UK Government

BUREAU OF ENERGY EFFICIENCY
Government of India, Ministry of Power

GOVERNMENT OF INDIA
MINISTRY OF POWER

ASPIRE
Programme

Consultation Workshop

Pathways for Energy Efficiency and Decarbonization in the Indian Aluminium Industry

New and Emerging Technologies for Decarbonizing the Aluminium Sector

Dr Anupam Agnihotri
Director, JNARDDC

28th August 2024
Vedanta, Jharsuguda

Aluminium Statistics

	FY 2023
Global Primary Aluminium Production	**69.45** million tons
Indian Primary Aluminium Production	**4.07** million tons (**6%** share)

Al industry faces the task of reducing its CO_2 emissions to be in line with climate targets

GDP

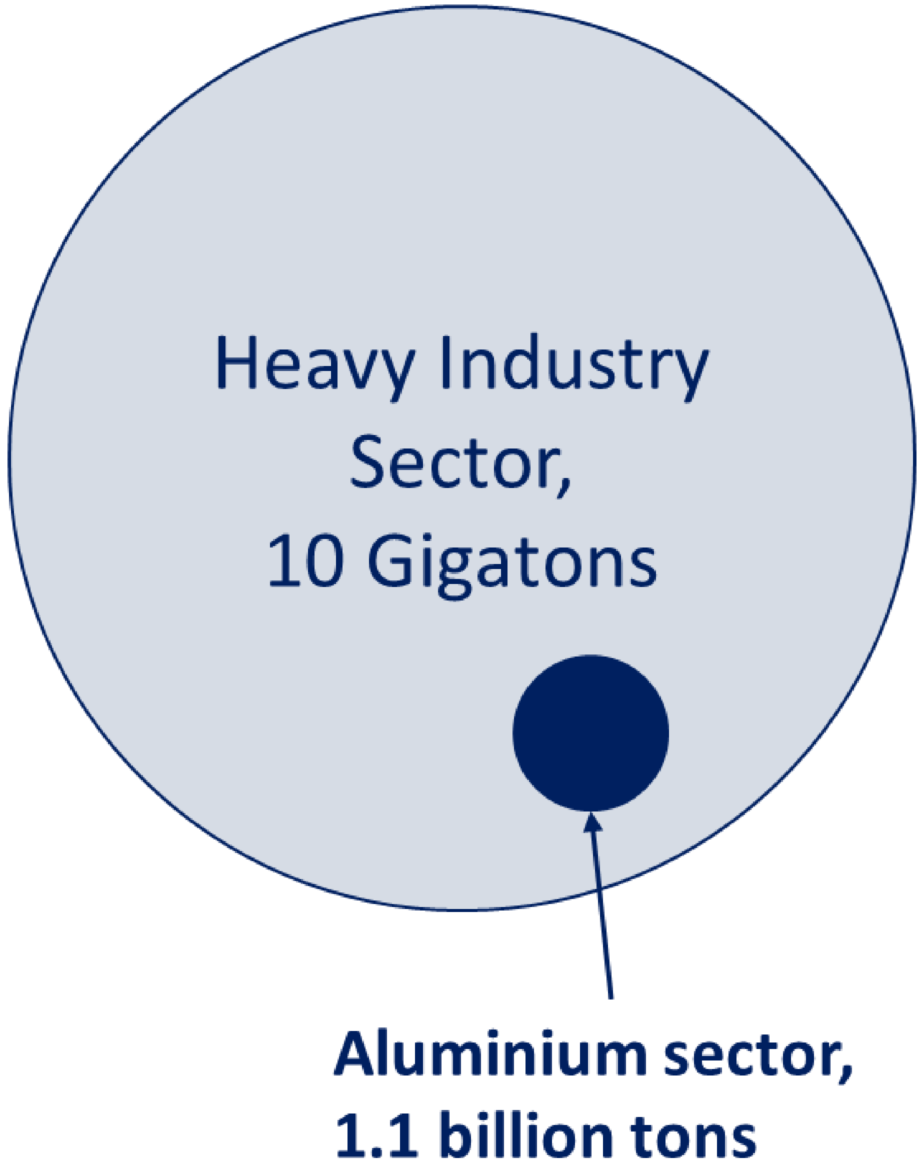
Aluminium contributes approximately 2% to India's overall manufacturing GDP.

GHG

Global average: 16t of CO_2e per ton of Al
India: 19 – 22t of CO_2e per ton of Al

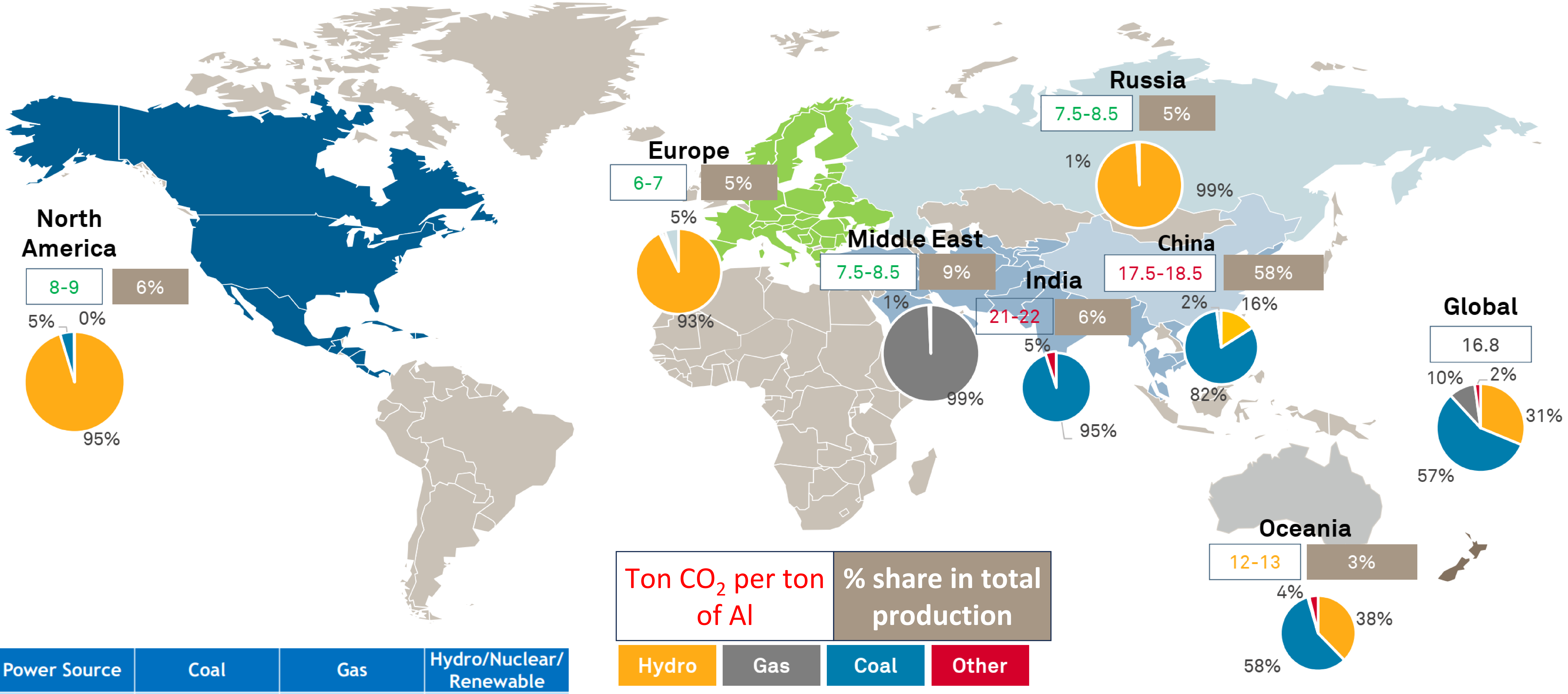
50%

Al sector emissions are predicted to increase by 50% by 2050 under a business-as-usual scenario



Sources: https://www3.weforum.org/docs/WEF_Aluminium_for_Climate_2020.pdf, https://international-aluminium.org/statistics/primary-aluminium-production/
CBAM dent awaits aluminium makers, CRISIL Report, June 2023

Global Aluminium GHG Emission



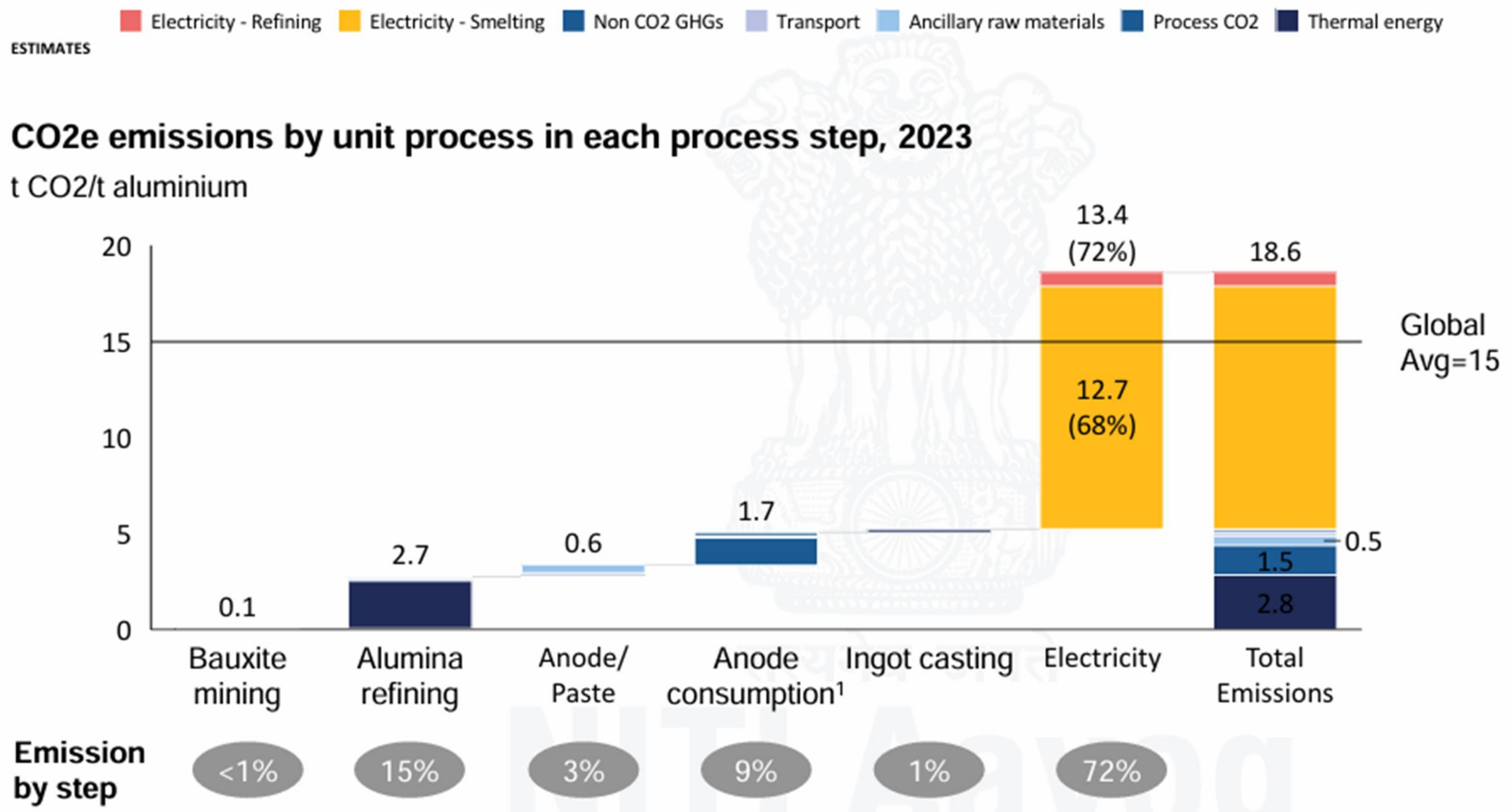
Ton CO_2 per ton of Al	% share in total production

Hydro | Gas | Coal | Other

Power Source	Coal	Gas	Hydro/Nuclear/ Renewable
CO_2 t/t Al	19.17	9.5	2.58

Source: CBAM dent awaits aluminium makers, CRISIL Report, June 2023

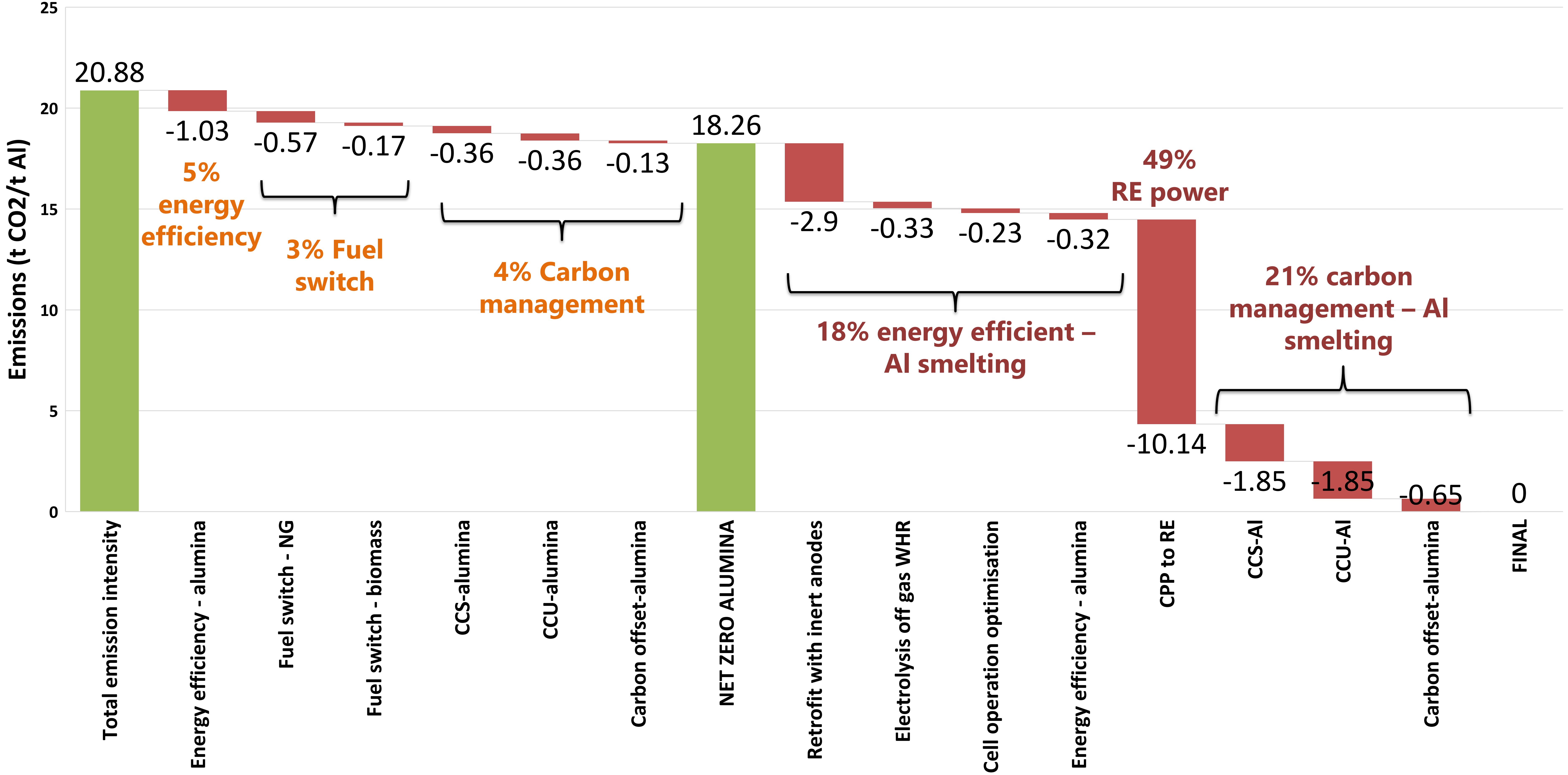
CO2e Emissions by Unit Process



There is potential to cut emission **by ~68%** via **shift from coal-based in electricity used for smelting process alone[2].**

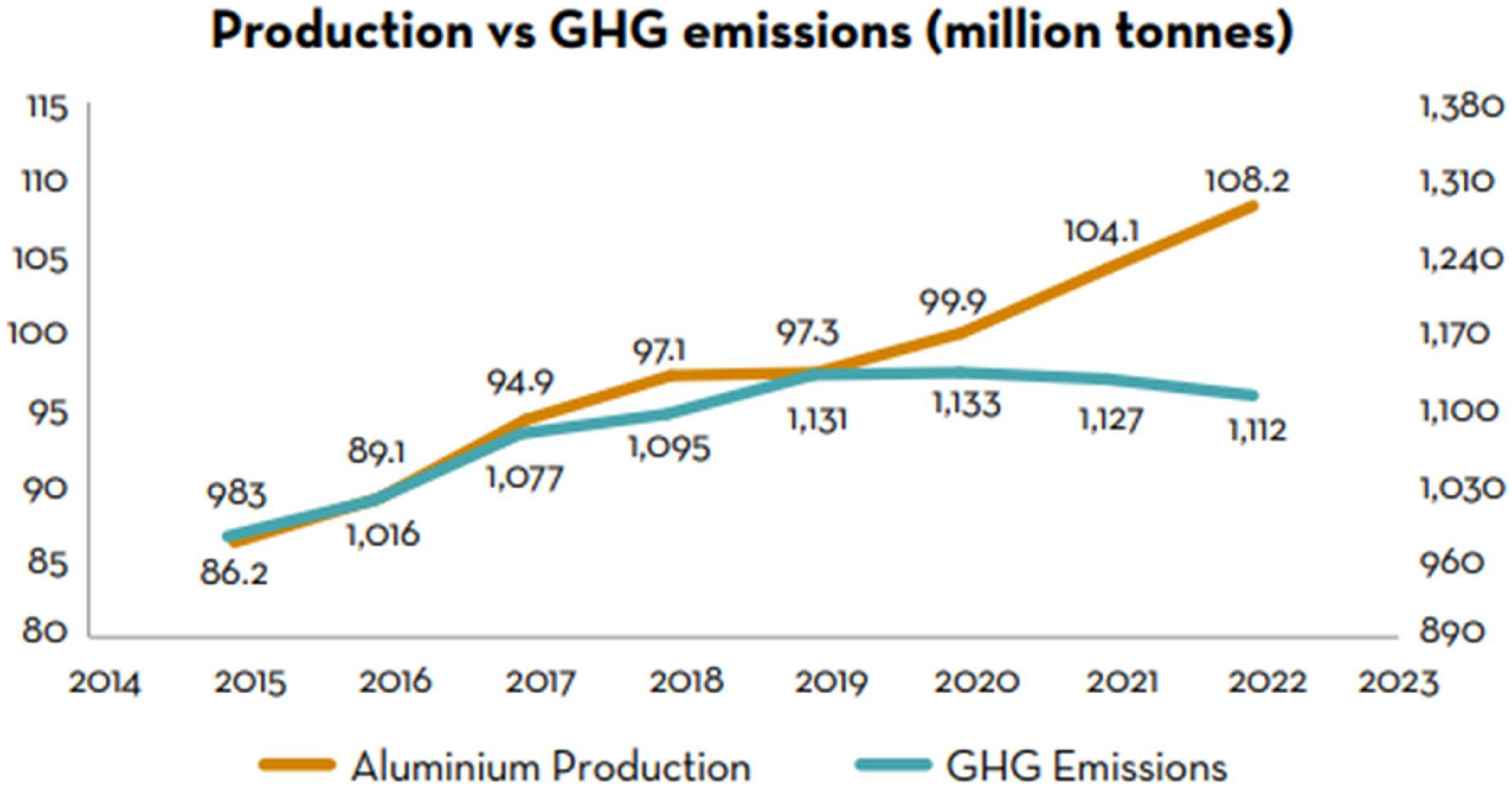
Other major emissions are in thermal energy consumed during alumina refining and process CO2 from primary aluminium smelting (respectively ~15% and ~9%)

Emission Mitigation Pathway for Indian Aluminium Sector



Source: https://www.ceew.in/publications/how-can-india-achieve-low-carbon-sustainable-aluminium-production-and-reduce-carbon-footprint

Production Vs GHG Emissions



GHG Emission Reduction

PATHWAY 1

Electricity Decarbonization

More than 60% of the aluminium sector's 1.1 billion tonnes of CO2e emissions (2018) are from the production of electricity consumed during the smelting process. **Decarbonised power generation** and the **deployment of carbon capture utilisation and storage** (CCUS) offer

PATHWAY 2

Direct Emission Reduction

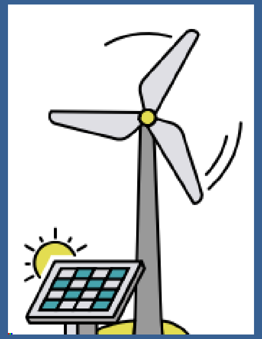
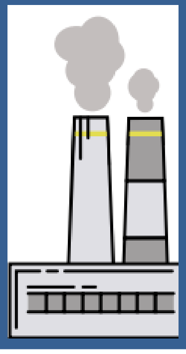
Electrification, fuel switching to green hydrogen and CCUS offer the most credible approach to reduce emissions from fuel combustion, while new technologies, such as **inert anodes**, can lower process emissions.

PATHWAY 3

Recycling and Resource Efficiency

Increasing collection rates, along with other resource efficiency actions, would **reduce the need for primary aluminium by 20%**, which in turn could cut the sector's annual emissions by around **300 million tonnes of CO2e**.

Decarbonisation Pathways

Pathway 1 Electricity Decarbonisation 			Pathway 2 Direct emission reduction 			Pathway 3 Recycling & Resource efficiency 		
Zero carbon electricity	Carbon capture, utilisation & storage (CCUS)	Energy efficiency	Carbon capture, utilisation & storage (CCUS)	Inert anodes	Refinery & cast house electrificatio n/ fuel switching	Near 100% end of life collection and alloy sorting	Elimination of pre-consumer scrap	Elimination of all metal losses during melting and casting
60% reduction	**50% reduction**	**10% reduction**	**35% reduction**	**15% reduction**	**15% reduction**	**15% reduction**	**4% reduction**	**8% reduction**

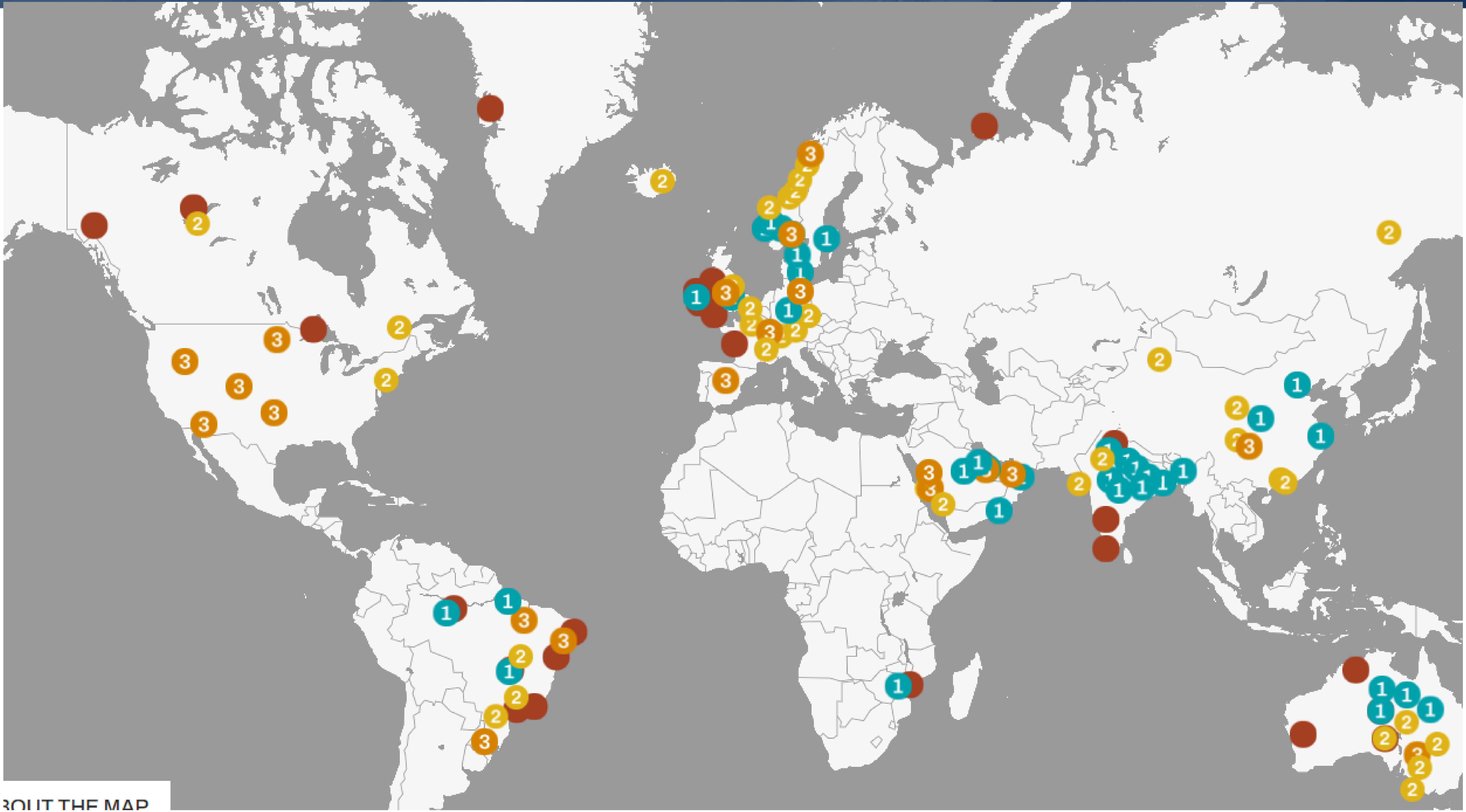
Decarbonized power generation and the deployment of CCUS offer the most significant opportunity for emissions reduction

Electrification, green hydrogen, concentrated solar thermal energy, and carbon capture utilisation and storage (CCUS) offer potential pathways to decarbonization

Near 100% aluminium recycling rates, improved scrap sorting, elimination of pre-consumer scrap and metal losses could reduce the need for primary aluminium by 20% by 2050

Source: CBAM dent awaits aluminium makers, CRISIL Report, June 2023

Aluminium Industry Innovations



Technological Innovations at a Glance

Worldwide Innovations : Pathway 1

1. Virtual battery

Germany

Increasing variable renewable energy in grid systems means aluminium smelters must find a way to deal with intermittent supply and operate flexibly. The addition of heat exchangers and ducting systems means smelters can act as virtual batteries responding to changes in electricity supply and demand as needed, as demonstrated in Germany.

2. Wind

Norway

Long-term contracts for renewable energy are being increasingly adopted to secure wind power supply to smelters. Such agreements enable further investment in wind turbines and growth in overall wind farm capacity.

4. Solar

UAE

The use of solar power for aluminium production has been demonstrated in UAE, where electricity received from the grid is tracked and traced through the International Renewable Energy Certification System from an expanding solar project to the smelter.

3. Hydropower

China

Over 4 million tonnes of smelting capacity will be relocated from coal-fired electricity-dependent regions to hydropower-rich provinces such as Yunnan. The change in power source for smelting could result in over 50 million tonnes of greenhouse gas emissions savings.

Worldwide Innovations: Pathway 2

5. Inert anode cells

North America and Russia

Commercial-scale prototype cells of inert anode technology are being tested in smelters in Canada and Russia. Inert anodes have the potential to eliminate all direct process greenhouse gas emissions from smelting.

6. Fuel switch

Brazil

Fuel switching can provide significant greenhouse gas savings. Switching a refinery from heavy fuel oil to liquefied natural gas could lower emissions by up to 600,000 tonnes at a single site.

7. Hydrogen

Norway and Australia

Hydrogen could be used as a fuel source to produce high-temperature heat for industrial use. In Europe, opportunities to develop and operate hydrogen facilities to replace the natural gas used in cast houses and anode production are being explored. While in Australia, the focus is on hydrogen as an alternative to natural gas in the calcination process at alumina refineries.

8. Mechanical Vapour Recompression

Australia

As part of a trial in Western Australia, recycled steam will be used in the refining process to produce alumina. Through mechanical vapour recompression powered by renewable energy, waste steam that would otherwise be released into the atmosphere is redirected to a compressor that raises the pressure and temperature of the steam ready for reuse.

9. Lightweighting/supply chain

India, Global

A leading aluminium rolling company is using lighter and fuel-efficient transport as part of its efforts to find greener ways to supply to its customers. Its all-aluminium bulker can save up to 15,000 litres of fuel and 25 tonnes of greenhouse gases, and its 10-metre-long trailer, made from high-strength aluminium alloy, is 50 per cent lighter than typical steel trailers.

Worldwide Innovations : Pathway 3

10. Closed-loop recycling

USA, Europe, Japan

Strengthening producer-consumer relationships has seen a rise in closed-loop recycling systems where manufacturing scrap can be collected and returned to the metal producer to be used again in the production process.

11. Scrap sorting

Germany

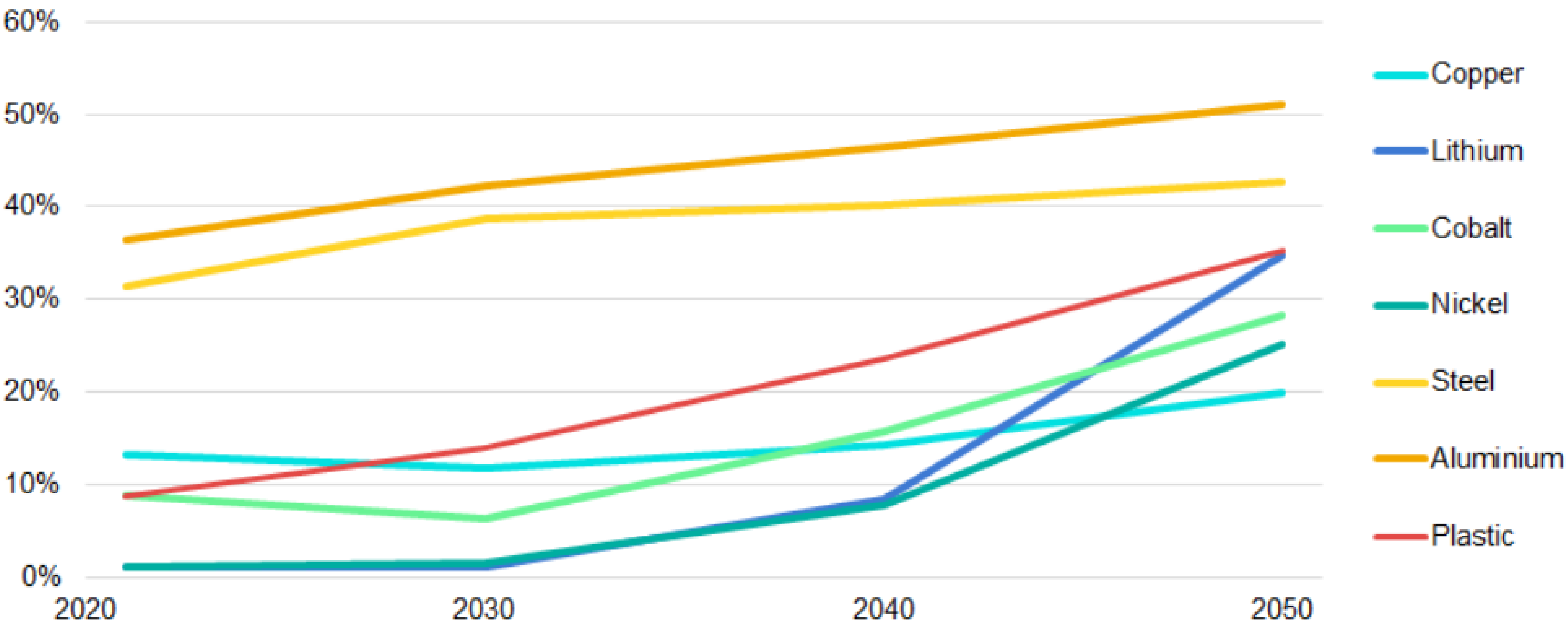
Recycling is more efficient if scrap is sorted by alloy type. Companies have invested in advanced scrap sorting and shredding technologies that use X-ray transmission and sensors to better separate certain alloys.

12. Recycling optimisation

Europe

Aluminium producers of cansheet and beverage cans in Europe are working towards a fully circular economy within 10 years. A new roadmap is aiming for 100% aluminium beverage can recycling by 2030 through improved waste collection systems; better-sorting infrastructure; recovering aluminium from bottom ash treatment; and better consumer engagement.

Share of Secondary Production in the Global Supply in NZE Scenario



Decarbonisation pathways – Direct emissions

Use of hydrogen (TRL 7-9)

- Co-feeding hydrogen alongside natural gas for industrial heating
- **Most affordable option in long term**
- Hydrogen as **reducing agent – operational difficulties** & lack of widespread infrastructure

Direct electrification

- Electrification in **alumina refining** and displacing conventional gas-fired furnaces in casting
- Electrification is integral to the decarbonization

Low temperature digestion (TRL 9)

- Technically achievable and currently implemented in selected alumina refineries
- **Dependent on the quality of the bauxite** utilized

Inert anode (TRL 4-5)

- Potential types of anodes: cermet conducting electrodes and metal anodes. Costs associated are uncertain
- Other electrode technologies include **wetted cathodes & multipolar cells**

CCUS (TRL 7-9)

- Potentially **practical intermediate solution**
- Significant potential for CCUS lies in its application to refineries
- **Highly expensive** for gas streams with **low CO_2**

Waste heat recovery (TRL 7-9)

- Approximately **30–45% is dissipated as waste heat**
- Commercially available technologies: energy modulation, shell heat exchangers & heat pipes etc.

Source: CBAM dent awaits aluminium makers, CRISIL Report, June 2023

Decarbonisation pathways – Direct emissions

Fluidized bed calciners (TRL 9)

- Technically viable and well-established
- **Greater energy efficiency** and the potential for substantial energy and cost reductions
- Industries are already adopting this technology

Electric boilers (TRL 4-5)

- Theoretically simple concept; **capital expenses can be limiting**
- Availability of affordable renewable energy plays a crucial role

Mechanical vapour recompression (TRL 7-8)

- Enables the **reuse of steam** and leads to substantial energy conservation
- Useful in the **refining of alumina**; **digestion**
- Requires **high levels of renewable electricity**

Carbothermic reduction of alumina (TRL 7-8)

- Potential to produce energy savings of 34 % compared to a modern HallHéroult carbon anode technology
- Another potential technology in research stage is **kaolinite reduction**

Lower electrolysis temperature (TRL 7-8)

- lowering the temperature to near the melting point can reduce electricity consumption by 1-1.5 MWh per ton
- Possible with **introduction of additives**; to consider purity of Al, cell voltage, corrosion of lining, etc.

New smelter technologies (TRL 7-9)

- **HAL4e Ultra Cells** in Årdal, Norway
- **Digital twinning** and distributed sensing, steady flow and heat preservation

Global Efforts for Decarbonisation Technologies

Country	Sector	Technologies	Name
Australia	Aluminium	Production/Alumina refining/Electricity in the Bayer process/	Alcoa Renewable Powered Electric Calcination Pilot
Australia	Aluminium	Production/Alumina refining/Electricity in the Bayer process/	Alcoa Mechanical Vapour Recompression for Low Carbon Alumina Refining Project
Australia	Aluminium	Production/Alumina refining/High share of biomass fuel in the Bayer process/	South32 Biomass in Alumina
Australia	Aluminium	Production/Alumina refining/Electricity in the Bayer process/	Yarwun Alumina Refinery
Canada	Aluminium	Production/Primary smelting/Primary smelting with inert anode/	Elysis
Germany	Aluminium	Production/Integration of heat exchangers to vary energy consumption and production levels/	TRIMET EnPot
Ireland	Aluminium	Production/Alumina refining/Electricity in the Bayer process/	AAL SEB
Russia	Aluminium	Production/Primary smelting/Primary smelting with inert anode/	Rusal's Krasnoyarsk (KrAZ) inert anode aluminum smelter

Conclusion

Climate action in the aluminium sector could be accelerated with:

Policy

Frameworks that recognise a range of different solutions will be needed to enable the scaling up of key technologies and to incentivise circularity.

Investment

Ensuring access to capital at local, national and regional levels would enable the transition and support solutions to mitigate climate change.

Transparency and disclosure

Clearly defined metrics and common approaches enable dialogue, track progress and allow for informed decision making.

Public-private partnerships

Combining private technology and innovation with public resources would reduce risk and deliver impactful projects.

Customer-producer partnerships

Foster beneficial relationships across the supply chain and work towards a shared value or vision.

Collaboration

Collaboration within the sector, between sectors and with other actors will help develop and deploy essential, high-capital infrastructure and technology.

Thank You

Anupam Agnihotri, Director

Jawaharlal Nehru Aluminium Research Development & Design Centre, Nagpur

director@jnarddc.gov.in

+91 9404084435

www.jnarddc.gov.in

सत्यमेव जयते
Ministry of Mines
Government of India

25 Years of Commendable Service to the Aluminium Industry
JNARDDC
Silver Jubilee Year
1989-2014