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Aluminium an Important metal for India's Sustainable and Circular Economy

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ABSTRACT

Metals are ubiquitous in everyone'slife and increasing consumption of metal has put pressure on natural resources which are now depleting at a faster pace. These resources can be used efficiently and preserved for future use by adopting circular economic model for sustainable development. Metals are best fit to circular economic model and aluminiumis one of the most important metals and a key contributor to the circular economic model because of its property and recyclability. In this context, the paper aims to analyse how aluminium metal can contribute to the circular and sustainable economic model. The contribution is analysed based on parameters like properties of aluminium, energy consumption,recycling ability, environmental and societal impacts. This paper also identifies the challenges and its solutions associated with the Indian aluminium industry and focuses on solutions which can enhance aluminium consumption in India. The methodology adopted in this paper is secondary research and data is collected from various sources like journal papers, published articles, government and institutional publications.

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1. Introduction

Natural resources are being consumed heavily because of the linear economic model which prefers the take-make-waste-dispose model of production and consumption, leading to depletion of natural resources, generate waste, and increases landfill pollution. However, in the circular economic model, the value of the product, raw material and resources are used as long as possible and after the useful life, waste is again transformed into the real resource.The circular economy is an opportunity to move towards a more efficient economy that utilizes secondary raw material, support technologies so that metal uses are maximized during the entire life cycle. European commission defined circular economy as "*Circular economy system keep the added value in products for as long as possible and eliminate waste. They keep resources within the economy when a product has reached the end of his life, so that they can beproductive and used again and again and hence create further value*" [European commission, 2014]

Fig. 1is the graphical representation of Linear and circular economic model. The linear economic model in the metal sector is not sustainable in future and associated with economic and socio-environmental cost. Therefore, metals need to embrace the circular economy so that waste can be brought back into the production process. According to Ellen MacArthur Foundation, the circular economic model is based on three main principles [Ellen Macarthur Foundation, 2019];

- Design out pollution and waste
- Keep the product and material in use
- Regenerate natural system

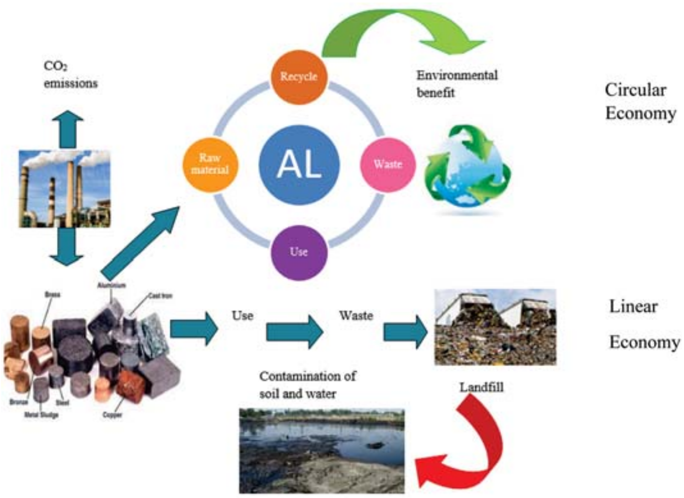

Fig. 1 Circular Economy Vs Linear Economy [Source: author]

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The linear economic model makes the perception of a constant supply of natural resources to business resulted in the practice of take-make-waste-dispose model. The current practices of linear economy are associated with many ecological disadvantages because goods are produced at the cost of productivity of our ecosystem. Therefore, the metal sector needs to practice circular economy so that maximum metal can be recycled after useful life. Many metals are being recycled nowadays and few at higher recycling rate. For Instance, globally, 67% for steel, more than 60% for aluminium and 35% for copper (45-50% in the EU) [Visser, 2015] are being recycled today. Fortunately, aluminium is the most circular metal which is 100% recyclable, and its inherent quality is preserved even after recycling. Although global recycling rate of aluminium is low at 60%, but in few countries recycling rate have been achieved to 90% for construction and automotive sector[European Aluminium, n.d] and expected to gain further momentum with its increaseddemand in sectors like manufacturing, automobile and packaging.

2. Impact of Linear economic model on environment and society

Rapid Industrialization and economic development have impacted the environment to such an extent that people are paying the high cost of such commercial activity and growth through loss in biodiversity, increase in landfills, pollution, inclement weather condition, and global warming. Linear economic model pushes the creation of landfill as the materials after use are not back into the production cycle, instead go to landfill, which is generally an inexpensive, simple and the most economical way of managing solid waste in developing countries [Boateng et al., 2019]. In developing country like India, the landfill problem is exacerbated due to the mismanagement of solid waste and lack of Govt. policy. In 2016, 43 million tonnes of solid waste were collected, 11.9 milliontonnes treated, and 31 million tonnes were disposed to landfill site [Javadekar, 2016]. Urban India generates nearly 62 million tonnes of solid waste annually, which is likely to increase 165 million tonnes by 2030 and 450 million tonnes by 2045[Samaddar et al., 2018]. Landfill waste contains toxic heavy metals, when seepage to human body through food and water, can cause chronic degenerative diseases [INSA, 2011] having symptoms being mental disorders, pain in muscle and joints, gastrointestinal disorders, vision problems, chronic fatigue, and susceptibility to fungal infections. In addition to heavy toxic metals, when light weight metal like aluminium when reaches the food chain, it interfaces with the metabolic process in mammals and birds [Rosseland et al.,1990]. WHO considered aluminium as neurotoxic with an adverse effect on neurological development and brain function [WHO, 1997]. Another detrimental effect is seen when aluminium gets mixed with other pollutant of landfill which changes the solubility and structure of aluminium. Chemical structure and solubility of aluminium is influenced by environmental factor, power of hydrogen (pH).Under acidic condition, aluminium is soluble and toxic to microorganism, which inhibits their growth [Purwantiet.al.,2019]. In alkaline environment when pH>8 aluminium reacts [Calder, 2019] as;

$$Al+(OH)^{-}_{(AQ)}+3H_2O_L= [Al(OH)_4]^{-1}_{(AQ)}+ 1.5\ H_2(gas)$$

The above is the most common reaction takes place in landfill, caused by presence of water and $(OH)^-$ and produces flammable hydrogen gases. Therefore, aluminium present in landfill is capable of reacting violently with water and generates toxic gases, vapour and fumes, poses a danger to human health and the environment. The above aluminium related harmful effects are alleviated when aluminium waste is recycled, and disposal to landfill is avoided. Recycling of aluminium have several benefits like slowing resource depletion, reduction in mining and pollution, saving electricity, reduction in emission of harmful gases and lower the cost of aluminium products. Thus, recycling is paradigm shift from produce-consume-dispose led linear economic model to reduce-reuse-recycle led circular economic model.

3. Aluminium an important metal in Circular economy

The aluminium's circular economy begins with internal recycling closed loop where aluminium is not actually consumed during the lifetime, but only used. Therefore, with the recycling of aluminium scrap, waste is again returned to the production loop, as shown in Fig. 2. Recycling of aluminium saves the bauxite resource, which indirectly saves resources that are consumed during the mining process and producing primary aluminium. Primary aluminium production is an energy intensive process compared to other metals. As shown in Table1, one ton of aluminium consumes 47000 MJ of energy, when it is obtained through secondary route (scrap) it consumes 2400 MJ of energy, which is only 5% of the energy required for production aluminium through primary route. [BIR, 2008].

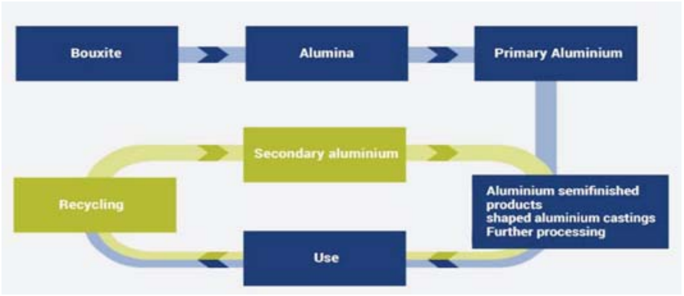

Fig. 2 Circular economy of aluminium metal [Source: GDA, n.d.]

Table 1 Energy requirement (in MJ) in 1 Ton of metal production through primary and secondary route [Source: BIR,2008]

Material	Primary Energy (MJ)	Secondary Energy (MJ)	Saving (MJ)/ Ton	% age of secondary energy to primary energy
Aluminium	47000	2400	44600	5%
Copper	16900	6300	10600	37%
Ferrous	14000	11700	2300	84%
Lead	10000	130	9870	1%
Nickel	20640	1860	18780	9%
Tin	18200	200	18000	1%
Zinc	24000	18000	6000	75%

Fig.3, represents the percentage of energy required in metal production when recycled compared to primary production [BIR, 2008]. Though Lead and Tin consumes 1% of energy compared to original metal when recycled but they are not suitable in wider application compared to aluminium. Aluminium is highly usable in packaging industry because it provides many advantages such as environmentally friendly, smooth logistics, and temper proof quality and recycling ability without losing its intrinsic property.

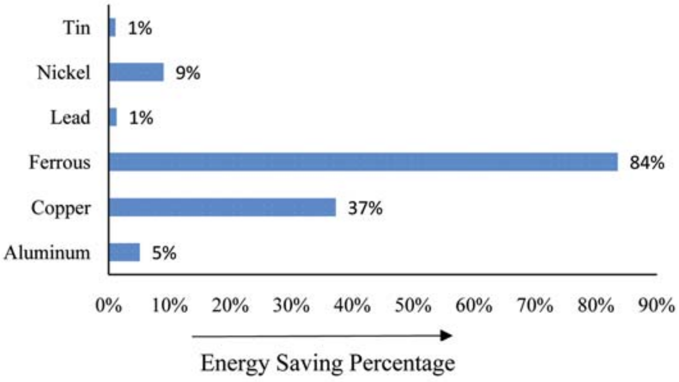

Fig.3 Percentage energy saving through secondary route in different metal category [Source: BIR,2008]

Globally, major utilisation of aluminium is in beverages can, profoundly used in European and American countries. If we look at the global benchmark, then 40-70 cans per capita are consumed in European countries, while India consumption is only, 1-3 can per capita [James, 2019]. Once the can is used it can be brought back to supermarket shelf within 60 days by recycling as shown in Fig. 4 [Hulamin, 2019]. Recycling is the most vital property of aluminium, and energy saved by one can is enough to provide energy for few hours to TV, LED and a desktop as shown in Fig. 5[The Aluminium Association,2011]

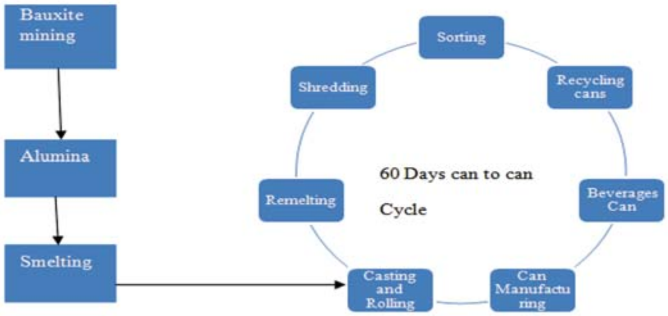

Fig. 4 Can to Can cycle [Source: Hulamin, 2019]

Table 2 CO_2 emission in aluminium productionthrough primary and secondary [Source: BIR 2008]

Primary and secondary aluminium production	Energy (TJ)/one lakh Ton of production	CO_2 emission(kt)/ onelakh ton of production
Energy requirement for primary production	4700	383
Energy requirement for secondary production	240	29

4.2 Aluminium uses in various sectors

Aluminium is an essential metal in engineering applications due to many beneficial properties and few significant properties of aluminium are discussed in the subsequent section.

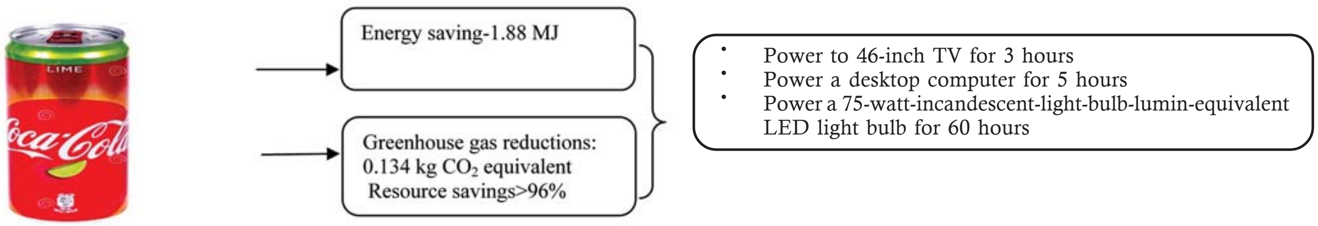

Fig. 5 Benefits of recycling a beverage can [Source: The Aluminium Association 2011]

4. Aluminium contribution in sustainability: Key Indicators of sustainability

4.1 Reducton of CO_2 emission in secondary aluminium production compared to primary aluminium

Primary aluminium is produced from the electrolysis processof alumina, as shown in Fig. 6. Alumina is obtained from bauxite known as aluminium oxide (Al_2O_3) which contains silicon, titanium, iron and other compounds. Primary aluminium is obtained from alumina through smelting, which is energy intensive process and releases harmful, greenhouse gases [Husband, 2011] such as CO_2, CF_4, C_2F_6 into the atmosphere which are potential to global warming. When recycling takes place, emission is minimized as smelting process is avoided for getting aluminium and aluminium is generated from scarp.

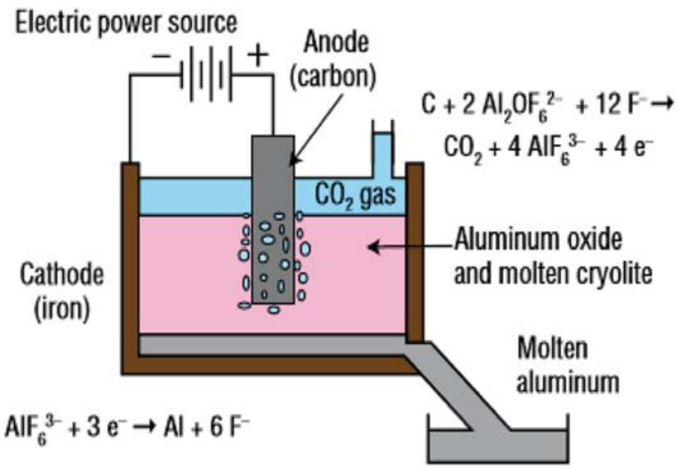

Fig. 6 Electrolysis process of aluminium production and GHG emission [Source: Husband, 2011]

Table 2 represents CO_2 emission in the production of primary and secondary aluminium. One lakh ton production of primary aluminium generates approximately 383 kt of CO_2, when aluminium is obtained through secondary route (from aluminium scrap) it reduces 1321% of CO_2 emission by emitting approximately 29 kt of CO_2 [BIR,2008].Thus, secondary aluminium production is environmentally beneficial as it minimizes CO_2 emission as well as reduces aluminium traces that go to landfill.

1. Low Density:

Aluminium has density of 2.7 g/cm^3, while steel, copper and brass have density of 7.83g/cm^3, 8.93g/cm^3 and 8.53g/cm^3 [Davis, 1999] respectively and because of low density it is useful in applications where weight is main concern such as aircraft and automobiles.

2. Strength:

Commercially available aluminium has tensile strength of about 90 MPa [Davis, 1999], when aluminium is mixed with other element silicon, manganese, magnesium, copper and zinc, its strength increases.

3. Corrosion resistance:

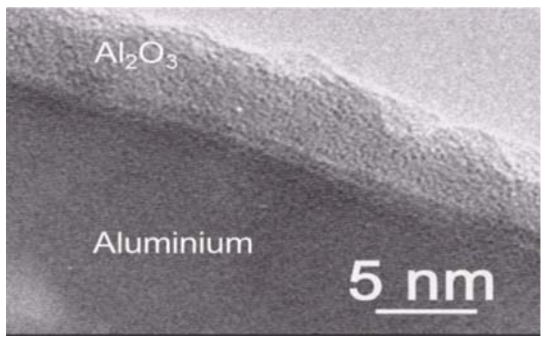

Fig. 7 Oxide film on aluminium [Source: Johnsen R et al., 2004,]

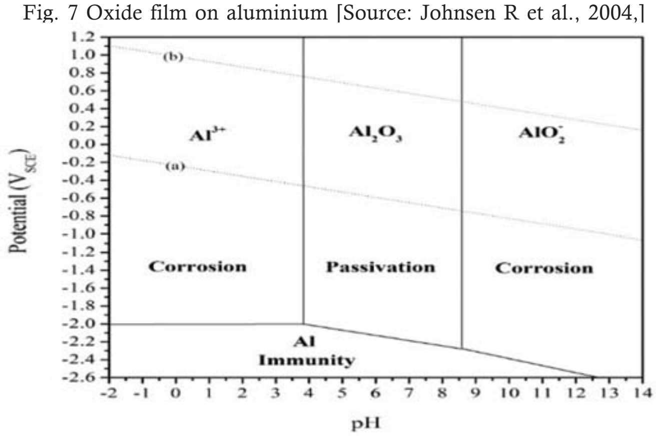

Fig. 8 E-pH diagram for pure Al at 25ÚC in aqueous solution-Pourbaix 1974 [Source:Sukiman, 2012

Corrosion is deterioration of metal and metallic alloy by chemical interaction with their environment. When aluminium surface is exposed to atmosphere a thin oxide layer (Fig. 7) is formed which protects metal from further oxidation and this self-protecting characteristic of aluminium is high resistance to corrosion [Johnsen et al., n.d.].Resistance to corrosion is an important factor that makes aluminium an ideal choice for construction of boats, vessels, patrol boats and workboats because of operation in marine environment.The average power of hydrogen (pH) of sea water is 8.2 but the range is found between 7.5 to 8.5 [UF, n.d] and aluminium is normally passive in the pH range of 4 to 9 due to presence of Al_2O_3 as shown in Fig. 8. In extreme condition aluminium shows corrosive effect due to formation of Al^{3+} and AlO_2^-[Sukiman, 2012].

Table 3 Aluminium alloys, properties and application

Alloy Group	Main alloying element	Properties	Application
1XXX	Unalloyed, Aluminium >99%	Excellent corrosion resistance, excellent workability high thermal and electrical conductivity	Tube, foil, aerospace and electrical conductor, transmission and power grid lines. Common alloy in this series are 1350 for electrical application and 1100 for food packaging
2XXX	Copper	High strength and toughness	Sheet, plate, aerospace, forging,
3XXX	Manganese	Moderate strength and good workability	Beverages can sheet material, heat exchanger and cooking utensils
4XXX	Silicon	Silicon combination, lower the melting point of aluminium without producing brittleness	Extrusion material requires work hardening
5XXX	Magnesium	Moderate to high strength, good weldability and resistance to corrosion in marine environment	Sheet, plate, rod, welding wire, automotive, marine
6XXX	Magnesium and silicon	Versatile alloy, heat treatable, weldability and excellent corrosion resistance	Sheet, plate, extrusion, forging, material requiring heat treatment
7XXX	Zinc	Zn is primary alloying agent but when added with Magnesium, results in high treatable and strength	Aerospace, Plate, sheet, foil
8XXX	Other element	Iron and Nickel are used to increase strength, Aluminium lithium alloy have high stiffness and strength	Aerospace, electrical distribution
9XXX			Reserved for future use

Aluminium and its alloy are best suited for marine industry compared to other metals because of aluminium's resilient to environmental condition like cold, wind, water, moisture and salt from seashore but affect the other metals like steel and copper. Aluminium alloy group from 1XXX to 8XXX are currently in use for various application according to their property and application, as shown in Table 3. Most commonly used aluminium alloy in marine application are; 5052, 5059, 5083, 5086, 6061, 6063 and the most common alloy used in corrosive environment are non-heat treatable, 5000 and heat-treatable, 6000. 6000 series alloys are stronger but less corrosive than 5000 series [Mishra, 2017].Corrosion effect have high economic cost. Worldwide corrosion cost on economy is estimated between •1.3 and •1.4 trillion, amounting to approximately 3.5% of developed nation GDP annually [Loto,2020].

4.3 High thermal and electrical conductivity:

Thermal conductivity is another crucial property of aluminium when the heat is transferred from one place to other, which makes it useful in utensils and heat exchanger applications. Each metric ton of aluminium contains approximately 22,963 x 10^23 aluminium atoms [The Aluminium Association, 2011] grouped with an attractive metallic bond of electrons and positive aluminium nucleus. Free mobility of electrons provides high electrical conductivity and make it useful in electrical application.

4.3.1 Aluminium uses in packaging Industry

The Indian packaging industry represents 4% [WEDC, 2017] of the global packaging industry. The market size of Indian packaging industry was valued at USD 50.5 billion in 2019 and expected to reach USD 204.81 billion by 2025[Mordor Intelligence, n.d.]on account of growth of food, pharmaceutical and beverage industry.Aluminium uses are growing in beverages industry because of its property of saving energy and space.Space and energy both are saved when aluminium can is used instead to plastic and glass. Additionally, aluminium also contains the highest recycling content compared to other material as represented in Fig. 9 [The Aluminium Association, 2019].

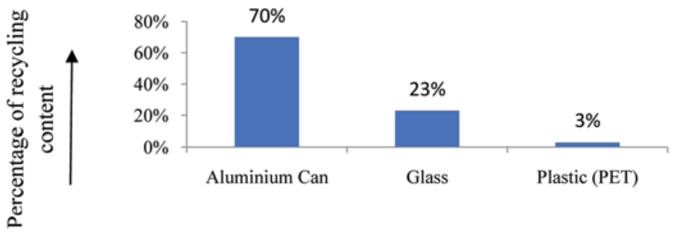

Fig. 9 Average recycling content of beverages containers [source: The Aluminium Association,2019]

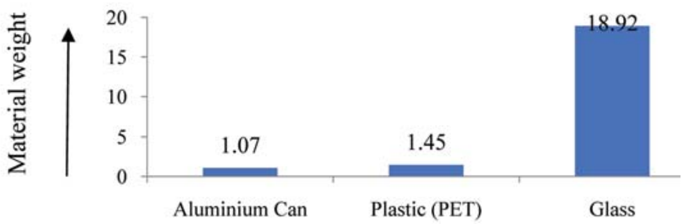

Fig. 10 Material weight per ounce of beverage package (grams) [Source: The Aluminium Association, 2017

It also consumes less martial per oz of beverages content [The Aluminium Association, 2017] compared to other competing material in similar use as shown in Fig. 10.

A research was conducted by ICF consulting to compare electrical energy demand for 12 oz of various packaging alternatives like 12-oz aluminium can, 12 oz glass bottle, 16.9-20 oz plastic bottle. Energy requirement for these packaging alternatives is represented in Fig. 11[ICF, 2016] and percentage energy consumption of aluminium can relative to other alternative material is presented in Table 4. It is found that 12 oz aluminium can consume 67% of energy compared to 12oz glass bottle when cooled in home refrigeration. Similarly comparing it with 16.9 oz plastic and 20 oz plastic bottle, it is found that energy consumed is 67% and 77% respectively, when cooled in home refrigeration. Lower enery consumption of aluminium can is also observed in commercial places (supermarket and grocery stores) comapred other packaging material.

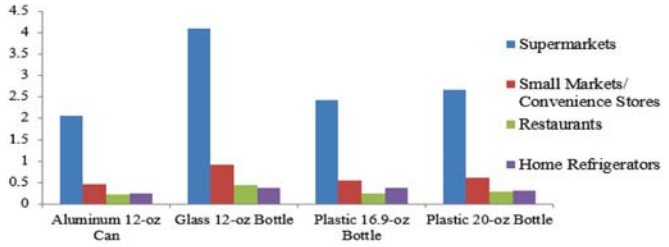

Fig. 11 Energy consumption (MJ/lit of beverages) for cooling of different type of beverages can [Source: ICF, 2016]

Table 4 Energy consumption of Aluminium can relative to other packaging material (in percentage)

Retail or End-Use Type	Glass 12-oz Bottle	Plastic 16.9-oz Bottle	Plastic 20-oz Bottle
Supermarkets	50%	85%	77%
Small Markets/ Convenience Stores	51%	85%	77%
Restaurants	51%	88%	79%
Home Refrigerators	67%	67%	77%

[Source: Fig. 11]

4.3.2 Aluminium application in Power sector:

India has an ambitious target of reaching 175 GW by 2022, which requires robust electrical transmission and distribution grid infrastructure, and this is an opportunity for Indian aluminium industry for increasing share in the power sector. Growing demand for renewable energy worldwide has given significant push to increase in demand of aluminium. According to an estimate of World Aluminium Organization in best case scenario, renewable energy market will require 10% additional use of aluminium led by use in module or collector surface, mounting and frames of the solar power plant. Aluminium and copper both are used in the electric cables of transmission and distribution lines, but aluminium is an economical option for getting the comparable property. Copper is being used in electrical cable for long time because it is a better conductor of electricity. At 20°C Copper has conductivity of 5.96x10^^{7}ó (S/m) while Al has 3.5 x 10^^{7}ó (S/m) [Helmenstine, 2019] but properties of aluminium and its alloy make it attractive for electrical cable. Aluminium conductor consists of alloy AA-1350 series to AA8000 series. AA-1350 series alloy has a minimum Al content of 99.5% [Anixer, 2014]. Also, the weight of aluminium (Al) is 30% to the weight of copper [Anixer, 2014] and useful in electrical application where weight is major concern. Therefore, aluminium conductors are most suitable for electrical overhead transmission lines when cost saving, and weight are two important factors.

4.3.3 Aluminium application in Automobile sectors:

Worldwide thegovernment regulations in various countries have given a push to automobile industries for decreasing CO_2 emission and fuel consumption through innovation in design and technology. Example, from 2021, in European Cars, fleet-wide average emission for new cars, expected to be 95 g/km [European Commission,2019].

Aluminium being lightweight metal,is highly demanded in the automobile Industry. For niche car's model, aluminium uses in various components provide a relative saving of 30-40% as shown in Fig. 12and absolute saving of 70 kg to 140 Kg as shown in Fig. 13.

A research was conducted by the International Aluminium Institute (IAI), European Aluminium Association (EAA) and Aluminum Association (AA), on lightweight vehicles for the reduction in GHG emission and primary energy.

The research concluded (Table 5) that aluminium replacing mild steel, cast iron, high strength steel in various component of car (compact car and large family car) saves 13 kg to 20 kg CO_2per kg of aluminium, leading to reduction of 170 MJ to 140 MJ of energy[The Aluminium Association, 2013].

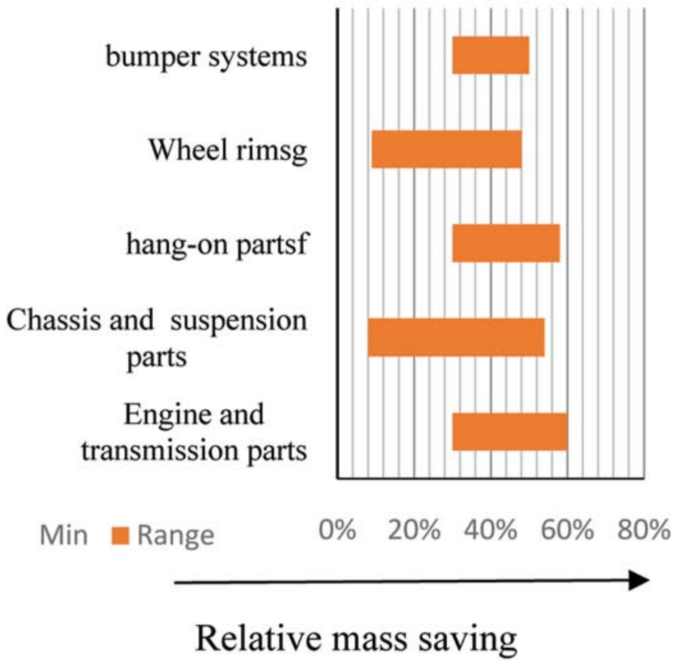

Fig. 12 Aluminium usage within passenger's car and relative mass saving [Source: Ng CH et al., 2017

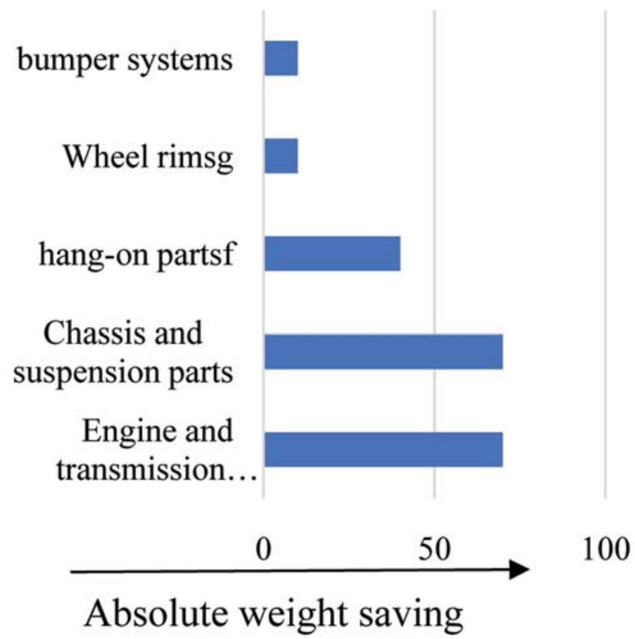

Fig. 13 Absolute mass saving in passenger Car through Aluminium usage [Source:Ng CH et al., 2017]

In India aluminium finds major application in automobile sector as Indian automobile sector is expected to grow in the future from Automotive Mission Plan 2026, National Mission for Electric Mobility 2030 and Make in India initiative. India has targeted 7 million electric cars by FY2020 [NEMMP,2020]. It is observed the fuel efficiency is major concern for automotive industries which is leading to use of light weight material and aluminium is emerging as preferred metal in automobile industry.

Table 5 Life cycle greenhouse gas and primary energy savings per kg of aluminium for a lifetime driving distance of 200,000 km [Source: The Aluminium Association, 2013]

Component	CO_2 eq savings (kg CO_2 eq/kg Al)	Primary energy savings (MJ/kg Al)
Bumper (aluminium-mild steel)	16	210
Bumper (aluminium-high Strength steel)	15	190
Front hood (aluminium – high strength steel)	13	170
Engine block (aluminium – cast iron)	20	280
Body-in-white (aluminium – mild steel)	15	190

4.3.4 Aluminium application in building construction:

Aluminium's properties of lightweight, corrosion-resistant, flexible and reflective material make it highly usable in building and construction. Few major aluminium products used in building have been discussed in Table 6.

Table 6. Various usage of aluminium in building construction. [Source: Wang, 2015]

Aluminium products	Various Applications
Sheet and Plate	Roofs, sidings and claddings, signs and wall decorations, blinds and screens, heat ventilation and air conditioning (HVAC) channels, gutters and downspouts, electric armours
Foil	HVAC systems, daylight collecting systems, solar devices
Extruded products	Windows and doors, skylights, curtain walls and facades, green houses and sunrooms, shades and screens, sports stadium structures and canopies, furniture and decorations, pipes and tubes, renewable energy devices
Forged products	Components of windows, doors, facades, curtain walls and other structural systems; furniture and decoration
Wire and cable	Electric systems, lighting systems
Casting/foundry products	Components of windows, doors, facades, curtain walls and other structural systems; furniture and decoration
Paste and powder	Coatings, pastes for electric and electronic devices

4.4 Job creation and societal development

In India aluminium industry has significantly contributed in the development of society by satisfying basic needs, housing, safety, education, health, food and medical care. Generally, aluminium production and mining process are remotely located and by establishment of plant and process, societies are developed under corporate social responsibility (CSR). Plants are involved in the continuous development of their employees by knowledge transfer, training and personnel development and indirectly develop their whole family. With increase in income, living standard increases and children have access to better education which enable them to give back to society in future.

The aluminium industry's contribution in the Indian job market (directly and indirectly) is approx. 800,000 jobs [Saraswat et al., 2018]and expected to increase with more share of aluminium metal in economy. Job creation in aluminium recycling sector is not much explored in India. In India, the recycling industry is mostly unorganized, and many people's livelihood is dependent on it. Unemployed people of slums area roam around in search of material that can be sold and earn them livelihood, which in stark contrast with foreign developed countries where recycling is mostly organized sector and considered as chores, and it is implemented in the habit of people which is considered as an obligation or something necessary to do. The developed economy has created the job in the recycling industry by making them part of an organized sector or helping industry through NGO, Voluntary organization.

Recycling industry is creating jobs across many verticals; collection, sorting, processing, preparing new material, re-use, and manufacturing. Recycling industry is capable of creating more jobs compared to virgin metal production as analysed in Table 7. Analysis is based on the reference of the job created by plastic industry in FY13-14 and assuming aluminium recycling rate scenario of 25% and 50%. In FY13-14, plastic industry created 0.44 jobs per ton of plastic. If same rate of job creation is considered at 25% recycling rate for aluminium, recycling industry would generate 402,222 jobs which gets doubled at 50% recycling rate.

Increase in secondary aluminium job market was also observed in US compared to primary aluminium sector. The US has seen decline in jobs by 67%, associated with primary aluminium production from 2013 to 2018, while secondary sector jobs have been increased by 10% [John Dunham & Associates, 2018].

4.5 Aluminium demand:

Aluminium is in demand due to engineering research and developments towards innovation. Every year, 41 million tonnes of aluminium are utilized in application such as electrical, auto bodies, aircraft skins and bear cans [ARC, 2019]. Industry ARC estimated global aluminium demand to grow at CAGR of 4.2% during period 2019-2025 [ARC, 2019] due to growth in key driving sectors such as construction, electrical, machinery&equipment and packaging & foil which are expected to grow, globally at the CAGR of 3-4%, 2-3%, 2-3%, 3-4% and 2-3% respectively between 2018-2028 [Fog, 2018]. A Research publication also estimated that from 2005 to 2050, aluminium demand is expected to grow by a factor between 2.6-3.5, while steel between 1.8-2.2 [Gutowski et al.,2013]. Hydro analysed primary aluminium and scarp demand to reach 85 million tonnes and 45 million tonnes by 2030 (Fig. 14) at CAGR of 3.9% and 4.2% respectively [Scharf-Bergmann, 2013,]. With the above promising demand forecasted by various aluminium leading industries and research,it

Table 7: Job creation prospects in secondary aluminium sector of India

Particular	Unit	Value	Data Source
a. Plastic recycled FY 2013-14	Million Tonne	3.6	[FICCI, 2018]
b. Jobs created by plastic recycling, FY 2013-14	No in million	1.6	[FICCI, 2018]
c. Jobs/ton of plastic recycled, FY 2013-14	No. (Jobs)/Tonne	0.44	(a/b)
d. Aluminium consumption in India, FY 2017-18	Tonne	3,620,000	[NITI Ayog, 2018]
e. Current employment in aluminium sector (directly and indirectly)	No of Jobs	800,000	[PTI, 2019]
f. Current Al recycling rate	%	25%	[NITI Ayog, 2018]
g. Quantity of recycled Al scrap	Tonnes	905000	d*f
h. Job creation as per rate of plastic recycling	No of Jobs	402,222	g*c
i. Al recycling rate	%	50%	Assumption
j. Quantity of recycled Al scrap	Tonne	1,810,000	d*i
k. Job creation as per rate of plastic recycling	No of Jobs	804,444	j*c

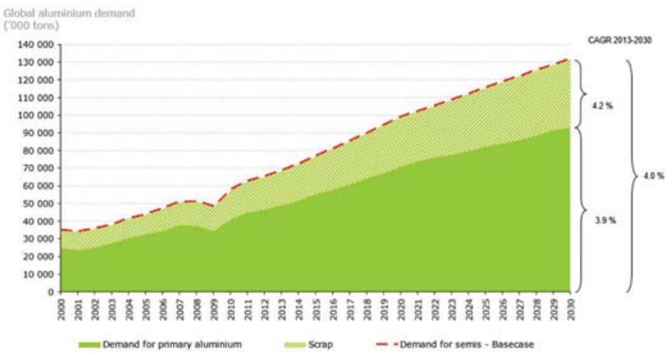

Fig. 14 Aluminium demand [Source; Scharf-Bergmann, 2013]

is clear that aluminium is a future sustainable metal and could facilitate economy in transiting towards more efficient and circular economy.

5. Present challenges to Indian Aluminium sector

Currently India's per capita aluminium consumption is 2.5 kg which is much below the world average of 11 kg. South Korea has highest per capita aluminium consumption of 46.7 kg followed by other countries Germany, China, US and Japan, having per capita consumption as 29.9 kg, 24 kg, 18 kg and 16 kg respectively [NITI Ayog, 2017]. Indian industry witnessed significant challenges (Fig. 15) for low aluminium consumption.

Fig. 15 Aluminium Industry Challenges in India [source: NITI Ayog, 2017]

5.1 Government policy:

Government policy and regulatory measures provide stimulus to industrial development, but it should be reviewed at regular interval for identifying gaps and improvement area. Monitoring of export, import, production and consumption patterns are essential for making trade policy.

Table 8 represents India's last four-year data of production, domestic sales, consumption and export for primary aluminium.It is clear that, although the average growth in production of primary aluminium is 18% in last two-year FY 16-17 and FY17-18 but the share of production in domestic sales is declined leading to increase the share of imports. Due to declining consumption of primary aluminium in domestic market manufacturer are looking at export as another option to stay in business but low global price and less export incentive are cutting the margins and threaten for survival of aluminium industry. According to news of economics times, in FY 2019, aluminium import reached 2.3 million tonnes, resulting the outflow of USD 5.5 billion forex consist of 58% of scrap import [Mazumdar,2020]. Excessive import of aluminium in India is major threat to Indian aluminium Industry.Current import duty on aluminium scrap is 2.5%. while 7.5% on primary metal and differential of import duty, increases the purchase of scrap and restrict the consumption of indigenous scrap. Import value of total aluminium product increased by 30% in 2017-18 compared to 2016-17 and scrap import increase by 46% as shown in Table 9. Largest exporter of aluminium to India is China, UAE, Malaysia, and UK (Table 10). Indian aluminium industries propose anti-dumping duty on aluminium scrap and other product to protect domestic industry. China and US have policies which support their domestic industries such as antidumping duty policy in interest of protection of domestic industry. Indian aluminium industries also face challenge of high interest loan on capex which is bottleneck in technology advancement and innovation.

Table 8: Aluminium production, domestic sales, Import, consumption and Export [NITI Ayog, 2018]

Year	Production (in Million Tonnes)	Domestic sales (in Million Tonnes)	Import (in Million Tonnes)	Consumption (in Million Tonnes)	Export (in Million Tonnes)	Share of primary produ-ction in dom-estic sales	Import share %
2014-15	2.05	1.26	1.59	2.85	1.04	61%	39%
2015-16	2.43	1.57	1.67	3.24	1.16	65%	35%
2016-17	2.86	1.55	1.75	3.30	1.54	54%	46%
2017-18	3.38	1.66	1.96	3.62	2.01	49%	51%

Table 9 Aluminium Import in USD million

Particular	2015-16	2016-17	2017-18
Total aluminium product made from it	3429	3478	4523
Aluminium waste and scrap	1326	1402	2044
Unwrought aluminium	798	784	805
aluminium foil	391	418	489

Table 10: India import contribution by countries

Countries	Quantity (Million tonnes)	% age contribution
China	0.24	12%
UAE	0.18	9%
Malaysia	0.18	9%
UK	0.18	9%
Saudi Arabia	0.15	8%
USA	0.11	5%
Rest of the world	0.93	47%
All countries	1.96	100%

5.2 Lack of Recycling

Increasing India's recycling capacity in metal sector is far more challenging. Current aluminium recycling rate in India is 25% and lower recycling rate is due to inadequate availability of scrap, infrastructure limitations and low consumption of aluminium in India.

The main sources of metal waste are urban living population, small and medium industries. Indian recycler gets aluminium scrap from import and domestically from unorganized sources as scrap industry in India is highly unorganized. The Indian recycling sector is unorganized because there is no formal recycling Industry structure, no dedicated zones and area for recycling. Industrial waste is disposed to landfill as an easy solution to avoid investment towards waste management. Moreover, recycling sector lacks formal policy for Industrial waste management and disposal, which increases the deployment of waste in landfill.

5.3 Infrastructure Challenge

Scrap recycling is chain of collection, segregation and treatment and being an un-organized in India, it involves major manual work in segregation process after collection. Collection and separation of scrap poses risk to human health because of unhygienic condition. A dedicated technology equipped recycling zone will improve the hygiene and safety of worker involved in recycling.

5.4 High Energy cost

Indian smelter is highly energy intensive and further high energy cost increases the overall cost of production. Most aluminium industries in India have fossil fuel based captive power plant as source of electricity which depends on coal. Indian coal has low Gross calorific value (GCV) leading to lower heat value compared to imported coal, which have high GCV. Electricity procurement is based on imported coal which is costlier in India because of taxes and duties on coal while Chinese manufacturers get subsidized coal. Foreign aluminium manufacturers get subsidy on coal and power such as Coal subsidies in China, natural gas subsidy in Russia (NITI Ayog, 2017) which help them to reduce production cost.

5.5 Outdated technology

Indian industry performs on old technology of production and require upgradation for efficient utilization of resources and increasing productivity.

In India, recycling facilities are not automated for sorting while developed economy has automated most of the recycling function to avoid human error and issues related to health and safety. Automation and technological innovation require investment in technology which is possible only when the sector is the part of organized structure. Example of technology innovation can be seen at leading aluminium producer Rio Tinto, who decreased the CO_2emission from primary aluminium production.

"Rio Tinto's RenewAl which is based on advanced AP technology reduced CO_2 emission significantly in the production process. RenewAl emits 4tonne of CO_2 per tonne of aluminium production, compared to an industry average of 11.8 tonnes of CO_2 per tonnes of aluminium"

5.5 Social awareness

Awareness to recycling is very less in India as people are in habit of use and throw of material, also there is no dumping facility made within community for dumping recyclable material separately like battery, deodorant bottle, glass, aluminium and steel products.In UK, through the successful awareness program "Every can Count"(Fig. 16), the country is increasing its recycling percentage year on year. Every can counts has aim of reaching 100% recycling rate in Europe and has programmes in 16 countries across Europe, distributed 15,600 collection boxes around the UK and has 7700 collection sites in UK so far.

Fig. 16 Social awareness for recycling [source: Every can counts, UK]

6. Solution to challenges and way forward for India

The current aluminium consumption is very low in India and to reach at world average level we require to enhance the existing useof aluminium in key sectors as discussed above. For strategic growth of Indian aluminium industry, balance is required between growth of primary and secondary aluminium. China and the United states are relying more on secondary route for aluminium production. India has not yet explored secondary aluminium production at the commercial level due to limitations like lower domestic demand, lack in availability of scrap and government policy. Indian aluminium sector requires reforms to provide growth to domestic industry and increasing consumption. Few major reforms which can provide growth to Indian aluminium industries are discussed below;

6.1 Reforms in Recycling sector

Increasing aluminium recycling in India is challenging but it has a bright future because of increasing demand in power, automobile, packaging, building and construction sector. Sectoral growth could lead the aluminium consumption but bringing back aluminium scarp again in the production process is even more important for responsible aluminium consumption.Few measures which can help recycling industry are as follows;

- Organizing the unorganized sector through dedicated zone and recycling park
- Enforcement of formalized industrial recycling policy for increasing domestic scarp consumption and decreasing dependency on imported scrap.
- India collected 120,000 tonnes of scrap in 2016, with 75% [NITI Ayog, 2019] share of automotive and power sector. Automotive sector contribution in aluminium scrap will increase as electric vehicle is future and utilizes more aluminium than previously used because of weight constraints. Thus, a dedicated vehicle dismantling facility would help in increasing the collection rate of aluminium scrap in the automotive segment.
- Support to recycling industry at initial phase of establishment from the government.
- Societal awareness for differentiating metal waste from domestic waste would help in maximizing collection rate.

6.2 Trade policy reforms

Indian aluminium industry requires policy reform related to trade agreement and trade agreement should be negotiated keeping in mind the growth of domestic industries and making them competitive at global level. The country's leading in aluminium sector have implemented policies which supports trade and growth of domestic industries and few of such policies are discussed in Table 11.

Some of these policies can also be implemented in India to support domestic industry and fair-trade flows. Few of these policies are given below;

- Imposing Anti-dumping duty on waste at the value which helps domestic industry for maximizing production
- CO_2 emission compliances in transport sector which indirectly affect aluminium industry demand
- Export restriction
- Tariff imposition for inefficient plants
- Financial support for green technology
- Bringing aluminium in trade monitoring or product control list as implemented in Canada (Table 11)
- Supportive policies for circular economic model
- Incentive for recycling industries, financial support and subsidy

6.3 Social awareness:

Social awareness is key for increasing secondary aluminium consumption. It is difficult to leave old practices of use and throw and adopt reduce-reuse-recycle based activity. Social awareness can be created through bottom-up approach. In bottom-up approach, society is more involved, and problems are identified at ground level which will helps in planning at the upper level. Demand is created by consumer and consumer needs to be aware of the benefits of aluminium and its recyclability.

Incentivizing consumer for recycling, community-based collection points, inter community and society-based competition for waste collection, involving schools and offices for their contribution in the waste collection are some measures which would help in creating awareness. For example, Every can counts in UK involves community, offices and society for maximizing collection of aluminium cans.

6.4 Aluminium as strategic metal

India should recognize aluminium metal in the strategic sector because several direct and indirect benefits of aluminium are connected with UN sustainable development goals.

Aluminium metal directly contributes to six sustainable development goals (Fig. 17); good health and well-being, affordable and clean energy, decent work and economic growth, Industrial innovation and infrastructure, sustainable cities and communities, responsible consumption and production and indirectly to four sustainable development goals; No poverty, Zero hunger, Climate Action and life on land.

Sustainable development goals are the pathways to achieve future sustainability and and aluminium fulfils all requirements of getting recognized as most sustainable and circular metal.

Table 11. Worldwide, Policies and its qualitative effects on Aluminium Industry

S. No	Country	Effect	Source
1	Canada		
	Canadian govt. adds some aluminium products to Import Control List (ICL)	It helps govt. to identify trade flow, address misclassification of aluminium and evasion of duties	[The aluminium Association, 2019]
	The Regional Economic Growth through Innovation (REGI) - Steel and Aluminium Initiative	Helps in innovation of small and medium enterprise projects under SME sector operating within steel and aluminium	[The Government of Canada, 2017]
		Support technology demonstration and commercialization of projects	
		The initiative provides non repayable funding support ranging from $150,000 to $1 million to eligible firms	
		Increases business capacity and create jobs	
	Low cost of power	Increase Global competitiveness of aluminium Industry. Ex-	[Sin, 2019]
		Canadian smelter pays power tariff between US $ 6-US $ 7 per MWh	
	Financial support	Canada provides support to research and development andnew projects Ex-export incentive for Quebec aluminium development plant (2015-2025)	[NITI Ayog, 2018]
2	China		
	Export restriction	China combines 15% export tax with Zero VAT rebate which result in export tax on primary aluminium exceeding 30%.	[OECD, 2019]
		It provides incentive for Chinese smelter not to export primary aluminium, instead sell it in domestic market at lower price	
	Tariff imposition for inefficient plant	China imposes extra tariff for smelter using more than 13,700 KWs for each tonne which aims at closing of inefficient plant and increasing efficiency	[OECD, 2019]
	Power subsidy	Few local governments in china offer power subsidy to increase production	[NITI Ayog, 2018]
	Import ban	China imposes import tariff for curbing scrap import and classified aluminium scrap in restricted import list as a protectionist measure for increasing domestic recycling capacity	[Dash, 2019]
	Financial support	Interest free low-cost loan, subsidized land to new smelter project, income tax and VAT rebate	[Suneja, 2019]
	Rebate on value added tax (VAT)	China provide VAT rebate to support export	[Suneja, 2019]
3	Europe		
	Anti-dumping and anti-subsidy	European aluminium is in favour of free trade but for fair trade effective trade defence instrument like anti-dumping and anti-legislation are applied	[European aluminium, n.d]
	CO_2 emission compliances on Cars, Vans and Heavy-Duty Vehicles	Aluminium industry indirectly gets benefit of being light weight material used in automobile sector	[European commission, n.d]
	Circular economy action plan	It is to boost the efficient use of resources, restore biodiversity and cut pollution and support to industry innovation for circular and sustainable economic model	[European commission, n.d]

Fig. 17 Sustainability Goal achieved by Aluminium metal [Source: United Nation]

Conclusion

The above discussion and analysis have identified various properties of Aluminium which make it a vital resource for climate neutral and circular economy and metal of future application. Aluminium have a wide application due to excellent physical properties like resistance to corrosion, lightweight, conductivity and recyclability. With high end recycling capacity, aluminium metal can play a leading role in low carbon and circular economy. Uses of secondary aluminium strengthen the resource conservation, energy saving and minimize the leakage of waste when produced through closed loop according to the principles of the circular economy. Aluminium and its alloy have several essential properties which can be leveraged in electric vehicle, renewable energy and building and construction sector. Increasing aluminium consumption in key sector will improve the supply of domestic aluminium scrap and opens the opportunity for future recycling. Indian recycling sector has several bottlenecks and require clear cut policy measures which can support make in India move. Section-5 identified main challenges which restrict the growth of the Indian aluminium sector. The Solution to these challenges as discussed in section 6, emphasized on policy instruments like antidumping duty, incentivizing export, subsidy for technology innovation to promote domestic industry which will enable Indian aluminium industry in capacity augmentation. Technological advancement and research activity should be promoted through innovation hub as in the European aluminium industry. India has limitations in the technology sector which can be overcome through association or partnership with institutions, for technology advancement. Societal awareness is crucial for creating the environment of responsible consumption and disposal, to minimize the waste leakage from production loop and gain from circular economy model. Therefore, Industry and government must act together in creating awareness for aluminium's uses and benefits.

Aluminium in itself is most circular and sustainable metal, by leveraging its property with adequate policy and technology measures, India could accelerate its transition from the linear economic model to the circular economic model.

List of abbreviation

Abbreviation	Full Form
AA	Aluminium Association
BIR	Bureau of International Recycling
CAGR	Compounded annual growth rate
CSR	Corporate Social responsibility
EAA	European Aluminium Association
EU	European Union
FICCI	The Federation of Indian Chambers of Commerce and Industry
GCV	Gross calorific value
HVAC	Heat ventilation and air conditioning
IAI	International Aluminium Institute
INSA	The Indian National Science Academy
Kt	Kilo tonne
MJ	Mega Joule
MPa	Mega pascal
NEMMP	National Electric Mobility Mission Plan
NITI	National Institution for Transforming India
OECD	The Organisation for Economic Co-operation and Development
Ph	Power of Hydrogen
REGI	Regional Economic Growth through Innovation
WHO	World Health Organization

References

1. Anixer, Wire wisdom,2014 NEC 310.106(B),https://www.anixter.com/content/dam/anixter/resources/wire-wisdom/anixter-aluminum-versus-copper-wire-wisdom-en.pdf. Accessed 14 July 2019
2. Boateng TK et al., 2019, Heavy metal contamination assessment of groundwater quality: a case study of Oti landfill site, Kumasi, Applied water science.
3. Bureau of International Recycling (BIR),2008, Report on the Environmental Benefits of Recycling, Imperial College London.
4. Calder G.V et al., 2010, Aluminum Reactions and Problems in Municipal Solid Waste Landûlls, DOI: 10.1061/ASCEHZ.1944-8376.0000045
5. Dash J, 2019, Aluminium scrap imports up 6.5% despite 13% slump in auto production, Business Standard. https://www.business-standard.com/article/markets/aluminium-scrap-imports-up-6-5-despite-13-slump-in-auto-production-119121701168_1.html. Accessed 12 August 2019.
6. Davis J.R., 1999, Corrosion of aluminium and alumina alloy, ASM International, www.asminternational.org. Accessed 16 February 2019.
7. Ellen Macarthur foundation, 2019, Completing the Picture - New circular economy and climate change paper presented at the COP25.https://www.ellenmacarthurfoundation.org/news/completing-the-picture-new-circular-economy-and-climate-change-paper-presented-at-the-cop25. Accessed 13 June 2019.
8. European aluminium, n.d, https://www.european-aluminium.eu/policy-areas/ Accessed 5 June 2019
9. European Aluminium, n.d, Recycling aluminium, A pathway to circular economy, Belgiumhttps://european-aluminium.eu/media/1712/ea_recycling-brochure-2016.pdf. Accessed 10 May 2019.
10. European Commission, 2019, Reducing CO_2 emissions from passenger cars. https://ec.europa.eu/clima/policies/transport/vehicles/cars_en. Accessed 6 May 2019
11. European commission, n.d, https://ec.europa.eu/info/node/123797. Accessed 6 May 2019
12. European Commission, 2014, Towards a circular economy: A zero waste programme for Europe Brussels, COM (2014) 398 final. https://ec.europa.eu/environment/circular-economy/pdf/circular-economy-communication.pdf. Accessed 7 May 2019
13. Every can counts, https://everycancounts.co.uk/, last accessed on 17 September 2019
14. Fog K, 2018, Market outlook, Hydro Demand, CRU, https://www.hydro.com. Accessed 8 May 2019
15. Federation of Indian Chambers of Commerce & Industry (FICCI), 2018, Delhi, Accelerating India's Economy shift
16. Gesamtverband der Aluminiumindustrie e. V (GDA), n.d, http://www.aluinfo.de/homepage.html. Accessed 11 May 2019
17. The Government of Canada, 2017, REGI - Steel and Aluminum Initiative, https://www.canada.ca/en/atlantic-canada-opportunities/services/steelaluminum.htmlAccessed 16 May 2019
18. Gutowski T., 2013, S. Sahil, J. Allwood, M. Ashby, E. Worrell, The Energy Required to Produce Materials: Constraint on Energy Intensity-improvements Parameters of Demand. Philosophical Transaction A, http://dx.doi.org/10.1098/rsta.2012.0003,
19. Helmenstine AM, 2019,Thoght Co., Table of Electrical Resistivity and Conductivity, https://www.thoughtco.com/table-of-electrical-resistivity-conductivity-608499. Accessed 08 April 2019
20. Hulamin, 2019,Recycling, https://www.hulamin.com/about/aluminium-recycling, 09 April 2019
21. Husband T, 2011, chemmatters, Recycling to Survive, London, United Kingdom
22. ICF International, 2016, Analysis of the Energy and Greenhouse Gas Emission Implications of Distributing and Refrigerating Beverages, Washington, DC.
23. Indian National Science Academy (INSA), 2011Hazardous metals and minerals pollution in India: source toxity and management, New Delhi
24. Industry ARC, 2019, Aluminum Market set to grow at a CAGR of 4.2% during the forecast period 2019-2025, https://www.industryarc.com/PressRelease/1859/Aluminium-Market-Research-Analysis.html. Accessed08 March 2019
25. James N, 2019,Hindalco in consortium to promote use of aluminium cans for beverages, India https://www.thehindubusinessline.com/companies/hindalco-in-consortium-to-promote-use-of-aluminium-cans-for-beverages/article 27058617.ece. Accessed 04 March 2019
26. Javadekar, 2016, Solid Waste Management Rules Revised After 16 Years; Rules Now Extend to Urban and Industrial Areas, Ministry of Environment and Forests http://home.iitk.ac.in/~anubha/H15.pdf. Accessed 16 March 2019
27. Johnsen R et al., 2004, Corrosion challenges with the use of aluminium in offshore and marine environment, Norwegian University of Science and Technology.https://www.bluemaritimecluster.no/download?objectPath=/upload_images/CA6A704C6D3F4F2196B367FC79E66DCE.pdf, Accessed 17 March 2019
28. John Dunham & Associates, 2018,Economic Impact of the Aluminum Industry,Brooklyn, New York
29. Kevin Sieff, 2017, The world is drowning in ever-growing mounds of garbage.https://www.washingtonpost.com/world/africa/the-world-is-drowning-in-ever-growing-mounds-of-garbage/2017/11/21/cf22e4bd-17a4-473c-89f8-873d48f968cd_story.html?noredirect=on, Accessed 18 March 2019
30. LotoR T et al., 2020, TemitayoMorenikeji, IdowuAyodeji Charles, 2020, Data on the corrosion inhibition effect of 2-meracaptobenzothiazole on 316 austenitic stainless steel, low carbon steel and 1060 aluminium in dilute acid media, Chemical Data Collections, 26 (2020) 100349, Accessed 18 February 2020
31. Mazumdar R, 2020, Aluminium association seeks import duty hike ahead of Budget, https://economictimes.indiatimes.com/news/economy/foreign-trade/aluminium-association-seeks-import-duty-hike-ahead-of-budget/articleshow/73738503.cms?from=mdr. Accessed 18 February 2020
32. Mishra Baibhav, 2017, Aluminium: The Metal for the Future of Shipbuilding, seanewshttps://seanews.co.uk/features/aluminium-the-metal-for-the-future-of-shipbuilding/. Accessed 15 February 2019

33. Mordor Intelligence, Packaging Industry in India-Growth, trends, and forecast (2020-2025), n.d.,https://www.mordorintelligence.com/industry-reports/packaging-industry-in-india, last accessed on 17 August 2019
34. National Electric Mobility Mission Plan (NEMMP),2020, Ministry of Heavy Industries and public Enterprises, Department of Heavy Industry, Government of India,.https://dhi.nic.in/writereaddata/Content/NEMMP2020.pdf. Accessed 18 February 2019
35. Ng CH et al.,2017. Reviews on aluminum alloy series and its applications. Acad. J. Sci. Res. 5(12): 708- 716.
36. NITI Ayog, 2018, Draft Strategy on Aluminium Resource Efficiency.
37. NITI Ayog, 2019, Strategy On Resource Efficiency in Aluminium Sector, New Delhi
38. OECD, 2019, measuring distortion in International market, The aluminium value chain
39. PTI, 2019 aluminium-producers-seek-import-duty-hike-ahead-of-budget, The Hindu Business Line, Bhubanewsar. https://www.thehindubusinessline.com/economy/aluminium-producers-seek-import-duty-hike-ahead-of-budget/article27956567.ece. Accessed 13 February 2019
40. PTI, 2019, India’s packaging industry to touch $72.6 billion by FY20: ASSOCHAM-EY study, Economics times. https://economictimes.indiatimes.com/industry/indl-goods/svs/packaging/indias-packaging-industry-to-touch-72-6-billion-by-fy20-assocham-ey-udy/articleshow/68032848.cms?from=mdr. Accessed 18 January 2019
41. Purwanti IF et al.,2019, Removal of Aluminium in Contaminated Soil using Locally Isolated Vibrio alginolyticus, Journal of Ecological Engineering, 135–140
42. Rosseland BO et al., 1990, Environmental effects of aluminium, Environ Geochem Health, US National Library of Medicine National Institutes of Health, (1-2):17-27
43. Samaddar S et al., 2018,There’s much to gain from recycling of waste, The Hindu, Business Line.https://www.thehindubusinessline.com/opinion/columns/theres-much-to-gain-from-recycling-of-waste/article24802735.ece.Accessed 07 January 2019
44. Saraswat et al., 2017, Need for aluminium policy in India, NITI Ayog.
45. Scharf-Bergmann R, 2013, A vision of global aluminium recycling in 2020, https://www.metalbulletin.com/events/download.ashx/document/speaker/6614/a0ID000000X0joVMAR/Presentation. Accessed 07 March 2019
46. Sin Categoría, 2019, Global aluminium smelters’ production costs on decline, http://www.anfre.com/category/sin-categoria/
47. Sukiman N. L. et al., 2012, Durability and Corrosion of Aluminium and Its Alloys: Overview, Property Space, Techniques and Developments, DOI: 10.5772/53752
48. Suneja K, 2019, RCEP: Aluminium, copper associations caution govt on China’s presence, Economics times. https://economictimes.indiatimes.com/news/economy/foreign-trade/rcep-aluminium-copper-associations-caution-govt-on-chinas-presence/articleshow/69415785.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst. Accessed 07 March 2019
49. The aluminium Association, 2019, The Aluminum Association Applauds Canadian Government for Adding Aluminum to Import Monitoring List. https://www.aluminum.org/news/aluminum-association-applauds-canadian-government-adding-aluminum-import-monitoring-list/ Accessed 07 March 2019
50. The Aluminium Association,2013, Transport and Aluminium. http://www.world-aluminium.org/media/filer_public/2013/01/15/fl0000172.pdf. Accessed 23 March 2019
51. The Aluminum Association, The Aluminum Can Advantage,2017,https://www.aluminum.org/sites/default/files/KPI%20Report%202017_0.pdf. Accessed 23 March 2019
52. The Aluminum Association, The Aluminum Can Advantage,2019,https://www.aluminum.org/sites/default/files/KPI%20Report%202019.pdf. Accessed 23 March 2019
53. The Aluminium Association,2011, Aluminium: The Element of Sustainability, A North American Aluminum Industry Sustainability Report.
54. The University of Florida (UF), (n.d) pH, Salinity and Temperature, https://sfyl.ifas.ufl.edu/media/sfylifasufledu/miami-dade/documents/sea-grant/Temperature,-Salinity-and-pH.pdf. Accessed 24 March 2019
55. VisserWanye, 2015, Sustainable Frontiers, Unlocking change through business, leadership and Innovation, Greenleaf Publishing Limited
56. Wang M J, 2015,The Aluminium Association, Aluminum in Green Buildings, USA
57. Wisconsin Economic Development Corporation (WEDC), India: the world’s fifth-largest packaging industry,2017.,https://wedc.org/export/market-intelligence/posts/india-worlds-fifth-largest-packaging-industry/ Accessed 21 March 2019
58. World Health Organization (WHO)/IPCS. Geneva: WHO/IPCS; 1997. Environmental Health Criteria 194, Aluminium.
59. United Nation, sustainable development goals, https://www.un.org/sustainabledevelopment/sustainable-development-goals/