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New From Old: The Global Potential for More Scrap Steel Recycling

Mature, Cost-competitive and Lower-emissions Technology Is Primed for Expansion

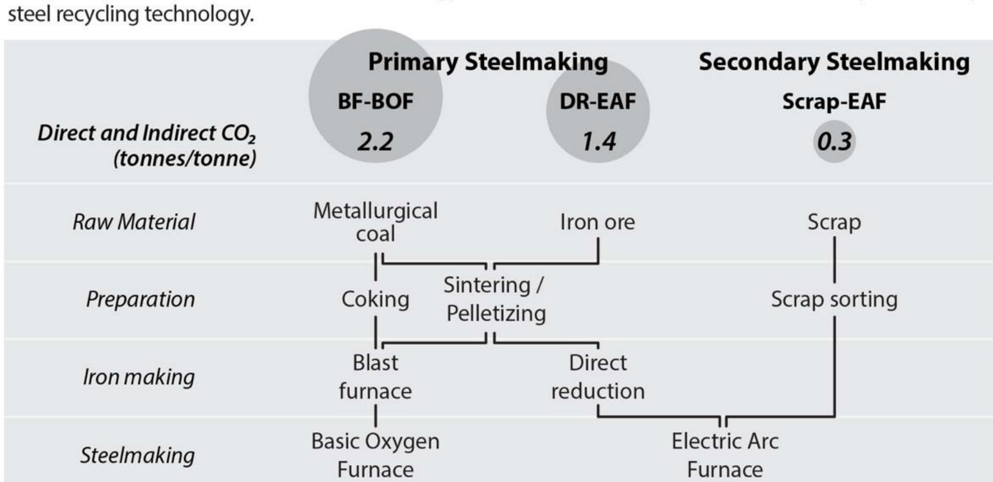
Executive Summary

Investors are increasingly pressuring global steel companies to set out credible decarbonisation plans. These demands are only going to intensify.

Recently, there has been much focus on the potential use of green hydrogen to produce direct reduced iron (DRI) to decarbonise steel production, which is currently highly reliant on energy- and carbon-intensive blast furnace and basic oxygen furnace technology (BF-BOF). However, cost-competitive green hydrogen to use at scale is years away.

Methods and Stages of Steel Production

Accounting for about 7% of global CO_2 emission, the steel sector is under increasing investor pressure to decarbonise. Dominant blast furnace technology is far more carbon intensive than cost-competitive scrap steel recycling technology.



Sources: IEA, Worldsteel IEEFA

Meanwhile, the use of scrap steel in electric arc furnaces (EAF) is already a widely practised, lower-emission steel production method. It is not on its own a solution to fully decarbonise the steel sector but it is poised to help the global steel sector reduce emissions for the rest of the 2020s and in following decades.

Scrap Steel Recycling: A Mature, Cost-Competitive and Widely-Used Technology

Steel is the most recycled material in the world. Scrap-EAF steelmaking is already cost-competitive with BF-BOF processes and is used in many countries, although rates of steel manufacture via EAF differ widely across the globe.

Steel production by the scrap-EAF route is by far the largest source of new steel in the U.S., assisted by the high availability of scrap in such a large and mature economy. In 2020, 71% of total crude steel production in the U.S. was via EAFs. In the EU, the figure was 42%. This strongly hints at the potential for more scrap use in economies such as China, Japan and South Korea where steel recycling rates are much lower.

Secondary steelmaking via scrap could be expanded in many nations.

Secondary steelmaking via scrap could be expanded in many nations, helping to decarbonize the steel sector as scrap-EAF's emissions are lower than the primary BF-BOF steel-making route that fundamentally relies on iron ore as the main metallic input as well as coal.

The energy consumption of BF-BOF processes is almost 10 times that of scrap-EAF. In addition, the direct CO_2 emission of a BF-BOF process using iron ore and coal is 30 times higher than a scrap-based process. A scrap-EAF process powered by electricity from renewable energy reduces carbon emissions to almost zero. Thanks to the declining cost of renewable energy, scrap-EAF is also cost-competitive when powered 100% by renewables.

Under the International Energy Agency's (IEA) Net Zero Emissions by 2050 (NZE) scenario – an emissions target that more and more steel manufacturers have pledged to reach – a "radical technological transformation" in the steel sector will be underpinned by a shift from coal to electricity. In this scenario, coal's share of energy use drops from 75% in 2020 to 22% in 2050 (assuming carbon capture use and storage is available), and by 2030 technologies that are already on the market – including scrap-EAF – deliver 85% of emissions savings in the steel sector. Scrap steel reaches 46% share of input in steel manufacturing globally by 2050 in this scenario.

China is by far the world's largest steel producer – whatever impacts the Chinese steel sector impacts the industry globally. In 2020, China produced 57% of the world's crude steel with 91% manufactured via the BF-BOF process. Just 9% was produced via EAFs, significantly lower than the global average of 26%.

Under the IEA's Announced Pledges Scenario (APS) – which reflects China's targets to reach net zero emissions in 2060 and peak carbon emissions before 2030 – output from scrap-based EAFs nearly doubles by 2030 and more than triples by

2060. Scrap-based EAFs account for more than half of Chinese steel production by 2060, while the country's crude steel production peaks in the mid-2020s and by 2060 drops 40% on 2020 levels in this scenario.

China's shift towards scrap-EAF use will benefit from a large increase in the availability of scrap steel as the economy matures.

There is debate over the potential for using scrap steel in producing some of the highest-quality grades, due to impurities such as copper in scrap steel, but these grades compromise a small portion of overall steel mill production. In 2020, the share of the automotive section – the most quality-sensitive category – was only 12% of total global steel consumption. The bulk of global steel production is for building and infrastructure products where impurities are less of an issue and these can be manufactured via scrap-EAF processes

Whatever impacts the Chinese steel sector impacts the industry globally.

The quality of steel made from recycled scrap is on the rise even as carbon emissions from the process are poised to drop further. Nucor Corporation, the largest steelmaker in the U.S., is also its largest recycler of scrap steel. The company is developing 3rd Generation Advanced High-Strength Steel (AHSS) for the automobile sector. Until recently, AHSS products could be made only via the BF-BOF route.

In October 2021, Nucor launched its Econiq net-zero steel brand, pairing scrap-EAF with renewable energy to produce high grade steel for the automotive sector. GM is to be the first customer for the Econiq brand, beginning in Q1 2022, with an expectation that all GM steel purchased from Nucor will be carbon neutral by the end of 2022.

Implications for Coking Coal and Iron Ore

As steelmaking through scrap-EAF processes does not use iron ore or coking coal, there are clear, long-term implications for exporters of these resources. Australia is by far the largest exporter of both.

Even without increasing international pressure to reduce carbon emissions, iron ore demand in China – the world's largest importer – will drop significantly in the coming years. As the Chinese economy continues to mature, steel production is expected to peak in the mid-2020s (if it hasn't done so already) and more steel recycling is guaranteed as more scrap becomes available. With China now targeting peak emissions by 2030, momentum is likely to grow for greater use of scrap-EAF to lower emissions. China's scrap steel consumption surged 47% to 138Mt in the first half of 2021.

There is even further incentive for China to increase scrap steel use. China has banned Australian coal imports and, for reasons both diplomatic and strategic, the country clearly also wishes to shift away from reliance on Australian iron ore imports. There are already ambitious plans for China to exploit iron ore resources in Guinea and increase domestic production to move away from reliance on Australian volumes and put downward pressure on prices. A push for more steel scrap recycling would help China's resource security aims.

There will be a global impact on iron ore and coking coal exporters, none more than Australia.

The ban on Australian coal imports means China is facing difficulties in sourcing sufficient coking coal from alternative markets such as the U.S., Canada, Russia and Mongolia. Increasing the rate of scrap-EAF steel production would allow China to lessen reliance on coking coal imports.

As China moves away from primary steelmaking towards more scrap-EAF processes while manufacturing volumes peak, there will be a global impact on iron ore and coking coal exporters, none more than Australia.

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Introduction

The steel industry faces a major challenge in contributing to the Paris Agreement objective of limiting global warming to well below 2.0°C, preferably 1.5°C, above pre-industrial levels. It is evaluated that the steel sector directly emits 7% of the global CO_2 pollution.[1] Investors are increasingly pressuring global steel companies to set out credible decarbonisation plans[2] and these demands are only going to increase.

Recently, there has been much focus on the potential use of green hydrogen to produce direct reduced iron (DRI) to decarbonise steel production, which is currently highly reliant on energy- and carbon-intensive blast furnace and basic oxygen furnace (BF-BOF) technology. However, cost-competitive green hydrogen to use at scale is years away[3] and a large percentage of global steelmaking capacity will reach the end of its operating campaign before 2030.

In China, 78% of current blast furnace capacity will require relining before 2030.[4] Other countries also have high levels of blast furnace capacity needing relining investment before 2030: U.S. 97%, EU 70%, Japan 76% and South Korea 72%. If these countries go with blast furnace relining for these capacities, that is, business-as-usual instead of investing in lower-carbon alternatives, assets are at risk of becoming stranded if governments increase efforts to meet net-zero emissions targets.

No company has announced a new industrial-scale carbon capture and storage (CCS) installation that could make coal-based steelmaking low-emissions.[5] A commercialised carbon capture system at a steel plant in Abu Dhabi is in fact using the captured carbon dioxide for enhanced oil recovery (EOR) i.e., further fossil fuel extraction. In addition, actual rates of carbon capture have never been released for this project.

The use of scrap steel in electric arc furnaces (EAF) is already widely practised.

Meanwhile, the use of scrap steel in electric arc furnaces (EAF) is already widely practised, is cost competitive now, produces lower emissions and – although it is not on its own a full solution to decarbonising the steel sector – is poised to help the global steel sector decarbonise throughout the rest of the 2020s and in following decades.

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[1] IEA. Iron and Steel Technology Roadmap. 2020.
[2] IIGCC. Global Sector Strategies: Investor interventions to accelerate net zero steel. 4 August 2021.
[3] S&P Platts. Renewable hydrogen 'cheaper than conventional hydrogen' by 2030: Australia CEFC executive. 27 October 2021.
[4] Agora Industry. Global Steel at a Crossroads. November 2021.
[5] Agora Industry. Global Steel at a Crossroads. November 2021.

Overview of Steel-Making Technology

Steel production currently involves three main processes. The most widespread is the integrated blast furnace and basic oxygen furnace process (BF-BOF) in which iron oxide is reduced to iron inside the blast furnace with coke (derived from coking coal) as a reducing agent. The product of the blast furnace is called pig iron, which in the next step is processed into steel in a basic oxygen furnace where oxygen is blown through the molten, carbon-rich pig iron to reduce its carbon content. In 2020, 73% of global crude steel production, totalling 1.88 billion tonnes, was made via the BF-BOF process.[6]

A second primary steelmaking pathway is to produce direct reduced iron (DRI), which is then further processed into steel in an electric arc furnace (EAF). DRI is produced by direct reduction of iron ore without melting, usually using a mixture of carbon monoxide and hydrogen derived from natural gas, although these can also be derived from gasified coal. Increasingly, steel companies are seeking to develop DRI-EAF technology that uses 100% hydrogen – potentially zero-carbon green hydrogen, produced via renewable energy-powered electrolysis once this technology becomes cost-competitive.

As an alternative to primary steel manufacture, scrap steel can be used in EAFs to recycle and produce new steel. The scrap-EAF (also called secondary steelmaking) technology does not involve iron ore or coking coal. An electric arc furnace is charged with steel scrap where it is heated and melted to form new steel. EAFs are powered by electricity which can be sourced from renewable energy, reducing carbon emissions for the process to almost zero.

The scrap-EAF (also called secondary steelmaking) technology does not involve iron ore or coking coal.

In 2020, steel produced from EAFs amounted to 26% of total global crude steel production, some of it via the DRI-EAF route in countries like India and Iran, but the bulk of it from the secondary scrap-EAF process.

Scrap Steel Recycling: A Mature, Widely-Used Technology

Steel is the most recycled material in the world. Its inherent magnetism makes it easy to recycle, which can be done without loss in quality.

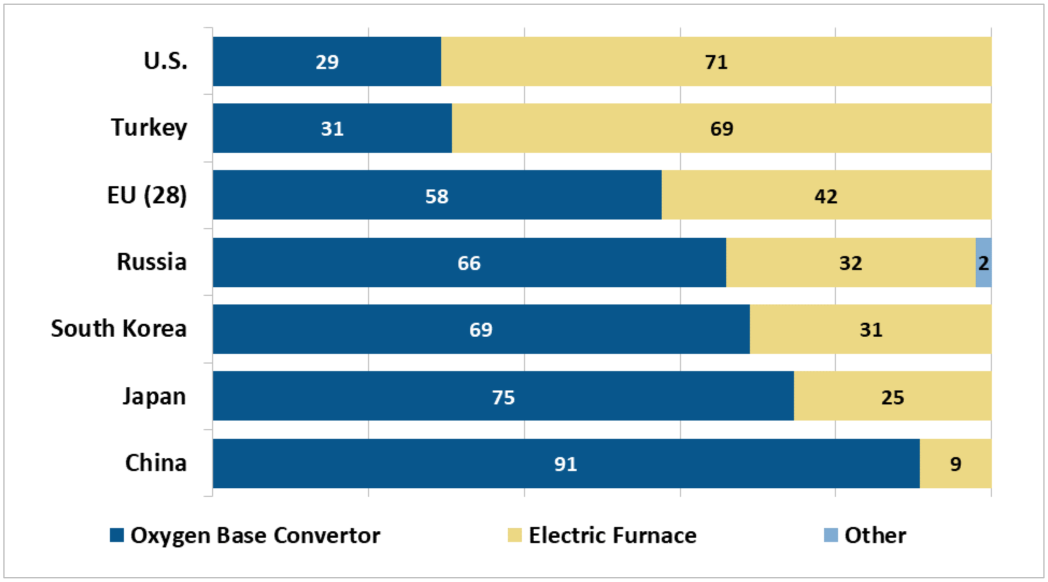
Scrap-EAF steelmaking is cost-competitive with BF-BOF processes and is already used in many countries, although rates of steel manufacture via EAF differ widely

[6] World Steel Association. World Steel in Figures. 2021.

across the globe.

Steel production from the scrap-EAF route is by far the largest source of new steel in the U.S., assisted by ample availability of scrap in such a large and mature economy (Figure 1). In 2020, 71% of crude steel production in the U.S. was via EAFs.[7]

Figure 1: Rates of Steel Recycling in Asia Are Much Lower Than in the U.S., Europe (Percentage of Steel Output by Process, 2020)



Source: World Steel Association – World Steel in Figures 2021.

In 2020, 42% of steel manufactured in the EU was via EAFs.[8] The EU has more than 114 EAF plants with 80 million tonnes total production capacity. Many countries in the EU are producing steel 100% based on scrap-EAF processes and there is also a high level of renewable electricity available to facilitate steel decarbonisation. More than 60% of this EAF capacity is in Italy, Spain and Germany.[9]

Rates of scrap-EAF steel production in the EU and U.S. strongly hint at the potential for more scrap use in economies such as China, Japan and South Korea, where steel recycling rates are much lower. In addition, much of the feedstock input into existing Chinese EAFs is carbon-intensive pig iron produced in blast furnaces, rather than scrap steel.[10]

Secondary steelmaking via scrap could be expanded in many nations, helping to decarbonize the steel sector – scrap-EAF has lower emissions compared to the primary BF-BOF steelmaking, which fundamentally relies on iron ore as the main metallic input and coal. Every tonne of scrap used for steel production could avoid

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[7] World Steel Association. World Steel in Figures. 2021.
[8] World Steel Association. World Steel in Figures. 2021.
[9] EUROFER. European steel in Figures. 2021.
[10] Global Efficiency Intelligence. Cleanest and Dirtiest Countries for Secondary (EAF) Steel Production. 28 September 2020.

emissions of 1.5 tonnes of CO_2 and the consumption of 1.4 tonnes of iron ore, 740kg of coal and 120kg of limestone.[11]

In addition to the scrap-EAF route, integrated BF-BOF steelmaking can use up to 30% scrap added to the molten steel in the BOF.

Under the IEA's Net Zero Emissions by 2050 (NZE) scenario – an emissions target that an increasing number of steel manufacturers have pledged to reach – a "radical technological transformation" takes place in the steel sector underpinned by a shift from coal to electricity.[12] In this scenario, coal's share of energy use drops from 75% in 2020 to 22% in 2050 (assuming carbon capture use and storage is available) and by 2030 technologies that are already on the market – including scrap-EAF – deliver 85% of emissions savings in the steel sector. Scrap steel reaches 46% share of input in steel manufacturing globally by 2050 in this scenario.

Table 1: Types of Scrap Steel

Stage	Definition	Point of Generation	Recycling Time	Source of Generation	Estimated Share %
Pre-consumer	Home scrap	Steelmaking process (crude steel production)	Couple of days	Imperfect products, trimmings of downstream lines	20
	Prompt scrap (new Scrap)	Manufacturing of steel products	Less than a year	Trimmings	30
Post-consumer	End-of-life scrap (obsolete scrap)	Back to the cycle from steel-containing products	More than a year	Construction steels, rails, pipelines, cars, food packaging etc.	50

Source: World Steel Association, IEEFA.

Table 1 presents different types of scrap and their related features. The pre-consumer scrap could be added to the steel production cycle in less than a year but there is a lag for recycling the obsolete scrap. The key point for transition into using more scrap is the availability of the end-of-life scrap on one side and the rate of recycling on the other side. Steel average life expectancy for different products is estimated to be 40 years.[13]

Steel Recycling is Already Cost-Competitive

Unlike potential future low-carbon steelmaking methods such as DRI-EAF using 100% green hydrogen, scrap-EAF is already cost-competitive with the dominant, energy- and carbon-intensive BF-BOF (Figure 2).

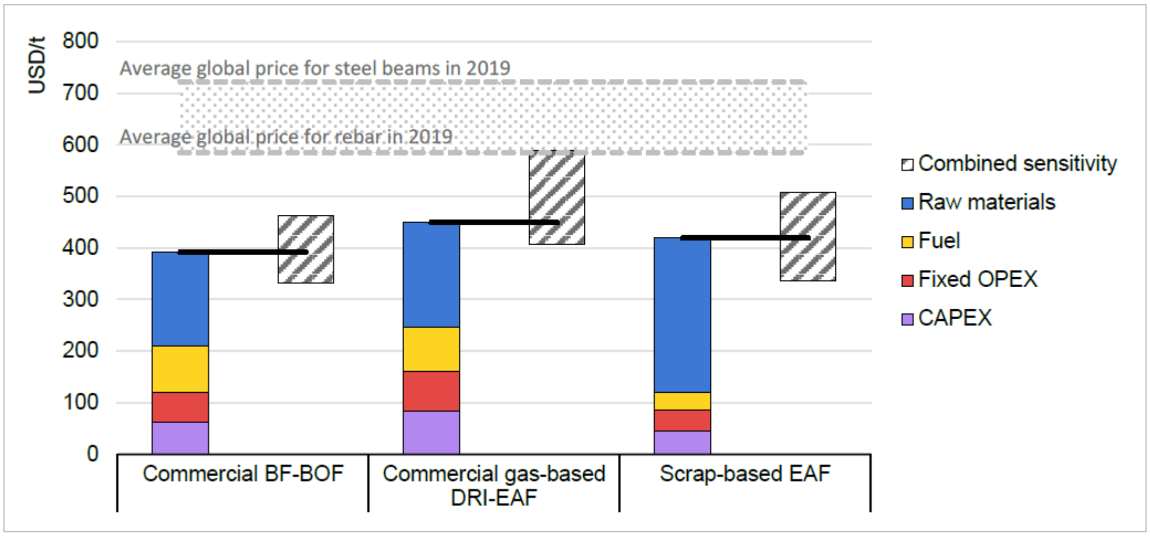
The cost of production via the scrap-EAF pathway is highly dependent on the price

[11] World Steel Association. Scrap use in the steel industry. May 2021.
[12] IEA. Net Zero by 2050: A Roadmap for the Global Energy Sector. May 2021.
[13] World Steel Association. Scrap use in the steel industry. 2021.

of scrap steel and, to a lesser extent, electricity cost.

The initial CAPEX of EAF is also lower than the integrated BF-BOF mills, as there is no need to erect ironmaking facilities like a coke oven, sintering, blast furnace, etc.

Figure 2: Average Cost of Steel Production Routes ($/T)



Source: IEA.
Note: Considering that estimation of the cost of steel production is highly dependent on the raw material, energy and other operational costs, which vary in different economies, scrap-based steelmaking is highly competitive on cost.

Thanks to the declining cost of renewable energy, scrap-EAF is also cost-competitive when powered 100% by renewable energy. According to BloombergNEF, the levelized cost of the scrap-EAF steelmaking per ton of crude steel in 2021based on renewable energy is $572 in the U.S., $551 in Germany and $642 in China. By 2050, further reductions in clean energy costs push this even lower.[14] (Table 2).

Zero-emissions steel production based on scrap and renewable energy is currently cheaper than other zero-emissions steel options, such as steel electrolysis and green hydrogen-based solutions, which currently are the centre of much attention. BloombergNEF calculates that the levelized cost of a ton of steel made from DRI-EAF processes using green hydrogen is currently $815 in the U.S., $658 in China and $889 in Germany, although the cost is expected to drop significantly in future.

The levelized cost of steel from new-build BF-BOF varies significantly according to the price of iron ore and coking coal. For example, where iron ore ranges between US$100/t and US$200/t, the levelized cost of BF-BOF steel ranges between about US$500/t and US$700/t in China, according to BloombergNEF.

[14] Bloomberg New Energy Finance. Decarbonising Steel. 25 August 2021.

Table 2: Levelized Cost of Scrap-Based Steel in China, U.S. and Germany Powered by Renewable Energy ($/T)

	2021	2050	2021	2050	2021	2050	2021	2050
Country	Renewable Electricity $/MWh		Scrap $/T		EAF Electrode $/T		Levelized Cost of Steel $/T	
U.S.	46.2	Low 28.7 High 42.7	343		3,594		572	568
Germany	71.3	Low 40.6 High 63.3	324		4,495		551	538
China	53.6	Low 26.0 High 45.2	427		4,500		642	620

Source: Bloomberg New Energy Finance, Decarbonizing Steel, 2021.
Note: Net zero steel calculation relies on renewable electricity as the source of energy.

Scrap-based Steel Energy and Carbon Intensity

In 2020, according to the World Steel Association figures, 21.5% of the crude steel was produced from secondary sources (i.e., from scrap steel) and the rest was produced from primary sources (73.2% was associated with BF-BOF production, 4.8% to DRI-EAF[15] and 0.5% other technologies). Table 3 shows different routes for steelmaking and associated CO_2 emissions and energy consumption.

Table 3: Carbon Emission and Energy Consumption of Different Steelmaking Routes

Sources	Technology Route	Direct CO_2(t)/Crude Steel (t)	Direct and Indirect* CO_2 /Ton of Crude Steel	Energy Consumption (GJ/t)		Share of Global Steel Production (%)
				IEA	Worldsteel**	
Secondary	Scrap-EAF	0.04	0.3	2.1	5.2	21.5
Primary	BF-BOF	1.2	2.2	21.4	22.7	73.2
	DRI-EAF	1.0	1.4	17.1	21.8	4.8

Source: IEA, World Steel Association, IEEFA calculation.
**Indirect GHG emissions from the generation of purchased energy consumed by a company.*
***The IEA states all energy intensities in final energy terms, whereas Worldsteel accounts for electricity consumption in primary energy terms, using a conversion factor of 9.8 GJ of fuel per MWh of electricity (equivalent to a 37% conversion efficiency). This means that processes that consume electricity will appear more energy intensive when quoted using the Worldsteel analytical boundary, relative to that used by the IEA.*

The energy consumption of BF-BOF processes is almost 10 times more than scrap-EAF. In addition, the direct CO_2 emission of a BF-BOF process using iron ore and

[15] 106Mt of direct reduced iron (DRI) was reported for 2020, approximately equal to 91Mt of crude steel.

coal is 30 times higher than for a scrap-based process.

Taking into account indirect emissions – which includes emissions from electricity generation used to power the EAF – the BF-BOF process is still more than seven times as emissions-intensive as the scrap-EAF process.

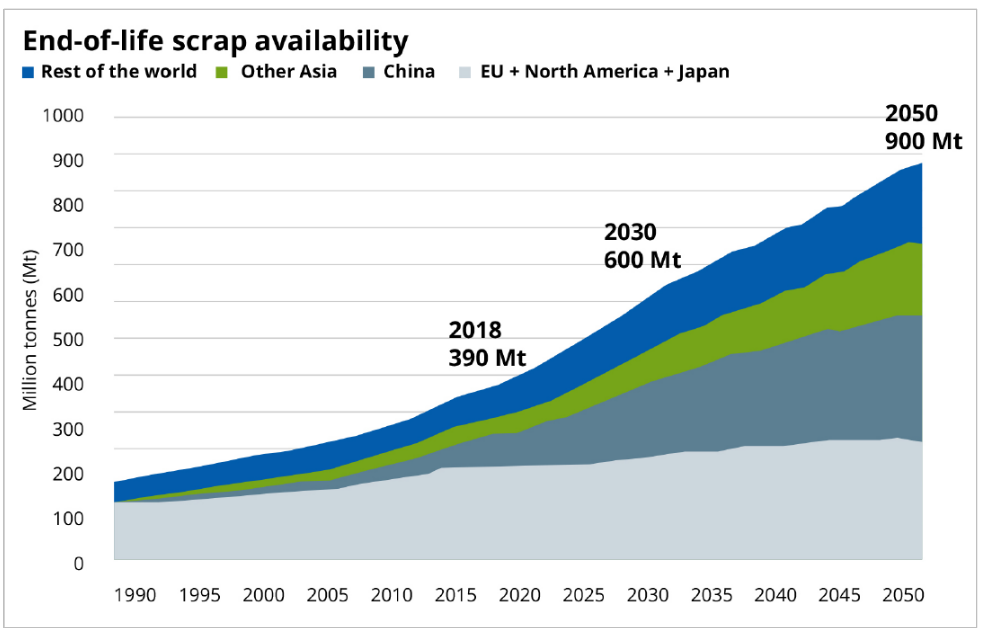
Scrap Availability

The amount of steel scrap is finite and is related to the rate of recyclability in different economies. In the current situation, the return rate of obsolete scrap is 85% and it will increase to near 100% in the next 30 years.[16]

In 2019 it is estimated that approximately 865Mt of scrap was available for use globally, comprised of about 20% home scrap (165Mt), 30% prompt scrap (255Mt) and 50% end-of-life scrap (445Mt). Of this, about 8% (70Mt) was used in foundries via a combination of internal recirculation and additional end-of-life scrap. This left just under 800Mt of scrap available for steel production.[17]

The World Steel Association estimates that global end-of-life scrap availability will reach about 600Mt in 2030 and 900Mt in 2050, a growth of more than 500Mt in one of the main steelmaking raw materials in the next 30 years (Figure 3).[18]

Figure 3: End-of-Life Scrap Availability (1990-2050)



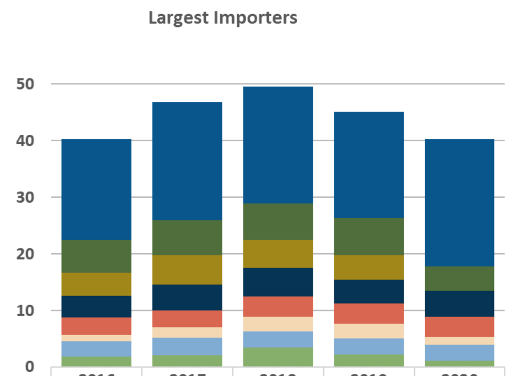
Source: World Steel Association.

[16] Bloomberg New Energy Finance, Decarbonizing Steel, 2021.
[17] IEA. Iron and Steel Technology Roadmap. 2020.
[18] World Steel Association. Scrap use in the steel industry. 2021.

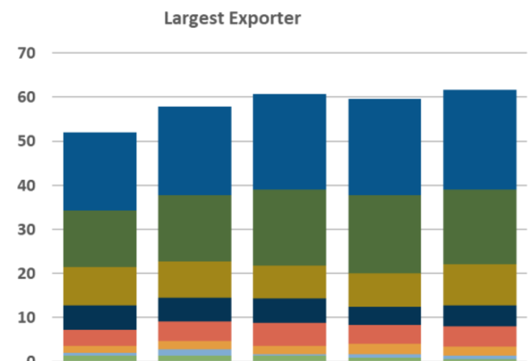
Scrap Market

Unlike iron ore and coking coal, which are traded globally, scrap steel recycling largely feeds domestic steel industries. However, some countries trade this valuable source of iron internationally. Figure 4 illustrates the global top exporters and importers of scrap steel.

Figure 4: Largest Exporters and Importers of Scrap (2016-2020) Mt



	2016	2017	2018	2019	2020
Turkey	17.72	20.98	20.66	18.86	22.44
Korea Republic	5.85	6.18	6.39	6.50	4.40
Pakistan	4.03	5.12	5.01	4.34	0
USA	3.86	4.64	5.03	4.27	4.51
Taiwan	3.16	2.92	3.63	3.52	3.61
Indonesia	1.02	1.86	2.51	2.61	1.42
EU-28	2.75	3.07	2.83	2.89	2.86
Canada	1.84	2.12	3.47	2.13	1.03



	2016	2017	2018	2019	2020
EU-28	17.77	20.09	21.66	21.79	22.68
USA	12.82	15.02	17.33	17.69	16.87
Japan	8.70	8.21	7.40	7.66	9.40
Russia	5.52	5.32	5.59	4.06	4.73
Canada	3.63	4.41	5.11	4.37	4.51
Australia	1.58	1.98	1.97	2.33	2.10
Brazil	0.61	1.38	0.36	0.69	0.73
HongKong	1.35	1.38	1.30	0.96	0.61

Source: Bureau of International Recycling - World steel recycling in Figures, 2021.
Note: Pakistan import data was not available at the editorial deadline.

Turkey is by far the largest producer of steel from imported scrap and is the seventh-largest steel producer globally.[19] Turkey produced 35.8Mt of crude steel in 2020, of which 24.7Mt directly came from the EAF route, and it imported 22.44Mt of ferrous scrap in that year.[20]

The dominant exporters of the obsolete scrap are developed countries including the EU28, the U.S. and Japan.

Scrap-EAF Potential in China

China is by far the world's largest steel producer – whatever impacts the Chinese steel sector impacts the industry globally.

In 2020, China produced 57% of the world's crude steel, with 91% manufactured via the BF-BOF process. Just 9% was produced via EAFs, significantly lower than the

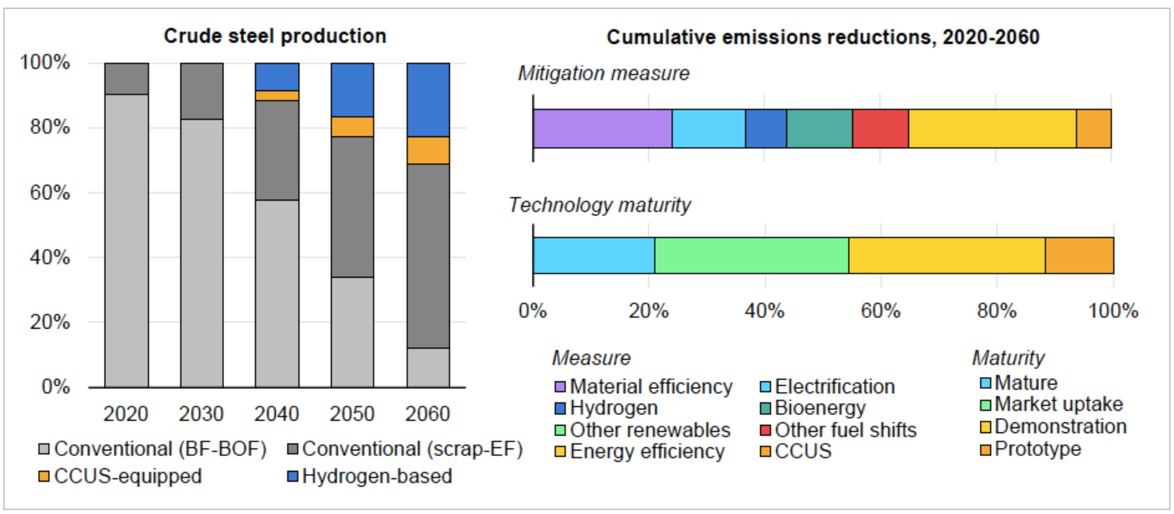
[19] World Steel Association. World Steel in Figures. 2021.
[20]Bureau of International Recycling, World Steel Recycling in Figures. 2021.

global average of 26%.[21] However, a shift to more scrap-EAF steelmaking is a stated aim of the Chinese Government[22] and it has set an economy-wide target to reach net-zero emissions by 2060. Major steel producers Baowu and HBIS have targeted net-zero by 2050.[23] [24]

The IEA released a report on China's decarbonisation path in September 2021.[25] Under the IEA's Announced Pledges Scenario (APS) – which reflects China's targets of net zero emissions in 2060 and peak carbon emissions before 2030 – output from scrap-based EAFs nearly doubles by 2030 and more than triples by 2060. Scrap-EAF accounts for more than half of Chinese steel production by 2060 under this scenario (Figure 5).

The IEA also sees crude steel production in China peaking in the mid-2020s and dropping 40% by 2060 compared to 2020 levels. However, China's current policy of capping steel production within the previous year's level looks set to continue for the foreseeable future.[26] This means China already could have reached peak steel production capacity, in 2020.[27]

Figure 5: Technology Change and Carbon Emissions Reductions in the Chinese Steel Sector Under the IEA's Announced Pledges Scenario



Source: IEA 2021.

The IEA foresees that China's shift towards scrap-EAF use will be facilitated by a large increase in the availability of scrap steel as its economy matures. In 2020,

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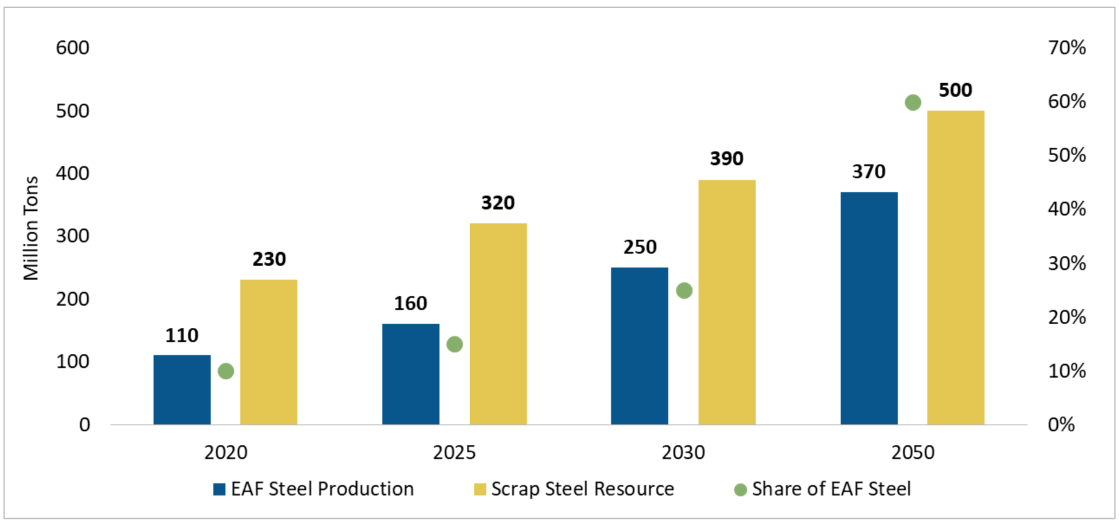
[21] World Steel Association. World Steel in Figures. 2021.
[22] Reuters. China to boost steel scrap usage by 23% in next five years. 7 July 2021.
[23] Baowu. China Baowu Signed Memorandum of Understanding with Vale. 22 November 2021.
[24] HBIS. HBIS Announces its Low Carbon and Green Development Action Plan. 12 March 2021.
[25] IEA. An Energy Sector Roadmap to Carbon Neutrality in China. September 2021.
[26] S&P Platts. China's steel industry may already have hit peak carbon emissions: sources. 27 October 2021.
[27] IEEFA. More than half of current global steel production may have already reached peak carbon emissions. 16 November 2021.

China recycled 260Mt of scrap steel, which replaced 410Mt of 62% iron ore. China's National Development and Reform Commission anticipates China recycling 320Mt of scrap steel by 2025.[28] Assuming a 40-year average lifespan for steel products, higher scrap volumes will be particularly available from about 2040 as the significant growth of Chinese steel production started about 2000.

According to the China Metallurgical Industry Planning and Research Institute, the estimated total scrap resources for steelmaking in China will reach 390Mt in 2030 and 500Mt in 2050 (Figure 6). By 2025, the overall share of steelmaking from EAFs in China is expected to rise from 9% to 15%. By 2050, scrap-EAF will make up 60% of total Chinese steel production, reaching 370Mt out of the annual total of 621Mt, according to their figures.[29]

In addition, by the end of 2025, China's steel sector aims to increase the share of the scrap charge to 30% in BOFs, up from current average consumption of about 15% to 25%. However, there remains some uncertainty over just how much scrap steel will be available in China to meet these targets and forecasts.

Figure 6: China Steelmaking Scrap Supply, Secondary Production and Secondary Steel's Share of Total Steel Production



Source: RMI, Pursuing Zero Carbon Steel in China, September 2021.

Scrap-EAF Potential in Japan and South Korea

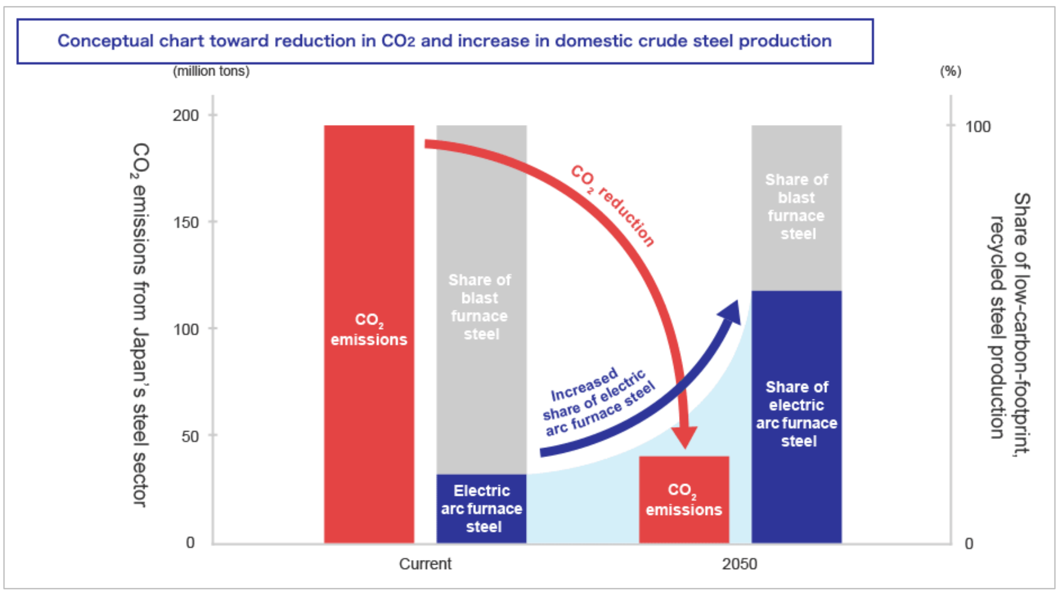
Japan was the third largest crude steel producer (83.2Mt) and exporter (29.8Mt) in the world in 2020, while also exporting 9.4Mt scrap. However, the share of EAF production was only 25%, compared to 71% in the U.S.[30] These figures suggest the potential for further steelmaking from scrap-EAF in Japan.

[28] S&P Platts. China's 2021-25 met coal market seen balanced, scrap usage to cut coal demand. 21 September 2021.
[29] RMI. Pursuing Zero-Carbon Steel in China. September 2021.
[30] World Steel Association. World Steel in Figures. 2021.

Nippon Steel, its largest steelmaker and the fifth-largest in the world by production, aims to be carbon neutral by 2050 and to decrease carbon emissions by 30% by 2030 (relative to 2013 emissions). As set out in its Carbon Neutral Vision 2050, the company is working towards the development of larger EAFs that can produce high-grade steel by 2030.[31]

The company has two EAF projects under construction. A new EAF at its Setouchi works in Hirohata is planned to start in the first half of FY2022 and will produce high-quality steel sheets. The second, a joint venture with Luxembourg's ArcelorMittal to build a new EAF in the U.S., is scheduled to start operations in the first half of FY2023. Among its products will be slabs for automotive flat products including advanced high-tensile steel sheets.[32] The new EAFs initially will use a mix of internal and processed scrap and pig iron.[33]

Figure 7: Potential Increase in Scrap- EAF Steel Production and Reduction in Carbon Emissions in Japan



Source: Tokyo Steel Long-Term Environmental Vision.

Japan's leading scrap-EAF steelmaker, Tokyo Steel, is even more positive about the future of this technology (Figure 7).

Tokyo Steel has a track record of finding solutions to questions over the quality of steel made from obsolete scrap. In its Long-Term Environmental Vision, the company states that the increasing availability of steel scrap in Japan will meet domestic steel demand by 2050.[34]

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[31] Nippon Steel. Carbon Neutral Vision 2050. 30 March 2021.
[32] Nippon Steel. Execution of Definitive Agreement to Newly Build an Electric Arc Furnace at AM/NS Calvert. 22 December 2020.
[33] Nippon Steel. Carbon Neutral Vision 2050. 30 March 2021.
[34] Tokyo Steel. Long-Term Environmental Vision.

South Korea's Hyundai Steel – the 16th largest global producer in 2020 – already has scrap-EAF technology making up 50% of its total capacity[35] indicating the potential for this process in South Korea given sufficient scrap supply.

Meanwhile, POSCO – South Korea's largest producer and the 6th largest globally in 2020 – is yet to commit to new EAF capacity but states that it is exploring the possibility in its inaugural 2020 Climate Action Report.[36] Instead, POSCO is currently more focused on increasing scrap use in its BF-BOF operations, use of unproven carbon capture technology and hydrogen-based steelmaking in the longer term. For this reason, POSCO's pursuit of its 2050 net-zero emissions target is heavily weighted to the post-2030 period, with targets of 20% emissions reduction by 2030 and 50% by 2040.

Potential Headwinds and Solutions

Scrap steel volumes may be in short supply in developing nations with accelerating steel demand and may remain in short supply until those economies mature and more scrap becomes available, as is about to happen in China. Steel stock in developed countries is 12 to 13 tonnes per capita, while in India and Africa it is only one tonne, which means these countries will need to continue using primary steel production as they develop.[37]

In addition, there are question marks over the quality of steel from scrap-EAF relative to the BF-BOF route. An advantage of the more widespread BF-BOF process is in more easily controlling impurities during the melting process, making it the ideal route for producing special grades of steel such as AHSS (advanced high-tensile steel) or IF (interstitial-free high strengths).

The presence of impurities triggers debate about the potential for using scrap in producing some of the highest-quality grades of steel but it must be considered that these grades are a small portion of the overall production mix. In 2020, the share of the automotive section – the most quality-sensitive category – was only 12% of total global steel consumption.

In the final users' various industries and sectors, there are unique technical and quality needs, requiring specific grades of steel. Figure 8 shows the global steel use in different market segments. Building and infrastructure products represent 52% of total steel consumption and the required grades in this sector – often long products – are less sensitive to scrap steel impurities and can be manufactured from scrap-EAF processes.

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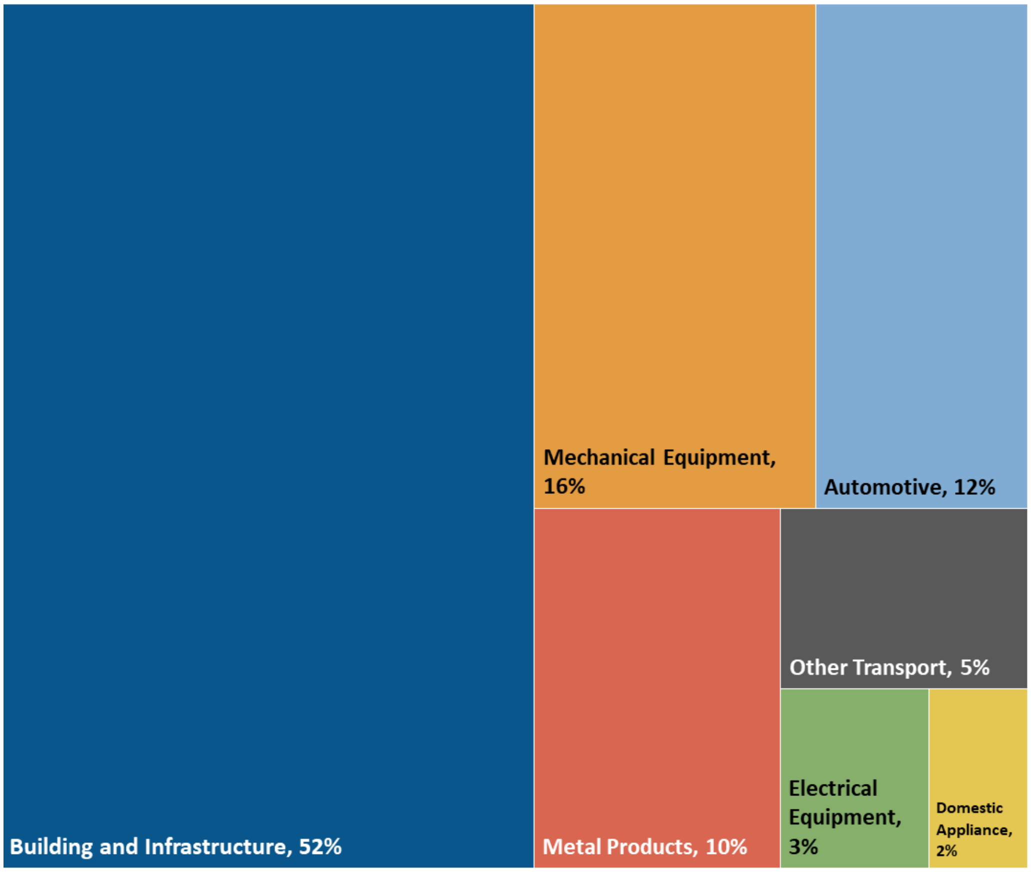
[35] Hyundai Steel. About Our Businesses.
[36] POSCO. Climate Action Report 2020.
[37] Energy Transition Commission. Mission Possible sectoral focus: steel. January 2019.

Figure 8: Final Steel Usage by Sector 2020



Source: World Steel Association, World steel in figures 2020.

Nippon Steel raises the issue of impurities in the scrap-EAF process in its 2050 Carbon Neutral Vision, noting in particular copper impurities and nitrogen contamination from the air. However, it also points out the range of steel products that can be manufactured even from lower-quality obsolete scrap (Figure 9).

The widespread use of scrap-EAF in the U.S., where scrap accounts for 71% of steel production, indicates the potential for large percentages of steel to be manufactured from scrap elsewhere without major quality concerns. EAFs in the U.S. produce higher-quality steel from higher-quality scrap.[38]

Nucor Corporation is the largest steelmaker in the U.S. and is also the largest recycler of scrap steel. The company is developing 3rd Generation Advanced High-Strength Steel (AHSS)[39] for the automotive sector. Until recently, AHSS products could be made only via the BF-BOF route.[40]

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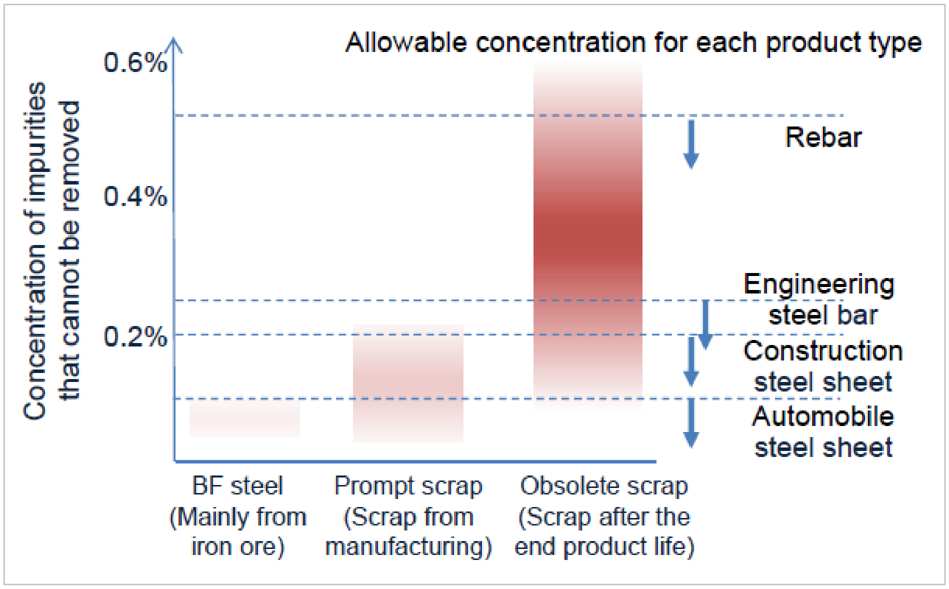
[38] S&P Platts. US steel sector thrives as mills move up the quality ladder. 9 May 2019

[39] World Steel Association. What makes 3rd generation AHSS grades so unique? 8 September 2021.

[40] Nucor Corp. Nucor Corporation Will Reduce Greenhouse Gas Emissions Intensity of Steel Mills to 77% Less Than Global Steelmaking Average. 15 July 2021.

In October 2021, Nucor launched its Econiq net-zero steel brand, pairing scrap-EAF with renewable energy. High-grade steel will be produced for the automotive sector – GM is to be the first customer for the Econiq brand beginning in Q1 2022 with an expectation that all steel GM purchases from Nucor will be carbon neutral by the end of 2022.[41]

Figure 9: Allowable Concentration of Impurities for Various Steel Products



Source: Nippon Steel Carbon Neutral Vision 2050.

Swedish steel producer Ovako is among the pioneer companies in Europe working on delivering high-quality low-carbon steel. Ovako employs scrap-EAF technology and uses 97% recycled input materials.[42] Ovako has introduced very high-performance steel for manufacturers such as Volvo.[43]

A switch toward a significantly larger share of scrap-EAF steel production will be dependent on increased scrap availability matching rising demand. Otherwise, increased demand for scrap will raise its cost making the scrap-EAF process less competitive with BF-BOF processes.[44] Limitations on the global availability of scrap steel constrain how much of BF-BOF steel manufacturing can be transferred to scrap-EAF.

To reach net-zero in the longer term, newer steel-making technologies such as DRI-EAF using 100% green hydrogen will be needed to supplement scrap-based EAF production. However, a build-out of EAFs to be fed by scrap is entirely compatible with increased future DRI-EAF using green hydrogen.

[41] Nucor Corp. Nucor Launches Econiq Net-Zero Steel. 5 October 2021.
[42] Ovako. Ovako's path to carbon-neutrality. 2020.
[43] Ovako. Cradle-to-gate – understanding CO2 footprint of hot-rolled bar steel products. 2019.
[44] S&P Platts. Steel vs plastics: race to sustainability. 22 October 2021.

Scrap-EAF has significantly lower emissions than BF-BOF technology but cannot claim zero emissions unless the electricity that powers the EAF is 100% renewable. It is possible to power EAFs from renewable energy – as demonstrated in the U.S. where a scrap-EAF steel mill is set to become 90% powered by solar energy.[45] Where such furnaces are powered from the electricity grid there will be a high percentage of fossil fuel-derived power (for now – the percentage of renewables on grids around the world is only travelling in one direction).

Some nations such as Japan – with relatively high population density and low solar resources – are faced with difficulty in installing enough renewable energy capacity to lower power sector emissions while meeting increased power demand through the electrification of industry, including the production of green hydrogen. In Japan's case, much will depend on the rate of development of floating offshore wind generation.

Implications for Coking Coal and Iron Ore

As steelmaking via scrap-EAF processes does not use iron ore or coking coal, there are clear, long-term implications for exporters of these resources. Australia is by far the largest exporter of both.

Even without increasing international pressure to reduce carbon emissions, iron ore demand in China – the world's largest importer – will drop significantly in coming years. As the Chinese economy continues to mature, steel production is expected to peak in the mid-2020s (if it hasn't already) and steel recycling is guaranteed to grow as more scrap becomes available. With China now targeting peak emissions by 2030, momentum is likely to grow for greater use of scrap-EAF to lower emissions.

As steelmaking via scrap-EAF processes does not use iron ore or coking coal, there are clear, long-term implications for exporters of these resources.

There is even further incentive for China to increase scrap steel use. China has already banned the import of Australian coal and clearly also wishes to shift away from reliance on importing Australian iron ore for both diplomatic and strategic reasons.[46] There are already ambitious plans for China to exploit iron ore resources in Guinea to move away from reliance on Australian volumes and put downward pressure on prices.[47] [48] China's strategy to reduce dependence on Australian iron

[45] Financial Times. Solar-powered steel mill blazes trail for green energy transition. 11 October 2021.
[46] Wood Mackenzie. Aiming high: can China's steel industry hit its ambitious targets? 15 February 2021.
[47] Australian Financial Review. China's African iron ore strategy spells danger for Australia. 9 April 2021.
[48] Nikkei Asia. China determined to build iron ore hub in Africa as Australia goes Quad. 31 March 2021.

ore also includes a plan to increase domestic iron ore production by 30% and raise scrap steel recycling rates in order to reach 45% iron ore "self-sufficiency" by 2025.[49]

China clearly sees that greater scrap steel recycling would help it achieve its resource security aims. A ban on the import of scrap steel was lifted in early 2021, a move that signposts China's desire to reduce industrial carbon emissions while becoming less reliant on Australian resources.[50] China's scrap steel consumption surged 47% to 138Mt in the first half of 2021.[51]

The ban on Australian coal imports means China is facing difficulties in sourcing sufficient coking coal from alternative markets such as the U.S., Canada, Russia and Mongolia. Increasing the rate of scrap-EAF steel production would allow China to lessen reliance on coking coal imports.[52]

As manufacturing volumes peak and China moves away from primary steelmaking towards more scrap-EAF processes, there will be a global impact on iron ore and coking coal exporters, none more than Australia.

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[49] Australian Financial Review. China's plan to end its Australian iron ore dependency. 2 December 2021

[50] Australian Financial Review. China lifts ban on scrap metal imports in new iron ore threat. 18 February 2021.

[51] S&P Platts. EC to announce waste shipment regulation Nov 17; EU H1 ferrous scrap exports soar 49.3%. 4 November 2021.

[52] S&P Platts. China's 2021-25 met coal market seen balanced, scrap usage to cut coal demand. 21 September 2021.

About IEEFA

The Institute for Energy Economics and Financial Analysis (IEEFA) examines issues related to energy markets, trends and policies. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy. www.ieefa.org

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