Coal, steel and the energy transition

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Key points:

- There are two main families of coals: Thermal coal, used to generate electricity and heat, and metallurgical coal, which is used to produce steel and other metals
- Steel production is responsible for 7% to 10% of CO_2 emissions
- Low-carbon steel technologies are available or under development but still lack either economic and/or technical maturity
- We believe setting up a metallurgical coal policy today is premature, but investors ought to be ready to act when deployment at scale of low-carbon steel technologies is in sight

Coal is not a commodity in the sense that it is not standardised, unlike other materials. Copper, for example, has its place in the periodic table as it is a 'pure' element, with a fixed chemical makeup.

Coal, on the other hand, is a complex combination of many elements, primarily carbon, along with different minerals and traces of metal.

A better comparison may be with raw ore from mines, before concentration and refining, when copper becomes Cu[1] and is fully fungible. There are different types of copper ores at the mining level, but at the end of the chain refined copper is the same metal everywhere.

Coal is different because what you dig is what you get. Coal is essentially the offspring of antique plants buried millions of years ago and transformed by time, pressure and heat. This geological process has led to coals of different qualities across mines. Those coals are classified by ranks - lignite, sub-bituminous, bituminous and anthracite – and differ in their physical and chemical features - calorific value, moisture, volatiles, ash and so on.[2]

Geology aside, society largely consumes two families of coal:

1. Thermal coal (or steam coal) is primarily used to produce electricity in power plants, but also to generate heat in certain industrial processes, such as for cement or glass manufacturing
2. Metallurgical coal (or coking coal) is generally used to produce metals, mainly steel through the blast furnace process

According to the International Energy Agency[3], world coal consumption was 8.69 billion tonnes (BT) in 2023, made up of 7.59BT of thermal coal (87%) and 1.10BT of metallurgical coal (13%).

Coal is also the main source of carbon dioxide (CO_2) emissions, accounting for 41% of fossil fuel emissions[4], with the bulk coming from thermal coal.

The metallurgical coal market

Given its chemical properties metallurgical coal can be transformed into coke when heated without oxygen – in a coke oven for about 18 hours. Coke, which is almost pure carbon, is then used in blast furnaces to produce crude steel[5].

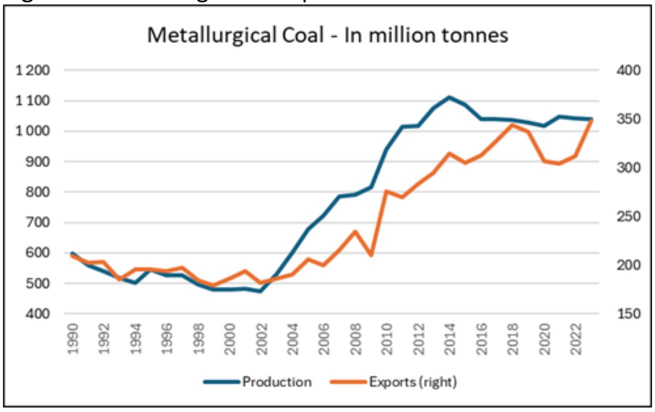
There are different qualities of metallurgical coals based on their reactions during the coking process. Hard and semi-hard coking coals stand at the top of the quality ladder, followed by semi-soft coking coal and at the low end by pulverised coal injection (PCI). Broadly speaking, hard and semi-hard account for 60% of the market, semi-soft for 20% and PCI for 20%[6].

Due to its physical properties, metallurgical coal is more expensive than thermal coal, especially hard and semi-hard coking coals which are rarer. Over the past 10 years, metallurgical coal had an average price premium of 75%[7].

Metallurgical coal production has been fluctuating between 1BT and 1.1BT for more than 10 years, after having doubled since the start of the century, mirroring the sharp increase in China's steel output.

As figure 1 shows, the metallurgical coal market experienced a period of slow decline in the 1990s but doubled in size during the first 15 years of this century, pushed up by the doubling of crude steel production, largely driven by China, which increased its production more than sixfold.[8]

Figure 1: Metallurgical coal production



Source: Australian Bureau of Resources

Figure 2 highlights that the metallurgical coal market is largely split in two between China and the rest of the world:

- China is the largest producer (at 56% to 60%), importer (at more than 30%) and consumer (at 66%) of metallurgical coal[9]. China is such a dominant actor because it produces more than half of the world's crude steel - and 69% is made through the blast furnace process[10] (some 90% of its steel is made in blast furnaces compared to 71% for the world average). China's imports come almost entirely from Mongolia and Russia. Practically, China is maxing out its own metallurgical coal production and uses imports to manage swings in the needs of its steel industry
- Outside of China, Australia is the largest producer and the dominant exporter, as Russia and Mongolia mostly export to China and India. As such, Australia accounts for more than 60% of the remaining export market

Figure 2: Metallurgical coal in 2023, in million tonnes

	Production	Exports
China	540	
Australia	161	151
Russia	105	49
India	65	
USA	60	46
Mongolia	51	44
Canada	31	29
Other	39	31
Total	**1 052**	**351**

Source: IEA, EIA, World Mining Data

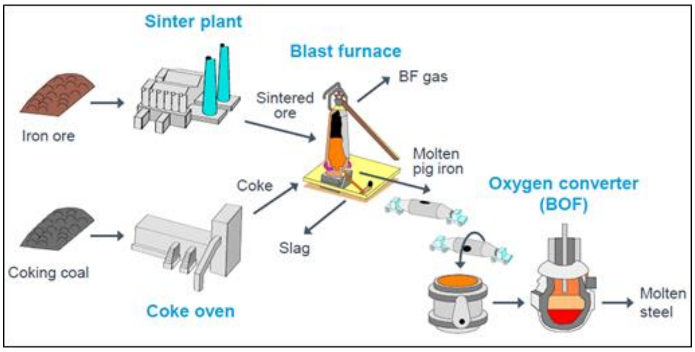
How steel is made and why use metallurgical coal?

Steel is an alloy made of iron and up to 2%[11] carbon. There are hundreds different grades of steel depending on the carbon content and the addition of other metals – such as manganese or vanadium – used to achieve specific physical properties.

According to the World Steel Association, 1,892 million tonnes of crude steel were produced in 2023[12]. Of this 71.1% was produced in blast furnaces (BF) and 28.6% in electric arc furnaces (EAF)[13]. Our interest lies here - blast furnaces produce virgin steel, while EAFs essentially produce steel from steel scrap, i.e., it is a recycling process.

The BF process is fundamentally about turning iron ore – mined minerals made of iron, oxygen and various impurities – into pig iron, which can then be turned into steel by removing excess carbon in a basic oxygen furnace (BOF). To do this, chemical reduction must be induced, i.e. oxygen must be removed from iron ore by binding it to another element, which in this case is carbon. Figure 3 presents a simplified illustration of this process.

Figure 3: The blast furnace (BF-BOF) steel making process



Source: Whitehaven Coal

Coke made from metallurgical coal[14] plays several roles in the BF-BOF process:

1. It is a source of heat as its carbon reacts with oxygen in the air
2. It provides the reducing agent in the chemical reduction reaction
3. It physically supports iron ore – providing a permeable bed – through which molten metal and slag can go down and heat and hot gases can rise

Steel and CO_2

At a global level, it is estimated that the steel industry is responsible for between three and four billion tonnes of CO_2, or 7% to 10% of total CO_2 emissions. This wide range comes from the integration, or not, of indirect emissions, such as methane leaks from metallurgical coal mines or emissions from power plants.

According to the World Steel Association[15], the average emissions intensity in recent years was 1.9 tonnes of CO_2 per tonne of steel. There is however a significant difference in intensity depending on the production route: at 2.3 tonnes of CO_2 per tonne of steel, the BF-BOF route is more than three times more intensive than the 0.7 tonnes produced via the EAF route (including power related emissions).

The CO_2 in the BF-BOF process is generated primarily by removing oxygen from iron ore, as well as from turning coal into coke and removing carbon from pig iron. Ultimately, the high heat needed to melt iron and the use of carbon as a reagent are the main emission drivers. In the EAF process, the main source of CO_2 is indirect as it largely comes from the power supply[16].

How to produce carbon-free steel

Let's start with the EAF process where the solution is simple: switch to clean power. But there is then the question of availability, reliability and power price - not of technological readiness. It is a solution that steel companies operating EAFs can implement now.

Also, growing the EAF-made steel market share would reduce the average emissions intensity of steel given the sharp difference with BF-BOF made steel. This clearly should be done, but this requires capital, and vitally, more scrap steel. This latter point is particularly important as it means that recycling circuits are expanded where they exist, or created, where they do not. There are however technical limits, especially to achieve the right steel qualities for certain final uses, and EAFs usually need to add small quantities of blast furnace produced pig iron to do so. In addition, steel is rarely recycled at more than 80%-90%[17] and, if steel demand is stable - more so if it is growing - new virgin steel will have to be produced.

In contrast to EAF, the blast furnace process is more difficult to decarbonise. Practically, there are two main avenues to achieve this:

- Keep the process as it is and capture the CO_2 from the blast furnace
- Remove coal / coke and reduce iron ore into pig iron in a different way

The technologies supporting this range from small prototypes to large projects under construction. They have names such as hydrogen-based Direct Reduced Iron (DRI), chemical absorption (essentially carbon capture) or molten iron electrolysis. The International Energy Agency (IEA) provides a handy review[18] of the technology readiness of low-carbon technologies. Agora Industry, a think-tank, has released a study[19] that compares and contrasts those technological options.

Hydrogen-based DRI is currently seen as a particularly promising solution that may be central to moving away from BF [20]. This technology decarbonises iron making by binding the oxygen in iron ore to hydrogen, hence rejecting H_2O, i.e., water, instead of CO_2. This is a mature technology and there are projects under way, for instance in Sweden[21]. A key challenge lies in developing a decarbonised hydrogen supply chain[22], notably so-called green hydrogen produced through the electrolysis of water. While there were strong expectations for green hydrogen a few years ago, they have been materially dampened, as highlighted in the latest IEA hydrogen review[23].

Common features of coal-less technologies, irrespective of their technical readiness, is that they require large capital outlays – largely because steel capacities must be rebuilt - and vast quantities of electricity, either to power the process itself, or to produce hydrogen.

Solutions using carbon capture face the challenge of needing a dedicated infrastructure to transport and store the CO_2[24].

In all cases, the economic equation is challenging, and public and policy supports will be needed.

What does it mean for investors?

Urgewald, a German non-governmental organisation, made its name by developing the well-regarded Global Coal Exit List – published in 2017 - of mostly electric utilities and mining companies exposed to thermal coal. It is main data source for AXA IM's thermal coal policy.[25]

In January 2025, Urgewald presented its first Metallurgical Coal Exit List. In the associated press release, Urgewald states that "While steel has long been considered a hard-to-abate sector, new technologies are now enabling the shift to coal-free steel production".[26]

We do not disagree with this assessment, but it needs to be heavily caveated in light of the technological and economic readiness of the available and potential technologies. There are serious solutions on the table to decarbonise steel making, but large-scale implementation remains distant.

This is in sharp contrast to thermal coal where technologies to produce low-carbon or decarbonised electricity have been available for many years and are economically superior to coal-based power.

As such, we believe that setting up a metallurgical coal policy today is premature. It will become relevant when there is a genuine line of sight for the deployment at scale of green steel technologies.

In the meantime, investors ought to do their groundwork and monitor developments in this area to be ready to act when the time is right. When engaging with steel producers, they ought to query them on their work and progress towards low-carbon technologies.

Of course, as China accounts for more than half of steel production, and more than two thirds of blast furnace produced steel, this is where the real decarbonisation of the steel industry will ultimately be decided.

[1] Cu is the chemical formula of copper in the Periodic table of Elements
[2]For more detail see Coal Quality Workshop - Thermal and Coking Coal, Whitehaven Coal
[3] Coal 2024: Analysis and forecast to 2027, IEA, December 2024
[4] Global Carbon Budget | GCB 2024
[5] It takes on average 1.5 tons of metallurgical coal to produce one tonne of coke, and about 400kg of coke to produce one tonne of crude steel. Coal use in the steel industry - January 2025
[6] Different Types of Global Metallurgical Coal Market - Maia Reports. Low quality metallurgical coal and PCI can sometimes be used as thermal coal equivalent in power plants, but only in certain infrequent market conditions when the price premium of metallurgical coal narrows
[7] Resources and energy quarterly: March 2025 | Department of Industry Science and Resources
[8] Data from World Seel Association
[9] Coal 2024: Analysis and forecast to 2027, IEA, December 2024
[10] 2024 World Steel in Figures, World Steel Association
[11] Above 2%, it is not steel anymore and is called cast iron
[12] World Steel in Figures 2024 - worldsteel.org
[13] The balancing 0.3% of total production came from either open hearth furnaces or Direct Reduced Iron plants
[14] Hard, medium and semi-soft coking coals are used to produce coke. PCI is mostly used as a substitute for more expensive metallurgical coals and is injected directly in the blast furnace. There is however a technical limit to this substitution, with no more than 30%-40% of PCI in a blast furnace.
[15] World Steel Association Sustainability-Indicators-Report-2024
[16] CRU Intensity Analysis 2022
[17] For instance, in the US, where 68% of the steel is made through the EAF process, steel is recycled between 80% and 90% (source: US Geological Survey)
[18] ETP Clean Energy Technology Guide – Data Tools - IEA
[19] Low-carbon technologies for the global steel transformation - 2024
[20] Note that there are already existing DRI plants, but they run on natural gas
[21] Stegra Boden – World's first large-scale green steel plant
[22] Hydrogen and the energy transition: One molecule to rule them all? | AXA IM UK
[23] Global Hydrogen Review 2024
[24] Carbon Capture and Storage, AXA IM, March 2022
[25] AXA IM Climate Risks Polic
[26] Time to End Metallurgical Coal Expansion – NGOs Launch First Met Coal Exit List for the Finance Industry | urgewald e.V.