China's green steel plans

Near-term policy challenges & Australia-China links in decarbonisation

Policy Brief

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1. Introduction

1.1 Conventional steelmaking approaches

Steelmaking is an energy-and-carbon intensive industry, and has the largest share of CO_2-emissions among all heavy industries (IEA, 2020). In 2020, total direct emissions from steelmaking were of the order of 2.6 billion ton, representing between 7% and 9% of global anthropogenic CO_2 emissions (World Steel Association, 2021).

More than 70% of global steel output is produced via the blast furnace-basic oxygen furnace (BF-BOF) route (Figure 1). The BF-BOF steelmaking route relies on inputs of coke, made from coking coal, for the reduction of iron ore (i.e., stripping oxygen from the iron ore). An alternative process known as Direct Reduced Ironmaking (DRI) uses reduction gas, commonly a mixture of H_2 and carbon monoxide [CO] syngas, typically produced from natural gas or coal for the reduction of iron ore (J. Zhao et al., 2020). This is a solid-state process, operated at much lower temperatures, below the melting point of iron (1,200°C) (Fan & Friedmann, 2021).

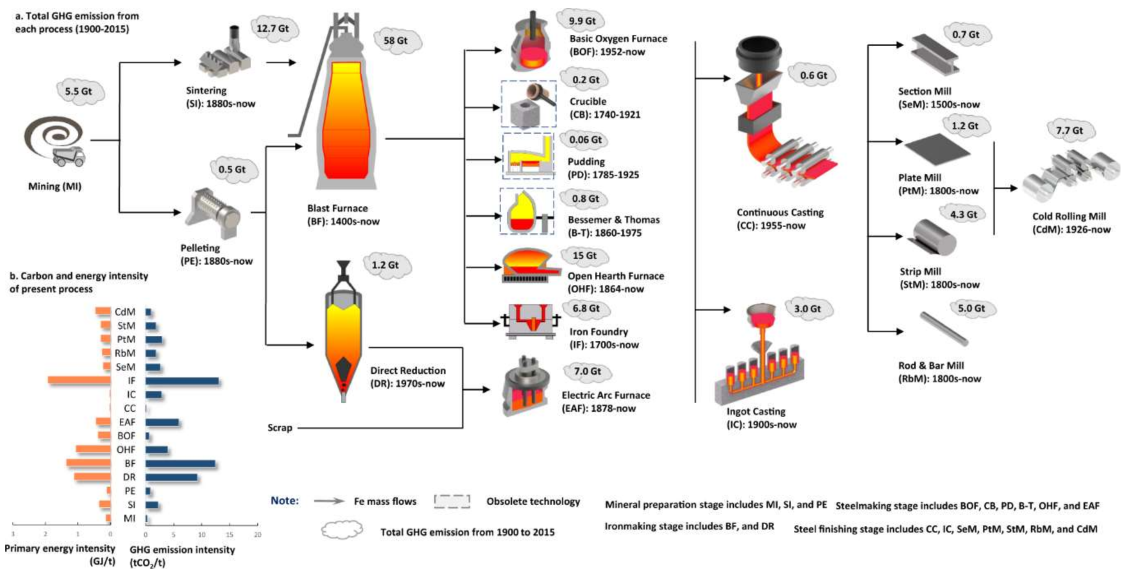

Figure 1. Steelmaking process and GHG emissions from 1900 to 2015. Source: (P. Wang et al., 2021).

A third route for steel making is through the electric arc furnace (EAF) process, which is the dominant approach for secondary steel production (i.e., steel made from scrap). The process produces around 29% of global steel (Fan & Friedmann, 2021). A more recently developed alternative that combines DRI and EAF can produce steel from sponge iron or pig iron (Figure 2). The carbon footprint of EAF steel is only about 10%–20% of conventional BF-BOF operations (Fan & Friedmann, 2021).

The production of steel through the EAF process is subject to limitations, however. First, steel scrap supplies are limited, in particular in emerging and developing economies, where consumption of steel and therefore the stock of steel in use lags behind. Steel from recycled scrap is also not be suitable for all types of applications, including because mixing of different alloys in scrap recycling may create difficulties ensuring specific physical properties of the resulting steel (Yellishetty et al., 2011).

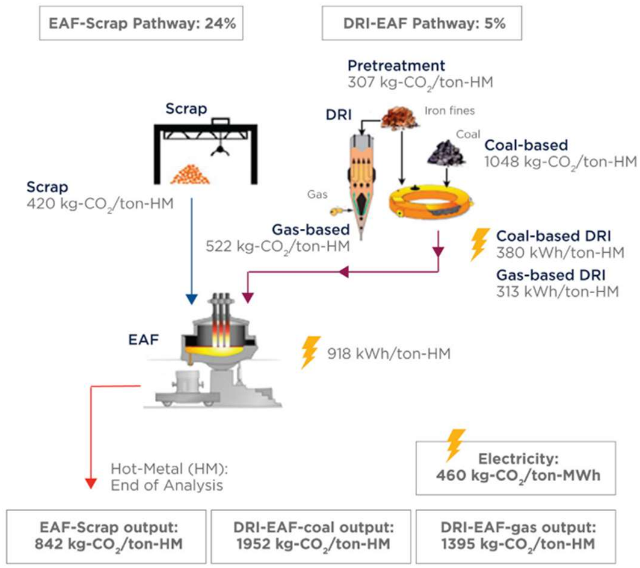

Figure 2. EAF-scrap (24% global steel production) and DRI-EAF (5% global steel production) steelmaking routes. Source: (Fan & Friedmann, 2021).

1.2 Novel and green approaches

The Ultra-Low Carbon Dioxide Steelmaking (ULCOS) program has evaluated over 80 technologies and assessed those four technologies may reduce carbon emissions from steel making by more than 50% (Table 1).

The most prominent amongst these green steelmaking technologies is hydrogen direct reduction (R. R. Wang et al., 2021). In conventional steel making processes, the carbon in coke is used as the reductants, i.e., used to strip oxygen from the iron ore, generating metallic iron and carbon dioxide. Hydrogen can similarly act as the reductant, generating emissions of water vapour rather than carbon dioxide.

HDR uses a direct reduction shaft, an electric arc furnace and an electrolyser, including a possible heat exchanger and hydrogen storage (Wood et al., 2020). If the energy in these processes including the electric arc furnace is supplied from renewable energy sources, the production process as a whole will have zero carbon emissions and produce truly green steel. The hydrogen storage is suggested as a buffer for possible intermittent supplies of renewable energy.

Table 1. Four future low carbon or green steelmaking technologies.

Technologies	Elaboration	Applications
Hydrogen direct reduction (HDR) (Wood et al., 2020)	Using hydrogen generated from renewable energy source as both alternate reductant and fuel	ArcelorMittal in France, Voestalpine in Austria (project H2FUTURE) and TATA in Netherland (project H2ERMES) are the only projects committed to use green hydrogen to make steel from the start (Bellona Europa, 2021).
Electrolysis in ironmaking (World Steel Association, 2021)	In electrolysis, iron ore is dissolved in a solvent of silicon dioxide and calcium oxide at 1,600°C, and an electric current passed through it. If the electricity used is carbon-free, then iron production is without CO2 emissions.	Electrolysis of iron ore has been demonstrated at the laboratory scale, producing metallic iron and oxygen as a co-product. The EU ULCOS project examined the prospects for electrolysis-based ironmaking through their ULCOTWIN initiative (World Steel Association, 2021).
Mixing biomass in steel making (Hammerschmid et al., 2021)	The biomass- based concept of sorption-enhanced reforming combined with oxyfuel combustion	1. The current commercial substitution for a proportion of the coal used in blast furnaces is charcoal, primarily in Brazil. 2. Australian CO2 breakthrough programme focuses on substituting coal used in pulverised coal injection (PCI) in the blast furnace with sustainable biochar. 3. TU Wien used Product gases from wood chips or biogas as reducing gases in the direct reduction route.
Carbon capture, utilisation and storage (CCUS) (Abdul Quader et al., 2016)	CCUS describes a suite of technologies that capture waste CO2, usually from large point sources, transport it to a storage site or utilise it in another industry process.	Currently, 26 commercial CCS facilities operate globally. Most of them (16) are located in North America and the overwhelming majority use captured CO2 in enhanced oil recovery (EOR) operations (World Steel Association, 2021).

2. The global steel sector and Australia-China links

2.1 China's steelmaking industry and carbon emissions

China is the world's largest producer and consumer of steel, by some distance. In 2020, its production peaked at 1,064 Mt, or just about 56% of global production (Figure 3). Covid-induced reductions in economic activity may have contributed to slightly levels of production in 2021, but the '2022 China and Global Steel Demand Forecast Report', by the China Metallurgical Industry Planning and Research Institute (MPI), projects a structural and continued decline, to levels of about 950 Mt for the near to medium term (Peng, 2021).

Globally, the steel sector is responsible for about 7 to 9% of carbon emissions. The heavy use of steel in China, driven largely by construction of housing and infrastructure (IEA, 2020), means that the sector is responsible for about 17% of Chinese carbon emissions (J. Chen et al., 2021).

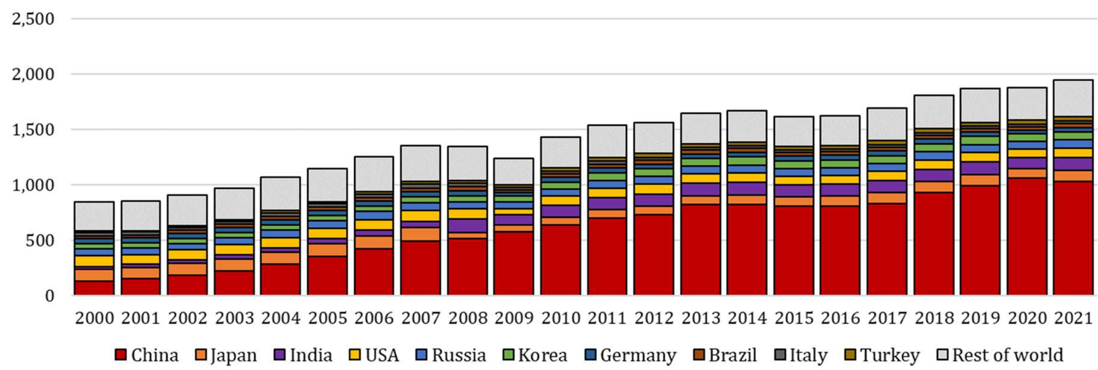

Figure 3. Global crude steel production (Mt). Source: (World Steel Association, 2022).

2.2 Current and projected levels of scrap consumption

Recycling of scrap steel is currently the primary route reducing emissions and resource consumption in the steel industry. Every tonne of scrap used for steel production avoids approximately 1.5 tonnes of carbon dioxide emissions, and the consumption of 1.4 tonnes of iron ore, 740 kg of coal and 120 kg of limestone (BIR, 2021).

The steep growth in Chinese steel production and consumption over a relatively short period also means that most of this steel in still in the stock in-use, and those volumes of steel that becomes available as scrap are still relatively limited.

China's use of scrap has grown rapidly very recent years, from 90 Mt in 2016 to 220 Mt in 2020, equivalent to 20.7% of total crude steel production, and replacing 410 Mt of iron ore consumption (BIR, 2021). This share of scrap in steel production is still limited compared to the 45% in advanced economies (World Steel Association, 2022). The supply of scrap in China is expected to continue to grow rapidly in China, with forecasts of supply varying between roughly 350 to 450 Mt by 2030 (Vercammen et al., 2017; Xuan & Yue, 2016).

2.3 Australia-China trade

Australia and China have a long and close trade relationship in resources for steel making.

Exports of iron ore stand out, in having been dominated by Chinese demand. Growth in export volumes has been due entirely due to growth in Chinese imports (Figure 5). The total value or iron ore exports has typically been close to $100 billion in previous years, but rose to almost $150 billion over 2020–21, on the back of record prices (DISER, 2022). Australian exports of iron ore to China along made up circa 23.5% of all Australian exports to all countries, combined.

Australian exports of coking coal typically bring in about $25 billion per year, and roughly $15 billion a year for thermal coal. Prices for both have spiked over 2021-2022 to about double and triple their usual values, but are expected to quickly return to these levels. Australian exports of both coal varieties are to a more diverse set of consumers, with roughly 20 to 25% of each destined for China. The Chinese import ban has meant that trade in coal with China has fallen to zero since late 2020, however, whilst exports of iron ore have been unaffected.

Seen from the Chinese side, Australia is by far the most important source of iron ore. China sources roughly only 10 to 15% of Its Iron ore form domestic sources (Uren, 2022). About 67% of Chinese iron ore imports are source from Australia, Brazil supplies another 25% (G. Chen, 2021).

For both coking coal and thermal coal, Chinese consumption is predominantly supplied from domestic sources. Of all thermal coal consumed in China, only about 6.5% is imported. Australia supplies approximately 1.5% of all thermal coal consumed in China, Indonesia about 3-4%. Of all metallurgical coal consumed in China, about 9.5% is imported. Australia supplies close to 5% of all metallurgical coal consumed in China, Mongolia currently supplies about 3-4% but is foreseeable increases in supplies to China.

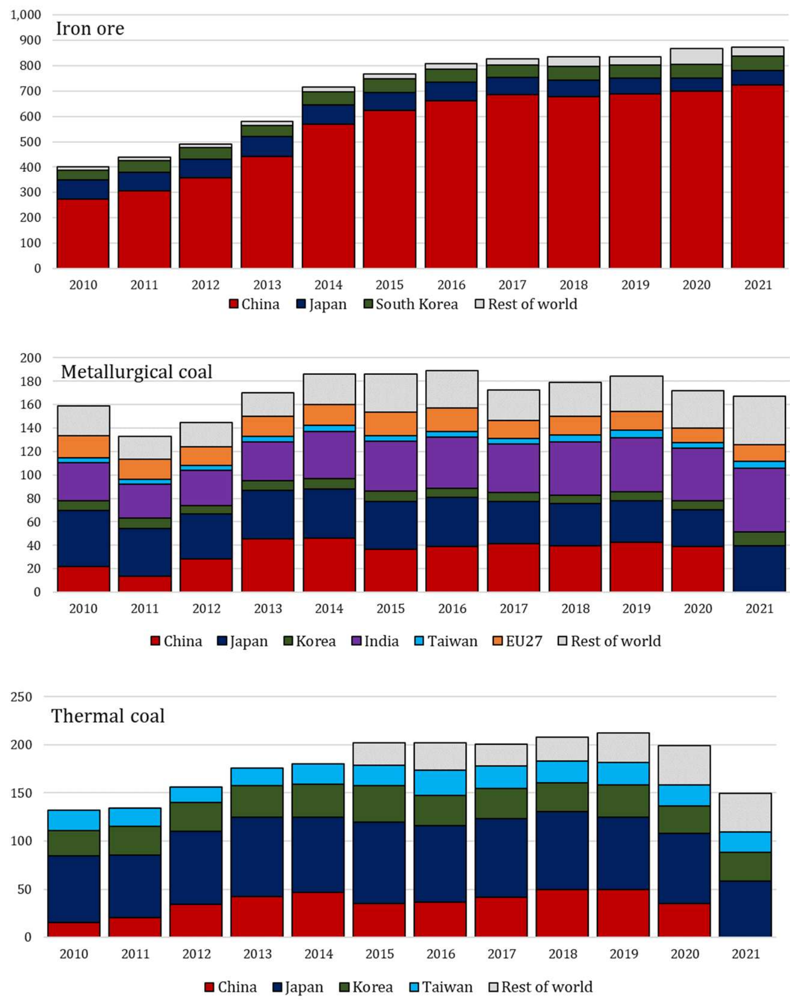

Figure 4. Australian iron ore, metallurgical and thermal coal exports. Source: (DISER, 2022).

3. China's clean and green steel plans

3.1 The 2000's and early 2010's: high-paced, then plateauing growth

The 10th and 11th Five-Year Plan period (2001-2010) saw the fastest development of China's steel industry. During this period, the output of steel enterprise in various forms of enterprise ownership, including state-owned, private and foreign-owned, grew in tandem with the national economy (Zhou, Li, & Yan, 2021). The industry was still plagued with problems such as a relatively low grade of steel product, fragmented organisation of the steel industry, and a large share of backward steel production capacity (MIIT, 2011). The high-paced growth and inefficient modes of production drove strong increases in total energy consumption and emissions of the steel industry over this period.

Over the '12th Five-Year Plan' (2011-2015) period, the growth in crude steel production started to slow substantially, peaking at 823 Mt in 2014. Energy efficiency and conservation efforts in the industry started to have a clear effect: energy consumption fell by 24.5% per unit of value added, exceeding the target of the government's plan for industrial energy conservation of a 6% reduction in energy consumption per unit of GDP (Reuters, 2015).

Large differences remain, whoever, in attention to energy saving in the management of the large number of different Chinese steel enterprises. There is also a big gap between energy-saving technologies such as waste heat recovery from rising pipes, coke oven coal wetting, steel slag waste heat utilization in China, compared to levels seen in advanced countries (Hao & Shang, 2017).

In 2015, after an extended period of slow growth, China's crude steel output and consumption actually fell for the first time since 1982 and 1996, respectively. For the first time since China's reform and opening up, large and medium-sized steel enterprises had an overall annual loss (Wang, Pei, Zhang, & Zhao, 2016).

3.2 Recent trends: production peaking, towards a clean transition

The 13th Five-Year Plan (2016-2020) period saw a revival of central government efforts to push up staggering economic growth rates with smokestack Industry stimulus. These drove up output of crude steel from 804 Mt in 2015 to a peak of 1,065 Mt in 2020 (Figure 3). The integrated energy consumption per ton of steel dropped from 572 to 555 kg of standard coal per ton, or by 3.0% over this period, far from enough to offset total output growth (Zhou W. , 2021).

From 2018 onwards, the Ministry of Industry and Information Technology (MIIT) has set 'capacity replacement' rules, stating that any new steel mill could only be built if existing capacity equal to 1.25 times the capacity of the new steel mill would be shuttered. In June of 2021, this 'capacity replacement' rule was increased to 1.5 times the capacity of the new steel mill, for key areas including Beijing, Tianjin, Hebei, the Yangtze River Delta, the Pearl River Delta, and the Fenwei plains areas (MIIT, 2021). These areas are home to the vast majority of China's steel mills, and are simultaneously the key areas identified for air pollution control. The capacity replacement rule does allow new steel mills using electric arc furnaces (EAF) to be built after shuttering an equal capacity of old BF/BOF blast furnaces steelmaking capacity. While the regulation is not explicit, policy makers have explained that new hydrogen-based and non-blast furnace projects such as Corex, Finex, HIsmelt etc, will also need to comply with the capacity replacement requirement (MIIT, 2021).

In 2021, for the first time, the Chinese government went further then limiting production capacity, and proposed to reduce annual production levels of crude steel. Despite being labelled as a very difficult task by the steel industry, the target was nevertheless accomplished on schedule by the end of 2021, with steel production over 2021 down 3% year-on-year, or nearly 30 million tons, to 1,033 Mt. Over Jan-Jun of 2022, national crude steel production was 526 Mt, down 6.5% year-on-year. In April 2022, the NDRC, MIIT and other departments issued a circular on '2022 crude steel production reduction work to be studied and deployed', revealing an ambition to further cut steel production (MIIT & NDRC, 2022).

China is further reducing the production of primary steel, with increased efforts at steel scrap recycling. The Ministry of Industry and Information Technology (MIIT) initially set a target for domestic steel scrap supply at 300 million tonnes by 2025, up from 260 Mt in 2020 (NDRC, 2021). Later, the NDRC announced the 14th Five-Year Plan for the development for a circular economy, which further raised the target for domestic scrap supply to 320 million tonnes by 2025. This increases the share of scrap in total crude steel production from roughly 21% in 2020 to roughly 30% to 35% by 2025, depending on crude steel production levels (NDRC, 2021). China also used to import substantial amounts of scrap steel for recycling, with imports peaking at 13.7 Mt in 2009, before banning scrap imports in 2018, as part of a more general ban on imports of foreign waste streams. As part of the steel sector emissions reduction plans, the ban on steel scrap imports was lifted again in 2021, although scrap imports recovered only to 560 kt so far. The same policy document also allowed imports of green steel (MEE, NDRC et al, 2020). By the end of 2021, there were 584 scrap steel processing plants across China, with an annual processing capacity of about 150 million tons of obsolete scrap, i.e., scrap collected from waste streams of end-of-life products. Approximately a further 100 to 120 Mt of scrap is home and prompt scrap, i.e., generated in steel mills and steel product manufacturing (Vercammen et al., 2017). This means that China has formed an industrialized scrap steel processing and distribution system, with further policy efforts underway to expand and improve efficiency of recycling of steel scrap resources (Liao & Deng, 2022).

Following the 2022 circular on reductions in steel production (Industry Division of NDRC, 2022), the MIIT, NDRC and MEE set targets for 2025, to improve industrial efficiency, smart manufacturing, and improved quality and technology levels to promote a transition to a green and global market-leading steel industry. To achieve these goals, the plan emphasizes increased R&D spending throughout the entire steel industry production chain on technologies such as low-carbon metallurgy and hydrogen metallurgy, and upgrading the steel production capacity. In particular, the plan targets for the share of electric arc furnaces to produce at least 15% of total crude steel production, and improve scrap recycling systems. The plan further targets retrofitting for ultra-low emission of more than 80% of steel production capacity, a reduction of energy intensity of more than 2% per ton of steel, a reduction of water consumption intensity by more than 10%, and to ensure that peak carbon emissions are reached before 2030 (MIIT, NDRC, & MEE, 2022).

A further measure to reduce the output of steel has been the introduction of a tiered electricity tariff for the steel industry, adding approximately 15% to the cost of electricity for large consumers In energy intensive industries, and raising the cost of steel production by an approximate 15 CNY/t (Iron & Steel Association, 2022; MIIT, 2021). The Chinese government has also repeatedly reiterated that the steel industry will be included in the national carbon emissions trading system before 2025 (Zhong, 2022). The costs associated with that will largely depend on the share of emission quota that are provided to industry without charge, or are auctioned and the price of the carbon at that time.

Other policy measures include financial support for companies that shutter production capacity, and green finance to increase financing for low carbon technologies for steel companies such as industrial desulphurisation, denitrification and dust removal (MIIT, 2021; Y. Zhao et al., 2022). For example, the "Implementation Opinions on Creating a Better Development Environment to Support the Healthy Development of Private Energy Conservation and Environmental Protection Enterprises" and the "Green Bond Support Project Catalogue (2021 Edition)" have a number of references to increasing financing support for cleaner steel production technologies. These include industrial desulfurization, denitrification and dust removal transformation, ultra-low emission transformation of iron and steel enterprises, centralized transformation of pollution treatment in parks, clean production transformation of key industries in parks, circular transformation of industrial links in parks and carbon emission trading services.

3.3 Market outlook

For the near future, Chinese emission reductions in the steel sector will mostly be determined by macro-economic policies that stimulate or cool down the construction sector, and the efforts at increasing scrap steel use. The same policies will largely determine demand for iron ore and coking coal. Over the longer term, the growth or reduction in total output of steel, including in China, will be an important factor determining the likelihood of meeting global warming targets (Figure 5).

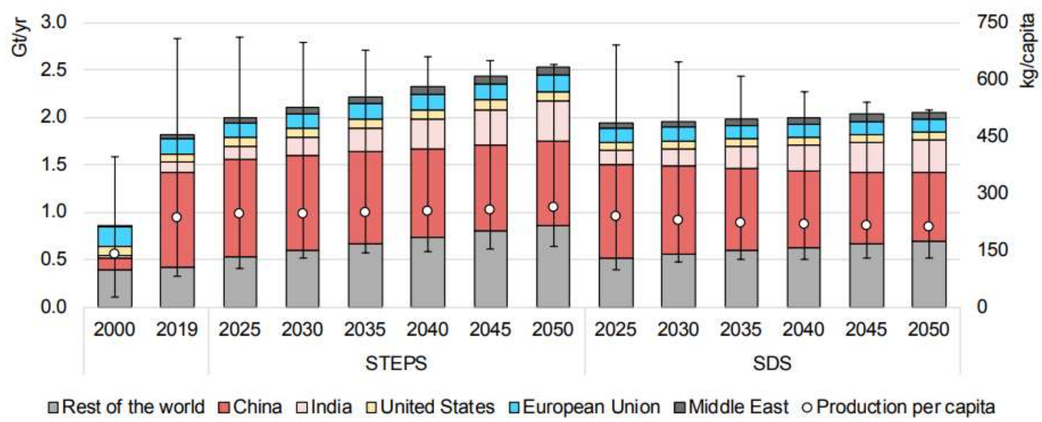

Figure 5. Regional steel production totals, and production per capita in the Stated Policies (STEPS) and Sustainable Development (SDS) Scenarios of the IEA. Source: (IEA, 2020).

Over the near term, there Is already some downward pressure on China's imports of key steel making resources. China's iron ore imports peaked at 1.17 billion ton in 2020, but were down 4.3% to 1.12 billion ton in 2021. The expectation is that iron ore imports will continue to decline to around 1.08 billion tonnes in 2022 on falling steel production and increasing usage of steel scrap (Zhang & Patton, 2022).

Coking coal imports are subject to the same pressures of reducing steel production and increased scrap use. Added to that is opening up of rail lines to the Tavan Tolgoi mining complex in neighbouring Mongolia; a supplier of low cost, high quality coking coal. A rail line providing a connection straight form Mongolia's mines to China's teel making heartland of Hebei with annual capacity of 30 Mt is expected to open In the second half of 2022 (Gosens et al., 2022).

China's plans for reduced levels of steel output, and the low emission production route of increased scrap use are likely to be far bigger emission reduction drivers than the production of green steel, for the foreseeable future. China's development plans for the steel sector, and its hydrogen developments plans, have been relatively quiet on the use of green steel production with hydrogen. These lack quantitative targets for green steel production for now, and refer to hydrogen use in the steel making sector mostly as a priority area for R&D, with actual large-scale application considered a medium to long-term target.

This also matches IEA expectations for the steel making sector even through 2050; where China is assumed to get substantial shares of steel production still from conventional BF-BOF steel making processes, and the largest low emissions production route being scrap fed in to electric arc furnaces (Figure 6). The IEA does note that progress in the steel making sector, globally, is not on track to achieve 'well below 2 degrees' climate goals (IEA, 2020).

Should China make big strides towards hydrogen based steel making, the volumes of hydrogen required would be enormous. Supposing a steel output of roughly 1,000 Mt and roughly half supplied from scrap steel, China would require about 500 Mt of primary steel from hydrogen direct reduction, which would consume roughly 25 Mt of hydrogen. This is also roughly total current production and consumption of conventional fossil-based hydrogen in China's ammonia, methanol and oil refining chemical industry (Zhou, Zhou, & Xu, 2022).

For Chinese policy makers and the steel industry, there are further concerns about stranded assets in such a transformation. The majority of China's BF-BOF equipment is no older than 10-15 years, and only 8 years old on average (He et al., 2020). Replacing this production capacity with electric arc furnaces over a relatively short period will put a huge economic burden on steel production enterprises, at a time of a worsening demand outlook.

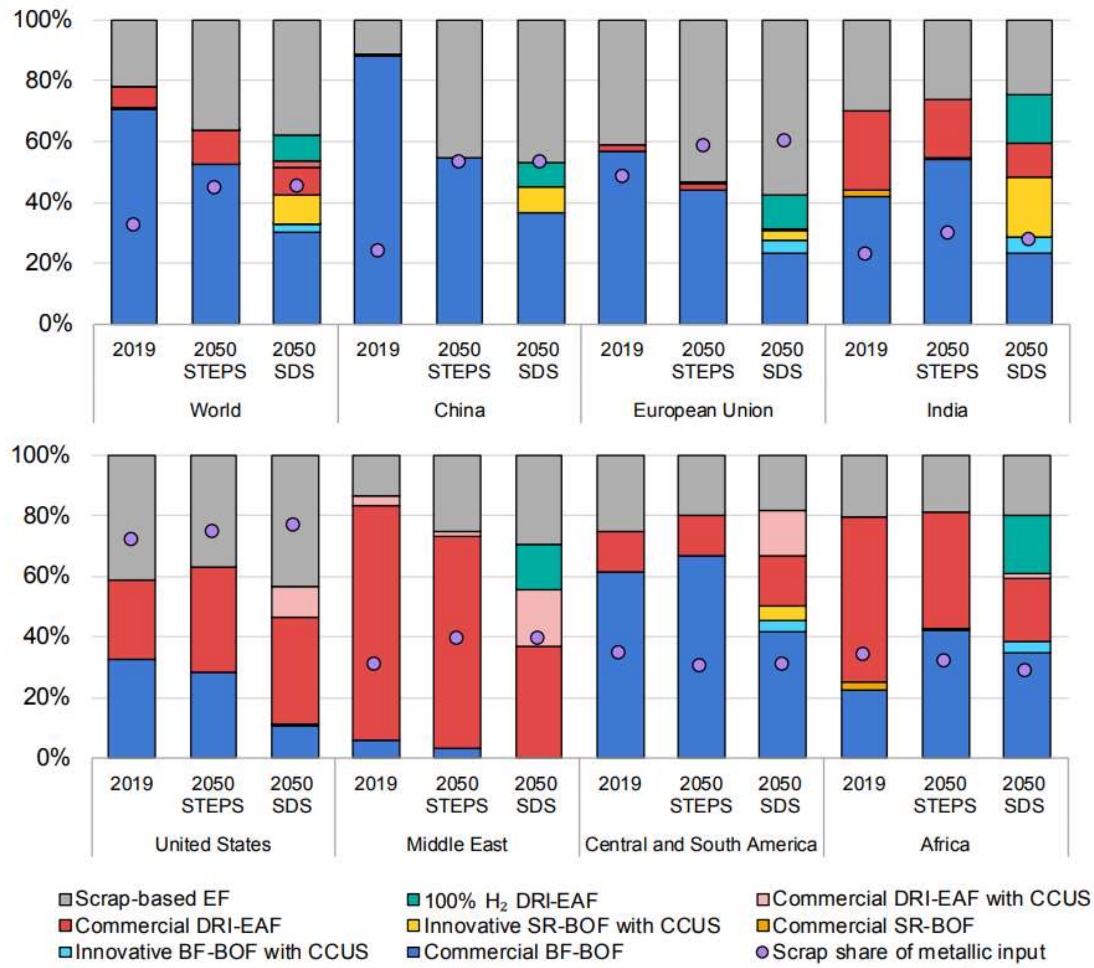

Figure 6. Crude steel production by process route and scenario in major steel-producing regions in the Stated Policies (STEPS) and Sustainable Development (SDS) Scenarios of the IEA. Source: (IEA, 2020).

4. Relevance for Australia

It is difficult to overstate the importance of the Chinese market to Australia's resources exports. Iron ore is Australia's biggest export in total value, and more than 80% of it is destined for China. China is also the destination of about 25% of Australia's exports of coking coal and thermal coal, also substantial export flows.

Recent ANU research modelled the effect of Chinese decarbonization and energy security policies on coal consumption from different suppliers. It found that increasing domestic production, additional mining capacity opening in neighbouring Mongolia, and improved transport infrastructure (rail and ports), are likely to reduce China's demand for seaborne coal imports. The research forecasts a drop of 25 to 45% percent in Chinese imports of Australian thermal coal by 2025, compared to 2019 levels, depending on the level of ambition in China's decarbonization policy. For coking coal, the expected reduction would be 25 to 30%, over the same period (Gosens et al., 2022).

For iron ore imports, much uncertainty remains on the likely level of demand for steel, driven largely by Chinese macro-economic policy for smokestack industry and construction sector stimulus. Despite plateauing steel production in recent years and the strong Chinese policy commitment to increase scrap recycling, DISER remains fairly optimistic in its Resources and Energy Quarterly, suggesting Chinese iron ore imports will remain roughly flat for the next five years, whilst Australian output will rise on the back of new mining capacity. The REQ does note that prices will return to pre-crisis levels, and keep falling from there (DISER, 2022).

In the field of green steel making, and other zero-carbon commodity exports, Australia has a strong position to become supplier of resources to the region. This includes a continued role to supply iron ore and of green hydrogen. Alternatively, that iron ore may be processed into green iron in Australia, or even into steel, using the co-located excellent renewable energy resources available In the Pillbara (Burke et al., 2022; Venkataraman et al., 2022).

There are also concerns, however, about the suitability of Australia, and other suppliers', iron ore for use in Hydrogen Direct Reduction processes. First, these processes typically demand iron ore with high concentrations of iron, ideally of 67% or more (IEEFA, 2022). Such high quality ores make up only a few percent of current global production, with Australia being one of the suppliers. There are processes to improve the quality of iron ores, to increase iron ore content and to reduce impurities. One of the economic processes is through crushing and magnetic separation, which requires iron ore of the magnetite variant. Magnetite currently makes up approximately only 4% of Australia's production, with larger volumes produced in China, a number of CIS member countries, North America, and India (IEEFA, 2022; Minerals Council of Australia, 2020).

Lastly, China has recently created a new State Owned Enterprise, 'China Mineral Resources Group' that has been put in charge of all of China's imports of iron ore, and of outbound investment. The move has been assessed to be a mechanism to improve China's buying power, including in determining iron ore price setting. The company will also oversee investment in the Simandou iron ore project in Guinea, considered a key route to reducing dependency on Australia as an iron ore supplier (Bloomberg News, 2022). This project would supply very high grade (66-68%) iron ore (Toscano, 2022).

In summary, Australia has good resources and overall prerequisites to supply green iron and possibly green steel to the world including to China, although the quality of ores might require new processing techniques. Whether and to what extent possible future cost advantages and other favourable locational factors in Australia would result in a partial re-location of new investments in the iron and steel industry to Australia, with commensurate adjustments in China, will depend on many factors including strategic considerations in China. The steel making industry carries strong political importance in China, with securitized supply through domestic production, and Chinese policy makers may want to avoid creating significant dependence on imported green steel or green iron in the context of decarbonisation of the steelmaking industry.

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