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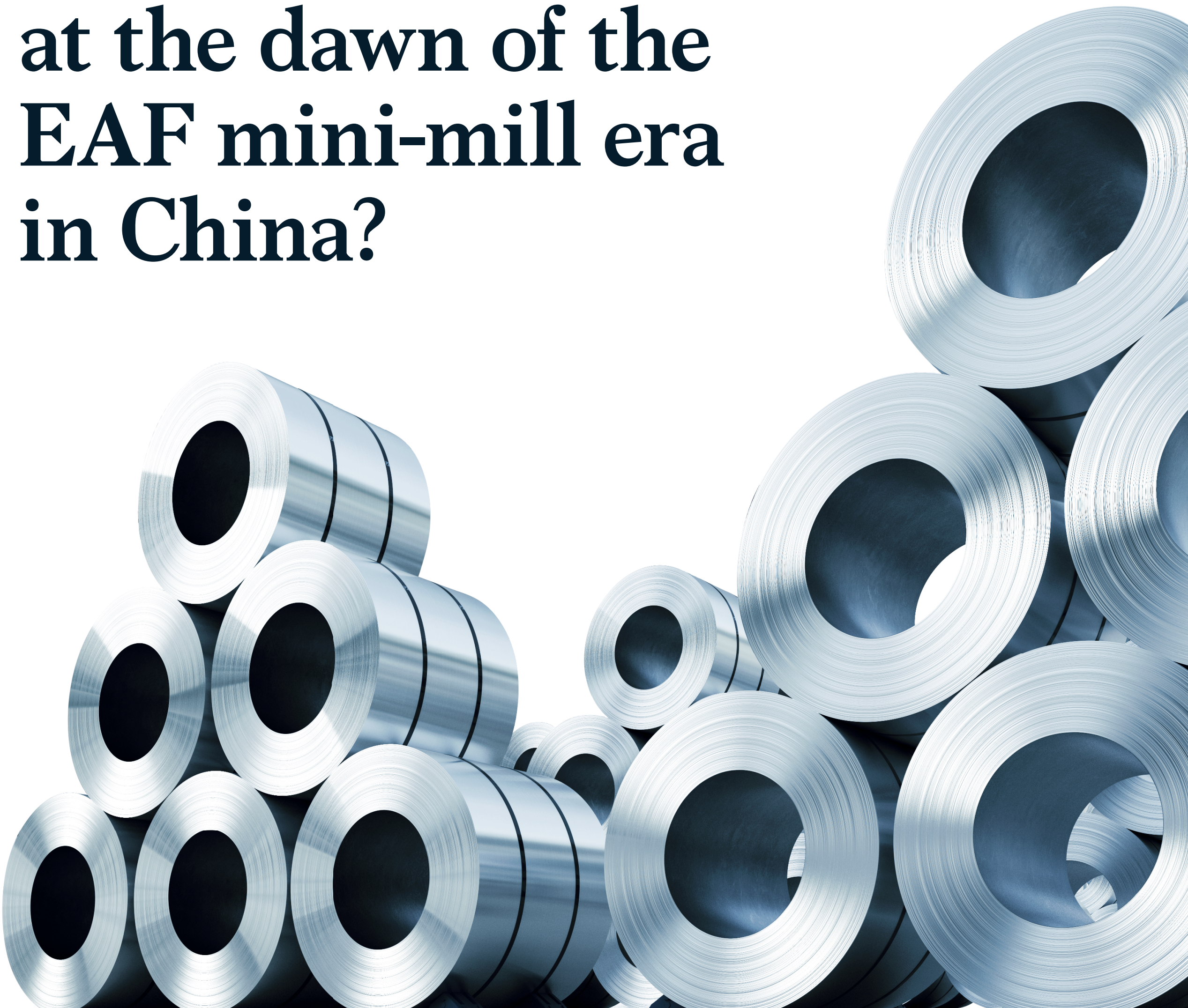
How should steelmakers adapt at the dawn of the EAF mini-mill era in China?



June 2019

Executive summary

China’s steel industry is on the cusp of a new era. Over the next decade, steel will increasingly be made by recycling domestic scrap in electric arc furnace (EAF) mini-mills as the government proceeds with policy-driven elimination of conventional induction furnaces (IF), and the replacement of integrated steel capacity. This landmark change, which encompasses economic and environmental benefits, will reshape the industry and require major adjustments in the steelmaking business model at the company level. To successfully adapt in this new environment, steel companies and other industry stakeholders should understand the context and motivating factors behind the transition.

In 2016 and 2017, China’s steel industry landscape was shaped by policy-driven elimination of IF capacity as the government sought to address a domestic supply glut. McKinsey research shows that in the following year, consumption of scrap steel in EAF and basic oxygen furnace (BOF) steel mills reached a record high of more than 200 million metric tons per year (mtpy). At the same time, China’s EAF capacity reached a new peak of 130 mtpy. As government policy restricts production by integrated mills in key areas, and encourages their vigorous replacement by EAF capacity, all signs point to the arrival of the EAF era in China.

A mixture of environmental regulation and market dynamics is likely to accelerate this pattern. On the policy side, the government is intent on enforcing stricter environmental protection measures in tandem with limits on vertically integrated mill capacity. Small-scale EAF mills offer outstanding energy-saving and polluting emissions advantages compared with conventional vertically integrated BOF mills, making them well suited to a more stringent era of environmental standards in China.

Meanwhile, EAF mini-mills entail lower initial investment and operating costs, and offer flexibility in terms of production planning, allowing their operators to respond quickly to market dynamics. In terms of location, their compact scale allows such mills to set up adjacent to sources of relatively inexpensive post-consumer scrap, from where they can also distribute products locally. On the other hand, integrated mills in inland areas suffer from high transportation costs of imported iron ore. These factors are likely to concentrate large-scale integrated mills along waterways – rivers, lakes, or coasts – while EAF mini-mills spread widely across mainland China.

There are several historical precedents for these shifts. EAF mini-mills played an important role in developed countries’ final stages of industrialization, with their share of steel output typically outgrowing that of integrated mills in the post-industrialization period. We expect China to tread a similar development path as the advantages of EAF mini-mills become more prominent, and forecast China’s EAF steel output ratio to increase from 10 percent in 2017–18 to 15 percent by 2025.

How should steel companies position themselves to take maximum advantage of the unfolding EAF era? We recommend three points of action:

— Innovate the business model. Establish a compact mini-mill business model with scale flexibility and low investment and operating costs; plan new EAF projects rationally based on scrap supply and local market demand.

— Upgrade products. China's growing EAF capacity has the potential to increase the share of higher-value flat products in companies' product mix. As both the quantity and quality of scrap are improved in parallel with the rise of the circular economy and recycling industry in China, the increased availability of high-purity scrap will favor the production of high-value products in EAF mini-mills.

— Optimize capex and opex. With a target set for new present value (NPV), conduct product planning and optimize design and tender/ procurement to significantly increase the ROI of EAF mini-mill projects. Implement strict scrap management and establish an end-to-end scrap management process, including thorough refinement of scrap standards, strict control of scrap input, and optimization of scrap procurement ratios based on production planning.

The EAF era arrives in China

Big increases in scrap supply, EAF capacity, and scrap intensity signal dawn of transition

During 2017 and 2018, scrap supply and EAF capacity both hit record highs in China, even as scrap intensity increased significantly. These landmark changes, along with government policies that encourage EAF adoption in line with its environmental, capex and logistical advantages, all indicate China's steel industry is entering the EAF era.

Scrap supply-demand structure heading for intense growth

In 2017 and 2018, the structure of scrap supply and demand in China underwent a fundamental change. The annual consumption of scrap in China's BOF and EAF steelmaking processes jumped from 110 mtpy in 2015 to over 200 mtpy in 2017 to 2018, with current scrap intensity in crude steel over 200 kg/ton. This "big bang" was mainly due to the actions taken by local governments in 2016 to 2017 to ban IF steel plants. A total of 140 mtpy of IF capacity was eliminated, resulting in a large amount of scrap surplus supply, and a significant increase in the scrap consumption of both EAF and BOF mills. The scrap intensity of some EAF plants has increased rapidly, rising from 20 to 30 percent in 2015 to 70 percent in 2018. At the same time, due to the impact of the state's policy to limit production in 2+26 cities (Beijing, Tianjin, and surrounding cities in Hebei province), the scrap intensity in some vertically integrated steel mills also increased to 20 to 25 percent in 2018 to improve the productivity in blast furnace (BF) and BOF mills.

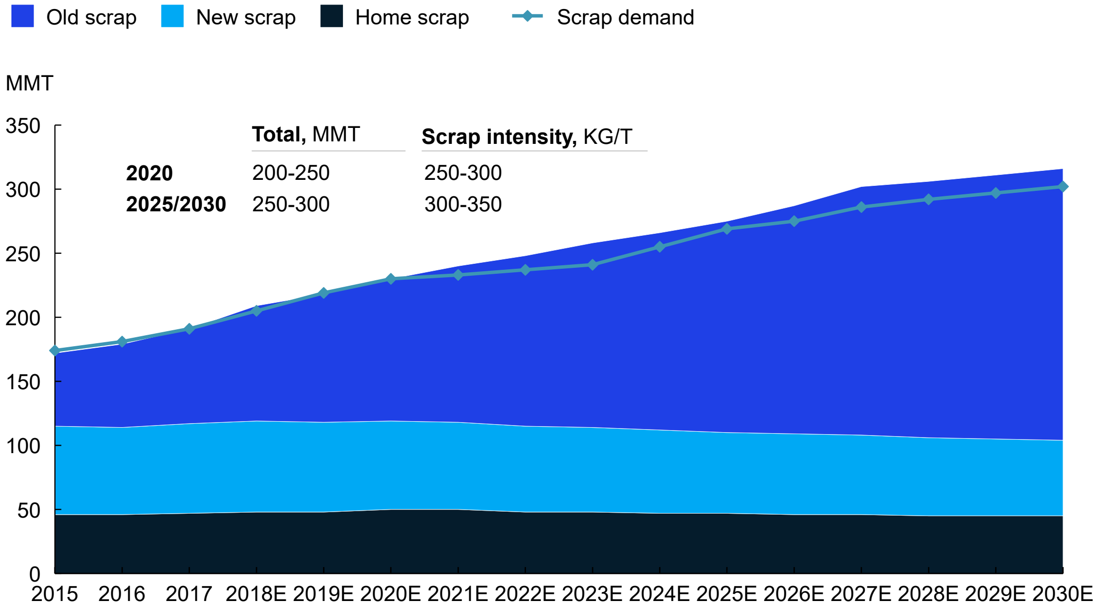
This growth appears set to continue. As stated in McKinsey's 2017 white paper[1] on China's scrap market: "With the gradual increase in the scrap available from aging downstream steel products, such as automobiles and home appliances, China's environmental protection policy requires corresponding improvements to the recycling and processing systems for downstream sectors."

As the supply of scrap expands, mills are increasing consumption, particularly as steel made from alternative raw material inputs falls subject to stricter environmental standards. As shown in Figure 1.1, China's scrap is expected to achieve supply/demand balance in 2020 as volume exceeds 220 mtpy. After 2020, domestic scrap supply will largely cover domestic BOF and EAF mills' demand as it grows to more than 300 mtpy in 2030.

[1] McKinsey's 2017/03 release "The growing importance of steel scrap in China", https://www.mckinsey.com/industries/metals-and-mining/our-insights/the-growing-importance-of-steel-Scrap-in-china

Figure 1.1

China scrap supply-demand forecast



SOURCE: McKinsey BMI China scrap supply-demand model

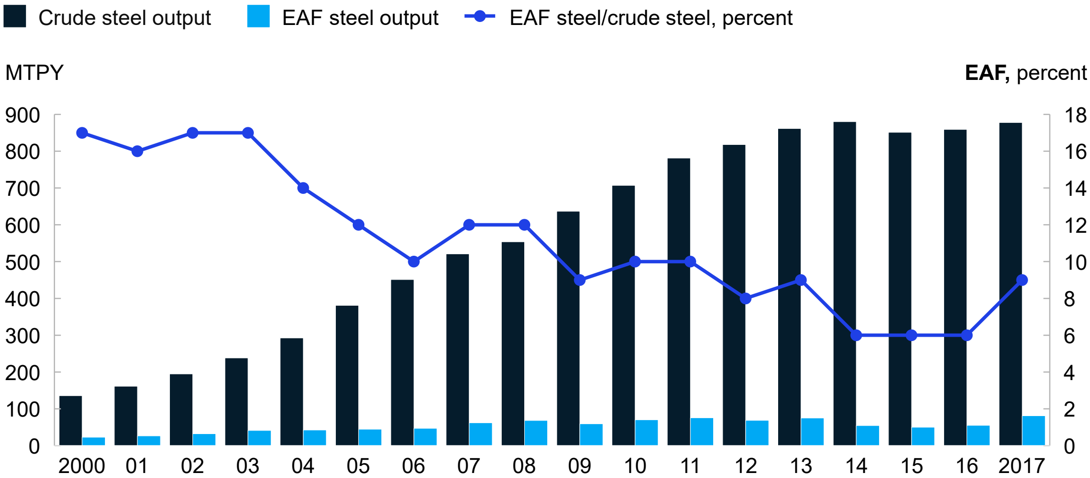
EAF capacity and output are starting to grow briskly

Despite strong growth, EAF steel output in 2017 remained low at 81 mtpy, or just 9 percent of China's 878 mtpy annual crude steel output, as shown in Figure 1.2. China's vigorous development of EAF steelmaking began in the late 1980s and early 1990s, but since 2000 has been rapidly outpaced by wider growth in domestic crude steel output. Constrained by major supply bottlenecks in domestic scrap and electric power, the EAF ratio declined from a peak of 20 percent in the 1990s to around 10 percent between 2007 and 2017.

In recent years, however, electricity supply has improved, and in April 2018, the Chinese government adopted a policy to reduce industrial electricity prices. These developments, along with a growing scrap steel surplus diverted from shut-down IF capacity, solved the supply-side bottlenecks and opened the door for China to begin scrap-based EAF production in earnest.

Figure 1.2

China's crude steel and EAF steel output, 2000-17



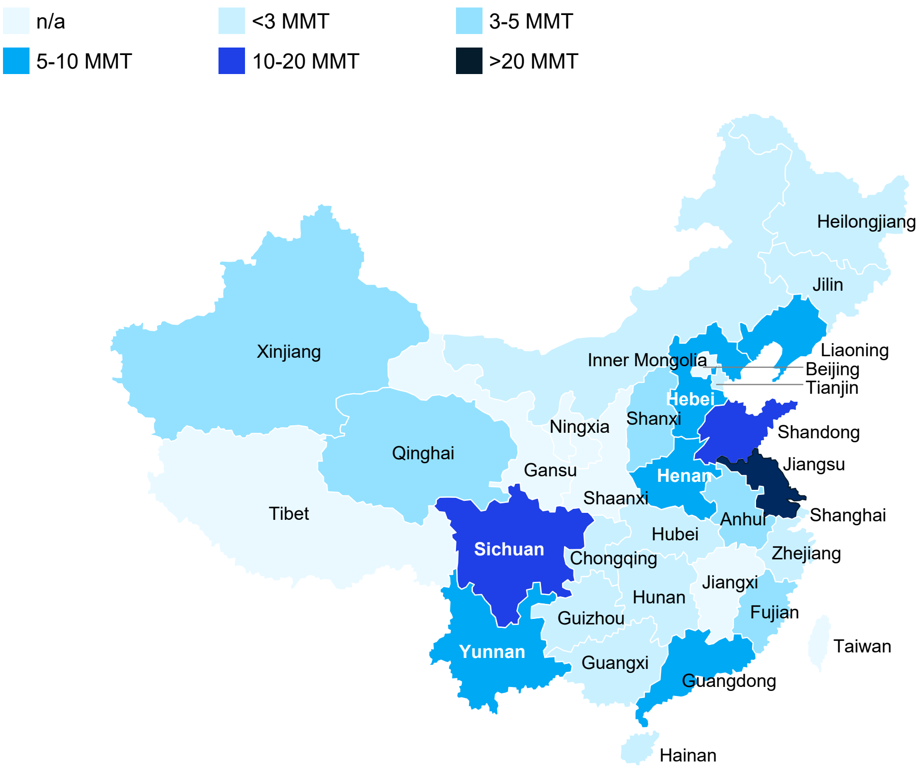
Note: Crude steel output includes BOF, EAF, IF production

SOURCE: McKinsey BMI analysis

During 2017 and 2018, China's EAF capacity growth broke historical records, reaching 130 mtpy after the addition of more than 40 mtpy. Around 50 new EAF furnaces were added, mainly in the southwest and inland areas such as Sichuan, Yunnan, and Henan provinces, with the result that 70 percent of capacity is now concentrated in the east, south, and inland (Figure 1.3). As this new capacity comes online, China's EAF steel output should touch new historical highs in the near future.

Figure 1.3

China's EAF capacity by location, 2017-18



SOURCE: McKinsey BMI analysis

Key trends and driving forces in China's EAF mini-mill development

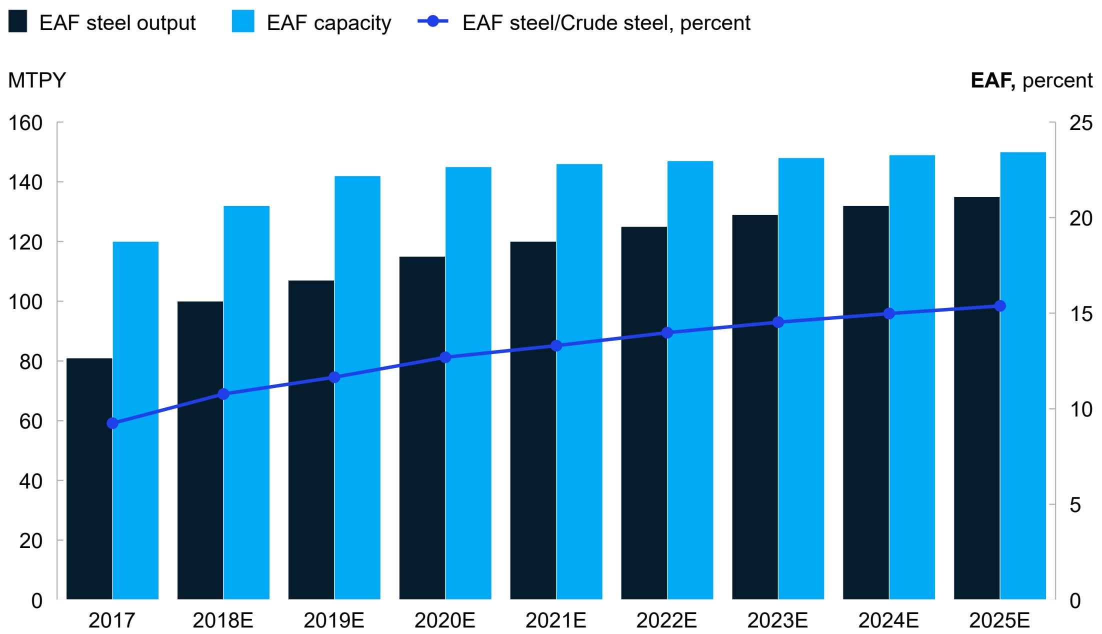
EAF's advantages favor faster adoption in China than other post-industrialized countries

The EAF route offers competitive capex and opex, less environmental pollution, and greater flexibility in responding to demand changes. In China, these inherent advantages are complemented by favorable government policies that suggest the country may make a relatively rapid transition to EAF models.

In early 2018, the Chinese government said that EAF development should be reasonably guided in the steel industry's work plan and encouraged the transformation of existing integrated steel mills into EAF enterprises. In light of this policy, and on the basis of patterns in developed countries' steel industries, we estimate that in 2025, EAF steel capacity should reach 150 mtpy, while output will hit 135 mtpy, and the EAF steel ratio will reach 15 percent (Figure 2.1).

Figure 2.1

Forecast of China's EAF steel output/EAF capacity



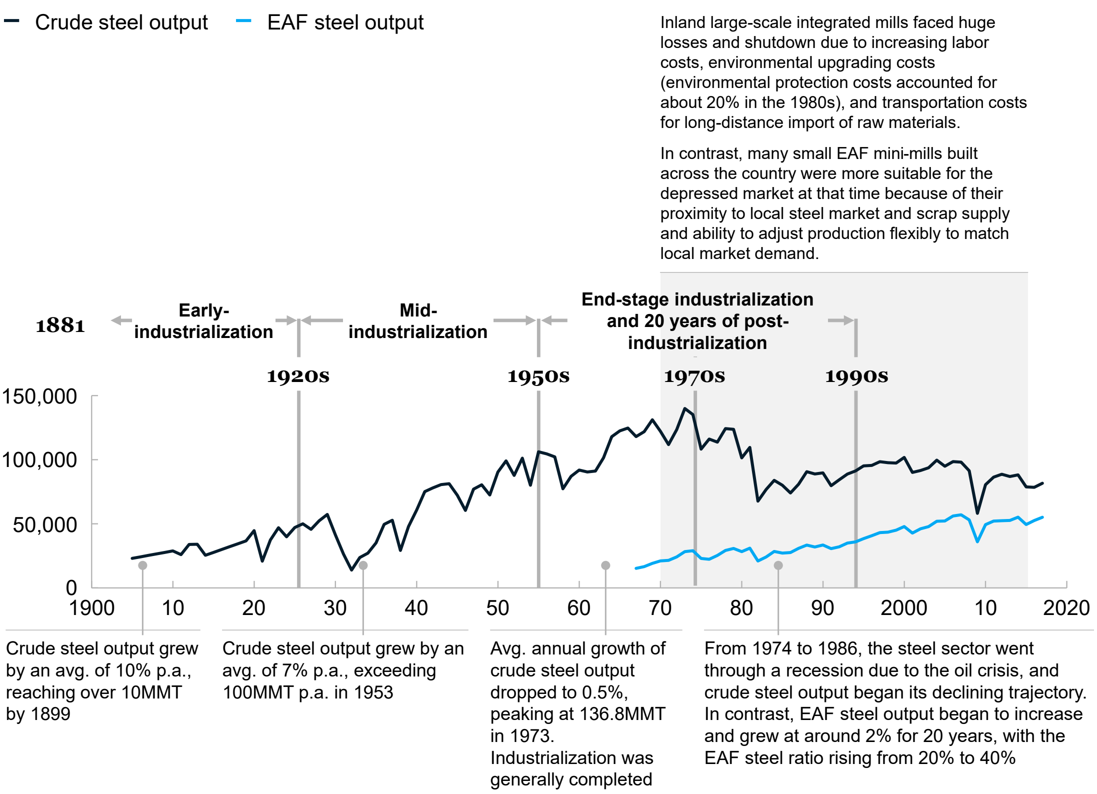
SOURCE: McKinsey BMI analysis

EAF's market share typically increases during post-industrialization

A deep dive into the history of the steel industry in developed countries, such as the US, Japan and Germany, shows steady growth of integrated steel mills during early and mid- industrialization. However, in the end stage and post-industrialization era, integrated steel mills' capacity dwindled amid rapid growth of EAF mini-mills. (Figures 2.2 to 2.4).

Figure 2.2

History of US crude steel output and EAF steel output (1,000 tons)

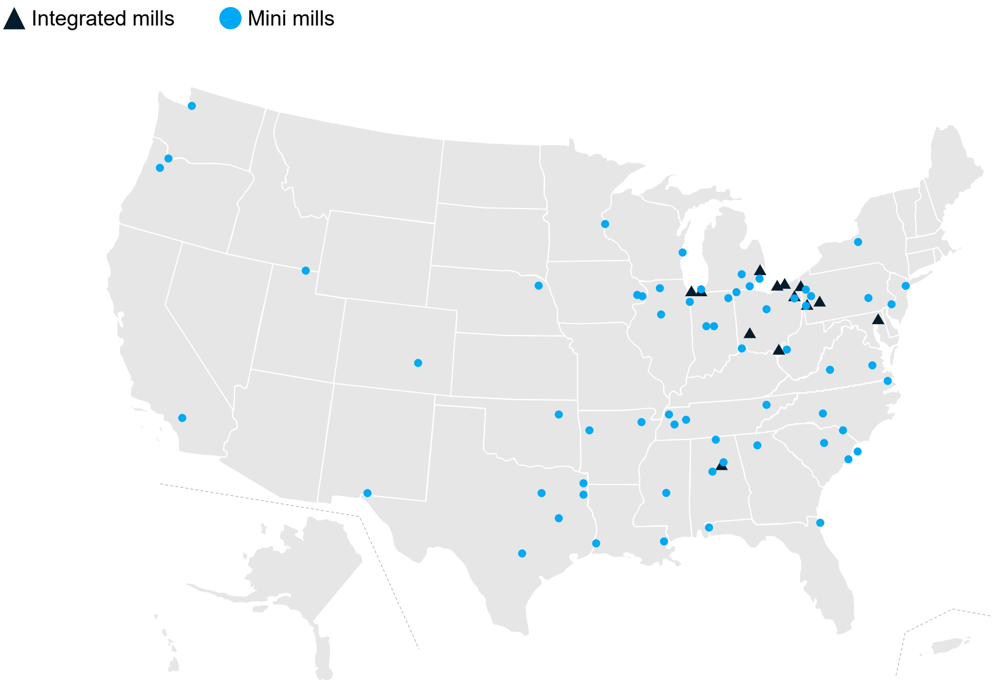


SOURCE: McKinsey BMI analysis

The arrival of post-industrialization in the US also ushered in structural changes in the steel industry. Due to the cost of long-distance transportation of raw materials, the inland large-scale integrated mills had to shut down, leaving only those in the Great Lakes region standing post-2000. In contrast, EAF mini-mills continued to spread widely and distribute products throughout the country. This pattern continues into the 21st century, as shown in Figure 2.3.

Figure 2.3

Nationwide distribution of integrated/mini-mills in the US during post-industrialization



SOURCE: EPA, 2005

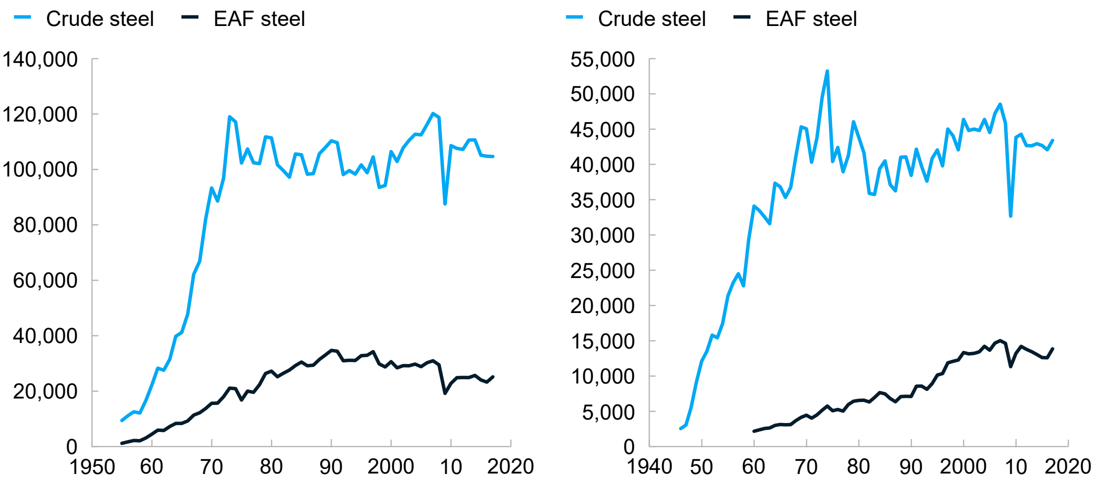
Other developed countries saw a similar pattern in their steel industries during the end stage of industrialization. As shown in Figure 2.4, Japan's crude steel output peaked in 1973 at 119 mtpy. Thereafter, in the post-industrialization period, output declined for 20 years. In parallel, EAF steel output grew continuously at an average of 2.36 percent p.a., and the ratio of EAF steel grew from 16 percent to over 30 percent. Germany was generally industrialized by the end of 1970; its annual crude steel output peaked in 1974 at 53 mtpy, followed by 20 years of negative growth. In the same period, the average annual growth of EAF steel output was 2.57 percent, and the EAF steel ratio increased from 10 percent to 20 percent. The Chinese steel industry has a chance to adopt EAF mini-mills more quickly than these historical precedents due to favorable government policies, and rational industrial planning.

Figure 2.4

Evolution of crude steel output and EAF steel output in Japan and Germany

Japan's crude steel output and EAF steel output, 1,000 tons

Germany's crude steel output and EAF steel output, 1,000 tons



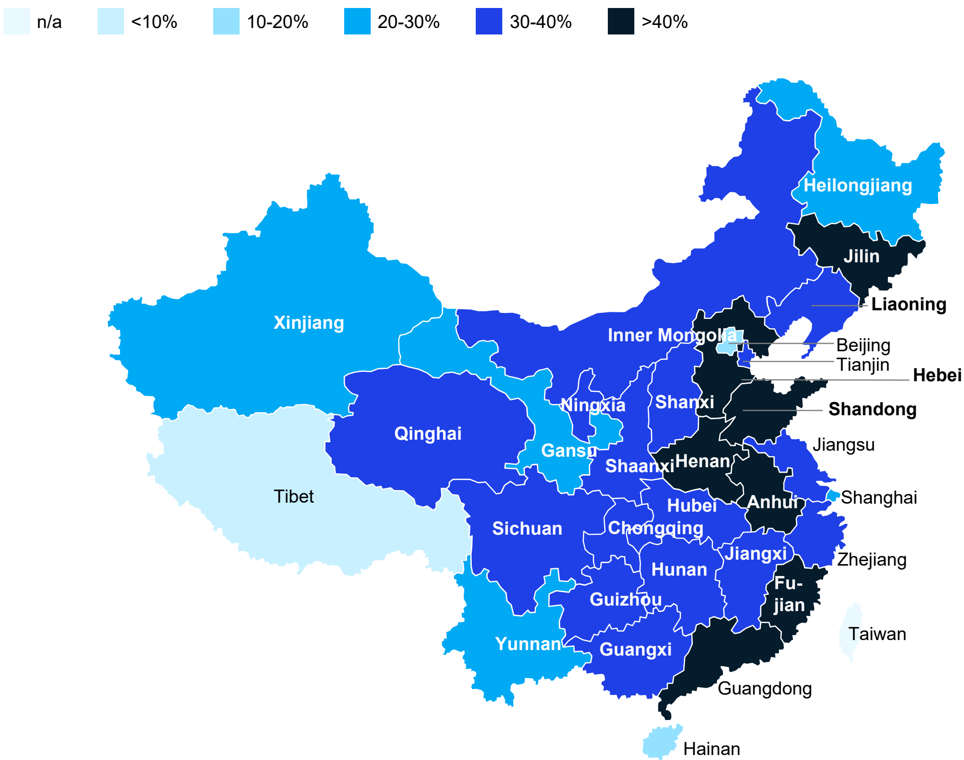
SOURCE: McKinsey BMI analysis

EAF advantages are gradually manifesting, supporting ongoing growth in EAF steel output

Despite geographical imbalances in economic growth, China has generally entered late or end-stage industrialization. As shown in Figure 2.5, the majority of China had an industrialization rate of around 30 to 40 percent in 2016. According to the "Industrialization Blue Paper: China Industrialization Progress Report (1995-2015)," published by the Chinese Academy of Social Sciences, China's industrialization process decelerated across the board during the 12th five-year plan (2011 to 2015), entering late industrialization in 2015. By 2020, China will have basically completed industrialization. The latest three-year Industry Action Plan released by the Ministry of Industry and Information Technology (MIIT) also mentions that, by 2020, the heavy-industry ratio in key locations will decrease visibly. The plan is to accelerate the end of industrialization, encouraging a more efficient industrial structure that favors accelerated adoption of EAF mini-mills.

Figure 2.5

Industrialization rate across China, 2016



Note: Industrialization rate percent = Industrial added value/GDP

SOURCE: McKinsey BMI analysis

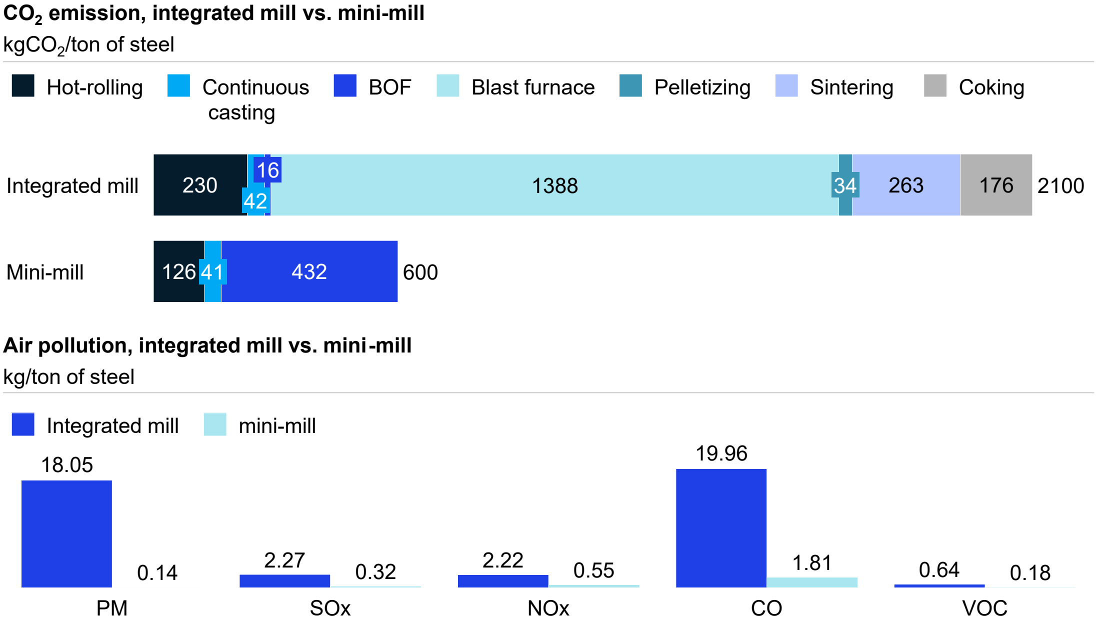
As China entered its late industrialization phase, the steel sector had to contend with stricter environmental policies, coupled with a more rigorous environmental inspection regime, resulting in the elimination of outdated capacity. Integrated mills with high pollution and/or energy consumption are being forced to limit production, shut down, or be replaced by EAF mini-mills. Unlike large integrated mills, EAF mini-mills will become more prominent because they offer a competitive edge, and plenty of development potential. They generate much less pollution, use energy more efficiently, have lower investment and operating costs, can flexibly adjust to demand, and can be built adjacent to post-consumer sources of scrap as their main raw material. These factors should stimulate strong growth of EAF mini-mills' capacity and output.

— **EAF mini-mills offer unique energy-saving and environmental protection advantages**

Compared with integrated mills, EAF mini-mills have great advantages in terms of reducing GHG emissions and energy costs. As shown in Figure 2.6, a typical integrated mill's CO_2 emissions are 3.5 times higher than an EAF mini-mill's; in terms of pollutants discharge, an integrated mill emits far more pollutants than an EAF mini-mill.

Figure 2.6

Integrated mill vs. mini-mill in carbon emission and pollutants discharge



Note: PM-particulate matter, CO-carbon monoxide, VOC-volatile organic compounds

SOURCE: Press search; McKinsey BMI analysis

China's EAF mini-mills are favorably positioned for the future relative to government environmental policy, which revolves around a push to reduce CO_2 emissions per unit of GDP in 2020 by 18 percent compared with 2015. This proposal is part of the government's "three-year action plan" – part of an overarching battle against industrial pollution that includes "10 Measures for Air Pollution Control"[2]. At integrated mills, these measures demand multiple investments in dedusting, desulfurization, and denitration to meet major air pollutant emission standards. At EAF mini-mills, investments are only required in dust collectors to reduce the emission of dioxin in flue gas. Yet even with compliant pollutant discharge, integrated mills still face multiple shutdowns and production restriction policies, especially for heavily polluting processes such as sintering and BF operations. Even some BFs launched after 2000 have been included in the government's capacity reduction targets.

2 China's State Council released "'3-year action plan' for its Blue Sky protection battle" 2018/07, http://www.gov.cn/zhengce/content/2018-07/03/content_5303158.htm

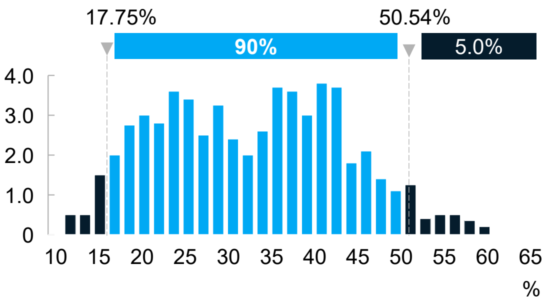
— **EAF mini-mills have the edge in capex and opex given restrictions on crude steel capacity**

McKinsey's investment return models show that new EAF projects have a competitive advantage in the current context of long-term, government-led BF production restrictions and shutdowns. As input, these models use the parameters of an integrated/mini-mill substitution program, combined with analysis of the biggest key factors, to project internal rate of return (IRR) and NPV. In 2017 and 2018, an EAF mini-mill with a liquid steel output of around 2 mtpy required an investment of less than RMB 2 billion, and at most 1.5 years to finalize construction. As shown in Figure 2.7, when the price of steel is around RMB 4,000/ton and raw material costs are around RMB 2000/ton, the project has a 90 percent likelihood of achieving an IRR of 24 to 38 percent with an NPV at RMB 2 billion to 2.3 billion.

Figure 2.7

Investment analysis for a new EAF project

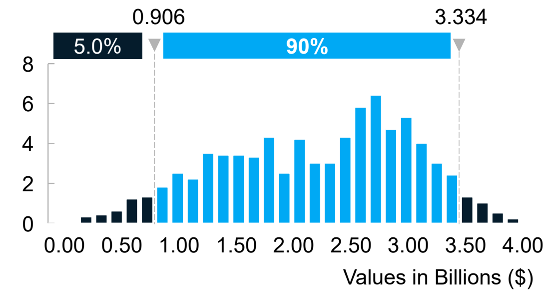
IRR



IRR	
Min	12.347%
Max	60.010%
Mean	33.427%
Std Dev	10.290%
Values	1000

NPV, Values in Billions ($)

Values X 10^-10



NPV	
Min	$278,517,219.27
Max	$3.881E+009
Mean	$2.224E+009
Std Dev	$763,882,143.38
Values	1000

Key input/hypothesis

Total investment: RMB 1.8 bn

Loan: RMB 400 m, interest rate 4.9%, 5 years

Duration: 18 months

Annual capacity: 2 m tons of liquid steel

Main products: bars

Assumption: price of other indicators will remain the same in the future

Steel price: RMB 4,200/ton

Scrap intensity: 60% scrap, 40% hot metal

Hot metal cost: RMB 2,120/ton

Average scrap price: RMB 1,900 /ton

Steel raw material costs (hot metal + scrap): RMB 2,093/ton

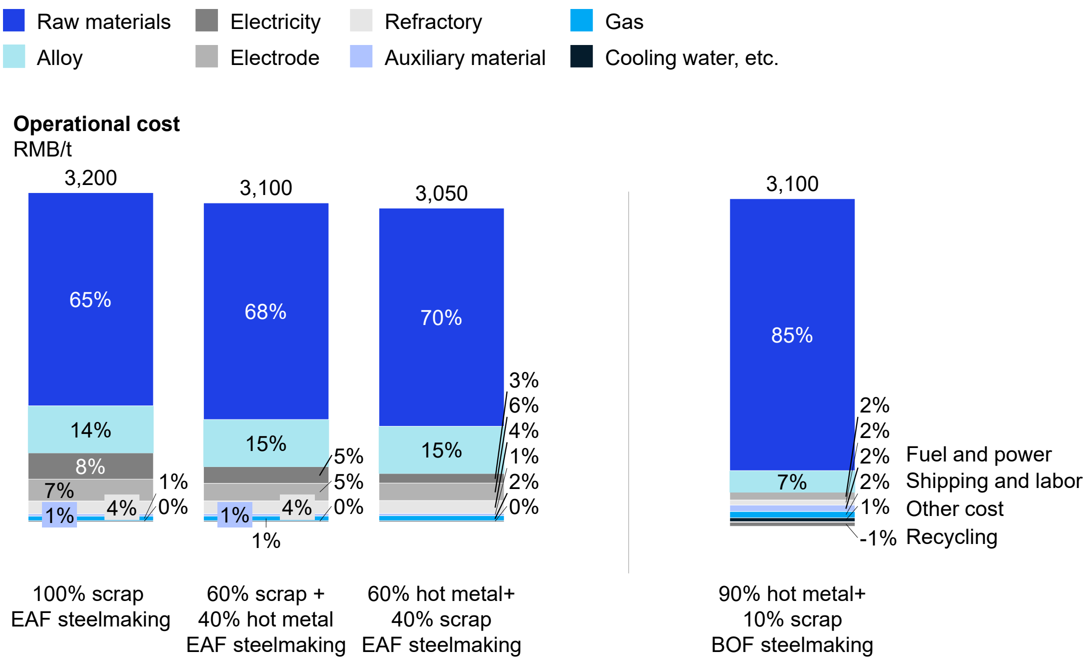
Electrode price: RMB140,000/ton

Total steelmaking opex: RMB 3,300 /ton

SOURCE: McKinsey China team analysis

Figure 2.8

Operational costs, integrated mill vs. mini-mill (2018 1st half)



SOURCE: McKinsey China team analysis

Figure 2.8 shows that, excluding additional costs from environmental protection and restrictions on production, an EAF mini-mill with a mix of liquid iron and scrap as raw materials achieves lowest cost. An EAF mini-mill with 100 percent scrap as raw material incurs a liquid steel cost that is RMB 100 to 200/ton higher than for other combinations of raw materials, as well as for integrated mills. The key variable affecting the operational costs for EAF mills is the cost of raw materials. As the comparison shows, EAF mini-mills are currently comparable with integrated mills on opex, but EAF may gain the advantage when China's scrap supply exceeds demand in future.

Factoring in extra costs incurred from environmental protection and restrictions on production, the cost advantage of EAF mini-mills gradually widens. At present, under government regulations for integrated mills, extra costs are incurred for dedusting, desulfurization, and denitration processes to meet major air pollutant emission standards. For EAF mini-mills, regulations require investment in electric precipitation to reduce the emission of dioxin. Taken together, the environment-oriented investment and operational costs of EAF mini-mills are only around 10 percent of outlays for integrated mills. These pronounced advantages are bound to speed up EAF capacity expansion.

— **EAF mini-mills have unique advantages in inland locations**

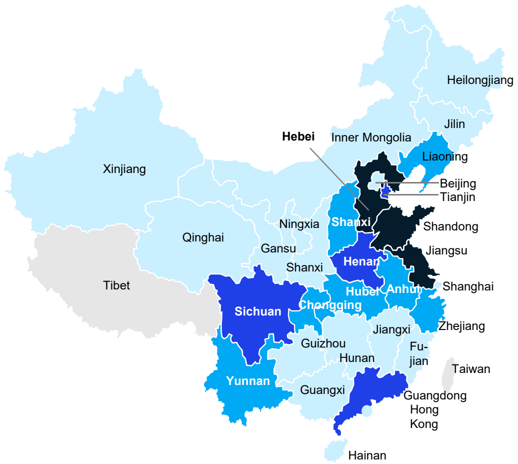
As the state has continued to roll out policies in the downstream scrap-recycling sector, the scrap sector has slowly entered a cycle of healthy growth. In the scrap-processing industry, the MIIT has released six batches of approved enterprises. At present, there are 180 scrap-processing and distribution enterprises across the country, with an annual distribution capacity of about 100 mtpy, and more than 500 scrap-shredding production lines (Figure 2.9). These scrap operations are mainly concentrated near the coast, as well as inland areas such as Sichuan, Henan, Yunnan, Chongqing, and Hubei. In parallel, state and local policies, including restrictions on the capacity of inland integrated mills, are driving major integrated mills to relocate to coastal areas.

Inland EAF mills can make full use of these widely distributed scrap-shredding production lines by virtue of their small-scale capacity and widespread dispersion, which allow them to absorb local post-consumer steel scrap, and distribute the finished-steel products nearby. Moreover, scrap prices in inland areas are generally lower than prices at the coast (Figure 2.9). As the availability of scrap increases, inland EAF enterprises will increasingly have the advantage over integrated mills due to lower raw material and transportation costs.

Figure 2.9

Quantity of China's scrap shredding production lines by location (2018)

n/a | <10 | 10-30 | 30-50 | >50

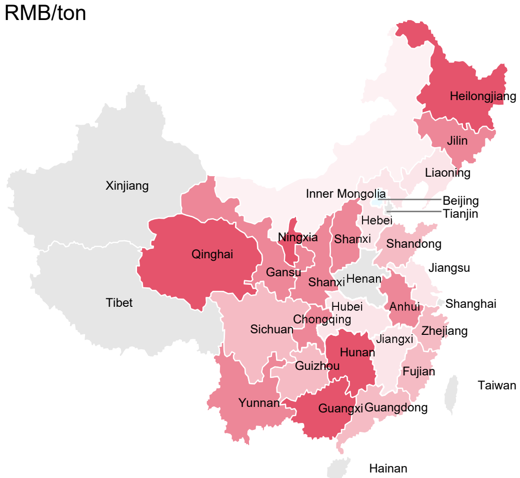


SOURCE: Mysteel; McKinsey analysis

Scrap[1] price distribution map across the country, RMB/ton

n/a | High 2,900-3,000 | Low 2,100-2,200

2018/10, national average price of scrap1 was 2,375 RMB/ton



1 Scrap prices are for heavy melt scrap (HMS) specifications >=6 mm

SOURCE: Mysteel; McKinsey analysis

How to adapt and seize opportunities as the EAF era evolves

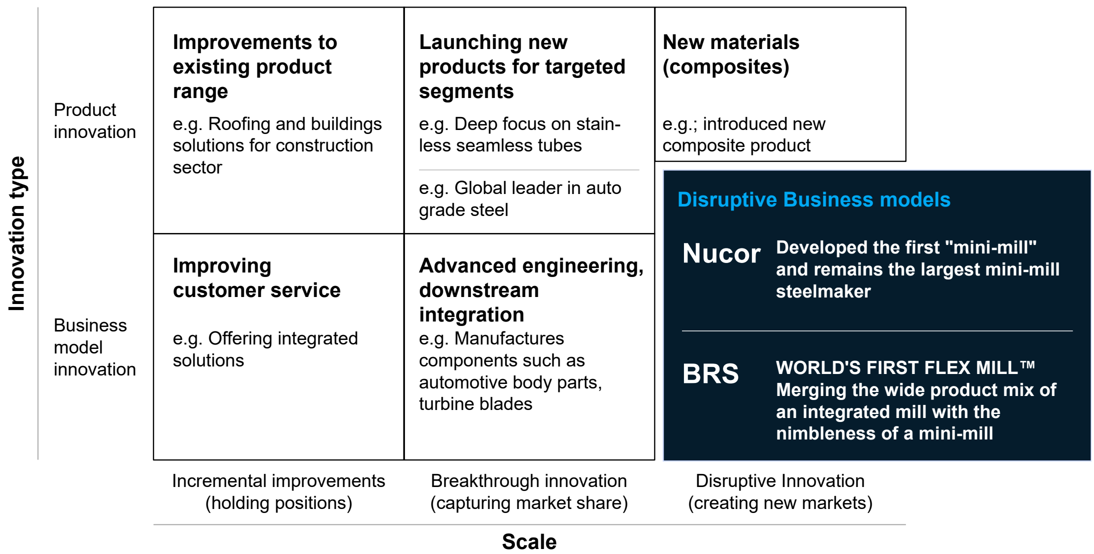
What is the best approach for steelmakers to capture the benefits from China's EAF transition? Three areas deserve executives' attention

Innovate EAF mini-mill business models

The majority of new EAF capacity in China comes from swaps with integrated mills. The EAF plants' business models are thus influenced by the original integrated mills, making it difficult to achieve major breakthroughs. McKinsey has studied various innovation models in the global steel sector (Figure 3.1), focusing on the innovative EAF mini-mills of Nucor and BRS. The essence of these models – which benefit both "swap" and new plants – is to ensure the same product quality as integrated mills while integrating continuous energy-saving processes and a compact layout. The scrap-fed EAF mini-mill process not only entails much lower investment costs, lower organizational staffing, and lower operating costs, but can also produce the quality of liquid steel required for the continuous casting and rolling processes associated with making high-grade steel products. Likewise, new (non-swap) Chinese EAF companies should establish their mini-mill business model with flexible scale, compact layout, and low investment and operating costs, while pursuing rational planning of new projects based on region-specific scrap resources and downstream markets.

Figure 3.1

Innovative products and business model of current steel makers



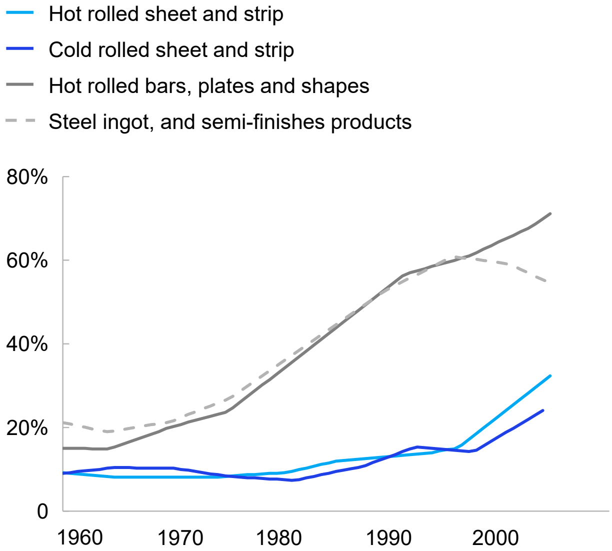
SOURCE: McKinsey analysis

Produce more high-value products

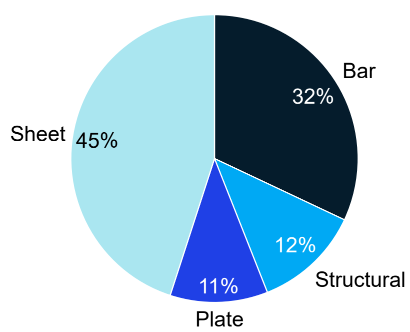
The EAF products category overseas is highly competitive not only in long products and special steel, but also in high-grade sheet and strip products, especially in the late industrialization and post-industrialization periods (Figure 3.2). In the US, the market shares of EAF steel products underwent tremendous changes from the 1970s to the 2000s, with hot-rolled and cold-rolled flat products increasing from 10 percent initially to 30 to 40 percent today. The top EAF enterprises produce a high ratio of flat products. Nucor, for example, is a 100-percent EAF steelmaker, with flat-steel capacity accounting for more than half its total EAF product category. The new BRS Steel (launched in 2016), with an annual capacity of 1.6 mtpy, built the first Flex Mill TM (EAF and RH) to produce mainly niche flat products.

Figure 3.2

EAF steel: market share trends in the US



EAF capacity structure at Nucor, world's largest EAF company



SOURCE: Allan Collard-Wexler and Jan De Loecker, Evidence from the U.S. Steel Industry; Press search

At present, China's EAF steel output is made up of the following product shares: long products such as rebar and wire rod account for 60 percent of total output, special steel/stainless steel products account for 30 percent, and flat products account for only 10 percent. However, from 2018 onwards, a growing number of Chinese EAF mills have applied the thin sheet/strip continuous casting/rolling process, which is leading an EAF product transition from mainly long products to high-value-added flat steel. For instance, ShaSteel was the first company in China to install Nucor's cutting-edge technology CASTRIP (Ultra-thin Cast Strip) in its EAF plant. Similarly, Guilin PingSteel and Dingsheng Steel are planning to install and conduct the most advanced mini-mill projects with quantum EAF and ESP (endless continuous casting/rolling). This will accelerate their product upgrades mainly for end uses in electronics, appliances, and the automotive industry. These EAF enterprises are potentially creating milestone demonstrations for the structural innovation and transformation of Chinese EAF mills. Meanwhile, China is aggressively promoting the domestic scrap industry at scrap-processing sites and large-scale distribution centers near large-scale steel enterprises nationwide. These efforts are expected to steadily improve the quantity and quality of scrap, thereby supporting EAF mini-mills' production of high-quality products.

Emphasize early project planning to achieve long-term success

It is foreseeable that new EAF capacity will continue to be installed in China. To optimize investment capex (and subsequent opex), it is important for decision-makers to consider that, according to analysis by McKinsey, they can achieve higher value creation through initial work – that is, through project design and tender/procurement optimization, as opposed to day-to-day operational management after the EAF plant is up and running (see Figure 2.7). Here are three steps to ensure your early project planning process remains on track:

— **Stress test the project program**

  In the feasibility study and basic design stages, companies can significantly reduce project risk and increase value by conducting thorough reviews and rigorous stress testing of key assumptions, such as the market value of the investment portfolio. In the equipment selection stage, applying the simplified technical solution principle (which states that the best way to satisfy a functional requirement is to use the simplest solution) can reduce overengineering and corresponding investment expenditure.

— **Optimize tender and procuremen**

  The main points of procurement optimization include formulating contract strategies at the initial stage of the project, determining a reasonable number of qualified suppliers, promoting localization, splitting and comparing the equipment and should-cost analyses, and conducting detailed negotiation strategy preparation.

— **Establish a scrap-to-finished-product management process**

  As the vital raw material for EAF mini-mills, the stability and economy of scrap supply has a direct impact on steelmaking profitability. We advise establishing a management control system for the whole scrap-to-finished-product process. Companies can start with initial levers – scrap reclamation, procurement planning, and controlling scrap standards and quality – while exploring the best intensity ratio for scrap steel input. Steel enterprises can consequently save at least RMB 20 to 40/ton of steel on scrap's value-in-use (VIU).

• • •

The development of scrap recycling and EAF mini-mills is pushing the Chinese steel industry into a new era. Backed by favorable government policies and EAF's inherent advantages, China's steel industry is rapidly transitioning as the final stages of industrialization unwind. Amid the onset of more vigorous environmental protection measures, vertically integrated steel players face new challenges such as restricted production, idle production, and increasing opex. Leveraging China's growing scrap supply to feed EAF plants retrofitted at integrated mills as well as new greenfield EAF mini-mills is a cost-effective and credible solution to these evolving industrial challenges.

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Avetik Chalabyan
Senior Partner
Moscow RUR
Avetik_Chalabyan@mckinsey.com

Yuanpeng Li
Partner
Shanghai
Yuanpeng_Li@mckinsey.com

Steven Vercammen
Senior Knowledge Expert
Brussels Innovation Center
Steven_Vercammen@mckinsey.com

Jane Zhou
Senior Research Analyst
Brussels Innovation Center
Jane_Zhou@mckinsey.com

Richard Tang
Expert
Shanghai
Richard_Tang@mckinsey.com

Vivi Zhao
Associate
Beijing
Vivi_Zhao@mckinsey.com

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