TransitionAsia
ACCELERATING EAST ASIAN CORPORATE CLIMATE ACTION

STEEL EXPLAINER
TECHNOLOGY PATHWAYS IN THE STEEL INDUSTRY FOR NON ENGINEERS

A guide to technology pathways that will decarbonise the steel industry in the near, medium and long term

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CONTENTS

KEY TAKEAWAYS

- Current steel production is dominated by blast furnaces and electric arc furnaces. The former dominates the emissions profile of primary steel production but both are reliant on fossil fuels for heat and power.
- Technology pathways already exist to transition from secondary steel as it is currently produced to secondary green steel driven by the use of new and existing electric arc furnace capacity powered by renewable electricity.
- In the medium term, low carbon direct reduced iron and electric arc furnaces are the likely decarbonisation technology pathway for primary green steel.
- By 2050, the use of blast furnaces needs to be minimal which raises red flags over any current or future greenfield blast furnace investment and/or relining of blast furnaces to extend their lifetime.

INTRODUCTION

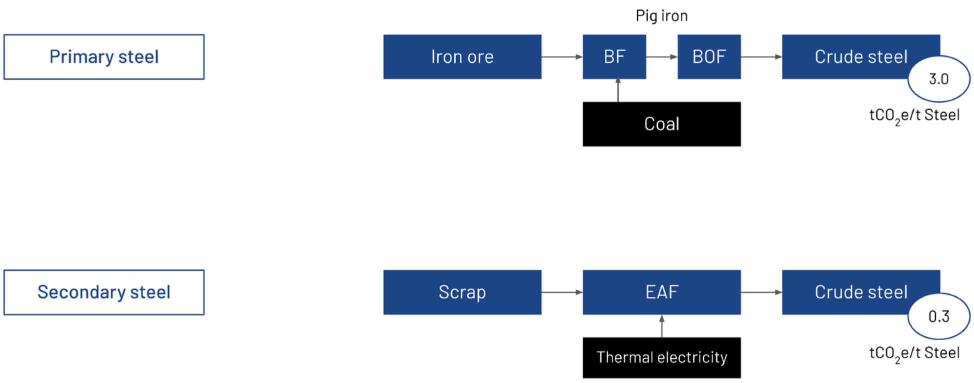
This paper is aimed at investors, media and NGOs that are following the decarbonisation of the steel industry, especially in East Asia. It presents the current methods of iron and steel production or “business as usual” production followed by near term and medium term technology pathways that deliver decarbonisation.

The aim is to do all of this with the minimum level of technical language necessary to follow industry trends, corporate strategy or emissions pledges in other analyses. This means there are simplifications and deliberate oversights in what is a complex sector, but readers should be able to use this document as a primer or explainer for further reading.

We are using carbon intensities, the amount of carbon produced per tonne of steel, that include direct and indirect emissions. That is, those from direct production process, electricity and the production of raw materials.

"BUSINESS AS USUAL"

Figure 1 - Business as usual steel production



PRIMARY STEEL

Currently, primary steel starts with the combustion or smelting of iron ore and metallurgical coal in a blast furnace (BF). There are other feedstocks required but these are the two core raw materials. There are also other processes necessary to prepare iron ore and coal for the blast furnace but, put simply, this step of making iron in the BF is the point at which most of the coal in the overall iron and steelmaking process is combusted and therefore the source of most CO_2 emissions, at around 70% of the total.

A BF makes pig iron which is then transferred to a basic oxygen furnace (BOF) which makes crude steel. The latter process converts molten pig iron into steel by blowing oxygen through a lance over the molten pig iron. The BOF is also often called a converter. Other feedstocks are part of this process, but in much smaller amounts.

Although the BF makes pig iron and the BOF makes steel, many data and analytics are presented as BF-BOF. Indeed, since molten pig iron goes straight from one to the other, BF-BOF are often called integrated steel mills. They are, for the most part, inseparable.

The BF-BOF process is responsible for around 70% of global steel production and capacity. It has a carbon intensity of around 3 tonnes of CO_2 per tonne of steel.

SECONDARY STEEL

Secondary steel is made in an electric arc furnace (EAF). Scrap steel and thermal electricity are the core raw material and power source in "business as usual" production. In most countries, scrap steel is the primary feedstock in an EAF. But an EAF can also use direct reduced iron (DRI - see decarbonisation medium term, below).

In an EAF, a high voltage electric arc is created between electrodes and the heat from this electric charge melts the scrap inside the furnace. The scrap in this process has zero emissions. However, the emissions of the electricity used depends on the source. At present, most steel companies generate their own electricity from thermal power i.e. coal or gas power. As such, the carbon footprint of this electric power is high. For example, Nippon Steel generates 95% of their own power, which is almost entirely from fossil fuels.

The EAF technology pathway is responsible for around 25% of steel production globally and is growing. It has a carbon intensity of around 0.3 tonnes of CO_2 per tonne of steel.

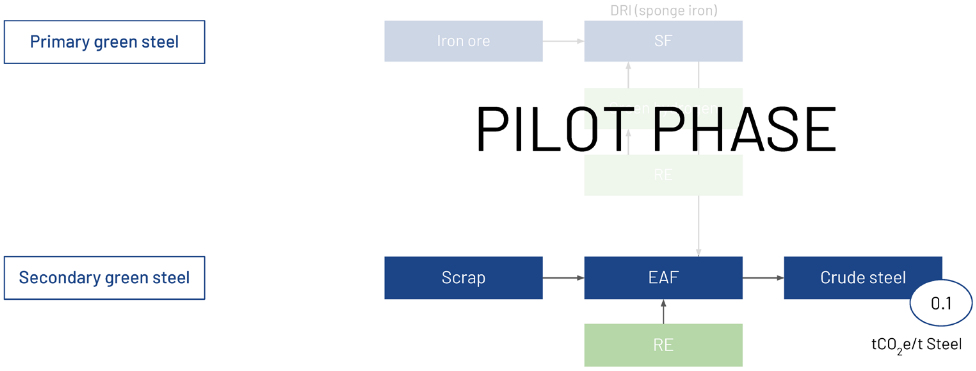
PRIMARY VERSUS SECONDARY STEEL QUALITIES

BF-BOF produces steel with the least impurities and most reliable quality. By extension, it is used in sectors which demand high finished quality like the automotive sector.

In practice, different processes can use a variety of feedstocks. For example, A BOF can use scrap steel as a raw material and an EAF can use pig iron or DRI as well; in China, EAFs use approximately 50% pig iron in EAF production. By definition this is not low carbon steel because pig iron is produced by the combustion of coal in a BF.

DECARBONISATION NEAR TERM

Figure 2 - Decarbonisation near term



There is no universally accepted definition of green steel but there are guides to how the carbon intensity of crude steel should decrease in various energy transition models, notably the IEA's Net Zero analysis.

Decarbonisation of iron and steel making in the near term relies on switching production from BF-BOF to EAFs, in addition to switching the electricity used in EAFs from thermal electricity to renewable electricity (RE) in order to lower carbon intensities. This is to say that the global share of EAF should increase at the same time as its carbon intensity falls. Secondary green steel (Figure 2) is currently the focus of decarbonisation strategies globally.

There is no technical barrier to an EAF being powered by renewable electricity (RE). The availability of RE at the location of the EAF is more fundamental. Steel producers that are used to creating their own thermal electricity have to supply the EAF from either a green grid, through power purchase agreements that secure RE or by constructing "captive" or islanded energy systems that are built using RE capacity.

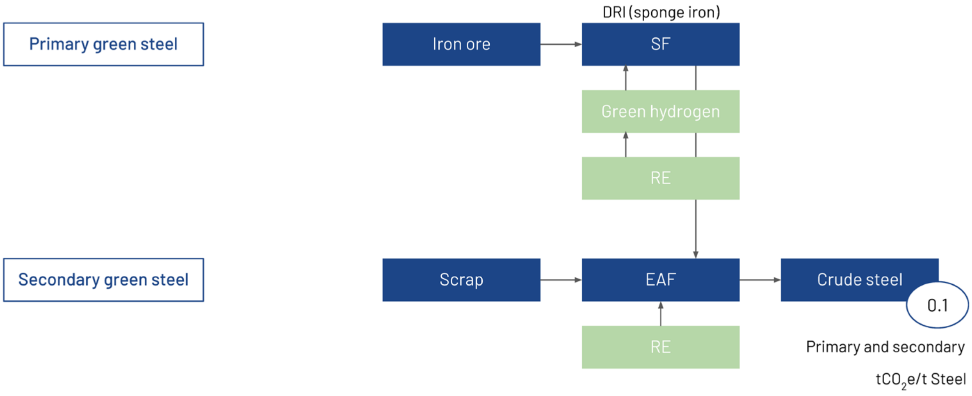
Here, there will be many combinations which result in different carbon intensities from 100% renewable electricity to grid level carbon footprints (where most electricity grids are powered by many different energy forms). As such, the IEA gives a benchmark for 2030 of 0.1 tonnes of CO_2 per tonne of steel but 0 tonnes of CO_2 per tonne of steel is feasible at present where renewable electricity is available. It is also likely that an EAF will produce steel with different carbon intensities in different batches. In practice, this will depend on availability and cost of RE as well as demand and pricing for green steel.

Primary green steel is in a pilot phase. What is not available in the near term is commercial and scalable solutions for the decarbonisation of primary steel production.

This takes us to the medium term.

DECARBONISATION MEDIUM TERM

Figure 3 - Decarbonisation medium term



The research and development of primary green steel production and its many pilot projects is examining the use of DRI to decarbonise iron and steel making in the medium term.

Currently, to make DRI, iron ore and a synthesis gas (usually carbon monoxide from the combustion of natural gas or coal) are processed in a shaft furnace (SF). The gas dissolves the oxygen in the iron ore and produces sponge iron. Here there is no combustion of coal in the SF itself, unlike the blast furnace for BF-BOF. While DRI is also made today and used commercially downstream in EAFs, it is currently made using fossil fuels to create the synthesis gas.

With commitments to lower emissions proliferating, steel producers are now rapidly exploring the economics, technology and scale for replacing this fossil gas with green hydrogen. That is, hydrogen made from the electrolysis of water with RE as the feedstock. Crucially, it is the dramatic fall in the prices of RE that is leading analysts to predict that green hydrogen will be competitive with hydrogen produced by fossil fuels by 2030 and therefore be a commercial proposition.

In this event, the production of green hydrogen from RE and DRI from green hydrogen in a SF (H2-DRI) is becoming the industry favourite for primary green steel production.

This means that H_2-DRI becomes a raw material for use in an EAF to make crude steel. In an EAF, the different shares of scrap and H2-DRI will have different impacts on power requirements. But in its forecast, the IEA suggests the carbon intensity can be close to zero.

It is worth noting that H_2-DRI and EAF can be separated and do not need to be in an integrated mill (see possibilities for Japanese steel producers below).

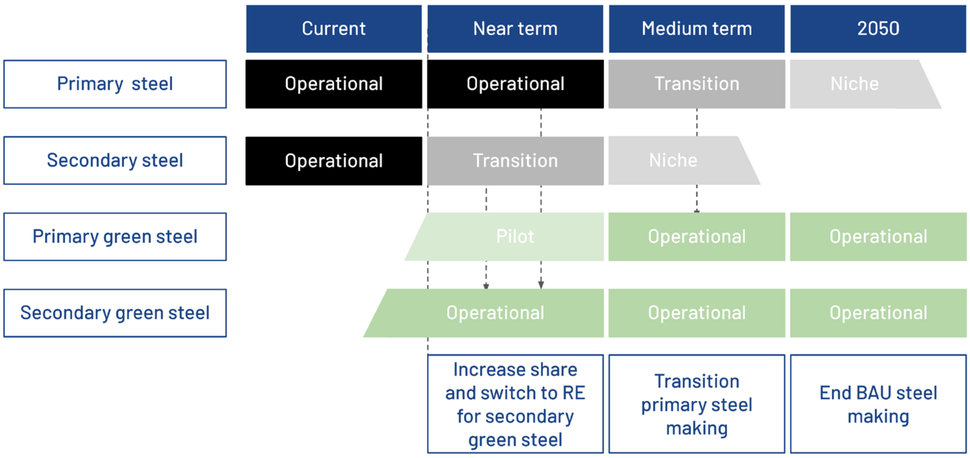
PRIMARY GREEN VERSUS SECONDARY GREEN STEEL QUALITIES

The use of H_2-DRI in the EAF can improve the quality of the crude steel but may consume more energy to produce the steel.

A new generation of hybrid EAFs is coming online that have higher capacities, more ability to process DRI as part of production and can be integrated into processes that provide high quality finished products.

A SUMMARY AND IMPLICATIONS FOR JAPAN

Figure 4 - Technology pathways over time



THE INDUSTRY IS MOVING OUTSIDE JAPAN

Near term solutions will be driven by increasing investment and production in EAFs using RE feedstocks. For EAF steel production, scrap inventories are an opportunity in Japan while the other key feedstock, RE will have to be delivered at speed and scale from government and utilities.

This is the easiest and quickest way to move away from coal intensive BF-BOF routes where efficiencies have flat lined, meaning switches in production methods from BF-BOF to EAF. As a consequence, the prospect of investment in greenfield BF-BOF by Japanese steel producers, either in Japan or overseas, is a clear signal about lack of climate ambition in general, not least because greenfield plant lifetimes would stretch beyond any net zero target date.

More fundamentally, in major decarbonisation analyses like those of the IEA, "technologies that are currently on the market deliver around 85% of emissions savings in steel production to 2030". That is, near term solutions are about commitment to change, and not commitment to new technology. H_2-DRI-EAF is not a core solution in the near term.

In the medium term the opposite is true. According to the IEA and most steel academics and analysts, the bulk of emission reductions "come from the use of technologies that are under development, including hydrogen-based DRI" . Solutions like H_2-DRI-EAF will adopt new technologies in iron and steelmaking to become the preeminent source of low carbon steel (especially primary green steel) to have any serious chance of decarbonisation. The sooner the better, especially as Japan is playing catch up when looking at H_2-DRI pilots overseas.

This replaces coal in the iron making process and suits those corporates in Japan that are internationalising and can foresee a new steel map. On this map China and India will be key players, as will steel producers like Nippon Steel and JFE with joint ventures there.

Moreover, where BF-BOF processes have led to highly integrated steel mills, DRI could be compacted at high temperatures into Hot Briquetted Iron (HBI) and stored and transported at the same kind of marginal costs as iron ore. This raises the tantalising strategic prospect that steel producers in Japan could separate HBI production from EAF steelmaking and expand the latter for a green steel market in Japan. Internationalisation is aligned to decarbonsiation.

Analysis also refutes the idea that Japan can sustainably import green hydrogen (or any other colour like grey hydrogen made from fossil fuels) or commercially export carbon (CCUS being a largely unproven route to decarbonisation) and still make sustainable and commercial steel.

In our analysis we also suggest that co-firing hydrogen with coal in a blast furnace - to reduce the total use of coal, is not a near term or medium term option for decarbonisation. It does not reduce the carbon intensity of steel in the same way as the pathways described above. Again, in Japan, securing low cost hydrogen would be problematic. For many of the same reasons the use of CCUS for steel from the BF-BOF process is not analysed here.

CAPITAL EXPENDITURE AND RENEWABLE ELECTRICITY ARE THE TWIN CONCERNS

In any event, financing new technology and new capacity with capital expenditure and the availability of RE through multiple routes for EAF production and H_2 electrolysis, will be the twin concerns. EAFs in Japan will need capacity scale renewable electricity resources in the form of captive power or PPAs until and unless grid electricity becomes decarbonised in Japan.

It is therefore imperative that alongside lobbying for state subsidies, steel producers in Japan lobby for a fit-for-purpose renewable electricity-driven power sector that can meet their needs and size in Japan and make them winners on a new steel map. And investors lobby steel producers for near term and medium term decarbonisation strategies and emissions reduction targets.

GLOSSARY

H_2-DRI	Direct Reduced Iron from Hydrogen
EAF	Electric Arc Furnace
DRI	Direct Reduced Iron
PPA	Power Purchase Agreement

DATA AND DISCLAIMER

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ABOUT TRANSITION ASIA

Founded in 2021, Transition Asia is a Hong Kong-based non-profit think tank that focuses on driving 1.5°C-aligned corporate climate action in East Asia through in-depth sectoral and policy analysis, investor insights, and strategic engagement. Transition Asia works with corporate, finance, and policy stakeholders across the globe to achieve transformative change for a net-zero, resilient future. Visit transitionasia.org or follow us @transitionasia to learn more.