UK Government

GOVERNMENT OF INDIA
MINISTRY OF POWER

Bureau of Energy Efficiency
Ministry of Power, Government of India

Accelerating Smart Power and Renewable Energy in India (ASPIRE) Programme

Draft Report on

Pathways for Energy Efficiency and Decarbonisation in the Indian Aluminium Industry

August 2024

Background

1 **India's Nationally Determined Contribution (NDC)**

- Reduce the emissions intensity of its GDP to 45% by 2030 from its 2005 level
- Increase the cumulative electric power installed capacity from non-fossil fuel-based energy resources to 50% by 2030
- Achieve a net-zero economy by 2070

2 **About Emissions**

- According to RBI, Manufacturing industry - 2nd Contributor of CO_2 emissions in India
- Aluminium industry alone accounts ~ 9% of total industrial GHG emissions and its carbon intensity ranges between 16-20 tonnes of CO_2 equivalent per tonne
- From PAT cycles I to IV, the aluminium sector has already achieved a total energy saving of 2.13 mTOe and ~ 8 $mTCO_2e$ saved in total GHG emissions
- New Carbon Regulations like Carbon Border Adjustment Mechanism (CBAM), and Carbon Credit Trading Scheme (CCTS).

3 **Indian Aluminium Industry**

- 2nd Largest producer of Aluminium in the world and contributes to ~6% of global output
- Total installed capacity to produce aluminium is about 4.1 million metric tonnes per annum (MMTPA) and about 9.2 MMTPA for alumina
- Market Value – 941 billion INR
- Expected Compound Annual Growth Rate (CAGR) for Aluminium demand - ~8 to ~10% from FY 2024 to 2030
- Aluminium exports growing at a CAGR of ~15% over the last 5 years (2018 - 2022)

Considering the context of international carbon tariffs and India's climate change commitments, a study on the development of 'Pathways for Energy Efficiency and Decarbonization in the Indian Aluminium Industry' was being carried out

Report Specifics (1/2)

Objectives

- Estimate emissions from the Indian aluminium industry and identifying leading practices on energy efficiency and decarbonisation being adopted by large aluminium companies across the globe
- Prepare an energy efficiency and decarbonisation strategy for Indian aluminium industry

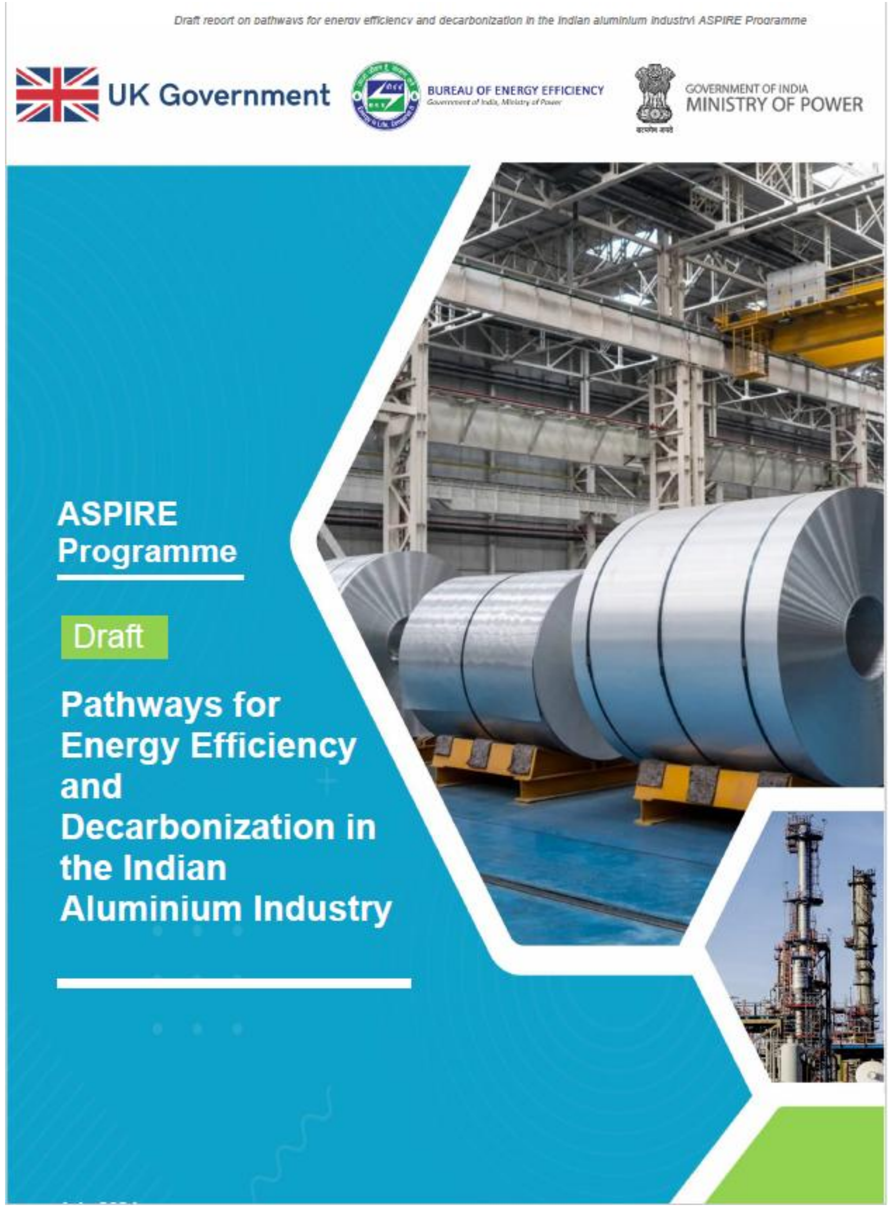
Target Audience

- Indian aluminium companies, policymakers, research institutes, technology providers etc.

ASPIRE Programme

- The report is prepared under ASPIRE Programme
- Accelerating Smart Power and Renewable Energy (ASPIRE) is a bilateral programme being implemented by the Foreign Commonwealth and Development Office (FCDO), Government of UK in association with the Ministry of Power and Ministry of New and Renewable Energy (MNRE), Government of India (GoI).

Report Specifics (2/2)



Content and Coverage of the Report

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08 Alumina refining , aluminum smelting and integrated (refining and smelting) units

09 Scope 1 & Scope 2 emissions only

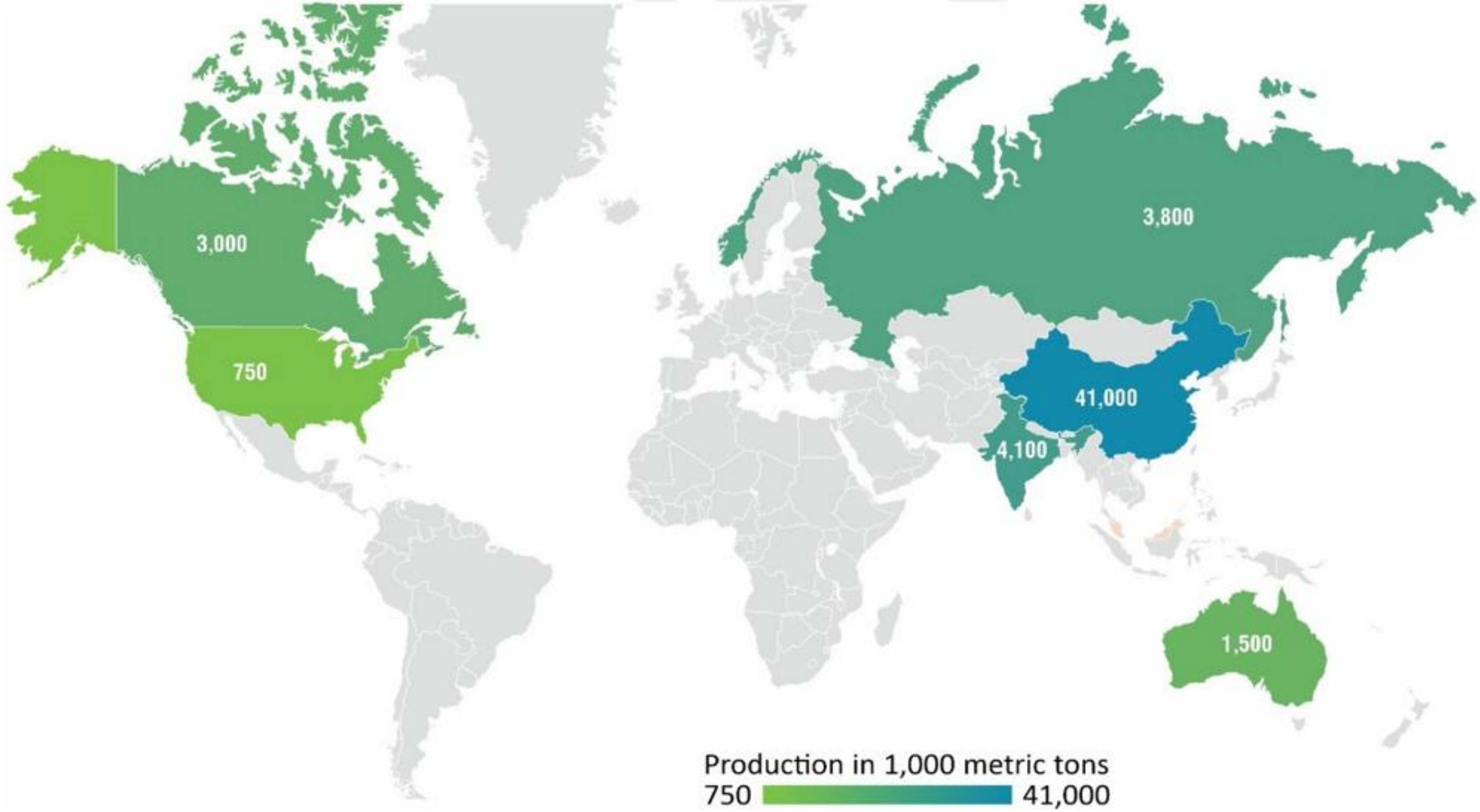
10 Gender Equality and Social Inclusion (GESI)

11 Base year FY 2022 – 23 to medium term (FY 2027-28) and long term (FY 2032-33)

OVERVIEW OF ALUMINIUM SECTOR: GLOBAL AND INDIA

Overview – Aluminium Production (Global level)

Global Landscape



India is the 2nd Largest Producer of Aluminium

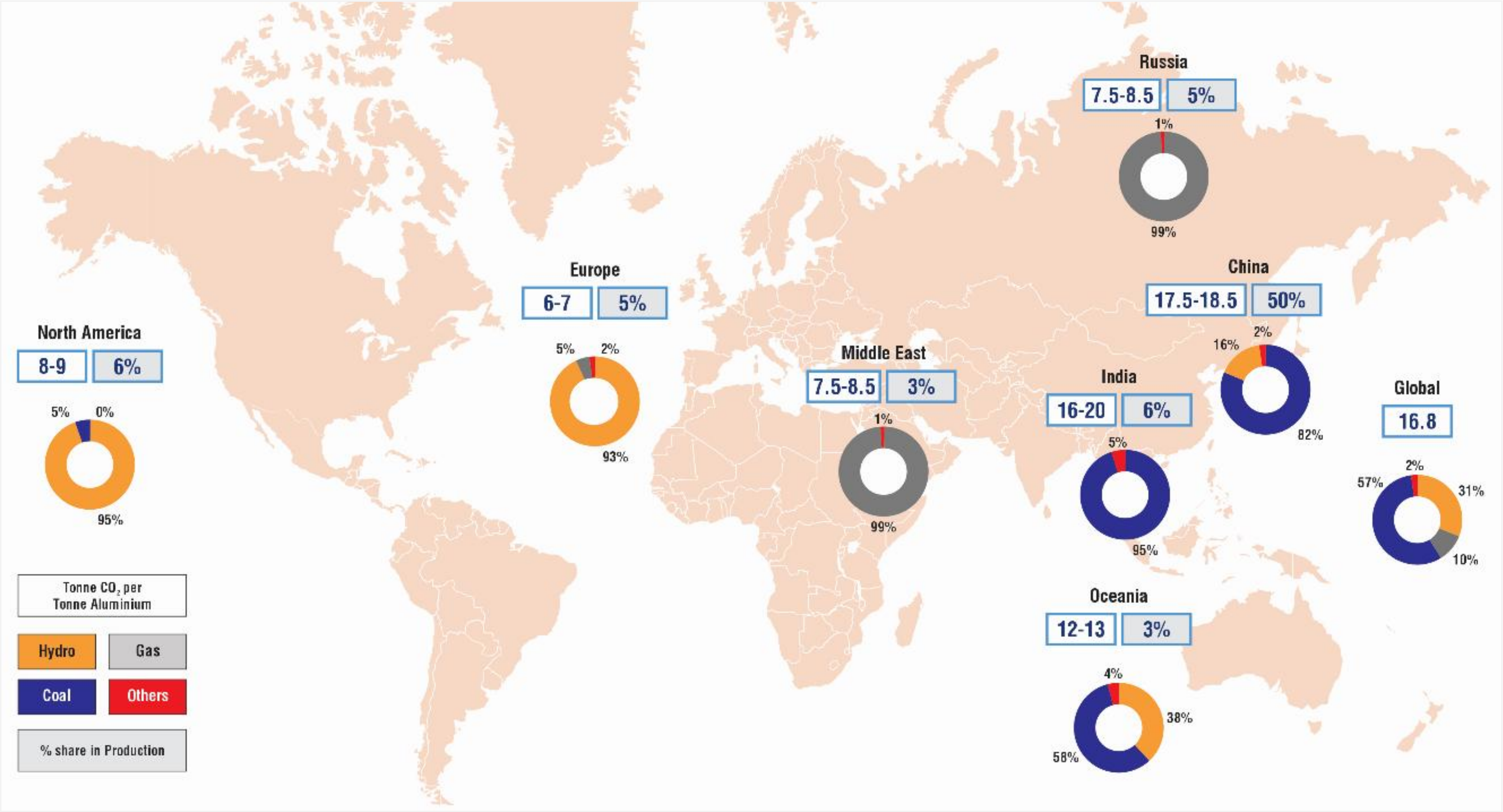
Global Aluminium Market (2023) : Market size: ~INR 14 trillion

Expected growth: CAGR of ~6%, reaching ~INR 23 trillion by 2032

Source: Aluminium production top countries 2023 | Statista

Overview – Emissions in Aluminium Industry (Global level)

Scenario of Energy mix and GHG emission intensity

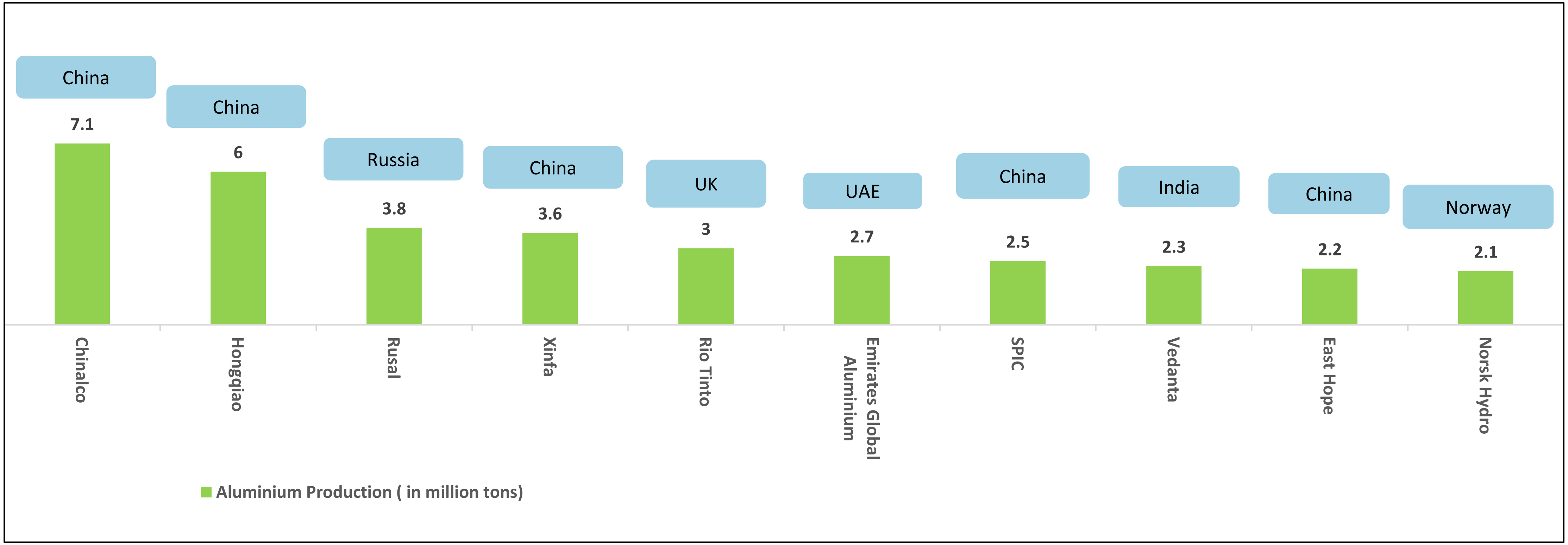


- Emission intensity across geographies is not consistent with the production of primary aluminium primarily due to difference in energy sources and technological advancements.
- Primary aluminium producers relying on hydropower (in Europe and North America) and gas (in Middle East) for fuel supply have an emission intensity of 6-9 tCO2e/Mt as compared to an average emission intensity of ~19 tCO2e/Mt for producers in Asian countries (such as India) which are more reliant on coal based thermal power plants

Source: Australia aluminium Association, CRISIL MI&A Research

Leading Aluminium Producers (FY 2022)

Primary aluminium production of leading aluminium manufacturers

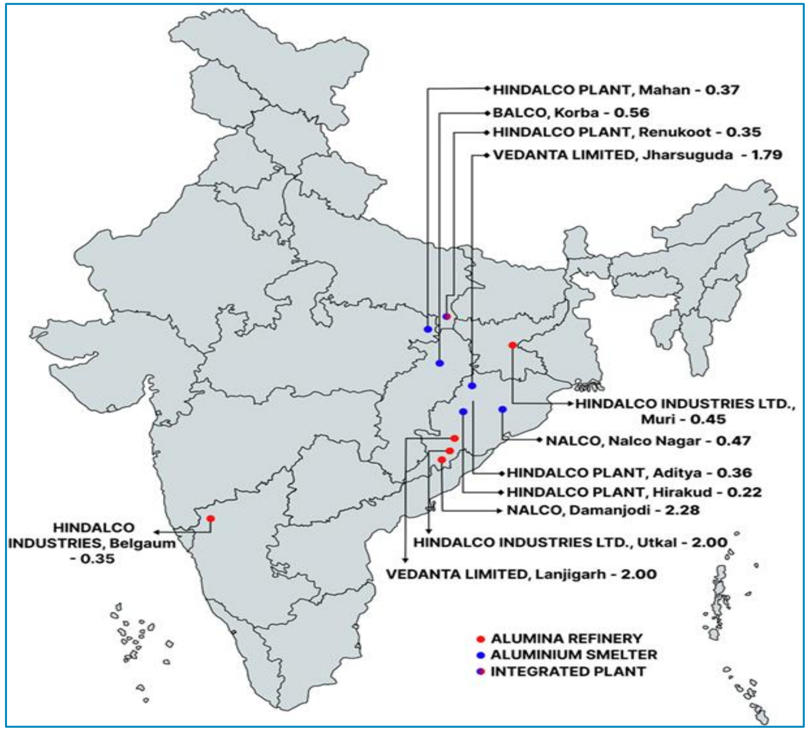


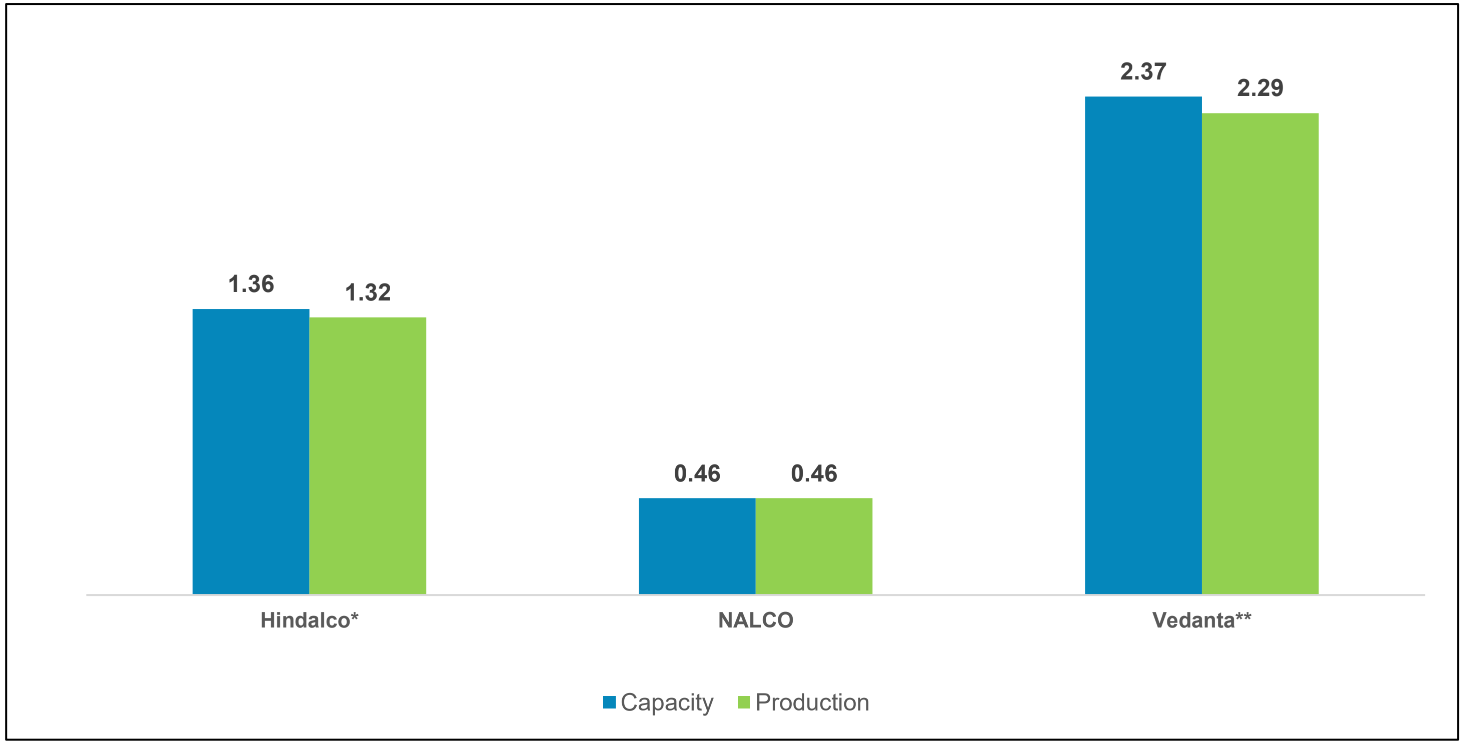
- With around 7.1MMT of aluminium produced, Chinalco was the world's largest aluminium producing company in 2022.
- Hongqiao, Rusal, and Xinfa were also ranked among the largest aluminium producers globally.
- UK based Rio Tinto holds the 5th position globally.
- Vedanta group based in India holds the 8th position globally, contributing to about 2.3 MMT of global aluminium production.

Source: Primary aluminium global company production ranking | Statista

Aluminium Industry – Industry Scenario

Plant capacity and production during FY 2022-23 (million metric tonnes)





- Vedanta: Largest producer with 2.4 MTPA capacity including BALCO; accounting for 48% of India's energy consumption in the Primary Aluminium production.
- Vedanta Jharsuguda: World's largest single-location smelter (1.75 MTPA).
- Hindalco: 2nd largest, 1.34 MTPA capacity; 39% of energy consumption.
- NALCO: 0.46 MTPA capacity; 13% of energy consumption.

Source: India: production volume of aluminium by producer 2023 | Statista , Monthly Summary on Minerals and Non-Ferrous Metals for the Month of April 2023

Approach for developing Energy Efficiency (EE) and Decarbonisation strategy

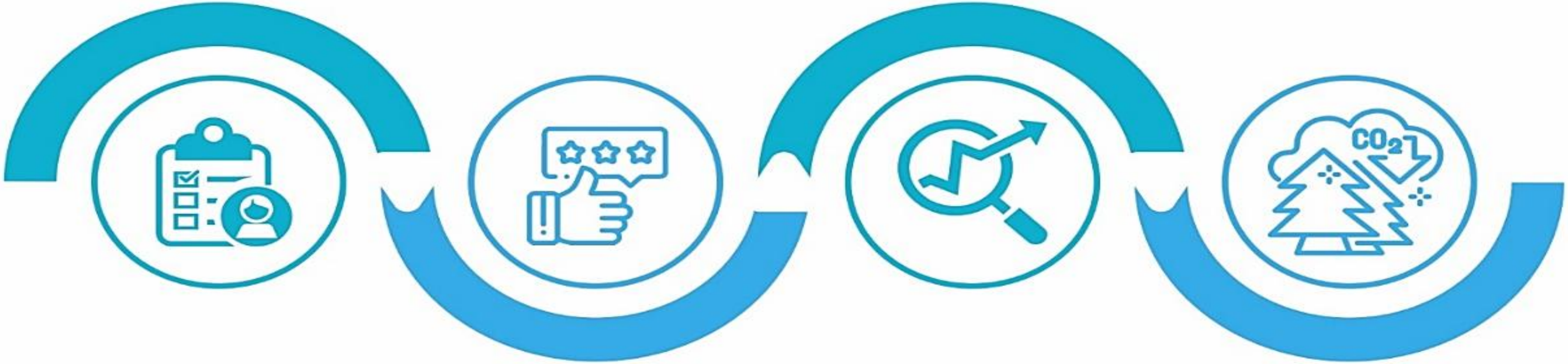
Approach & Methodology

Assessment

- Overview of production process & corresponding emissions
- Emissions from Indian aluminium industry
- Stakeholder consultations

Analysis

- Estimation of emission intensity for Indian aluminium industry
- Decarbonization pathways
- Enlisting decarbonization interventions



Review

- Identification of indicators & relevant peers for comparative analysis
- Performance review of select peers w.r.t Indian companies
- Leading EE & decarbonisation practices

EE & Decarbonisation

- Policy enablement
- Leadership commitments
- Research & Development Collaboration

Framework for developing decarbonisation strategy

1 Assessment

Data Collection:
- Information gathered from sustainability reports, global decarbonisation studies, and research papers.
- Lack of uniform data reporting standards across companies.

Stakeholder Consultations:
- Engaged with industry players, research institutes, and low-carbon tech providers.

Foundation for Assessment:
- Established groundwork to compare Indian aluminium industry performance with global peers.

2 Review

Performance Indicators:
- Selected based on criticality for decarbonisation and energy efficiency (EE).
- Indicators chosen through stakeholder consultations.

Reference Year:
- FY 2021-22 selected for data consistency across global peers.

Global Comparators:
- Key Players: Rio Tinto, Emirates Global Aluminium, Alcoa, Norsk Hydro, Alba.
- **Rationale:**
  - Account for ~20% of global aluminium production.
  - Leaders in sustainability, low-carbon technologies, and green aluminium initiatives.

Key parameters for performance assessment

- Production Capacity and Production (MTPA)
- Fuel Source, Energy Consumption (GJ), SEC (GJ/MT of Al, kWh/ T of Al
- Emission Intensity (TCO2e/ MT Al
- Target for Net-Zero
- Existing Decarbonisation Measures

Framework for developing decarbonisation strategy

1 Assessment

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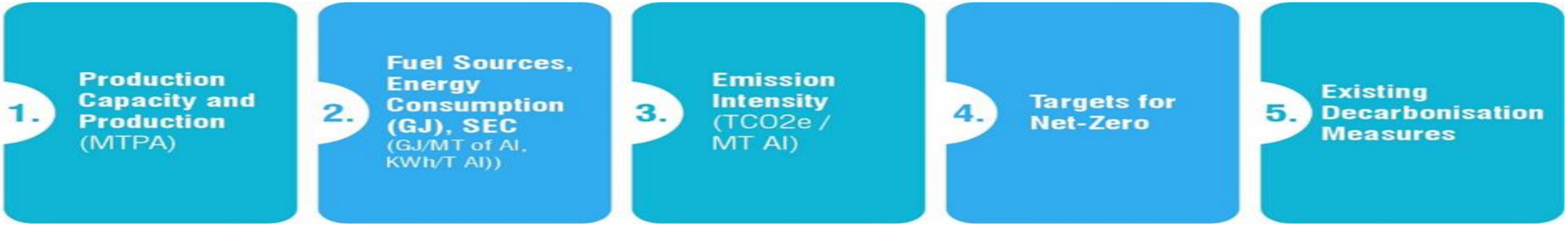


Global Leaders Considered:

1. Rio Tinto (UK)
2. Emirates Global aluminium (UAE)
3. Alcoa Corporation (USA)
4. Norsk Hydro ASA (Norway)
5. Alba (Bahrain)

Framework for developing decarbonisation strategy

Analysis

1. Aluminium Production Estimates

- Historical trend of production over last five years
- Planned capacity addition in next ten years is considered
- Limiting maximum capacity utilisation for each company at 110%

2. Energy Consumption Estimates

- Estimated based on the projected production numbers and historical SEC of last 5 years
- Assumed that the performance of EE achieved by the aluminium players will hold for the next decade

3. Emission Intensity Estimates

- Emissions are projected under two different scenarios BAU, and optimistic.
- Under optimistic scenario, curtailment in emissions is on account of RE penetration and simultaneously implementation various EE measures

Production Trends

- Estimated based on historical data (FY 2012-23) and company capacity additions.
- Production expected to reach 5.87 MTPA by FY 2032-33, with maximum capacity utilization capped at 110%.

Energy & Emission Estimates:

- BAU Scenario: Assumes maintaining energy intensity at 168 MGJ/MT and emission intensity at 18.31 MTCO2/MT.
- Optimistic Scenario: Assumes 1% annual improvement in energy efficiency (EE) and RE penetration from ~30% in FY 2024-25 to ~50% in FY 2032-33.

Comparative assessment of Indian aluminium industries with global peers

Comparative assessment

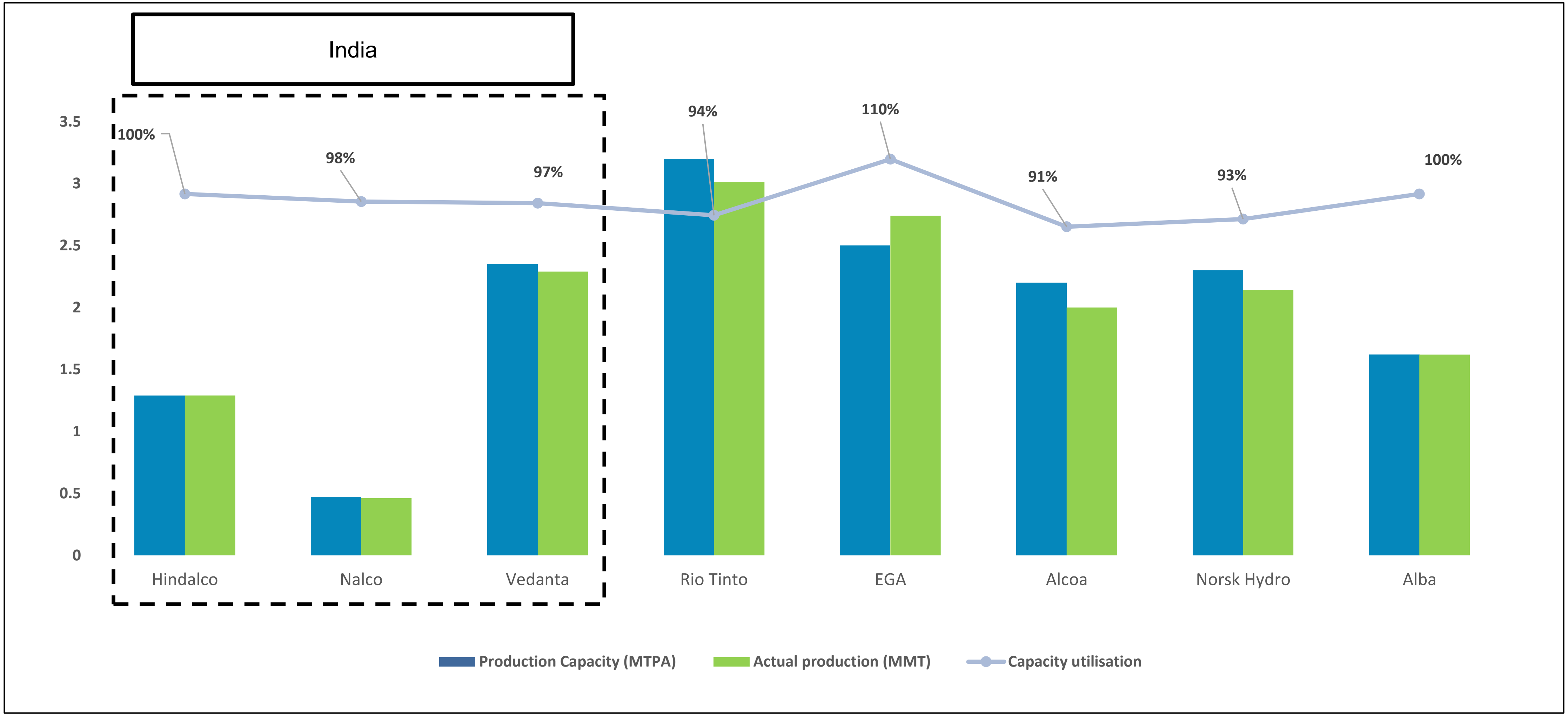
Highlights of the comparative assessment of Indian aluminium sector with global peers

S.No	Parameters	Indian aluminium sector	Global peers (Rio Tinto (UK)/ Emirates Global Al (UAE)/Alcoa (USA)/ Norsk Hydro ASA (Norway/ Alba (Bahrain
1	**Production and Capacity Utilisation**	▪ Production capacity of primary aluminium in India: 4.02 MMT in FY2021-22 (~5% of global production) ▪ Capacity utilisation : o Hindalco ~102% (maximum) o NALCO ~99% o Vedanta ~97%	▪ These 5 global peers (refer Table 2) have a cumulative capacity of ~11.82 MTPA. ▪ Capacity utilisation : o EGA has highest utilisation of ~109% followed by Alba (~100%). o Other global peers have utilisation of less than 100%
2	**Energy Consumption**	▪ Leading performer: ~53 GJ/Mt of primary aluminium	▪ Leading performer: ~50 GJ/Mt of primary aluminium
	DC Electricity Consumption	▪ Leading performer: 12,973 kilowatt-hours per metric tonne (kWh/Mt) ▪ Average: ~13,320 kWh/Mt	▪ Leading performer: 12,500 kWh/Mt ▪ Average: ~13,745 kWh/Mt
	RE Usage	▪ 0.8% of the total energy consumption is RE based	▪ Companies in European, North American, and South American regions derive more than 90% of power from hydro generation
3	**Emission Intensity**	▪ Leading performer: ~16.2 tCO_2e/Mt ▪ Average: ~ 18 $MtCO_2$e/Mt	▪ Leading performer: ~1.6 tCO_2e/Mt ▪ Average: ~ 11.2 tCO_2e/Mt
4	**Net-Zero Targets**	▪ Hindalco and Vedanta: Net-Zero by 2050 ▪ NALCO: Net-Zero by 2060	▪ Rio Tinto, Norsk Hydro, EGA, Alcoa: Net-zero by 2050 ▪ Alba: Net-zero by 2060
5	**Existing EE/ decarbonisation measures**	▪ Equipment modifications and process improvement ▪ Energy management solutions ▪ Recycling and circular economy	▪ RE adoption ▪ Technological advancements ▪ Recycling and circular economy

Source: Sustainability reports of respective companies

Production Capacity and Utilisation

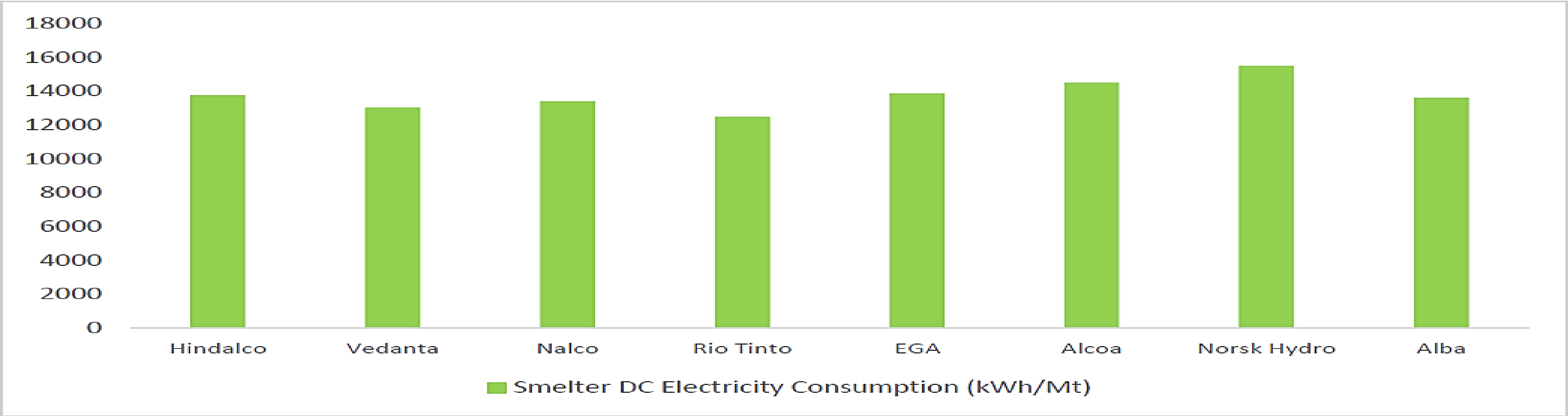
Smelter capacity, aluminium production and capacity utilisation, FY 2021–22



Source: Sustainability reports of respective companies

Fuel sources and SEC

Specific DC electricity consumption of Indian and 5 key global smelters, FY 2022-23



Specific DC electricity consumption of India and global (kWh/Mt)

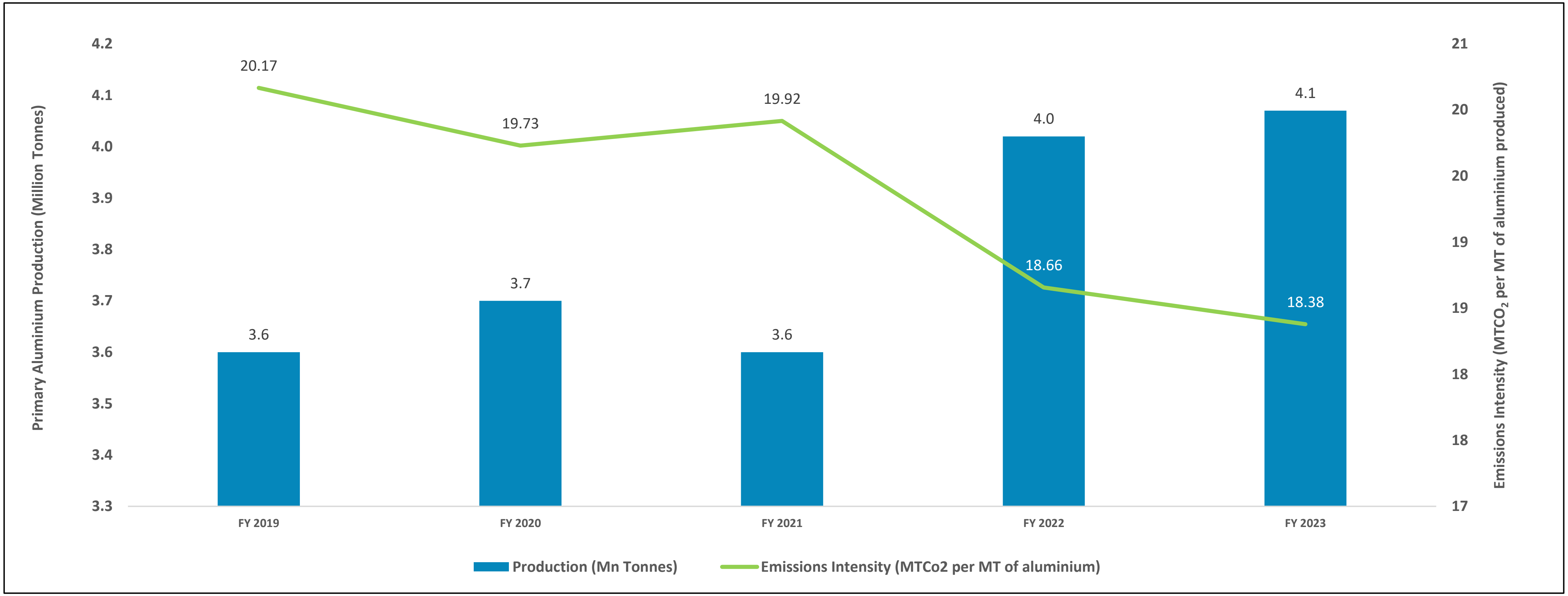
	INDIA	GLOBAL
Lowest	12,973	12,500
Average	13,322	13,745

India's aluminium smelters rely heavily on coal (98% of energy mix), with minimal renewable energy (~0.8%). In contrast, global players like Alba and EGA use natural gas (99%), Norsk Hydro relies on hydropower (95%), and Alcoa and Rio Tinto depend significantly on renewable energy (86% and 72%, respectively).

Indian smelters' Specific Energy Consumption (SEC) averages 52-71 GJ/Mt, aligning with global standards, although comparisons are challenging due to differing technologies..

Emission intensity – Indian Producers

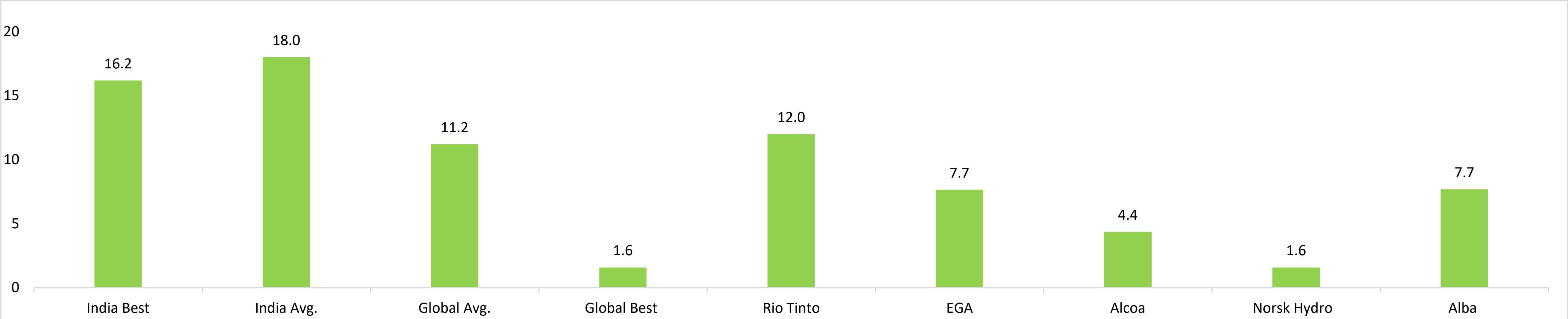
Primary aluminium annual production, and emissions intensity of Indian producers (FY 2019 – 2023)



Source: Analysis based on sustainability reports of primary aluminium producers in India.

Emission intensity

Emission intensity (tCO_2e/t)



Emission intensity of India and global in tCO_2-e/t

	INDIA	GLOBAL
Lowest	**~16.2**	**~1.6**
Average	**~18**	**~11.2**

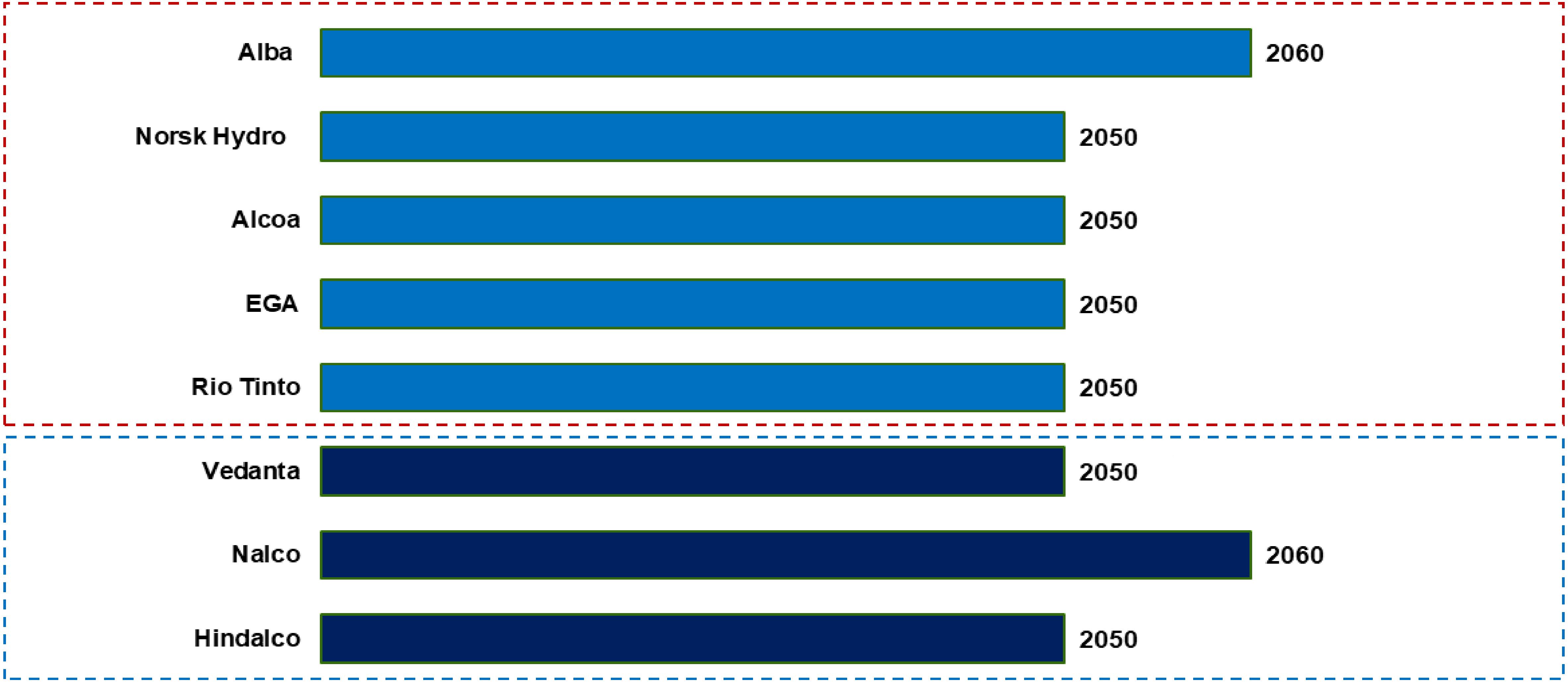
Emission intensity measures CO_2 emissions per tonne of aluminium produced. Norsk Hydro leads globally with the lowest intensity (~1.6 tCO_2e/t).

Indian smelters have the highest global emission intensities, with the best performing at ~16.2 tCO_2e/t, compared to a national average of ~18 tCO_2e/t, but still higher than the global average of ~11.2 tCO_2e/t. Other global smelters, like Alcoa and Rio Tinto, benefit from low-emission power sources.

Note:
The emission data for Indian players combines figures for both alumina and aluminium production (downstream production)).
Emission intensity for Hindalco, Nalco and Vedanta is calculated based on the data available in their respective sustainability reports.

Net-zero targets

Net-zero targets by year of national and international companies in the aluminium ecosystem



Note: *NALCO Net Zero 2060 or earlier.

Leading Decarbonisation Practices

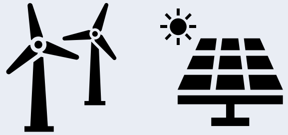
Leading decarbonisation practices

Indian aluminium companies have high emission intensity (~18 tCO_2e/t) compared to the global average (~11.2 tCO_2e/t) due to reliance on coal-based power.

Key Decarbonisation Practices

Low Carbon Energy Sources	Energy Efficiency (EE) & Monitoring	Circular Economy & Waste Management	Technological Advancements
Use alternatives to fossil fuels.	Process improvements, equipment upgrades, and energy management.	Increase aluminium reuse and recycling.	Adopt low-carbon technologies to reduce emissions.

Summary of Leading Decarbonisation Practices (1/4)

Decarbonisation practice/ technology	Readiness level	Specific conditions where options work best	Abatement Potential	Barriers to adoption
Low carbon energy sources				
Adoption of RE 	High (Proven)	Dedicated transmission line from the grid to receive quality and uninterrupted power	• ~70% of total emissions in sector is on account of electricity consumption during smelting • RE adoption aids significant reduction in emissions arising from electricity use	• Availability of round the clock power • Reliability of the grid
Use of Green Hydrogen in Calciner 	High	Favourable for new Calciners in Refineries, however, can also be retrofitted to old calciners	• Rio Tinto has partnered with ARENA to conduct a feasibility study into using clean hydrogen to replace natural gas in the calcination stage at their Yarwun alumina refinery in Gladstone • Rio Tinto has also filed patents for the hydrogen calcination process.	• Availability, transportation and storage infrastructure of green hydrogen • High Capital Cost

Summary of Leading Decarbonisation Practices (2/4)

Decarbonisation practice/ technology	Readiness level	Specific conditions where options work best	Abatement Potential	Barriers to adoption
Energy monitoring and efficiency interventions				
Copper insert and onsert collector bars	Medium to High	Potential energy reduction works for low amperage cells if the thermal balance is maintained.	• Using copper insert has the potential of energy reduction in low amperage cell	• Inappropriate designing can lead to underperformance
Magnetic compensation loop (MCL) for reducing DC consumption	High	Favourable for new Calciners in Refineries, however, can also be retrofitted to old calciners	• Rio Tinto has partnered with ARENA to conduct a feasibility study into using clean hydrogen to replace natural gas in the calcination stage at their Yarwun alumina refinery in Gladstone • Rio Tinto has also filed patents for the hydrogen calcination process	• Availability, transportation and storage infrastructure of green hydrogen • High Capital Cost
Digital Twin	High		• It has the potential to monitor parameters such as current intensity, bath temperature, and pot life, eventually helping in reduced energy consumption and carbon emissions.	• Lack of technical know how

Summary of Leading Decarbonisation Practices (3/4)

Decarbonisation practice/ technology	Readiness level	Specific conditions where options work best	Abatement Potential	Barriers to adoption
Circular economy and waste management				
Bauxite Residue – Holistic use	Medium	Proximity to the industries that can utilise red mud, such as cement industry	It has the potential to be used in cement industry thus contributing towards circular economy.	• High Alkalinity of the Bauxite residue • Higher Na_2O content in Bauxite residue makes it difficult to use in various application
Spent pot lining – Use in cement etc.	High	Proximity to the industries that can utilise SPL, such as cement industries.	It has the potential to be used in cement industry, contributing towards circular economy.	• Spent pot lining contains hazardous materials such as fluorides, cyanides, and polycyclic aromatic hydrocarbons, which pose challenges in its safe handling and disposal • Transportation costs, storage requirements, and regulatory compliance during transit
Dross – Recycling and use	High	Both for Green Field Projects and retrofitting in existing Smelter units	It has potential applications in sectors like auto, construction, electrical etc., thus contributing to circular economy.	• Dross recycling for use in Green Field Projects or retrofitting existing smelters requires high-quality material with consistent composition • Establishing recycling facilities or modifying existing smelters to accommodate dross recycling demands substantial investment in infrastructure and technology.

Summary of Leading Decarbonisation Practices (4/4)

Decarbonisation practice/ technology	Readiness level	Specific conditions where options work best	Abatement Potential	Barriers to adoption
Technological advancements				
Inert anodes	Medium	More suitable for new smelting pots but can be retrofitted to existing smelting pots	Inert Anodes have potential to reduce emissions from smelting. In comparison to full-scope industry average emissions, metal produced with inert anodes has an 85% lower carbon footprint.	▪ Increased energy demand resulting in higher GHG emissions specifically when energy is derived from fossil fuels ▪ Ambiguity in terms of commercialisation
Carbon Capture Utilisation and Storage (CCUS)	Medium	Captive Thermal Power Plants and Smelter Process (Mostly applicable for Thermal Power Plants) or in the processes where concentration of CO_2 emissions is high	Reduction in GHG emissions from the flue gases. Alvance is framing a pilot to launch by 2024 in the hope of capturing up to 70% of emissions from the smelting process.	▪ High initial cost ▪ Absence of Carbon Utilising Industries in nearby vicinity ▪ Lack of Infrastructure for storage ▪ Flue gases in aluminium smelters have around 1% CO2, whereas most carbon capture technologies are designed for higher CO2 levels, typically above 4%. ▪ Pollutants in aluminium smelter flue gases hinder compatibility with existing capture technologies.
Hal Zero Technology	Low to Medium	Smelter Process	Reduction process GHG emission. This technology can result in releasing only oxygen during smelting process	▪ The technology is still in developmental stage
Mechanical Vapour Recompression (MVR) for Alumina Refinery	High	Green Field Projects and retrofitting in existing alumina refinery – applicability depends on configuration.	Early estimates predict that MVR powered by RE could reduce carbon emissions from alumina refineries by ~70%	▪ High capital cost and applicability based on configuration of existing plant ▪ Availability of round the clock renewable power

Success story from UK

Alvance British Aluminium

Some of their noteworthy achievements as of 2022 are:

Headquartered in Lochaber, Scotland

Operates the only smelter unit in the UK

Capacity: 48,000 tonnes per annum

Aim to be carbon neutral by 2030

About 16% of employees were female

Over 20% decrease in PFC and PM Emission intensity since 2021

Around 88% of electricity is sourced from the Lochaber Power & Hydro scheme, pivotal in achieving exceptionally low carbon intensity.

Carbon footprint: **62,422 tCO_2-e**

Energy intensity: **14.2MWh/t aluminium**

Carbon intensity: **1.99 tCO_2-e/t aluminium**

Leader in aluminium recycling

About 86% of all waste produced in 2022 was recycled/ reused.

Aluminium Recycling and Billet Casting Facility construction is planned adjacent to the smelter.

Further, increasing capacity from 48KTPA-100KTPA also reducing carbon footprint.

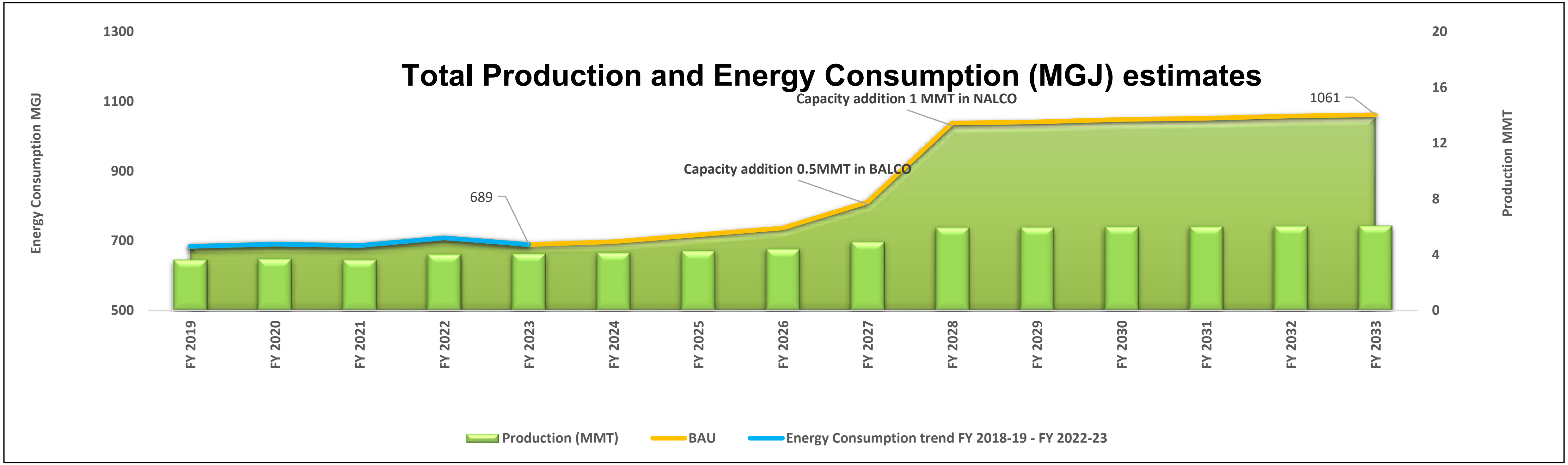
Green energy & molten aluminium from existing smelter will be used in the facility alongside the recycled scrap metal to produce aluminium as depicted below.

Decarbonisation pathways for Indian aluminium sector

Emission forecast for Indian aluminium sector (1/3)

Energy consumption estimates

Production & energy consumption estimate for the sector in medium (5 years) and long term (10 years)



Projected Increase: Energy consumption will rise to ~1,060 MGJ, up 1.5 times from 2023, driven by an increase in production capacity to ~6 MMT.

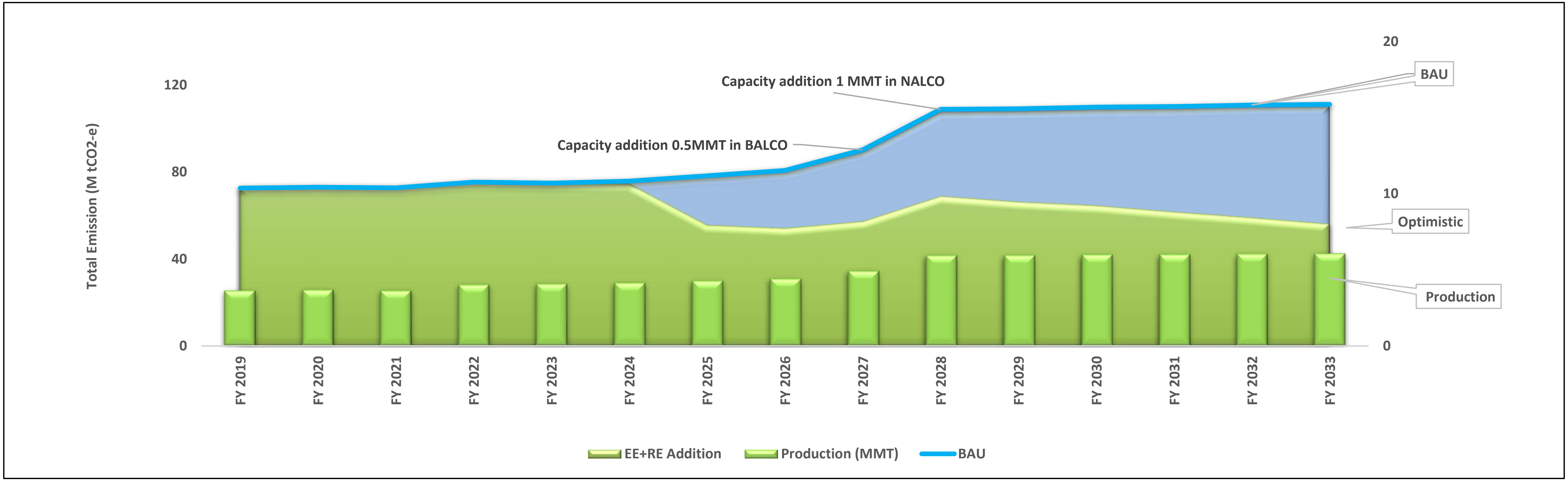
Planned Expansions:
- Vedanta: 0.5 MMT smelter capacity increase by FY 2026-27.
- NALCO: 1 MMT capacity increase by FY 2027-28.

Note:
Energy consumption for BAU is calculated considering the minimum SEC for individual company for the period of 2018-2019 to 2022-2023

Emission forecast for Indian aluminium sector (2/3)

Total Emissions (Scope 1 & 2) estimates

Production & Total emission (MtCO2e) estimate for the sector in medium (5 years) and long term (10 years)



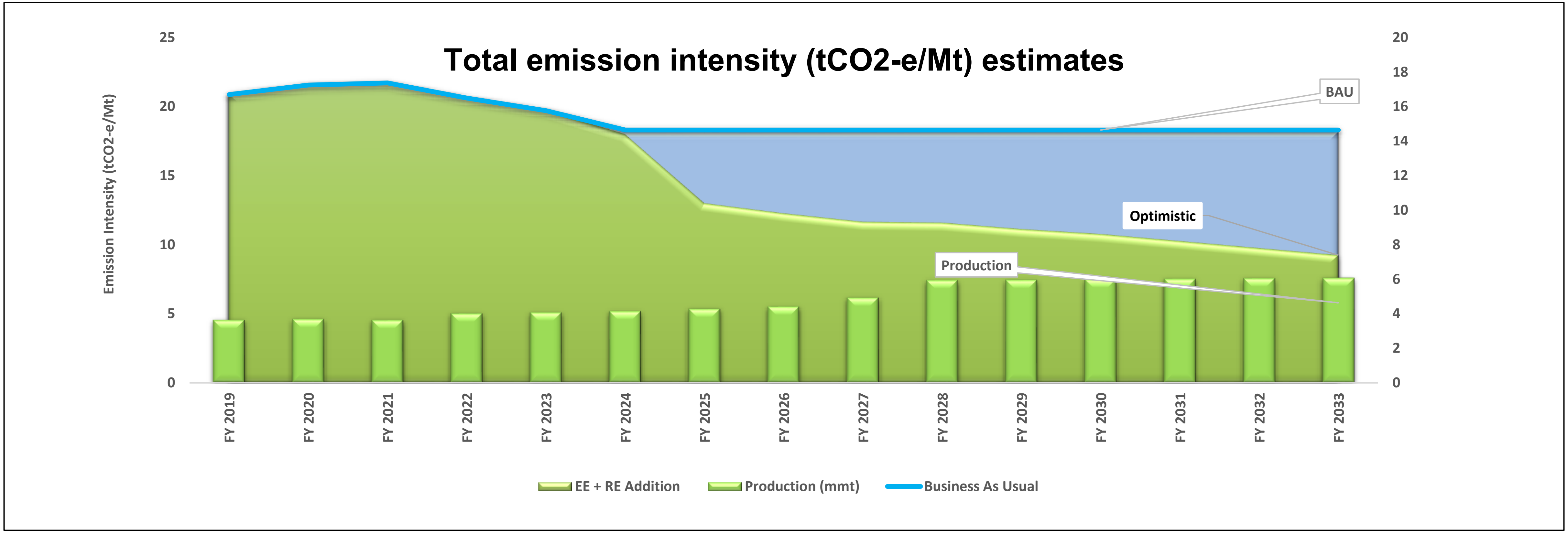
Note:

1. Emission for BAU is calculated considering the minimum emission Intensity for individual company for the period of 2018-2019 to 2022-2023.
2. For coal-based power plants, 1 MWh is considered equivalent to reducing ~0.97 tCO2-e for calculating emission reductions.
3. Additionally, based on stakeholder discussions, the impact of EE measures is estimated to result in a 1% reduction in energy consumption and emissions over a 10-year period.

Emission forecast for Indian aluminium sector (3/3)

Emission Intensity estimates

Production & emission intensity estimate for the sector in medium (5 years) and long term (10 years)



- **Emission Intensity (FY 2022-23)**:~18 tCO2-e/Mt.
- **Future Projections**: With Renewable and EE measures, emission intensity could drop to ~9-10 tCO2-e/Mt by FY 2032-33.
- **Key Actions for Reduction**: Adoption of RE-based electricity and EE improvements.

Conclusion and way forward

Conclusion and way forward

Uplifting Sustainability in Aluminium Ecosystem

Policy Enablement | **Leadership Commitments** | **Collaboration** | **Research & Development**

Key pillars for enabling decarbonisation & energy efficiency in the indian aluminium industry

Policy Enablement

- Incentives to reduce RE cost
- Enhance finance availability for low-carbon technologies
- Create standard certifications
- Update procurement policy
- Focus on circular economy
- Enforce the Environment Protection Act and Vehicle Scrap Policy
- Introduce quality standards and guidelines for imported scrap
- Establishing a domestic carbon market

Leadership Commitments

- Engaging industry players in the processes of EE and decarbonisation target setting
- Developing appropriate capacity building measures.
- Organizing periodic cross-industry workshops
- Introducing specific career progression measures addressing the needs of women.

Collaboration

- Collaborative research like Mission possible partnership (MPP) and platforms such as IDEEKSHA platform.
- Leveraging the 2030 Roadmap for India-UK future relations, joint training programmes could be organised to enhance skills related to circular economy practices.
- Collaboration on the development of certifications and standards for aluminium with lower carbon footprint.

Research & Development

- Indian research institutes to work closely with key stakeholders to implement extended producer responsibility.
- Lead and promote demonstration of advanced low carbon technologies.
- Work closely with relevant agencies for introduction of certifications for aluminium with low carbon footprint and secondary aluminium.
- Encourage R&D through collaboration

Thank you