JMK Research & Analytics

April
2025

Green Power Procurement

ALUMINIUM
Sector in India

DEEP-DIVE INTO VEDANTA ALUMINIUM
CASE STUDY

JMK Research & Analytics is a specialist consultancy firm that provides research and advisory services to Indian and International clients across Renewables, Electric mobility, and the Battery storage markets.

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SED Fund is a philanthropic initiative to support the Sustainable Development Goals (SDGs) of clean air, access to energy, clean water, climate action and equity, by backing efforts of governments and civil society on clean energy transition, according to principles of sustainability, diversity and equity. The fund intends to amplify impact by consolidating philanthropic resources, strengthening country level institutions and civil society groups and supporting initiatives that will have the most impact in support of these goals.

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GLOSSARY OF TERMS

Abbreviation	Definition
MTPA	Million tonnes per annum
MT	Million tonnes
TWh	Terawatt hour
GHG	Greenhouse gas
$MTCO_2e$	Million tonnes of CO_2 equivalent
GJ	Gigajoules
EJ	Exajoules
PJ	Petajoules
CBAM	Carbon border adjustment mechanism
NALCO	National Aluminium Company Limited
BALCO	Bharat Aluminium Company
IEA	International Energy Agency
IAI	International Aluminium Institute
WSH	Wind-solar hybrid
MVR	Mechanical vapour recompression
CCS	Carbon capture and storage
RTC	Round-the-clock
CPP	Coal based captive power plants

ALUMINIUM SECTOR IN INDIA

The aluminium sector in India plays a crucial role in the country's industrial landscape, significantly contributing to economic growth and finding applications in various sectors such as power, transportation, building, and construction. The production of aluminium in India began in 1944 with the establishment of the first plant in Asansol, West Bengal. As of 2024, India contributes approximately 5.5% of global aluminium production and is the world's second largest producer.[1]

Table 1: Aluminium sector overview

Parameters	Description
Indian primary aluminium production capacity* (FY2024)	4.1 million tonnes per annum (MTPA)
Indian secondary aluminium production capacity (2024)	2-2.2 MTPA
Indian alumina** capacity (FY2024)	7.5 MTPA
Global alumina production (2024)	147 million tonnes (MT)
Indian alumina production (FY2024)	7.5 MT
Global aluminium production (2024)	~ 72 MT
Indian aluminium production (FY2024)	~ 4 MT
Indian aluminium market size	Rs.1,09,950 crore (US$ 12.14 billion)
India's aluminium consumption (FY2024)	5 MT
India's Bauxite reserves (as of 2020)	4958 MT
India's share in global aluminium production (2024)	Approximately 5.5%
Key Players	Hindalco, National Aluminium Company & Vedanta

[1] USA Geological Survey | **Aluminum Statistics and Information** | 2025

Parameters	Description
Alumina imports (2024)	2.45 MT
Aluminium scrap imports (2024)	1.75 MT
Electricity consumption (2023)	52.3 Terawatt hour (TWh)
Global greenhouse gas (GHG) (scope 1+ scope 2) emissions (2023)	About 992 $MTCO_2e$ (million tonne CO_2 equivalent)
Indian GHG (scope 1+ scope 2) emissions (FY2024)	About 73 $MTCO_2e$
Contribution to India's GDP	Approximately 0.34%
Current Employment (direct + indirect)***	About 2 million

Source: Indian Bureau of Mines, CEA, Big Mint, PIB, JMK Research
Note: *Smelting capacity
**Alumina or aluminium oxide (Al_2O_3) is a substance produced from bauxite ore and serves as a raw material for production of aluminium metal.
*** Direct employment covers core operations like mining, refining, etc. while indirect employment includes supply chain and support industries.

Aluminium is highly recyclable and resistant to corrosion, prolonging its lifespan and making it a preferred material in various industries. Its durability and ability to be recycled have led to its increasing use as a replacement for iron and steel in automotive, aerospace, packaging, and electrical applications. The figure below shows a comparative infographic between aluminium and steel.

Figure 1: Comparison of Aluminium and Steel

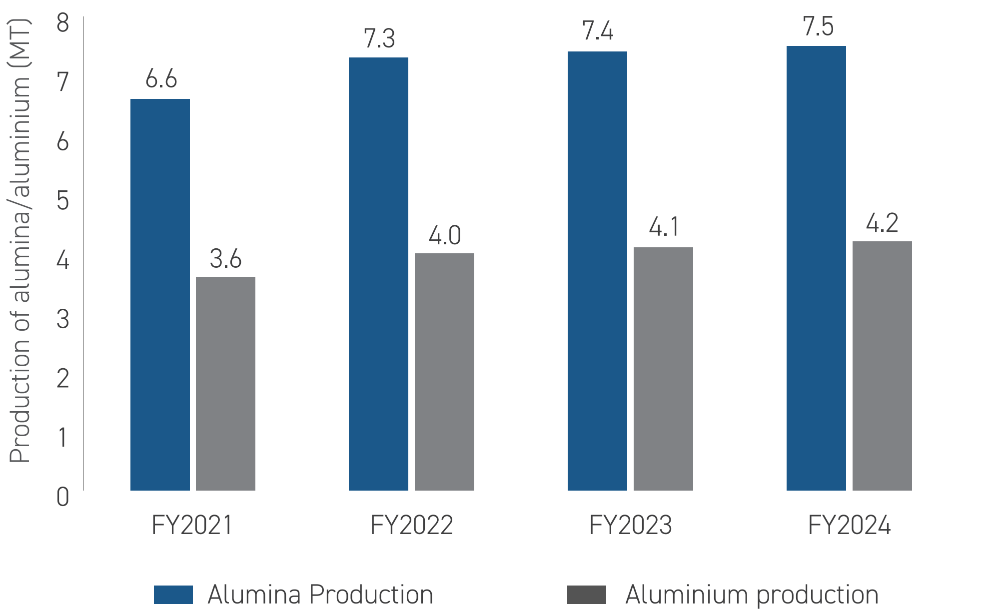
	Annual Production (Million Tonnes)	Properties	Energy Intensity (GJ/tonne of metal)	Emission Intensity (tCO_2/tonne of output)	Sectors where Aluminium is replacing Steel
Aluminium	4	High Recyclability, Corrosion resistant	70-80	15-18	Automotive, Aerospace, Construction, Packaging
Steel	144	Strength, Density	24-28	2.4-4.8	-

Source: Industry Reports, Ministry of Steel, JMK Research
Note: Annual production numbers are for India for FY2024, The steel figures are based on per tonne of crude steel

ALUMINIUM PRODUCTION TRENDS IN INDIA

From FY2021 to FY2024, India's aluminium production has seen moderate growth, increasing from 3.6 million tonnes (MT) to 4.2 MT, reflecting a compound annual growth rate (CAGR) of 5.3%. Similarly, alumina production has grown steadily at a CAGR of 4.4%, rising from 6.6 to 7.5 MT during the same period.

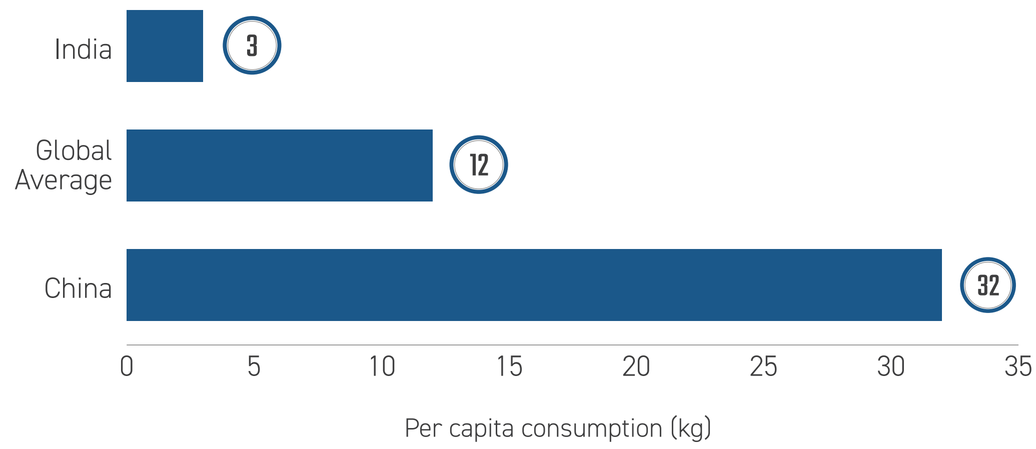
Figure 2: India's aluminium and alumina production trend



Source: Ministry of Mines, Indian Bureau of Mines, JMK Research
Note: This report focuses on primary aluminium sector

Although there has been modest growth in alumina and aluminium production, India's installed aluminium capacity has remained unchanged at 4.1 million tonnes per annum (MTPA) from FY2021 to FY2024. A significant reason for this stagnation was the stabilization of both global and domestic demand during this period. Instead of pursuing costly capacity expansions, the aluminium industry focused on optimizing existing capacity to meet demand. This strategy was influenced by uncertainties in global aluminium prices, rising input costs, and efforts to improve operational efficiency at current smelters.

Figure 3: Aluminium per capita consumption by country in 2024



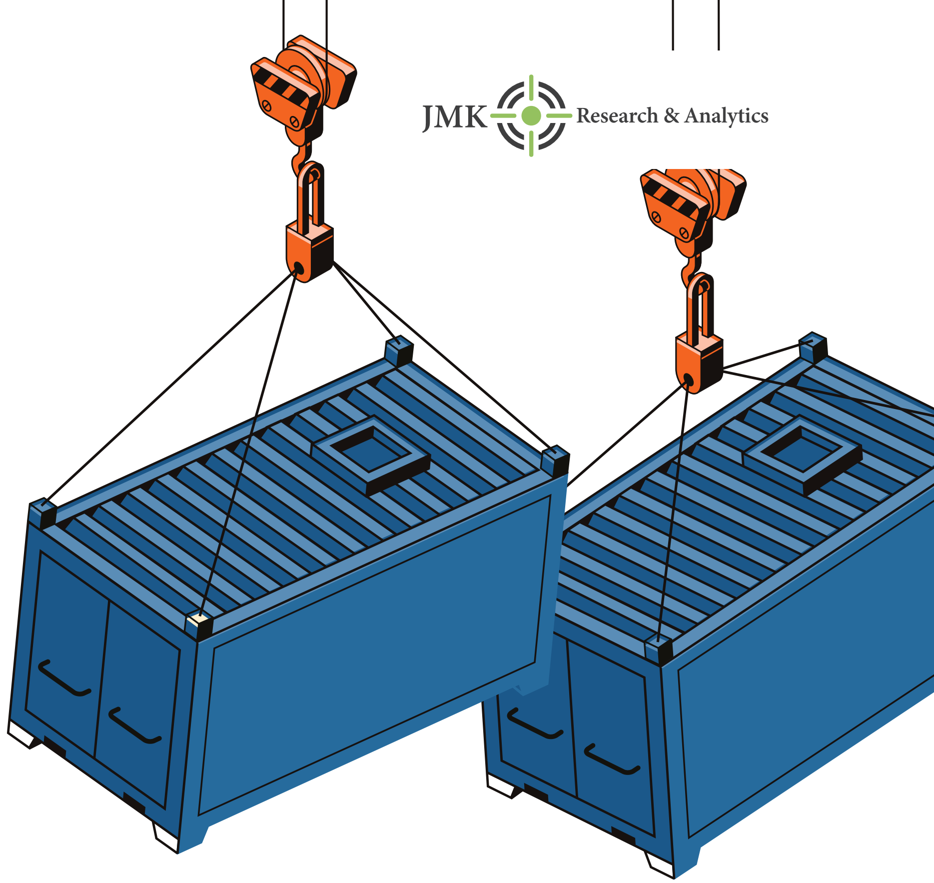
Source: Industry annual reports, JMK Research

China is the largest producer of aluminium in the world, accounting for approximately 59% of global production. India ranks second, but its output is only about one-tenth of China's total. The rest of the world's aluminium production is distributed among countries such as Russia, Canada, and the UAE, among others.

India, despite being the second largest[2] aluminium producer, has a per capita consumption of just 3 kilograms, significantly lower than the global average of 12 kilograms.[3] This situation indicates substantial potential for growth, especially as demand for aluminium in the infrastructure, transportation, and energy sectors is expected to increase.

[2] PIB | India is the 2nd Largest Aluminium Producer in the World | August 2024

[3] AL Circle | India's requirement for aluminium intensifies amidst global economic crisis and dismay | September 2023



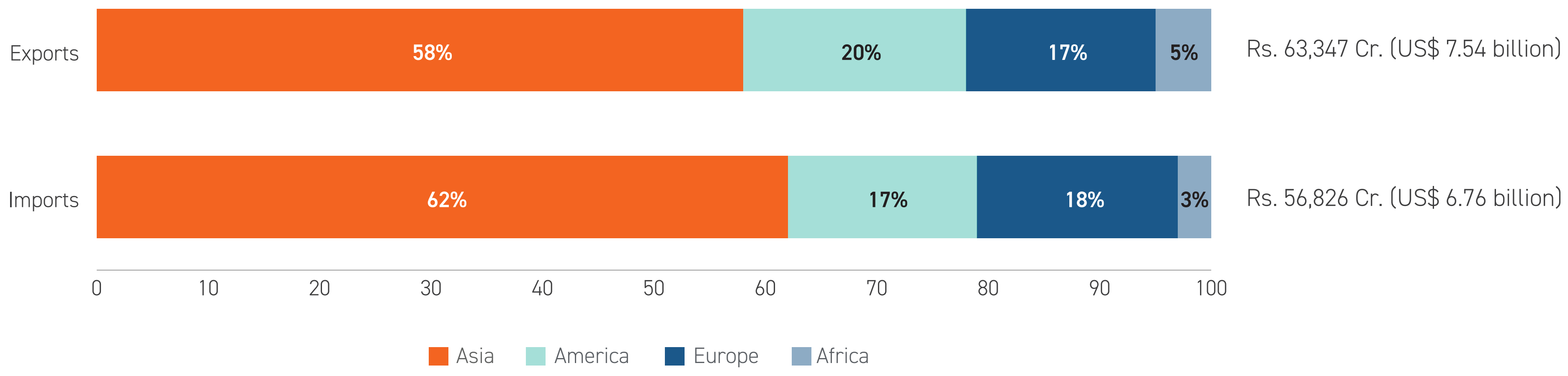
ALUMINIUM IMPORTS AND EXPORTS

In FY2024, India maintained its position as a net exporter of aluminium. The country recorded exports of aluminium, and its related articles worth Rs. 63,347 crores (US$ 7.54 billion), exceeding its imports, which stood at Rs. 56,826 crores (US$ 6.76 billion).[4]

However, the European Union's forthcoming Carbon Border Adjustment Mechanism (CBAM), set to come into effect in 2026, is beginning to influence the trade patterns. The EU, historically a key destination for Indian aluminium exports, accounted for 30% of India's total aluminium exports in FY2023. This share decreased to 17% in FY2024, reflecting the anticipation of CBAM's carbon pricing impacts and the adjustments being made by exporters in response to the regulations.

In response to these challenges, India's aluminium exports have increasingly focused on the Asian region. The share of Indian aluminium exports to Asia grew from 44% in FY2023 to 58% in FY2024, illustrating the country's shift to diversify its export markets in light of the evolving global trade landscape.

Figure 4: Region-wise breakdown of India's aluminium exports and imports (FY2024, in monetary terms)



Source: Ministry of Commerce & Industry, JMK Research

[4] Ministry of Commerce | Export & Import Data Bank

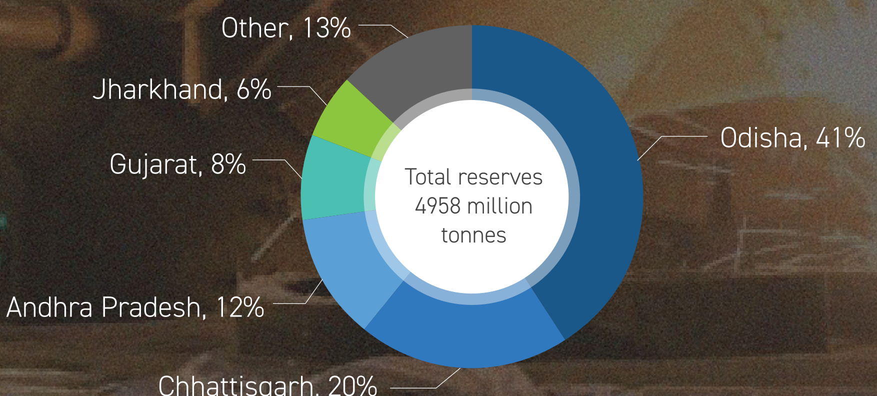
STATE-WISE SHARE

Bauxite ore, the primary raw material for alumina and aluminium, is abundantly available in India, with reserves estimated at approximately 4,958 million tonnes (MT). The majority of these reserves are found in Odisha, Chhattisgarh, and Andhra Pradesh, which together account for 73% of the country's reserves.[5]

In terms of aluminium production capacity by state, Odisha, Chhattisgarh, Madhya Pradesh, and Uttar Pradesh have the highest production capacities. Together, these states play a significant role in India's overall aluminium production by leveraging their access to abundant bauxite deposits and established industrial infrastructure.

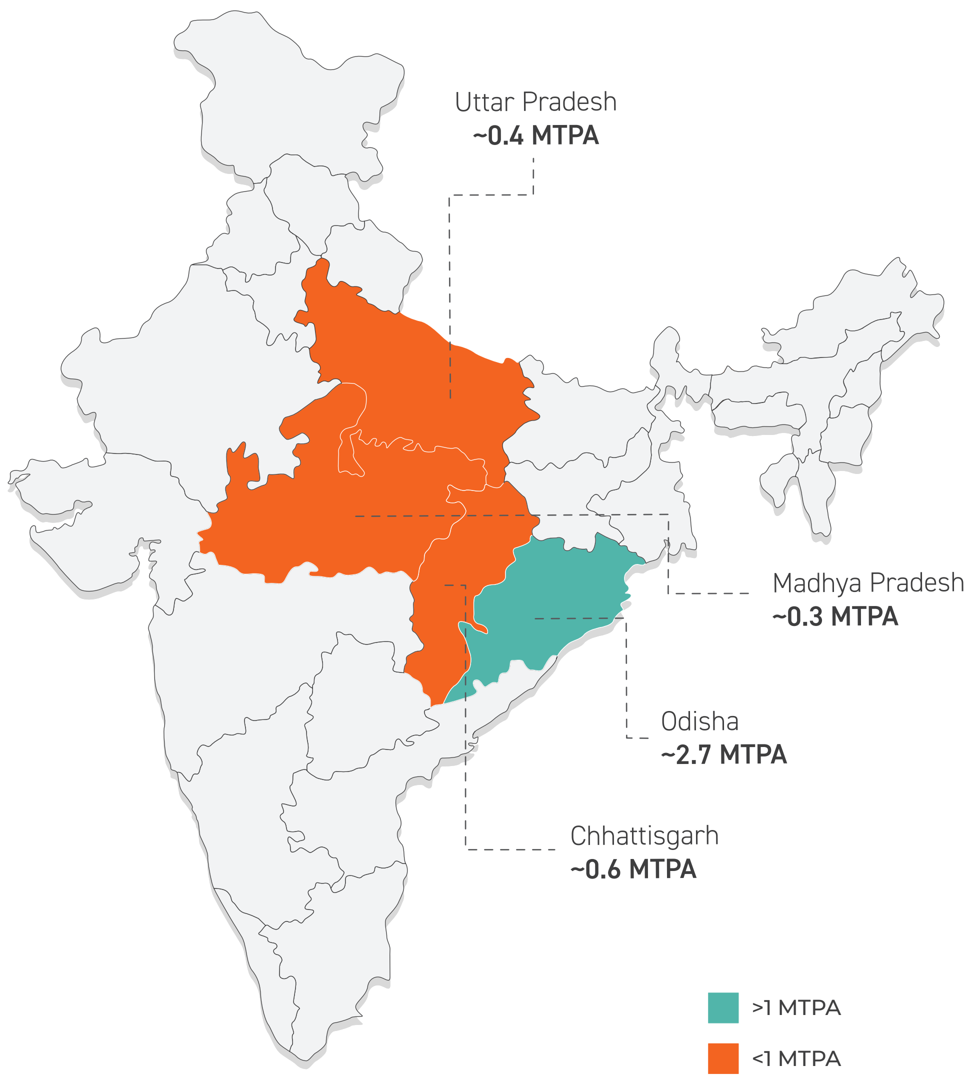
India's primary aluminium producers ensure a stable and cost-effective bauxite supply through captive mining and procurement agreements. National Aluminium Company Limited (NALCO) fulfils its bauxite requirements entirely from its captive mines. Meanwhile, Vedanta and Hindalco have secured long-term linkage agreements with the Odisha Mining Corporation (OMC) to supplement their supply needs. In addition to these sources, aluminium producers acquire bauxite through auctions and state-owned mining corporations such as the Andhra Pradesh Mineral Development Corporation (APMDC) and Gujarat Mineral Development Corporation (GMDC). These measures enhance raw material security, support uninterrupted aluminium production, and mitigate supply chain risks.

Figure 5: India's Bauxite Reserves (as of 2020)



Source: Indian Bureau of Mines, JMK Research

Figure 6: State-wise distribution of aluminium production capacity, 2024



Source: Indian Bureau of Mines, JMK Research

[5] Indian Bureau of Mines | Metals and Alloys Review | 2022

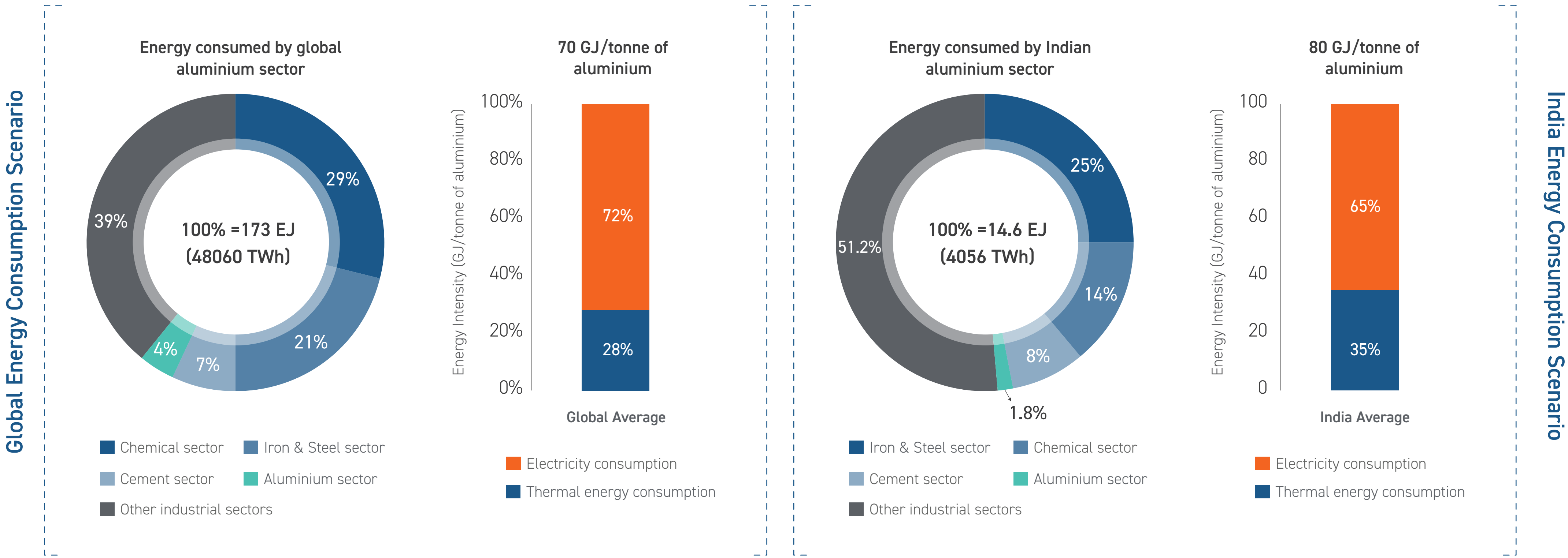
ENERGY CONSUMPTION AND ENERGY INTENSITY

In 2023, the global aluminium sector was the fourth-largest industrial energy consumer, consuming approximately 7 Exajoules (EJ) or 1944 Terawatt hour (TWh). This consumption accounted for about 4% of the total global industrial energy consumption.

In India, the aluminium sector ranked as one of the significant industrial energy consumers, utilizing approximately 0.28 EJ (77.7 TWh) of energy. This represented about 2% of the nation's total industrial energy consumption, highlighting its crucial role in India's industrial landscape.[6]

In terms of energy intensity, the Indian aluminium sector consumes slightly more energy than the global average. The global energy intensity for aluminium production is 70 GJ per tonne, while in India, it stands at 80 GJ per tonne.[7]

Figure 7: Energy Consumption in aluminium sector (Global vs India 2023)



Source: IEA, International Aluminium Institute (IAI), JMK Research

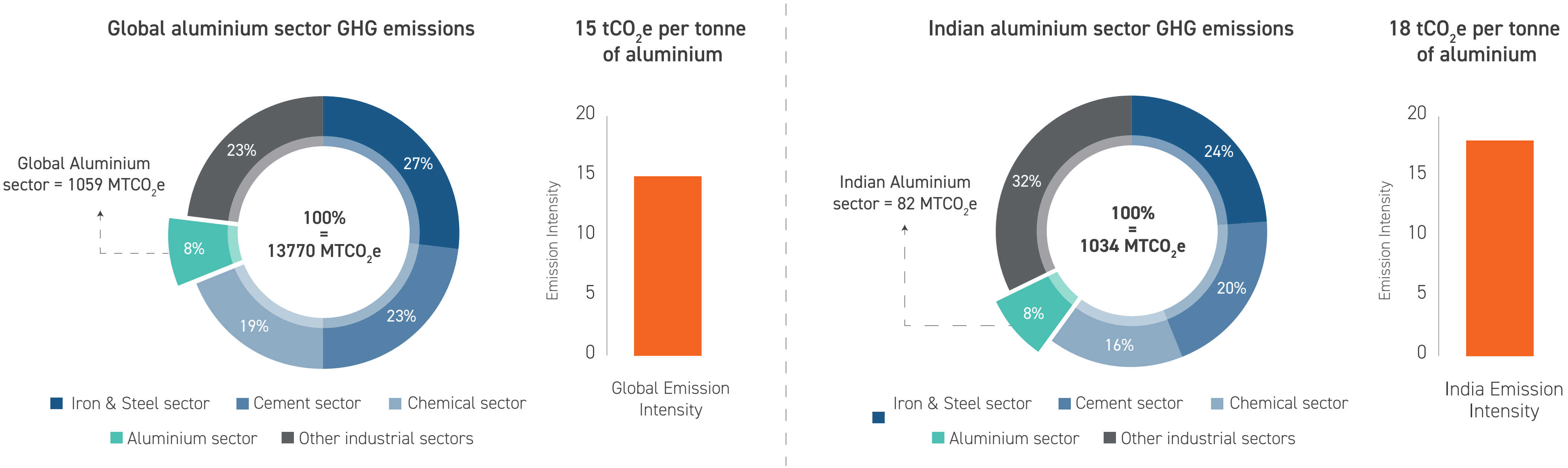
[6] IEA | World Energy Outlook 2024 | October 2024

[7] International Aluminium Institute | Statistics | 2024

GREENHOUSE GAS EMISSIONS

In 2023, global industrial greenhouse gas (GHG) emissions totalled approximately 13770 million tonnes CO_2 equivalent ($MTCO_2e$), with the aluminium sector contributing around 1059 $MTCO_2e$, accounting for approximately 8% of total industrial emissions. This positions the aluminium industry as a significant emitter, though its share is smaller compared to sectors like steel and cement.

Figure 8: GHG emission and emission intensity in aluminium sector (Global vs India 2023)



Source: IEA, JMK Research

In 2023, India's industrial GHG emissions reached approximately 1034 $MtCO_2e$, with the aluminium sector contributing around 8% due to its energy-intensive production processes.

Globally, the average GHG emissions intensity for primary aluminium production is 15 tCO_2e per tonne.[8] In comparison, the GHG emission intensity for India is significantly higher at about 18 tCO_2e per tonne of aluminium.[9] This disparity is largely due to the reliance on coal-based captive power plants for energy, which dominate the sector's energy mix. By contrast, aluminium producers in regions like the European Union and Russia have significantly lower emissions intensities due to their reliance on cleaner energy sources. In the EU, a high share of renewable energy in the electricity mix has helped drive emissions intensities well below the global average. Notably, in 2023, 78% of the electricity used by European aluminium smelters came from renewable sources. Similarly, Russian producers benefit from a substantial reliance on hydropower, further reducing their carbon footprint.

[8] International Aluminium Institute | Primary Aluminium Greenhouse Gas Emissions Intensity | 2024

[9] ICRA | Primary Non-ferrous metal Industry | March 2023

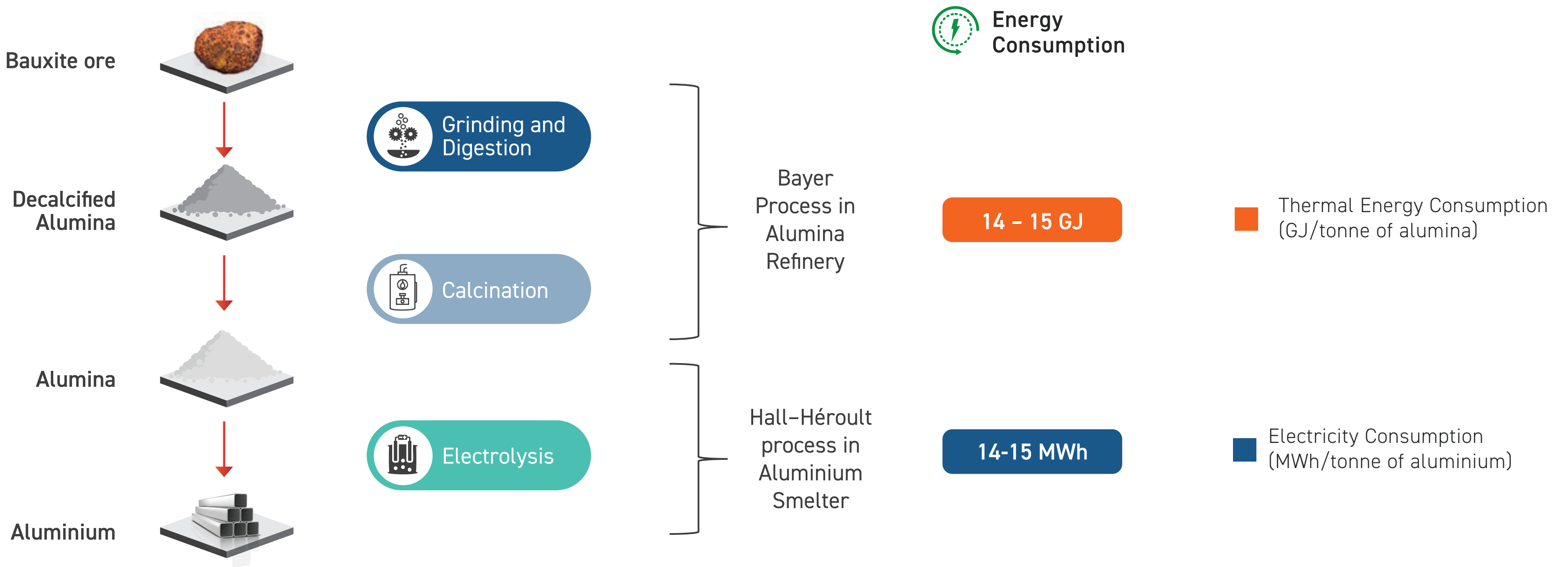
ALUMINIUM MANUFACTURING PROCESS

Aluminium is produced from bauxite ore, which contains a mixture of aluminium oxide (alumina) and various other minerals. The process of refining bauxite ore into alumina is known as the Bayer process, which is carried out in an alumina refinery. The Bayer process primarily uses thermal energy for heating, typically derived from coal in India. As a result, alumina refineries contribute to substantial CO_2 emissions, along with sulphur and nitrogen oxides.

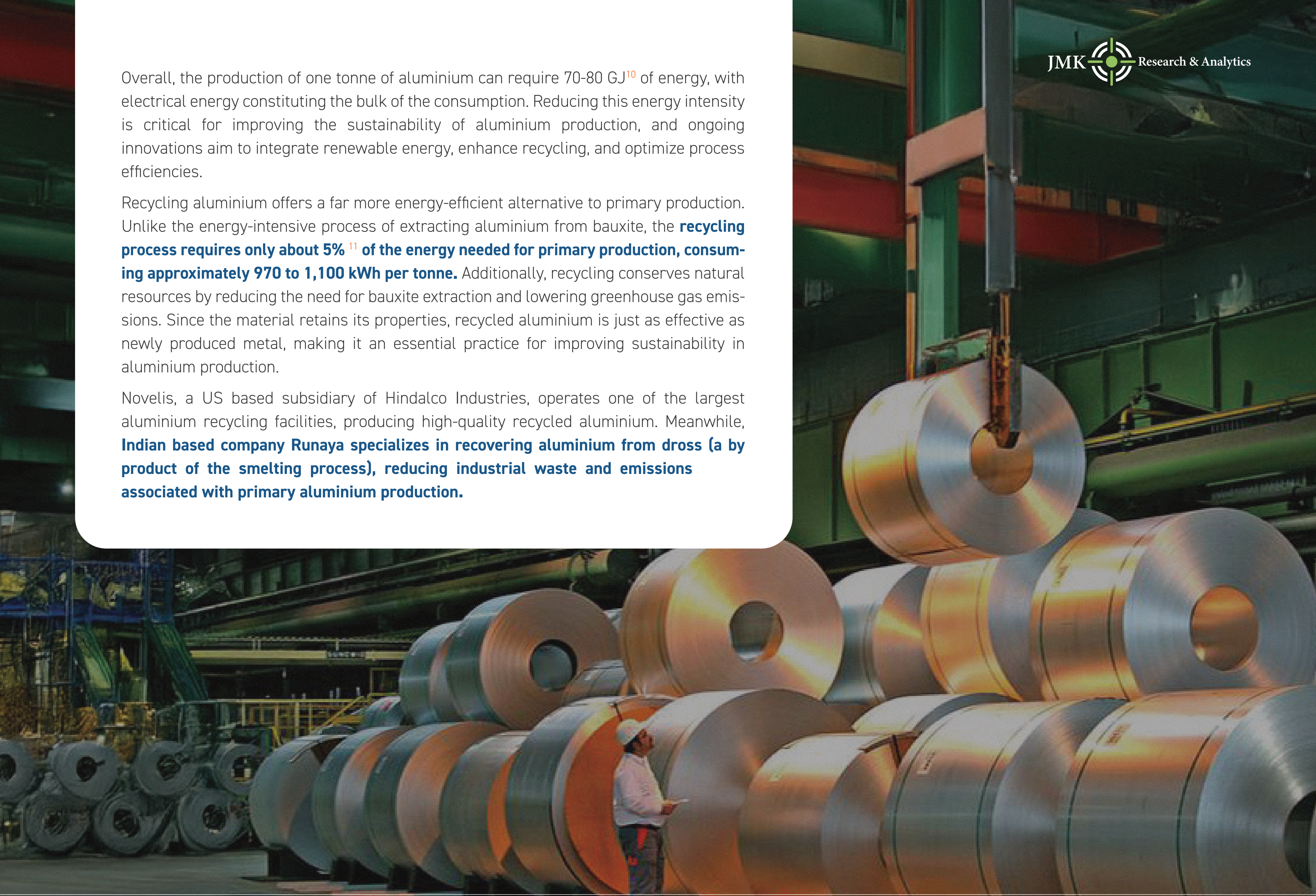
Once alumina is produced, it is subjected to the Hall-Héroult process in aluminium smelters to extract pure aluminium. In this process, alumina undergoes electrolysis to separate aluminium metal from oxygen. This process is highly energy-intensive, requiring large amounts of electrical energy, making it one of the most electricity-consuming steps in aluminium production.

In the aluminium industry, alumina production and the subsequent extraction of aluminium metal can occur in separate facilities or an integrated manner. Alumina refineries may operate independently, supplying alumina to various smelters or integrated with aluminium smelters within a single production complex. This separation or integration of operations depends on resource availability, logistical considerations, and economic efficiency. For instance, Vedanta's alumina refinery in Lanjigarh (Odisha) operates separately, supplying alumina to various smelters, while Hindalco's Renukoot (Uttar Pradesh) facility is an integrated operation where both alumina refining and aluminium smelting occur within the same complex.

Figure 9: Aluminium manufacturing process



Source: Research Papers, International Aluminium Institute (IAI), JMK Research
Note: Approximately 6-7 tonnes of bauxite ore produce about 2 tonnes of alumina, which in turn yields 1 tonne of aluminium.



Overall, the production of one tonne of aluminium can require 70-80 GJ[10] of energy, with electrical energy constituting the bulk of the consumption. Reducing this energy intensity is critical for improving the sustainability of aluminium production, and ongoing innovations aim to integrate renewable energy, enhance recycling, and optimize process efficiencies.

Recycling aluminium offers a far more energy-efficient alternative to primary production. Unlike the energy-intensive process of extracting aluminium from bauxite, the **recycling process requires only about 5%** [11] **of the energy needed for primary production, consuming approximately 970 to 1,100 kWh per tonne.** Additionally, recycling conserves natural resources by reducing the need for bauxite extraction and lowering greenhouse gas emissions. Since the material retains its properties, recycled aluminium is just as effective as newly produced metal, making it an essential practice for improving sustainability in aluminium production.

Novelis, a US based subsidiary of Hindalco Industries, operates one of the largest aluminium recycling facilities, producing high-quality recycled aluminium. Meanwhile, **Indian based company Runaya specializes in recovering aluminium from dross (a by product of the smelting process), reducing industrial waste and emissions associated with primary aluminium production.**

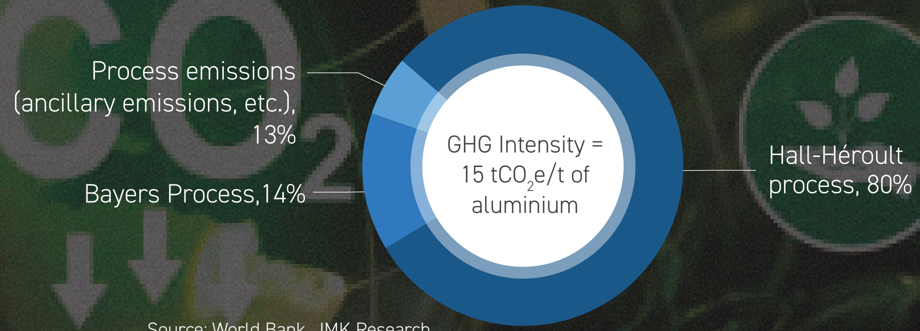
[10] WEF | **Aluminium industry net zero tracker** | 2023

[11] International Aluminium Institute | Aluminium recycling saves 95% of the energy needed for primary aluminium production

WAYS TO DECARBONIZE

The aluminium industry is considered hard-to-abate due to the carbon-intensive processes involved in alumina refining and primary aluminium smelting. A large portion of the GHG emissions in this sector arises from electricity consumption (around 80%), particularly in smelting operations using the Hall-Héroult process. Additionally, 14% of emissions stem from thermal energy used in alumina refining, while the remaining emissions come from process-related emissions, i.e. emissions as a result of chemical reactions such as anode consumption and perfluorocarbon (PFC) emissions.[12]

Figure 10: GHG intensity of aluminium, by process



Source: World Bank, JMK Research

To address the significant emissions in the aluminium sector, there are four main decarbonization levers: **renewable energy, energy efficiency, carbon capture and storage (CCS), and inert anodes.** The following matrix presents a comparative evaluation of the decarbonization levers for the aluminium industry based on their technical and economic feasibility.

Figure 11: Key Decarbonization levers for the Aluminium sector in India

		Technical Feasibility		Economic Feasibility		
Lever	Description	Maturity	Scalability	Capital Cost	Payback Period	Carbon Abatement Potential
Renewable Energy	Transitioning the aluminium smelting process from fossil fuel-based captive power plants to renewable energy sources	Proven	High	Medium	Medium	High
Energy Efficiency	Enhancing energy efficiency to recover waste heat by upgrading smelting technologies	Proven	Medium	Low	Low	Low
Carbon Capture Storage (CCS)	Capturing the CO_2 released from the calcination process in alumina refinery	Nascent	Medium	High	High	High
Inert Anode	Replacing carbon-based anodes with inert anodes in aluminium smelting	Nascent	Low	High	High	Medium
Mechanical Vapor Recompression (MVR)	Reducing steam demand and dependence on fossil fuels in alumina refining by capturing and reusing otherwise wasted heat.	Evolving	High	Medium	Medium	Low

Source: Mission Possible Partnership, JMK Research

[12] World Bank Group & Climate-Smart Mining | Competitiveness of Global Aluminum Supply Chains Under Carbon Pricing Scenarios for Solar PV | March 2023

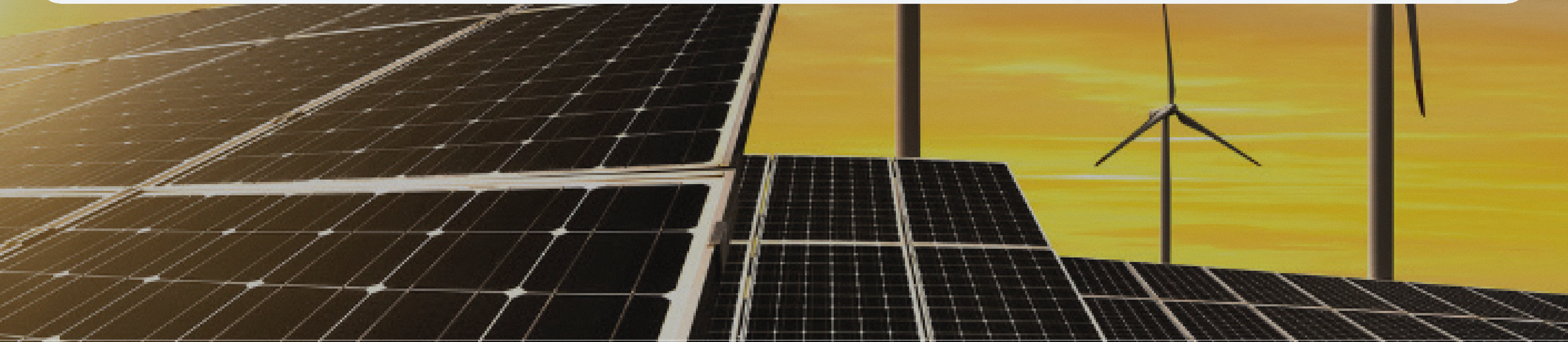
Among the various decarbonization levers, renewable energy- specifically wind solar hybrid, renewable coupled with storage systems- offers the most significant potential for reducing emissions in the aluminium sector. **Wind-solar hybrid (WSH) systems, with their complementary generation profiles, make them well-suited for aluminium smelters that consume large amounts of electrical energy.**

Energy storage solutions such as battery energy storage systems (BESS) and pumped hydro storage could be crucial in ensuring round-the-clock stability. The drastically falling cost of BESS enhances its viability, allowing aluminium producers to store excess renewable energy. Meanwhile, pumped hydro storage remains a proven large-scale solution for ensuring round the clock stability of energy supply.

Besides renewable energy adoption, energy efficiency is another key decarbonization lever. Companies can employ technologies like heat exchangers (for efficient heat transfer and recovery), advanced heat recovery systems (to capture and reuse waste heat), and process optimization tools (to enhance energy use). For instance, mechanical vapour recompression (MVR) can capture waste heat from steam that would otherwise be discharged, increasing its pressure and temperature for reuse. In alumina refining, MVR could reduce reliance on fossil fuel-based thermal energy and address up to 70% of thermal energy emissions, potentially emissions by 87MTCO_2e annually.[13]

Technologies such as Carbon Capture and Storage (CCS) and inert anodes present promising solutions for reducing emissions in the aluminium sector. **A key source of process-related emissions is the consumption of carbon anodes during electrolysis, which releases CO_2. Inert anodes mitigate this by using non-consumable materials, such as ceramics, eliminating direct carbon emissions.** Meanwhile, CCS can capture CO_2 from smelting and refining operations, with potential for retrofitting in the calcination process.

However, both technologies require substantial capital investment, which is a barrier to widespread adoption. Their feasibility depends on ongoing technological advancements to lower costs and supportive policies that incentivise implementation.



[13] Mission Possible Partnership | Closing the gap for aluminium emissions: Technologies to accelerate deep decarbonization of direct emissions | 2022

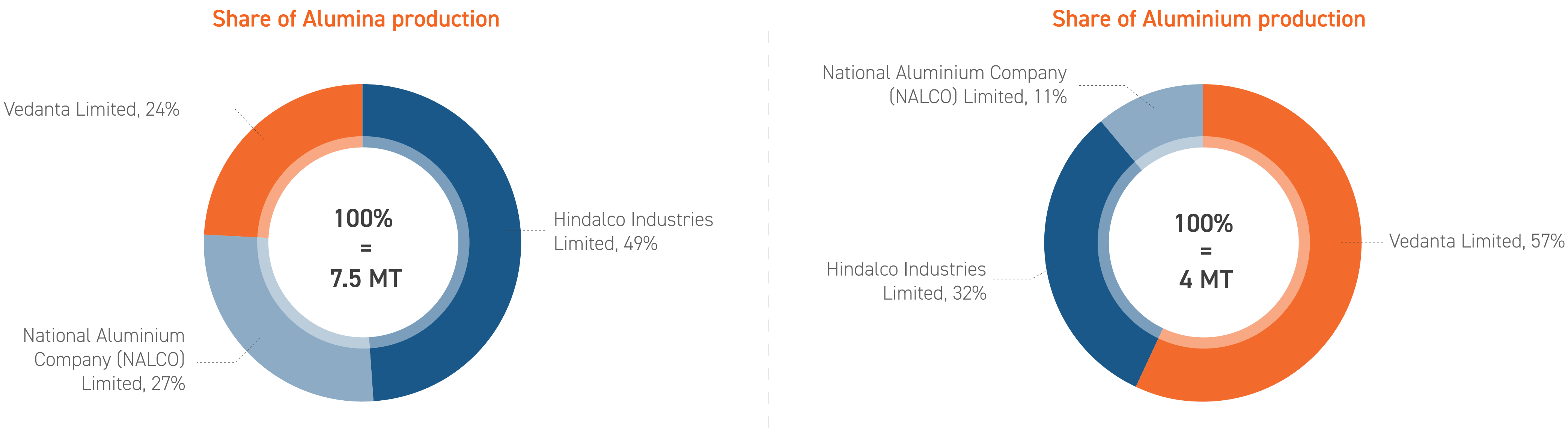
LEADING PLAYERS IN ALUMINIUM SECTOR

The Indian aluminium industry is a highly concentrated sector, dominated by three primary producers: National Aluminium Company (NALCO), Hindalco Industries Limited, and Vedanta Limited. Private companies, including Hindalco and Vedanta, are responsible for approximately 90% of the country's total production capacity. Hindalco, part of the Aditya Birla Group, is well-known for its subsidiary, Utkal Alumina, a major contributor to alumina production. Vedanta, a diversified natural resources conglomerate, leads the industry in overall aluminium production and owns Bharat Aluminium Company (BALCO). NALCO, a public sector enterprise under the Ministry of Mines, completes the trio of major producers in the sector.

Hindalco Industries Limited is the country's leading alumina producer, contributing nearly half of the total output of 7.5 MT in FY2024. This dominance is primarily driven by its subsidiary- Utkal Alumina, acquired in 2007, which ensures a strong captive alumina supply. Following Hindalco, National Aluminium Company (NALCO) holds a 27% share, while Vedanta Limited, which accounts for the remaining 24%.

Vedanta Limited leads India's aluminium production, accounting for over half (57%) of the country's output of 4 MT in FY2024. Hindalco, the largest producer of alumina, contributes 32% towards aluminium production, as a significant portion of its aluminium is used for its downstream operations. With an 11% market share, NALCO maintains a stable presence by balancing aluminium and alumina production.

Figure 12: Production share of alumina and aluminium by leading players, FY2024



Source: Industry annual reports, JMK Research

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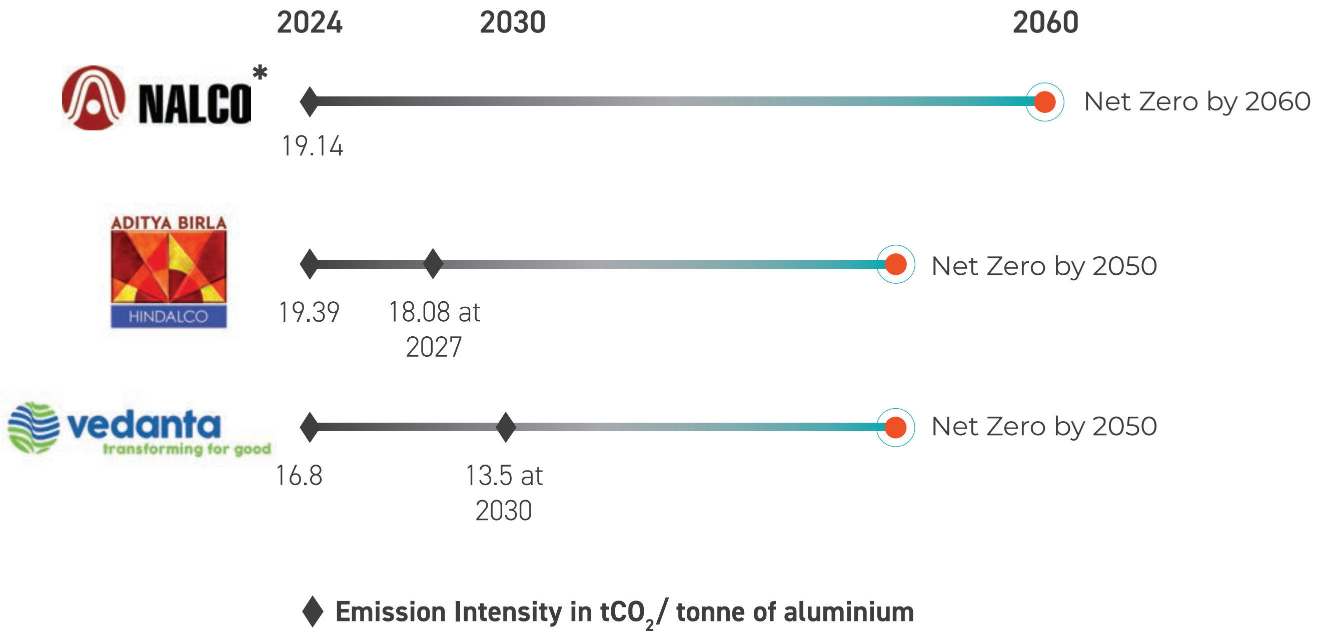
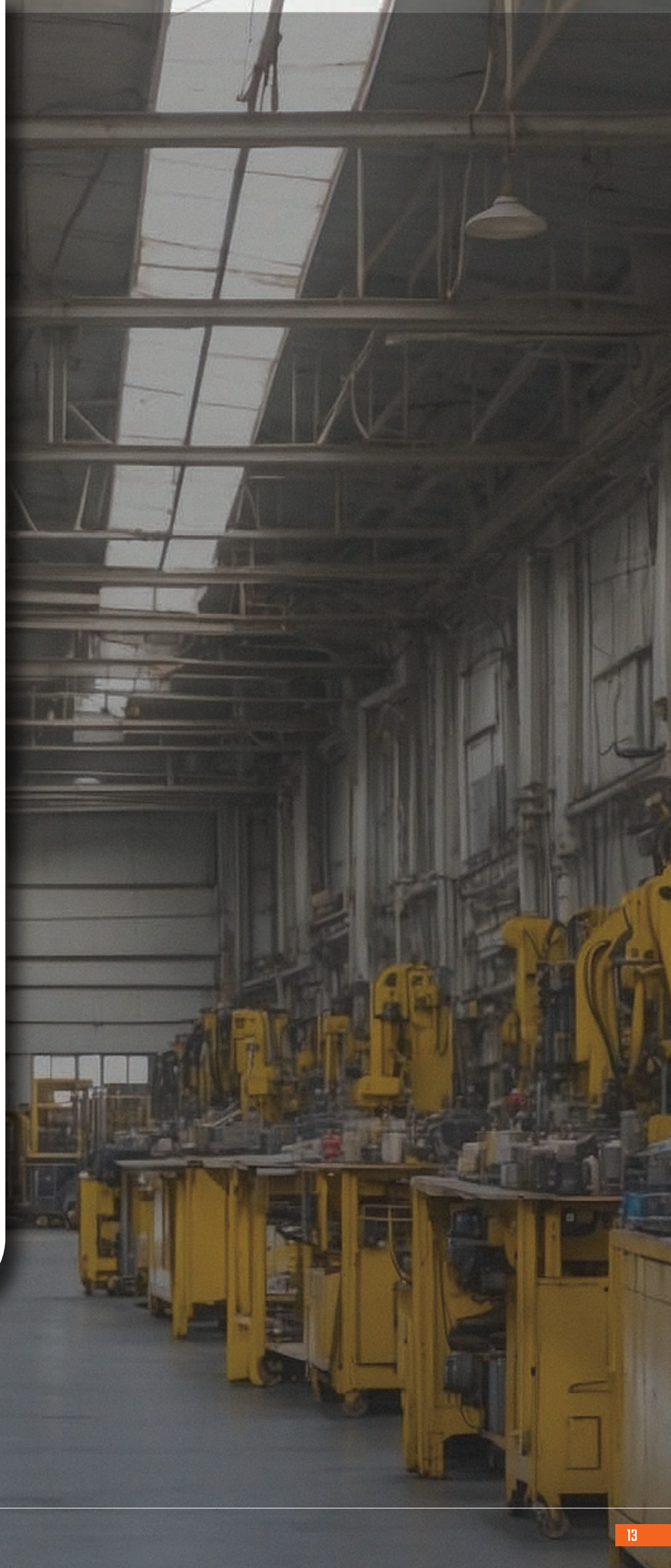
Aluminium sector players in India have committed to reducing emissions and achieving net-zero goals by adopting targets that align with the Paris Agreement. Among these, NALCO has set its net-zero target year as 2060, while private players Hindalco and Vedanta aim to achieve net zero by 2050.

Figure 13: Net zero roadmap of aluminium players



Source: Industry Annual reports, JMK Research

Note*: Net zero as per CII National Award for Excellence in Energy Efficiency.

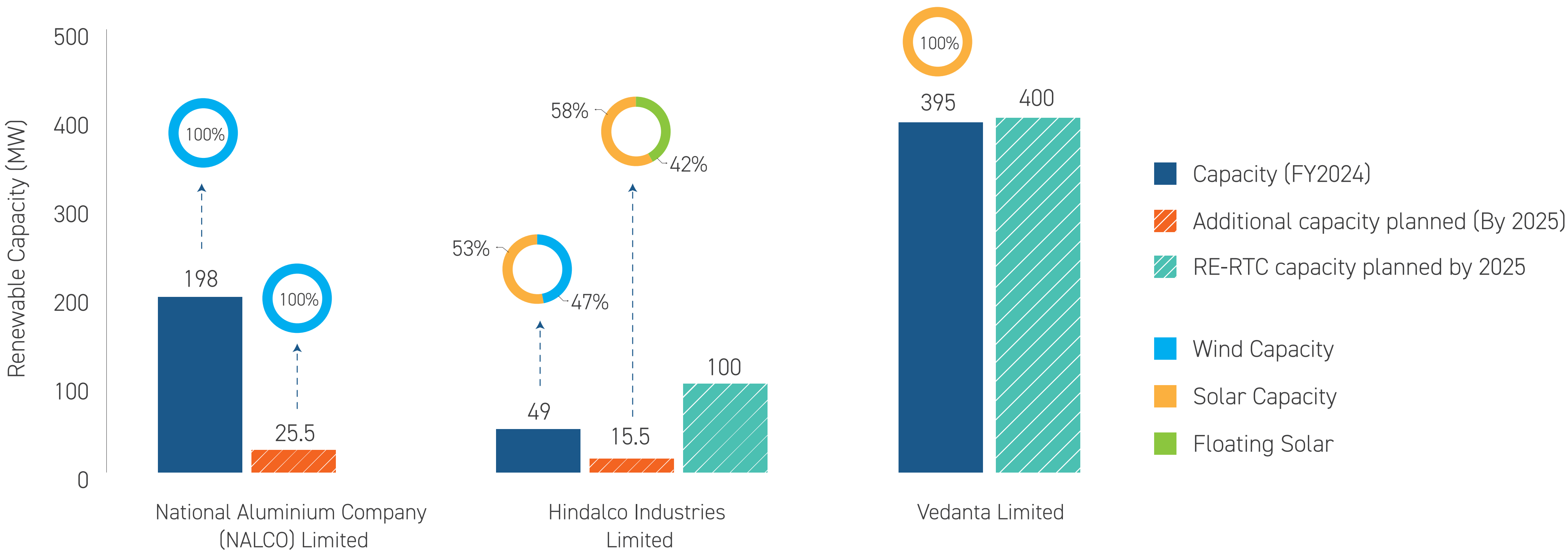


RENEWABLE ENERGY ADOPTION TRENDS

Aluminium players in India have started adopting renewable energy solutions to align with global sustainability trends and decarbonization goals. Currently, the share of renewables in electricity consumption in the aluminium sector is about 4–6%.

As of FY2024, the total renewable energy capacity across the aluminium sector is over 642 MW, with solar energy contributing more than half of this capacity. By the end of 2025, the sector plans to operationalize an additional 500 MW of round-the-clock (RTC) renewable energy capacity. Hindalco Industries Limited has partnered with Greenko Energies Private Limited to develop a 100 MW RTC capacity. This initiative will establish 375-400 MW of solar and wind capacity augmented by pumped hydro storage to supply power to Hindalco's aluminium smelter in Odisha.

Figure 14: Renewable capacity by aluminium players, installed (as of FY2024) and proposed



Source: Industry Annual reports, JMK Research

CASE STUDY - VEDANTA ALUMINIUM

Company Overview

Vedanta Limited (Formerly Sesa Sterlite Limited), a subsidiary of Vedanta Resources Limited, is a major player in the global natural resources industry with operations across India, South Africa, Namibia, Liberia, UAE, Korea, Taiwan, and Japan. India is Vedanta's largest market. The company has diversified operations in Oil & Gas, Zinc, Lead, Silver, Copper, Iron & Steel, Nickel, Aluminium & Power, and foraying into electronics and display glass manufacturing.

The aluminium business is Vedanta Limited's primary revenue driver with a share of 34%. Vedanta Aluminium (hereafter referring to Vedanta Limited's aluminium business, i.e., BALCO and VAL) holds a 45% market share among primary aluminium producers in India and boasts the largest installed aluminium production capacity in the country at 2.4 MTPA. To enhance sustainability, Vedanta has undertaken significant initiatives to decarbonize its aluminium production. These include investing in green energy sources and aligning operations with its long-term goal of achieving net zero carbon emissions by 2050.

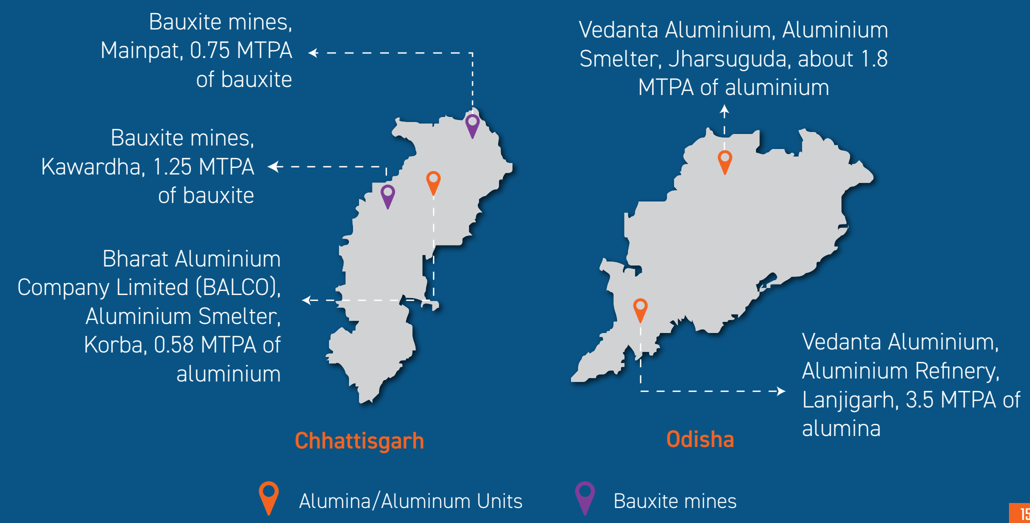
Table 2: Vedanta Limited Company Overview

Parameters	Details
Name	Vedanta Limited (formerly Sesa Sterlite Limited)
Year of establishment	1965
Parent Company	Vedanta Resources Limited
No. of plants	Aluminium-3 Others- 30
Headquarters	Mumbai, India
No. of employees (FY2024)	Vedanta Aluminium: 5,339 Vedanta Limited: 13,045 (96.32% in India)
Revenue (FY2024)	Vedanta Aluminium: Rs. 48,371 crores (about US$ 5.5 trillion) Vedanta Limited: Rs. 1,41,793 crores (about US$ 16.66 trillion)
Aluminium producing subsidiaries	Bharat Aluminium Company Limited (BALCO) Vedanta Aluminium Limited (VAL)
Coal-based captive power plant (CPP)	5.1 GW
Aluminium Production (FY2024)	2.37 MT
Total GHG Emissions - Scope 1 & 2 in aluminium business (FY2024)	34.18 $MTCO_2e$
Total energy consumption (FY2024)	Overall: 649 Petajoules (PJ) Aluminium: 400 PJ

Source: Vedanta Annual Report, JMK Research

Vedanta Aluminium owns bauxite mines in Kawardha and Mainpat in Chhattisgarh, which have a combined capacity of 2 MT. To meet its additional raw material requirements, Vedanta Aluminium has a long-term linkage arrangement with Odisha Mining Corporation, allowing it to purchase bauxite for Rs. 1,000 (about US$ 12) per MT. The extracted bauxite is processed at an alumina refinery in Lanjigarh, Odisha, with a production capacity of 3.5 MTPA. The resulting alumina is then utilized at aluminium smelters in Jharsuguda, Odisha and the other in Korba, Chhattisgarh. Together, they have a combined production capacity of 2.4 MTPA.

Figure 15: **Vedanta Aluminium: Locations and Annual Production Capacity**

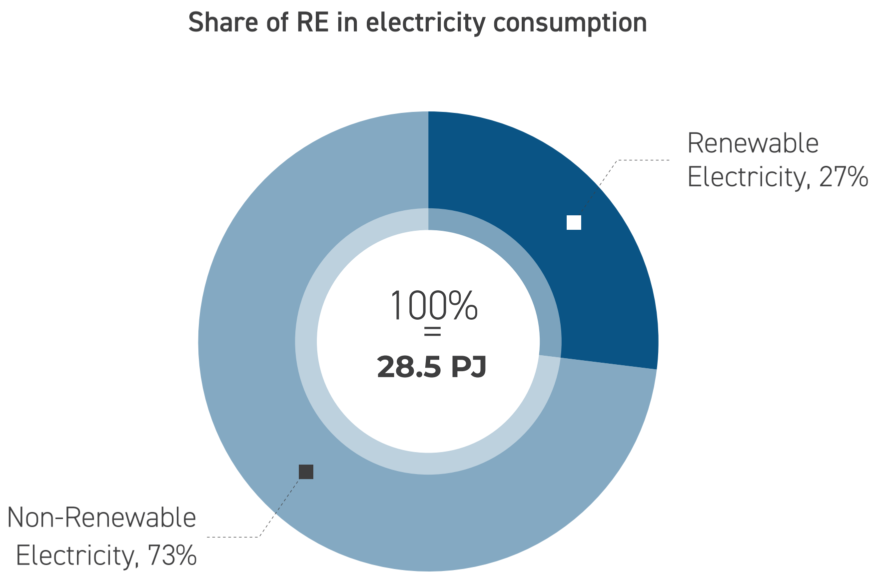


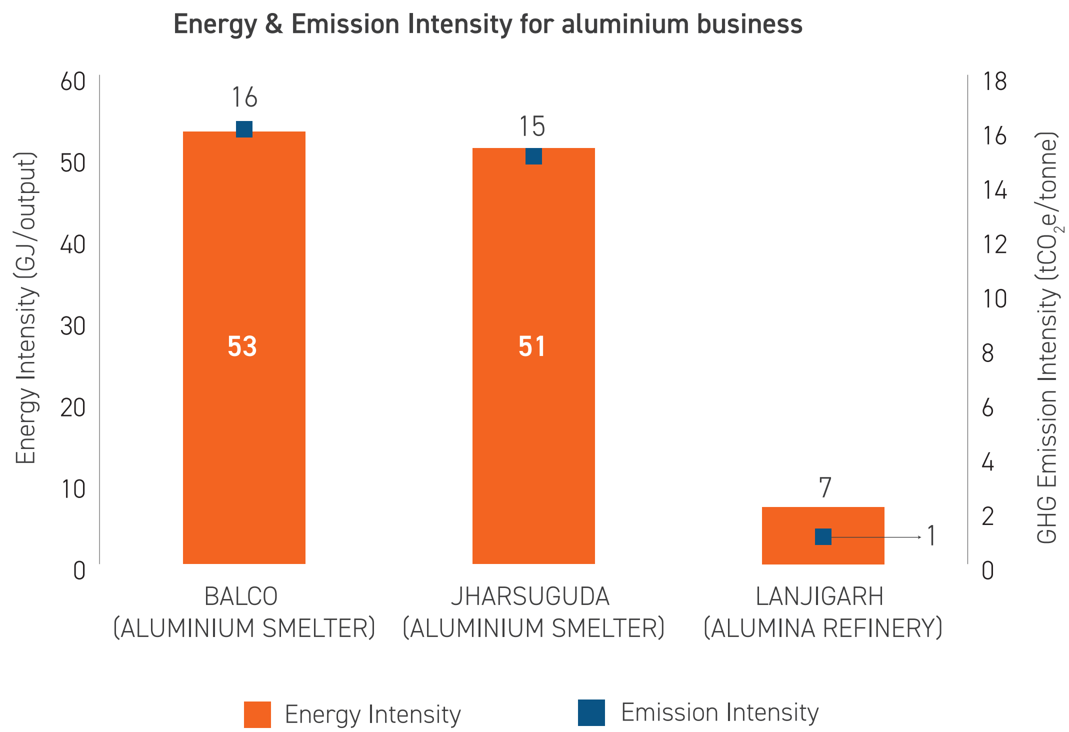
ENERGY CONSUMPTION AND EMISSIONS

In FY2024, Vedanta's total energy consumption amounted to 649 PJ, with non-renewable sources comprising the overwhelming majority at 99%, while renewable sources contributed a modest 1%. However, a notable shift is observed in electricity consumption, where renewable energy accounted for 27% of the total electricity usage in FY2024, reflecting a meaningful, though still limited, integration of sustainable energy sources into the company's operations.

With a current total capacity of 5.1 GW from coal-based captive power plants, Vedanta is prioritizing the integration of cleaner energy sources. This shift is part of the company's strategic direction, as it has no plans to add any new coal-based captive power plants.[14] Vedanta Aluminium has announced a Rs.1 lakh crore investment to establish an alumina refinery and an aluminium plant in Odisha (Rayagada). The planned 6 MTPA alumina refinery and 3 MTPA plant will focus on producing green aluminium powered by renewable energy, aligning with the company's broader decarbonization strategy. [15]

Figure 16: Vedanta energy consumption and energy & emissions intensity for aluminium business (FY2024)





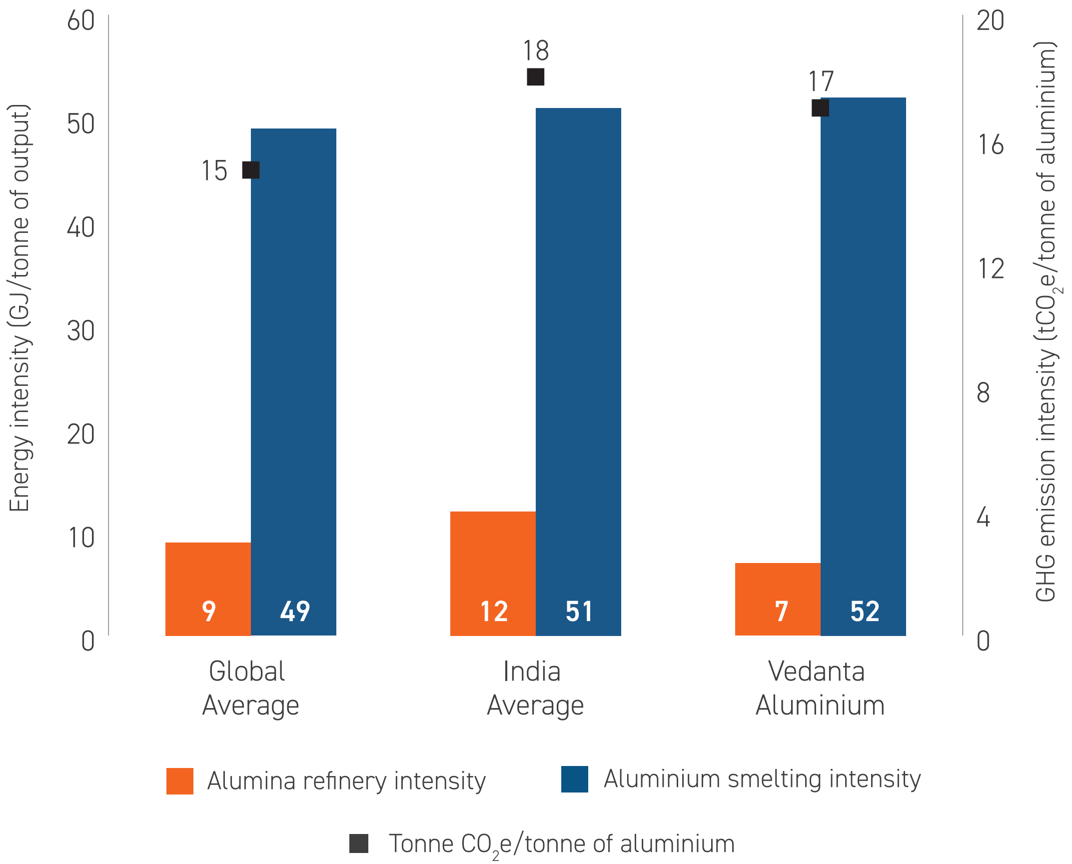
Source: Vedanta Annual Report, Vedanta Aluminium, JMK Research

[14] The Economic Times | Vedanta Aluminium turning to renewables, not adding coal capacity: CEO John Slaven | May 2024

[15] Vedanta Aluminium | Vedanta inks MoU worth Rs. 1 Lakh Crore with Govt. of Odisha at Utkarsh Odisha – Make in Odisha Conclave 2025 | 28th January 2025

The figure below compares Vedanta Aluminium's refining and smelting operations with global and India industry averages. As evident from the graph, Vedanta's Lanjigarh alumina refinery outperforms both the Indian and global alumina refining averages. This is primarily due to a patented process that reduces byproduct during the manufacturing process (red mud) by 30%, increases alumina yield, and significantly enhances energy efficiency during refining.

Figure 17: Vedanta's aluminium energy and emission intensity compared with the Global Average and India Average



Source: Vedanta Annual Report, WEF, International Aluminium Institute, JMK Research

SUSTAINABILITY INITIATIVES

Vedanta Limited has set a goal to achieve net-zero carbon emissions by 2050 and plans to invest $5 billion over the next 10 years to reach this target. To reach this target, the company has joined several prominent initiatives focused on sustainability and climate action. The accompanying figure illustrates the various organizations with which Vedanta has partnered to drive these ambitious sustainability goals.

Figure 18: Sustainability Initiatives of Vedanta Limited

TCFD — TASK FORCE ON CLIMATE-RELATED FINANCIAL DISCLOSURES

Aligns with the TCFD, demonstrating its commitment to transparent climate risk management & integrating sustainability in business

CII — Confederation of Indian Industry

Signatory to the CII Climate Action Charter, commitment to achieving Net Zero and promoting climate action throughout its value chain.

CDP — Carbon Disclosure Project

Commitment to transparency by reporting its environmental impact & progress toward reducing emissions in alignment with global sustainability goals

asi — Aluminium Stewardship Initiative

Vedanta aluminium is ASI certified across all its manufacturing units and is committed to responsible production and stewardship of aluminium

SCIENCE BASED TARGETS

Committed to the SBTi initiative, setting science-based targets to reduce emissions

सत्यमेव जयते
NITI Aayog

Partnered with NITI Aayog to develop decarbonization strategies and a roadmap for the Indian aluminium industry.

Source: Vedanta Aluminium Sustainability Report, JMK Research

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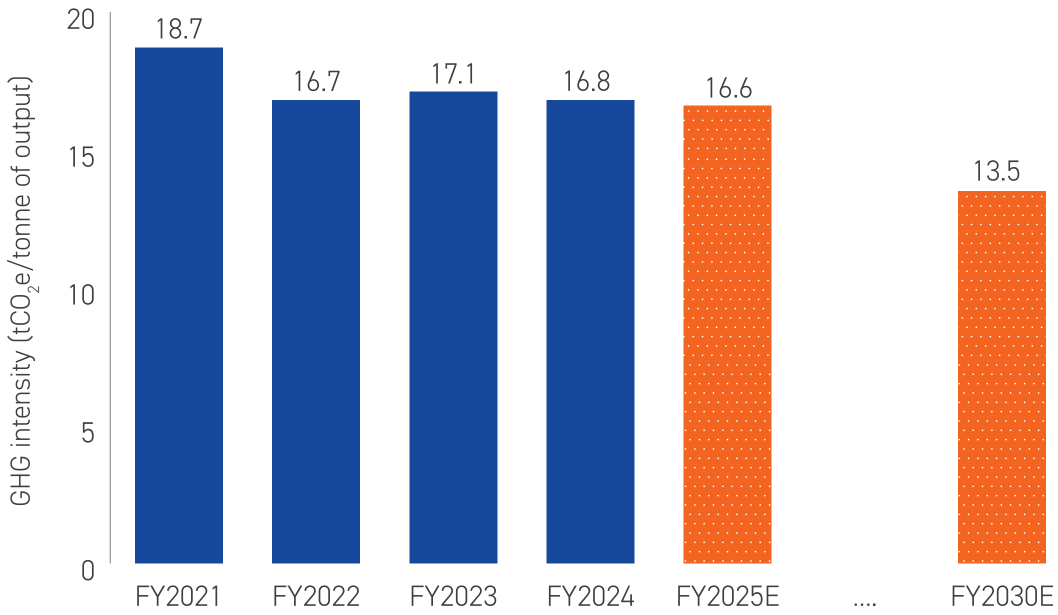
In 2024, Vedanta Limited has introduced an internal carbon pricing mechanism of $15/$tCO_2$e (approximately Rs. 1,287 /tCO_2e) across all its business sectors, including aluminium. Internal carbon pricing is a strategy that assigns a cost to carbon emissions, incentivizing businesses to reduce their carbon footprint. The funds generated from this mechanism will be invested in clean energy initiatives.

Building on these efforts, Vedanta Aluminium has achieved an 11% reduction in its GHG emissions intensity in FY2024, compared to FY2021. This progress brings the company closer to its Science-Based Targets initiative (SBTi) goal of lowering emissions to 13.5 tCO_2 per tonne of output by FY2030.

Figure 19: Emission intensity (scope1 + scope 2) of Vedanta Aluminium over the years



Source: Vedanta Aluminium, JMK Research

In FY2022, Vedanta Aluminium became the first Indian company to introduce low-carbon aluminium brands- Restora and Restora Ultra. The company aims to make low-carbon aluminium account for 30% of its product portfolio by FY2030. The table below provides details about these low-carbon aluminium brands.

Table 3: Vedanta Aluminium low-carbon brands

Brand	Description
Restora (Low carbon aluminium)	Restora is produced at a smelter that utilizes renewable energy sources, resulting in GHG emissions of 2-2.5 tCO_2e per tonne of aluminium.
Restora Ultra (Ultra-low carbon aluminium)	Produced from aluminium recovered from dross (a by-product of smelting process), having GHGemissions of around 0.4-0.8 tCO_2e per tonne of aluminium

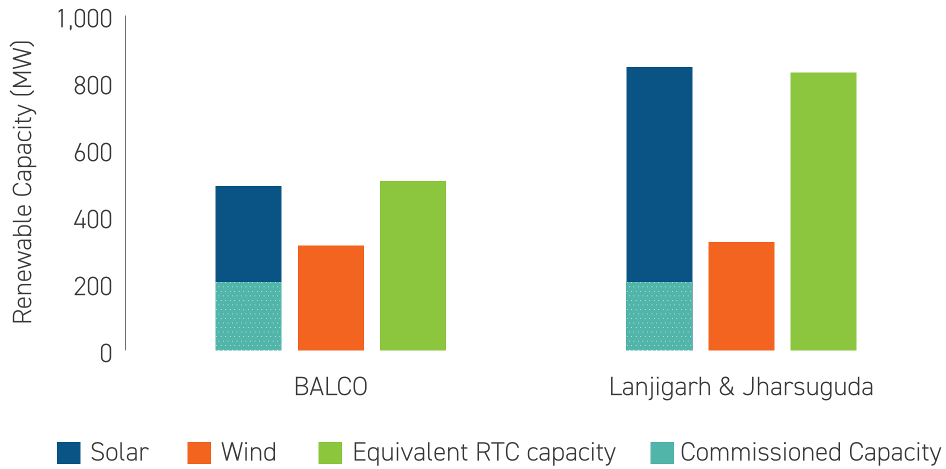
Source: Vedanta investor presentation, JMK Research

RENEWABLE ENERGY ADOPTION

Vedanta Limited is making significant progress towards its net-zero goals by incorporating renewable energy into its operations. It has set an ambitious target to deploy 1.3 GW of round-the-clock (RTC) renewable energy by 2030 as part of its sustainability commitment. To achieve this, the company is leveraging solar and wind energy for reliable power supply while collaborating with Serentica Renewables and Sterlite Power, both companies under the Vedanta Group. Serentica Renewables will develop and operate Vedanta's renewable energy projects, ensuring a stable and reliable supply. Meanwhile, Sterlite Power will establish the necessary transmission infrastructure to integrate and deliver this energy.

The figure below shows the location wise plan of Vedanta Aluminium to integrate renewables at its units.

Figure 20: Installed and planned (by 2030) renewable capacity by location for Vedanta Aluminium



Source: Vedanta Aluminium, Serentica Renewables, JMK Research

Out of the 869 MW of renewable capacity planned, currently only 395 MW of solar renewable capacity is commissioned. The details of the commissioned capacity are provided in the table below.

Table 4: **Vedanta Aluminium commissioned RE project details**

Parameters	Description
Capacity	395 MW solar
Project developer	Serentica Renewables Pvt Ltd
Project location	Bikaner, Rajasthan
Project off-taker	Vedanta Aluminium
Contractual structure	25-year power purchase agreement
Date of commissioning	Sept - Oct 2024
Power delivery agreement structure	200 MW at Jharsuguda & Lanjigarh, Odisha 195 MW at BLACO, Chhattisgarh
Estimated annual RE generation	865 GWh

Source: Vedanta Aluminium, Serentica Renewables, JMK Research

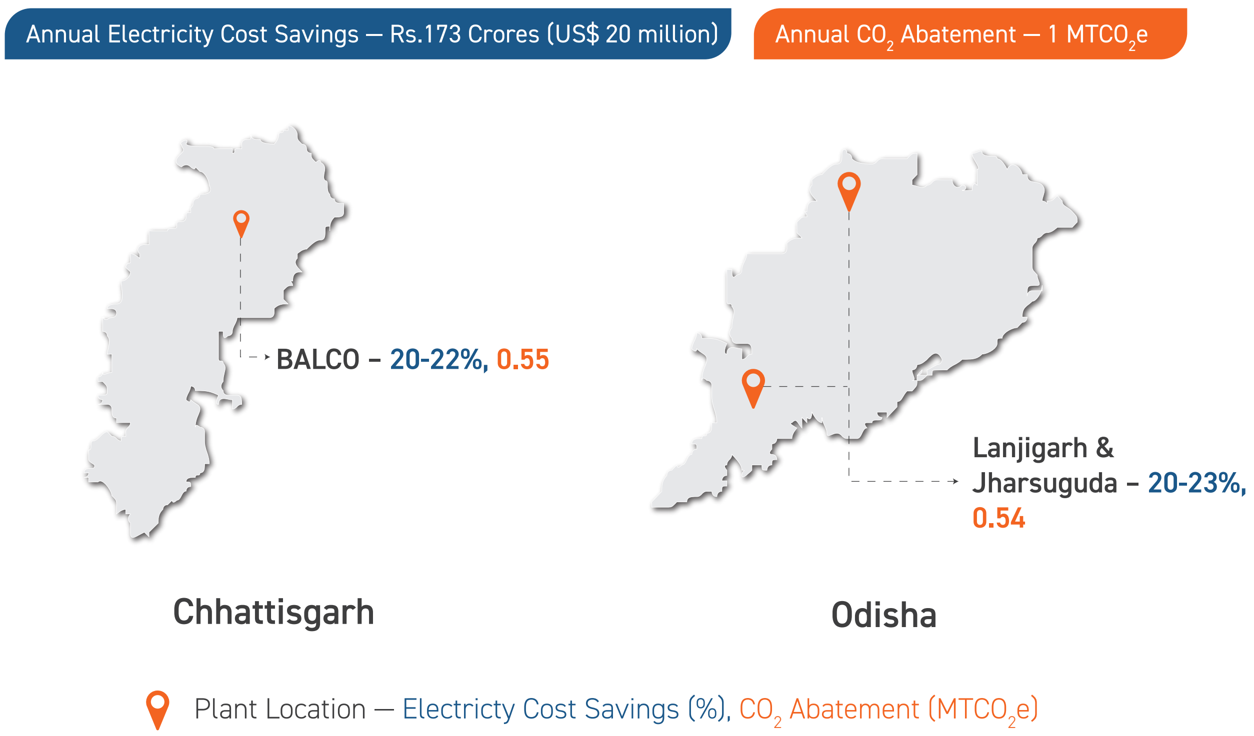
Looking ahead, Vedanta Aluminium aims to operationalize 400 MW of round-the-clock (RTC) renewable energy by 2025. This initiative is a key step towards increasing the share of renewable energy consumption in electricity in its aluminium business from nearly 1% to 7%. Furthermore, with the planned commissioning of 1.3 GW of RTC renewable capacity, the company targets raising its renewable energy share to 30% by 2030, reinforcing its commitment to sustainability and cleaner energy adoption.

RENEWABLE ENERGY BENEFITS

Vedanta Aluminium has shifted from relying on captive coal power plants to adopting a greener energy mix. This transition has resulted in reduced carbon emissions and savings in electricity costs.

The commissioning of the 395 MW of renewable capacity has enabled Vedanta Aluminium units in Chhattisgarh and Odisha to achieve annual **electricity cost savings of approximately Rs. 173 crore (US$ 20 million), translating to a 20–23% reduction.** This transition will also help the company **mitigate annual carbon emissions by 1 MTCO_2e.**

Figure 21: Annual electricity cost savings and equivalent carbon abatement of Vedanta Aluminium



Source: Vedanta Aluminium, JMK Research

OTHER DECARBONIZATION AND SUSTAINABILITY MEASURES

In addition to utilizing renewable energy for decarbonization, Vedanta Aluminium has made progress towards decarbonization and sustainability using the following measures:

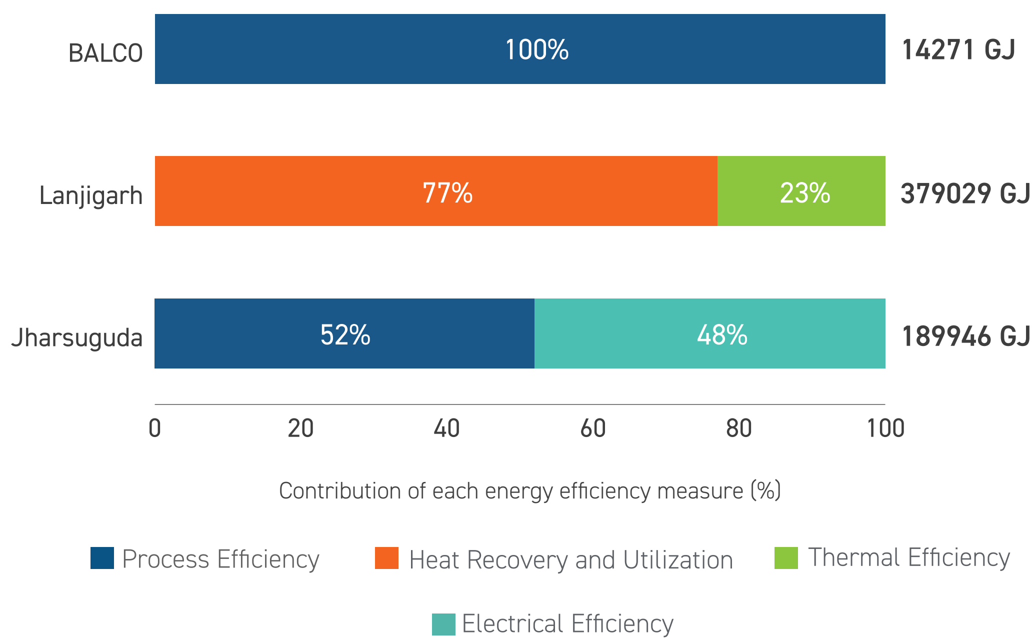
Energy Efficiency Measures

In FY2024, Vedanta Aluminium achieved significant energy savings of approximately 583,246 GJ through the implementation of diverse energy efficiency measures across its operations. These efforts are categorized into four key areas:

- **Process Efficiency:** Optimizing operational workflows and minimizing inefficiencies in core processes. This includes upgrades in cathode technology at BALCO and Jharsuguda smelters to improve performance and energy use. Process efficiency contributed 19% of the total energy savings accrued by Vedanta Aluminium.
- **Heat Recovery and Utilization:** Capturing and reusing waste heat from high-temperature systems. At Lanjigarh, projects such as replacing heat recovery components in boilers, have contributed 50% of the total energy savings.
- **Thermal Efficiency:** Improving heat retention in high-temperature equipment resulted in 15% of the energy savings. For instance, enhancements in insulation materials at Lanjigarh have helped reduce heat loss, making operations more energy efficient
- **Electrical Energy Efficiency:** Involves optimizing electrical systems to enhance energy usage. At Jharsuguda, initiatives such as reducing cathode voltage drop and improving power regulation have achieved 16% of the total energy savings.

The figure below illustrates the percentage contribution of each energy efficiency measure at each aluminium unit.

Figure 22: Energy efficiency measures employed at Vedanta Aluminium units (Gigajoules)



Source: Vedanta Aluminium, JMK Research

Electric Mobility

Vedanta has integrated electric mobility into its decarbonization efforts by introducing electric lithium-ion forklifts at its aluminium and alumina manufacturing units. This initiative represents a significant move toward reducing the carbon footprint of its industrial vehicle operations, leading to an annual reduction of approximately 1600 tonnes of CO_2 emissions.

Biomass

Vedanta Aluminium has adopted biomass briquettes from agricultural residues procured by local farmers. Currently, the company utilizes 20 tonnes of these briquettes per day at its alumina refinery in Lanjigarh (Odisha).[16] Additionally, BALCO (Chhattisgarh) utilizes 40-50 tonnes of briquettes per day for its thermal power generation. This initiative will abate emissions by about 0.43 $MTCO_2e$ annually by reducing the reliance on fossil fuels.[17]

Other initiatives

Vedanta Aluminium has made efforts to adopt several other sustainable practices, such as reducing water consumption, enhancing sustainable sourcing, improving waste management, etc. The accompanying table showcases the other sustainability measures achieved by the company.

Table 5: Other sustainability measures

Initiative	Description
Waste recycling	Approximately 0.37 MT (97.6%) of hazardous waste and 28.44 MT (99.5%) of non-hazardous waste were recycled in FY2024.
Fly ash utilization	BALCO partnered with Shree Cement to supply 90,000 MT of fly ash for the sustainable utilization of fly ash in the cement industry. In FY2024 alone, BALCO Supplied more than 4 million metric tonnes of fly ash and achieve 133% ash utilization.
Water recycling	15 billion litres of water recycled across its operations

Source: Vedanta Aluminium, JMK Research

[16] Vedanta Aluminium press release | Earth Day: Vedanta Aluminium accelerates shift to renewables, deploys biomass for power generation | April 2024

[17] BALCO press release | BALCO greenifies its fuel mix with biomass for power generation | June 2022

WAY FORWARD FOR ALUMINIUM SECTOR

The Indian aluminium industry is dominated by a few large primary producers and remains one of the most energy intensive sector due to its reliance on coal. Currently, renewable energy sources fulfil only about 5% of the sector's electricity demand. However, this percentage is expected to increase significantly as primary aluminium manufacturers have plans to adopt renewable energy-round-the-clock (RE-RTC) solutions. By 2030, renewables are projected to constitute approximately 25% of the sector's energy mix. As per JMK Research estimates, renewable energy is projected to scale up considering the following growth opportunities by 2030:

Scenario 1- By 2030, 50% of additional power demand for upcoming aluminium capacity is to be met by renewable energy:

By 2030, India's primary aluminium capacity is projected to reach around 8.6 MTPA, mainly due to expansion plans from primary aluminium producers. To meet decarbonization goals, 50% of the additional power demand for upcoming aluminium capacity is assumed to be met through renewable energy, while the remaining half will rely on thermal CPPs. The shift to renewables could potentially add up to 9 GW of renewable capacity between 2025 and 2030 for primary aluminium producers. However, in a business-as-usual scenario, this would be replaced by an estimated 14 GW of additional coal-based captive power plants to support the sector's growth.

Scenario 2- Electricity imports from grid is transitioned to renewable energy

The aluminium sector currently uses grid electricity to meet about 5% of its energy requirements for smelting operations. If the entire electricity supply for this sector shifts to renewable energy, it is projected to lead to substantial growth in renewable capacity, adding approximately 1 GW of renewable energy.

Scenario 3- Using alternative fuel sources such as green hydrogen and biomass in aluminium sector by 2030

Green hydrogen can act as a sustainable alternative to coal in alumina refineries by replacing conventional fossil fuels in high-temperature processes, such as calcination. However, its initial adoption is expected to be prioritized in industries like fertilizer and steel before being implemented in aluminium production. By 2030, it is assumed that 5% of the energy currently derived from of coal in alumina refineries will shift to green hydrogen. As green hydrogen relies on renewable electricity, its adoption will drive the addition of 374 MW of renewable capacity along with 104 MW of energy storage systems.

Biomass is currently used in the aluminium sector, with approximately 1 lakh tonne being utilized annually as a renewable energy source, primarily through co-firing in coal-based power plants. As the industry shifts towards more sustainable practices, the adoption of biomass is expected to increase, driven by its ability to reduce carbon emissions. In the coming years, alternative fuel usage in aluminium sector is likely to expand, complementing other renewable energy sources like solar and wind.

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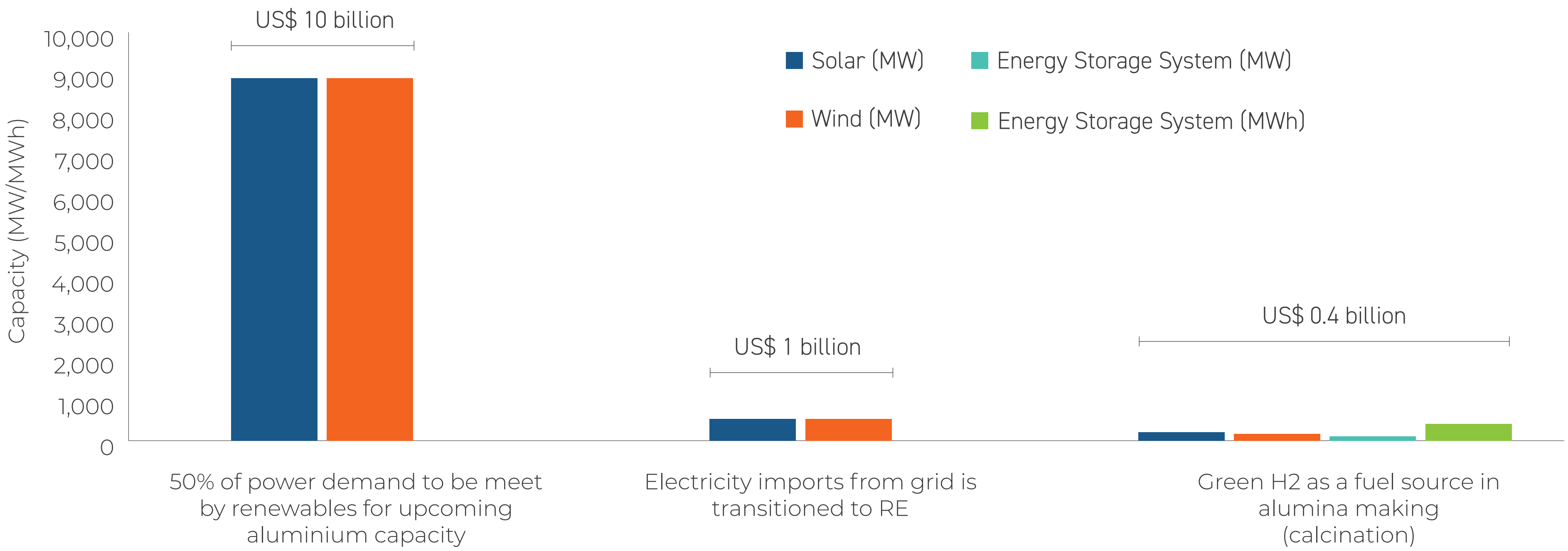
Figure 23: Expected Renewable installations under various scenarios in aluminium sector by 2030



Source: JMK Research

The analysis indicates that by 2030, the Indian aluminium sector is expected to integrate approximately 18-20 GW of solar and wind capacity, which will require about 104 MW/ 416 MWh Energy Storage System. This transition will necessitate an estimated investment of around US$ 5 Billion (about Rs. 425 billion crores).

With 2070 net zero target in place, aluminium producers in India are accelerating decarbonization efforts, highlighting an urgent need for adoption of renewable energy and improvements in energy efficiency. While the potential role of green hydrogen as a fuel in alumina making is being explored, the feasibility of its adoption in the long term will depend on cost competitiveness and infrastructure development. Achieving these goals will require a cohesive effort from industry stakeholders, policymakers, and investors to build a robust ecosystem that supports sustainable aluminium production.

A key opportunity lies in establishing India as a global leader in green aluminium, a low-carbon aluminium that aligns with the rising global demand for sustainable materials. To turn this vision into reality, the **Indian government should introduce a comprehensive aluminium decarbonization policy, offering clear regulatory frameworks, targeted financial incentives, and a well-defined technological roadmap.** Global trends highlight the urgency of this transition. In regions like the Europe and Russia, aluminium producers benefit from a cleaner energy mix, giving them a competitive advantage in carbon-conscious markets. Without similar efforts, India risks falling behind, facing trade barriers and losing access to key export markets as sustainability regulations tighten. Proactive decarbonization, particularly through large-scale adoption of renewable energy and energy-efficient technologies, will be essential in positioning India as a leader in the green aluminium transition

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