ACCELERATING EAST ASIAN CORPORATE CLIMATE ACTION

THE CHINESE ALUMINIUM SECTOR:

CHALLENGES AND OPPORTUNITIES FOR DECARBONISATION

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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 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 to learn more.

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INTRODUCTION

The full decarbonisation of the aluminium sector in China could remove 5% of the country's total GHG emissions. This has wider impacts on China's climate goals as aluminium is the preferred material used in high growth sectors such as Electric Vehicles (EVs) and renewable energies infrastructure. With China leading in the mentioned downstream sectors globally, unless this sector is decarbonised, future emissions could increase.

Emissions from aluminium production largely emerge from the smelting process which depends heavily on coal fired power. In China, this is not only about coal power leading the grid electricity mix but the use of captive coal power plants that power the aluminium industry in coal rich regions. This paper provides provincial level analysis regarding emissions from both sources and highlights challenges for decarbonisation respectively. It also stresses that potential decarbonisation pathways rely on increasing renewable energy consumption and increasing scrap utilisation.

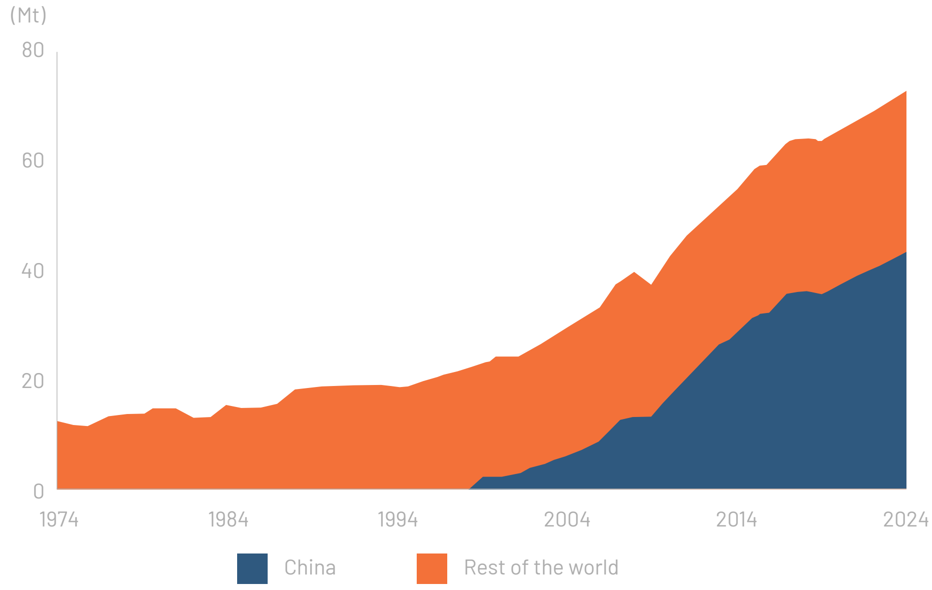
Challenges in decarbonising the sector persist, but policy signals are starting to guide the industry towards a lower-carbon future. Trade protectionism can be a boon for low carbon production, while the green transition policies set quantitative targets requiring more integration of renewable energy in the sector and forbid captive coal plants expansion. If implemented effectively and consistently, the Chinese ETS which covers both the power sector and aluminium sector, could become the most impactful decarbonisation policy measure.

By evaluating these intertwined dynamics, this paper provides an overview of China aluminium industry and outlines potential challenges and opportunities in the path to a low carbon future.

A HISTORICAL DEVELOPMENT OF CHINA'S ALUMINIUM INDUSTRY

China is the largest producer and consumer of aluminium today, accounting for around 60% of global production. In 2024, China produced more than 40 mt electrolytic aluminium growing from a modest production of 10 tonnes in 1949, the aluminium industry in China has undergone significant transformation in the past 70 years (figure 1).

Figure 1. Primary Aluminium Production in China and Rest of the World, 1974–2024



Source: IAI, TA analysis

After 1949, China prioritised heavy industry, designating aluminium as a key sector under the Ministry of Metallurgical Industry. The First Five-Year Plan (1953–1957) saw the establishment of China's first alumina refinery, in Shandong and electrolytic aluminium plant, in Fushun, laying the industry's foundation. By 1956, the first aluminium processing facility, theNortheast Light Alloy Plant was operational.[1]

In the 1960s, the "Third Front" strategy drove aluminium expansion, relocating plants westward for national defense. Smelters like Guizhou and Qingtongxia, along with processing plants, formed a comprehensive aluminium industry.[2]

Reforms in the late 1970s accelerated growth, leading to industry expansion and modernisation. The 1983 restructuring created the China Nonferrous Metal Industry Corporation, driving new refineries in regions such as Shanxi and Zhongzhou, as well as smelters in Yunnan and Baiyin.[3] [4] Post-1992 reforms introduced a market-driven corporate system, culminating in the 1998 establishment of the National Bureau of Nonferrous Metals Industry and advancements in electrolytic cell technology.[5]

In the 21st century, economic growth raised the average GDP growth to 8%.[6] China's aluminium sector entered into exponential expansion. Domestically the industry was driven by the real-estate investment boom. With electricity prices already low compared to other countries, largely due to coal reserves and additional favourable electricity rates provided by the local government, aluminium smelters have gained significant cost advantages, driving the growth of the industry. The aluminium sector also benefitted from a number of financial incentives such as concessionary rates on loans and tax rebates on exports as the government has sought to expand this strategically important industry. Joining WTO in 2001 offered special opportunities for companies to expand overseas, China has been the net exporter of aluminium semis and manufactured products ever since.

In this period, a number of dominant players have emerged as the industry has consolidated. These players have shifted to vertical integration of operations and developed overseas strategy, SOEs led mergers with government backed finance have acquired smaller players under the strict capacity compliance and increasing regulation. Today, a number of companies dominate the aluminum sector, China Aluminium Corporation (Chinalco), Hongqiao Group, Shandong Xinfa Aluminium Group (Xinfa Group), East Hope Group and Inner Mongolia Huomei Hongjun Aluminium & Electricity (Huomei) lead the market. Chinalco is a state owned enterprise, also the largest aluminium company in the world. Established in 2001, it went public overseas and expanded business in 9 provinces in China. It also acquired Yunnan Aluminium, the third-largest aluminium company in China reaffirming its top position. Hongqiao Group is a privately-owned company. Hongqiao Group developed into the second largest player in the Chinese aluminium industry by securing lower electricity prices from own-built grid and captive thermal power plants in the coal rich provinces of the North East of China. Xinfa, East Hope and Huomei started their business in thermal power plants, making use of the coal rich provinces of China, leveraging this for Aluminium production.

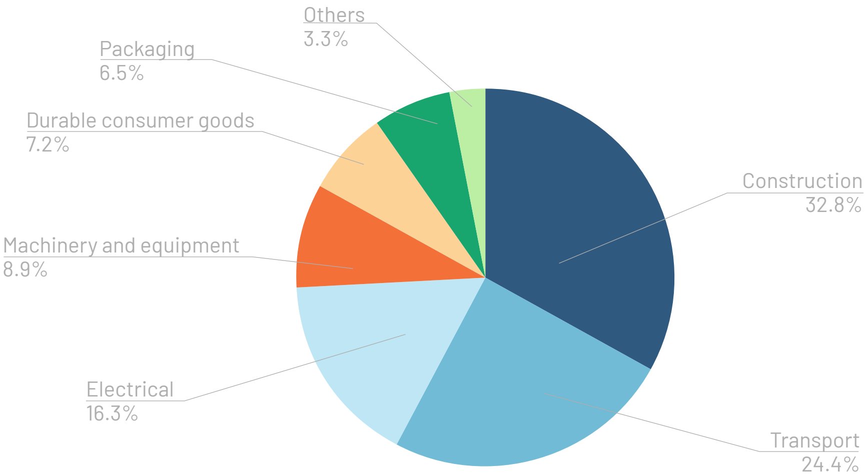
ALUMINIUM DEMAND SHIFTS TOWARD AUTOMOTIVE AND RENEWABLE SECTORS

In China, aluminium is widely used in the construction, transport, electrical sector and packaging. In 2023, the construction sector consumed most aluminium products, contributing 33% of the total aluminium demand. However, as the property crisis dampens the pace of new construction, the transport sector has gained momentum, now accounting for 25% of total aluminium demand. Aluminium's unique characteristics, such as its lightweight, durability and metal stability, are driving its growing use and replacing steel in key structural components in the transport sector.

In the transport sector, aluminium alloys are used for high-speed trains traveling at speeds over 300 km/h. And with train carriages travelling over 350 km/h, almost all components are made entirely from aluminium alloy, except for the chassis. The Chinese high-speed rail network will continue the momentum of high aluminium demand with plans to reach 60,000 kilometers by 2030. The continuous growth in EVs sales and the trend towards lightweighting EVs in China is expected to further stimulate aluminium demand in the near future. Electric vehicles require significantly more aluminium than traditional internal combustion engine vehicles. In vehicle structures, aluminium can reduce weight while maintaining durability. In battery housing, aluminium is an optimal choice being lightweight and having good thermal conductivity.

The electrical sector is the second fastest growing sector following transport contributing 16% of current demand. The rapid expansion of renewable energy sources, particularly solar photovoltaic (PV) and wind power, is driving a forecast fivefold increase in aluminium demand by 2035.[7] Aluminium is widely used in Solar PV modules, mounting structures especially for distributed solar PV, inverters and cells, as well as in wind turbines, including the nacelle, internal components and external facilities. It is also an ideal material for power transmission and distribution cables for its excellent conductivity. To accommodate the increasing power generation sources, both transmission and distribution grids need expansion and replacement. According to IEA projections, transmission and distribution grid lengths are expected to reach 1.5 times the 2021 level by 2030 and triple by 2050.[8]

Figure 2. Aluminium Consumption in China, 2023



Source: Bloomberg, TA analysis

HIGH RELIANCE ON IMPORTED RAW MATERIAL—BAUXITE

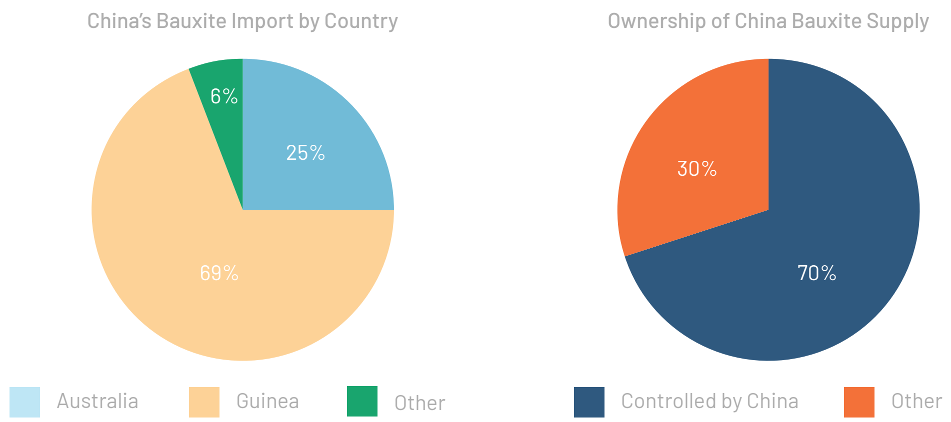
China has high reliance on imported bauxite as it owns only 2% of global bauxite reserves. Being the world's largest importer of bauxite, China's import is almost twice its 2023 production and mainly comes from Guinea and Australia. Domestically, bauxite reserves are concentrated in the provinces of Shanxi, Henan, Guangxi and Guizhou. Most of the mines are composed of lower-quality monohydrate bauxite except Guangxi where higher quality bauxite, gibbsite, has a higher share. The declining quality and reserves of domestic bauxite plus stricter safety and environmental regulations have slowed the approval and development of mining projects in recent years.

Subsequently, China has been encouraging enterprises to invest overseas since 2000 when the "Go Out" policy was announced. Specific policy supports for bauxite import to secure reserves include zero tariffs and overarching strategies encouraging international cooperation in bauxite mining, such as the Work plan for stabilizing growth in the nonferrous metals industry and The National Mineral Resources Plan.[9 10] The Chinese government also encourages domestic refineries to sign long-term contracts with overseas suppliers.

Historically, China's import of bauxite has been distributed across a number of countries with Southeast Asian and Australian mines providing the majority of Bauxite. In 2015 Malaysia was China's top bauxite trading partner, but the partnership abruptly stopped due to environmental considerations, notably at the Kuantan mine.[11] Since then, China's bauxite trade has become markedly more consolidated. Guinea has become China's biggest bauxite trading partner, together with Australia, contributing 94% of China's total bauxite import in 2024. Indonesia ranked as the third top exporter before the mining ban issued in 2023.[12]

Chinese aluminium companies have developed a strategic investment in Guinean bauxite mines and now, China imports the majority of its bauxite reserves from the West African country. This trade in 2022 reached 70 mt which equates to 82% of Guinea's total bauxite exports.[13] Chinese companies have a significant presence in Guinea's bauxite mining sector, by 2023, at least 70% of total bauxite imported from Guinea comes from Chinese companies or Sino-foreign consortiums. The history can be traced back to 2007 when China Henan International Cooperation Group first joined the market, followed by Chinalco in 2011 and Winning Consortium SMB in 2014. Those companies remain the key players in Guinea's bauxite mining scheme.

Figure 3. China's Sources of Bauxite and % of Bauxite Supply under Chinese Control, 2024



Source: China custom data, public information and TA analysis

Australia, China's second largest importing source of bauxite ore, reached USD 1.5 billion in trade value in 2022. Australia's bauxite exports are highly exposed to Chinese demand with 98% of total bauxite exports flowing to China.[14] Australia started bauxite mining in 1963 and has been expanding to be the world's largest bauxite producer today under government support.[15] Today, there are currently 6 bauxite mines in Australia and they are all owned by Australian companies.[16]

ALUMINIUM PRODUCTS: IMPORTS AND EXPORTS

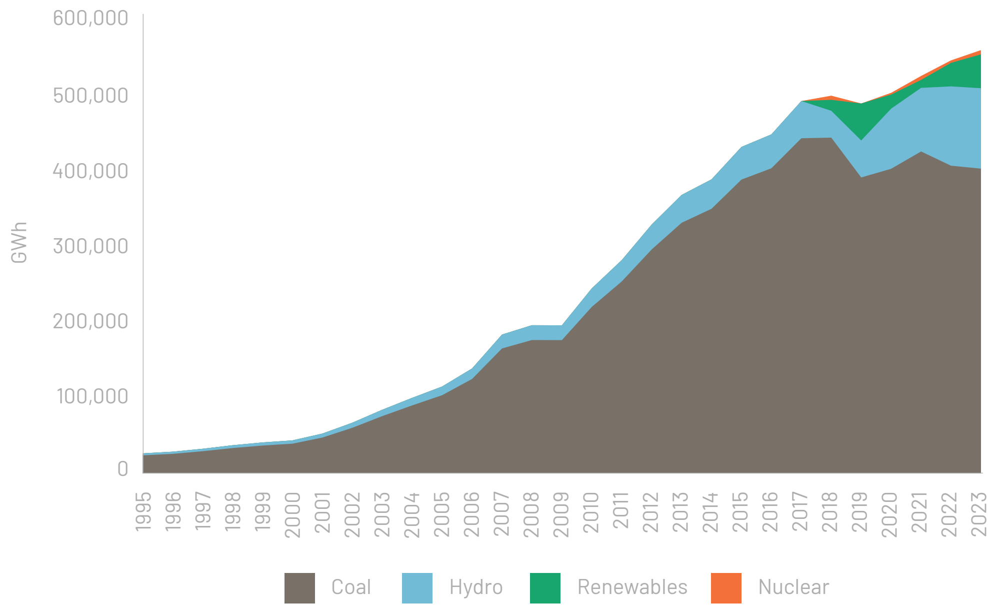
In trade, aluminium products are primarily exported whilst imports are mainly focused on primary aluminium and scrap. Russia has been an important source of primary aluminium and surpassed India in 2022 to become China's main source of imported aluminium, constituting more than 50% of total primary aluminium imports in 2024. India used to be a main source until a sharp shut down due to custom policy conflict.[17] Scrap imports account for around 20% of total scrap supply over the past 10 years and there has been an increasing trend of imports from other Asian countries such as Malaysia, Thailand and Japan in recent years.[18] Historically, the US was the dominant source for imported scrap until Malaysia took over in 2020. Ever since, Malaysia remains the biggest source for scrap imports, accounting for 24% of total scrap imports in 2024.

China is the world's largest exporter of aluminium products, including both semis and finished products. In 2024, China exported around 6 mt of semi-manufactured products and around 3 mt of manufactured products, together they accounted for 22% of total domestic primary production. As a leading aluminium manufacturing country, China exports varied types of semis such as Aluminium sheet rolls, aluminium foil, aluminium strips and profiles. Exporting destinations are not as concentrated as primary aluminium, especially after 2017 when trade disagreements triggered the significant decline of exports to the US. Ever since, products have been mainly shipped to Mexico, South Korea, Southeast Asia and India.[19] Similarly, the exports of finished products are also relatively distributed. The US has remained the main destination for finished aluminium products ranging between 10% to 20% of total manufactured product exports over the past ten years.

PRIMARY ALUMINIUM EMISSIONS

Aluminium making process is highly energy intensive largely due to huge electricity required by the electrolytic process. The smelting process alone accounts for 3% of world electricity demand and 7% of that in China in 2023, a demand higher than the electricity generation of countries such as France and Germany.[20] [21] In China, coal has been the dominant power source for this process since the emergence of the industry. The abundant availability of domestic coal resources provided cost advantages relative to other fossil fuels and the logistical convenience of transportation have firmly established coal as a dominant energy source, not only within China's electricity generation mix but also as the preferred option for aluminium plant operators. Hydropower is the second largest energy source and has rapidly increased in share since 2018 when Chinese aluminium companies started to use more hydropower for smelting. Notably, this benefited hydro-rich provinces such as Yunnan and Sichuan. From 2018 to 2023, use of hydropower for smelting increased threefold, however, the share of this zero emission energy still remains low compared to coal. In the same period, renewables sources, solar and wind began to assume an increasing role in the electricity mix and pushed down the coal power share at the same time. Renewable energy such as solar PV and wind only began to power smelters after 2017 and has since squeezed the share for coal power usage. Aluminium companies have recently started to invest in captive renewables plants. By 2024, at least 17 aluminium companies owned distributed solar PV systems and 3 companies owned wind farms.[22]

Figure 4. Primary Aluminium Smelting Power Consumption in China, 1995–2023



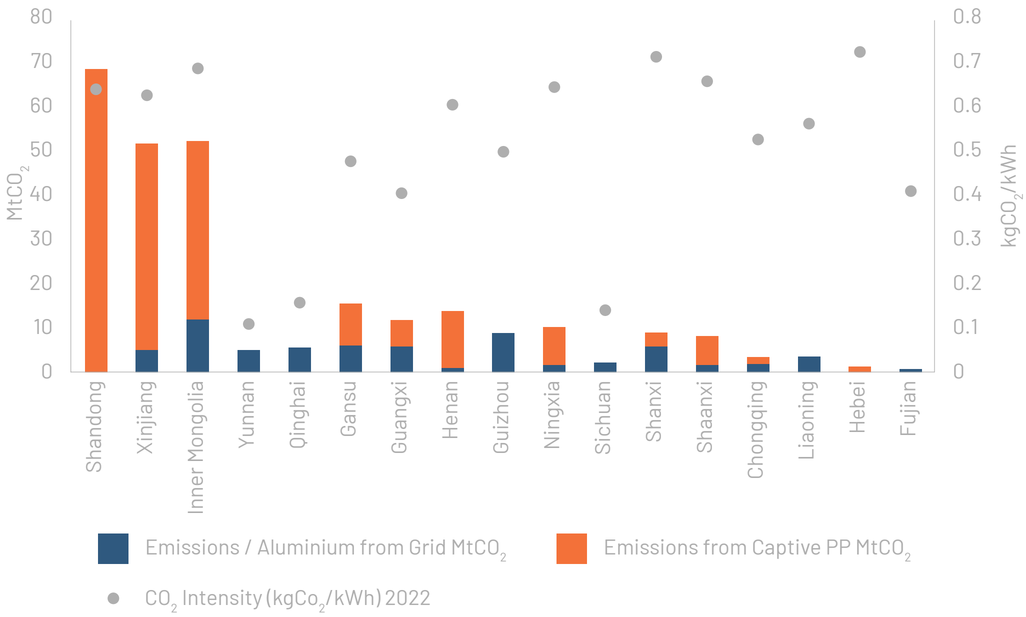
Source: IAI, TA analysis

In China, aluminium production and emissions are concentrated in Shandong, Xinjiang, Inner Mongolia and Yunnan provinces, accounting for 60% of total production in 2021. Shandong, with its advantageous port infrastructure, self-supplied electricity holds the largest share of electrolytic aluminium capacity nationwide. Xinjiang and Inner Mongolia, endowed with abundant coal resources, rank second and third in terms of domestic production capacity, respectively. This high concentration in production coupled with relatively high provincial grid intensity poses great challenges in decarbonisation. The average grid emission intensity in the top 3 production provinces reached 0.65 kg CO_2/kWh, exceeding the national average by 0.1 and 6 times higher than Yunnan where grid electricity is the cleanest.

Provinces that are lower in production but high in total emissions such as Henan, Ningxia, Shanxi and Shaanxi also share the same problem. Even if recent deployment of renewable capacity is catching up, coal is still dominating the electricity generation in the grid. For both cases, solutions have been laid in moving capacity to the southwest regions where hydropower dominates grid electricity.

The southwestern region of China, with minimal emissions associated thanks to its rich hydropower resources, has indeed increasingly attracted electrolytic aluminium production capacity with minimal emissions. In the past 6 years, production in Yunnan provinces tripled. The second largest aluminium company in China has also clearly stated in its annual report to transfer capacity from Shandong to Yunnan provinces. By 2022, of the 6.46 million tonnes of compliant electrolytic aluminium capacity held by Weiqiao Chuangye Group (the parent company of Hongqiao Group), approximately 4 million tonnes have been relocated to Yunnan Province for the development of hydropower-based aluminium production.[23] Unfortunately, hydropower in China's south has not been the easy solution for aluminium decarbonisation. As many industries transferred operations to Yunnan sharing limited hydrosources plus the frequent droughts in the southeast, the hydropower supply has become unstable, making electricity shortages increasingly prominent. During the dry seasons of 2022 and 2023, electrolytic aluminium companies were forced to reduce or halt production multiple times, exposing the vulnerability of Yunnan's power supply. Furthermore, Yunnan prioritises electricity use to meet essential public needs, such as residential and agricultural use. All these factors put power supply for high-energy-consuming industries including electrolytic aluminium under great uncertainty.

Figure 5. Emissions by Types Based on 2021 Provincial Production and Correspondent Grid CO_2 Intensity in 2022



Note: Provinces in the x-axis are in descending order based on 2021 production from left to right

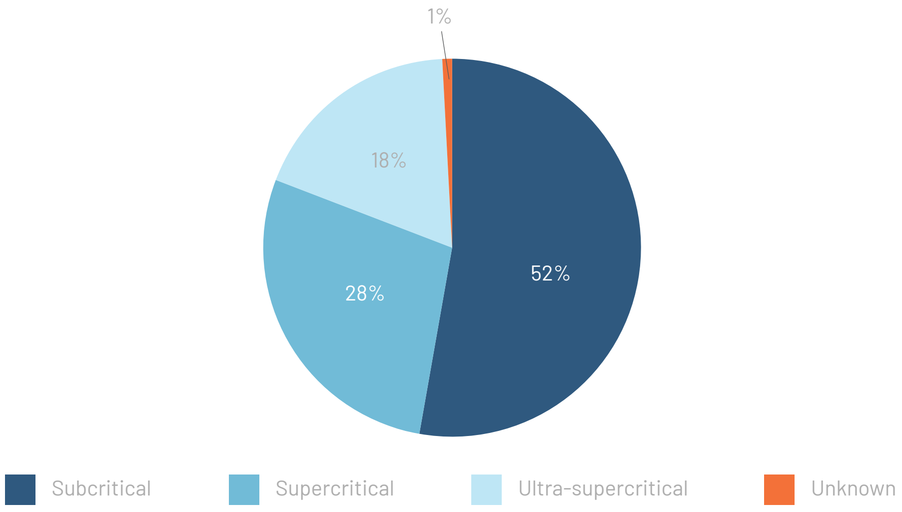
Source: MEE[24], Tan et al., 2025[25], TA analysis

Captive coal power plants remain a strong headwind for aluminium sector decarbonisation in China. Those plants, for a long time, helped to secure electricity supply and minimise electricity cost, lower than subsidised grid tariffs.

Currently, in China, more than 80GW of captive coal power plants are still in use, accounting for 7% of total coal capacity installed in China. In 2021, captive coal plants were responsible for approximately 75% of the greenhouse gas emissions generated by electricity consumption in aluminium smelting in 2021. In provinces where both captive plants and grid electricity are used, captive plants' emissions intensity are up to three times higher than that of local grids. In Shandong, Xinjiang and Inner Mongolia which has the most captive power production, the utilisation of captive plants is so high that grid electricity is not needed.

In 2021, more than 50% of captive capacity built for aluminium production was still based on inefficient, subcritical combustion technology. Most capacities were built in Shandong and owned by Hongqiao Group. Moreover, subcritical coal power plants were still being constructed as late as 2020, particularly in regions with abundant coal resources such as inner Mongolia.

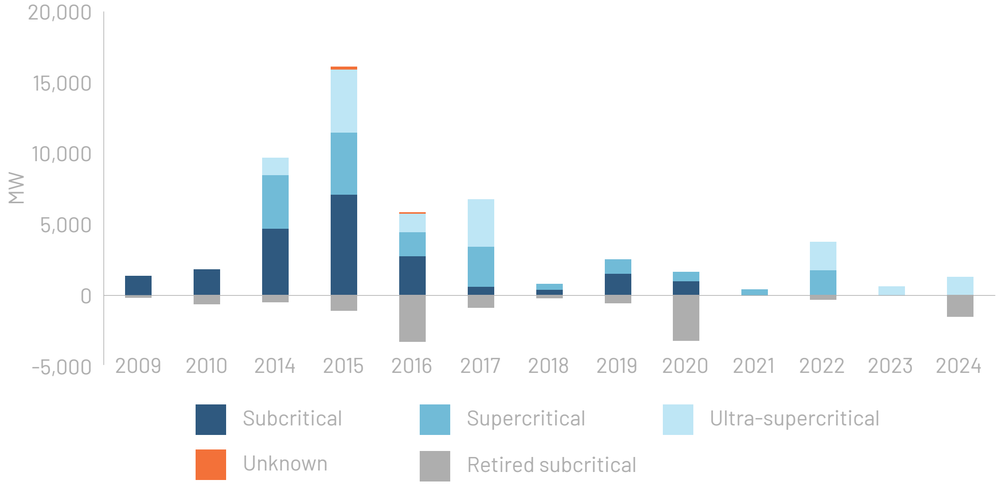
Figure 6. Share of Different Type of Generators Used in Captive Coal Power Plants in China, 2021



Source: GEM, Tan et al., 2025[26], TA analysis

Over the past 15 years, the majority of power plants added have been supercritical and ultra-supercritical generators, totaling around 27 GW whilst captive subcritical coal have been steadily retired in the past 5 years. Supercritical and ultra-supercritical technologies have been favoured due to their higher efficiency and lower emission intensity compared to subcritical plants. On average, subcritical coal plants emit around 800–850 gCO_2/kWh while supercritical coal plants emit approximately 750–800 gCO_2/kWh and ultra-supercritical plants emit around 700–750 gCO_2/kWh.[27] With only two coal fired power plants globally having CCS units attached, with controversial efficacy, coal power plants can not achieve decarbonisation goals and they are embedded with future costs triggered by ETS's inclusion of aluminium sector.

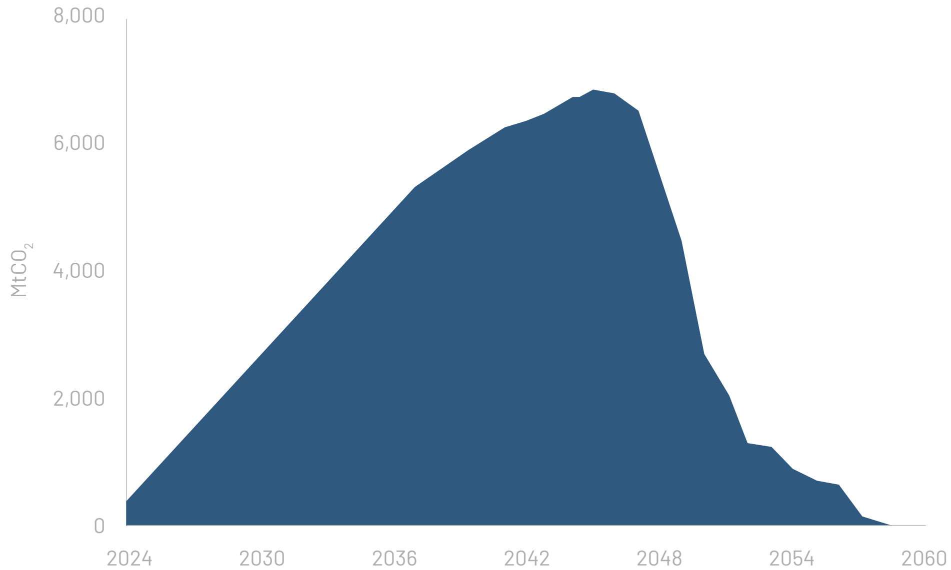
Figure 7. Capacity Addition by Captive Coal Plants Type and Retirement of Captive Subcritical Coal Power Plants in China, 2009–24



Source: GEM, TA analysis

There are signs of change from both authorities and aluminium companies as China continues to advance its "dual carbon" targets. Local governments are actively promoting the development of wind and solar resources, transitioning from coal-based power generation to renewable energy and transforming regions such as the Horinger area in Inner Mongolia. Originally relying on its rich coal resources to develop a coal-electricity-aluminium industrial cluster, the region is now shifting toward becoming a "green-electricity-aluminium" hub. By the end of 2025, the region will have 6 GW installed capacity of renewable energy solely for local consumption.[28] As of 2023, clean energy share reached 27% in China's electrolytic aluminium industry.The aluminium industry's green electricity projects witnessed material growth, with several major aluminium companies announcing the successful integration of Solar PV projects into the grid. For instance, Yunnan Aluminium has launched 175.4 MW distributed PV projects across six industrial parks.[29] Additionally, Inner Mongolia Jinlian Aluminium and Henan's Yulian Industrial Park have completed solar PV projects of 80 and 40 MW separately.[30]

Figure 8. Total Cumulative Lock-in Emissions from Captive Coal Power Plants in China, 2024–60



Source: GEM, TA analysis

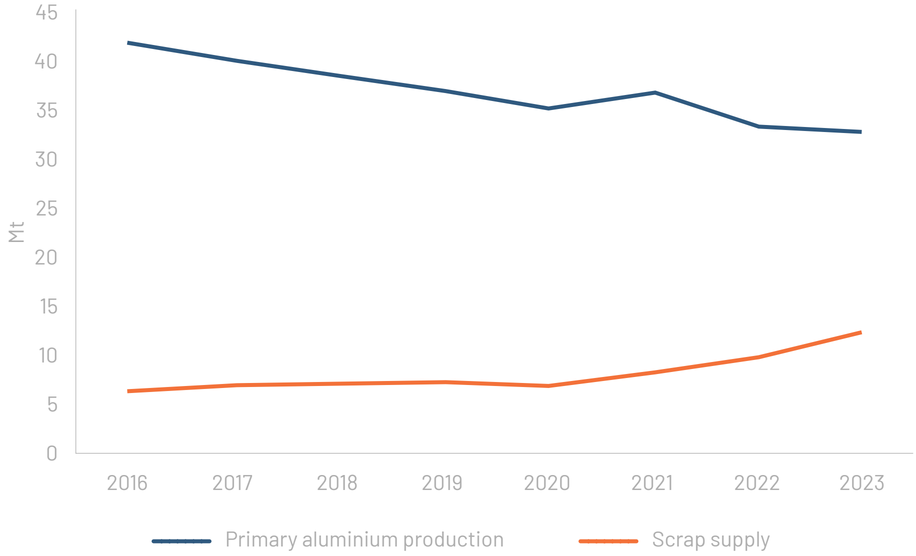
While expanding renewable energy sources, captive coal power plants should be gradually phased out, to reduce risks of locked-in CO_2 emissions in the next 35 years. In China, most captive plants are relatively young and still have 20–30 years of remaining lifetime. If existing plants continue to operate at current levels and without effective carbon capture utilisation and storage (CCUS) retrofits or co-firing with low-emissions fuels over the rest of their technical lifetime, 9.5 billion tonnes of CO_2 emissions could be emitted from 2024 to 2060, which is almost 18 times the sectoral emission in China 2023. Captive plants emission will continue to grow and peak only by 2045 at around 6.9 billion tonnes of CO_2, almost 5 times the total CO_2 emissions that China needs to reduce in 10 years according to its NDC target.[31]

EMISSIONS FROM SCRAP BASED ALUMINIUM

Aluminium scrap has a significant role in the sector's decarbonisation. Producing aluminium from scrap needs only 5% of the energy required to produce aluminium from bauxite ore, a total saving of 95%.[32] Scrap can be recycled from various stages from final products, semis production and foundries, extruders, or rolling mills. Scrap from final products are commonly known as old scrap or post-consumer scrap which arise from the disposal of products such as cans or window frames after being used. Scrap from semis production is new scrap which is generated during the production of final product from semis. Those generated from foundries, extruders or rolling mills are internal scrap which typically has internal scrap loop processes. As scrap originates from different aluminium alloys, it can contain different alloying elements in different amounts which requires various pretreatments and poses challenges to obtain the targeted alloy composition required by final products. The common procedure for scrap to be recycled after collection includes comminution, sorting and heat treatment to gain higher quality scrap, remelting to produce wrought alloys mainly from clean and sorted wrought alloy scrap, refining to add alloy elements and remove undesired elements to obtain the desired alloy composition, casting into ingots then to final products.

Secondary aluminium supply in China has steadily increased in the past 10 years and accelerated since 2022 exceeding 10 mt in 2023. Around 80% of scrap is domestically supplied. However due to high levels of primary production, the share of secondary supply as a percentage of total supply in the same period has averaged around 20% over the same period. Historically, this rate, i.e. aluminium recycled input rate (RIR) has averaged 35%worldwide.[33] As aluminium recycling is a young business in China, only in recent years has the RIR exceeded 20% rising to nearly 30% in 2023. However, China has huge potential for long term secondary supply in the future as by 2023 China's aluminium reserves reached 480 mt and the gap between primary production and secondary production (figure. 11) implies abundant incoming supply. Moreover, as domestic products enter into the recycling circle the supply share of domestic scrap aluminium is expected to further increase. In general, the transport sector is the biggest source of aluminium scrap in China accounting for around 41% with an average lifetime of 8 to 20 years.[34] The construction sector is the second largest source accounting for 34% of the total recycle sources with a lifetime of 30–50 years followed by packaging at around 21%. For vehicles and building materials, scrap recycle rates can achieve 90%.

Figure 9. Primary Aluminium Production vs Aluminium Scrap Supply in China, 2016–23



Source: NBS, Report of Recycled Resources of China, 2016–23, TA analysis

Scrap emissions in China are very low. According to a life-cycle study in China, the GHG emissions of recycled aluminium production is only 4.45% of the primary aluminium, which is around 657 kg CO_2-eq/t Al scrap. The average energy consumption per tonne of recycled aluminium is about 9,207 MJ/t, which is only 6% of primary aluminium. In terms of share breakdown, smelting is where most energy consumption comes from exceeding 50% followed by scrap pretreatment at around 18%. For pretreatment, large recycling companies usually have more advanced equipment and more effective techniques. For example, major companies use magnetic separators to remove iron, while small companies in China separate waste iron using human labour.[35]

Natural gas is the main energy source for melting devices, namely rotary furnaces and reverberatory furnaces. The choice of furnaces depends on the quality and quantity of the scrap. Scrap with more impurities, requires the use of rotary furnaces which are usually more expensive than reverberatory furnaces due to inefficiency. Electric furnaces exist but are typically used in small processing operations.

Importantly enterprises tend to use recycled aluminium scrap to produce the same types of aluminium alloys, i.e. wrought scrap for wrought alloy and casting scrap for casting alloy. Wrought alloys are produced by re-melters and are of higher quality than casting alloys. While casting alloys are produced in refineries where additions of alloying elements happen. Wrought scrap can be used to produce casting alloys however, this is not cost effective as wrought scrap is priced higher and has less silicon content which needs to be added back if more wrought scrap is used to make casting alloys.[36] In practice, if the origin or composition of scrap is uncertain, there are two ways to manage it: downgrading, by mixing it with other unknown alloys to reduce the purity of the final product, or dilution, by blending it with primary aluminium to improve purity.

POLICIES ON GREEN TRANSITION, CAPACITY CONTROL, AND ELECTRICITY PRICING

In recent years, China's policy on the electrolytic aluminium industry has great aim at reducing carbon emissions, improving energy efficiency and transitioning to cleaner energy sources. These policies are part of the broader national strategy to achieve the dual carbon goals—peaking carbon emissions by 2030 and achieving carbon neutrality by 2060.

Table 1. Significant National Policies Development Focusing on Green Aluminium

Year	Policy title	Key Note
2024	2024 & 2025 electrolytic aluminium industry's share of green electricity[37]	Target green electricity share in total electricity consumption for electrolytic aluminium industry by provinces: 2024: 21%-70%, 2025: 22%-70%
2024	Action Plan for Energy Conservation and Carbon Reduction in the Electrolytic Aluminium Industry[38]	• No more new smelting capacity in air pollution prevention and control areas. • New additions or expansions need to reach an efficiency benchmark and A level of environmental performance standard. • Phase out outdated low efficient capacity, pre-baked anode aluminium electrolysis cell below 200kA • Theoretically, no additions of captive coal power plants By 2025: • Capacity reach energy efficiency benchmark will be higher than 30%; The proportion of renewable energy usage will exceed 25%; • Recycled aluminium production to reach 11.5 mt 2024-2025: aluminium smelting to save 2.5 mt standard coal, 6.5 mt CO_2 reduction
2024	Energy Conservation and Carbon Reduction Action Plan for 2024-2025[39]	• Optimise the capacity layout of non-ferrous metals. • Strictly implement the capacity replacement for electrolytic aluminium and rigorously control the addition of new smelting capacities for copper, alumina and other metals. By 2025: • The proportion of electrolytic aluminium industry capacity that meets or exceeds energy efficiency benchmark levels will reach 30% • The proportion of renewable energy usage will exceed 25%

Year	Policy title	Key Note
2021	The 14th Five-Year Plan for the Development of the Raw Materials Industry[40]	• By 2025 electrolytic aluminium smelting carbon emissions to reduce 5% • Execution of tiered electricity tariffs for aluminium smelting industry
2021	The Power Sector ETS[41 42 43]	• Introduction of thermal power plants emitting more the 26000tCO_2 into the ETS • Covered entities must use one allowance per tCO_2e emitted for covered emissions, the allocation of allowances is based on an emissions intensity benchmark.

Outside of environmental focused policies, policies regarding manufacturing capacity control and electricity prices have shaped the Chinese aluminium industry. In terms of capacity control, China has undergone a serious reform on the supply side. Historically, the industry was characterised by widespread use of small and low efficient electrolysers, which have since been upgraded and led to production overcapacity. The Chinese government has released a series of policies such as opinions for addressing projects that violated laws or regulation with specific timelines (indicating projects constructed before 2013 or after 2013) and implementation measures for capacity replacement in 2015 to control this issue.[44 45] Early stage effects from these policies produced unsatisfying results with the turning point coming from one specific policy released in 2017. This policy, the "Special Action Plan for illegal and unlawful projects" focused on the electrolytic aluminium industry followed by a detailed notice indicating which are the capacities that can be used for replacement and which should be phased-out.[46] Gradually, pre-baked anode cells with capacities below 200 kA were phased out, as they were deemed too inefficient to meet modern energy and environmental standards. After 2018, aluminium capacity has been relatively fixed due to strict regulation as capacity additions can almost only be realised by offsetting retired or outdated facilities. Manufacturing capacity increased only from around 40 mt in 2018 to 44 mt in 2024.

Policies regarding electricity price and captive coal power plants have had a significant impact on the industry in China. Key milestones include the development of the tiered electricity pricing policy in 2013, no more new captive coal power plants throughout 2018 and an update notice in 2021 on electricity pricing which allows consumption of variable renewables electricity to partially offset electricity price.[47 48] The latter policy also strengthens the enforcement of fee collection and penalties for non-compliance which has added another layer of financial pressure. Companies failing to pay tiered pricing fees on time face penalties of 1.5 times the original fee, restrictions on market participation and potential reputational damage.

To attract companies, local governments used to provide a preferential tariff lower than the grid. For example, in eastern Inner Mongolia, the electricity price for electrolytic aluminium production was 0.05 RMB/kWh, lower than that for other major industrial electricity users. In the western region of Inner Mongolia, it was 0.043 RMB/kWh lower than that for other industrial and commercial electricity users under the two-part price mechanism.[49] This preferential price was cancelled out only in 2018 and was not the only case. In Yunnan province, the local government used to guarantee a lower than grid tariff for aluminium companies. However, after 2021 the preferential tariff was canceled and a tiered pricing system was implemented.[50]

Building captive plants allowed companies to cut electricity costs but these plants bypassed regulations faced by grid based power plants. Dodging cross-subsidies duty was very common and they were notorious for high levels of pollution.[51] It was only until 2018 when a *Special Rectification Plan for Regulating the Construction and Operation of Coal-Fired Self-Generated Power Plant* was released that illegal capacities were closed and construction of own use grid systems was banned.[52] Since then, captive power plants have gradually been converted into public utility power plants and integrated into the national grid management and dispatch system.

CHALLENGES AND OPPORTUNITIES

MEASURES AGAINST GEOPOLITICAL RISKS CAN OFFER OPPORTUNITIES TO DECARBONISATION

The recent US tariff hike on aluminium could accelerate China's decarbonisation efforts by redirecting trade to climate-conscious markets. This policy raised the aluminium tariff to 25% and cancelled tariff exemptions to Canada and Mexico. This would affect around 15% of Chinese aluminium products exports to the US. Those exports can potentially be consumed by countries such as Australia, UK and Southeast Asian countries which are among China's top destinations today and also have mechanisms favourable to decarbonisation. For instance, Australia is reviewing the feasibility of a Carbon Border Adjustment Mechanism (CBAM), Thailand is drafting a climate change bill incorporating CBAM and the UK plans to implement its own CBAM by 2027. These emerging carbon border policies present an opportunity for Chinese aluminium companies with lower carbon footprints to gain a competitive edge when exporting to these markets.

China's domestic bauxite reserves account for just 2.39% of the global total, forcing imports to cover almost 70% of demand.[53] This high reliance on imported bauxite poses trade vulnerability. By 2024, 95% of these imports originated from Guinea and Australia, exposing the industry to supply chain disruptions from geopolitical tensions such as Guinea's political instability or export restrictions. Previous disruptions have occurred when Indonesia issued a mining ban in 2023 and Malaysia stopped mining several times since 2016 due to environmental concerns.

Securing high quality bauxite is key to ensure low emissions from the alumina refining process.[54] The process currently relies on fossil fuels and decarbonisation technologies which have not been proven commercially.[55] High quality bauxite can be refined at lower temperatures and up to 4 times lower energy intensity reducing refining costs and environmental footprints. In China, bauxite quality is declining, with most reserves being low-grade monohydrate ore.

To counter the risk, Chinese firms put around 70% of bauxite resources under its own control, including 80% of Guinea's bauxite exports, i.e., 90 million tonnes annually. This strategy secures sufficient supply, reduces raw material price volatility and production costs, which are crucial for surging demand in China.

Either producing low carbon aluminium or securing high quality bauxite have a spillover effect on the downstream sector especially when China dominates global EV sales and renewables infrastructure deployment. EVs use 30% more aluminium than ICE vehicles, primarily in battery housings and lightweight frames. With China's EV sales hitting 9.5 million units in 2023 (40% of global sales), demand for high-strength alloys could grow 15% annually through 2030. Solar PV frames, wind turbine nacelles and grid expansion will also drive aluminium consumption. The IEA estimates China's grid infrastructure must triple by 2050, requiring 5 million tonnes of aluminium annually for cables and components. In the downstream, corporates also show increasing demand for green products. Solar PV provider Jinkopower has committed to net zero solar PV production and supply, memorandums are signed regarding green electrolytic aluminium and aluminium scrap (e.g. between Brilliance Auto and Henan Shenhuo group, between Volvo and Yunnan aluminium).

THE GREEN ENERGY TRANSITION TREND IS SHIFTING CARBON-INTENSIVE ENERGY STRUCTURE

The aluminium sector accounts for 7% of China's electricity consumption, with coal-fired power dominating smelting operations. Captive coal plants, which account for 6% of total coal capacity installed, exacerbate emissions. These plants, often using outdated subcritical technology, are still relatively new and if unaddressed, could lead to a lock-in emission of 9.5 billion tonnes of CO_2 from 2024 to 2060, derailing China's carbon neutrality goals. Whilst these plants secure stable and low cost electricity they are expensive to retrofit or phase out, making them a persistent challenge.

While grid electricity offers a costlier alternative to cheap captive power, it is not a quick fix if regional grids remain dependent on coal-fired plants. Provinces like Shandong, Xinjiang and Inner Mongolia—responsible for 60% of production—rely on grids with average emissions intensity 25% above the national average. This is due to the high proportion of coal fired power plants delivering power to the grid in those provinces. Hydropower rich provinces with lower grid intensities are no longer an easy option for decarbonisation. Seasonal shortage in rainfall and regular curtailment to industries are expected to remain as the effects of climate change compound.

The aluminium sector needs long term, stable electricity supply from zero carbon sources and this provides the opportunity to integrate power and smelling infrastructure. For example, Inner Mongolia's "Green Electricity-Aluminium" clusters are using wind and solar power to replace coal. Yunnan Aluminium installed 175 MW rooftop solar, cutting costs and emissions. Integrated projects can be effective in securing renewable electricity supply in some regions but to improve nationwide consumption, a unified and well-regulated electricity market regulation is equally important. The introduction of a mid-to-long-term electricity market in 2020 is a promising start enabling companies to secure PPAs from renewable electricity projects. However, as renewable electricity projects have the option of being fully-purchased back by the government securing a constant income, the market has been inactive.[56]

Recently, this renewable electricity offtake solution has been annulled for projects built after June 2025. A contract-for-difference (CfD) mechanism, with auction-based pricing will be enforced instead.[57] Should the electricity reform mature, capacity value and flexibility contribution of renewable plants, especially for those built on industrial sites, can be recognised and their ability in providing grid ancillary services rewarded. While still in transition, China's evolving market structure could provide the ingredients set to improve cost competitiveness for renewables, as long as policies ensuring coal power plants dominance are simultaneously restricted.[58]

Meanwhile, policies continue to add pressure to aluminium companies to increase renewables consumption by setting targets, requiring minimum green electricity use in aluminium smelting. Stricter environmental regulations including tiered electricity pricing and China's ETS are raising costs to coal power usage.[59] Significantly, captive coal power plants expansion is banned and a phase-out of old capacities has begun.

ETS AS A DOUBLE EDGED SWORD

The power sector ETS has already included most of the captive coal power plants that supply the aluminium sector with electricity but its emission mitigation impacts are limited. It theoretically encourages retrofits of current fleets, the use of more efficient combustion technology and the phase-out of small and low efficient coal power plants. But the common perception is that intensity benchmarks are not stringent enough, leading to low trade volumes especially for large electricity companies who have generous allowance. It has also led to trading concentrated around compliance deadlines instead of a more continuous market.

Recently, the aluminium sector was officially included in the ETS. The Aluminium ETS takes into account emissions from all GHGs including CO2, CF4 and C2F6 and counts only direct emissions. The inclusion of the aluminium sector into the ETS will largely impact the emissions occurring from anode effects within the electrolysis. This impacts the shift to more efficient smelters and uncommercialised zero carbon inert anodes, as it is through the industry standard carbon anodes where much of the CF4 and C2F6 emissions are produced. As these emissions are low, in comparison to the electricity used in the smelting stage (covered by the power sector ETS), it is unlikely to be a large driver for aluminium sector decarbonisation. There will be limited immediate impacts as free allowances will be allocated for the first compliance year while only benchmarking intensity in the next 2 years. Indirect emissions from electricity purchased from the grid or captive power plants are excluded as they are already covered by the power sector ETS.

This ETS can be a game-changer for the industry if well designed. After 3 years of power sector implementation, the intensity of thermal power plants did decrease marginally. The reward-penalty mechanism has been established and added carbon cost to companies. Should the regulatory design of the ETS mature, ensuring that low-carbon aluminium production are rewarded for their emissions profiles and, respectively, high-carbon aluminium production penalised, this trend should continue. In the longer term, when stringent benchmarks are set and indirect emissions are included, this policy can act as the most material decarbonisation measure for industrial decarbonisation in China.

Whilst there are regulatory challenges associated with China's ETS that affect its impact on the decarbonisation of the aluminium sector, the framework itself remains to be a gamechanger for the industry.

SCRAP POTENTIAL

The lower than 1tCO_2/t aluminium intensity makes scaling up aluminium recycling a low hanging fruit for aluminium industry decarbonisation. China's scrap aluminium supply has been lower than primary production for a long time leaving large untapped scrap resources for the future. China's historical recycled input rate is lower than the global level averaging at around 20% due to high levels of primary production.[61] A wave of end-of-life vehicles (8–20 year lifespan) and buildings (30–50 years) will further unlock the potential.[62 63] To further spur the scrap potential, an acceleration in scrap recycling is needed together with the scale-up of recycling capacity. Currently, China has around 14 mt of recycling capacity which is 30% of 2024 primary production. Manufacturing capacity can be further improved with more modernised technology as many small companies are still using human labor for sorting. Moreover, the current 2025 11.5 mt policy target falls short of the current capacity. If the market is grown, scrap replacement can be a high impact process to aid the decarbonisation of the aluminium sector in the near term.

ENDNOTES

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