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TECHNICAL LECTURE SERIES

LOW CARBON ALUMINIUM: SUSTAINABLE METAL OF THE FUTURE

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Scheme of Presentation

- Context
- Aluminium Industry Emissions
- Pathways to Low-carbon aluminium
- Low carbon Aluminium Global Initiatives
- Recycling Aluminium
- Sustainability of Green Aluminium
- Way Forward

Context

- Climate Change Challenge & environment degradation
- Root Cause is Global warming due to emission of GHG
- Paris Agreement ,2015: global warming below 2^0c by end of century above preindustrial level (1850-1900)
- COP 26:
- Global Net ZERO emission by 2050
- India committed to achieve by 2070
- - 40% renewal energy by 2030 (45O GW capacity)
- Avg. rise in temperature limited to 1.5 deg.

Net – Zero Emission

- Net-Zero emission is reducing GHG emissions across all sectors of economy.
- Net-Zero level : Global warming will stabilize
- IPCC report : Global warming to exceed 1.5 degree this century without deep reductions in GHG emissions
- Impacts: Extreme weather events, sea level rise, flash floods, cyclones etc.

Aluminium Industry Emissions

- Aluminium industry contributes 2% of global
- GHG emissions.
- GHG emissions from primary smelting reported in CO_2 eq.
- Primary aluminium consumes 4% of World's electricity
- More than 60% emissions in aluminium production are indirect emissions attributed to electricity consumption.

Emissions of Aluminium Industry

Best way of presenting GHG emission of production process is to use Life Cycle Methodology i.e. Mine to end product

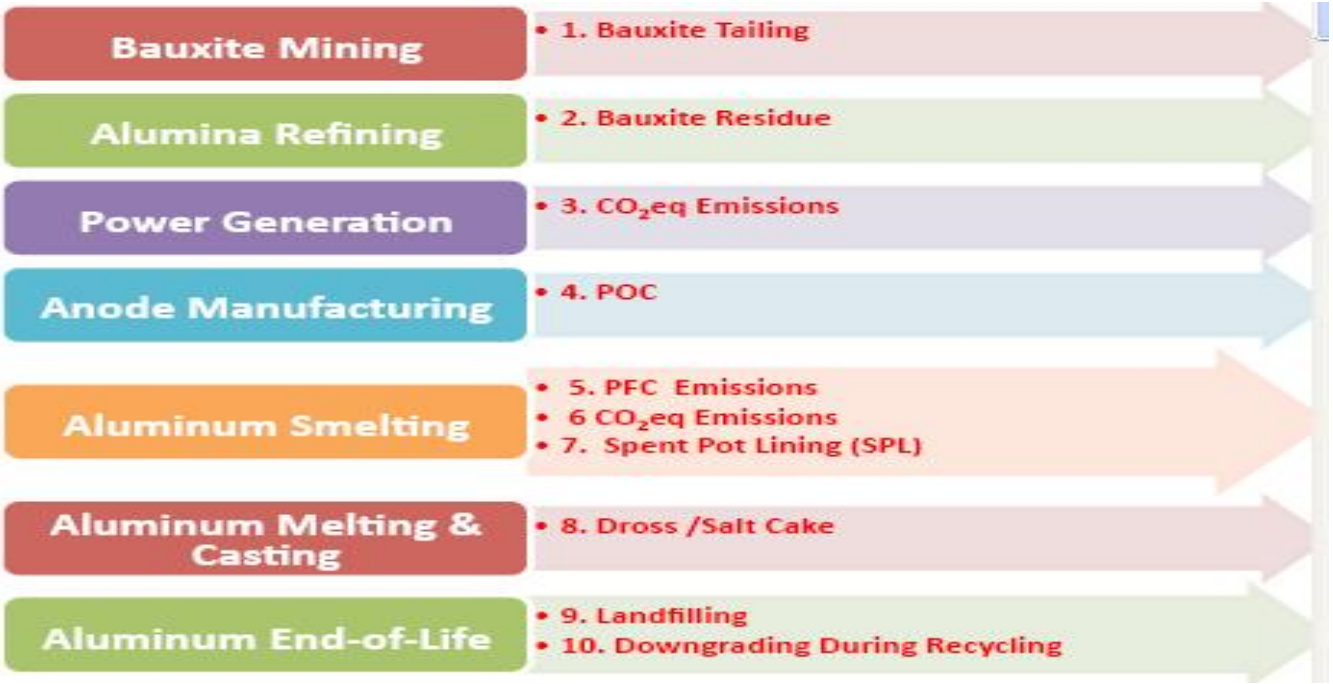


Fig.1: Aluminium production processes/ by product emissions
Source: Light Metal Age, Feb.2021

Emissions in primary aluminium production

- Direct emissions (Process) : CO_2, CO,HF, PFC (CF_4, C_2F_6), SO_2
- Indirect emissions: Coal-fired power generation
- 80% Carbon eq emissions across aluminium value chain is smelting operation
- Reducing carbon footprint is major goal
- Aluminium production is energy & Carbon intensive
- World Sp. Energy Consumption : 12000-14000kwh/t_{Al}
- India: 13200 - 1400 Kwh/t_{Al}

Global primary aluminium industry emissions

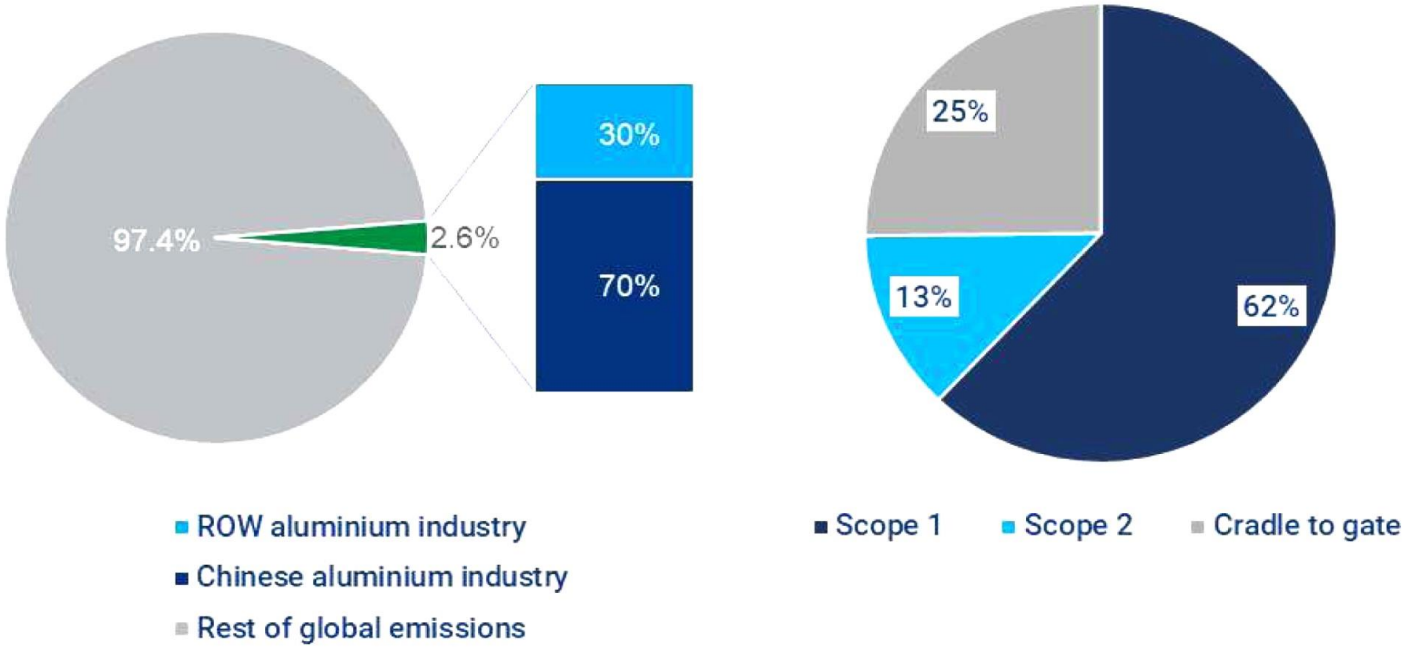


Fig. 2: Global primary aluminium industry emissions

Table 1: Emissions in Aluminium Production (Kg CO2 eq/t Al)

Sources Of Emissions	Mining	Alumina Refinery	Anode Production	Smelting	Casting	Total $KgCO_2$ eq/t
Process	-	-	388	1,626	-	2,104
Electricity		58	63	5,801*	77	5,999
Fossil Fuel	16	789	135	133	155	1,228
Transport	32	61	8	4	136	241
Auxillary	-	84	255	-	-	239
PFCs	2	-	-	2,226	-	2,226
Total	48	992	849	9,790	368	12,047

Source: Light Metal Age,Feb'21

Power Mix for Al vs Total Power Mix

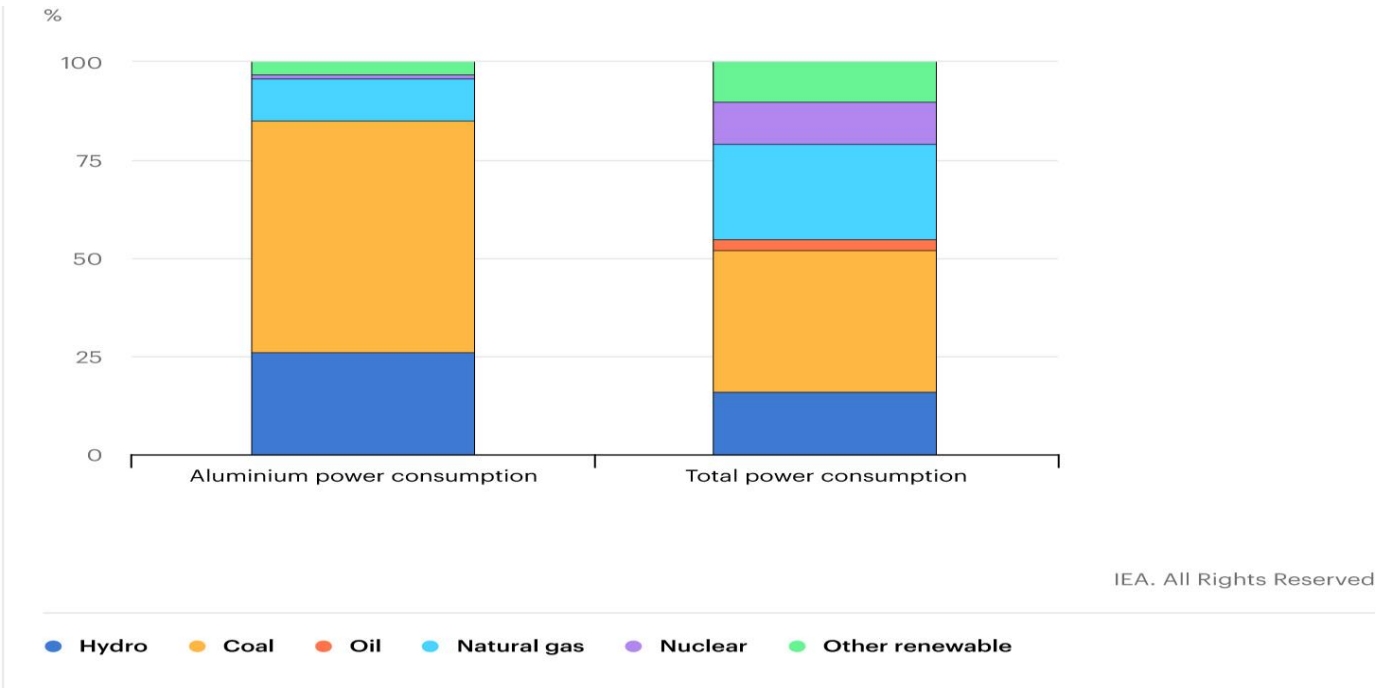


Fig. 3 : Global aluminium industry power mix compared with the total power mix, 2020

Global Power Mix & primary Aluminium Production

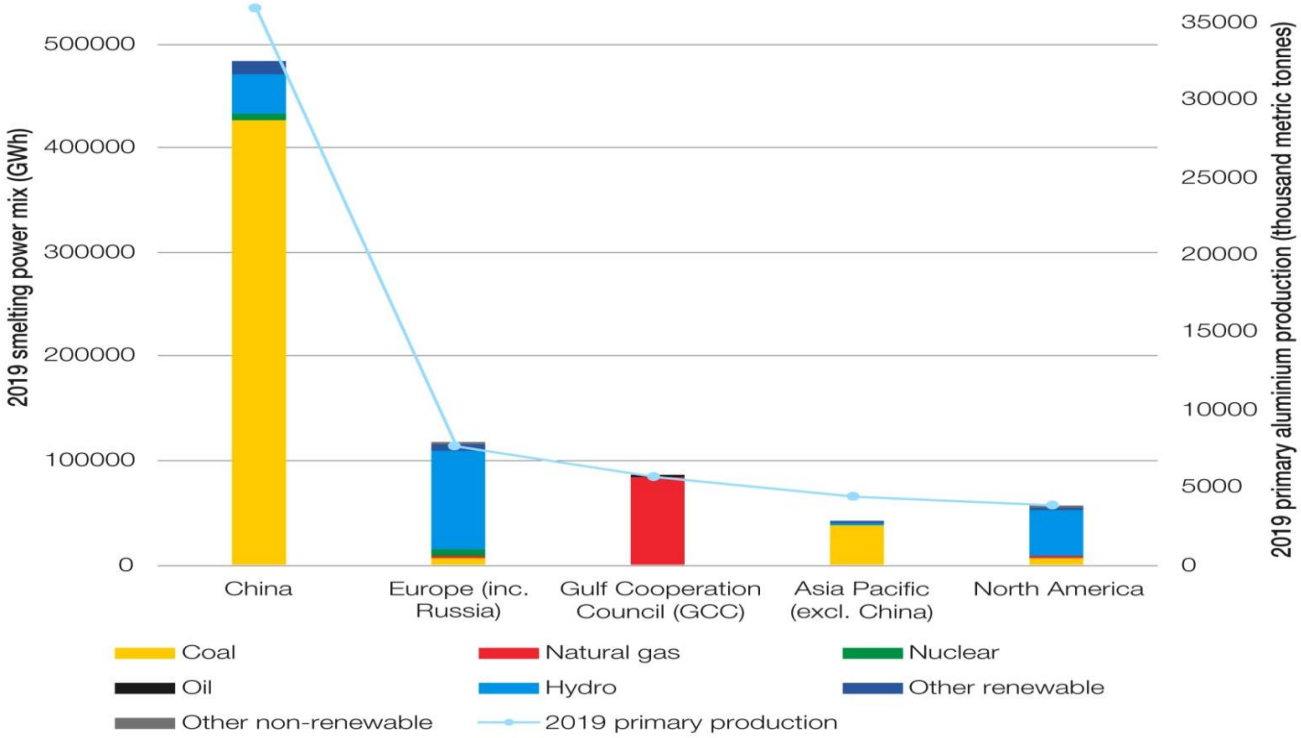


Fig. 4: Global Power Mix & primary Aluminium Production (2019)
Source: International Aluminium Institute (IAI)

Challenges to Decarbonization

- Fossil fuel releases CO_2 & CH_4
- Thermal energy is fuel for heating in anode production & casting while steam is used in alumina production.
- Countries like China & India are heavily dependent on thermal power while Gulf countries are dependent on natural gas.
- Tendency to operate high amperage cells (400-600KA) for higher productivity. Carbon footprint increases by requirement of more coal-fired power.

Challenges to Decarbonization

- Emission levels :

  Thermal : 16 -18tonnes CO_2eq/t_{Al}

  Hydropower: 2-4 tonnes CO_2/t_{Al}

  Gas powered : 5-8 tonnes CO_2 eq/ t_{Al}

- Total emission of 3.5 t CO2eq is possible for cells with best available technology in all parts of aluminium production steps including renewable production.

Pathways to Decarbonisation

- Improve energy efficiency of operations
- Benchmark Sp. energy consumption (APxe) is 12.9 KWH/kg Al against 12-14 KWH/kg Al world level.
- Reduce net carbon consumption by improving anode quality, best practices & anode covering . This corresponds to 1.4 kg CO_2eq /t_{Al}
- Increase share of low emission energy sources like renewable energy
- Europe: Renewal mix of Hydro, Nuclear& Wind
- India: Renewal mix of thermal, solar, Wind , Nuclear
- LNG may be explored for substituting HFO in cast House & carbon plant

Energy Consumption vs Cell Voltage

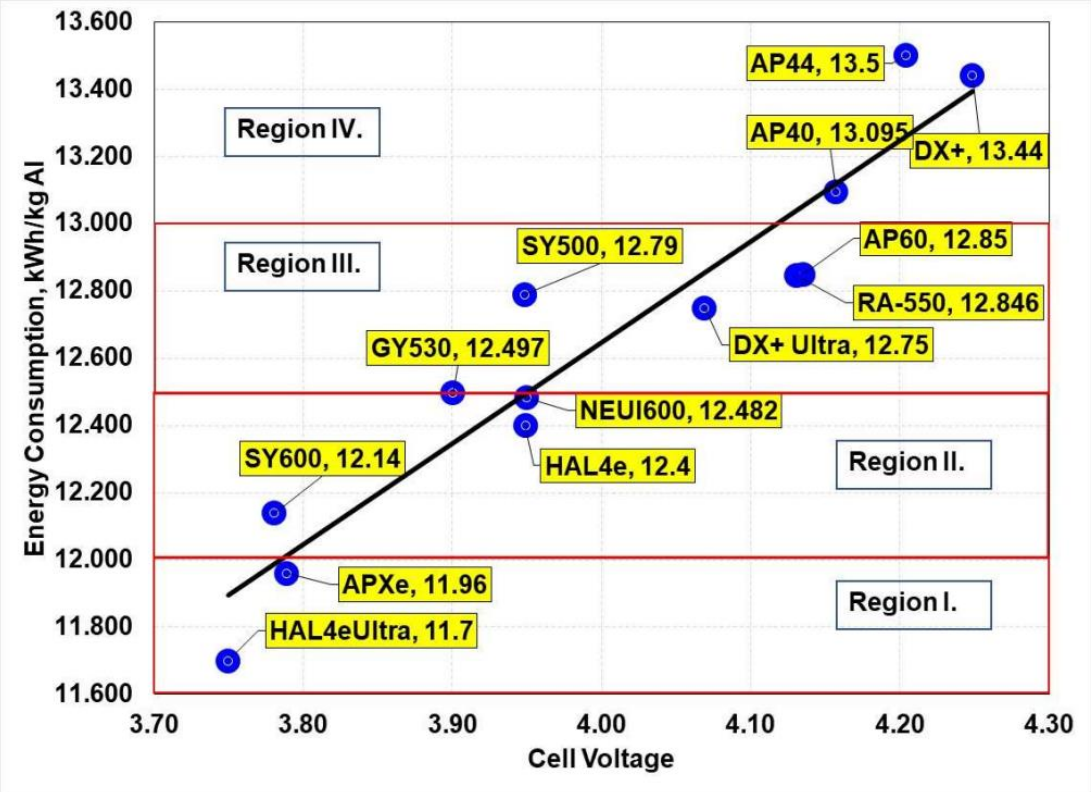


Fig 5: Comparison of the energy consumption and cell voltage for advanced aluminum cell technologies

Emissions from byproducts

RED MUD : Leakage
SPL: Fluoride, Cyanide
50% Land filled
DROSS: 5% of production
Generate salt slag

- HINDALCO uses Redmud in cement industry
- ALBA Recycles SPL, commercially through zero waste approach
- Dross : As per media report, Vedanta Aluminium reported commercially recovesr (Runya Refining) Aluminium using patented technology of M/s. Taha International.

Inert Anode : Futuristic technology

- Alternative to consumable anode in smelting
- Emits oxygen in place of CO_2
- Best option to reduce direct emissions associated with carbon anode consumption – around 1 5 % with the use of renewal energy.
- Energy requirement is higher but can be retrofitted in existing cells along with inert cathode, side lining materials & cell design
- Technology is not yet commercialized though successful in pilot scale in several locations
- Costs of inert anodes are not known

Development Of Inert Anode

- ELYSIS, is a Joint venture between Alcoa, Rio Tinto to produce inert anodes to produce low carbon aluminium.
- Two demonstration pots at ALMA Smelter (450KA) is in process. Hope to commercialize by 2024
- RUSAL successful in Pilot batch low carbon production (0.01 tonnes CO_2e /t_{Al})
- Arctus Aluminium R&D along with the Innovation Centre , Iceland has produced high purity (99.9%) aluminium in test cells.

Carbon Capture & Storage (CCUS)

- CCUS is the capture of direct CO_2 emissions from industrial processes that are then transported, used as an input to create another product or stored permanently underground.
- It is viable in sectors where off gas concentration is > 4% and so promising solution that have access to cheap fossil fuels, have no recourse to affordable renewals& have access to affordable carbon transportation& storage facilities.

CCUS Technology

- Highly expensive for gas streams with low CO_2 concentration(around 1Vol%) like aluminium smelter.
- Demands large amount of energy
- Potentially attractive for captive power plants with CO2 concentration approx. 14%
- China around 44 pilot plants in process
- Alvance (Scotland)is framing a pilot to launch by 2024 in order to capture emissions from smelting process

Green Hydrogen : Future Fuel

- Shift from fossil fuels to renewable energy through green hydrogen
- Uses renewable energy powered electrolysers to produce hydrogen from water.
- Green hydrogen use is limited at a commercial scale but electrolysers themselves are a established technology
- Indian oil Corporation, Panipat Oil Refinery pilot scale trial successful& cost effective.

Recycling : Oppourtunities

- Aluminium supports more circular & sustainable economy.
- World aluminium recycling efficiency 76% while in India it is 25%.
- Aluminium is infinitely recyclable with energy input required for recycling is about 5% that for primary aluminium.
- Recycling reduces GHG emissions by 95% compared to primary aluminium.1% increase in aluminium recycling rate can reduce overall product footprint by 80 kg of CO_2eq /ton of aluminium
- Non-ferrous metal scrap recycling regulation 2020(Ministry of Mines, Govt, Of India)

Challenges: Indian scenario

- Scrap recycling confined to unorganized sector
- High level of contaminants including toxic compounds, steel, plastics, & other debris in purchased scrap
- Challenge in shredding, sorting and further refinement of metal to achieve acceptable purity levels particularly in some premium alloys
- Standardization of melting practices

Low Carbon Aluminium

- Low carbon aluminium (green aluminium),primary aluminium produced using 100% renewable energy.
- Consumers are demanding sustainable, low carbon aluminium which protect environment, conserve natural resources & support circular economy.
- Carbon footprint 4 t CO_2eq/t_{Al} (Direct& Indirect emissions)
- The Aluminium Stewardship initiative (ASI) sustainable Standard limit: 8 t CO_2eq/t_{Al} (Scope1 & Scope 2) are certified as Low Carbon Aluminium.
- LME Trading Platform for end users with premium

Product Footprint Boundary

- IAI definition: cradle- to – up to & including ingot casting
- Level 1: Emissions from aluminium electrolysis, aluminium ingot casting, anode/paste from generating electricity & heat consumed in these processes
- Level 2:In addition to Level 1 emissions, direct emissions from bauxite mining & alumina refining, plus associated emissions from electricity & heat consumption and fuel combustion at these two production unit processes.
- Level 3: A complete cradle to gate carbon footprint of aluminium ingot. This incudes GHG emission from bauxite mining, alumina production, carbon anode production, aluminium electrolysis & ingot casting processes, raw materials transport ,electricity & heat generation and aluminium dross processing.

Table 2: Low Carbon Aluminium Products

SL. No.	Company	Brand	Carbon Footprint Threshold CO_2eq/t_{Al}	Remark
1.	HYDRO	HYDRO CIRCAL 75R & HYDRO REDUXA 4.0 (HYDRO POWER)	4.0 CO_2 eq/t_{Al}	➢CIRCAL Minm 75% recycled, post consumer scrap & certified carbon footprint <2.3tCO_2 eq /t_{Al} ➢ CIRCAL 100R in recycling plant (Cleravaux, Luxemburg) using 100% postconsumer scrap to meet needed composition for the alloy. ➢0.5-1kg CO_2 eq/kg Aluminium through the value chain

Table 2: Low Carbon Aluminium Products

SL. No.	Company	Brand	Carbon Footprint Threshold CO_2eq/t_{Al}	Remark
2	RIO-TINTO	RenewAl (Hydropower)	≤ 4tCO2 eq/t Al	➢ START , a natural " nutrition label" using blockchain technology. Label provide key information about the site where aluminium was responsibly produced covering several criteria. ➢ To help customers meet demand from consumers for transparency

Table 2: Low Carbon Aluminium Products

SL. No.	Company	Brand	Carbon Footprint Threshold CO_2eq/t_{Al}	Remark
3	ALCOA	Ecolum is brand using hydropower	≥ 4 ton CO2 eq/t Al cradle to gate	➢ The product comes with certification of , confirming sustainability metrics of the product line. ➢3rd party verification of Environmental Product Declaration

Table 2: Low Carbon Aluminium Products

SL. No.	Company	Brand	Carbon Footprint Threshold CO_2eq/t_{Al}	Remark
4	UC RUSAL	ALLOW	$4tCO_2$ eq/t_{Al} including smelter direct & indirect emissions	➢Certified by British Standards Institution ➢ Pilot study using inert anode electrolytic cell is expected to reduce significantly carbon footprint

Table 2: Low Carbon Aluminium Products

SL. No.	Company	Brand	Carbon Footprint Threshold CO_2eq/t_{Al}	Remark
5	Vedanta Aluminium	“RESTORA” green aluminium brand using renewal energy in partnership with Runaya refining (startup) for processing dross at vedanta plant, Jharsuguda	< 4 ton CO2 eq /t Al	➢“Restora Ultra” brand , near Zero carbon footprint.

Table 2: Low Carbon Aluminium Products

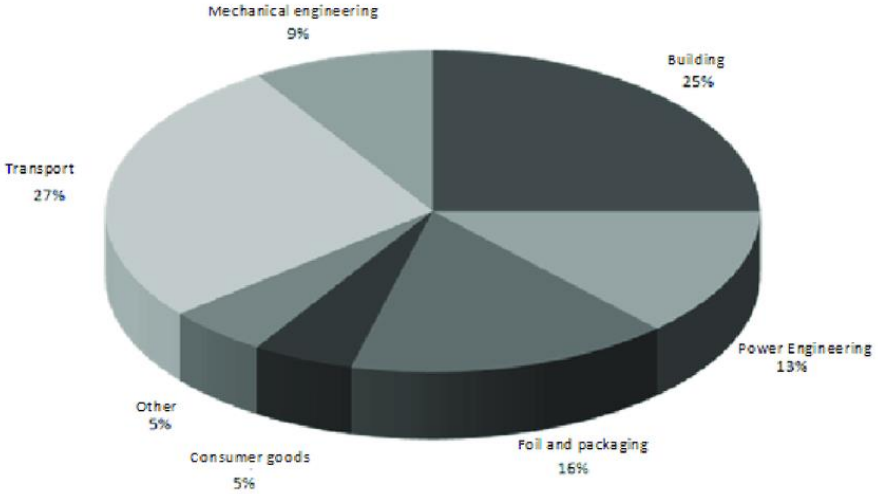
SL. No.	Company	Brand	Carbon Footprint Threshold CO_2eq/t_{Al}	Remark
6	Emeritus Global Aluminium (EGA)	"Celestial" brand , first commercialised low carbon aluminium(2021) using solar power in association with Dubai Electricity & Water Authority(DEWA)	Not Available	➢EGA has very recently announced to build a 1,50,00 tonnes /yr aluminium recycling plant& intends to market recyled aluminium under brand name "EternAL".

Table 2: Low Carbon Aluminium Products

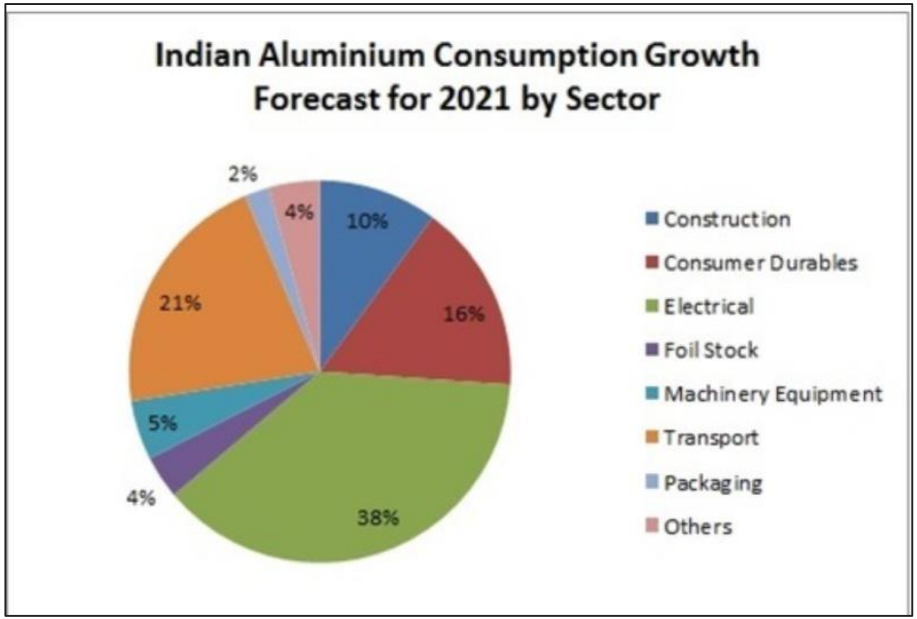
SL. No.	Company	Brand	Carbon Footprint Threshold CO_2eq/t_{Al}	Remark
7	HARBOR ALUMINIUM	USMWT1020-Green Aluminum Spot Premium	≤4.5 t CO_2eq/t_{Al}	➢The product is specified as spot pysical 99.7% high grade Aluminium (IAI scope 1&2)

Aluminium Consumption Pattern

World Consumption



Consumption in India



Comparative Analysis of Aluminum vs Steel

- Aluminum emits 11.7 tons CO_2 eq/ t Al compared to 2.5 tons CO_2 / t Al in steel
- Al production consumes 8 times more energy per kg than steel production
- Lifecycle cost analysis reveals 20 tons CO2 emission saved in its life cycle as compared to steel
- Aluminum is 100% recyclable with more than 95% recovery which is comparatively lower in steel
- High strength to weight ratio makes Aluminum sustainable for applications in aerospace(high strength aluminium alloys) and in light combat aircraft (LCA)
- Light weight of Aluminum ($1/3^{rd}$ of steel) makes it ideal for automotives for fuel saving
- Melting point of Aluminum being low compared to steel results in high re-melting cost

Low Carbon Aluminium: Sustainable Metal Of the Future

- Aluminium is sustainable metal of future due to lightweight, high strength to weight ratio, excellent corrosion resistance, excellent electrical& thermal conductivity as well as 100% recyclability at end of life with minimal energy without loss of quality.
- Building & Construction sector responsible for over 3rd of global energy usage.
- Aluminium strength makes it the first choice for structural frame works while it's reflectivity makes building more energy efficient.

Green Building

- When used as base metal in construction ,aluminium structures weigh 35-65% less than traditional metals like steel, while providing equivalent strength.
- World avg. consumption in building construction is 24% as compared to 11% in India mainly due to high cost.
- Aluminium doors& windows gaining increasing prominence in architecture for benefits of structures, sustainability& aesthetics.

- In extreme weather conditions like India, it is preferred material for fenestration since it is nonreactive, noncorrosive& recyclable.
- Intricate shape in interiors of building by using extruded doors& windows allow for maximum air flow
- The design of façade minimised windload of “Sanghi Tower”, China reduced the amount of material needed for construction due to low weight of façade.

Green Building

- Aluminium Composite Panel (ACP) in green building contribute to sustainability due to inherent properties of anticorrosion of aluminium
- Al with small amount of zinc (sink aluminium alloys) is replacing galvanised roofing sheet keeping corrosion resistance in tact along with weight reduction
- Substantial savings in energy usage achieved using aluminium facades which acts as solar reflectors & themal buffer

Automotive Sector

- Aluminium is replacing steel due to light weight($1/3^{rd}$) reducing carbon foot print & improved fuel saving. The use of 1 kg of aluminium could save a net 20kg of CO_2 over the life of vehicle.
- consumption in Europe in almost all parts of passenger carlike engine, chasis & suspension, brakes, interiors while in India it is limited.
- From a share of 8% in 2018 CRU predicts Electric Vehicals to account for 30% by 2030

Solar Applications

- Aluminium use in solar cells account for 85% of most PV components in form of frames & mounting structures .
- Aluminum is quick to cool down which is an advantage in in solar PV , since increase in temperature of PV cells reduces efficiency of electricity generation.
- Huge demand for PV panel in India around 10 GW/yr by 2030 (now PV capacity 2.5 GW/year)
- Componets of solar cells, modules are imported from china

Railway Transport

- Extensive use of aluminium alloys for vehicle manufacture in US, Europe& Japan for their metros, passenger trains & express trains.
- The lower lifecycle costs (reduced weight, less wear & tear. etc)for aluminium coaches offsets higher initial investment when compared to carbon steel coaches.
- India's first aluminium body metro train went into operation in Titagarh, West Bengal in March 2022. Light weight enables to carry more payload& ensures high speed performance .

ADDITIVE MANUFACTURING : GAME CHANGER

- Innovative technology(3D Printing Technology) developed in advanced countries for high value , low volume complex products.
- Small size components in Aerospace & automotive sectors
- Energy saving : 5-15% ,low cost, less cycle time
- Higher yield as no sub-processes ;melting, casting
- Wide range of sustainable aluminium alloys can be made

WAY-FORWARD

- Though Low Carbon Aluminium (Green Aluminium is costly(high premium) from Life Cycle Cost point of view is attractive due to lower emissions & energy saving potential.
- Aluminium is sustainable metal of future due to high strength to weight ratio, long life& excellent corrossion resistance compared to steel
- Additive manufacturing(3D Printing) process is customized &sustainable for use in aerospace(aluminium alloys) & automotive components due to less cycle time, energy savings & cost effectiveness owing to higher yield compared to conventional processes.

Recommendation for Indian Smelters to go Green

- Procure mix of solar, hydro, wind green energy online through Indian energy exchange (IEX) platform or alternate green energy exchange/ sources at competitive price on long term agreement basis.
- Adopt best practices to improve energy efficiency
- Reduce Net Carbon consumption to a level of 390-410kg/t Al
- Smelters can go for Aluminium Stewardship Initiative (ASI Certification) for Aluminium products which is international standard for sustainable and responsible production
- Smelters can go for ISO 14067:2018 (E) standard for quantifying carbon footprints of products

Recommendation for Indian Smelters to go Green

- Aluminium producers should plan investing for renewable energy generation on their own
- They should go for advanced technologies in future expansions like AP- Xe (500kA,) RA-550 of UC Rusal NEUI (600kA), China, DX Ultra (EGA) for best energy efficiency in the range 12000 – 12500 kwh/ t Al
- Natural gas can be used as substitute for HFO/ LDO in cast house and carbon plant
- Green hydrogen as a fuel maybe explored for auxiliary purposes
- Digitalisation of smelter will optimise process efficiency and supply chain efficiency
- Focus on development of Aluminum alloys for specific applications mainly in automotives, building and construction, aerospace sectors

Thank you

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