of Green Steel Exist, Based on Different Production Technologies



1. Includes scope 1, 2 and 3 upstream Note: HRC = Hot Rolled Coil; BF-BOF = Blast Furnace – Basic Oxygen Furnace; DRI-EAF = Direct Reduction Iron – Electric Arc Furnace; RE = Renewable Energy; Sust. SC = Sustainable Supply-Chain; H_2 = Hydrogen; CCS = Carbon Capture and Storage Note: Includes cradle-to-gate emissions (i.e., approx. scope 1, 2 & 3 Upstream from steel producers' perspective); Charge Mix: 20% Scrap Share in BF-BOF & DRI-EAF, 100% Scrap in Scrap-EAF; 80% capturing rate and electricity self-sufficiency from waste gases for BF-BOF + CCS **Source:** BCG

cradle-to-gate CO_2e footprint of steel products will center around the crude steel supply chain and will likely involve actions such as localizing and decarbonizing iron ore, lime, and alloy inputs. However, further progress will also be required to increase scrap usage and improve scrap recycling efficiency.

The European market in green flat steel will emerge in three phases

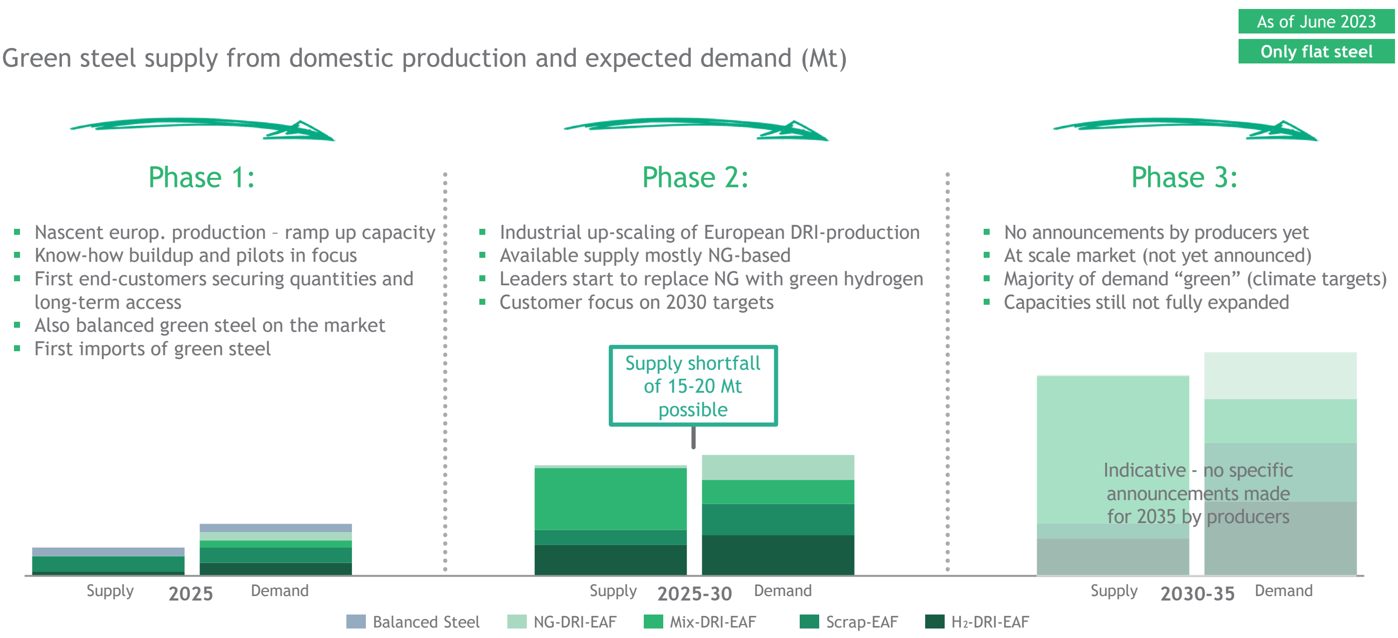
We anticipate that the emergence and development of a European market in green flat steel will occur over the next 15 years and take place in three phases. (See Exhibit 2.) Besides, it is also essential to observe geographies beyond Europe since their momentum has the potential to rival or surpass that of the European markets.

Deliveries from now until 2025:

- **Supply:** The BF-BOF route continues to be a major source of flat steel, with green production limited to a few pilot plants and a small number of high-quality scrap-EAF plants that can deliver some of the lower grades of flat steel as well as making long products. A relatively large share of green flat steel supply will still involve balanced products.

- **Demand:** Steel customers focus on lighthouse projects that signal their green leadership and try to secure long-term access. At this stage, they will still use pilot projects to test whether green steel meets their production requirements before moving ahead with plans to purchase green steel on an industrial scale. Given the small volumes involved, customers will be relatively insensitive to price. However, customers with the most advanced sustainability plans will (and in some cases already have) sign offtake agreements to ensure they have sufficient green steel ahead of a looming supply shortage. Such agreements are particularly prevalent in the automotive, renewable energy, and white goods space as well as for selected construction projects. Even without a contract in place yet, other companies have also committed to procure predefined shares of their steel from green sources by 2030 as part of the First Movers Coalition and other initiatives.

Exhibit 2 - European Green Steel Market and Green Premiums Will Emerge in Three Phases



Note: Supply and demand estimates visualized for final year of respective phase. **Source:** BCG

Deliveries between 2025 and 2030:

- **Supply:** European steelmakers will open the first DRI-EAF plants, in line with their announced plans and emission reduction goals. This will create industrial scale of at least greener steel production capacity in Europe of up to 30 Mt by 2030. (See Exhibit 3.) Most of this production will come from plants that use a mix of green H_2 and natural gas. Balanced green steel products will disappear as market participants become more mature and as customers, investors, and standard setters prioritize physically greener steel. As these volumes come online, steelmakers will have another reason to phase out their balanced products: to avoid branding issues and cannibalization.

- **Demand:** Big steel customers, such as automotive OEMs, will aim to secure significant volumes of physically green steel well before 2030 to meet their near-term emission reduction targets on the one hand (which by now will typically be certified by the Science-Based Targets initiative) and to sell greener end-products to their customers on the other. Given the large volumes involved, customers will increasingly try to minimize any additional costs while coming to terms with the new cost structures of physically green steel and growing competition due to scarce supply. Steel customers that face high reputational risks if they don't meet their emission reduction goals (such as government-owned organizations) will find it hardest to navigate these conflicting pressures. Consequently, they will need to act early to secure sufficient supplies at a good price.

Deliveries between 2030 and 2035:

- **Supply:** European flat steel production will be predominantly green thanks to the addition of new DRI-EAF plants (although some of these plants have yet to be announced). Differentiation between steelmakers will come from the amount of green H_2 they use in their production processes.

- **Demand:** Customers will want most of their flat steel deliveries to be green steel with low emissions made using either scrap-EAF or H_2-DRI-EAF plants. This is because of the looming "hockey stick" of emissions reductions needed after 2030 if companies are to

Exhibit 3 - Steel Producers Have Announced Green Volumes Across All Shades

As of June 2023

Steel producers	2022	2023	2024	2025	2026	2027	2028	2029	2030
ArcelorMittal	~0.5Mt			~2.3Mt					~8.5Mt
thyssenkrupp					~2.5Mt				
Tata Steel									2.5Mt[3]
voestalpine						*not specified*			*not specified*
Salzgitter AG	*trial plant*			~2.1Mt					*not specified*
SSAB HYBRIT	*pilot plant*				~1.3Mt				~1.3Mt
H2 Green Steel				~2.5Mt					~2.5Mt
USS					*- no specific announcements -*				
Arvedi	~3.8Mt								
GravitHy						~2.0Mt[1]			
Aker					*- no specific announcements -*				
Dillinger									~1.7Mt[2]
Blastr Green Steel					~2.5Mt				
Hydnum Steel (ES)					~1.5Mt				~1.1Mt

Mixed DRI-EAF   Scrap-EAF H_2-DRI-EAF

Note: Capacities of announced DRI plants shown where green steel capacities are not mentioned; 1. GravitHy using nuclear to cover baseload; 2. Dillinger: SHS flat steel (public announcement of 3.5Mt for SHS Group, assuming 50% of this Dillinger); 3. Not publicly specified but feasibility study refers to 2.5Mt capacity plant **Source:** Company presentations and press announcements; BCG meet their net-zero commitments (which requires the biggest emission cuts to happen mainly between 2040 and 2050). Besides the steel consumer-driven substitution of gray steel with greener variants, a strong pull effect from the end-customer could further accelerate an increase in green demand. This demand could further gain momentum as customers assess the potential to fully or partially substitute materials with higher CO_2e intensity with green steel.

The looming supply shortage in green steel

Up to 2030, the balance between announced supplies of green steel and demand based on companies' emission reduction goals is already short. This would still give many steel customers a pathway to meet their 2030 targets. In this scenario, particularly green steel made using the green H_2-DRI-EAF and scrap-EAF production methods experiences a significant supply shortage. These two categories are short across all periods. This is primarily due to the limited supply of scrap steel and the difficulty of securing sufficient green H_2 at competitive prices.

This shortage in green steel becomes even more significant when considering structural factors that could limit the ramp-up in supply based on planned capacity additions. We believe four dimensions will likely reduce the amount of new capacity that actually comes online by 2030. These comprise: 1) the annual capacity of European Engineering, Procurement, and Construction companies for building new DRI plants; 2) the availability of scrap and DR pellets for European steel production; 3) the availability of renewable electricity for use by DRI-EAF plants; and 4) the availability of green H_2. Nonetheless, the particularly long investment cycles in the industry mean that producers must act now. Otherwise, those stuck with gray production routes risk holding stranded assets.

On the demand side, an important reason for demand for steel made using H_2-DRI-EAF and scrap-EAF production routes outpacing supply is that these two categories give steel customers advantages with branding and long-term planning due to their particularly low emissions.

But the scarcity in green steel as a whole is exacerbated if we assume that corporate emission reduction targets – a key demand-side factor - could be more widespread and ambitious from here on. For now, suppliers are mostly promoting green products to their customers. Once these steel procurers learn and understand the palpable benefits of a green business model, such as the attainable premiums, this push will quickly turn into a pull of much greater magnitude. Indeed, if green transitions in other industries have taught us anything, it is that the market in green steel will emerge more abruptly and at a more rapid pace than we anticipate today. The impact of electric vehicles on the global automotive market is just one example. Consequently, we estimate that the combination of all these supply-side and demand-side factors could increase the shortage of green steel in 2030 to up to 20Mt.

The opportunity to shake off cost-plus pricing

The green premium in steel (the premium customers will pay for green steel rather than traditional gray steel products) will also emerge along the same three market phases. Prices for green steel in Europe already include significant premiums of 25-40% per ton of HRC, relative to the respective gray price index over the last 6 months or so. But given the low volumes and the nature of the available products (which include a significant share of balanced products), this may say little about price levels in a future industrial-scale green steel market.

Going forward, the price setting is likely to be determined by three elements. First, green steel producers want to, at the very least, recoup their higher cost of production relative to gray alternatives. This provides a floor for prices. The remaining two factors then come into play on the value side. One is the question of how much consumers are willing to pay to achieve the emissions reductions obtainable by utilizing green versus gray steel. The remaining element comes down to the dynamics of supply and demand, just as in any other market.

Here, given the persisting scarcity as demand rises commensurably with expanding supply, the size of the green premium will ultimately be set by the industry with the highest willingness-to-pay.

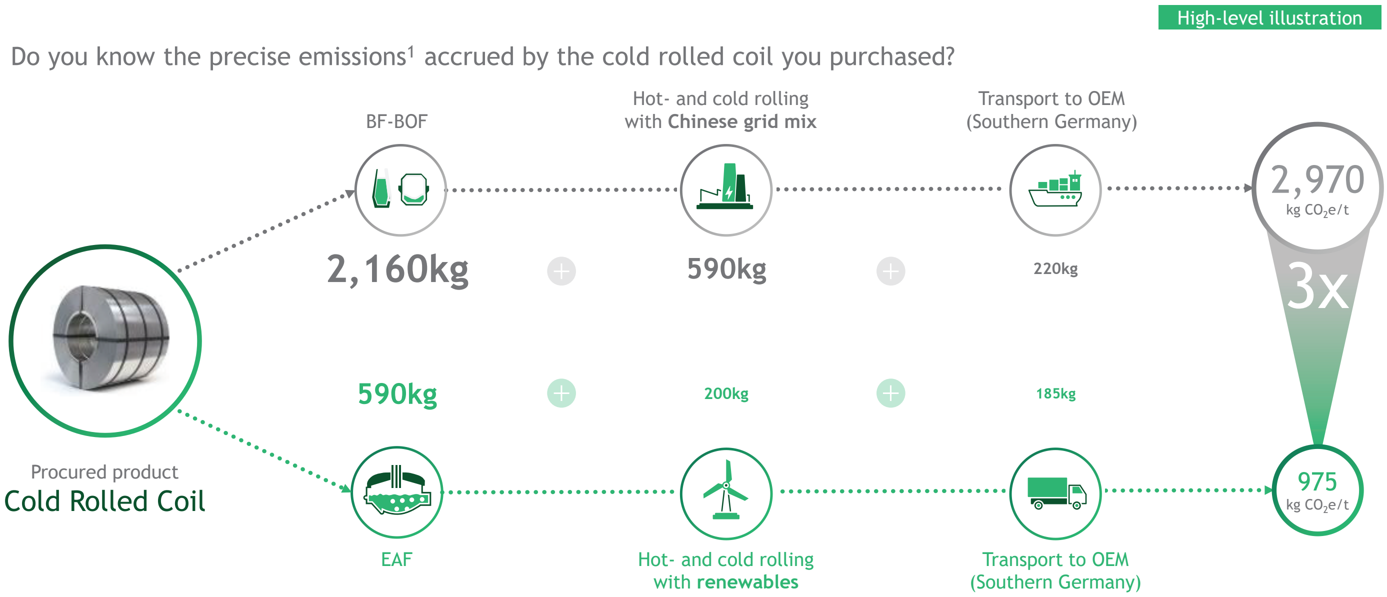
At this point, it is important to note that such premiums will not necessarily result in drastic increases in consumer prices. A study co-authored by the World Economic Forum (WEF) on decarbonizing supply chains [LINK] has calculated that even with ambitious upstream reduction targets, the impact on consumer prices is relatively low in the medium term if zero supply-chain emissions are the goal. For example, a home constructed this way would see its average costs increase by less than 3% and a car even by less than 2%. For both products, gray steel is currently only one of many input materials, however, in terms of carbon intensity a highly relevant one.

For steelmakers to tap into the green steel value pool, it is imperative that they prove to customers that their steel products actually deliver the level of emission reductions that they promise.

Steelmakers can do this by calculating the CO_2e footprint of their products using globally recognized standards, such as Greenhouse Gas Protocol and ISO ones. They also need to have the calculation certified by a widely recognized external organization, such as TÜV SUD or TÜV Rheinland, to produce a credible cradle-to-gate PCF. This differs from a corporate carbon footprint (CCF), which includes the total amount of emissions arising from the company's activities over the span of 12 months. While a CCF allows a firm to stay in business, it is the PCF that enables it to achieve a green premium.

If steel suppliers provide a PCF for their products, their customers are able to make greener procurement decisions. Customers may be purchasing several units of the same type of product but the CO_2e footprint of individual items could vary widely depending on the production techniques used and how they were transported. Exhibit 4 shows the magnitude of the discrepancies possible with today's technologies. This spread is only expected to widen as new production paths (such as H_2-DRI-EAF) mature. As a result, steelmakers and suppliers need their own tools that allow them to calculate PCFs for individual products based on real-time data. Ultimately, they can then use these PCFs with customers to achieve a green premium.

Exhibit 4 - Tools Can Provide Transparency and Deaverage Your Procurement Footprint



1. Includes scope 1, 2 and 3 Upstream
Source: ecoinvent database, worldsteel, BCG project experience

The PCF value proposition for green product buyers

For buyers of green steel, a PCF also offers tangible benefits beyond validation of the green product status. As end-consumers and regulators demand ever higher transparency from companies regarding their carbon footprint, it becomes imperative to know the emissions from purchased goods and services. Crucially, this includes the emissions embedded in input materials such as steel – a number that it is almost impossible to determine beyond industry averages without receiving a PCF from suppliers.

However, customers are also faced with the conundrum that PCFs and carbon accounting in general are not yet established in any industry. Therefore, the emissions number means little to them in absolute terms and its accuracy can be difficult to assess for those handling the declarations. Here, trust is a crucial factor that can be fostered by obtaining the aforementioned external certifications.

Such specification is furthermore essential to harmonize PCF calculation logic between different products and materials. Ultimately, all declarations are worth less if they cannot be compared amongst each other. Here, common methodologies (e.g., ISO) are just as important as setting identical system boundaries (e.g., cradle-to-gate according to GHGP). Consistency across industries, beyond steel, enables buyers to make CO_2e-conscious choices between material types and products to then minimize their footprint. This level of comparability could not be achieved by a simpler labelling system without a PCF. Given the current momentum in steel's decarbonization trajectory relative to other materials such as plastics, substitution could further add to the acceleration in green demand mentioned above.

Apart from certification, there are other considerations steelmakers need to bear in mind to capitalize on the opportunity in green steel. They need to ask themselves the following questions: what is my customers' 'willingness to pay' a premium for green steel?; how can I adapt my organization to enhance and capture green value?; do I need to alter my existing pricing approach to take account of green products?; how can I use real-time data from my own IT systems and from my suppliers' to calculate the PCF of my products?; what are my and my competitors' emissions and costs for green and gray steel?; and what is the value for my customers?

Steel suppliers offering gray steel today will need to thoughtfully manage their product portfolios as they make the shift from gray to green steel. A rapid entry into the green metals market is essential in order to maintain overall market share and participate in this developing market. The production of gray steel must be strictly managed, especially in the transition phase from gray to green steel, to ensure it contributes to profitability on a continuous basis. Moreover, as the market is dynamically evolving, a high degree of organizational flexibility is required.

Conclusion

The transition to green steel will have a huge impact on the steel industry. We believe the winners will be actors across the value chain that position themselves early and decisively enough to capture this value opportunity. A key enabler in this process will be PCFs and the participation of as many actors as possible. Steelmakers will have the opportunity to secure a green premium for their products, helping them to earn back their cost of capital. Automotive OEMs and other big customers can build a justified reputation as sustainability leaders. And consumers worldwide will benefit from a green version of a material whose unique properties make it an essential part of their everyday lives.

About The Authors

Nicole Voigt – Managing Director & Partner, Dusseldorf, Voigt.Nicole@bcg.com

Nicole Voigt is a member of the leadership team of the Materials & Process Industries practice area at Boston Consulting Group and leads the firm's global metals activities. She has deep expertise in working with all metals clients, e.g., in steel, aluminium, copper and battery materials.

Nicole is focusing on sustainability, the circular economy, and operational excellence. She provides thought leadership to the steel industry on trade policy and supports steel manufacturers in optimizing their CO2e footprint in light of global climate considerations.

Diana Dimitrova – Managing Director & Partner, London, Dimitrova.Diana@bcg.com

Diana Dimitrova is a core member of BCG's Climate & Sustainability and Tech build (Digital) practices. She is a climate and sustainability specialist with a focus on addressing the challenges of hard-to-abate sectors with Corporate Carbon Footprint (CCF) and Product Carbon Footprint (PCF) at the core. She has extensive tech expertise in the context of climate, around tech build of new solutions, scalability, and climate ecosystem build for impact. In addition, Diana is also one of BCG's leading experts in Green Steel. She has worked at BCG since 2007, previously working in the firm's Toronto, Melbourne, Sydney, and Johannesburg offices.

Prior to BCG, Diana worked at Merrill Lynch, Hedge Funds and Goldman Sachs, investment banking.

Marie-Luise Meyer – Partner, Berlin, Meyer.Marie-Luise@bcg.com

Marie-Luise Meyer works with clients in the industrial goods practice. Marie-Luise focuses on climate and sustainability transformations, particularly on commercial matters relating to green metals and on leveraging product carbon footprints as an important key performance indicator (KPI) for green products. Meyer.marie-luise@bcg.com

Alexander Klueber – Project Leader, Berlin, Klueber.Alexander@bcg.com

Alexander Klueber is a Project Leader in BCG's Berlin office. He works with clients at the intersection of industrial goods and climate, with a particular focus on hard-to-abate sectors. There his emphasis has been commercial strategies for green products.

About The Authors

Felix Schmitz – Head of Investor Relations & Head of Strategic Sustainability, Klöckner & Co,
Felix.Schmitz@kloeckner.com

Felix Schmitz holds a double role as Head of Investor Relations and Head of Strategic Sustainability at Klöckner & Co SE. His responsibilities include the development of sustainable business models at one of the world's largest producer-independent steel & metal distributors and leading steel service companies. In particular, he leads all global activities related to CO_2e-reduced customer solutions. In addition, as Head of Investor Relations he is responsible for all issues relevant to the capital markets.

Tim Milde – Head of Business Development Europe, Klöckner & Co,
Tim.Milde@kloeckner.com

Tim Milde is active as the Head of Business Development at Klöckner & Co in Europe. He is responsible for the business expansion of Sales and Procurement as well as the coordination of global customer accounts. Furthermore, he is one of the heads behind Klöckner's global strategy project for green steel and sustainability innovation. Tim has spent the last ten years of his career driving the digitalisation in the chemicals and steel industry through leading the Klöckner innovation hub and building up the platform venture Chemondis at specialty chemical company LANXESS. Previously, he has worked in a variety of operational roles across multiple sectors.

François-David Martino – CEO, Becker Stahl-Service GmbH,
F.Martino@becker-stahl-service.de

Francois-David Martino has held executive roles in Asia and Europe for many years, working in various fields and industries. After obtaining his degree in mechanical engineering, he served in numerous leadership positions at companies including thyssenkrupp, Siemens and ZF Friedrichshafen. Prior to his current role, he was the President & CEO China at Danieli & C. Officine Meccaniche S.p.A. Francois-David's reputation includes international recognition for his expertise in the fields of supply chains and operational excellence as well as in the successful realization of growth strategies. Aside from the implementation of the new Group strategy at Becker Stahl-Service GmbH, Francois-David Martino focuses on expanding the product and processing portfolio as well as the technical expertise in manufacturing while equally enhancing the service level for customers and partners.

Disclaimer

This document has been prepared in good faith on the basis of information available at the date of publication without any independent verification. BCG and/or any other party involved in the preparation of this document do not guarantee or make any representation or warranty as to the accuracy, reliability, completeness, or currency of the information in this document nor its usefulness in achieving any purpose. Readers are responsible for assessing the relevance and accuracy of the content of this document. It is unreasonable for any party to rely on this document for any purpose and BCG and/or any other party involved in the preparation of this document will not be liable for any loss, damage, cost, or expense incurred or arising by reason of any person using or relying on information in this document. To the fullest extent permitted by law (and except to the extent otherwise agreed in a signed writing by BCG), BCG and/or any other party involved in the preparation of this document shall have no liability whatsoever to any party, and any person using this document hereby waives any rights and claims it may have at any time against BCG with regard to the document. Receipt and review of this document shall be deemed agreement with and consideration for the foregoing.

This document is based on a primary qualitative and quantitative research executed by BCG. BCG does not provide legal, accounting, or tax advice. Readers are responsible for obtaining independent advice concerning these matters. This advice may affect the guidance in the document. Further, BCG and/or any other party involved in the preparation of this document has made no undertaking to update the document after the date hereof, notwithstanding that such information may become outdated or inaccurate. BCG and/or any other party involved in the preparation of this document do not provide fairness opinions or valuations of market transactions, and this document should not be relied on or construed as such. Further, any evaluations, projected market information, and conclusions contained in this document are based upon standard valuation methodologies, are not definitive forecasts, and are not guaranteed by BCG and/or any other party involved in the preparation of this document. BCG has used data from various sources and assumptions provided to BCG from other sources. BCG has not independently verified the data and assumptions from these sources used in these analyses. Changes in the underlying data or operating assumptions will clearly impact the analyses and conclusions.

This document is not intended to make or influence any recommendation and should not be construed as such by the reader or any other entity.

This document does not purport to represent the views of the companies mentioned in the document. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by BCG.