


Asian Insights SparX

Aluminium

DBS Group Research . Equity

29 Jul 2021

Carbon neutrality – opportunity beyond challenges

- Carbon neutrality will compel the aluminium sector to reduce greenhouse gas emissions significantly via various policy measures, including the introduction of EU's carbon tax in 2026 and China's 30/60 plan.
- Due to the high energy density of aluminium products, the sector is en route to decarbonising its energy sources from fossil fuels to renewables and is exploring new technologies to reduce energy consumption and CO2 emissions. The Aluminium Stewardship Initiative certifies companies that are actively reducing their carbon footprint. Less carbon emissions will thus be a critical factor to determine aluminium players' competitiveness in the future.
- The outlook for aluminium demand is bright, backed by rapid urbanisation and higher usage in Electric Vehicles (EVs), while primary aluminium supply growth will decelerate due to push towards carbon neutrality and Chinese restrictions on capacity expansion. This will tighten the aluminium market and lead to better price levels, going forward.
- Despite being a laggard in the carbon neutrality landscape, China Hongqiao harbours great potential to improve its performance in this aspect, following the shift towards hydro power by moving its major plants to Yunnan province. This will drive a re-rating of the stock.

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STOCKS

	Price HK$	Mkt Cap US$m	12-mth Target Price HK$	Performance (%) 3 mth	Performance (%) 12 mth	Rating
China Hongqiao Group	9.46	10,609	16.00	(20.6)	113.1	BUY

Source: DBS Bank, Bloomberg Finance L.P.
Closing price as of 28 Jul 2021

ed: CK/ sa: SS, PY, CS

Contents

Special thanks to Thomas Yoonsoo Choi for his contributions to the report

Investment summary

Carbon neutrality policies are being implemented globally, with EU as the front runner. In particular, the EU Carbon Border Adjustment Mechanism (CBAM) will price in carbon emissions for imported products from 2026 onwards. Under the CBAM, trading is performed via certificates, which are based on direct carbon emissions from the products. From 2026 onwards, importers of high carbon emitting industries must purchase certificates corresponding to the volume of goods and their carbon emissions. In December 2020, the Chinese government announced an enterprising plan to tackle climate change: China's 30/60 plan. According to this roadmap, China will hit its carbon peak by 2030, and achieve carbon neutrality by 2060.

In response to carbon neutrality, the global aluminium industry established the Aluminium Stewardship Initiative (ASI) in 2012. In 2017, the ASI Standards programme was created to enable the aluminium industry to demonstrate environmental responsibility and reinforce downstream industrial users and consumers' confidence in aluminium products. Major players such as Alcoa and Chalco are certified. Its greenhouse emissions standards require any aluminium smelters in production in 2020 to produce less than 8 tonnes of CO2-equivalent per metric tonne of aluminium by 2030.

Aluminium has high energy density and in other words, high carbon density. Among all metals, aluminium production ranks only second behind steel in greenhouse gas emissions, and accounts for 1% of global emissions. On average, one tonne of aluminium requires 75GJ of energy if processed directly from bauxite to primary aluminium, while primary aluminium smelting takes up 69% of total energy consumption. The CO2 emission per tonne of production is 11.5 tonnes for all aluminium products, and 16 tonnes for primary aluminium alone.

To tackle the carbon emission issue, the first step required for the sector is to reduce energy density. In fact, the energy intensity of aluminium production has declined considerably in recent years, largely owing to best available technology deployment in China, which are "raised" NSC Cathode Blocks and new structures for anode and cathode blocks. Going forward, major aluminium players are exploring ways to reduce carbon emissions such as inert anodes, Energia Potior to use more stable renewable energy, and carbon capture and storage.

Another way to reduce energy density and CO2 is secondary production using aluminium scrap. Production with scrap usage of up to 75% reduced CO2 emissions to 2.3 tonnes per tonne of aluminium. Moreover, secondary production using 100% of scrap aluminium emits only 0.5 tonne of CO2 per tonne of aluminium.

However, there is much room for improvement as global primary aluminium production still relies heavily on coal-based energy, c. 60% of energy consumption. This is especially true in China, where 88% of primary aluminium smelting still depends on coal power. In addition, IEA's projection indicates that the LCOE (levelised cost of energy) of Chinese coal power plants will increase by US$27/MWh assuming US$30/t of CO2 emissions vs. zero cost for CO2 and will exceed that of onshore wind power. Consequently, the **decarbonisation of aluminium production is unavoidable and is the way forward for aluminium players.**

The outlook for aluminium demand is brighter, backed by rapid urbanisation and higher usage in EVs. Given its durability, flexibility, lightweight nature, non-corrosiveness, and conductivity, aluminium's scope of applications has been expanding. We expect aluminium demand to grow at a 3.9% CAGR by 2025. In particular, aluminium demand from EVs is projected to grow to 3m tonnes by 2025 and 8m tonnes by 2030 based on 250kg/unit consumption of aluminum in EVs as it is used for battery pack casings. This is equivalent to 12% of total primary aluminium consumption in 2020 and c. 10% of total aluminium demand from a mere 750k tonnes or 0.9% to the total aluminium demand in 2020.

Facing scarcity of bauxite, Chinese aluminium players have invested in overseas mines, especially in Guinea, Africa and integrated their value chains by importing bauxite and producing alumina in China. Thanks to ample projects there and also further development in Indonesia, **we expect bauxite supply to be sufficient to meet demand**. On the other hand, due to the expected c. 30m tonnes of additional alumina capacity to be built by 2025, **the market supply should remain in a surplus for the next few years.**

Meanwhile, primary aluminium supply growth should decelerate due to Chinese restriction on capacity expansion and carbon neutrality. China's new capacity growth will moderate as the government has capped total capacity at 45mtpa (m tonnes per annum) versus 2020's 42mtpa. Aluminium smelters will lose their cost competitiveness due to increasing power cost in line with carbon neutrality, constraining supply. By 2025, global output expansion is expected to reach 2.6% p.a., bolstered by a 3.4% annual growth in China.

This will tighten the aluminium market and lead to better prices going forward. The global aluminium market will remain in a surplus in 2021 and 2022 as new capacity will commence production. This will hinder further price hikes with tightening monetary policies from the US. Accordingly, we expect the average LME aluminium price to decline in 2022. However, we believe aluminium prices will return to an uptrend from 2023 onwards, as the market is expected be in a deficit. The key risk for our forecast would be the stronger growth of aluminium production from scrap to meet demand for primary aluminium.

China Hongqiao is our top pick. Despite the current laggard position in the carbon neutrality landscape, China Hongqiao harbours great potential to improve its performance in this aspect, following the shift towards hydro power by moving major plants to Yunnan province. This will drive a re-rating of the stock. Our top pick is China Hongqiao given i) the integration of its business models from bauxite, alumina, and aluminium operations with captive power supply to support its lucrative margins, and ii) the decarbonisation of energy by moving half of its capacity (3m out of 6.4m tonnes) to Yunnan province, where it would be further equipped with hydropower.

Carbon neutrality initiatives for aluminium sector

EU – frontrunner in carbon neutrality

EU Emission Trading System (ETS) continues to exert influence. In efforts to achieve carbon neutrality by 2050, the EU created the first and largest carbon market – the EU Emissions Trading System (EU ETS), in 2005. Using a cap-and-trade system, the EU ETS sets limits on the total greenhouse emissions that an installation can produce with emission allowances. These emission allowances can be traded between installations that do not use all of their emission allowances with those that are expected to exceed the cap. The EU ETS covers various installation types, from electricity and heat generation to energy-intensive industry sectors such as metal and chemicals.

Currently, it is in its 4th phase which starts from 2021 to 2030, focusing on several key objectives. The fourth phase aims to strengthen the ETS as an investment driver, while also increasing the annual cap reduction to 2.2% annually. Moreover, the ETS will reinforce the Market Stability Reserve, which is a mechanism to reduce surplus emission allowances and improve the ETS' resilience to possible future shocks. And lastly, it will aid the industries in making technological advances and investments for low carbon transitions through its Innovation Fund and Modernisation Fund.

EU Carbon Border Adjustment Mechanism (CBAM) to price carbon emissions for imported products. The European Commission is looking to add the CBAM to tackle carbon leakage, as this will ensure that the price of imports will reflect its carbon emission footprint. Since the EU ETS is implemented only within the EU, the CBAM will potentially stop EU citizens from buying imports that have a high carbon footprint to avoid carbon leakage.

The proposed CBAM will affect the imports of iron and steel, aluminium, cement, organic basic chemicals, fertilisers, and electricity to reduce the risk of carbon leakage. The CBAM transitional phase will take place until the end of 2025, with which gradual introduction will be set against a corresponding reduction of free allowances allocated under the EU ETS.

From 2026, goods importers are required to purchase carbon certificates. The CBAM is based on trading in certificates, which are based on direct carbon emissions from products. From 2026 onwards, the importers of the forementioned industries must purchase certificates corresponding to the volume of goods and carbon emissions of the goods. The price of the certificates will be dependent on the weekly average auction price of EU ETS' allowances in the week prior to purchase. Furthermore, an authorised declarant, an entity that represents one or more importers, must submit an annual declaration of the carbon emissions tied to the goods imported to the EU, with which those figures will be used to determine the number of certificates need to be purchased. However, it is possible to reduce the number of required CBAM certificates if the importer pays a carbon price for those emissions in other jurisdictions.

Considering that the CBAM will currently only account for direct emissions, it is possible that smelters that are powered by coal will pay the same CBAM costs as those powered by hydropower. However, the CBAM proposal mentioned that it could be expanded to cover indirect emissions as well.

Aluminium Stewardship Initiative (ASI)

ASI established by a global major aluminium player. The Aluminium Stewardship Initiative (ASI) has been established to ensure the aluminium sustainability and material stewardship. In 2012, a global group of major stakeholders in the aluminium industry met to find solutions to the most pressing issues facing the sector. The major players have joined as members include Alcoa and CHALCO (for details on the members, please refer to the appendix). The goals of ASI are to i) enable the aluminium industry to demonstrate environmental responsibility, ii) provide independent and credible assurance of performance, iii) reinforce and promote consumer and stakeholder confidence in aluminium products, and iv) address the expressed needs of downstream industrial users and consumers for achieving responsible sourcing of aluminium.

Core program, ASI performance standard. Subsequently in Dec. 2017, the ASI Standards programme was created to enable aluminium industry to demonstrate environmental responsibility and reinforce downstream industrial users and consumers' confidence in aluminium products. The ASI Performance Standard is applicable for all stages of aluminium production, including bauxite mining, alumina refining, aluminium production, semi fabrication, and remelting recycled scrap. The ASI Performance Standard has various ESG guidelines that a company must uphold. Most notable from the guidelines is its greenhouse gas emissions standards. For any aluminium smelters in production up to and including 2020, they must produce less than 8 tonnes of CO2-equivalent per metric tonne of aluminium by 2030. For smelters in production after 2020, they must produce below 8 tonnes of CO2-equivalent per metric tonne of aluminium. ASI aspires to provide an independent and reputable assurance of ESG performance for any aluminium player.

China's 30/60 plan and policy implementation for aluminium

China targets to reach carbon neutrality by 2030. In December 2020, the Chinese government announced an enterprising plan to tackle climate change: **China's 30/60 plan**. By 2030, China will hit its carbon peak, and by 2060 China will achieve carbon neutrality. One of China's main reasons for tackling climate change is to resolve the chronic air pollution issue in the country. Since the announcement, the Chinese government has been aggressively targeting and planning for production cuts for commodities that have high carbon emissions, such as aluminium and steel. As one of the major importers and exporters for various commodities, China's push for carbon neutrality will have a fundamental impact on the commodity market, both in the near and long term.

Carbon neutrality related policies

Time	Meeting	Related content
Sep-20	75th United Nations General Assembly	China's carbon dioxide emissions strive to achieve peaks in 2030 and neutrality in 2060.
Oct-20	19th Fifth Plenary Session	During the 14th FYP, the Chinese government unveiled its intention to accelerate the development of green low-carbon production, reduce carbon emission and support the conditions to reach the peak of carbon emission, formulate action plans, promote carbon trading market, and strengthen the global climate warming observation.
Oct-20	Ministry of Ecology Environment	Recommended the removal of aluminium industry from the catalogue for the western China development policy.
Dec-20	Climate Ambition	By 2030, China's domestic production of total CO2 emission will be reduced >65% from 2005, non-fossil fuel energy to account for 25%, amount of forest accumulation increases by 6bn cubic meter, and wind/solar power total installation capacity to reach 1.2bn kW.
Dec-20	Central Economic Work Conference	Set up carbon reduction action plan towards 2030, accelerate to optimise industrial structure, energy mix, promote coal consumption to achieve the peak, development new energy, establish national power and carbon emission trading market, improve energy consumption control mechanism.
Jan-21	Inner Mongolia Autonomous Region Development and Reform Commission	Adjust electricity price policy for smelting plants located in the western region and surcharge for captive power plant.
Feb-21	Ministry of Industry and Information Technology	Target low-carbon development pathway for the aluminium industry.

Source: DBS HK

Carbon market development pathway in China

In 2011, National Development and Reform Commission was approved in the Pilot of Carbon Emission Right to Trade to be implemented in 7 provinces.

In Oct 2013, National Development and Reform Commission issued the mandate for Chinese aluminium production enterprises to report their greenhouse gas emissions. This is the first official guideline formulated for measuring the industry's carbon emissions.

In May 2014, Chongqing Municipal Development and Reform Commission issued the Chongqing Industrial Enterprise Carbon Emissions Accounting and Report Guide to set a specific calculation formula.

In Nov 2015, State Administration of Quality Supervision announced industrial gas emission accounting and reporting standards for 10 industries, including the aluminium sector.

In Jan 2016, National Development and Reform Commission issued the Notice on the Practical Operation of National Carbon Equity Trading Market to cover key industries, including aluminium, in the first phase of the national carbon emissions trading market.

In 2017, National Development and Reform Commission issued the National Carbon Equity Right Market Construction Program (Power Generation Industry).

In Nov 2019, China Nonferrous Metal Industry Association to formulate guidelines on establishing carbon emission transaction management system and implementing technical guide for carbon emission. In Nov 2020, the Ecological Environment Department officially incorporate power generation industries, including self-supplied power plants for 40 aluminium smelters, into national carbon trading regulations. It clarified that carbon quota is primarily on a free distribution basis in Dec 2020.

Source: DBS HK

China's target for renewable power. China's National Energy Administration (NEA) has set a target for renewable power (wind and solar) for end-2025 to help support the country's emission goals. The NEA called for the addition of more facilities such as pumped storage power stations, peak-shaving gas-fired power plants and flexible transformation projects for existing coal-fired units. It expects renewables to play a dominant role in China's electricity growth.

China's primary energy consumption mix and target by 2025

(%)	Thermal	Renewable
2020	84.2	15.8
2025	< 78.5	21.5

Source: China Sustainability Tribune

Electricity tariff to drop due to higher participation of renewable energy in the electricity market. In fact, China's electricity market is semi-liberalised with >40% of electricity consumption being traded at market-driven prices. The market-driven prices are usually at an 8-10% discount to benchmark tariffs. Going forward, we foresee that China's government will further liberalise the market, with the proportion of market-based transactions on the rise. We expect more electricity to be generated by renewables and its participation in the spot electricity market will also increase. In terms of power price, we believe electricity tariffs will be lowered as a result of the declining installation costs of renewable energy. Despite this, we note that there are risks to future government policies in standardising the market transaction behaviour of the spot markets. This would probably lead to volatility in electricity tariffs – subject to other variables, such as resource allocation, grid constraints, and load changes.

Indonesia's policy shift to renewable energy and other actions in the industry

Indonesia state-owned electricity producer's push for renewable energy. In Indonesia, the electricity is market is primarily controlled by a state-owned electricity company, Perusahaan Listrik Negara (PLN), which generates all the electricity in Indonesia. There is private participation in the market, but this takes place through independent power producer agreements or public private partnerships with PLN. Most of electricity is generated through coal and around 11% of electricity is sourced from renewable energy.

Indonesia electricity sources (2019)

Source	% share
Coal	62.98%
Gas	21.4%
Renewable Energy (hydropower, geothermal, bioenergy, wind, solar)	11.44% (6.37% - hydropower; 5.3% - geothermal)
Oil	4.18%

Source: DGE's Performance Report

To increase renewable energy's contribution to 23% by 2025. The National Electricity General Plan outlines Indonesia's electricity plan from 2019-2038, which calls for reviewing the safety of electricity supply, reducing carbon emissions, and prioritising renewable energy. PLN has commenced the construction of 35 power plants that use renewable energy, which are slated to commence operations between 2019 and 2021. Furthermore, Indonesia aims to have renewable energy making up 23% of its electricity generation by 2025, and 54% by 2050. However, Indonesia's largest obstacle in implementing renewable energy sources pertains to its economic and financial feasibility, despite having vast potential renewable energy resources. Electricity costs from renewable energy sources are considerably higher than those from fossil fuels. So, the government needs to put in place new regulations to encourage and incentivise the use of renewable energy.

Industry's move towards low carbon footprint ahead of government regulations. While there are no major regulations on clean power supply for the metal & mining sector by the government, smelters or metal mining companies are aiming to use cleaner energy sources such as hydro power plants to lower the sector's carbon footprint across the end users' supply chain. Such efforts will be reinforced by the ASI and EU's CBAM for metal products that require green certificates.

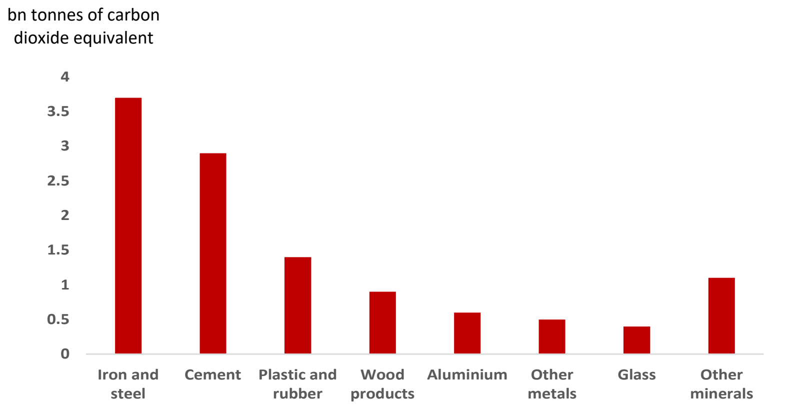
How to achieve decarbonisation for aluminium sector

Heavy energy and carbon density of aluminium sector

Why does carbon neutrality matter to the aluminium sector? The greenhouse gas (GHG) from the production of iron and steel amounted to approximately 3.7bn metric tonnes of carbon dioxide equivalent in 2019. After steel, the production of aluminium ranks the highest in greenhouse gas emissions among the production of all metals. In 2019 alone, aluminium production emitted 0.6bn metric tonnes of carbon dioxide equivalent into the atmosphere, which accounted for 1% of global emissions. Despite the total GHG emissions from aluminium being lower than that for steel, the emission per tonne for the production of aluminium is much higher than steel, which is estimated at c.2 metric tonnes of carbon dioxide equivalent per tonne of steel. The global average CO_2 emissions for both primary and recycled aluminium production was 11.5 metric tonnes of CO_2 per tonne of aluminium.

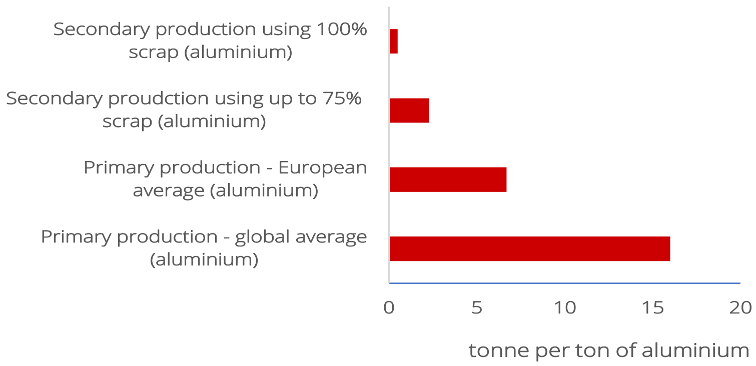
Primary aluminium generates more carbon than secondary aluminium. The primary production of aluminium emits 16 tonnes of CO_2 per tonne of aluminium. As governments around the world are focusing on combatting climate change, reducing GHG emissions from high-emitting metal production like aluminium has become a paramount concern. To deal with carbon neutrality, aluminium smelters can use green energy sources to power their electricity, invest in new technologies and processes to lower carbon emissions during production, or even use recycled aluminium.

Greenhouse gas emissions from global production processes (2019)



Source: UNEP, DBS Bank

CO2 emissions for aluminium production (2019)



Source: UNEP, DBS Bank

From bauxite to aluminium, via alumina refining/aluminium smelting process. Primary aluminium production is a lengthy process that takes energy to transform aluminium's raw material twice to create the desired end product. Bauxite is the most abundant form of aluminium in nature. It must be broken down and refined into alumina, which is then smelted into aluminium. Before aluminium is smelted, carbon anodes need to be produced for alumina to undergo electrolysis. Once aluminium is smelted, there are further steps in the production process to cast it into the desired shape. The detailed production process is outlined in the appendix of this report. Alumina refining requires a substantial amount of heat energy to transform bauxite into alumina, with the power mainly coming from non-green sources.

High energy density/carbon emissions for aluminium production. The high CO2 emissions in the aluminium industry are due to the procedures in aluminium production that require high energy usage. On average, one tonne of aluminium requires 75GJ of energy if processed directly from bauxite. In particular, the reduction cells in the aluminium smelting process are run on electricity, with massive amounts of electricity being consumed during the process. The process of turning alumina into aluminium is called electrolysis, which accounts for 69% of the total energy consumption in the aluminium production process. Accordingly, aluminium smelting accounts for 72% and alumina refining consumes 27% of energy usage for aluminium production. On the other hand, carbon emissions in the aluminium smelting procedure accounts for 75% of total emissions, which is higher than the contribution of energy usage. This is due to the usage of anode (made of graphite) in the electrolysis process that produces CO2 as a by-product.

Energy usage and carbon emissions for aluminium production

Process	Energy Usage (GJ/t Aluminium)	% Contribution	Emissions (tCO2/t Aluminium)	% Emissions
Alumina Refining			2.4	22%
- Digestion	13.3	18%		
- Calcination	6.5	9%		
Anode Production	2.3	3%	0.2	3%
Aluminium Smelting	51.3	69%		75%
- Power			7.3	
- Anode Consumption			1.5	
Casting	1.1	1%	0.1	1%
Total	74.5	100%	11.5	100%

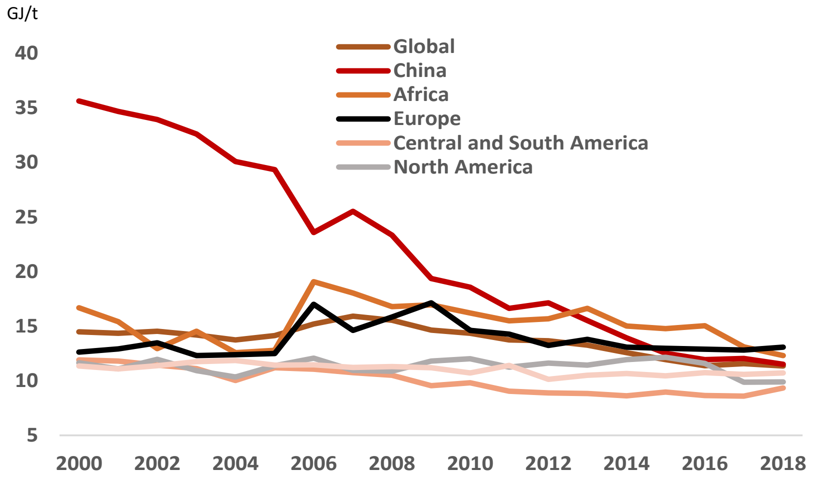
Source: IAI, DBS Bank

Reduction of energy density in aluminium sector

Reduction of energy intensity crucial for achieving carbon neutrality. It is imperative to improve energy efficiency in aluminium production, especially regarding reduction cells to reduce energy consumption and carbon emissions. According to the International Energy Agency (IEA), global energy density in the production of both alumina and aluminium has declined. From 2000–2018, the global energy intensity in alumina refining decreased by an average of 1.3% each year, thanks to significant improvements in China that registered a 6.1% annual decline. This can be attributed to more than half of new capacity increase in China being equipped with the best-available technology that offers unparalleled performance.

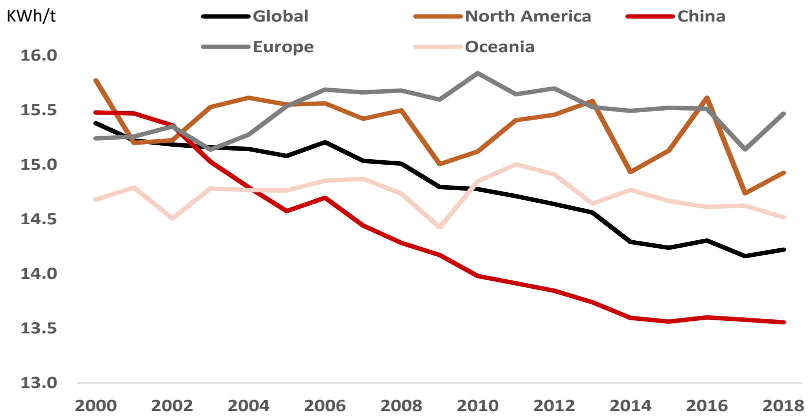
For primary aluminium smelting, global electricity intensity also declined by 0.4% annually during 2000-2018, supported by an annual reduction of 0.7% in China. As a result, energy density in China has posted the lowest level of 13.6m Wh/tonne vs. 14.2m Wh/tonne of global intensity for primary aluminium smelting in 2018. It is important to note that primary production is about ten times more energy intensive than secondary production. To meet the IEA's Sustainable Development Scenario (SDS) that aims to provide a template for transforming global energy systems to achieve the energy-related goals of United Nations, the energy intensity of aluminium production must continue to decrease at 1.2% each year until 2030.

Electricity intensity of alumina refining by region



Source: IEA, DBS Bank

Electricity intensity of primary aluminium smelting by region



Source: IEA, DBS Bank

Technology developments in China that led to the reduction of energy density and carbon emissions. The decreasing global energy density in recent years can be credited to China's efforts in decreasing its energy intensity since the 2000s. This was largely attributed to its advancements in aluminium production technology, which are deployed all over China. The Chinese government has been encouraging aluminium producers to use advanced technologies with high energy efficiency and less pollution since the late 2000s. As a result, China has developed large high ampere reduction cells. Moreover, throughout the 2010s, new techniques were developed such as "Raised" NSC Cathode Blocks and new structures for anode and cathode blocks. Developed by Professor Naixiang Feng in 2012, the Raised NSC Cathode block is able to save more than 0.3V on cell voltage, which represents a significant increase in current and energy efficiency. The new structures of anode and cathode blocks, depending on the type of structure, can save anywhere from 30-80 mV. Also, Chalco has successfully implemented a functional plant that is able to recycle spent carbon lining from reduction cells, which also decreases the aluminium production's carbon footprint.

Alcoa's development of technology to reuse waste vapor.
Alcoa is exploring the commercialisation of Mechanical Vapor Recompression (MVR). This will turn waste vapor from alumina refining into steam, which can then be used to provide refinery process heat. MVR technology, if ran on renewable energy sources, can reduce alumina refining emissions by as much as 70%.

Growing role of aluminium scrap in carbon neutrality

Rising role of aluminium scrap. Recycling aluminium scrap is also a viable method in reducing carbon emissions, which is also known as secondary aluminium production. Moreover, as more aluminium scrap will be available over the next decade, with many products reaching their lifecycle's end, aluminium production using recycled aluminium (scrap) will have increasing importance.

Huge reduction of CO2 for secondary production versus primary production. In 2018, the global average of CO2 intensity for primary production was 16 tonnes of CO2 per tonne of aluminium, whereas secondary production using up to 75% scrap was 2.3 per tonne of aluminium. <u>Moreover, secondary production using 100% scrap of aluminium produced 0.5 tonnes of CO2 per tonne of aluminium.</u> The primary source of emissions from secondary production is from remelting scrap, which accounts for 50% of the total emissions. Moreover, in terms of energy usage, we mentioned that primary aluminium requires 75GJ/t of aluminium, but 100% scrap secondary production requires only less than 5GJ per tonne. As depicted in the table below, the total energy and emission intensity for 100% scrap production are only a fraction of those of primary production.

1/3 of aluminium production pertains to secondary production. Since 2000, secondary production has been around 32% of total aluminium production, and in 2018, 33% of aluminium produced came from new and old scrap. Due to its energy efficiency and smaller carbon footprint, we can expect some aluminium producers to incorporate more secondary production into its total aluminium output. One of the main challenges with increasing secondary production is the amount of scrap available. In order to tackle this issue, infrastructure must be established to ensure that most of the aluminium already produced is recycled.

100% Scrap Secondary Production: Direct Energy and Emissions Intensity (2018)

Process	Energy Usage (GJ/t Aluminium)	Emissions (tCO2/t Aluminium)	% Emissions
Sorting	1	0.14	30%
Re-melting	2.7	0.25	50%
Casting	1	0.1	20%
Total	4.7	0.49	100%

Source: IAI, DBS Bank

Net-zero recycling. Beyond increasing the percentage of secondary production, there are also ways to further reduce the carbon footprint in the aluminium industry, i.e., net-zero recycling. The energy that is consumed for secondary production will have to be switched to green sources such as hydropower, solar, etc. Although currently the power prices from renewables are higher than those of traditional sources, the price of renewable energy is expected to continue trending down until it is competitive with traditional power source prices.

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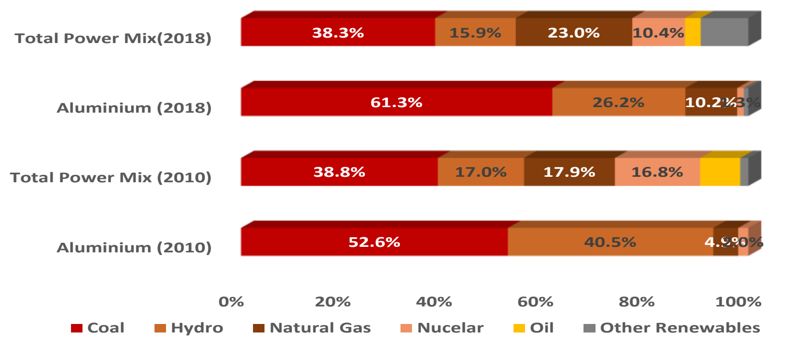
Power supply decarbonisation, a crucial and utmost option

Power supply decarbonisation, the fastest way to decarbonise aluminium production. Since some technologies are not currently available for widespread commercial use, the fastest way to decarbonise aluminium production in the near future is decarbonising the production's power supply. 70% of the global aluminium emissions are attributed to the emissions caused from both direct and indirect emissions from power generation of aluminium production. Expanding the use of green power generation can have a huge positive impact on reducing carbon emissions from aluminium production.

Deteriorating power mix in aluminium sector for last decade. Compared to the global total power mix, the aluminium sector has been relying on coal-based power over long periods of time. Coal accounts for 61.3% of the power mix for aluminium production, which is far higher than 38.3% of the global power generation in 2018. The contribution of hydro power to the aluminium production power mix declined to 26.2% in 2018 from 40.5% in 2010, according to the IEA. In terms of hydro power's contribution to the power mix, the sector has seen a deterioration in the last decade, which is mainly due to capacity growth of coal-fired power plants in China.

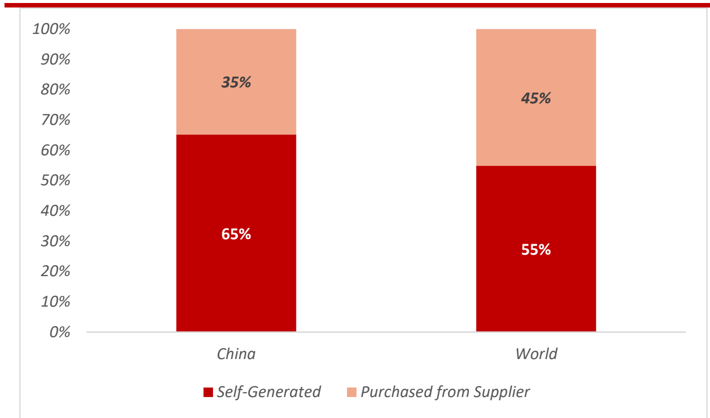
Global aluminium industry power mix vs. global total power mix



Source: IEA, DBS Bank

China, the largest power consumer for aluminium sector, relies on self-generated power. The power consumption of primary aluminium smelting was 848 TWh in 2019 and China accounted for 57% of the global consumption, followed by the EU's 14%, which is in line with its contribution in primary aluminium production. Of the total global power consumption, 55% is self-generated power and 45% is purchased from grid suppliers. On the other hand, the contribution of self-generated power in China is higher than the global figure of 65%, with the remaining 35% coming from purchased power. Thus, the transition into renewable power supplies is not improbable, as this lies with the decisions of the aluminium sector or companies.

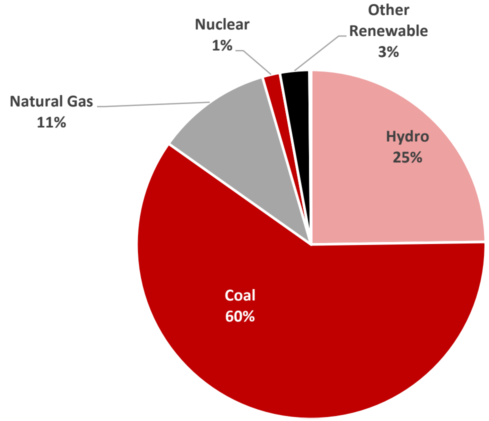
Primary aluminium smelting power consumption by source (2019)



Source: IAI, DBS Bank

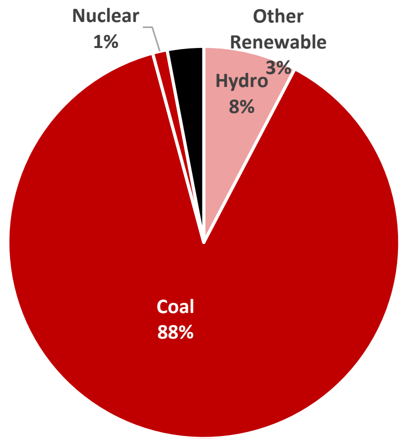
Chinese primary aluminium production relies heavily on coal-based power. In terms of power mix, global primary aluminium production relies on coal for 60% of its power consumption, followed by 25% from hydropower. On the other hand, the dependency on coal-fired power for primary aluminium production is much higher than the global figure of 88% for total power consumption in China. As 75% of power consumption for the aluminium sector lies with primary aluminium smelting, the decarbonisation of power supply for the sector, especially in China, is crucial to reducing GHS emissions from the sector.

Global primary aluminium smelting power mix (2019)



Source: IEA, DBS Bank

China primary aluminium smelting power mix (2019)



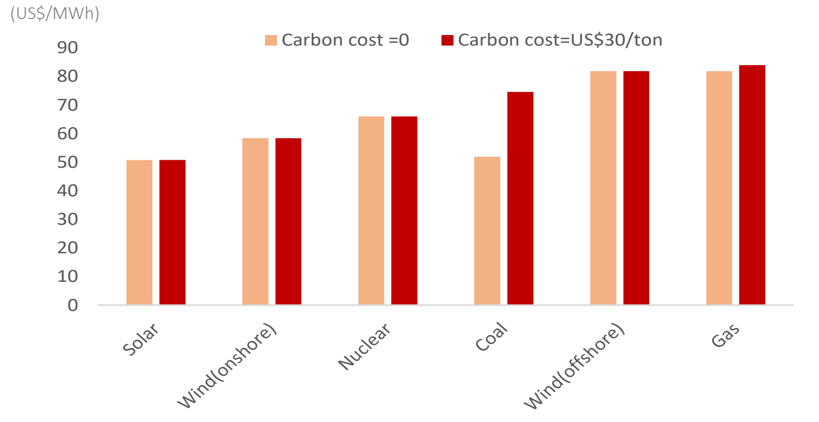
Source: IEA, DBS Bank

LCOE underlines importance of power decarbonisation

Levelized Cost of Electricity (LCOE) suggests low carbon energy to become cost competitive. According to IEA (projected cost of generating electricity 2020), the levelized costs of electricity generation of low-carbon generation technologies are falling and are increasingly below the costs of conventional fossil fuel generation. LCOE is a measure of the average net present cost of electricity generation for a generating plant over its lifetime. On top of declining renewable energy costs in recent years, the rising cost of carbon emissions will also help accelerate the cost competitiveness of renewable energy sources. With an assumed moderate emission cost of US$30/tCO2, renewable energy sources are now cost competitive, in LCOE terms, with dispatchable fossil fuel-based electricity generation in many countries.

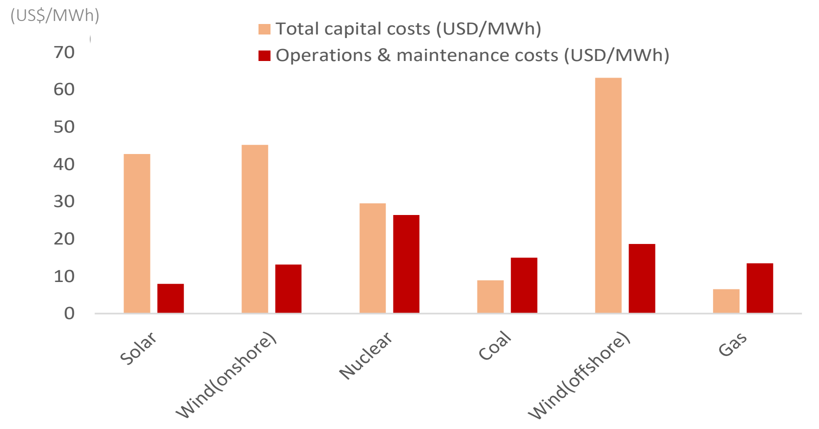
Coal power plants to lose cost competitiveness when carbon tax is introduced. In particular, the projected LCOE for coal power plants in China reveals that their LCOE will increase significantly when carbon costs are introduced. The LCOE of China's coal power plants will increase by U$27/MWh on the assumption of a cost of US$30/t CO2 vs. zero cost for CO2 and will become higher than onshore wind power. Despite the low capital cost for the construction of coal power plants, higher operating and management costs and volatile coal prices would lead to their rising LCOE. In addition, carbon taxes would contribute to coal power plants losing their cost competitiveness over the longer term.

China: Estimated LCOE by power source (2020)



Source: IEA, DBS Bank

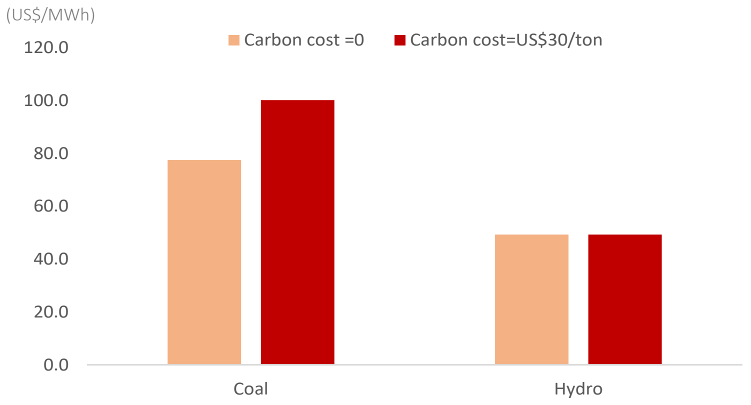
China: Estimated capital/operating costs for power plant (2020)



Source: IEA, DBS Bank

Hydro power plants to gain cost competitiveness under carbon tax regime. Comparing coal and hydro power plants in India, the LCOE of hydro power plants is estimated at US$50/MWh, 64% of the LCOE of coal. When US$30/tCO2 carbon cost is charged, the LCOE of hydro would be 50% of that of coal, as the latter will increase by US$23/tonne. This underscores the reason the aluminium sector needs to shift its source of power consumption. Aside from climate change factors, it is also largely a matter of cost competitiveness and sustainability for the aluminium players.

India: Estimated LCOE by power source (2020)



Source: IEA, DBS Bank

Looking ahead, decarbonisation is the best path forward. In the near term, the fastest way for the aluminium industry to address carbon neutrality is to decarbonise its power supply. Although there will be substantial switching costs initially (related to building renewable energy power sources and integrating it into existing infrastructure), decarbonising its power supply can lead to massive reductions in carbon emissions, specifically in aluminium electrolysis and smelting. Furthermore, the wide adoption of green energy sources can and will drive down energy prices, akin to those for traditional power sources such as coal. CCS is also a viable alternative but considering the added production costs arising from energy usage, it may not be the optimal option. Moreover, for CCS to properly reduce carbon emissions, the power generated must come from green energy sources.

Other technologies for achieving carbon neutrality

Alcoa's Sustana product line. Aluminium producers all over the world are also offering aluminium products that have small carbon footprint, such as aluminium smelting that runs only on renewable energy. For example, Alcoa, the world's lowest carbon intensity alumina producer, has the Sustana line, which are made up of green aluminium products: EcoSource, EcoLum, and EcoDura. EcoSource is smelter grade alumina that has no more than 0.6 metric tonnes of CO2 equivalent for every tonne of alumina. EcoLum has less than 4.0 tonnes CO2 equivalent per tonne of aluminium, and EcoDura is aluminium that has at least 50% recycled content. We can expect other large aluminium producers to come out with similar product lines in the future.

Inert Anodes not ready in the near term. Companies such as Rusal and Elysis (a JV between Alcoa and RioTinto) are looking to inert anodes (that consist of ceramics and other alloys), as opposed to graphite (pure carbon). With proper implementation, inert anodes could eliminate all greenhouse gas emissions that are emitted during aluminium electrolysis. For zero-emission aluminium production, inert anodes will have to be paired with green energy sources so that the electricity consumed for electrolysis does not produce carbon emissions. Although this is a promising technology, inert anodes are still in the testing phase and will not be commercially viable until 2024, according to Elysis

In the future, inert anodes seem to be able to play a large role in further reducing carbon emissions. To ascertain its feasibility, we must wait for tests to be carried out successfully to determine its scalability before making any decision.

Energia Potior to use more stable renewable energy. Currently, one of the major drawbacks for renewable energy (hydropower, solar, and wind) is its lack of consistent power output. Since it relies on harnessing energy from natural sources, it tends to undergo seasonal and daily intermittencies, which can damage equipment if power is not outputted for longer than two hours. To combat these intermittencies, smelters can use technologies like Energia Potior (EnPot). EnPot is a mechanism that allows smelters to vary their electricity demand by 20%, depending on the electricity output of green energy sources but doing so will add costs of up to US$125,000/MW. Cost-effective retrofitting is sufficient to perform downward modulation, but upward modulation requires more investment.

Carbon capture and storage have high integration and production costs. When a carbon capture and storage (CCS) unit is attached to a power plant or furnace, it is able to collect up to 90% of the carbon emissions. If the CSS unit is a direct air capture system, it can recover 100% of emissions from the plant. CCS can be used at various points in the aluminium production process: smelting, refining alumina, and secondary production. As most CCS systems are retrofitted to the existing point source, there are minimal process constraints, but they require a unique design to operate within the aluminium production process. On top of integration costs, operating CCS requires additional energy costs as it consumes 250-300kWh/t of CO2. Moreover, it requires 80-120 kWh/t of CO2 for compressing CO2. To reach zero emission production, the energy must come from clean sources. CCS units are also not widely used in the aluminium industry, since they need to be paired with green energy sources to be effective. The energy and integration costs might make CCS a more costly option to achieve carbon neutrality.

Hydrogen fuel is a viable, though currently expensive, solution for reducing emissions in aluminium recycling. Hydrogen fuel is produced by splitting water into its atomic components by using electricity. If done using clean power sources, it has zero emissions. Hydrogen can be burned to get high temperatures for refining alumina and recycling aluminium, thus removing all emissions from those two parts of aluminium production. However, it cannot be used in primary aluminium smelting. Much of the technology needed for green hydrogen is not only expensive but is not yet produced at scale. Moreover, retrofitting needs to be done for aluminium recycling and alumina production equipment to use hydrogen fuel, and special storage and transportation is needed for hydrogen fuel. Despite the limitations, as it is able to completely eliminate emissions from secondary production, hydrogen fuel can be adopted for aluminium recycling.

Electrification of certain aspects of production possible, but requires more research. Like hydrogen fuel, electrification can be used to decrease emissions in alumina refining and recycling aluminium. For alumina refining, electric boilers or heat pumps can be used during the digestion phase and electric furnaces can be used during calcination. Electric furnaces can only be used to eliminate all carbon emissions from secondary production. However, all electric equipment has yet to adopt this implementation or design for commercial scale, which is more cost effective than its fossil fuelled counterparts. Most electric equipment is designed for smaller facilities; additionally, each equipment faces its own specific issues such as high capital expenditures and dependence on power prices. Once large-scale use is available and proven, the aluminium industry could look at adopting this technology rapidly.

Looking forward, investment and research into finding more efficient and less carbon emitting processes will help in the transition towards carbon neutrality and also ensure that companies can comply with carbon emissions goals of its operating countries.

China's new supply reforms towards carbon neutrality

China aluminium sector consumes c.7% of total electricity. As one of the largest electricity consumers, China's primary aluminium industry is expected to be under further pressure to lower carbon emissions to reach the country's goals of reaching a carbon emissions peak by 2030 and achieving carbon neutrality by 2060. China's primary aluminium output amounted to 37m tonnes in 2020, consuming about 500bn kWh of electricity. Assuming 13,500kWh per tonne of primary aluminium was produced, this would account for 7% of China's total electricity consumption.

China's restrictions on supply to contribute carbon neutrality. Industry data shows there is upcoming commissioned production capacity of primary aluminium in Gansu and Inner Mongolia in 2Q21. The data also reveals several projects under development in provinces that are rich in renewable resources such as Yunnan and Guangxi. However, there are several supply-side factors that are constricting the industry's production: (1) the energy consumption restriction for Inner Mongolia would limit its effective production capacity, (2) the ceiling imposed on China's total smelting capacity, (3) stricter approvals for new replacement quota amid the current capacity swap programme, (4) restrictions on new capacity expansion in the Xinjiang market, and imposition of off-peak production limits during autumn and winter seasons for cities located in 2+26 region, and (5) monitoring of coal-fired power and reduction of coal usage for Shandong. This should contribute to not only supply restrictions but also carbon neutrality.

Capacity caps. According to Chinese Aluminium Industry's carbon reduction plan, China will limit its annual aluminium production capacity at 45m tonnes. It is important to note that in 2020 its aluminium production stood at 42m tonnes with an operating rate of >93%. Industry data show that there would be 3m tonnes of new capacity expected to come online by 2021. This does not include an estimated 1m tonnes of projects (mostly in Inner Mongolia) to be halted, since the double limit policy was announced.

Double limits (unit GDP energy consumption and total energy consumption) and benefits of scrap usage. According to the China Non-ferrous Metal Industry Association, each tonne of primary aluminium consumes 5 tonnes of bauxite, 550kg of anode material, 9.6 tonnes of standard coal, and 13500kWh of electricity. Moreover, it releases 16 tonnes of CO2 emissions if the thermal power grid is used, 10 tonnes from captive power, and zero tonnes from hydro power. Based on China's aluminium production scale in 2020, 500bn kWh of total power was consumed or 6.5% of China's total power. In 2020, China's aluminium industry's CO2 emissions amounted to 426m tonnes or 5% of China's total emissions. Alternatively, CO2 carbon emissions are only 0.23 tonne for scrap aluminium production, as its total energy consumption is 5% of that of smelting production. To further promote scrap production, China aims to benefit from significantly lower carbon emission levels for its 14th Five-Year Plan.

Carbon policy and industry decarbonisation pathway. Since carbon capture utilisation and storage (CCUS) technology remains immature for most smelting machines, redesign and transform processes are required to achieve low CO2 concentration from gas streams discharged from power plants. An ideal level is within 500-15,000ppm (parts per million). Large amounts of heat and steam are required from fuel for the alumina production process. Fuel combustion (providing heat and steam) reduces direct discharge when converting alumina into aluminium. The adoption of renewable energy would reduce emissions during alumina production and anode consumption. Capex spending is required for both the power grid and captive power plants to invest in: (1) electricity decarbonisation, (2) reduction of direct emissions and (3) circular utilisation and resource efficiency.

Winter policy. China's Ministry of Ecology and Environment (MEE) published a letter on Soliciting Opinions for "Beijing-Tianjin-Hebei and Surrounding Areas, Fenwei Plain, Autumn and Winter Air Pollution Comprehensive Control Action Plan for 2020- 2021 (Draft for Comment)" on 28 September. According to the draft, the winter production cuts will be implemented this year.

Stringent restrictions on coal consumption, as attested by Inner Mongolia case. Based on the assessment carried out by the National Development and Reform Commission on the total energy consumption and intensity dual-control measures in 2019, Inner Mongolia has failed to achieve the required levels.

On 10 Feb 2021, Inner Mongolia's government abolished the power tariff discount for aluminium plants located in the western region. Captive power plants paid for the spontaneous self-consumed power generated, by strictly abiding to the tiering electricity price policies for eight major pollutant intensive industries (including aluminium). According to the plan, the electricity price would be further revised up by 30% for the restriction and 50% for elimination categories in 2022 and 2023, based on 2021's level. Accordingly, the weighted average cost of Inner Mongolia has increased by RMB288/tonne, which is negligible compared to the current industry average unit gross profit level. In March, Inner Mongolia's government set a 2021 target for unit GDP energy consumption that is 3% lower than its 2020 target. Furthermore, it aims to control the increase in total energy consumption from standard coal by 5m tonnes (<2%) and not approved any new capacity expansion. Accordingly, several aluminium enterprises in Inner Mongolia have suspended their production to lower their power intensity, and a few other smelters in the peripheral region had additional plans for maintenance. Plants under construction such as the Baiyinhua Aluminium coal-based project were halted. Also, Huayun Aluminium Phase II & III were terminated. Moreover, production was suspended for Baotou Aluminium and East Hope in Baotou in response to the red warning pollution alert in the district.

Impact on aluminium smelters

Inner Mongolia will forbid the addition of primary aluminium capacity and abolish preferential electricity prices to mark the beginning of stricter carbon emission controls. The cost analysis for aluminium players will depend on their electricity supply source. Assuming no major differences in local and import supplies of alumina, every RMB0.025/kWh increase will increase aluminium costs by RMB288/tonne, or 2%-3%. As the benchmark tariff is likely to migrate towards the liberalised market level, we expect this to incentivise smelters to accelerate the adoption of renewable production, thus driving the sustainable change in industry development landscape.

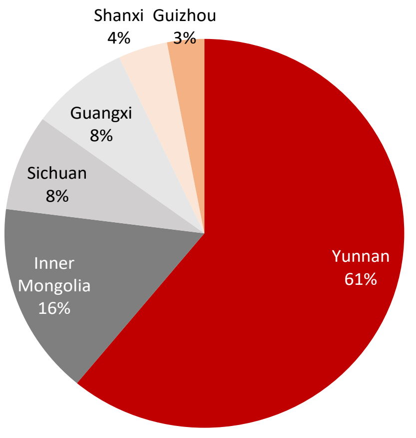
Tariff impact on smelters

RMB/tonne	Grid power	Captive power
Prevailing cost	14,100	10,400
Proforma per RMB0.025/kWh±	13,800-14,400	10,100-10,700

Source: DBS HK

Migrating towards renewables. One development trend in the industry is shifting capacity towards renewable based energy sources. Smelters are moving from coal-based provinces to provinces like Yunnan and Guangxi where utilisation of hydro power resources is common. As such, CHALCO's Wenshan plans to commission 400ktp smelting capacity in Yunnan province while China Hongqiao's Hongtai commenced operations in Yunnan. As of end-2020, 3m tonnes of aluminium smelting capacity has been relocated to Yunnan province. Based on the low-carbon-aluminium development plan proposed by the industry association, it would transfer 3m to 5m tonnes of capacity in the next few years, reaching a target of 8m tonnes. However, hydro-powered aluminium production contribution remains low compared to global standards of >25%.

China new aluminium capacity geographical distribution, FY20



Source: Wind, DBS HK

Key players' strategy for a thriving future

What determines a player's performance?

Top 10 aluminium players account for 52% of global output. With around 6.6m metric tonnes of aluminium produced, CHALCO was the largest aluminium company in 2020. China Hongqiao, Rusal, and Xinfa are also ranked among the largest aluminium producers globally. The top 10 players account for 52% of global aluminium production and the five Chinese companies among them contribute 31% of global production.

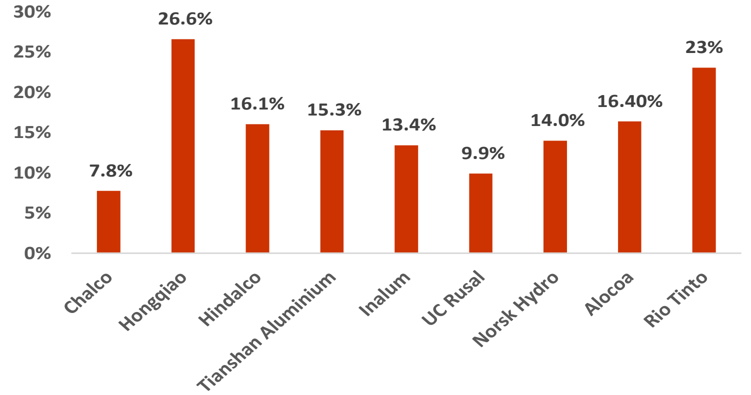
Top global aluminium players (2020)

	(m tonnes)	Contribution
CHALCO (China)	6.6	10%
China Hongqiao (China)	5.7	9%
Rusal (Russia)	3.8	6%
Xinfa (China)	3.3	5%
Rio Tinto (UK/Australia)	3.2	5%
EGA (UAE)	2.5	4%
SPIC (China)	2.5	4%
Alcoa (U.S.)	2.3	3%
East Hope (China)	2.2	3%
Norsk Hydro (Norway)	2.1	3%

Source: WBMS, DBS bank

Players with integrated value chains command lucrative margins. Among the top players, China Hongqiao's EBITDA margin was the highest, followed by Rio Tinto's 23% in the aluminium segment. Beside these two companies, most players' EBITDA margins ranged from 10-15%. The superior margins of these two companies stem from their integrated value chains for the aluminium business, from bauxite mines to alumina smelting and aluminium refining. China Hongqiao has a captive mine in Guinea which is sufficient to supply bauxite for its China alumina operations. Rio Tinto also produces aluminium from bauxite in Canada, Australia and New Zealand. About 50% of its revenue in the aluminium segment is from sales of aluminium and bauxite, while alumina accounts for the other 50%.

Key players' EBITDA margins in 2020

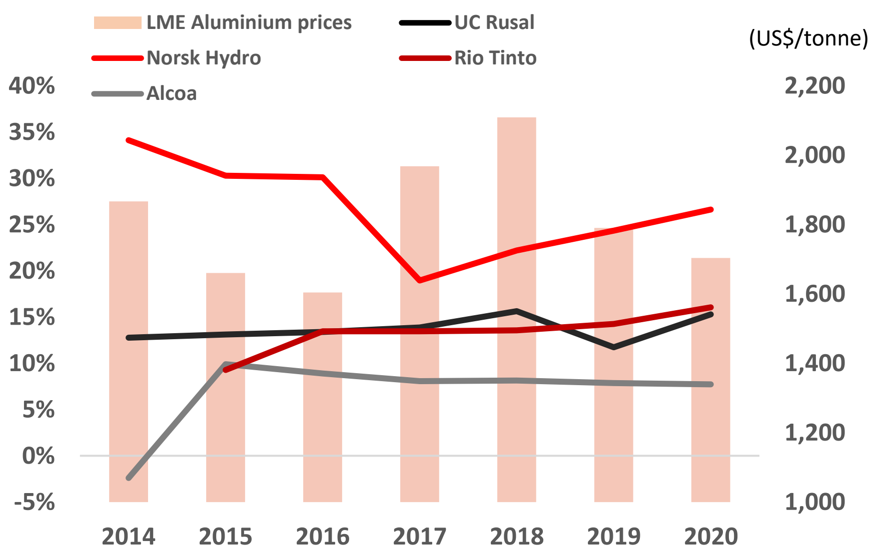


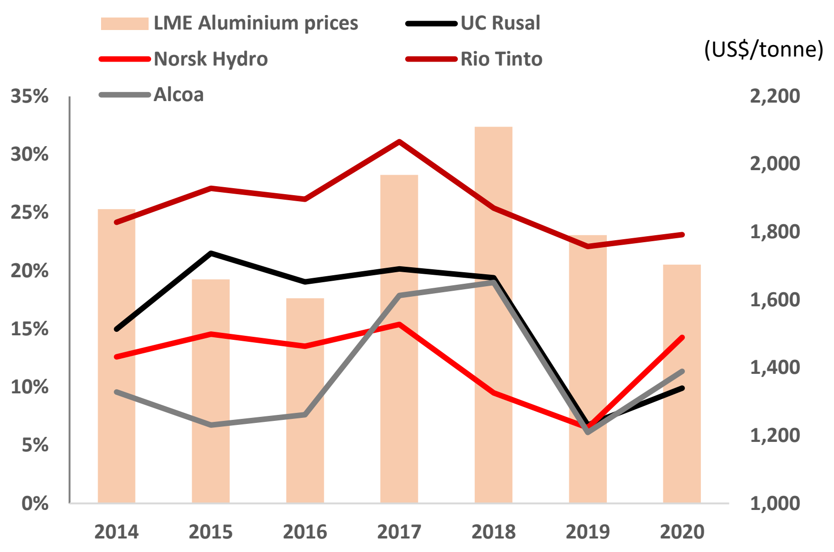
Rio Tinto and Hindalco: EBiTDA margins in aluminium segment.

Source: Company, DBS Bank

Earnings do not just depend on aluminium prices. The interesting finding is that a company's earnings are not always in line with aluminium prices. Beside aluminium prices, other factors such as alumina and energy costs, and business restructuring are also key determinants of the company's performance. In particular, government actions and policies are also important factors that determine Chinese aluminium players' performance.

LME Aluminium prices vs. EBITDA margins of key players

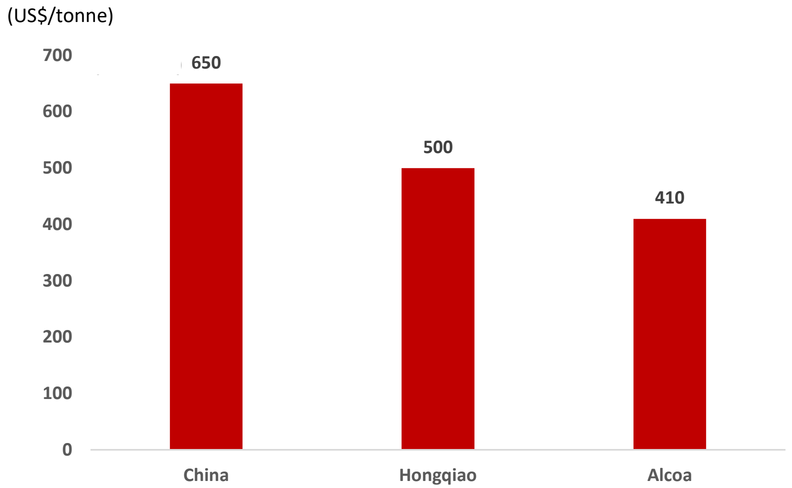




Source: Company, DBS Bank

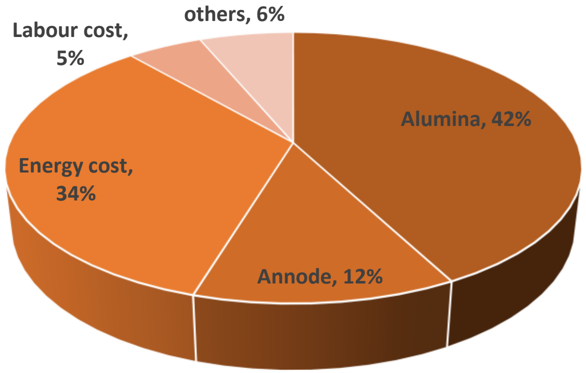
Energy cost matters for performance. One of the key determinants of a company's performance is energy cost. Compared to the sector average, the outperformers have low energy costs for aluminium production. China's average energy cost per tonne of primary aluminium is estimated at US$650, while that for China Hongqiao and Alcoa are US$500 and US$410 respectively. Accordingly, the proportion of energy cost to total production cost is lower than the sector average, which is estimated at 30% and 28% for China Hongqiao and Alcoa respectively versus the Chinese average of 34%.

Energy cost per tonne of primary aluminium (2020)

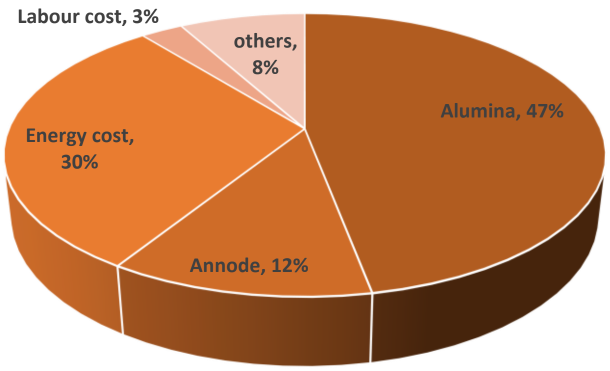


Source: Antaike, Company, DBS Bank

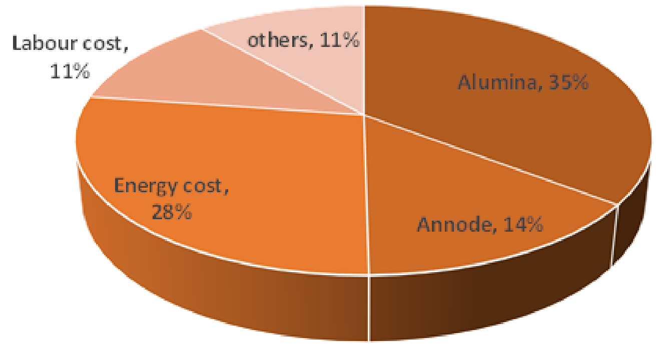
Alcoa: Primary aluminium cost structure (2020)



China Hongqiao: Primary aluminium cost structure (2020)



Alcoa: Primary aluminium cost structure (2020)



Source: Antaike, Company, DBS Bank

Key strategies of top players for a thriving future

Investments in upstream business by Chinese companies. Over the last decade, the outstanding strategy for Chinese players was to secure bauxite from the overseas markets to meet their smelting and refining business needs. China Hongqiao's investment in a bauxite mine in Guinea is a case in point. The company confirmed that it had in March 2015 reached an agreement on various mining and port investments amounting to US$120m to promote the development and export of bauxite. In November 2015, 170k tonnes of bauxite were shipped from Guinea to China. Prior to that, it had established Hongfa Weili Alumina Co. Ltd., with a joint investment of US$1bn to build an annual output capacity of 2m tonnes of aluminum in Indonesia's West Kalimantan province. In 2016, the company opened its first production facility in Indonesia with an output of 1m tonnes per year. China Hongqiao holds a 56% stake in PT Well Harvest Alumina. This was both the first Chinese investment in an alumina refining plant and the first aluminium factory built in Indonesia.

CHALCO had also invested US$706m in its first overseas bauxite mine in Boffa, Guinea in October 2018. The project, with an annual capacity of 12m tonnes, was completed and commenced operations in April 2020.

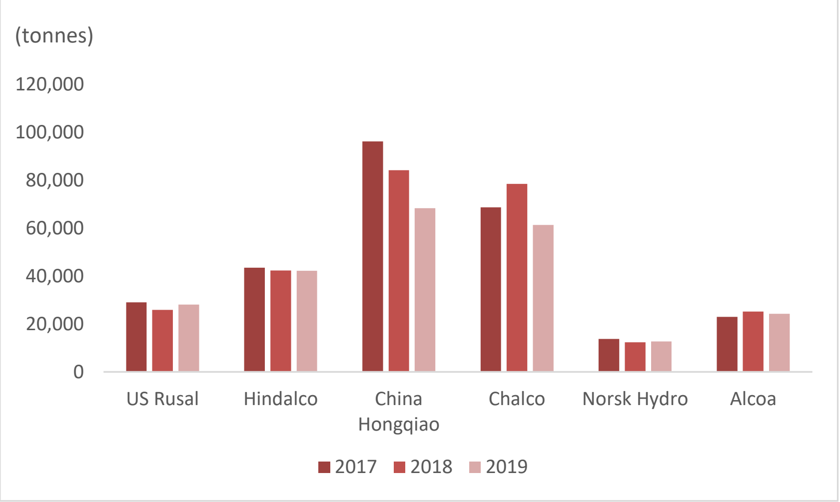
Expanding business into value-added aluminium products. Aluminium producers are increasingly expanding their value chain into the downstream business of value-added products where booming demand will bolster business growth. Alcoa spun off into the downstream business in 2016 via Arconic Incin, which is engaged in lightweight metals engineering and manufacturing. The company operates through three segments: Global Rolled Products, Engineered Products and Solutions, and Transportation and Construction Solutions. In 2017, Norsk Hydro fully acquired aluminium products firm Sapa for US$3.2bn. Sapa produces aluminium products for the aircraft, automotive and construction industries. Rusal has established a downstream division focused on the development of value-added production and expects sales of value-added products such as alloyed ingots and slabs, to grow from approximately 42% of total sales in 2019 to 60.0% by 2025. Also, Chinese firms such as CHALCO will follow suit and move up the value chain into higher value-added products catering to the aerospace and automotive companies.

GHS emissions have declined especially for Chinese companies. In recent years, key aluminium players have been reducing their Globally Harmonised System (GHS) emissions. Meanwhile, the emissions of players such as Alco and Norsk Hydro, which are mainly hydro power-based, have been flattish. Elsewhere, Chinese companies with coal power plants as their major energy source have reduced their GHS emissions significantly.

Strategy to reduce carbon emissions. Without doubt, the key strategy to thrive in the future is to reduce carbon emissions. The major efforts are in decarbonisation of energy sources which are being implemented in China. UC Rusal has set its goals for 2025 which are to utilise 95% of electricity from hydroelectric power, reduce direct specific greenhouse gas emissions by 15% (from 2014) and power consumption by 7% (from 2011). In addition, the global key players such as Alcoa and Rio Tinto are exploring the technology to reduce carbon emission such as inert anodes, Energia Potior to use more stable renewable energy, carbon capture and storage. We summarise the strategy of each company in the table below.

China's move for decarbonisation of energy. The Chinese government is pushing for consolidation and stricter environmental regulations intended to shut down higher-cost or less-efficient capacity and secure green energy to produce aluminium. Following this policy, CHALCO acquired Yunnan Aluminium in 2019 and created a new business structure. As a result, its hydro power capacity will be expanded to c.3mtpa by end-2021, or roughly >40% of the group's post-merger total capacity. Meanwhile, China Hongqiao has committed to moving 2mtpa of its capacity from Shandong in eastern China to Yunnan's Wenshan prefecture in the southwest. This is to allow easier access to a cheaper power source for the energy-intensive aluminium smelting process. The first phase of the Wenshan project started in September 2020, and it will transfer an additional 1mtpa to the neighbouring prefecture of Honghe. This implies that 3mtpa of aluminium production will be based on hydro power in Yunnan which is almost half of China Hongqiao's 6.46mtpa of annual primary aluminium capacity.

Greenhouse gas emissions by company



Source: Antaike, Company, DBS Bank

Key strategy of the players

Player	Major shareholder(s)	Value chain	Asset location	Key features and strategy
Alcoa	Vanguard Group (8.9%) Blackrock Fund Advisor (6.86%) Dimensional Fund Advisors (4.51%)	Bauxite, alumina, primary aluminium	Australia, Brazil, Guinea, Saudi Arabia	Bauxite - World's second-largest miner with assets across four continents - World-class mine rehabilitation - Best-in-class mining methods in high biodiversity areas Alumina - Largest third part alumina producer - Lowest CO2e intensity refiner; sustainable residue management and press filtration Aluminium Low CO2e intensity producer, 78% of production from renewable energy (targeting 95%) Sustana Product Lines - EcoSource: smelter grade alumina with emissions of < 0.6t CO2e/tonne of alumina - EcoLum: aluminium with emissions of less than 4t CO2e/tonne of aluminium - EcoDura: aluminium that contains at least 50% of recycled aluminium
Rio Tinto	Fisher Asset Management (1%) State Farm Investment Management (0.97%) Franklin Advisers (0.69%)	Bauxite, alumina, primary aluminium	Australia, Brazil, Guinea, Saudi Arabia	Aluminium Production - ELYSIS: Inert Anodes - ELYSIS will reach commercial maturity in 2024 - Apple has already bought ELYSIS aluminium for the production of its Macbooks Reduced emissions by 1.1m tonnes of CO2e relative to 2018 baseline Bauxite and Alumina - 6.4m tonnes of CO2e in 2020 (20% of total CO2e output) - Emissions from coal and natural gas used for heat and calcination Aluminium (Atlantic) - 5.3m tonnes of CO2e in 2020 (17% of total CO2e output) - 100% of electricity supplied by renewable power - Emissions from carbon anodes Aluminium (Pacific) - 10.1m tonnes of CO2e in 2020 (32% of total CO2e output) - Boyne and Tomago smelters in Australia are based on coal-fired power generation

Key strategy of the players (cont'd)				
Hindalco	IGH Holdings Pvt Ltd (15.6%) Aditiya Birla Group (10.6%) Life Insurance Corp of India (8.38%)	Alumina, aluminium	India	Zero Waste to Landfill & Zero Discharge Fresh water consumption reduced by 8.5% ~79% of water has been recycled and reused 62% of bauxite residue recycled 82% of fly ash recycled Renewable Energy Total renewable capacity of Hindalco to 49MW (September 2020) Target of 100MW by FY22 Exploring -> energy storage, carbon capture & utilisation, hydrogen as fuel Novelis Global leader in aluminium recycling
CHALCO	Aluminum Corporation of China (31.1%) China Life (3.9%)	Bauxite, alumina, primary aluminium	China, Indonesia, Guinea	Technology Advancements - It has self-developed the industrial application of the carbon-slag-free production technology - In 2020, it completed the first wet oxidative desulfurisation and decarbonisation and organics removal test line and put it into operation - Carbon residue-free anodising production technology completed for reducing carbon residue, gross consumption of anode and DC power consumption
China Hongqiao	China Hongqiao Holdings (68.4%) CITIC (9.8%)	Bauxite, alumina, primary aluminium	China, Indonesia, Guinea	Technologies The world's most advanced 600KA electrolysis technology which is independently designed and developed by the company - Adopts non-electric pump system to reduce electricity consumption - Adopts start-up through intermediate pressure cylinder technology to reduce energy consumption during commissioning and production - Uses a single set of fully dissolution production lines with 1m tonnes of annual alumina capacity to improve equipment operating efficiency and reduce energy consumption Green Projects Yunnan green aluminium innovation industrial park - The production capacity of Yunnan Hongtai green aluminum project is 2.03m tonnes per year (hydropower green aluminium production)

				Secondary aluminium and circular economy project - Partnering with Germany's Scholz China GmbH to form a joint venture company - Focused on R&D and production of secondary aluminium, scrap metal vehicles, white goods recycling, battery recycling and recycling technology
Key strategy of the players (cont'd)				
UC Rusal	Mr. Deripaska (44.9%) En+ (21.3%)	Bauxite, alumina, primary aluminium	Jamaica, Guyana, Guinea, Russia	ALLOW - Bespoke brand for low carbon aluminium with a certified carbon footprint launched by Rusal in 2017 - Carbon footprint: 4 tonnes of CO2 per tonne of primary aluminium - In 2018, ALLOW aluminium made up 78% of the company's total output 2025 goals: 95% of electricity from hydroelectric power, reduce direct specific greenhouse gas emissions by 15% (from 2014) and power consumption by 7% (from 2011) Currently investing in inert anode technology
Tianshan Aluminium	Shihezi City Jintong Energy (19.6%) Shihezi Jinhui Energy (7.4%) Chairman Ceng Chaolin (6.4%)	Primary aluminium, fabrication	China	Primarily reacting to government policies and prevention of heavy pollution Management is formulating a strategy to reduce carbon emissions moving forward - Established a prevention plan for heavy pollution according to the local government's requirements - Taking measures such as production reduction and suspension to enable the completion of emergency response work
PT Inalum		Aluminium	Indonesia	HF Gas Cleaning System Hydrogen fluoride (HF) gas is produced from reduction cells HF gas is then captured by alumina through a binding reaction which creates Reacted Alumina. Reacted Alumina will then release H20 as a by-product Reduction of 2,976 tonnes of CO2 equivalent per year of greenhouse gas emissions

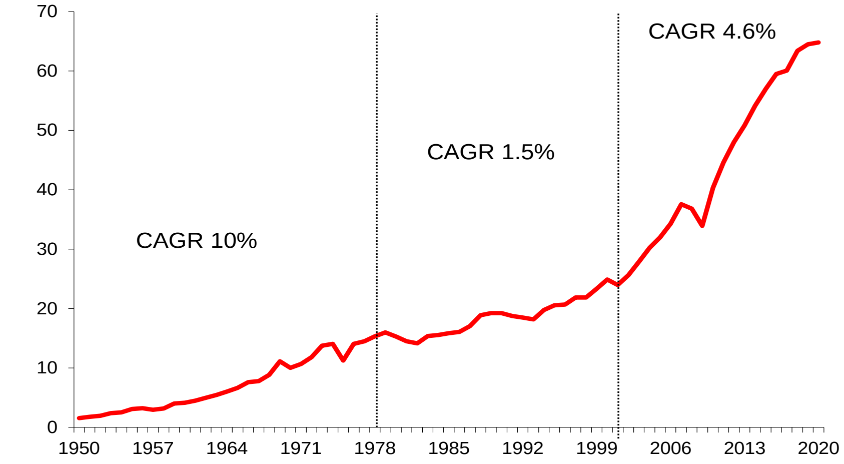
Source: Company, DBS Bank

Aluminium demand outlook – expanding its future applications

Demand has been growing rapidly since 2002. The aluminium industry is the world's second largest metal industry, after steel. In 2020, world consumption of primary aluminium was 64.8m tonnes and secondary aluminium production, estimated to be similar to secondary consumption, was 15.7.m tonnes, according to WBMS. From 1950 to the mid-1970s, aluminium consumption grew at 10% CAGR, supported by the economic development of developed countries. Growth then decelerated to 1.5% CAGR until 1992. Fuelled by economic growth in the larger developing countries, especially China, the growth momentum accelerated to 4.6% CAGR over 2002 to 2020.

Higher demand elasticity to GDP. In the 2000s, the aluminium demand elasticity to GDP was significantly higher than in the 1990s. From 2010 to 2020, the ratio of aluminium demand elasticity to world GDP stood at 2.3, meaning global aluminium consumption grew 2.3% for every 1% increase in global GDP. This is much higher than the ratio of 1.7 over 2000 to 2010 and 0.9 over 1990 to 2000. Increased elasticity implies that recent economy growth has prompted further aluminium consumption, which should bode well for aluminium demand going forward.

Global primary aluminium consumption



Source: WBMS, DBS Bank

Aluminium consumption's elasticity to world GDP

	World GDP growth	Aluminium consumption growth	Elasticity to GDP
1990~2000	2.8%	2.6%	0.9
2000~2010	2.8%	4.9%	1.7
2010~2020	2.2%	4.9%	2.3

Source: WBMS, DBS Bank

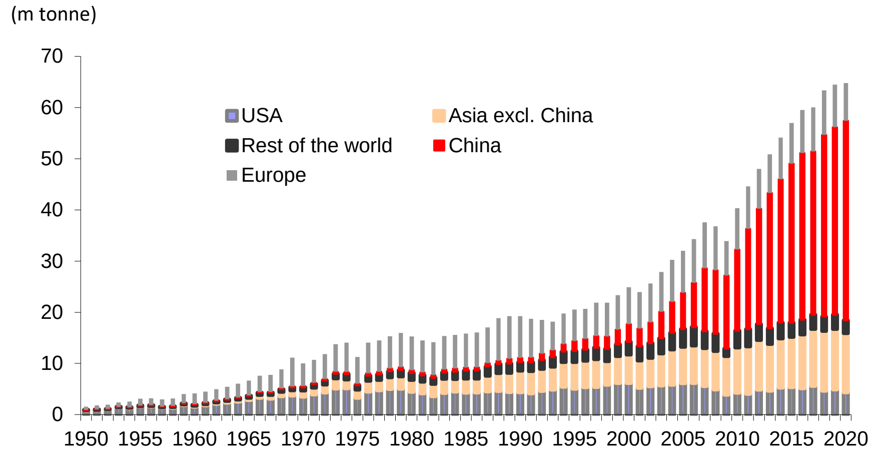
China, the biggest contributor for strong demand growth. As expected, China has been the key contributor to global demand growth, with a demand CAGR of 13.2% over 1992 to 2000. Asia, excluding China, has posted 3.6% annual demand growth, which was contributed by Vietnam (CAGR of 21.5%) and India (CAGR of 12.2%). In particular, the outstanding demand growth in Vietnam is attributed to the surge in aluminium production after the completion of Dak Nong Aluminium Company's refined aluminium plant. It is important to note that the apparent consumption is captured as production + imports – exports.

Asia accounts for 78% of global aluminium market. In 2020, Asia accounted for 78% of the global aluminium market, with China itself accounting for 60% of the global market. This has been increasing significantly over last 20 years, with contributions of Asia and China to global aluminium consumption at 36% and 14% in 2020, respectively. Asia's dominance is likely to continue given that 1) Asia's economic growth rate is projected to be higher than the other regions, and 2) GDP per capita from most Asian countries is still below US$10,000.

Fastest growth in country's aluminium consumption occurs until its GDP per capita hits US$10,000. The charts on the next page show the relationship between per capita consumption of aluminium and GDP per capita in several countries. We reckon that the aluminium consumption per capita grows at the fastest pace until the nation's GDP per capita reaches US$10,000. As GDP/capita surpasses US$10,000, the growth in aluminium consumption per capita slows and consumption will tend to fluctuate, depending on business and economic cycles. The peak aluminium consumption in the US, Japan and Germany were 24kg/capita, 20kg/capita and 19kg/capita when their GDP per capita were US$7,800, US$25,000 and US$27,000 respectively. An interesting trend in aluminium consumption was seen in developed countries when their GDP per capital reached US$30,000/tonne, i.e., their aluminium consumption per capita would rise again. We believe this could be driven by the renovation of cities and infrastructure in developed economies. Meanwhile, the aluminium consumption per capita in India was a mere 1.2kg/capita in 2020, which suggests a huge growth potential for aluminium consumption in the country.

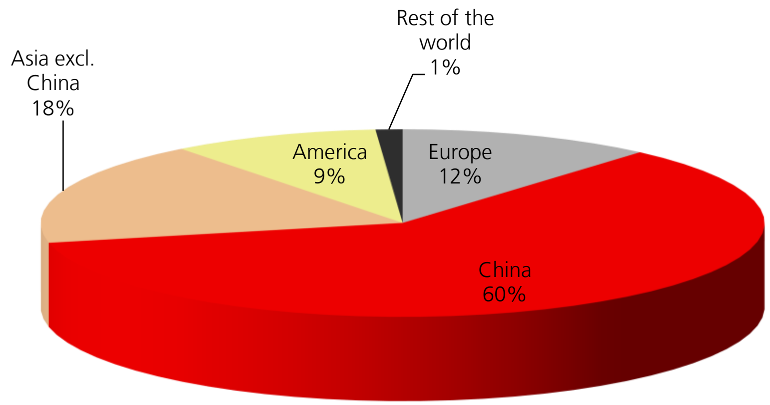
China's aluminium consumption per capita is highest in the world
The aluminium consumption trends in South Korea and China have seen trajectories that are different from developed economies. The aluminium consumption per capita in South Korea has continually increased until its economy reached US$30,000/capita in 2016, peaking at 28kg/capita. On the other hand, China has already reached an aluminium consumption of 28kg/capita in 2020 when its GDP per capita was US$10,500, the highest globally. Moreover, the consumption growth in China was outstanding compared to the other countries, as China's aluminium consumption per capita was merely 2.8kg/capita in 2000, increasing 10 times in the last 20 years. The structure of the economy also plays a role in aluminium consumption, as countries that have reached a high level of specialisation in manufacturing tend to support strong aluminium demand.

Global primary aluminium consumption by region

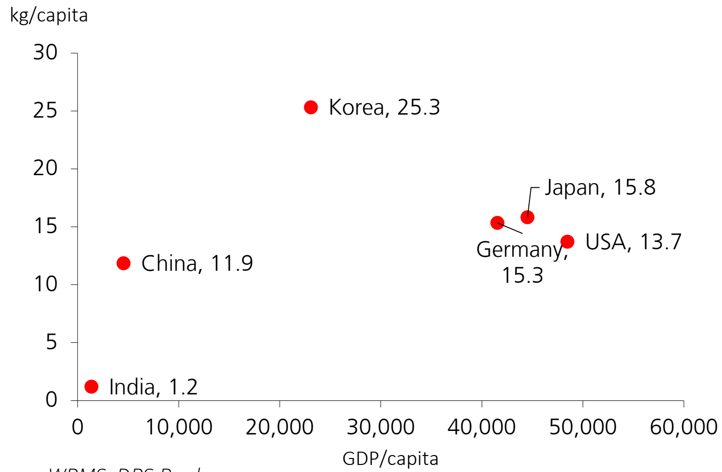


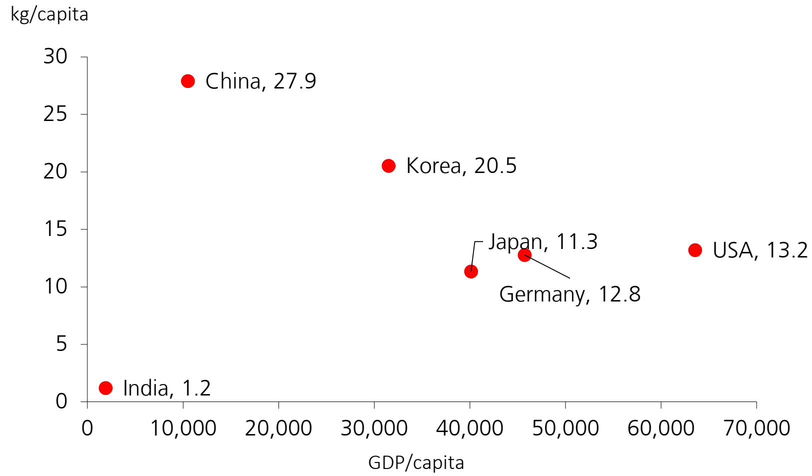
Source: WBMS, DBS Bank

Contribution to global aluminium consumption by region (2020)



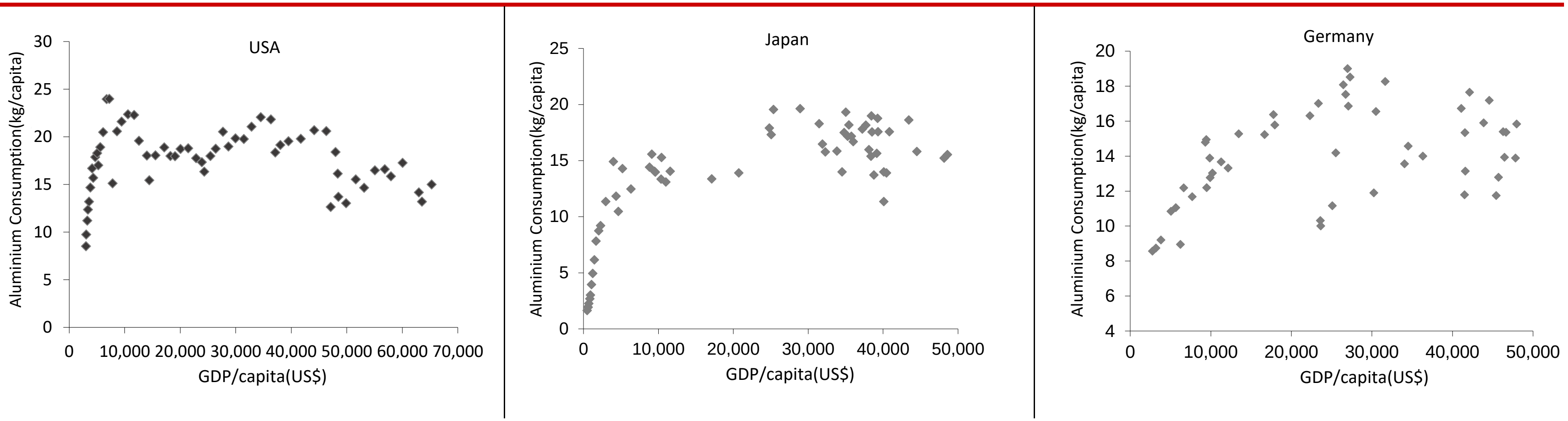
Aluminium consumption per capita vs. GDP per capita: 2010 vs. 2020





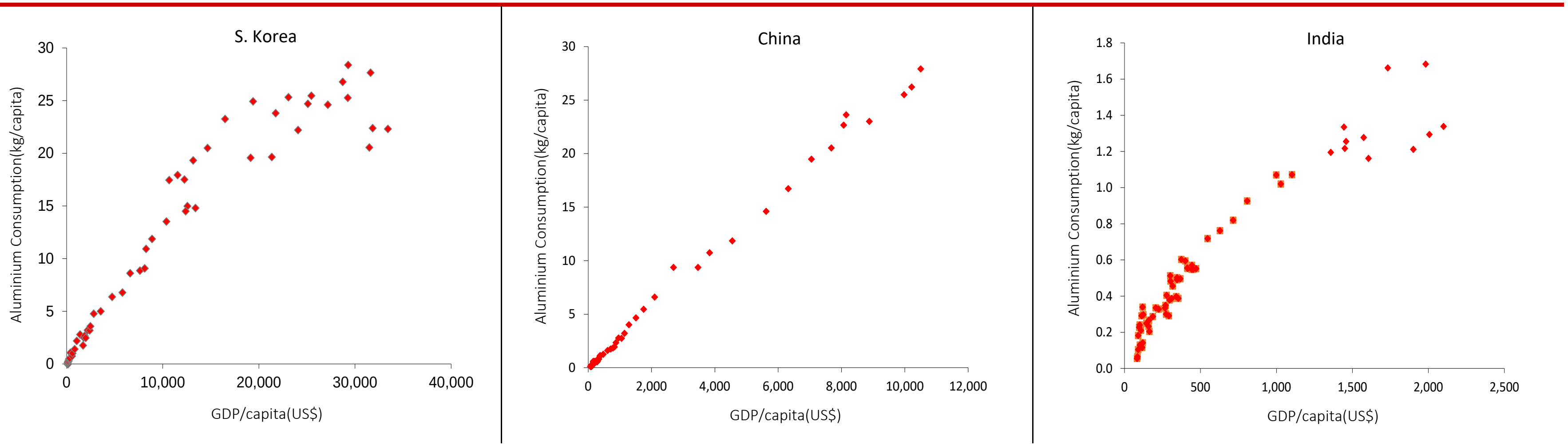
Source: WBMS, DBS Bank

Aluminium consumption per capita vs. GDP per capita: Historical trajectory



Source: WBMS, DBS Bank

Aluminium consumption per capita vs. GDP per capita: Historical trajectory

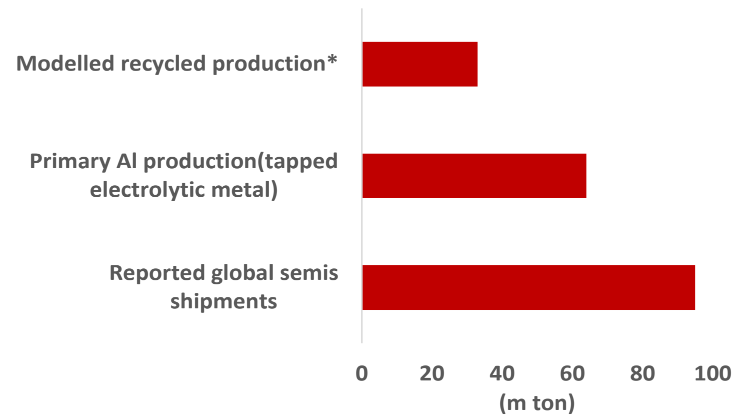


Source: WBMS, CRU, DBS Bank

C.30% of aluminium consumption from recycled aluminium. Apparent primary aluminium consumption stood at c.65m tonnes in 2020; however, the total consumption of aluminium products is estimated to be c.90m tonnes. According to the International Aluminium Institute (IAI), total aluminium production including recycled production was 33m tonnes and the total shipments of semi products reached 95m tonnes. Unfortunately, while concrete statistics for total secondary aluminium consumption in the sector are not available, some institutes estimate secondary production through their own models. According to IAI, total aluminium demand could be met by a 50:50 balance of recycled and primary metal by 2050, based on 2019 collection rates for end-of-life products. Thanks to its recyclability, aluminium is viewed as a "green" and "environmentally friendly" material, as the recycling of aluminium requires 95% less energy compared to primary aluminium production. However, the higher energy density of primary aluminium products poses challenges to the sector with regards to climate change.

Transportation and construction sectors are largest end users of aluminium. For primary aluminium consumption, the construction and transportation sectors are the biggest end users, accounting for 25% and 23% respectively. Machinery & equipment and electrical contributes 11% and 12% of the total consumption. Foil stocks and packaging such as beverage cans account for 9% and 8% respectively.

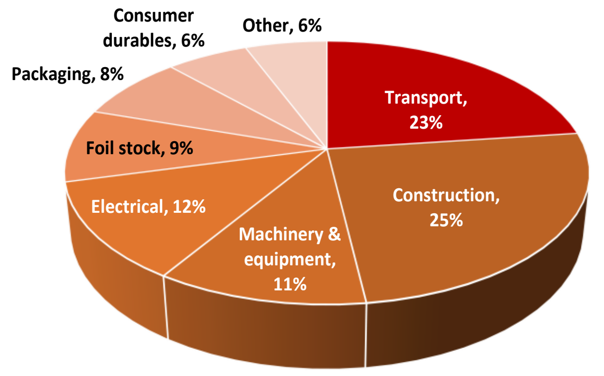
Global aluminium production (2020)



**excluding alloying elements added at the remelting plant*

Source: IAI

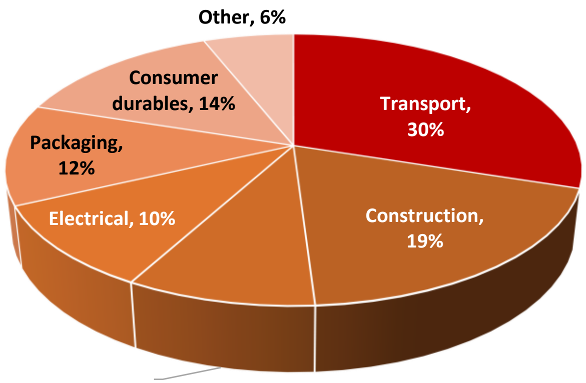
Global end use of primary aluminium by sector (2020)



Source: Norsk Hydro

Bright demand prospects for aluminium arising from urbanisation. Rapid urbanisation – the continuing migration from rural to urban areas around the globe and resulting in the growth of mega-cities (with population of >10m) – should be a key determinant of strong demand growth for aluminium. In a recent research report conducted by IAI, consumer durables are likely to register the strongest demand growth, contributing 14% of global aluminium demand in 2050 vs. 6% in 2020, as a result of the rapid urbanisation in developing economies such as India and ASEAN.

Global end use of aluminium by sector (2025)



**excluding alloying elements added at the remelting plant*

Source: IAI

Aluminium demand to recover stronger than expected in 2021. Global aluminium demand is expected to rebound strongly from the negative developments stemming from COVID-19. China is expected to continue delivering strong demand growth of 5.8% in 2021, following growth of 6.4% in 2020. The demand in the US and EU will outpace GDP growth, with a strong recovery in the transportation sector and aggressive restocking across sectors that use aluminium. Also, the demand in other countries is projected to have a firm recovery trajectory. However, recent findings pertaining to variant strains of the coronavirus could pose a key risk to demand growth.

Positive outlook for global aluminium demand. Global aluminium demand is expected to grow at a CAGR of 3.9% by 2025, backed by the expansion of applications for aluminium and the high rates of aluminium consumption in terms of kg/capita, which is one of the clear indicators of a robust and well-developed economy. As there is strong demand growth for developing countries including India and increasing urbanisation and industrialisation in ASEAN countries, we forecast 5.2% annual demand growth in Asia excluding China. However, demand growth in China alone is expected to register a CAGR of 3.6%, lower than that of Asia.

On the other hand, the EU and America are likely to post demand CAGRs of 3.6% and 3.5% by 2025 respectively, which are higher compared to the other metals, driven by the higher penetration of electric vehicles (EVs) and infrastructure investment. On another positive note, IAI forecasts a global CAGR of 4.2% over the 30-year period to 2050, resulting in an annual demand of approximately 335m tonnes per year by 2050.

Global primary aluminium consumption forecast

(k tonne)	2017	2018	2019	2020	2021F	2022F	2023F	2024F	2025F	CAGR (20-25)
Europe	8,601	8,716	8,319	7,363	7,805	8,117	8,280	8,362	8,446	**2.8%**
Y-o-y %	2.5%	1.3%	-4.6%	-11.5%	6.0%	4.0%	2.0%	1.0%	1.0%	
Africa	564	607	589	413	413	433	451	464	478	**3.0%**
Asia	43,087	47,305	48,547	50,660	53,700	55,848	57,524	58,674	59,847	**3.4%**
Y-o-y %	-0.2%	9.8%	2.6%	4.4%	6.0%	4.0%	3.0%	2.0%	2.0%	
China	31,908	35,521	36,648	39,005	41,268	42,588	43,653	44,526	45,417	**3.1%**
Y-o-y %	-2.0%	11.3%	3.2%	6.4%	5.8%	3.2%	2.5%	2.0%	2.0%	
India	2,253	1,750	1,829	1,655	1,722	1,808	1,871	1,936	1,995	**3.8%**
Y-o-y %	2.4%	-22.3%	4.5%	-9.5%	4.0%	5.0%	3.5%	3.5%	3.0%	
Vietnam	200	1,253	1,405	1,639	1,737	1,824	1,897	1,954	2,032	**4.4%**
Y-o-y %	33.3%	526.7%	12.1%	16.6%	6.0%	5.0%	4.0%	3.0%	4.0%	
America	7,447	6,472	6,739	6,033	6,334	6,651	6,851	6,988	7,093	**3.3%**
Y-o-y %	7.2%	-13.1%	4.1%	-10.5%	5.0%	5.0%	3.0%	2.0%	1.5%	
Oceania	336	281	284	327	327	333	343	350	357	**1.8%**
Total	**60,035**	**63,382**	**64,478**	**64,796**	**68,579**	**71,383**	**73,448**	**74,838**	**76,221**	**3.3%**
Y-o-y %	0.9%	5.6%	1.7%	0.5%	5.8%	4.1%	2.9%	1.9%	1.8%	

Source: WBMS, DBS Bank

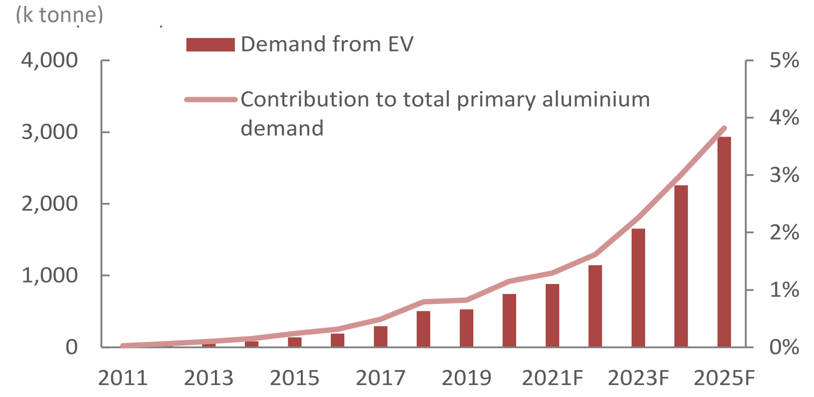
Aluminium demand from EVs

Aluminium demand from EV to grow to 10% of total demand. Given the silver metal's unique characteristics such as its durability, flexibility, lightweight nature, non-corrosiveness, and conductivity, aluminium's scope of applications has been expanding. The area that is expected to see the highest growth is electric vehicles (EVs). The main usage of aluminium in the EV space pertains to battery packs and we expect the global EV sales to reach c.32m units, accounting for 36% of total new car sales in 2030 vs. c.3m units or 5% of new car sales in 2020. Considering there is on average 250kg of aluminium per EV, aluminium demand from only EVs will equate to 3m tonnes by 2025 and 8m tonnes by 2030. This is equivalent to 12% of total primary aluminium consumption of 2020 and c 10% of total aluminium demand from a mere 750k tonne or 0.9% to the total aluminium demand in 2020.

Aluminium's role in EV. Aluminium's lightweight is a key factor that increases the potential for its further demand growth. The weight of a car is crucial for energy efficiency and cost, especially for EVs. Every 100kg weight saved increases an EV's milage by 10-11% and cuts battery costs by 20%, according to industry analysis. When lighter materials, such as aluminium, are used to make EV car bodies, this can help offset the weight of batteries.

Because of its lightweight, aluminium should contribute to reducing CO_2 emissions, too. As 1kg of aluminium could replace 2kg of steel in the automotive industry, which implies a reduction of 13-23kg CO_2 per kg of aluminium over the vehicle's lifetime, according to the automotive industry.

Aluminium demand from EVs



Source: WBMS, EY, IAI, DBS Bank

Aluminium consumption per car has promising growth outlook. The weight of ICE vehicles in meeting CAFE and other regulations on emissions has been felt for many years. The automotive sector, which includes auto body sheets (ABS), extrusions and Al-Si castings, is currently a strong growth market for aluminium. According to a survey by Druker, the average aluminium content of a European automobile will increase by 19.6kg/unit to 198.8kg/unit in 2025, from 179.2kg/unit in 2019. Also, it further forecasts aluminium content in vehicles in the EU to grow at an average CAGR of 3-4% to 4.2m tonne per annum in 2028. For North America, Ducker reports growth in aluminium intensity for all vehicles of more than 5 kg/vehicle per year. Over 30 years, this represents an additional 150 kg per vehicle.

Average aluminium content of a European automobile

Source: IAI, DBS Bank

Aluminium usage in EV infrastructure. Aluminium is commonly used as a housing material for EV charging stations, as 45% of charging station producers use aluminium extrusions for housings. Due to different types/shapes of charging stations, it is difficult to estimate the precise aluminium demand, but the demand will grow in line with EV penetration rates and the industry's expected total demand is several hundred thousand tonnes. Moreover, the International Copper Association estimates more than 40m ports will be needed over the next decade, which will consume an extra 100,000 tonnes of copper per year by 2027. However, the Aluminium Institute expects demand for aluminium to be greater than that of copper for EV infrastructure.

Aluminium in EV battery. The content of aluminium in cathodes of NCA type of batteries, used by Tesla cars, is up to 5%, while the newer lithium-sulphur batteries, which also promise high performance-to-weight ratio, consist of 5-15% of aluminium content. According to BNEF, aluminium demand for batteries (including battery enclosures) will reach about 1.9m tonnes/year by 2030.

Recently Indian Oil Corp., the nation's largest oil refiner, has teamed up with start-up Phinergy Ltd. to develop the Israeli company's aluminium-air battery. This is a new battery technology that uses aluminium rather than lithium as the key ingredient to reduce dependence on imported materials and technology, especially from China. Lithium is scare in the country, but aluminium is abundantly available, as India is among the top 10 bauxite producers in the world. The battery works by using the electricity generated when aluminium plates react with oxygen, and this has one of the highest energy densities for a battery. However, the high cost and its inability to be recharged is what stopped it from being adopted widely when it was first proposed in the 1960s.

Aluminium demand in China

China's aluminium consumption to grow at estimated 3% CAGR in 2021-2025, up from 1.7% in 2020. China's industrial output growth and investments were boosted by the strong economic recovery amid the Chinese government's stimulus policies and loosened monetary environment. As such, China's aluminium consumption market has swiftly rebounded after being disrupted by the outbreak of COVID-19. In anticipation of the keen demand for the lightweight material from the transportation and package industries, China's aluminium consumption growth is estimated to be 3% in 2021-2025, vs. 2020's 1.7%.

Construction (28% of China's consumption). In January-June 2021, total investment in real estate development increased by 15% vs. the average of c.11% p.a. during 2011-2020. In terms of GFA, commodity housing sales increased by 38% y-o-y in 1H2021. On the residential side, the GFA of new starts increased by 5.5% while completed GFA increased by 27%. GFA under construction in the real estate sector remained stable at >10%. On a positive note, China's property market is expected to enter the phase of huge housing upgrade demand, driven by the improvements of location, apartment type, housing function, etc. According to the China Index Academy, urban renewal is set to continue via the demolition of old houses at an annual rate of 1.2-1.4%, resulting in additional renovation demand for aluminium going forward.

Transportation (19% of China's consumption). The national passenger vehicle market has stabilised and the new energy vehicle (NEV) market has been swiftly expanding under the government's carbon policies. Based on the first six months' data, China's new energy vehicle sales is expected to exceed 2m units, vs. 2020's 1.3m units. As such, we believe the increasing usage of aluminium for its lighter weight and energy-saving benefits.

Machinery equipment (20% of China's consumption). Construction machinery sales surged as sales of excavators, cranes and loaders rose 38%, 32% and 33% y-o-y in January-June 2021. The strong growth is attributed to the continuous pick-up in the electrical and transportation machinery investments and growth in machinery used for environmental conservation projects. This will also continue to contribute to the sector's consumption growth.

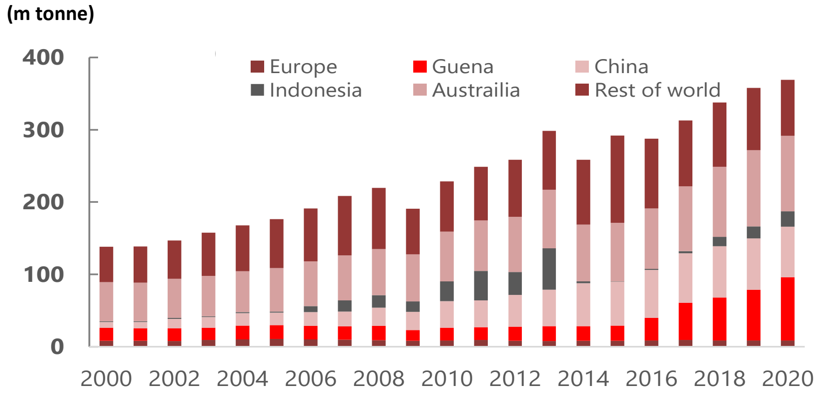
Bauxite and Alumina to fully support aluminium sector

Global Bauxite industry

Ample bauxite reserves. According to the US Geological Survey in 2019, global bauxite reserves are estimated to be anywhere between 55bn and 75bn tonnes. The reserve is more than 150bn of annual bauxite production, which suggests plenty of reserves for the future. Moreover, Australia and Guinea have the largest proven reserves, which stand at 6bn tonnes and 7.4bn tonnes, respectively.

Strong growth of global bauxite output. As the demand for aluminium has been increasing, bauxite production volume has increased by 2.7x to 369m tonnes in 2020 compared to 138m tonnes in 2000, which implies 5% annual growth for the last 20 years.

Global bauxite production by region



Source: WBMS, DBS Bank

Australia and Guinea are largest producing countries. The global bauxite mine output in 2020 came in 369m tonnes. Of this, about 85% is converted into alumina for aluminium smelting due to aluminium's various industrial uses. The three largest bauxite producers are Australia, Guinea, and China, which made up 28%, 24%, and 19% of total bauxite production in 2020.

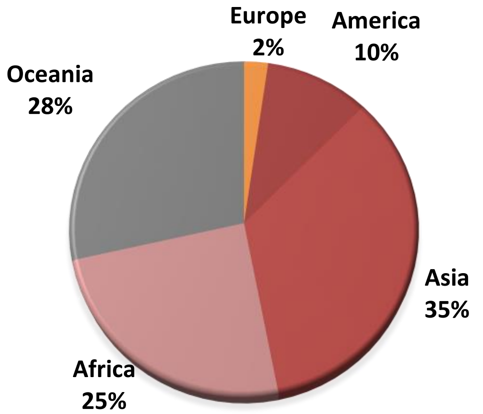
Top Bauxite Producing Countries in 2020

	Output (m tonne)	Contribution (%)
Australia	104.3	28%
Guinea	87.7	24%
China	79.6	19%
Brazil	28.6	8%
Indonesia	21.3	6%
India	20.4	6%
Global Production	369.0	100%

Source: WBMS, DBS Bank

Oceania and Asia supply almost 2/3 of world's bauxite. According to the International Aluminium Institute, Australia (Oceania) is the world's largest producer of bauxite in 2020, accounting for about 28% of global production. Since 2000, Australia has been consistently increasing its bauxite production at about 3.4% annually and has remained an important player in the bauxite industry. Asia is ranked second, whose contribution mainly comes from China, Indonesia and India.

Global bauxite production by region (2020)

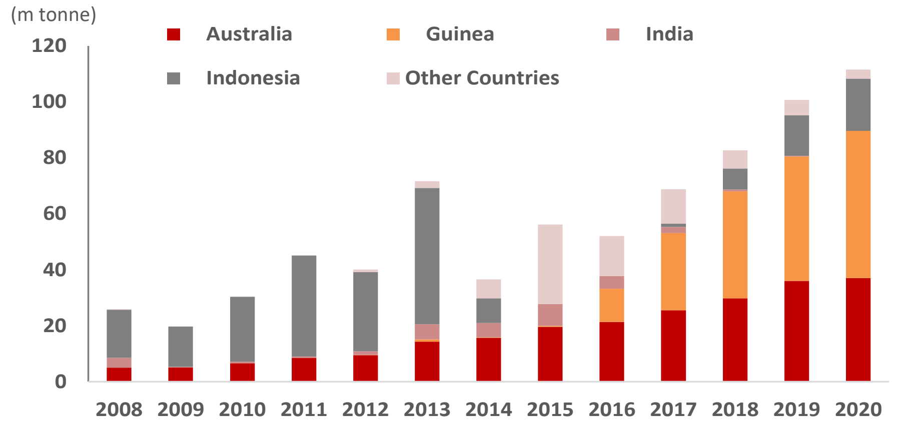


Source: WBMS, DBS Bank

Guinea emerging as a key producer for bauxite. Guinea's bauxite industry has undergone an opposite trend compared to that of China's. From 2000-2010, Guinea's bauxite production decreased at an annual rate of 0.2%. Bauxite production remained stable until 2014, when Chinese investments were directed to Guinean bauxite mines. Its bauxite production in 2014 was 20.3m tonnes and this surged to 31.3m tonnes in 2016. From 2010-2020, bauxite production in Guinea increased annually at a rate of 17.4% and currently accounts for 96.8% of Africa's total bauxite production. In 2020, roughly half of the bauxite exports were bought by China, Spain, Ireland, and Ukraine. Moreover, Guinean bauxite exports accounted for 55.6% of global bauxite exports in 2020.

China, the biggest importer of bauxite; imports from Guinea surged. The Chinese bauxite sector has seen strong growth since 2000, with its production increasing at an average rate of 11.5%. However, during the past decade, it has shown signs of decelerating growth, with an annual increase of 6.6% from 2010-2020. Recently, in China, several bauxite mines in Shanxi and Henan were shut down due to the decrease in quality; however, Guizhou is now viewed as a potential hub for bauxite, as it has an estimated reserve of 162m tonnes. China's decelerating growth of bauxite production can be attributed to increased imports and investments overseas going into bauxite production. China is one of the largest bauxite importers with much of its bauxite coming from Guinea, Australia, and Indonesia. In 2020, China accounted for 81% of global bauxite imports.

China's bauxite imports



Source: Bloomberg Finance L.P., DBS Bank

Indonesia's ban on bauxite exports impacted the sector. In 2014, the Indonesian government banned the exports of bauxite to encourage local miners and alumina producers to refine bauxite into alumina for export. In the early 2000s, Indonesia was the largest bauxite exporter to China. Despite being very reliant on Indonesian bauxite exports, China found other bauxite suppliers in Malaysia and Guinea after 2014, although the Indonesian government had hoped to rake in Chinese investments in local alumina production. The ban on bauxite exports only led to the construction of one alumina refinery. According to the World Bureau of Metal Statistics (WBMS), there was a steep decrease in Indonesia's bauxite production from 57m tonnes in 2013 to 2.5m tonnes in 2014, respectively.

Relaxation of bauxite exports. As a result, the government relaxed the ban in 2017, and aims to allow exports in 2022. However, due to the COVID19 pandemic, the relaxation of the ban has been postponed to June 2023. In May 2020, several restrictions on bauxite mining were lifted, such as strict time constraints on mine operating permits. Moreover, later in the year in October 2020, Indonesia's parliament redrew the regulatory landscape, including rules that govern mining. From 2015 to 2020, bauxite production volume in Indonesia increased about 80.8% annually from 611,000 tonnes in 2015 to 21.3m tonnes in 2020. We can expect the uptrend to continue.

Expect global bauxite supply growth to be enough to meet demand growth. Currently, there are several bauxite projects being developed globally, led by Cameroon, Guinea and Guyana. Within five years, the projects in the three countries will produce over 26m tonnes of bauxite, which is c.9% of the current bauxite output. We expect bauxite production volume to grow 5.5% and 4.2% in 2021 and 2022, respectively. Going forward, we expect more bauxite production in Indonesia with the completion of its alumina plants in 2022.

Bauxite industry's environmental concerns. In the bauxite mining industry, one of the key environmental focuses is land conservation. For native ecosystems to return to bauxite mine sites, the topsoil needs to be replaced once mining is completed. As such, it is common practice to store the topsoil for mining sites, so that it can be replaced once the mine closes and rehabilitation to the land site can begin. On average, 80% of the land is properly rehabilitated.

DBS Live more, Bank less

World largest bauxite projects

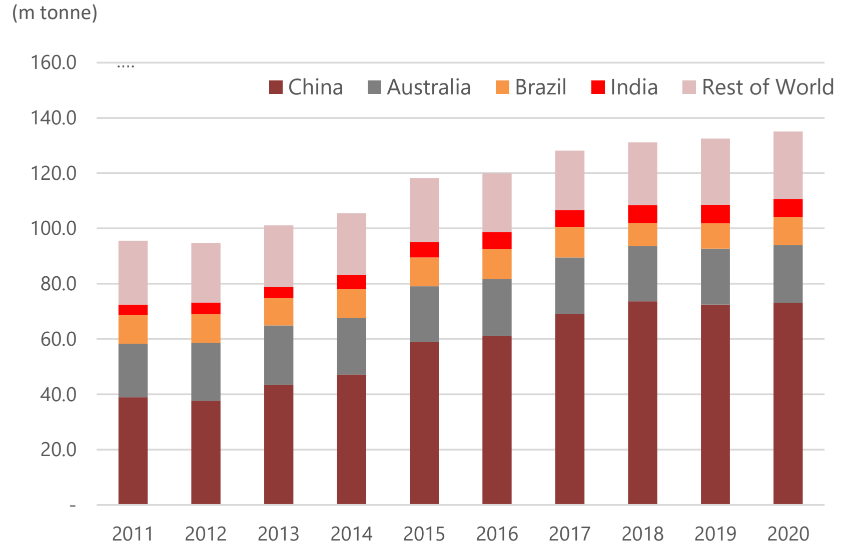
Country	# of Projects	Total Capex (m USD)	Yearly Production and Reserves
New Developments			
Cameroon	1	201	Production: 4.9mnt/yr Total Reserves: 97.3m tonnes Notes: Reported Reserves in Aug. 2020
Guinea	3	969	Production: - 0.84mnt/ yr (2020) - 10mnt/yr (2021) - 10mnt/yr (2024) Total Reserves: 1,182.7m tonnes
Guyana	1	319	Production: 0.320mnt/yr Total Reserves: 1.7m tonnes Notes: Project commissioned in Feb 2020
Operational			
Guinea	3	1,926	Production: 22.84mnt/yr Total Reserves: 2,170.8m tonnes Notes: Started production from 2018 – 2020
Saudi Arabia	1	10,800	Production: 4.3825mnt/yr Total Reserves: 69m tonnes Notes: Mines Bauxite and Refines Alumina
Australia	1	1,978	Production: 22.8mnt/yr Total Reserves: 287m tonnes Notes: Started production Dec. 2018
Vietnam	1	700	Production: 0.65mnt/yr

Source: Various, DBS Bank

Global Alumina Industry

Strong growth of alumina production for last decade. In 2020, the global alumina production was 135m tonnes, which represents an average increase of 5% p.a. from 2000 to 2020. From 2000 to 2010, production increased by 1% annually, but in the next decade (2011 to 2020) there was a 4% annual increase in alumina production. This rise can be attributed to China's drastic ramping up of alumina production during the same period.

Global alumina production by region



Source: WBMS, DBS Bank

China produces more than half of global alumina output. More than three quarters of the world's alumina is produced by the top four producing countries – China, Australia, Brazil, and India. China produces the most amount of alumina, arising from its status as the largest bauxite importer in the world. While China has been steadily increasing its alumina production, Australia and Brazil have been showing marginal growth, with CAGRs of 1% and close to 0% from 2011-2020 respectively. India, on the other hand, has been increasing its bauxite production by 6% annually.

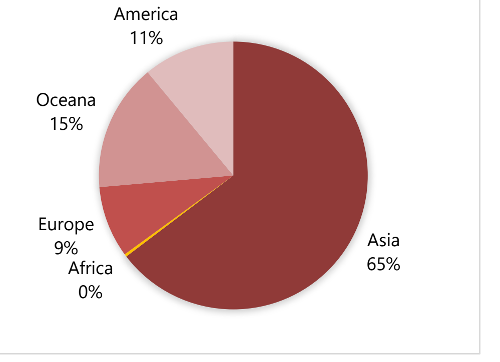
Global alumina production trend by region

Country	(m tonnes)	% contribution
China	73.1	54%
Australia	20.8	15%
Brazil	10.2	8%
India	6.5	5%
Others	24.4	18%
Total	135	100%

Source: WBMS, DBS Bank

Alumina refining in Asia accounts for the majority of global production, as China and India constitute the bulk of the production. In America, Brazil is a major producer. Interestingly, despite having the largest bauxite production, Guinea has a very low alumina output, which did not even break a million tonnes in 2020, which shows that the majority of its bauxite production is exported. In Europe, Russia is the largest alumina producer, producing 2.8m tonnes in 2020.

Global alumina production contribution by region (2020)



Source: WBMS, DBS Bank

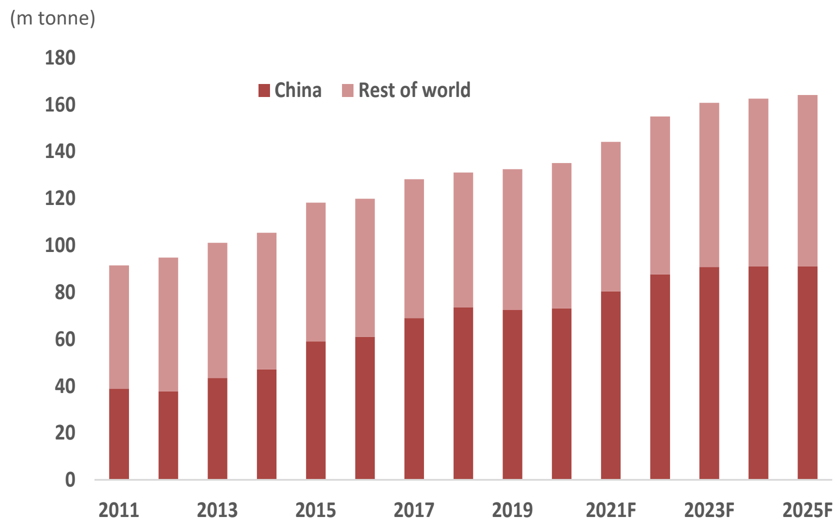
While China's alumina production has surged, it remains a net importer. From 2011 to 2020, China's alumina production increased on average 7% annually. Currently, it has surpassed Australia as the world's largest alumina producer. Although China raked in 80.8% of global bauxite imports, it did not export any alumina in 2020, meaning that it uses all of its alumina production to produce various end-products such as aluminium. The significant increase in alumina production was achieved through the increase in bauxite imports from countries like Guinea. Furthermore, despite China's large production of alumina, it is still a net importing country of alumina with 3.8m tonnes of bauxite imports in 2020, which represent 15% of global alumina imports.

Australia – largest exporter of alumina with solid output growth. Although Australia was the largest alumina producer back in 2009, contributing 40% to global alumina production, its alumina production accounted for 15% of

2020's global alumina production. However, it remained the largest exporter of alumina, exporting 18m tonnes, which accounts for 47.4% of global alumina exports. From 2011 to 2020, Australia's production rose steadily, increasing by 7% annually.

Alumina market to remain in surplus. Due to the high alumina output and current projects in development, the market will remain in a surplus for the next few years. Chinese aluminium companies have become self-sufficient in alumina since 2019 and are now vertically integrated with bauxite supplies in Guinea. The market expects c.30mt of additional capacity building by 2025, of which c.8mt is scheduled to come online in China. Of these projects, most are expected to be commissioned in the next two years. Accordingly, global alumina production is expected to grow 6.7% and 7.5% in 2021 and 2022 respectively and register an annual growth of 4% by 2025.

Aluminium production forecasts



Source: WBMS, DBS Bank

Global map of bauxite and alumina production (2020)

North America

Bauxite: 2.2%
Alumina: 3.4%
Key bauxite production countries: USA, Jamaica

Europe

Bauxite: 2.3%
Alumina: 8.6%
Key production countries:

Asia

Bauxite: 34.5%
Alumina: 64.7%
Key production countries: China, Indonesia, India,

South America

Bauxite: 7.9%
Alumina: 7.6%
Key bauxite production countries: Brazil, Guyana

Africa

Bauxite: 24.6%
Alumina: 0.3%
Key bauxite production countries:

Oceania/Australia

Bauxite: 28.5%
Alumina: 15.4%
Key bauxite production countries: Australia

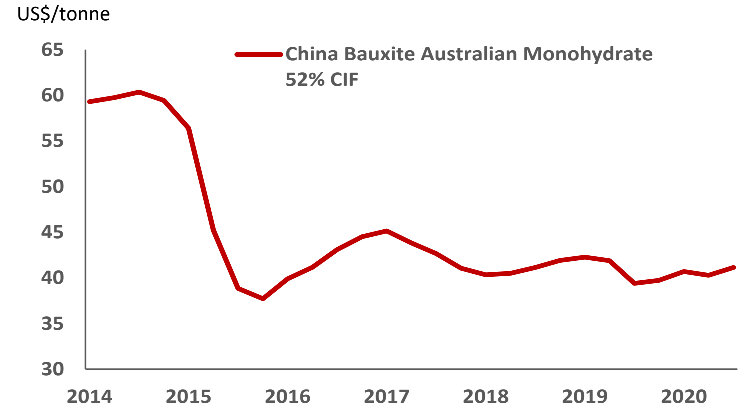
Source: IAI

Bauxite & alumina prices trended down on ample supply

Bauxite prices, stable at US$40-45/tonne.
In 2016 when the market had faced significant oversupply, bauxite prices collapsed to below US$40/tonne from US$60/tonne in 2015, in line with the fall of aluminium prices. Since 2017, bauxite prices have recovered slightly following the rebound of aluminium prices; however, they have been stable at US$40-45/tonne level despite Indonesia's ban on bauxite exports in 2014. This is mainly thanks to strong production in Guinea which has fulfilled the bauxite demand in China. Chinese aluminium players have been investing in mines outside China, especially in Guinea, due to insufficient domestic resources. With the capacity cap for aluminium in China, bauxite prices are likely to remain stable at current levels.

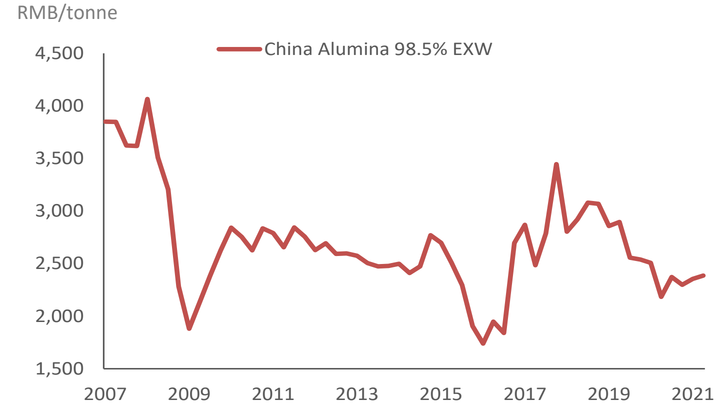
Alumina's prices remain subdued from oversupply.
Like bauxite, alumina prices have been trending down for a decade, although its correlation with aluminium prices is greater than that with bauxite prices. Since 2018, alumina prices have weakened regardless of aluminium price changes. This can be attributed to the upstream integration of Chinese aluminium smelters through higher alumina capacity and the securing of bauxite mines. Accordingly, the spot alumina market is still oversupplied, which represents a more favourable market structure for aluminium smelters. Alumina prices are likely to remain weak going forward.

Bauxite prices



Source: Bloomberg Finance L.P., DBS Bank

China alumina prices

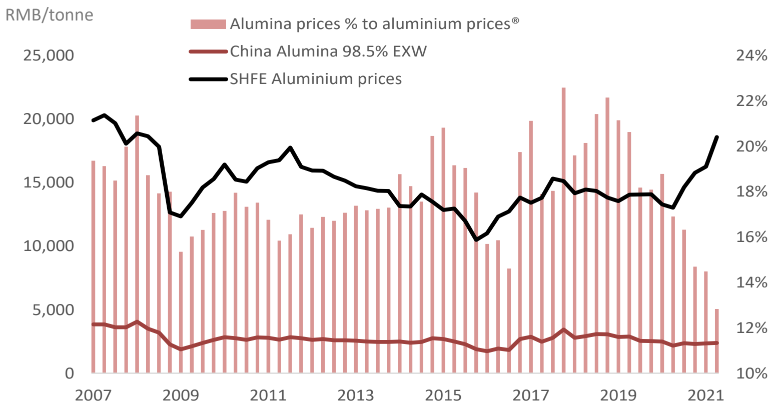


Source: Bloomberg Finance L.P., DBS Bank

Alumina is priced at 16% of LME prices on average.
Alumina is priced in one of two ways. It is either sold on a spot basis, at a fixed price for a specified period (usually one year) or based on a formula related to the London Metal Exchange (LME) metal price, the simplest of which is a straightforward percentage of the LME metal price. Since 2007, Chinese alumina (98.5% EXW) prices have ranged from 12-25%, with 18% as the average to the Shanghai Futures Exchange (SHFE) aluminium spot prices. The percentage of alumina prices to aluminium prices tends to surge when aluminium prices improve, which implies that smelters are willing to pay higher prices for alumina.

However, the ratio has declined to 13% recently despite the strong surge in aluminium prices due to abundant alumina supply.

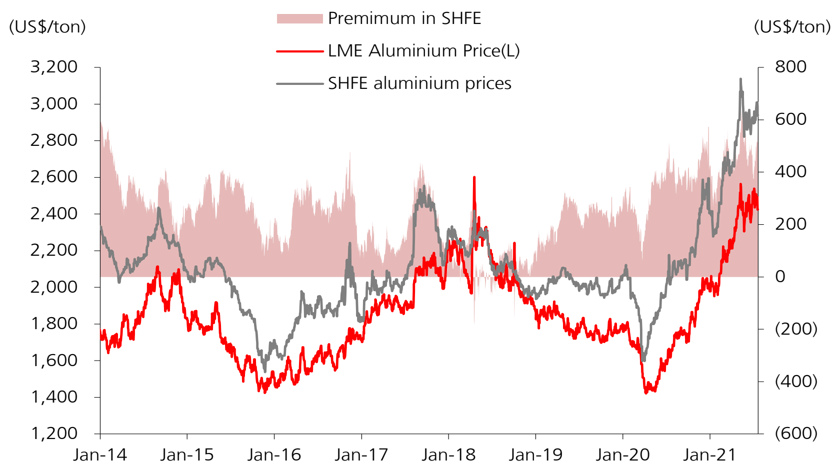
LME Aluminium vs. Alumina prices



Source: Bloomberg Finance L.P., CRU, DBS Bank

China's price premium during the financial crisis.
Post-financial crisis, aluminium prices were higher than LME prices. The fundamental price distinction between the LME and SHFE is grounded in the physical markets, i.e., the supply-demand balance and actual transportation costs connecting the two markets. The premium in China tends to increase when aluminium prices increase, and recently going over US$500/tonne.

Aluminium prices: LME vs. SHFE



Source: Bloomberg Finance L.P., DBS Bank

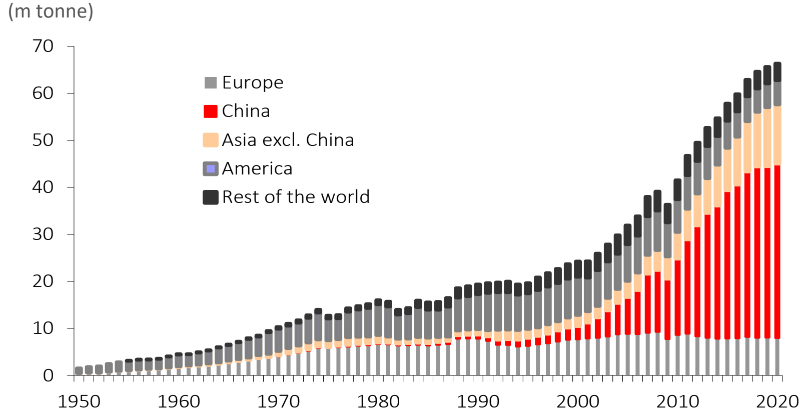
Aluminium supply growth to decelerate

Global aluminium capacity and production: Jump driven by China

China's production has spiked up over the last decade. The biggest change in the global aluminium production landscape over the last 20 years has been the rapid growth of China as a producer. In 2000, the Chinese primary aluminium production was 2.8m tonnes, accounting for 12% of global aluminium production. Production has grown more than 13-fold to 37.1m tonnes (12% CAGR), making up a larger 56% of total global aluminium output. China has now become the single largest producer in the world based on annual production. Thanks to China's production growth, global aluminium production volume has also been growing 5% p.a. since 2000, more than double the 2.3% growth rate in the 1990s.

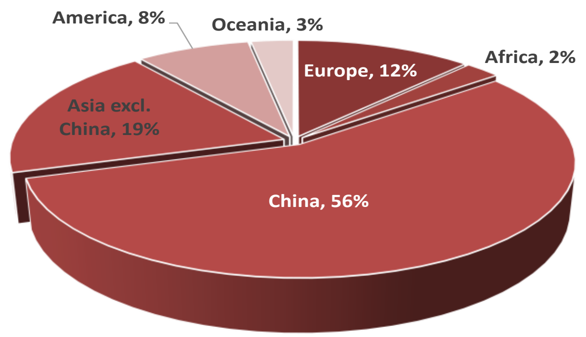
China's rapid capacity expansion fuelled by demand growth. From 2000 to 2017, global primary aluminium production capacity expanded by 52m tonnes, with China contributing 82% of the expansion. Over this period, Chinese primary aluminium production capacity had grown enormously from 2.6m to 45m tonnes, fuelled by a rapidly growing domestic market as well as its lower capital, labour, and realisation costs which had led to an oversupply of the aluminium market. To resolve the supply glut, the Chinese government introduced supply reforms in 2016. As a result, China's capacity has declined by more than c.2m tonnes during the last three years.

Global primary aluminium production



Source: WBMS, DBS Bank

Global primary aluminium production by region (2020)



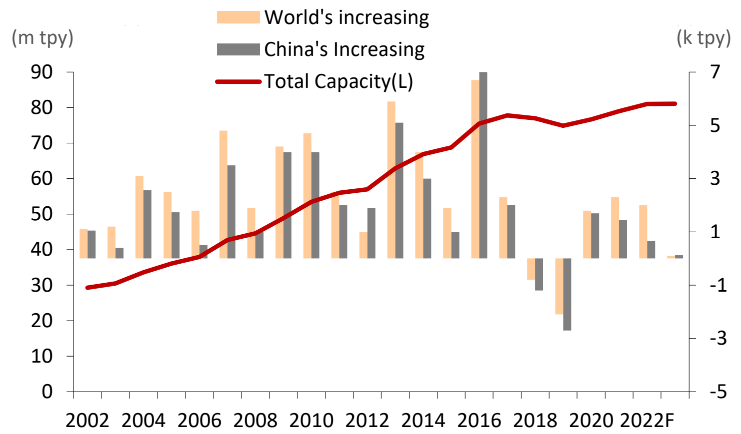
Source: WBMS, IAI, Antaike, DBS Bank

Promising near-term growth, but medium-term deceleration on the cards

Global capacity to expand in the near term, driven by China. In the aluminium industry, the closure and expansion of capacity is a more common occurrence compared to other industries. Despite a series of capacity closures from Xinjiang and Shandong in 2017, China's capacity is expected to grow further to 45m tonnes within the next two years, which is the ceiling capacity set by the government. In the Chinese aluminium industry, the smelters are shifting their capacity to the Yunan province. One representative project is Weiqio Wenshan's smelting construction in the Yunnan province. Going forward, more aluminium smelting investment and construction activities are expected in Yunnan, which will bring its capacity to 45m tonnes. Moreover, higher production will be seen from the increased utilisation.

Indonesia to rise as a key contributor to production growth. As Indonesia lifts the relaxation of bauxite exports ban, there will be two major aluminium smelting projects rolled out by Inalum and Indonesia Huaqing Aluminium. Indonesia Huaqing Aluminum is a joint venture between Huafeng Group and Qingshan Industrial. Its project is located in Qingshan Industrial Park on Sulawesi Island, Indonesia, where the construction of a plant with an annual output of 4m tonnes of alumina, 2m tonnes of electrolytic aluminium, 1m tonnes of pre-baked anodes, and 4780MW cogeneration units, is planned. The first phase of the project consists of reaching production capacities of 1m tonnes of electrolytic aluminium per year and 500k tonnes of pre-baked anodes per year. It will also include the construction of 4 × 380MW cogeneration generating sets and supporting public auxiliary facilities. Upon completion of the project, Indonesia Huaqing Aluminum will become the largest aluminium enterprise in Southeast Asia. On the other hand, Inalum has plans to increase its aluminium smelting capacity after the completion of several alumina projects with CHALCO and ANTM.

Global primary aluminium capacity



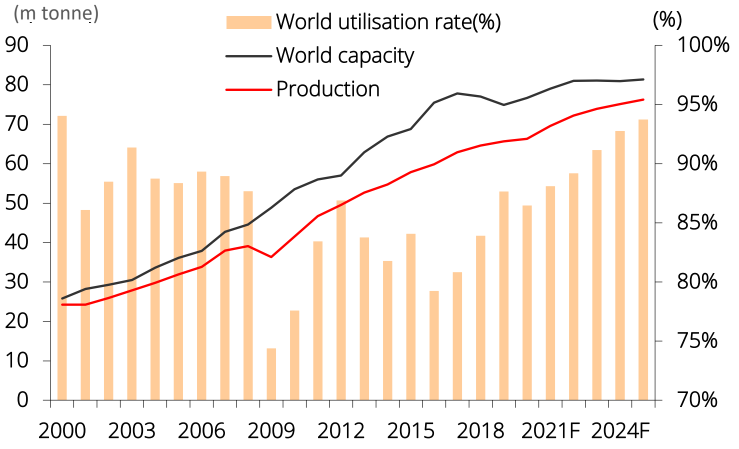
Source: WBMS, IAI, Antaike, DBS Bank

Growth potential in Russia and India. Russian aluminium production will increase in 2021 due to United Company Rusal's commissioning of its Taishet smelter, which had previously been delayed due to the impact of COVID-19. Going forward, its production will be supported by the firm's multi-year deal with Glencore to supply up to 6.9mnt of aluminium over the period of 2020 to 2024.

On the other hand, Indian aluminium production will benefit from a US$17.7bn investment that was announced in January 2021, by the country's National Aluminium Company over the coming years. By 2027-2028, the firm will have undertaken a 500kt tonne capacity expansion at its Angul aluminium smelter. For the past three years, India's smelting capacity has remained at 4.1m tonnes.

Production to move in line with capacity expansion but restrained by power cost. According to the IAI, committed projects are expected to add 5m tonnes of aluminium capacity by 2023, and there is limited capacity growth after 2024. In line with capacity growth, global primary aluminium output is expected to increase 5% and 3.8% in 2021 and 2022 respectively. By 2025, global output growth is expected to reach 2.6% p.a., bolstered by 3.4% annual growth in China. The utilisation of global primary aluminium will continue to rise towards 2025, given the promising outlook for demand and limited capacity development. The carbon neutrality and capacity ceiling in China will be the key drivers for the improving performance in the aluminium sector.

Global aluminium: Capacity, output & utilisation rates



Source: WBMS, IAI, Antaike, DBS Bank

China's total capacity ceiling set at 45mtpa by 2022. China's aluminium production grew 10.1% in 6M21, accelerating from 1.7% growth in 1H20 and 8.8% growth in 3M21. This was due to higher product margins that incentivised a ramp-up in production. Given China's new capacity growth, the government has set an industry total capacity cap of 45mtpa by 2022 vs. 2020's 42mtpa. This indicates that the market will expect future new capacity expansion to come in at around 3mtpa.

Moreover, carbon policies will affect aluminium supplies as smelters look to relocate capacity and transition to new energy sources. Furthermore, an industry consolidation would result in improvements in market supply discipline. In 2021, aluminium production is expected to grow 5.8%, with stable industry capacity utilisation, which would be below the average of c.8% p.a. during 2011-2020.

Global primary aluminium production forecast

(k tonne)	2017	2018	2019	2020	2021F	2022F	2023F	2024F	2025F	CAGR (20-25)
Europe	8,191	8,017	8,044	7,981	8,088	8,335	8,499	8,541	8,584	1.5%
Y-o-y %	3.6%	-2.1%	0.3%	-0.8%	1.3%	3.1%	2.0%	0.5%	0.5%	
Africa	1,679	1,670	1,643	1,605	1,637	1,637	1,637	1,637	1,637	0.4%
Asia	45,869	48,030	48,974	49,683	52,692	54,927	56,334	56,883	57,437	2.9%
Y-o-y %	7.0%	4.7%	2.0%	1.4%	6.1%	4.2%	2.6%	1.0%	1.0%	
China	35,189	36,447	36,447	37,080	39,676	41,660	42,910	43,339	43,772	3.4%
Y-o-y %	7.6%	3.6%	0.0%	1.7%	7.0%	5.0%	3.0%	1.0%	1.0%	
America	5,323	4,980	5,068	5,130	5,233	5,364	5,471	5,635	5,804	2.5%
Y-o-y %	-1.2%	-6.4%	1.8%	1.2%	2.0%	2.5%	2.0%	3.0%	3.0%	
Oceania	1,825	1,914	1,921	1,916	1,954	1,974	1,994	2,013	2,034	1.2%
Total	62,886	64,611	65,650	66,315	69,605	72,237	73,934	74,710	75,496	2.6%
Y-o-y %	5.1%	2.7%	1.6%	1.0%	5.0%	3.8%	2.4%	1.0%	1.1%	

Source: WBMS, DBS Bank

Aluminium market and price outlook, bullish for mid to long term

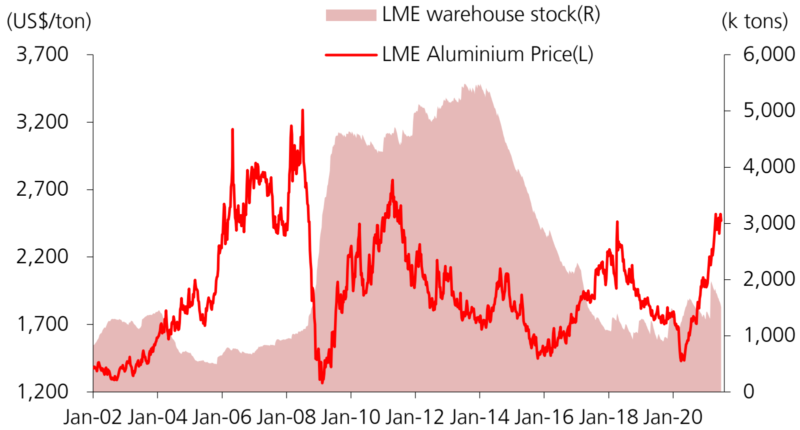
Surge in prices after lukewarm market for many years.
The phrase "the start of a super cycle" is being used increasingly with reference to the increase in prices among metals. However, aluminium prices have responded to the positive sentiment later than the other metals. LME cash aluminium prices peaked at US$2,565/tonne on 10 May, which is the highest in a decade. The record high for LME aluminium prices of US$3,292/tonne was hit in July 2008. Despite recent price retreats for the metal in the wake of China's rollout of price cooling measures for commodities such as the release of national reserves, aluminium prices have remained firm and hovered at around US$2,500/tonne. This is mainly thanks to firm demand, prospects of supply reduction that could lead to a tighter market, and the possibility of more entrenched import demand.

Tight market to give rise to 32% price jump in 2021. Aluminium prices are expected to soften towards the end of year as the tight market situation is likely to ease, backed by production growth and better logistics. The recent price surge is partially attributed to significant container shortages and the temporary blockage of the Suez Canal. As a result, customers are subject to higher premiums, especially in the US and Europe. The average LME aluminium prices are expected to increase by 32% to US$2,250/tonne in 2021.

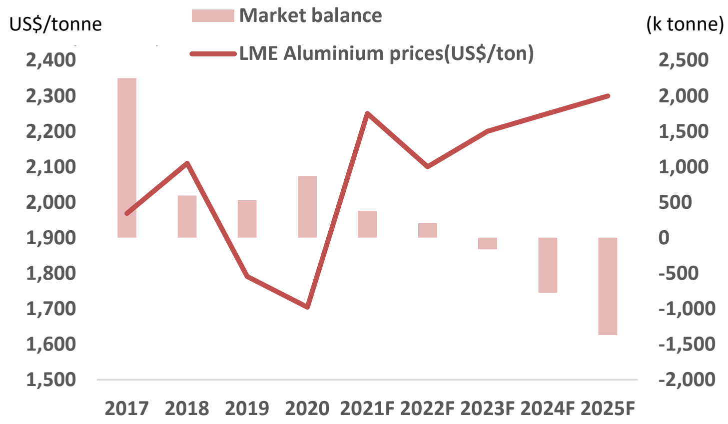
Positive macro-environment in Chinese aluminium market. China's economic growth momentum continues to strengthen on the back of improved sentiment among consumers and private firms, with the ongoing loose monetary environment, new infrastructure construction and current fiscal policies creating a positive outlook. Although the stabilisation of the global COVID-19 situation bodes well for aluminium trade flows across global markets, any overhanging issue for individual countries, such as Russia imposing an aluminium export tax, will affect the overseas supply to local markets.

Aluminium market to face shortages from 2023 onwards. The global aluminium market will remain in a surplus in 2021 and 2022, as new production capacity comes online. This will hinder further price increases, along with tighter monetary policies in the US. Accordingly, the average LME aluminium price is expected to decline in 2022. However, aluminium prices are forecasted to return to an uptrend from 2023 onwards, as the market then is expected to be in a deficit. In particular, carbon neutrality initiatives are likely to constrain the supply growth of primary aluminium. The key risk to our forecast would be the stronger supply growth of aluminium scrap that can act as a substitute for primary aluminium.

Primary aluminium: LME prices vs. warehouse stock



Aluminium market balance vs. LME aluminium prices



Source: Bloomberg Finance L.P., DBS Bank

Global aluminium: Market balance and price forecasts

(k tonne)	2017	2018	2019	2020	2021F	2022F	2023F	2024F	2025F
Bauxite production	312,908	337,680	358,017	368,869	389,157	405,502	418,883	430,612	441,378
Alumina production	128,161	131,121	132,508	135,097	144,213	155,016	160,784	162,540	164,093
Primary aluminium production	62,886	64,611	65,650	66,315	69,605	72,237	73,934	74,710	75,496
Primary aluminium consumption	60,635	64,016	65,123	65,444	69,227	72,031	74,096	75,486	76,869
World supply/demand balance	2,251	596	527	871	378	206	-161	-776	-1,373
LME price (US$/tonne)	1,969	2,110	1,791	1,704	2,250	2,100	2,200	2,250	2,300
y-o-y	22.7%	7.2%	-15.1%	-4.9%	32.0%	-6.7%	4.8%	2.3%	2.2%

Source: WBMS, Bloomberg Finance L.P., CRU, EIU, DBS Bank

Stock picks and recommendation

China Hongqiao is our preferred sector pick. We view China Hongqiao's business model favourably, which is well-integrated with bauxite, alumina, and aluminium operations benefitting from captive power supply. The company is also relocating its capacity and extending its supply chain towards the recycling business and lightweight auto sheets to enhance its market position. Its superior production efficiency enables it to be in the first quartile of the industry's cost curve, placing it at an unrivalled position.

Valuation re-rating catalyst for China Hongqiao. In a bid to make a direct comparison between the two top producers in the market, China Hongqiao and CHALCO, we highlight that China Hongqiao had traded at a premium to CHALCO (>30%) prior to 2014. The trend reversed in subsequent years (2015-2019) as China Hongqiao had to bear impairment charges on its obsolete capacity to comply with regulations. The market subsequently started to re-rate China Hongqiao during 2020 and its valuation discount versus CHALCO narrowed. We believe that China Hongqiao's consistent earnings performance above its peers can justify the premium valuation that it enjoyed pre-2014, and lead to a further re-rating of its share price.

Huge room for improvement from ESG perspective. Greenhouse gas (GHG) data is a primary indicator of a company's production efficiency relating to carbon performance. Since Chinese smelters still rely on coal-burning resources, we expect both China Hongqiao and CHALCO to have great room for improvement from the ESG perspective. As shown in the table below, China Hongqiao has seen lower emissions in both Scope 1 and Scope 2 scorings, primarily attributed to its relatively newer electricity cells for lower energy consumption. Both companies are taking a similar path by tapping on hydropower resources in Yunnan, estimated to expand to 30-40% of their total capacity in 2022/2023 from almost 0% as at end-2020, in line with the China's sustainable industry development trend.

Greenhouse Gas (GHG) comparison

	China Hongqiao		CHALCO	
10,000 tonnes of CO2 equivalent	Scope 1	Scope 2	Scope 1&2	Scope 2
2017	7,097	2,524	6,862	NA
2018	6,658	1,765	7,848	NA
2019	5,499	1,331	6,699	2,695
2020	5,003	2,608	7,331	2,795

**Note Scope 1 covers direct emissions from owned or controlled sources. Scope 2 covers indirect emissions from the generation of purchased electricity, steam, heating and cooling consumed by the reporting company.*

Source: Company data

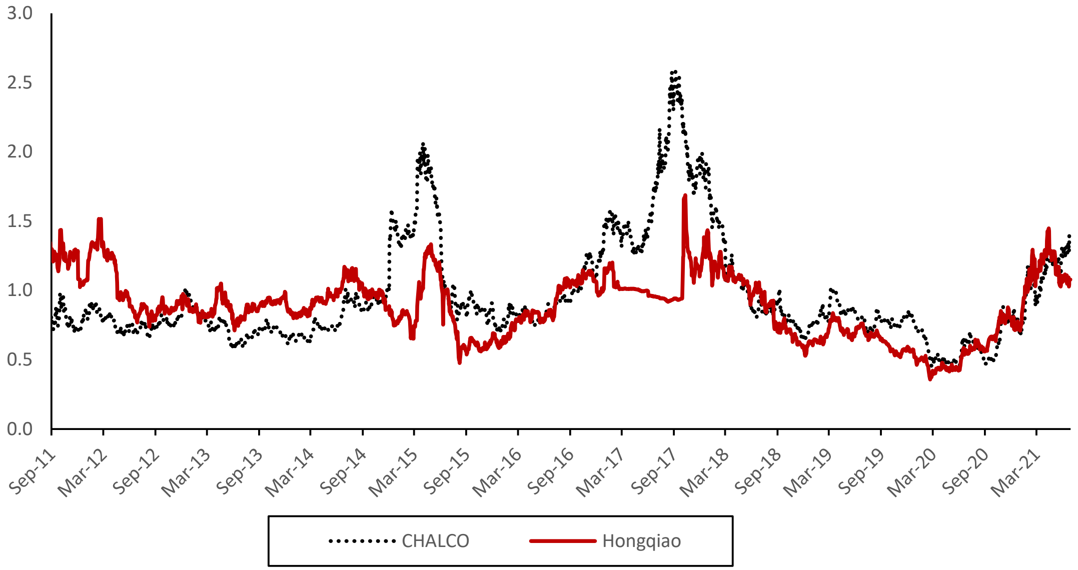
Live more, Bank less

Business comparison (China Hongqiao vs. CHALCO)

		Hongqiao		CHALCO	
		FY20	FY21	FY20	FY21
Production volume, FY20					
Alumina	k tonnes	6,734	5,900	7,740	11,570
Aluminium	k tonnes	5,060	5,800	3,680	3,680
Revenue, FY20	RMB m	86,145	111,648	185,994	195,555
Revenue contribution by product, FY20					
Alumina	%	15.0	10.5	7.0	12.1
Aluminium	%	83.0	88.7	22.0	24.4
Operating Profit, FY20	RMB m	14,903	26,253	7,809	12,848
Market Cap (as of 17 May 2021)	HK$ m	111,280	111,280	102,375	102,375
	US$ m	14,329	14,329	13,182	13,182
Net Debt, FY20	RMB m	23,374	24,654	81,538	74,561
GP margin, FY20	%	22.5	28.8	7.2	9.1
EBITDA margin, FY20	%	28.3	31.5	8.3	10.8
ROE, FY20	%	15.6	23.9	1.4	5.5

Source: Company, Bloomberg Finance L.P., DBS HK

P/BV comparison between CHALCO and Hongqiao



Source: Bloomberg Finance L.P., DBS Bank

Peer comparison

Company Name	Code	Currency	Price Local$	Mkt Cap US$m	Fiscal Yr	EPS growth 21F %	EPS growth 22F %	PE 21F x	PE 22F x	Yield 21F %	P/Bk 21F x	P/Bk 22F x	EV/EBITDA 21F x	EV/EBITDA 22F x	ROE 21F %	ROE 22F %	Net gearing %	Latest reported Gross margin %	Latest reported Net margin %
HK																			
CHALCO*	2600 HK	HKD	4.84	15,129	Dec	311.0	35.8	22.6	16.6	0.0	1.2	1.1	7.7	6.6	5.5	7.0	148.1	7.1	0.3
China Hongqiao*	1378 HK	HKD	10.36	12,162	Dec	61.6	7.7	4.4	4.1	11.0	1.0	0.9	3.1	2.7	23.9	23.0	39.2	22.5	12.2
United Company (Hkg) I	486 HK	HKD	5.04	9,855	Dec	n.a.	6.8	3.0	2.8	2.8	1.0	0.8	6.0	5.1	39.0	28.2	82.0	16.6	8.9
China																			
CHALCO 'A'*	601600 CH	CNY	6.28	15,129	Dec	311.0	35.8	35.1	25.8	0.0	1.9	1.7	9.6	8.2	5.5	7.0	148.1	7.1	0.3
SD Nanshan Almn. 'A'	600219 CH	CNY	5.19	9,570	Dec	61.4	18.5	18.8	15.9	1.2	1.5	1.4	6.3	5.2	8.0	8.8	Cash	22.7	9.2
Yunnan Alum. 'A'	000807 CH	CNY	14	6,757	Dec	266.4	12.0	13.2	11.8	4.0	3.1	2.5	7.4	6.2	22.8	22.8	132.7	13.4	3.1
Overseas																			
Alumina	AWC AU	AUD	1.62	3,461	Dec	7.5	51.7	20.6	13.6	5.2	2.0	1.9	n.a.	n.a.	10.6	14.0	2.9	100.0	146897.2
Alcoa	AA US	USD	37.06	6,920	Dec	n.a.	(1.7)	7.7	7.8	0.0	1.6	1.3	3.0	2.8	26.1	20.1	22.1	7.2	(1.8)
Hindalco Industries#	HNDL IN	INR	391.75	11,799	Mar	145.2	5.5	9.4	8.9	0.6	1.2	1.1	5.3	5.2	13.8	12.6	56.6	13.8	3.2

Source: Bloomberg Finance L.P., DBS Bank

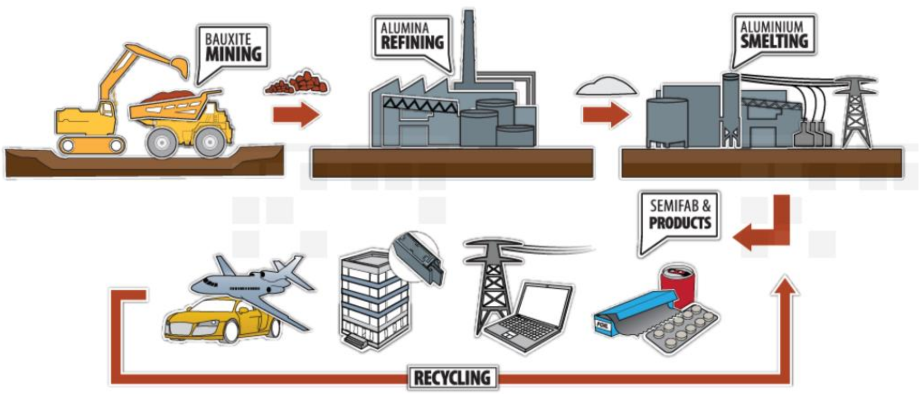
APPENDIX

APPENDIX 1: Overview of Aluminium Sector – value chain

What is aluminium? Aluminium is a silvery metal that has a combination of properties that make it extremely useful and a key engineering material. Although pure aluminium cannot be found naturally on earth, it is the most widespread metal on earth, making up at least 8% of the Earth's core mass. Aluminium's most common form is aluminium sulphate, which is found in bauxite. Aluminium has four properties that make it useful – light weight, durability, ductility, and corrosion resistance. This allows it to be used in various engineering applications and transformed into virtually any shape. Moreover, as it can easily bind with other chemical elements, it can be used to make a wide array of aluminium alloys for different applications.

Where is it used? Aluminium's unique combination of properties have made it integral for modern day engineering. Advances in the construction, automotive, aviation, energy, food, and various other industries would not have been possible without aluminium.

Aluminium industry flow



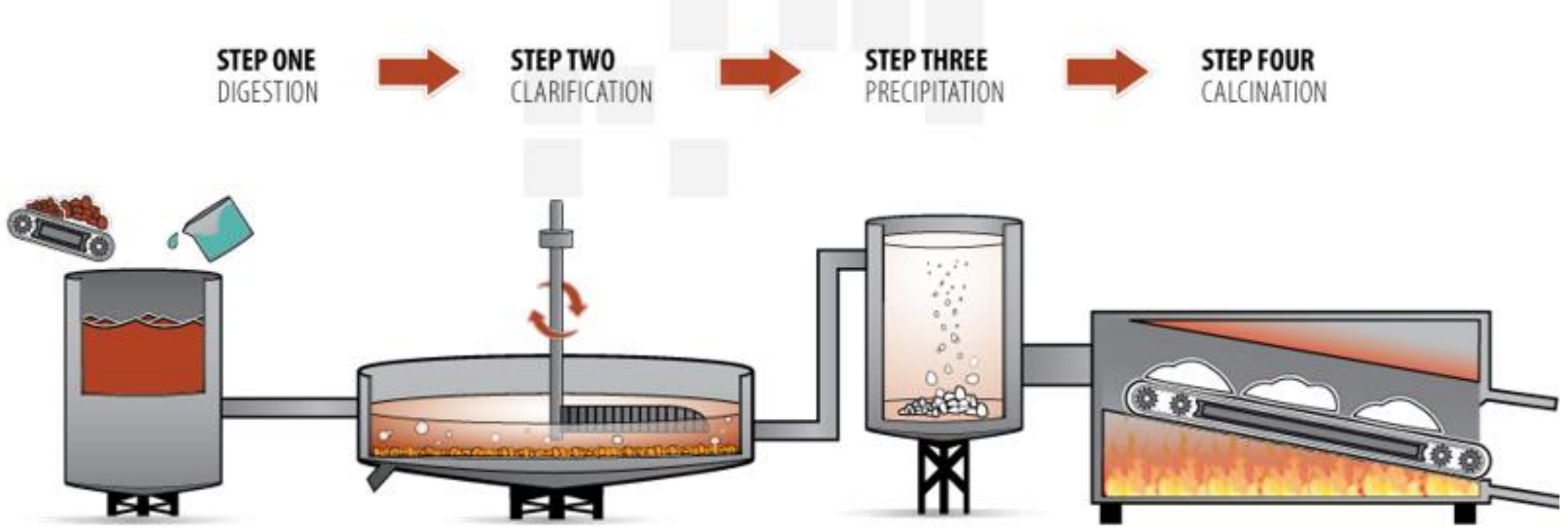
Source: Austrailian Aluminium Council Ltd

How is it produced?

Aluminium's natural and most abundant form is bauxite. In order to create aluminium, bauxite must be first refined to alumina, which is then smelted into aluminium. As a general conversion, refining four tonnes of bauxite results in two tonnes of alumina, and smelting two tonnes of alumina creates one tonne of pure aluminium.

Bauxite is turned into alumina using the Bayer Process. The Bayer Process consists of four steps – digestion, clarification and precipitation, filtration, and calcination. Digestion involves mixing ground bauxite with sodium hydroxide (caustic soda) under high temperature and pressure to form a saturated sodium aluminate solution. The bauxite residue settles at the bottom of the mixture, which is then filtered out (clarification). The remaining mixture is cooled and treated with seed crystals, which helps crystallisation and leads to the formation of aluminium hydrate. The resulting aluminium hydrate is separated from the caustic soda mixture, and then is heated to 1,100 ºC. The heating removes any water molecules and produces aluminium oxide (alumina).

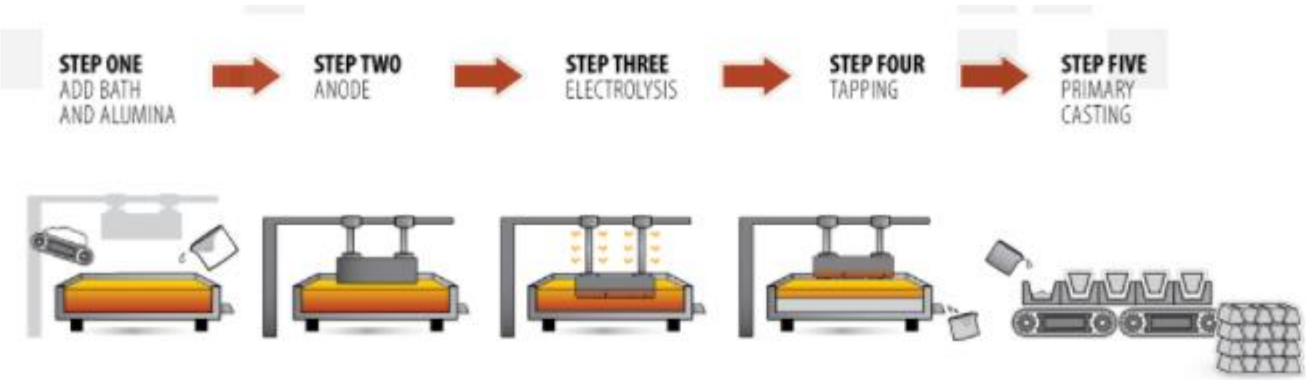
Alumina Refining



Source: Austrailian Aluminium Council Ltd

For alumina to turn into aluminium, the former needs to undergo the Hall-Heroult process. Aluminium smelting requires large amounts of electrical energy, and the process takes place in a reduction cell. The reduction cell is lined with carbon lining at the bottom and carbon blocks are placed at the top of the tank. And the tank is filled with cryolite base electrolyte that is mixed with alumina. When electricity is run through the reduction cell, the carbon lining acts as a cathode and the carbon blocks act as an anode, thus creating an electric current through the electrolyte and alumina mixture. The electric current separates alumina into molten aluminium and oxygen, which binds with carbon anode to generate carbon dioxide. Carbon dioxide is released out of the reduction cell, while the molten aluminium settles at the bottom – ready to be collected. The binding of oxygen and carbon is the reason why aluminium smelting has such a large carbon footprint.

Aluminium Smelting



Source: Austrailian Aluminium Council Ltd

Global aluminium volume by vaule chain

Bauxite	Alumina	Primary Aluminium	Secondary Aluminium
Global output :369m tonnes	Global output: 122m tonnes(China 73m tonnes)	Global output: 66m tonnes (China 37m tonnes)	Global output: 16m tonnes (c20% of total aluminium production)
Export: 148m tonnes (Guinea 80m tonnes, Austrailia 37m tonnes)	Export 38m tonnes (Austrailia 18m tonnes)	Export 20m tonnes (Canada 2.98m tonnes, China 0.2m tonnes)	Contribution: China (44%), USA (20%) , EU(17%)
Import 122m tonnes (China 112m tonnes)	Import 26m tonnes (Argentina and Romania: c 5m tonness)	Import 26m tonnes (USA3.5m tonnes, China 2.3m tonnes)	

Source: WBMS DBS Bank

Appendix II. ASI Performance Standard Certified

Name	Member Class	Country Certified in
Albras-Aluminio Brasileiro S/A	Production and Transformation	Brazil
Alcoa Corporation	Production and Transformation	Australia, Brazil, Spain, Canada, Norway, Iceland
Alu Met GmbH (Austria)	Production and Transformation	Germany, Austria
Aludium Premium Aluminium	Production and Transformation	France, Spain
Aluminerie Alouette	Production and Transformation	Canada
Aluminium Bahrain	Production and Transformation	Bahrain
ALVANCE Aluminium Dunkerque	Production and Transformation	France
AMAG Austria Metall AG	Production and Transformation	Austria
Amcor Limited	Industrial Users	Germany, France, Switzerland
Arconic	Industrial Users	US
Assan Aluminium	Production and Transformation	Turkey
Audi	Industrial Users	Belgium, Hungary, Germany
Ball Corporation	Production and Transformation	UK, Spain, France, Italy, Switzerland, Austria, Germany, Czech Republic, Sweden, Serbia, Finland, Russia Turkey, Egypt, Poland, Saudi Arabia
BMW AG	Industrial Users	Germany
Bridgnorth Aluminium Ltd	Production and Transformation	UK
C.S. Aluminium Corporation	Production and Transformation	Taiwan
Carcano	Production and Transformation	Italy
Century Aluminium Company	Production and Transformation	US, Iceland
Chalco Ruimin Co., Ltd	Production and Transformation	China
Companhia Brasileira de Aluminio	Production and Transformation	Brazil

Name	Member Class	Country Certified in
Constantia Flexibles International GmbH	Production and Transformation	20 countries (not listed)
Constellium	Production and Transformation	Germany
Elval	Production and Transformation	Greece
Emirates Global Aluminium PJSC	Production and Transformation	UAE
Eurofoil	Production and Transformation	France, Luxembourg
Granges	Production and Transformation	China
Hammerer Aluminium Industries	Production and Transformation	Germany, Romania
Henan Zhongfu High Precision Aluminium	Production and Transformation	China
Hydro	Production and Transformation	Netherlands, Germany, Norway, France, Italy, Portugal, UK, Poland, Italy, Sweden, Belgium,
Impol d.o.o	Production and Transformation	Slovenia
IPI SRL	Industrial Users	Italy
Jiangsu Dingsheng New Materials Joint-Stock Co.,	Production and Transformation	China
Jiangsu Zhongji Lamination Materials Co., Ltd	Production and Transformation	China
Jupiter Aluminium	Production and Transformation	US
Kaiser Aluminium Corporation	Industrial Users	US
Kunshan Aluminium Co., Ltd.	Production and Transformation	China
Laminizione Sottile Group	Production and Transformation	Italy
Lotte Aluminium Co. Ltd.	Production and Transformation	South Korea
Luoyang Wanji Aluminium Processing Co., Ltd	Production and Transformation	China
Nestle Nespresso	Industrial User	Not Listed
Novelis Inc.	Production and Transformation	Germany, Switzerland, UK, Italy

Name	Member Class	Country Certified in
Raffmetal and Fondital	Production and Transformation	Italy
Rio Tinto	Production and Transformation	Canada, Australia, New Zealand
S.A. DAMM	Industrial Users	Iberian Peninsula (Spain. Portugal)
Schuco International KG	Industrial Users	Germany, France, Italy, UK
Shandong Nanshan Aluminium Co., Ltd.	Production and Transformation	China
Shanghai Sunho Aluminium Foil Co., Ltd.	Production and Transformation	China
Shangqiu Yangguang Aluminium Product Co., Ltd.	Production and Transformation	China
SIG Combibloc	Industrial Users	Germany, Switzerland,
Slim Aluminium S.p.A.	Production and Transformation	Italy
StockachAlu	Production and Transformation	Germany
Suntown Technology Group Corporation Limited	Production and Transformation	China
Tetra Pak	Industrial User	Sweden
Tainjin Zhongwang Aluminium Co., Ltd.	Production and Transformation	China
UC Rusal	Production and Transformation	Russia, Sweden
Xiamen Xiashun Aluminium Foil Co., Ltd.	Production and Transformation	China
Yunnan Yongshun Aluminium Co., Ltd.	Production and Transformation	China

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BUY (>15% total return over the next 12 months for small caps, >10% for large caps)
HOLD (-10% to +15% total return over the next 12 months for small caps, -10% to +10% for large caps)
FULLY VALUED (negative total return, i.e., > -10% over the next 12 months)
SELL (negative total return of > -20% over the next 3 months, with identifiable share price catalysts within this time frame)

**Share price appreciation + dividends*

Completed Date: 29 Jul 2021 17:05:22 (SGT
Dissemination Date: 29 Jul 2021 21:38:14 (SGT)

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