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Ministry of Mines
Government of India

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NITI Aayog

STRATEGY ON RESOURCE EFFICIENCY IN ALUMINIUM SECTOR

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This strategy paper has been compiled by Jawaharlal Nehru Aluminium Research Development and Design Centre, Nagpur

FOREWORD

Resource Efficiency is a key element of sustainable development. This is directly reflected in SDG Goal 12: Ensure Responsible Consumption and Production Patterns. Eight other goals (2, 6, 7, 8, 9, 11, 14 and 15) also relate to resource efficiency and circular economy.

In accordance with the commitment of the Government of India to SDG Vision 2030, NITI Aayog along with EU Delegation to India released a Strategy on Resource Efficiency in November 2017.

The strategy has provided detailed recommendations to improve resource efficiency at each stage of the production process and along the entire life cycle of a product. In accordance with this strategy action plan, it was inter-alia decided to formulate a Strategy on Resource Efficiency in Aluminium Sector.

India ranks 3rd in the production of primary aluminium in the world. Directly and indirectly, the Indian aluminium industry provides employment to more than 0.75 million (7.5 lakh) people. The secondary aluminium sector constitutes nearly 30% of the total aluminium consumed in India and has been rapidly growing.

Aluminium is a critical metal for meeting world's commitment towards 2015 Paris commitment of low carbon footprint. It is one of the most recycled and most recyclable materials in the market today. As India embarks on a growing aluminium consumption trajectory, both primary and scrap-recycling industries are essential to the vision of India's Aluminium Policy. In order to meet the growing demand, the efficiencies associated with the mining of bauxite ore, alumina extraction, and primary production must be improved. Measures are required to boost aluminium production through recycling of scrap which is a global trend.

It is with this background that a strategy has been proposed in the report containing 11 recommendations which is expected to provide impetus to Scrap Based Aluminium Industry, increase its competitiveness as well as circularize the production process. It will also go a long way in reducing CO_2 emissions significantly as well as generating livelihood opportunities.

I would like to thank Mr Prithul Kumar, Nodal Officer from the Ministry of Mines, and Dr Anupam Agnihotri, Director, JNARDDC, for their contribution in preparing this strategy paper. I also thank the EU Delegation and the European Union's Resource Efficiency Initiative (EU-REI) team members consisting of Dr Dieter Mutz, Dr Rachna Arora, Mr Pranav Sinha and Dr Reva Prakash along with all other stakeholders in the Aluminium sector who have contributed. I would like to especially thank Mr B.N. Satpathy, Senior Consultant, EAC-PM, NITI Aayog and Mr Suneet Mohan, Young Professional, NITI Aayog for their vital support in coordinating the development of all sectoral strategies.

I hope this strategy paper on aluminium will open a new chapter in economywide mainstreaming of Resource Efficiency and Circular Economy in the country.

Ratan P Watal

Ratan P. Watal
Principal Advisor, NITI Aayog and
Member Secretary, EAC to PM

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1.0 Executive Summary

Closed loop economy for aluminium has great benefits, both for resource conservation and for environmental impacts. In fact, a shift towards secondary production is the only option to significantly reduce the energy use related to aluminium production. Aluminium recycling rates are already quite high for most of the applications. However, secondary production is presently not providing a large share in total supply. This is due to the fact that demand is still rising rapidly. The societal stock of aluminium is still building up. Only when the stock is built up, equilibrium can be reached in inflows (demand) and outflows (waste), and secondary production can catch up with demand.

Aluminium is the second most used metal in the world after steel with an annual consumption of 88 Million Tons (including scrap). Aluminium Consumption in India at 2.5 kg per capita is much below the global average of 11kg per capita. To reach the global average of 11 kg per capita, India will require an additional annual consumption of 16mn tons, thus, making it the second largest consumer in the world (absolute terms). The aluminium industry comprises two basic segments: upstream, and downstream. The upstream sector produces primary or "unwrought" aluminium from raw materials Primary aluminium is the starting block for aluminium products and is mainly in the form of ingots and billets. The processing of aluminium into semi-finished aluminium goods such as rods, bars, rolled products, castings, forgings and extrusions comprises the downstream segment of the industry. These aluminium products can be manufactured using primary or secondary aluminium (recycled), or a combination of both depending on the specification of the final product.

Globally, auto & transport account for 23% of aluminium consumption, followed by construction (22%), packaging (13%), electrical (12%), machinery and equipment (8.5%), consumer durables (4.5%), and other segments (4%). While in India the major consumer of aluminium metal is electrical sector (48%) and is followed by transport (15%), Construction (13%), and Consumer Durables (7%).

As Indian Aluminium industry is forging ahead with rapid expansion in both primary metal and downstream sectors. With the continuing trend of economic growth, the demand and consumption of aluminium is expected to increase rapidly. Primary demand for increased consumption is expected to come from the power sector while secondary demand for aluminium consumption will ride on the growth in the automotive sector. Further, here is huge potential for increasing the consumption of aluminium due to government initiatives like, Make in India, Smart Cities, Housing for all, rural electrification, freight corridors, bullet trains, power to every household, energy efficient/electric automobile, aluminium wagons and many more. Aluminium is already set to play a key role in the progress of industrial development in India because it serves as a basic input for a number of industries apart from its use as a strategic metal. Aluminium is considered a strategic sector by various industrialized economies due to-high linkage effect, high market potential, high technological intensity and high value addition. Many industrialized nations have included non-ferrous metals/ aluminium industry as a strategic sector in their industrial strategy/plan.

Aluminium is also one of the critical metals for world's commitment towards 2015 Paris commitment of low carbon footprint. According to a World Bank study titled, "The Growing Role of Minerals and Metals for a Low Carbon Future", Aluminium will play a significant role in achieving low carbon footprint. The report states that a growing demand for minerals and metals to supply a low-carbon future, if not properly managed, could bely the efforts and policies of supplying countries to meet national objectives and commitments regarding climate change and related sustainable development goals and it is imperative that that recycling metal scrap is a must in today's scenario as India badly needs to reduce its carbon footprint while making judicious use of its natural resources.

Aluminium is a sustainable metal and can be recycled over and over again. Aluminium is one of the most recycled and most recyclable materials on the market today. Aluminium recycling industry includes: refiners, remelters, and also involves collectors, dismantlers, scrap merchants & processors, which deal with the collection and treatment of scrap. Recovering aluminium from recycling is not only economically viable, but also energy efficient and ecologically sound. In many countries, authorities are encouraging to recycle more aluminium. Norway has also set strategic goals to increase the production of recycled metal. Japan – stopped domestic primary aluminium production and switched to aluminium recycling in the 1980s. China, India and Russia – has started increasing their recycling activities. Also, various policy documents and standards related to aluminium recycling have been implemented in these countries.

As India embarks on a growing aluminium consumption trajectory, it must realize that both primary and scrap-recycling industries are essential to the vision of India's Aluminium Policy. Therefore, a fine balance must be maintained for the co-existence of primary and scrap so that it can cater to the future demand, both domestic and foreign. Secondary aluminium sector constitutes nearly 30% of total aluminium consumed in India and has been rapidly growing. In the past six years, secondary aluminium demand has almost doubled to 1.1 million tons, of which some 90% is imported. In 2016, some 120,000 tons of aluminium scrap was generated in India, with the automotive and power segments together accounting for 75% of the total. India's metal recycling rate is just about 25% and heavily reliant on imported scrap (0.93 mT during 2016-17). All the activities related to aluminium scrap recovery are limited to the unorganised sector, catering mostly to the utensil, casting and extrusion industries. There are limited laws governing the scrap sector or recycling industry.

It has been projected that for India, the dynamics of primary and scrap production and consumption will follow two phases. Phase one will see India's consumption of aluminium grow up strongly owing to investments in infrastructure and defense. Both Primary and Scrap need to fuel this consumption demand. In the absence of a formalized and standardized scrap recycling policy and industry, our consumption needs would make us unduly rely on foreign imports, despite significant scrap generation and processing potential. Phase two will witness India hitting some steady-state value of Aluminium consumption. In this phase, it's the scrap that can be recycled again and again to cater to steady state demand. Currently, In India we do not have any formal organized Metals Recycling industry structure. The industry is not highly regulated and there are no specially designated zones/areas for Metals Recycling.

The national aluminium policy needs to focus on a holistic short-term, medium and long-term vision identifying growth targets for demand augmentation and capacity addition. This requires a strategy for achieving the targets in terms of raw material, infrastructure, value-addition, power, energy requirements and scrap recycling. Aluminium, like most metals, has a rapidly increasing demand on the world market. As a consequence, world production is also increasing rapidly. The growth, both of demand and supply, occurs outside the India as well as in India. For India the production and demand is continuously increasing at a CAGR rate of 9% and above.

The main reported sustainability problem related to aluminium is the high energy intensity of its production: primary aluminium production requires much energy, especially related to the smelting step where aluminium in its metallic form is produced from alumina, i.e.; aluminium oxide. Secondary aluminium production is much less energy intensive, but despite relatively high recycling rates still forms a limited fraction of supply. Aluminium production is also associated with high GHG emissions and solid waste. GHG gases are mainly related to energy use, but also originate from other sources.

For a large share of secondary production, EOL recycling rates need to grow as well. This is something that can be influenced and should be, since market conditions have a large influence on this development.

Aluminium in the built environment is a very well recyclable stock, probably the best one. This is illustrated by the fact that EOL recycling rates are already very high, well over 90% in Europe. From the point of view of closing the loop, therefore, building applications are ideal. As far as we are aware there are no barriers that stop aluminium from being collected and recycled. The improvement that could be made, according to representatives of the industry, is to pay more attention to the separate collection of different types of aluminium (molded and cast). This would improve the applicability of recycled aluminium to be comparable with virgin aluminium.

2.0 Overview of Aluminium Industry

Aluminium is the 2nd most used metal in the world after steel with an annual consumption of 88 Million Tons (including scrap). It is also the fastest growing metal which has grown by nearly 20 times in the last sixty years (compared to 6 to 7 times for other metals). Some of its unique properties like lightweight, recyclability, conductivity, non- corrosiveness and durability have helped establish it as a metal of choice for various applications across different segments of the manufacturing sector. Aluminium is also called 'Metal of Future', 'Strategic Metal' & 'green Metal' due to the above properties.

The production of primary aluminium metal commences with bauxite ore, which is composed of hydrated aluminium oxide (40%-60%) mixed with silica and iron oxide. Roughly 6.5-7 tons of bauxite ore are refined to produce approximately 2 tons of alumina. These 2 tons of alumina is smelted to produce approximately 1 ton of aluminium. Production of aluminium is a very capital and energy intensive process. Production of aluminium is energy intensive and energy costs constitute about 30-35% of the production cost. Alumina, power and labour account for 75-80% of total cost depending on the region where it operates.

Globally, auto & transport account for 23% of aluminium consumption, followed by construction (22%), packaging (13%), electrical (12%), machinery and equipment (8.5%), consumer durables (4.5%), and other segments (4%).

2.1. Global Aluminium Industry Structure

The aluminium industry comprises two basic segments: upstream, and downstream. The upstream sectors are involved in extraction of aluminium from its bauxite and produce primary or "unwrought" aluminium. Primary aluminium is the starting block for aluminium products and is mainly in the form of ingots and billets or slabs. Major global players in the primary aluminium industry are Hongqiao, Rusal, Rio Tinto, Shandong, Chalco and Alcoa. The processing of aluminium into semi-finished aluminium goods such as rods, bars, rolled products, castings, forgings and extrusions comprises the downstream segment of the industry. These aluminium products can be manufactured using primary or secondary aluminium, or a combination of both depending on the specification of the final product. Aluminium production from recycled scrap is termed as secondary production.

2.1.1 Aluminium production process

The main raw material for primary aluminium production is bauxite. Aluminium oxide is extracted from the bauxite, and is used in an electrolytic reduction process to produce primary aluminium. Roughly, 6.5-7 tons of bauxite is refined to produce approx. 2 tons of alumina and these 2 tons of alumina is smelted to produce about 1 ton of aluminium. Primary aluminium is alloyed with other metals and is then fabricated into a range of products through casting, extrusion and rolling.

Main steps of primary aluminium production are shown in the Figure 1 below.

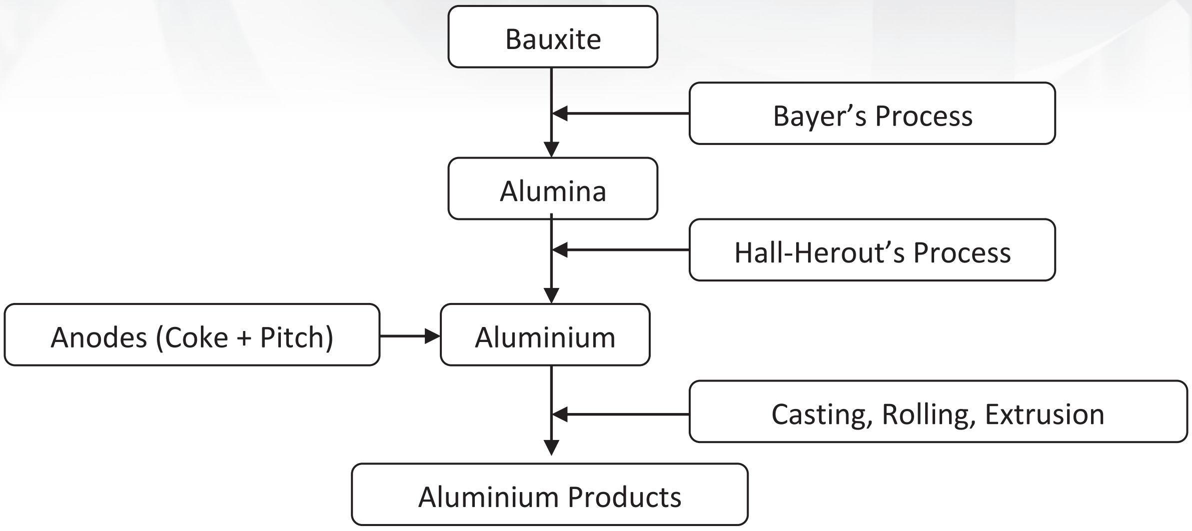


Figure 1: Aluminium production process steps

- **Bauxite Mining:** approximately 7 percent of the earth's crust is aluminium, where it is the third most abundant element after oxygen and silicon. Technically, aluminium can be extracted from many different ores, and the supply is then in theory unlimited. However, bauxite is the only ore that is used for commercial extraction of aluminium today. However, the aluminium industry recognizes that availability of bauxite resources may become a constraint in the longer term, and that it may have to be prepared for other ores than bauxite in the future.
- **Alumina Refining:** 6.5-t tons of bauxite are required to produce one tonne of alumina. For logistic reasons, most alumina refineries are located close to the bauxite mine, or at the nearest harbour, where the alumina can be shipped. Bayer process is used to extract the alumina from the bauxite, the aluminous minerals in bauxite are dissolved in a hot solution of caustic soda (sodium hydroxide) and lime (calcium oxide). Insoluble materials are then separated from the sodium aluminate solution in thickeners and filters. The process residue is then washed, combined, and then stored in a landfill. The wash water, containing caustic soda, is recycled to the process. Aluminium hydroxide is precipitated by cooling of the liquid and adding crystal seeds. The precipitate is filtered and washed to remove and recover entrained caustic solution. Aluminium hydroxide is calcined in kilns at temperatures in excess of 960°C. Free water and water that is chemically combined are removed to produce commercially pure alumina.
- **Primary aluminium production processes:** The basis for all primary aluminium-smelting plants is the Hall-Héroult Process. Alumina is dissolved in an electrolytic bath of molten cryolite (sodium aluminium fluoride, Na_3AlF_6) within a large carbon or graphite lined steel container known as a "pot" and electric current passed through the electrolyte at low voltage, but very high current, typically 200,000 amperes and up to 500,000 amperes for the latest generations. The electric current flows between a carbon anode (made of petroleum coke and pitch, and a cathode (formed by the thick carbon or graphite lining of the pot). The carbon anode is consumed in the process, releasing CO_2 with the potgas. Molten aluminium is deposited at the bottom of the pot and is siphoned off periodically, taken to a holding furnace, which may =be alloyed with other alloying elements if required, cleaned and then cast into different semi-products.
- **Aluminium products:** The most common methods for processing primary aluminium are extruding, rolling and casting.

- **Extruded products –** Extrusion logs (billets), 4 to 7 meters in length and from 15 to 30 centimetres in diameter, are the basis for extrusion. The logs are cut into suitable lengths and heated prior to extrusion. After extrusion, the sections are cooled and hardened, and then surface treated if required.
- **Rolled products –** Rolling sheet ingots (Slabs), 4 - 8 meters long and up to 60 centimetres thick, are heated and rolled into strip 2 - 6 mm thick (hot rolling). Aluminium strip can also be cast directly from molten metal in 6 millimetre thicknesses (strip casting). The strip is cooled and rolled to the actual strip thicknesses (cold rolling) and heat treated. A quarter of the finished rolled strip is coated in strip coating facilities.
- **Cast products –** Secondary foundry alloys are mainly used either as molten metal directly from the plants or in the form of ingots for casting finished products. The most common alloy materials added to aluminium are copper, magnesium and silicon. For reasons of quality, the grain refining substances strontium, sodium, or titanium/titanium boride, are added in small quantities.

2.2. Sustainability Issues in Global Aluminium Industries

2.2.1 Bauxite

The main raw material for primary aluminium production is bauxite. Aluminium oxide is extracted from the bauxite, and is used in an electrolytic reduction process to produce primary aluminium. It takes roughly 6.5-7 tons of bauxite to produce 2 tons of alumina, which again yield 1 ton of aluminium. Primary aluminium is alloyed with other metals and is then fabricated into a range of products through casting, extrusion and rolling. Bauxite is the widely used material in the production of alumina on a commercial scale. Although currently not economically competitive with bauxite, vast resources of clay are technically feasible sources of alumina. Other raw materials, such as alunite, anorthosite, coal wastes, and oil shales, offer additional potential alumina sources. Synthetic mullite, produced from kaolin, bauxitic kaolin, kyanite, and sillimanite, substitutes for bauxite-based refractories. Silicon carbide and alumina-zirconia can substitute for bauxite-based abrasives but cost more. Aluminium is the most widely distributed metal and is third in abundance of the elements in the earth's crust, following oxygen and silicon. It is nearly twice as abundant as iron and constitutes about 7.85 % of the earth's crust. Due to great affinity to oxygen, aluminium always occurs as oxidized compound. The aluminium bearing minerals are given in Table 01.

Mineral	Chemical formula	Al2O3%
Orthoclase	$K_2O\ Al_2O_3\ 6SiO_2$	18.4
Mica	$K_2O\ 3Al_2O3\ 6\ SiO_2\ 2\ H_2O$	28.5
Kaolinite	$Al_2O3\ 2SiO_2\ 2H_2O$	39.5
Lencile	$K_2O\ Al_2O_3\ 4\ SiO_2$	23.5
Siliminite / Gynite	$Al_2O3\ SiO_2$	63.2
Gibbsite	$Al_2O_3\ 3H_2O$	65.4
Diaspore	$Al_2O3\ H_2O$	85.0
Corundum	Al_2O_3	100
Alunite	$K_2SO_4\ Al_2(SO_4)_3\ 2Al_2(OH)_6$	37
Cryolite	$3NaF\ AlF_3$	29.3
2017	101.0	87.20

Table 01: Aluminium Bearing Minerals

Aluminium ores are in abundance in the world containing 10-30% of aluminium. Most of them are lean ores and aluminium cannot be extracted economically. The aluminium ores must be:

1. Rich in aluminium
2. Contain Al_2O_3 in extractable form

The principal ore for the manufacture of alumina is Bauxite. The Bayer process is the principal industrial means of refining bauxite to produce alumina (aluminium oxide). The majority of global alumina production is through Bayer's process. India is endowed with good quality of bauxite ore and it is currently the fifth largest deposit in the world. Deposits of bauxite of commercial importance are located near, Katni, Bilaspur, Mandla, Surguja and Jashpur in Central India, Belgaum (Karnataka), Ranchi (Jharkhand). Tamil Nadu, Orissa and Gujarat also possess good deposits of bauxite. Bauxite found in India varies in composition and properties. It presents certain chemical peculiarities, which are not generally found in bauxites elsewhere in the world. Indian bauxites, the mineralogy varies from source to source. They are mainly of the tri-hydrate type, but some deposits contain varying amounts of monohydrate with tri-hydrate. As per the latest USGS Mineral Industry survey the world bauxite resources are estimated to be 55-75 billion tones. The distribution of World bauxite resources located in major Countries are presented in Table 02 and world production of bauxite is presented in Table 03.

Sl. No.	Country	Bauxite (MlnT)	Percentage of World Total
01	Guinea	18.4	28.8%
02	Australia	13.5	21.1%
03	Vietnam	6.5	10.1%
04	Brazil	5.3	8.3%
05	China	4.0	6.3%
06	India	3.8	5.9%
07	Cambodia	2.3	3.6%
08	Indonesia	1.6	2.5%
09	Cameroon	1.3	2.0%
10	Guyana	1.1	1.7%
	Others	6.2	9.7%
	Total	64.0	

Table 02: Reserve Position of Bauxite

Sl. No.	Country	Bauxite (MlnT)	Percentage of World Total
01	China	91.2	30.7%
02	Australia	86.2	29%
03	Brazil	34.5	11.6%
04	Guinea	28.2	9.5%
05	India	24.6*	8.3%
06	Jamaica	9.3	3.1%
07	Russia	5.8	2.0%
08	Saudi Arabia	3.2	1.0%
09	Guyana	2.0	0.7%
10	Venezuela	1.7	0.6%
	Others	10.6	3.5%
	Total	297.3	

*IBM Data

Source: Wood Mackenzie

Table 03: World Bauxite production

2.2.1.1. Bauxite mining operations

The vast majority of world bauxite production is from surface mines and very limited from underground excavations. Bauxite may be covered by an overburden of rock and clay, which has to be removed before mining of the bauxite. Mined bauxite is generally loaded into trucks or railroad cars and transported to crushing or washing plants and then to stockpiles. Many bauxite deposits contain various other minerals, which have to be removed by some combination of washing, wet screening and cycloning.

2.2.1.2. Environmental issues related to bauxite mining

Due to its location close to the surface and relatively shallow thickness, bauxite mining involves disturbance of relatively large land areas. On average one square meter of land is mined (including roads and infrastructure) in order to give one tonne of aluminium metal. The annual worldwide encroachment on new land related to bauxite mining is about 40-50 square kilometres. This means that although the resource is spread out, the area opened at any time is normally small.

Depending on the local circumstances, the mining operations may involve a number of environmental issues:

- Change of landscape
- Control of erosion and run off from the mine
- Disturbance of hydrology
- Waste disposal (tailings)
- Dusting/noise due to mining operations and transport of bauxite

Loss of bio-diversity and eco-systems are among the world's top environmental issues, and tropical forest areas are among the most threatened areas. Mining in such areas may therefore be controversial. According to the United National Food and Agriculture Organization, it is estimated that the global rate of destruction of tropical forests is about 80 000 square kilometres per year. About 20 percent of the 40 square kilometres annual land taken by bauxite mining is in tropical forest areas.

2.2.2 Alumina Refining

Between two and four tonnes of bauxite are required to produce one tonne of alumina. For logistic reasons, most alumina refineries are located close to the bauxite mine, or at the nearest harbour, where the alumina can be shipped out. The Bayer's process is used to extract the alumina from the bauxite where aluminous minerals in bauxite are dissolved in a hot solution of caustic soda (sodium hydroxide) and lime (calcium oxide). Insoluble materials are then separated from the sodium aluminate solution in thickeners and filters. The bauxite residue is then washed, combined, and then stored in a landfill. The wash water, containing caustic soda, is recycled to the process. Aluminium hydroxide is precipitated by cooling of the liquid and adding crystal seeds. The precipitate is filtered and washed to remove and recover entrained caustic solution. The aluminium hydroxide is calcined in kilns at temperatures in excess of 960°C.

2.2.2.1. Environmental Issues Related to Alumina Production

The main environmental issues related to alumina production are:

- Disposal of the bauxite residue (red mud)
- Energy consumption / energy efficiency
- Water management
- Physical footprint of the plant with infrastructure and the red mud disposal area

Disposal of the bauxite residue is a challenging aspect of alumina production due to relatively large volumes, occupying land areas, and due to the alkalinity of the residue and the run-off water. The industry is moving away from storage of the residue in slurry form in lagoons towards dry stacking. Dry stacking allows the residue to be stored in higher piles, using less land and eliminating risk of flooding adjacent areas. Modern bauxite residue stockpiles are lined with an HDPE (high density polyethylene) liner and enough buffer capacity to manage run-off, avoiding uncontrolled spills and leakages to the environment. The run-off water from the stockpile is either neutralized before discharge, or recycled to the process. Dry stacking allows for better recovery of the caustic liquor entrained in the residue.

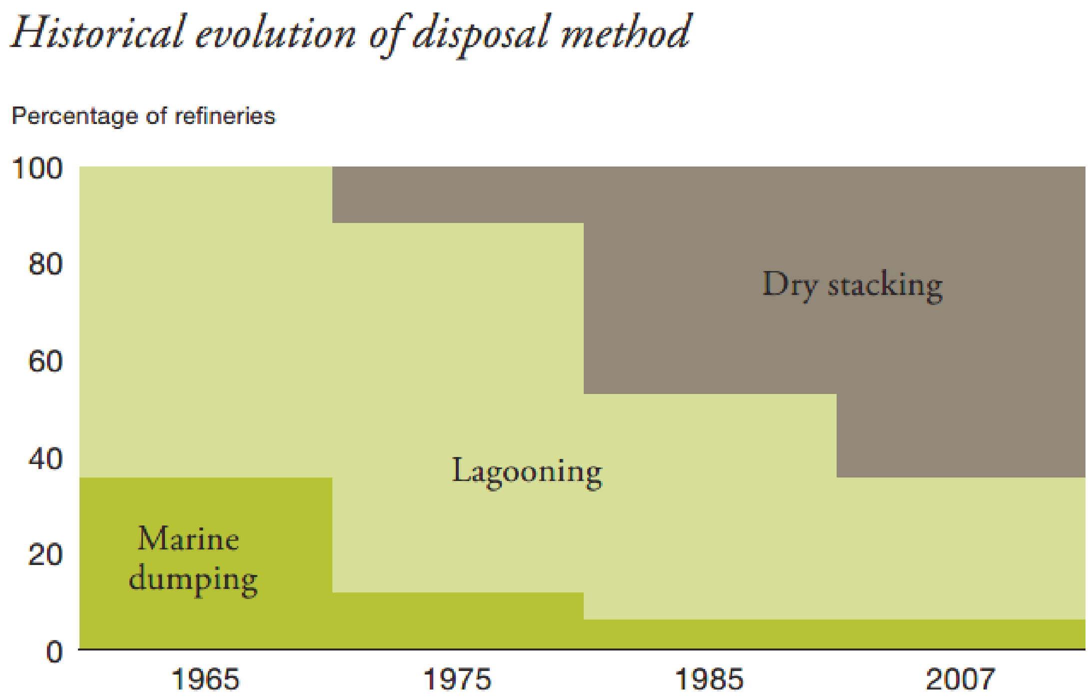


Figure 2: Historical evolution of disposal method (Hydro)

2.2.3 Production of Primary Metal

Production processes for all primary aluminium-smelting plants is the Hall-Héroult Process, invented in 1886. Alumina is dissolved in an electrolytic bath of molten cryolite within a large carbon or graphite lined steel container known as a "pot". An electric current is passed through the electrolyte at low voltage, but very high current, typically 200,000 amperes and up to 500,000 amperes for the latest generations. The electric current flows between a carbon anode (positive), made of petroleum coke and pitch, and a cathode (negative), formed by the thick carbon or graphite lining of the pot. The carbon anode is consumed in the process, releasing CO2 with the potgas. Molten aluminium is deposited at the bottom of the pot and is siphoned off periodically, taken to a holding furnace cleaned and then cast into unalloyed ingots and different semi-products. An aluminium smelter consists of one or more "potlines". Each of them typically counts around 300-350 pots and may produce 100-300,000 metric tons of aluminium annually. A typical smelter will produce 300,000 metric tons per year and the largest ones up to 1 million metric tons. Almost 30-40% of smelting cost accounts for power required for electrolysis process. For making Aluminium Industry cost effective, Aluminium sector should be treated with par with core sector for linkage coal & supply should be made like IPP. For better energy security, coal blocks should be provided to the Aluminium Industry.

2.2.3.1. Environmental issues related to primary aluminium production

The main issues related to production of primary aluminium are:

- Energy production, transmission and consumption
- Emissions of greenhouse gases
- Emissions of fluoride, SO2, dust and PAH
- Liquid effluents
- Waste disposal

2.2.3.2. Energy supply issues

Because aluminium production is energy-intensive, energy costs constitute a decisive part of overall production costs of aluminium. Energy costs may account for about 20-40 percent of the total production cost, depending on local power prices. Historically, the development of a smelter has often been a trigger for developing a local power source, and vice versa. Due to limited transmission capacity in earlier days, the smelters also had to be located close to the power source.

In industrialized countries, aluminium plants are typically exposed to market prices on energy, either directly or via long-term contracts. Several of them are struggling to survive due to increasing power prices. Because aluminium is a globally traded commodity, producers are unable to transfer these regional costs to their customers. This has already resulted in plant closures, although many of the plants in the developed countries have better environmental performance than other developing countries. It is therefore a major challenge for policy makers to create a "level playing field", where those plants which are really the best, will survive.

2.3 Aluminium as a Strategic Sector

Many industrialized nations have classified non-ferrous metals/ aluminium industry as a strategic sector in their industrial strategy.

- China in 2006 identified the aluminium sector amongst the nine 'pillar' industries where the government was supposed to play a predominant role.
- USA has recognized aluminium as a strategic metal for Defence, National Security and Critical Infrastructure.
- Russia identifies aluminium as a strategic metal for defence. The Ministry of Industry and Trade (MIT) has approved a development strategy for non-ferrous industry up to 2030.
- South Korea's heavy industry drive in 1973 identified six strategic sectors including non-ferrous metals where the government provided benefits like low interest rates, reduced tax liability etc. to drive the growth of specific sectors.
- European Union has drafted a strategic vision for non-ferrous metals titled, "Non-ferrous Metals Manufacturing: Vision for 2050 and Actions needed" (2017). It defines, "(1) a long-term vision for the non-ferrous metals manufacturing industry and (2) proposes concrete actions for the industry, policymakers, and other stakeholders, to address the challenges faced by the sector (trade and competition, innovation, resources, business integrity and skills) on its path towards the vision."
- Canada provides support to aluminium plants in Quebec province. Quebec Aluminium Development Plan (2015 – 2025) focuses on financial support for R&D, new projects, carbon footprint, and export incentives.
- Taiwan in 1982 categorized Non-ferrous as a strategic sector where government provided preferential measures like low interest rate loans and technology and management assistance.
- Malaysia's 2017 draft industry plan recognized metal as a focus sector with high potential for growth and identified policy interventions to support the industry.

- In Indonesia too, pioneer sectors were expanded to include upstream metal in 2015. Benefits like tax holiday scheme, accelerated depreciation and amortization, compensation losses extended from 5 to10 years have been provided.
- Aluminium is a key sector for Dubai's industrial growth and a part of Dubai and UAE's Industrial strategy for 2030. As a part of the strategy, hosts of benefits are provided including low corporate tax, cheaper electricity costs and easy access to financing and capital.

Aluminium can also be endlessly recycled with only 5% of energy & emissions needed to produce a new aluminium product. Aluminium availability is critical to achieve low carbon footprint using wind, solar and energy storage batteries as per a World Bank study 2017. According to a World Bank study titled, "The Growing Role of Minerals and Metals for a Low Carbon Future", Aluminium will play a significant role in achieving low carbon footprint. Using wind, solar, and energy storage batteries as proxies, the study examines which metals will likely see a rise in demand to deliver a carbon-constrained future. Recycling is one of the easiest ways to the industry carbon footprint

3.0 Indian Aluminium Industry

The Indian Aluminium industry is forging ahead with rapid expansion in both primary metal and downstream sectors. With the continuing trend of economic growth, the demand and consumption of aluminium is expected to increase rapidly. India's downstream processing industry is likely to witness a phenomenal progress in coming years as growth of aluminium consumption looks imminent through value added products. Aluminium consumption in India is poised to grow from current levels of 3.3 million tonne in 2015-16 to 5.3 million tonnes in 2020-21. Per capita aluminium consumption in India is only 2.5 kg against world average of 11 kg and 24 kg in China (Figure 3). There is huge potential for increasing the consumption of aluminium due to government initiatives like, Make in India, Smart Cities, Housing for all, rural electrification, freight corridors, bullet trains, power to every household, energy efficient/electric automobile, aluminium wagons and many more. Aluminium is already set to play a key role in the progress of industrial development in India because it serves as a basic input for a number of industries apart from its use as a strategic metal (Figure 4). In everyday life, one finds aluminium in large number of applications, starting from household utensils to space vehicles. Today's engineering demands materials that are lightweight, strong, corrosion resistant and with good aesthetics. The materials need to meet the ever demanding structural, thermal, aesthetic and acoustic challenges of the 21st century. An obvious choice of material is aluminium with its unique properties, making it an innate partner for many applications. Aluminium is indeed a versatile metal and can be termed as a "Metal of the Century" with a host of areas and methods of application. This "Wonder Metal" is light, ductile, good conductor of heat and electricity, nonmagnetic, nontoxic, corrosion resistant and decorative. It can be alloyed with copper, magnesium, zinc, silicon, manganese, etc. to form various kinds of cast, rolled, extruded, forged, and drawn products. Aluminium is also environmentally friendly that it can be called "Green Metal" and it has become the thrust non-ferrous metal of the future and is also going to be called as "Metal of Future".

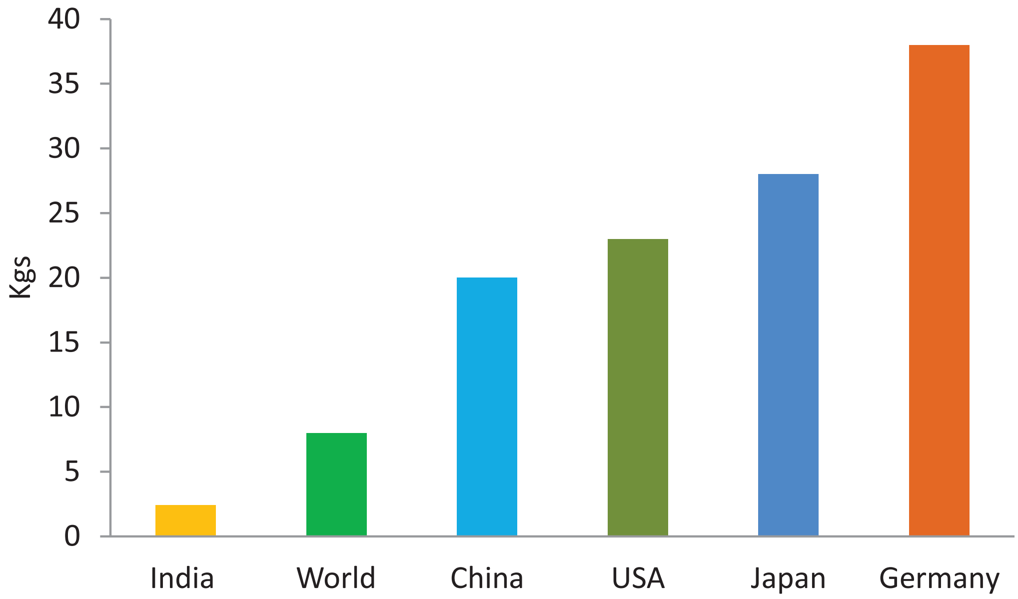


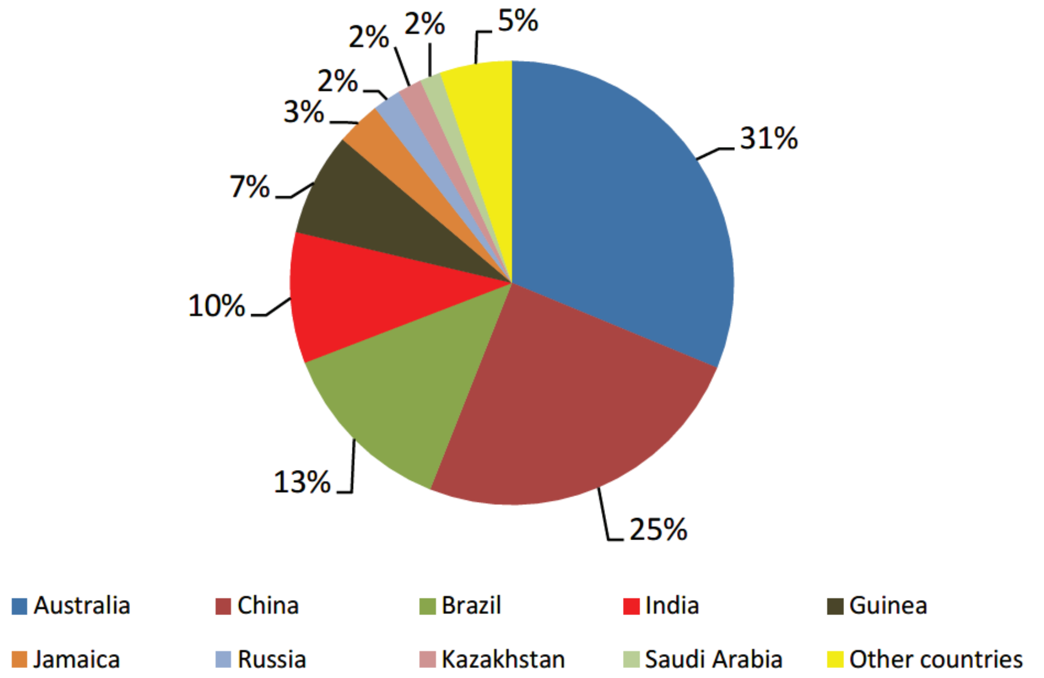
Figure 3: Per capita aluminium consumption

Figure 4: Impact of various sectors on Al, Cu & Zn (KPMG India's analysis, 2017)

The aluminium industry in India is strategically well-placed and is one of the largest producers in the world with discernible growth plans and prospects for the future. India's rich bauxite mineral base renders a competitive edge to the industry as compared to its counterparts globally. The Indian aluminium industry in India scaled lofty notches since the establishment of the first manufacturing company, namely, Indian Aluminium Company (INDAL) in 1938.

3.1 Bauxite

India is the fourth largest bauxite producer (Figure 5) India has 593 million tons of bauxite reserves and is naturally endowed with large deposits of gibbsitic bauxite. According to Indian Bureau of Mines there are reported 152 mines of which 134 operate in the private sector and 18 mines fall under the public sector. State of Odisha ranks 1st in production of bauxite and is followed by Gujarat, Jharkhand and Maharashtra. The abundant reserves of bauxite have made India a net exporter of bauxite. Bauxite is primarily used for the production of alumina, other than that it is also used in refractories, abrasives, chemicals, aluminous cements, and miscellaneous products like proppants.



Source: United States Geological Survey (USGS) minerals commodity handbook, 2017

Figure 5: World bauxite mine production for calendar year 2016

Production of bauxite is growing at a healthy rate of 10.5% CAGR from FY 2012-13 to FY 2016-17 (Figure 6). As India has bountiful bauxite reserves and mining potential, there is a constant rise in the production and mining of bauxite. On the other hand apparent consumption is growing at a CAGR of 18.4% from FY 2012-13 to FY 2016-17. Till FY 2015-16 India was consuming around 75%-80% of the bauxites produced while the rest of the commodity was being exported. Now due to the rise in the demand of aluminium in the domestic markets there has been a sudden drop in the exports in FY 2016-17.

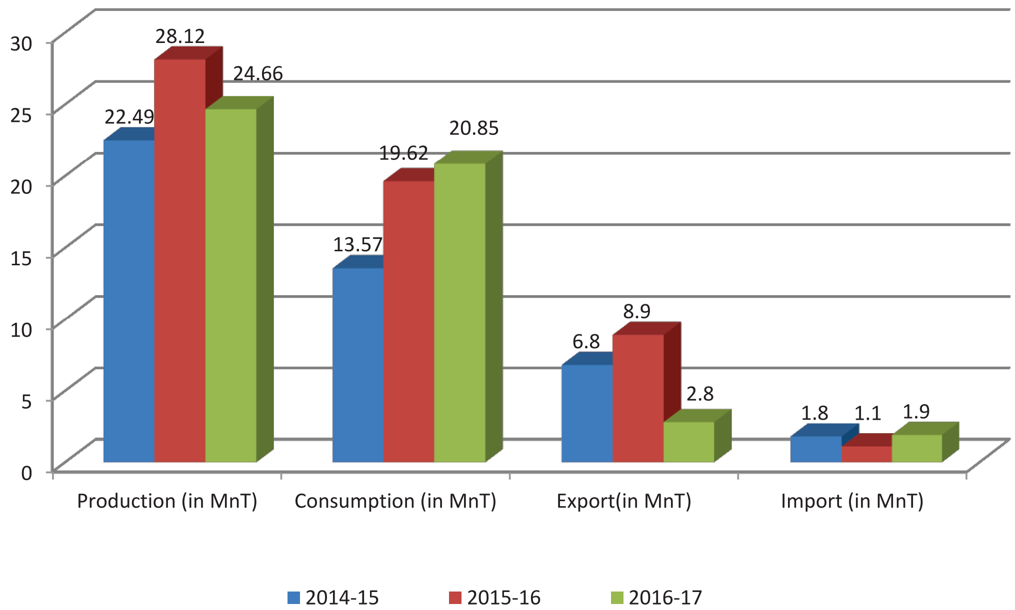


Figure 6: Production & consumption of bauxite & export-import trend

India exports bauxites to China, Nepal, Saudi Arabia, France, Japan, Slovenia, USA, UK, Oman, Italy and Kuwait. China is the main importer of bauxites from India, almost to an extent of 90% of the total bauxite exports. Imports are quite negligible in comparison to the exports but whatever little India imports its' from Guinea and Brazil. With abundant quantity of high-quality bauxite available in country the availability of good quality of bauxite for refractory is limited and hence the country has to import good quality of refractory grade and even metallurgical grade of bauxite through imports. The import of bauxite was 11,16,010 tonnes in 2015-16 and 18,94,927 tonnes in 2016-17. Similarly, India is exporting bauxite to china and other countries and the quantities exported are 89,14,624 tonnes in 2015-16 and 27,90,675 tonnes in 2016-17.

3.2 Coal

Fossil fuels are the major drivers of the economy and coal continues to be a major source of energy for India. Power sector consumes the most coal, while a large consumer, tends to switch to alternatives such as pet coke when coal prices are high. They use cheaper alternatives to reduce operation costs. Steel and sponge iron do not have alternatives to their coal requirements. As Indian aluminium industry is largely dependent on captive power plants which operate on coal-based systems policy issues that affect power sector from generation, transmission, transport and fuel mix will impact coal demand growth.

Coal deposits are mainly confined to eastern and south-central parts of the country. The states of Jharkhand, Odisha, Chhattisgarh, West Bengal, Madhya Pradesh, Telangana and Maharashtra account for 98.20% of the total coal reserves in the country. The State of Jharkhand had the maximum share (26.16%) in the overall reserves of coal in the country as on 31st March 2017 followed by the State of Odisha (24.52%). As on 31.03.17, the estimated reserves of coal were 315.14 billion tonnes, an addition of 6.34 billion tonnes over the last year. There has been an increase of 2.05% in the estimated coal reserves during the year 2016-17 with Maharashtra accounting for the maximum increase of 7.15%. The estimated total reserves of lignite as on 31.03.17 was 44.70.

3.3 Alumina

Once the bauxite passes through the Bayer process of manufacturing, the finished product is alumina. Alumina is processed in the refinery plants. Metallurgical alumina is used for the manufacturing of aluminium. Chemical alumina and hydrates are used in range of industries including water treatment, fillers in cables and plastics, refractories and ceramics, glass among others.

Smelter-grade alumina accounts for 90% of all alumina produced; it is transported to aluminium plants, where it is electrolyzed into aluminium metal.

According to the recent USGS report, India ranks 4th in terms of production of Alumina and India also produce 5% of the world alumina (Figure 7). China leads in terms of alumina production. Domestic Alumina plants are owned by the dominant three players of the aluminium industry of the country i.e. Government of India, Aditya Birla & Vedanta.

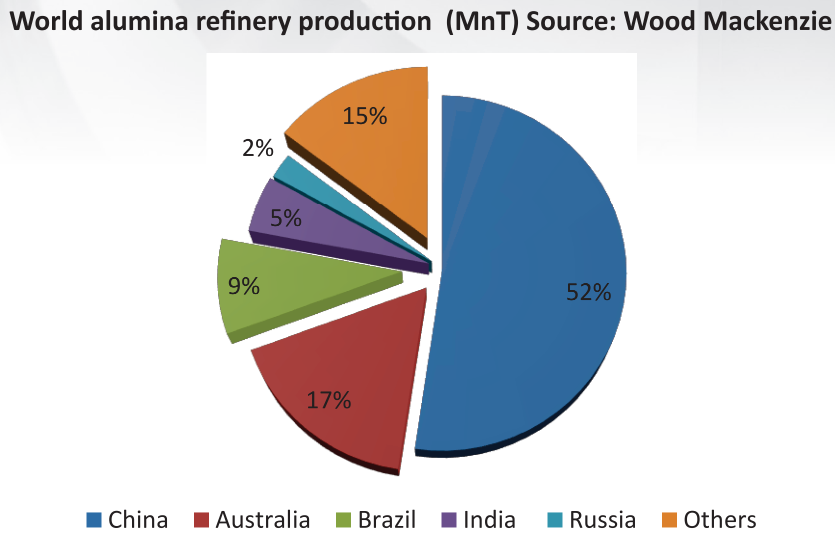


Figure 7: World alumina refinery production for calendar year 2017

Domestic Alumina production is increasing at a growth rate of 13.7% CAGR from FY 2012-13 to FY 2016-17 (Figure 8). In terms of production there has been an 8.4% increase y-o-y from FY 2015-16 to FY 2016-17. Most of the alumina produced is used for domestic consumption i.e. by the respective companies which manufacture it, for the manufacturing of aluminium metal.

The surplus alumina is exported. Consumption of alumina on the other hand is growing at a growth rate of 11.6% CAGR FY 2012-13 onwards. There has been a 12.5% y-o-y increase in from FY 2015-16 to FY 2016-17 of alumina consumption. An increase in the consumption of alumina is reflected in the production of aluminium.

India is a net exporter of alumina as most of the companies in the aluminium sector are backward integrated, i.e. 'Backward integration' refers to the ownership of mines to fulfil its ore requirement. Those players who have access to bauxite mines, further process the ore to alumina and export a certain amount of alumina which is left out after captive consumption. Other players, who do not have access to bauxite mines, either import the ore or alumina to feed their refinery/smelters. With a growth in consumption of aluminium there has been a rise in the imports for alumina.

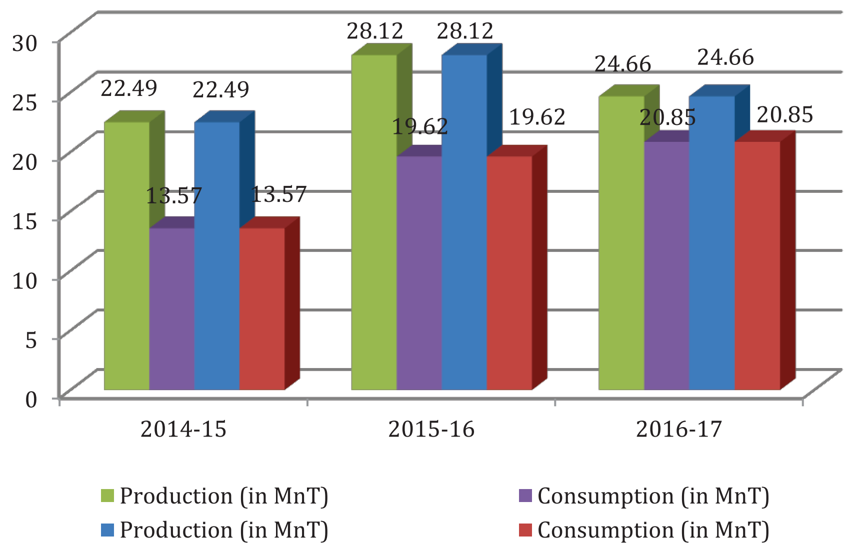


Figure 8: Production -consumption & export-import trend of alumina

Refineries are supplied power from the captive power plants. The regional trend of capacities clearly indicates that the new capacities for alumina refining have emerged in the close vicinity of bauxite reserves as against the close proximity of cheap power. Each player is trying to backward integrate himself by focusing on securing its raw material requirements, as the bauxite cost is one of the key elements in determining the cost of production. The acquisition of mines or mining rights has huge gained importance and the companies, who have achieved to do so, have grown stronger and are more able to survive in the down-turns Vedanta Alumina refinery is located at Odisha, Lanjigarh. Hindalco alumina refinery is located in the state of Odisha (Utkal), Jharkhand (Muri), Uttar Pradesh (Renukoot) and Karnataka (Belgaum). NALCO refinery is also located in Odisha (Damanjodi).

In India most of the alumina refineries are situated in east coast which consist of Public sector undertaking National Aluminium Company having capacity of 2.275 million ton/annum at Damanjodi in Koraput district in Odisha following Atmospheric pressure digestion Technology supplied by Rio Tinto Alcan (RTA). The plant is going to expand its production capacity in 5th Phase to 3.275 Million tons/annum in which the new line will be medium pressure digestion technology. Vedanta Alumina Refinery at Lanjigarh is having a rated capacity of 2.0 Million ton/annum following medium pressure digestion technology. The company due to problem of bauxite in the last financial year could attain a capacity was 1.2 Million tons/annum in 2016-17. The Utkal Alumina Refinery at Rayagada following Medium pressure digestion technology in Odisha is having a rated capacity of 1.5 Million tons/annum. The refinery on the west coast is Hindalco Belgavi alumina refinery following medium pressure digestion technology is having rated capacity of 0.39 Million tons/annum. The alumina refinery of Hindalco following double digestion technology at Renukoot has rated capacity of 0.75 Million Ton/annum. The Hindalco Alumina Refinery at Muri is following double digestion technology and is having a rated capacity of 0.45 Million Ton/annum. The Anarak Aluminium Refinery at Visakhapatnam has installed capacity is 1.5 Million Ton/annum following medium pressure digestion technology but it is yet to start its production due to bauxite problem. The rated alumina capacity in India is 6.560 Million ton/annum. Indian alumina refineries produced 5.62 Million ton/annum of alumina in 2015-16 and 6.20 Million ton/annum of alumina in 2016-17. The installed capacity of Indian alumina refineries along with their location are given in Table. 4.

Name of the Unit	Installed Capacity Million ton/annum	Actual Production Million ton/annum
National Aluminium Company, NALCO, Damanjodi	2.275 expanding production to 3.275 after 5th Stream commissioning	2.275
Hindalco, Renukoot	0.75	0.75
Hindalco, Belgavi	0.39	0.39
Hindalco, Muri	0.45	0.45
Utkal Alumina Refinery at Rayagada of Aditya Birla	1.5	1.5
Vedanta Alumina Refinery at Lanjigarh	2.0	1.2

Table 04: Production capacity of alumina refineries in the domestic markets

Problem faced by Alumina Refineries (Bauxite & Red Mud)

Red mud is a waste product of the industrial process of extraction of Aluminium Oxide or Alumina from the ore bauxite. Every 1 million ton of Alumina production generates about 1.4 to 1.5 million tons of red mud. The red mud comprises of 50 to 55% iron oxide and also other associated metals in small amounts. At present, no suitable technology is available to extract iron oxide from red mud. Emphasis is to be given to develop suitable process for extraction of iron oxide and other metals from red mud economically.

Bauxite has been one of the major problems faced by refineries like Vedanta Alumina refinery at Lanjigarh which do not have captive mines. They had to purchase bauxite from mine owners from Chattisgarh, Gujarat and Odisha. Due to non –availability of consistent good quality bauxite, they had to import bauxite from Guinea and use it for blending with other bauxite to produce alumina at high operating expenses. Similarly, Anarak Aluminium company at Vishakapatnam could not start production due to naxalite problem in mining Jarrela bauxite at Andhra Pradesh.

Apart from these the other major problem faced by all alumina producers worldwide is due to red mud produced in the process of alumina extraction from bauxite. Usually for the production of 1 tonne of alumina generates 1.0 - 1.5 tonnes of red mud depending upon the mineralogical composition of the bauxite and extraction efficiencies. Thus for 1 tonne of aluminium production approximately 2.0-3.0 tonne of red mud is generated. The disposal of red mud is a major problem in alumina plants throughout the world. Red mud is highly alkaline, which is a potential pollution threat to water and land of close proximity of the alumina refinery plant. In this context, development of its effective handling, storage, usage and management therefore stands as a burning issue for the global community as a whole. Meanwhile, high costs are associated with the large area of land needed for storage of the residue and also the polythene lining on the surface in the storage pond provided to avoid ground water contamination. The treatment and utilisation of high-volume red mud waste has been a major challenge for the alumina industry. A typical chemical analysis would reveal that red mud contains soda, silica, aluminium, iron, calcium, titanium, as well as an array of minor constituents, namely: K, Cr, V, Ni, Ba, Cu, Mn, Pb, Zn, Ga etc. In red mud sodium is present in two forms: free soda and bound soda form. Free sodium is the caustic soda in the entrained liquor of red mud slurry which gets incorporated during digestion process and remains with red mud in spite of repeated washings. The red mud generated from Indian alumina refineries can be roughly divided into two categories, namely those generated from east coast bauxites which contain high amount of iron and low titanium and other generated using central India bauxite. The Table.6 Shows the typical composition of the red mud generated from east coast and central Indian bauxite.

S. No.	Constituent	Red Mud generated from East Coast Bauxite (Weight %)	Red Mud generated from Central Indian Bauxite (Weight %)
1	Al2O3	18 - 20	18 - 20
2	Fe2O3	50 - 55	35 - 37
3	TiO2	4.0 - 5.0	18 - 20
4	SiO2	5.0 - 6.0	7.0 - 9.0
5	Na2O	4.5 - 6.0	5.0 - 6.0
6	CaO	0.1 – 0.6	1 – 2
7	L.O.I	11 -12	11 -12

Table 05: Typical composition of the Indian red mud generated.

Presently a lot of research has been carried out for utilization of red mud for manufacture of red mud bricks using fly ash and other additives. The quality of bricks produced are of good quality but the biggest hurdles is the transportation cost and difficulties involved in removing red mud from red mud ponds which are located at remote areas. Thus, when the process is technically feasible the commercial viability of the process is limited unless the government offers some subsidy and sops for the entrepreneurs and assures purchase of their product. Use of red mud bricks/blocks will help in saving a large amount of natural resources like clay which are primarily used for manufacture of bricks. The use of red mud bricks and blocks will be very much useful in realizing the dream of prime minister of housing for all by 2022.

International Scenario of Red Mud Disposal & Utilization

The approximate world production of red mud is 75 Million Ton/annum out of which presently Indian Alumina Refinery is contributing around 8.34 Million/Ton annum of red mud. Presently a large amount of secure landfill is used for storing red mud with mostly wet disposal system. Many alumina refineries have switched to dry or semi-solid disposal method to reduce the land requirement for storage of land. A number of alumina manufacturers worldwide has carried out research activities for using red mud for various applications such as constructional bricks/blocks, pavers, as soil amendments etc. But still no process has gone for commercialization as many of the red mud generated in Australia and Jamaica showed radioactivity thus stopping its use for constructional bricks and block application. Presently most of the alumina refineries worldwide are either going for recovery of iron from red mud using low cost reductant and cheap electricity but none of the process has been commercialized. Most of the refineries are storing red mud in ponds.

Presently there is need to utilise and recover the different mineral values from red mud such as iron, titanium and rare earths. The main objective is to minimise the waste generation by recovering the mineral values. The iron phase minerals are almost 40-60% in the red mud. If 70-80% of iron values can be recovered, a good amount of waste generation can be minimised. The major challenge is to aim for bulk utilization of red mud in a reliable manner.

Every alumina refinery has a captive power plant through which it satisfies its power needs as well it is a cogeneration plant supplying steam at low pressure and medium pressure for digestion, pre-desilication and evaporation units. Most of the alkaline condensate obtained is utilized for red mud washing while the remaining amount is neutralized.

3.4 Aluminium

The end product once alumina is passed through the Hall-Heroult process is aluminium. Primary aluminium which is initially in liquid form is casted into extrusion ingots, sheet ingots or foundry alloys, all depending on what it will be used for. Aluminium is three times lighter than iron but it is as strong as steel, extremely flexible and corrosion resistant due to the thin layer of aluminium oxide. Aluminium has been continuously finding new applications due to rising price competence, superior weight to strength ratio, corrosion resistance, formability and dampness.

Accordingly to CRU, India ranks 3rd in terms of primary aluminium production. China continued to be the single largest producer of aluminium, contributing 57% of the total world production.

World primary aluminium production (MnT) - Source: CRU

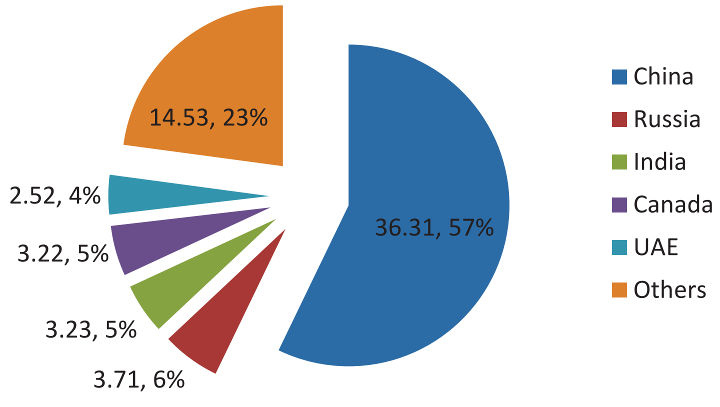


Figure 9: World primary aluminium production 2017

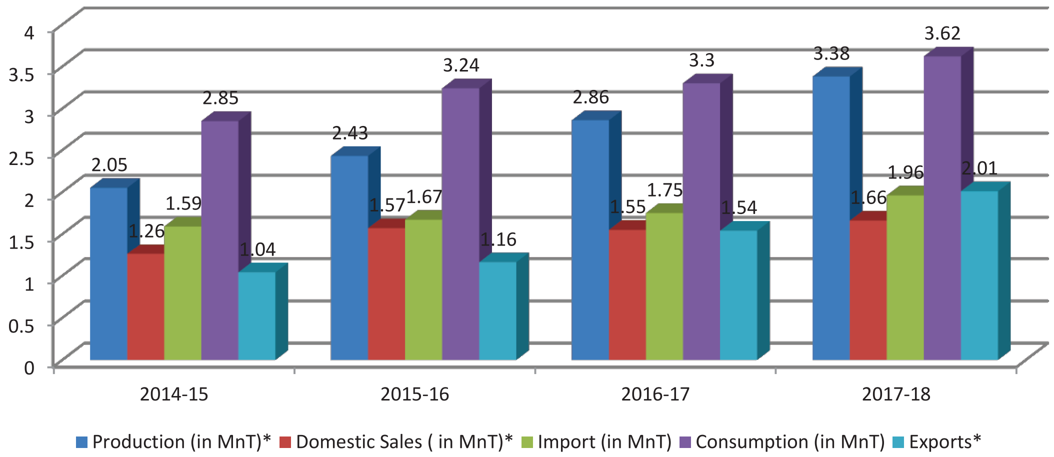
Three major primary producers, National Aluminium Co. Ltd, Hindalco Industries Ltd, and Vedanta Aluminium Ltd (VAL) are at the forefront of aluminium production. Their installed capacity is presentable in Table 02. The primary producers have a strong presence in the sheet business and are enlarging their roles in the foil segment. The primary producers are also in the extrusion segment in which a large number of secondary manufacturers participate with fragmental capacities.

Company	Smelting Capacity (MT)	Location	Remarks
NALCO	4,60,000	Angul, Odisha	
HINDALCO	13,54,000	Renukoot, UP & Hirakud, Odisha	Renukoot : 4.30 Lakh MT Hirakud : 2.06 Lakh MT. Mahan, Madhya Pradesh: 3.59 Lakh MT, Aditya Aluminium, Odisha: 3.59 Lakh MT
BALCO	5,75,000	Korba, MP	
Vedanta Ltd.	17,40,000	Jharsuguda, Odisha	Jharsuguda I : 5.50 Lakh MT capacity ; Jharsuguda II : 11.90 Lakh MT capacity
TOTAL	41,29,000		

Table 06: Installed capacity of aluminium (by producers)

Primary domestic aluminium production is growing at a CAGR of 13% from FY2012-13 onwards (Figure 10). Production of aluminium needs abundant amount of energy. Domestic players rely on coal-fired captive plants for power and fuel requirements. Power accounts for 30% of the total cost of production for aluminium. Indian manufacturers have an advantage of abundant source of bauxite, access to cheap labour and access to captive power plants which aid in increasing the efficiency of the production.

Consumption of Aluminium on the other hand is growing at a CAGR of 3% from FY 2012-13 onwards. Surplus stock is exported mainly to South Korea, Malaysia, Mexico, Italy, Turkey, USA, Taiwan, Spain, Japan, Indonesia, Bangladesh, Singapore, Brazil and Netherlands. South Korea accounts for around 38% of overall primary aluminium exports of India followed by Malaysia at 14%. Exports of aluminium ingots are growing at a CAGR of 48% from FY2012-13 to FY2016-17. Exports of aluminium ingots have been increasing on a y-o-y basis, 21% from FY 2014-15 to FY 2015-16 and 52% from FY 2015-16 to FY 2016-17.



*includes figures pertaining to primary aluminium producers only.

Figure 10: Production -consumption & export-import trend of primary aluminium

Indian players are constantly increasing their production capacities to cater primarily to the domestic markets and to export the surplus stock to countries deficient of aluminium. Cost of production plays an important role in differentiating companies within the industry. It is the most important primal point, which helps a company strategize to remain competitive with respect to its peers. Cost of production of an aluminium manufacturing company can vary significantly depending upon the availability of its own resources. The more the company is backward integrated, the lesser is the cost of production. Apart from the mining rights, the source of power is also important as it accounts for a significant portion of the aluminium production process.

Vedanta aluminium smelter is located at Odisha (Jharsuguda) and Chhattisgarh (BALCO). Hindalco aluminium smelter is located in the state of Odisha (Aditya Aluminium & Hirakud), Madhya Pradesh (Mahan Aluminium) and Uttar Pradesh (Renukoot). NALCO refinery is also located in Odisha (Angul). Most of the aluminium smelters are located near their respective alumina refineries to save on transportation cost and freight.

Worldwide aluminium is produced by electrolysis of alumina at high temperature (~960 °C) in molten cryolite/ AlF3 bath in electrolysis pot. The electrolysis pot is provided with electrically conductive carbon linings which is act as a cathode in electrolysis pot. During the electrolysis process direct current is conducted into the melt through prebaked carbon anode to electrolyze the dissolved alumina. In the electrolysis process the carbon anode get consumed as per the chemical reaction given below.

$$2\ Al_2O_3 + 3\ C = 4\ Al + 2\ CO_2\uparrow$$

Opposite to carbon anode, the carbon cathode does not participate in any reaction and hence do not get consumed and remain intact in operation for longer period of time. But, over a period of electrolysis pot operations, the carbon lining gradually deteriorates due to penetration of elemental sodium and liquid bath materials into the pores of carbon lining material. This results into the cracks or heaving/swelling of cathode which results into the reduction in the integrity of linings. Pot of this type may be used for considerable periods of time, e.g. up to seven years. The pot is said to be fail when iron is detected in molten aluminium, when cell voltage increases or when pot leaks molten metal or electrolytes. Upon failure of pot, the pot is emptied and cool down. The top most layer of the cathode is called 1st cut SPL which is fully made up of carbon material to provide current and avoid reaction of corrosive bath with refractory linings. Approximate thickness of carbon ling is 380 mm. Adjacent to carbon blocks and on the periphery, there are silicon carbide refractory bricks. Below to carbon lining there is approximate 145-150 mm dry barrier mix to support carbon blocks and reduce the heat loss. Below the dry barrier mix there is 64 mm layer of high strength insulation brick. Below the high strength insulation layer there is approximately 65 mm layer of Hysil bricks. Below Hysil bricks there are 1-2 mm layer of alumina powder and Last one is steel shell.

Once the pot gets cooled down, the various linings of pot (carbon: 60-70% and refractory: 30-40%) are dismantled/removed by mechanical drilling from steel shell either in pot room or working area. Removed/ stripped lining are called spent pot lining or in short SPL. The purpose of stripping/removing of lining from steel shell is to reuse the steel shell for electrolysis process with appropriate repairing and re-lining the pot with new materials. During the stripping process the linings are separated into two fractions named as carbon portion (1st cut SPL) and refractory portion (2nd cut SPL). Due to high toxicity of leachable cyanide and fluoride in SPL, it is generally stored with high precautions in rail cars, dumpsters, or piles prior to treatment and disposal. Recently most of the countries are banned the disposal of SPL in landfill.

SPL is classified as hazardous waste mainly due to presence of toxic fluoride and cyanide that are leachable in water. It is corrosive as it exhibits high pH due to alkali metals and its oxides. It is potentially explosive as it contains Al4C3 and Al2N2 which may produce ammonia and methane gas on reacting with water.

Due to hazardous nature of SPL, Central Pollution Control Board (CPCB, INDIA) has classified SPL from Aluminium Industries as a hazardous waste material under Class A. According to CPCB guidelines, if any material which contains more than 20 mg/lit (TLCP) leachable cyanide more than 180 mg/lit (STLP) leachable fluoride is considered as hazardous waste and classified under class A category of its hazardous-waste-manual guide line (part-II). As per CPCB guide lines hazardous waste could not be used in land-fill and requires safe disposable practices or proper treatment prior to its disposal. As per EPA (Environmental protection Agency), USA definition of hazardous waste under section K088 is leachable cyanide should be less than 30 mg/kg and total cyanide should be less than 600 mg/kg.

Generation of SPL in India and Worldwide

Spent pot lining is a waste material generated in the primary aluminium smelting industry. Recovery of Carbon from spent pot lining and reusing as fuel is a technology challenge. Disposal of spent pot lining or its use in totality is itself a technology challenge to primary aluminium producers.

It is estimated that 20-40 kg SPL is generated per ton of Aluminium produced (Technology dependent). This translates to 1-2 million tons of SPL is generated worldwide per annum. In INDIA there are three major primary Aluminium producers NALCO, INDALCO and VEDANTA. Table 7 presented the per annum Aluminium production by these Aluminium industries. Recently total primary aluminium production in India is reaches to 3.426 million tons per annum which results into the generation of 70,000 - 1,40,000 tons of SPL per annum.

Primary Aluminium Industry	Aluminium Production (Million tons/annum)
HINDALCO	1.28
VEDANTA	1.67
NALCO	0.43
Total	**3.426**

Table 07: Primary Indian Aluminium production 2017-18

Various processes developed worldwide for SPL disposal/treatment

The research on recycling of SPL and industrial application is going on worldwide. At present most of the recycling ways particularly stresses on environmental protection and did not pay comparative attention to economic benefits. Research is going on in the laboratory rather than applied to industry. Some of the methods adopted worldwide for disposal/utilisation of SPL are listed below

Landfill

More than 50 % of the produced SPL is land filled without any special treatment. Legislation varies between countries, but a usual minimum requirement today is storage in a building or a covered pit with a non-permeable base to prevent fluoride poisoning of drinking water from an earlier non-covered SPL site. Storage in a basin on the seashore was an earlier practice in Norway and Iceland. The cyanides were oxidized in a basin and possible runoff of fluorides is not a poison in seawater. A study in Iceland found no ill effect on the marine environment. The practice has, however, been stopped. Today Hydro landfill the SPL in a former limestone quarry on an island in the Oslo fjord.

Use of SPL in other Industries

Addition to cement has been the most successful use of SPL in other industries. The carbon part has caloric value and can be used as fuel substitute mixed with coal. Refractory part is a source of SiO2 and Al2O3. Fluorides are beneficial to the clinker reaction, so that the cement process may run at a slightly lower temperature. The cyanides are destroyed at the cement process temperature. The sodium in the spent potlining is a problem, however. Some cement factories want to produce low sodium cement and may not want to add extra sodium. Generally, a typical addition of SPL to cement is 0.2 %. It is also wanted to have the composition as even as possible and without any aluminium metal particles. Such particles are deleterious in the finished cement. There is also some uncertainty in the industry about any long-term effect. Addition to cement is carried out in France, Russia, Brazil and South Africa.

SELCA ECOINDUSTRY in Italy has used First cut SPL as an additive in steelmaking. The fluorides will improve slag formation and can substitute for CaF2 addition. Use of SPL in steelmaking has been tried in Russia, China, United States and Brazil but the present amounts treated are believed to be small.

Pyrometallurgical SPL Processes

Reynolds, later Alcoa, developed a detoxification process where a blend of pre-sized SPL, limestone and an anti-agglomeration agent are calcined in a rotary kiln using natural gas as the heat source. The concept is that CaO will convert NaF-AlF3 to CaF2 which is much less soluble. The cyanides are destroyed by the process. The product was delisted by EPA, US, as hazardous waste in 1991, but the delisting was repealed in 1997. The reason was that the real leachability of fluorides was higher than demonstrated by the used American test. The test used one single leaching for 18 hours with acetic acid. This test gave an unrealistic low leachability due to buffering of the alkaline SPL. A French test which used distilled water with 3 consecutive leachings for 16 hours gives a much higher leachability. In lack of better processes, the Reynolds process with a controlled landfill is still in operation.

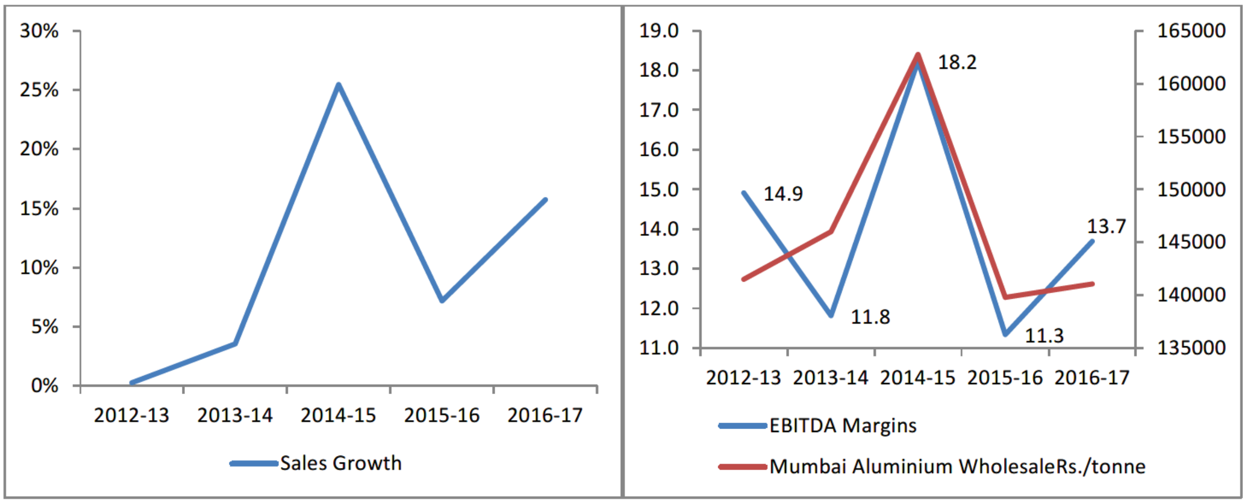
Process developed by JNARDDC relates to processing of the SPL to produce carbon mineral other value-added products. The process steps involve heat treatment of SPL followed by recovery of sodium and fluorine. cyanide free carbon, obtained from SPL could be used as a fuel in boiler, fuel as well as mineralizer for cement industries, recycling into anode, or recycling into ramming pastes based on the quality of carbon residue obtained after treatment. The recovered sodium is useful in the Bayer alumina refinery. During the recovery process no impurities were build-up in the carbon residue and possess higher gross calorific value (GCV) compared to original SPL sample. The Hardgrove grindability index of treated SPL residue (treated) has higher HIG value (55.45) and easily crushable compared to raw SPL. Also, the hazardous elements in treated SPL is much below the permissible limits given by CPCB.

Aqueous Processes for Treatment of SPL

Alcan, now Rio Tinto, has developed the so-called LCL&L (Low Caustic Leaching & Liming) process. The first step is handling and storage in SPL containers. The SPL is ground (less than 300 µm) by an air-swept autogenous mill with air classification and screening to ground SPL storage. The wet sector consists of leaching steps, first with water to extract soluble fluorides and most of the cyanides followed a low caustic to extract the remaining cyanides and fluorides. Carbon and insolubles are filtered out. The filtrate is treated in a pressurized reactor at 180 °C to destroy the cyanides. The liquor after cyanide destruction is concentrated by evaporation and NaF is precipitated out. The remaining liquor is used in an adjacent Bayer plant. NaF may be converted to the less leachable CaF2 by reaction with lime.

3.5 Financials of the Aluminium Industry

The sales realisation and operating profit margins of the domestic aluminium players largely depends on the aluminium prices globally and in the domestic markets. Global commodity prices were extremely volatile during the FY 2014-15 onwards due to the slowdown in the Chinese economy which in turn affected the domestic prices for aluminium which had a direct bearing on the sales growth and operating profit margins of the domestic aluminium players (Figure 11). Higher price of metal in FY 2014-15 has led to a higher growth in sales and increased operating profit margins.



Source: BSE India

Figure 11: Sales growth rate & operating profit margin of Indian aluminium industry

In FY 2015-16, the aluminium industry witnessed significant challenges as the average realisations declined. The price of aluminium globally was 16% lower than the previous year. FY 2016-17 a recovery in the prices of aluminium has also reflected in an improved operating profit margin and sales growth.

India is amongst the lowest cost producers of aluminium across the world, owing to easy availability of raw materials and comparatively labour costs. The growing demand for aluminium in the last decade, driven by India's underlying growth story has resulted into expansion of smelting capacities of the major domestic players. With the addition of new aluminium capacities India aims at not only satisfying the domestic demand, but also play a major role in the global aluminium market.

Production is expected to grow to cater to the domestic demand rise due to various initiatives taken up by the government and the surplus stock will continue to be exported (Table 03 & 04).

With the ramping up of the smelter capacities, India is likely to increase its aluminium production in line with increasing domestic demand. The industry is also likely to be in a position to export the surplus production, owing to its low-cost advantage.

Consumption of Aluminium is picking up pace. Reforms proposed by the Government of India like the Make in India Campaign, Smart Cities, Rural Electrification and a focus on building renewable energy projects under the National Electricity Policy can drive up the consumption of the metal.

	FY 2016-17	FY 2017-18 (E)	FY 2018-19 (E)	FY 2019-2020
Bauxite	24.80	26.29	28.13	30.38
Alumina	6.10	6.47	9.92	7.47
Aluminium	2.80	2.94	3.12	3.33

Source: CARE Ratings Industry Research

Table 08: Production trend of bauxite, alumina and aluminium (mn tons)

	FY 2016-17	FY 2017-18 (E)	FY 2018-19 (E)	FY 2019-2020
Bauxite	24.50	25.97	27.79	30.01
Alumina	5.80	6.09	6.46	6.91
Aluminium	1.90	1.96	2.03	2.11

Source: CARE Ratings Industry Research

Table 09: Consumption trend of bauxite, alumina and aluminium (mn tons)

Today, the Indian aluminium industry is on the cusp of transformation and this augurs well for the domestic manufacturers. There is enough demand for quality aluminium alloys in India's navy, defence and aerospace sectors. But India's aluminium makers lack innovative product design, design parameters conversion and integration. The players are unable to meet the domestic demand for aluminium due to issues pertaining to the quality of alloys, impurity, texture, scratch freeness and aesthetics. The manufacturing technology of high strength aluminium alloys is challenging in terms of scientific knowhow and expertise compared to the production of commercial aluminium alloys. Product development being a dynamic initiative, the modern aluminium manufacturers in India must seek to leverage with the Research and Development. While developed countries are working towards development of new alloys for strategic applications to improve the performance of the end product, the research emphasis is lacking in India where R&D and innovation only can widen downstream applications of aluminium.

3.6 Changing Perspectives

India has been a country that consumes aluminium in sectors having typically long useful life and lower recoverability rate such as electrical (48%), followed transport (15%), construction (13%), and Consumer Durables (7%) accounts for the major percentage of aluminium consumption (Figure 12). World's consumption is presented in Figure 13.

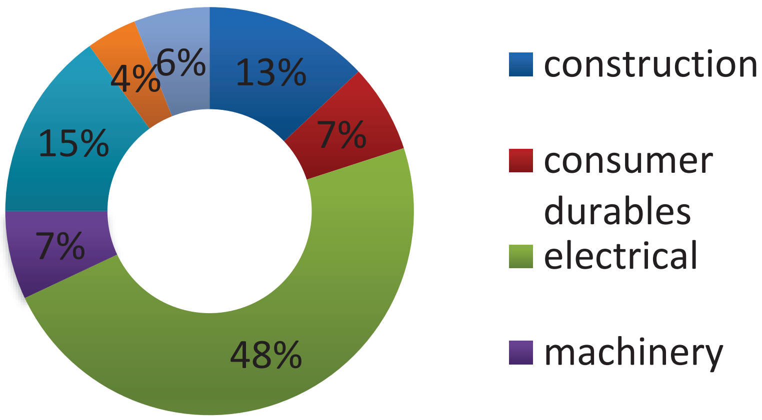


Figure 12: Present aluminium consumption pattern in India

For the country to achieve a whopping 5.3 million tons aluminium demand target by 2020-2021 from the current 3.3 million tons (in 2015-2016), its downstream segment has to grow considerably. Aluminium demand in the country is poised to log CAGR (compounded annual growth rate) of 10 per cent in the next five years, beating the global run rate of six per cent year-on-year growth. So are downstream products the next drivers?

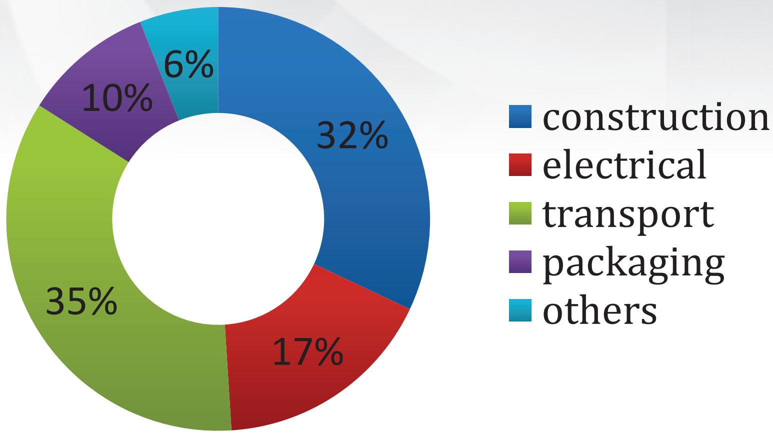


Figure 13: World consumption of aluminium

Traditionally, the Indian aluminium story is linked to power and transport segments, which take up nearly 60 per cent of the consumption pie. Opportunities abound in a plethora of emerging areas, which the makers can unlock. A recent study by Vedanta Aluminium showed that India's aluminium consumption pattern will change and look somewhat like Figure 14 by 2021: This clearly indicates the growth driving sectors for aluminium in the country.

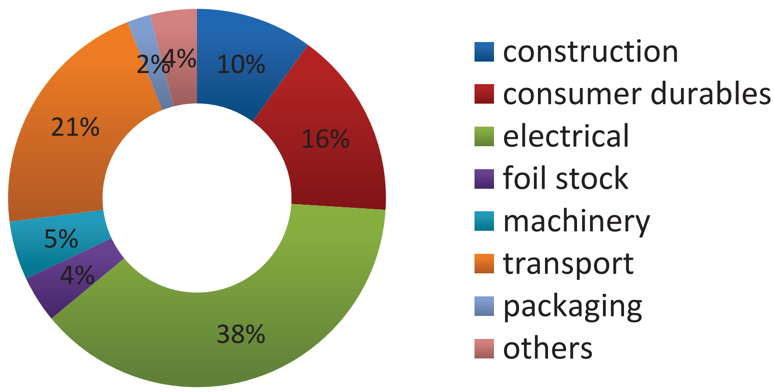


Figure 14: Indian aluminium consumption growth forecast for 2021

Primary demand for increased consumption is expected to come from the power sector where investments from state distribution companies and central government schemes totalling Rs 4.3 trillion are being planned over the next five years to expand India's transmission and distribution network. The electrical sector consists of machinery and equipment for the generation, transmission and distribution of electricity. The increase in industrial development, rapid urbanisation and infrastructure developments and government initiatives for electrification of villages has resulted in healthy growth in the sector. Indian railways have Rs. 8.5 lakh Crores committed over the 5-year period with focus on: enhancing safety of passenger cars, increasing speed of the trains, driving Energy and cost efficiency.

Secondary demand for aluminium consumption will be in the automotive sector where stringent vehicular emission norms leading to manufacturers reducing vehicle curb weight as well as introduction of the light weight electrical vehicles have come as a boon to aluminium due to its knows advantages in the automobile sector. Newer and stricter fuel and emission laws and regulations in several international markets have created favourable conditions for downstream aluminium manufacturers.

Building & construction sector, comprising real estate, industrial construction and infrastructure segments is a key driver for the overall growth of the Indian economy. The government's push to build Smart Cities coupled with the growing trend of high rises has encouraged a greater concern for environmentally friendly construction where aluminium can fit into potential applications like fenestration, facades, curtain walling, structural glazings, roofing and cladding applications.

Further, both aerospace and defence are two areas which bode well for aluminium use in the future, especially in the Indian context. The Government of India's push for 'Make in India' especially in defence sector is expected to open up a gamut of opportunities for the future metal where aluminium is widely used in defence equipment like military aircraft, ammunition hardware and missiles in the form of sheets, forgings and extrusions.

Aluminium's lightweight structure, resistance and durability have made it crucial to many rail transport applications in developed economies. As India bets big on high speed and state-of-the-art metro rails for commuting, there is a huge potential for use of aluminium sheet metal and extrusions. Government has already initiated the activities for aluminium coach at under PPP mode at Palakkad coach factory as well as at Integral Coach Factory, Chennai.

With India's expanding GDP and per capita income, packaging should be seen a big opportunity for aluminium consumption in the years to come. Aluminium demand in applications like beverage cans, foils for the pharmaceuticals and food sector, and pilfer proof caps for bottling, are some of the most common expanding applications.

Aluminium is also finding increasing application in various areas of the healthcare industry - in medical cases, trays and general hospital and devices due to its intrinsic properties. Aluminium extrusions are being used to create a thorough framework for solar panels in a variety of situations, including frames, supports and connectors as it is lighter than other metals, making them easier to transport and assemble in remote locations. Aluminium finds applications in shipbuilding and fabrication of components in offshore platforms due to its unique properties such as corrosion resistance, light weights superior mechanical properties, high recyclability etc.

Thus, considering the strong economic prospects, a thrust on manufacturing sector growth, the expected growth in key end-use segments and advent of new application areas, the demand for non-ferrous metals is expected to witness strong growth in very near future.

3.7 Aluminium Downstream Industry and Employment

According to McKinsey's report statistics indicate that India's overall labour-force participation declined between 2011 and 2015. In fact, report clears that Indian labour markets are in fact undergoing a significant structural shift, away from agriculture and towards the non-farm sector, particularly construction, trade, and transport where employment in agriculture shrank by 26 million in 2011 to 2015, while non-farm jobs rose by 33 million over this period (Figure 15).

Increased urbanization & rising middle-class with disposable income along with Make in India, Rural electrification, Housing for all, Smart Cities and investments of Rs.4.3 trillion in next 5 years from state DISCOMS & central government schemes is likely to increase domestic demand from 3.62 million tons in 2017-18 to 7 million tons in 2022-23.

It has been projected that the Aluminium consumption in India is poised to grow from 3.3 million tonne (mt) in 2015-16 to 5.3 mt in 2020-21 and 8.0 mt by 2025 riding on a host of government initiatives like, Make in India, Smart Cities, Housing for all, rural electrification, and freight corridors. Aluminium industry already started on set up of aluminium Park where major primary aluminium producers are showing interest in setting up industrial parks for aluminium-processing units either within their existing smelter complexes or close to their smelters. Vedanta Aluminium, which owns an aluminium smelter at Jharsuguda in Orissa and at Korba in Chhattisgarh, is investing heavily to build industrial parks for hosting small and medium-sized units manufacturing aluminium extrusions and fabricated aluminium products. The State-owned National Aluminium Company (NALCO), too, is giving high priority to building industrial parks comprising SMEs that will add value to the primary metal it produces.

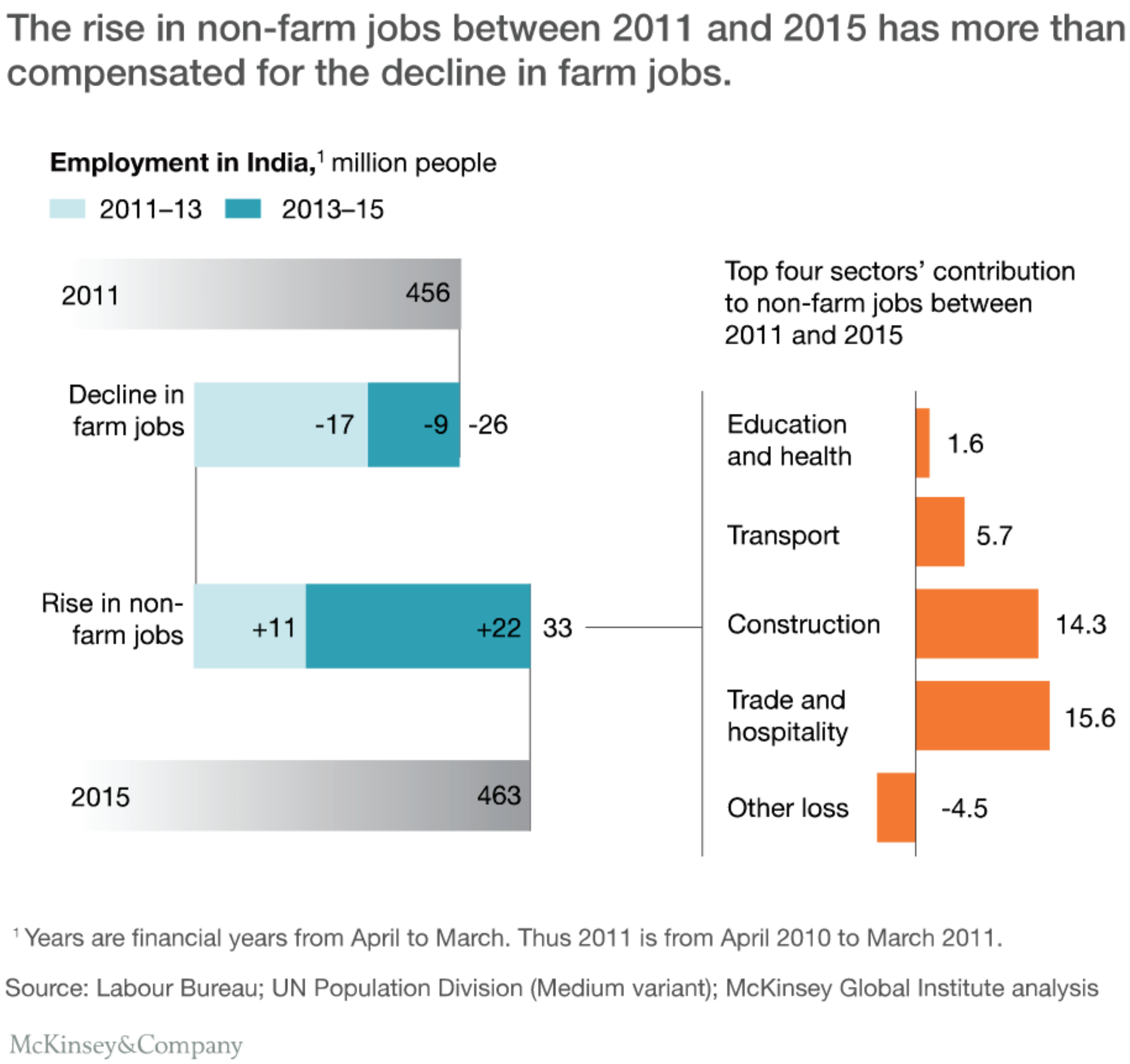


Figure 15: Shifting of labour-force (McKinsey & Company)

NALCO in association with Odisha State Government has started the ball rolling at Angul in Odisha for the first phase of a state-of-the-art Aluminium Park, aiming at creating 15,000 job opportunities, will soon come up at Angul in Odisha. HINDALCO has a target of doubling its downstream aluminium capacity in very near future, Hindalco Industries Ltd, India's biggest aluminium producer, hopes to set up a high-end alloy plate manufacturing unit for the country's defence sector. Other downstream manufacturing is also picking up among other SMEs as well which includes auto components manufacturers, extruders etc.

3.8 Recommendations

Raw material/mining stage (Bauxite)– India has fourth largest bauxite reserve but the scale and extent of bauxite mining in India is primarily located in the eastern region. Since resource efficiency emphasise on the optimum utilization of raw material, it is required to explore the possibility and challenges of large-scale bauxite mining in other bauxite bearing states like Chhattisgarh, Jharkhand, Gujarat. Since eastern bauxite region are sooner or later going to be deplete in volume and quality, it is advisable to focus on "how other bauxite bearing states can be developed for large scale bauxite mining" to achieve sustainable growth in aluminium industry.

Raw material/mining stage (Coal): almost 30% of smelting cost accounts for power required for electrolysis process. Aluminium does have inherent advantage over steel but one of the prime reasons why steel is still the first choice for consumers is the high cost of aluminium metal. In order to succeed in making aluminium as metal of choice, it is imperative to make aluminium cost competitive with steel. One of the ways to achieve this is by focusing on providing coal security to aluminium producers in the close vicinity of smelting plant. Smelters are utilising coal being secured either by spot auction, linkage or captive coal blocks but at higher cost. Movement of coal from far located coal mines to smelters contribute into pollution due to logistic cycle. Providing fuel security to smelters by allocation of coal blocks in close vicinity will help in reducing aluminium manufacturing cost which will eventually help to make aluminium as the metal of choice.

Value from By-Products generated

While producing 1 tonne of Primary Aluminium, the Industry produces about 8-10 tonne of By-Products, such as, Bauxite Residue (Red Mud), Fly Ash, Spent Pot Liner (SPL), Dross etc. All these materials have great potential for value added applications. For the Circular Economy of the Indian Aluminium Industry greater focus is necessary in this area.

Bauxite Residue (Red Mud) and Fly Ash

- At National level a comprehensive strategy needs to be made on utilization of Red Mud mainly in following five areas a) Cement making b) Bulk construction – road, embankment, marine clay reclamation and mine backfilling c) brick/block/paver block/plaster etc for housing and roads d) man-made soil for green belt development e) metal / non-metal value recovery. On each of these areas a National level Mission Projects need to be launched and these projects to be executed in parallel. Participating organizations in these missions will be from industry, academia, research labs and Govt. agencies and preferably, to be led by industry sector. The projects should focus on complete solution including commercial scale technology development, demonstration & implementation, preparation of policy guidelines and standards.
- Initiative on Bulk construction application is already being led by IIT Bombay along with Hindalco Industries Ltd. The same may be extended to other partnering organizations including Govt Agencies to make it the Mission Project and expedite demonstration and implementation of the technology.
- NITI Aayog's on-going initiative to extract Rare Earth Element (REE) from Red Mud (and Fly Ash) to be expanded to complete Value Recovery (Fe, Ti, Al, REE & Non-metals). The committee recommendation on the potential process/technology route, expected by Dec, 2018, to be taken as the basis for launching the National Mission Project for technology demonstration on Value Recovery from Red Mud.
- JNARDDC Nagpur, Hindalco, NML Jamshedpur and Others have the process knowhow for producing bricks/blocks/paver blocks/plasters etc for housing and road applications. While these processes are technically well established, they are not economically attractive mainly due to high transportation cost either of end product or the raw materials. Government support in the form of subsidy and sops for the entrepreneurs and assurance for the purchase of their product may help in implementing this.

Spent Pot Lining (SPL)

- The 1st cut SPL is carbon reach and should be used as a fuel. Since SPL contains cyanide, fluoride etc, the same needs to be de-toxified. The process developed by JNARDDC Nagpur needs to be adopted for bulk consumption of the material, especially in power plants, cement plants and in other industries.
- The other potential uses of SPL are for blast furnace injection as fuel for iron-making, as flux for steelmaking or as reducing agent for slag cleaning furnaces, like copper.

Dross

- Various technologies are available for recovering aluminium metal trapped in dross. These technologies to be adopted. Also, more pilot studies to be carried out for finding value added use of the non-metallic fraction of the Dross.

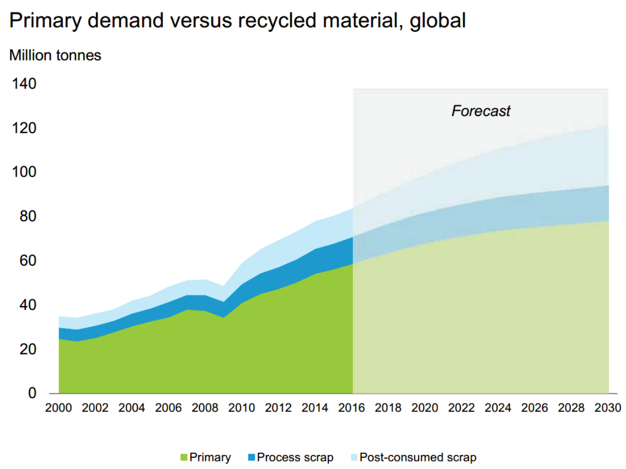
4.0 Aluminium Recycling Economy

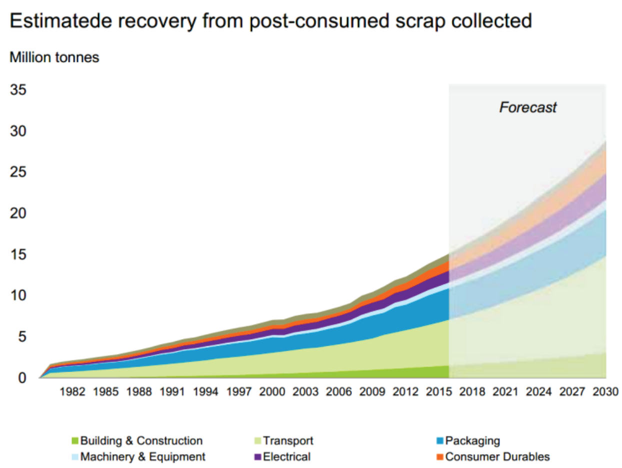
Markets for many classes of potentially recyclable materials are growing due to economic & environmental advantages. However, the markets for many potentially recyclable materials are affected by information failures, technological externalities which in turn control the prices, quantity, and quality of materials traded. Ultimately, such factors can even destabilize the development of the market entirely.

When designing policies to increase recycling rates, it is important to have a good understanding of all potential inefficiencies that may exist in such markets, and how such inefficiencies may be overcome through public policy interventions. Recycling is an important economic sector in terms of employment, turnover, and investments. However, when recycling takes place within the firm (e.g. the reuse of “home” scrap by the metal fabrication sectors) evaluating the economic importance of recycling can be problematic. In addition, in many sectors, post-consumption secondary material inputs may not pass through dedicated recovery facilities (i.e. use of used newsprint in production of pulp).

Aluminium scrap has considerable market value because most of the energy required for the production of primary aluminium is embodied in the metal itself and, consequently, in the scrap. Therefore, the energy needed to melt aluminium scrap is only a fraction of that required for primary aluminium production. Furthermore, if pre-treated and/or sorted, aluminium products can be recycled for use in almost all aluminium applications since the metal’s atomic structure is not altered during melting.

The amount of aluminium produced from old scrap has grown from one million tons in 1980 to 17 million tons in 2016 (Figure 16). Since the 1980s the transport sector has been the most important resource for recycled aluminium from end-of-life products. As aluminium construction products often have lifetimes running into decades, scrap from building applications has only become available in the 2000s and only in the quantities put into such applications when the buildings were constructed, over 30 years ago. Today recycled aluminium produced from old scrap originates 40% from transport, 20% from packaging, 30% from engineering and cables and only 10% from building applications, due to their long-life times. In 2016, around 28 million tons of recycled aluminium are produced annually by refiners and remelters from old and traded new scrap, compared with 58 million tons of primary aluminium.





Source: GARC, CRU/Hydro analysis

Figure 16: Global secondary aluminium trend & forecast

4.1 Recycling Role in a Green Economy

In general, the definitions of the green economy proposed over the last two decades are strikingly similar. Key elements include:

- internalising externalities
- improving material and energy efficiency and ultimately decoupling material and energy use from economic growth
- shifting from a linear economy to a circular economy
- shifting from non-renewable to renewable resources
- Recycling contributes in several ways to each of these four principles.
- The growing recycling industry also helps to generate ‘green jobs’.
- A large part of recycling is closely linked to non-renewable resources, above all metals. As such, recycling helps reduce virgin non-renewable resource use, directly helping decouple material use from economic growth.
- Numerous opportunities exist for eco-innovation and development of new technologies in the recycling sector, potentially creating markets for new products and services.
- Recycling ensures that resources remain in the economy via a closed-loop process.
- It contributes to a shift to a circular economy and away from a linear economy model characterised by resource depletion and waste.
- In most cases recycling has lower environmental impacts compared to producing virgin materials. As such, recycling is ranked third in the waste hierarchy: it is less desirable than preventing and reusing waste but preferable to energy recovery and disposal.
- Recycling helps businesses, other organisations and communities avoid the costs associated with landfills and incinerators — both in terms of financial expenditures and environmental impacts. Figure 17 indicates the savings in terms of energy & CO_2 savings of different metals produced through recycling.

Aluminium	**> 95%**	Aluminium	**> 92%**
Copper	**> 85%**	Copper	**> 65%**
Plastic	**> 80%**	Ferrous	**> 58%**
Paper	**> 65%**	Paper	**> 18%**
Steel	**> 74%**	Nickel	**> 90%**
Zinc	**> 60%**	Zinc	**> 76%**
Lead	**> 65%**	Lead	**> 99%**
Energy Savings		Tin	**> 99%**
		CO_2 Savings*	

Figure 17: Energy & CO_2 savings by recyling

4.2 Aluminium Recycling and its Socio-economic Implications

In the present socio-economic scenario where the world is buzzing with issues like a soaring global population, increasing carbon emission, higher energy cost and insufficient feedstock, recycling is turning out to be the need of the hour rather than a matter of concern. Fortunately, aluminium is one metal that is 100% recyclable and its natural quality does not get affected in the recycling process. Aluminium recycling supports the twin concepts of sustainability and stewardship that encourage a responsible and thoughtful use of resources and urge manufacturers to take responsibility for the environmental, health, and safety effects of a product.

Recycling needs less energy and aluminium can be reproduced from the scrap with only 5% of the total energy used to produce aluminium from bauxite ore. The scrap aluminium is melted to get back the metal. The process involves much lesser cost. Though recycled aluminium is called secondary aluminium, it carries the same physical properties as primary aluminium. As recycling does not damage the metal's structure, aluminium has the potentiality to be recycled indefinitely and it is used in manufacturing any downstream products for which primary aluminium is used.

Today, the total global aluminium production is close to 56 million tons (with close to 18 million tons recycled from scrap). The growing environmental and economic concerns and heightened social responsibility have served to boost recycling activity. Aluminium economy is a circular economy where the metal is just 'used' and never 'consumed' during its lifetime and it can regain its life at the end of its lifetime. From the environmental standpoint, aluminium recycling emits only 5% of the total greenhouse gas created during aluminium production process. While reducing carbon emissions is intended for preserving ecosystem, carbon management is also productive from business point of view. Emission reduction can cut costs by enhancing process efficiency, lowering energy usage, and reducing consumption of scarce raw materials.

Now the question is how to realize the fullest potential benefits of recycling, both from a business and an environmental point of view. Global aluminium industry is reeling under pressure due to high energy cost and dropping metal price. Big names like Alcoa, Norsk Hydro or Novelis are actively promoting recycling campaigns to create awareness about the process. Novelis has plans to double the proportion of scrap it uses as raw material by 2020. It also plans to build its own processing facilities to protect itself from supply restrictions caused by dropping LME price. Once flourishing, Australian bauxite industry is under threat due to high energy cost and dropping aluminium price. The Indian scenario is not very encouraging either where unexplored raw materials and irregular coal supply are affecting aluminium production. Under such conditions, the secondary or recycled aluminium industry is showing enormous growth potential as one of the most sustainable ways to lower carbon footprint, conserve resources and survive the high energy cost associated with aluminium production.

4.3 Life Cycle Analysis (LCA)

All materials and products have a life cycle. A life cycle is the journey a material or product goes through during its entire life. Every material starts in some raw form, is processed, and is made into a finished product. After some period of time, the material or product reaches the end of its useful life. When a product (or other materials object) reaches the end of its useful life, the question arises as to what to do with it. In some situations, it may be reusable through simple processing (e.g. washing of glass bottles), repairs, modifications or remanufacturing. In other situations, the product may be recycled as secondary material to a manufacturing process, or the individual components or materials from which it is made may be able to be separated and recycled as secondary materials. Eventually, reuse or recycling may no longer be possible, and some form of disposal is necessary. The most common disposal option used is to bury it in landfill sites, but this should only occur if the material is deemed not too polluting.

Other disposal options include burning (usually to produce useful energy) if combustible, or put into permanent storage if it is too hazardous to the environment or humans (eg. radioactive materials). A schematic diagram of the materials or product life cycle is shown in Figure 16, which starts with materials being obtained from the Earth, transformed into a product and then used before finally being returned to the Earth.

At all stages over this life cycle there are material and energy inputs, and various airborne and waterborne emissions, along with solid residuals. Concerns in recent years regarding the sustainable utilisation of natural resources have seen a life cycle thinking approach being applied to the production of goods and services. Life cycle assessment (LCA) is a methodology that has been developed to assist in this task, and essentially accounts for all the inputs and outputs for the product life cycle shown in Figure 18. The product life cycle is generally considered in two parts:

- cradle-to-gate – that part of the cycle extending from raw materials extraction from the Earth through to the production of refined materials;
- gate-to-grave – the remaining part of the cycle extending from product manufacture using refined materials through to disposal back to the Earth.

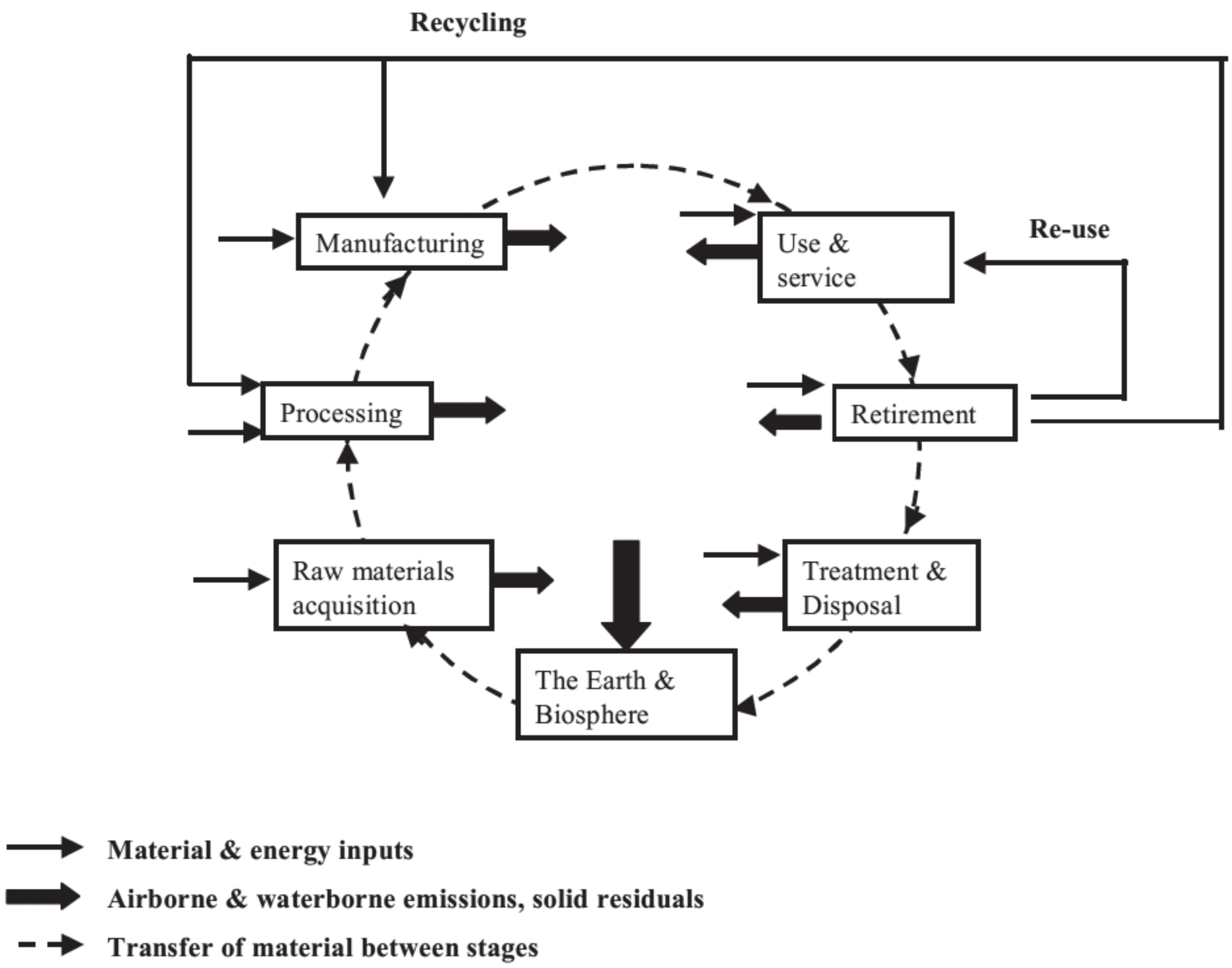
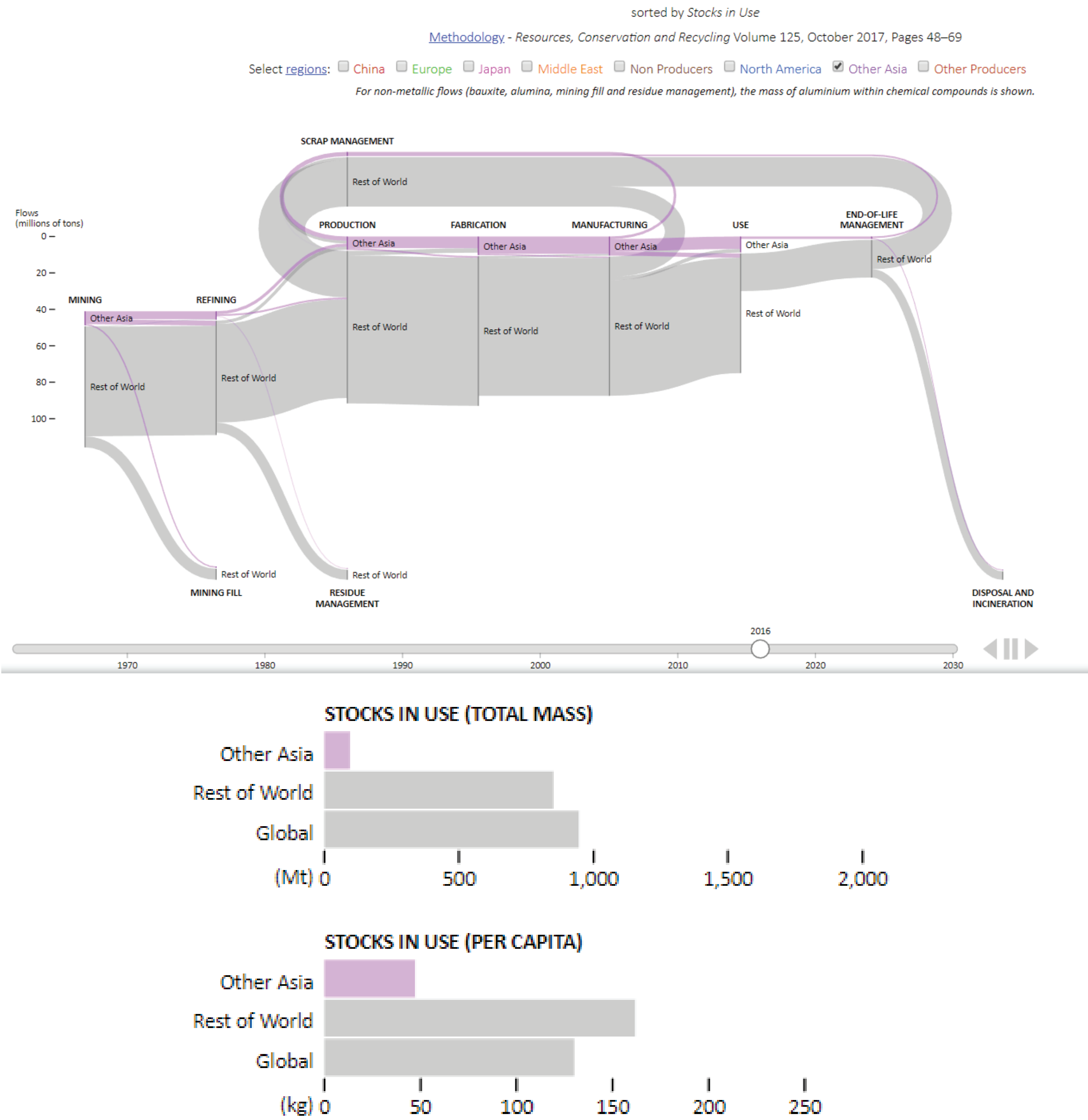


Figure 18: Life cycle of materials

- Extensive 'cradle-to-gate" LCA studies of primary metal production have been carried out at Process Science and Engineering over many years involving various processing routes (e.g. pyrometallurgical versus hydrometallurgical), energy sources and ore grades. Metals considered include copper, nickel, lead, zinc, aluminium, titanium, iron and steel, ferroalloys and gold. However, recycling will play a critical role in the sustainable production and utilisation of metals into the future, and it is essential that LCA methodology also be applied to secondary metal production by various recycling systems and processes if the principles of sustainability are to be achieved.

4.4 Mass Flow Model: Tracking Aluminium through its Life Cycle

The property of recyclability means that the world's increasing stock in use of aluminium acts like a resource bank, over time delivering more and more practical use and value from the energy embodied in the metal at the time of its production. Global Aluminium recycle map is showed in Figure 19.



Other Asia: India, Indonesia, Malaysia, Pakistan, Rep. of Korea, Singapore, Taiwan, Thailand, Viet Nam (94,663,000t) rest of the world (850,799,000t)

Figure19: Global aluminium cycle 2016 (http://www.world-aluminium.org)

Of the estimated 900 million tons of aluminium produced since 1880, three quarters is still in productive use. Around 35% is located in buildings, 30% in electrical cables and machinery and 30% within transport applications. Recycling the metal currently stored in use would equal up to 17 years' worth of current annual primary aluminium production.

The amount of aluminium produced from old scrap has grown from one million tons in 1980 to 17 million tons in 2016. Since the 1980s the transport sector has been the most important resource for recycled aluminium from end-of-life products. As aluminium construction products often have lifetimes running into decades, scrap from building applications has only become available in the 2000s and only in the quantities put into such applications when the buildings were constructed, over 30 years ago. Today recycled aluminium produced from old scrap originates from 42% transport, 28% packaging, 11% engineering and cables and only 8% from building applications due to its long-life time.

5.0 Aluminium Metal Recycling

Reducing the rate of depletion of metal reserves by recycling of "metals-in-use" will contribute to the sustainable use of metals. Re-use and re-manufacture complement recycling and although generally more desirable than recycling, finite product lives means that eventually the product will have to be recycled. It is widely recognised that recycling of metals results in significant savings in energy consumption (and hence reductions in associated greenhouse gas emissions) when compared to primary metal production. While the amount of energy used in metal recycling depends largely on the metal in question, its application and the recycling process used, typical energy savings reported for metal recycling over primary metal production are aluminium 95%, nickel 90%, copper 84%, zinc 75%, lead 65% and steel 60% as shown in Figure 20. The circle areas in this figure are proportional to the embodied energies of production of the respective primary metals, with the areas of the segments below the horizontal line representing the proportions of these primary embodied energies used in recycling of the metals. Thus, the areas above the horizontal line represent the primary metal embodied energies saved by recycling.

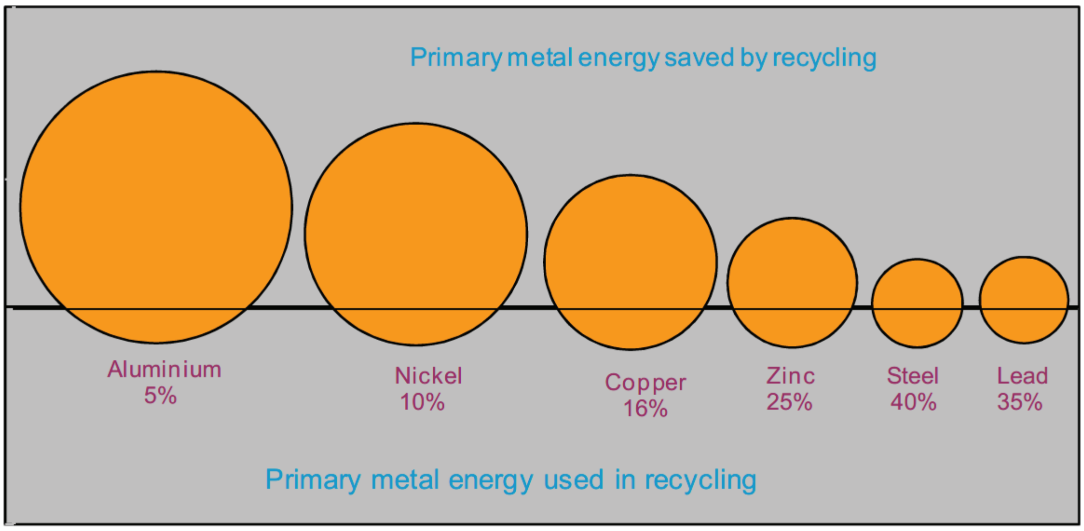


Figure 20: Primary versus secondary (recycled) metal production energy

Scrap is generally categorised as home, new or old with these types being as follows:

- home scrap is material generated during material production or during fabrication or manufacturing that can be directly re-inserted in the process that generated it, and it is therefore excluded from recycling statistics and not considered further here;
- new scrap, where new indicates pre-consumer sources (e.g. turnings, trimmings, cuttings and off specification material produced during metal shaping and part manufacture) – although also originating from a fabrication or manufacturing process, unlike home scrap it is not recycled within the same facility but rather transferred to the scrap market;
- old scrap, which indicates post-consumer sources (e.g. used beverage cans, motor vehicles) – recycling of old scrap requires more effort, particularly when the metal is a small part of a complex product.

Some reported metal recycling rates are based on both new and old scrap, but as much of new scrap supply is derived from new mine production, it hardly seems to be secondary supply. Old scrap, by contrast, comes from products that have reached the end of their useful lives. Therefore, recycling rates based on old scrap only are probably more appropriate measures of society's recycling performance. Recycling rates and recycled contents for some common metals derived from a number of sources (e.g. US Geological Survey, International Aluminium Institute, World Steel Association, Bureau of International Recycling) are shown in Table 5.

Metal	Recycling rate			Recycled content
	United States		World	World
	Old scrap	Old & new scrap		
Aluminium				
- general	25	56		33
- cans	54	-	63	80
Steel				
- general	NA	67	50	40
- cans	65	-	68	
Copper	6	32	40	32
Nickel	NA	48	70	33
Lead	77	79	66	63
Zinc	10	27	70	30

Table 10: Recycling rates and recycled contents (%) for various metals

Compared with the production of primary aluminium, recycling of aluminium products needs as little as 5% of the energy and emits only 5% of the green-house gas. Recycling is a major aspect of continued aluminium use, as more than a third of all the aluminium currently produced globally originates from old, traded and new scrap. The high intrinsic value of aluminium scrap has always been the main impetus for recycling, independent of any legislative or political initiatives. For some products, in addition to this obvious economic dimension, growing environmental concerns and heightened social responsibility, over the last decade in particular, have served to boost recycling activity, in order to conserve resources and to avoid littering.

The aluminium economy is a circular economy. Indeed, for most aluminium products, aluminium is not actually consumed during a lifetime, but simply used. Therefore, the life cycle of an aluminium product is not the traditional "cradle-to-grave" sequence, but rather a renewable "cradle-to-cradle". If scrap is pre-treated and/or sorted appropriately, the recycled aluminium can be utilised for almost all aluminium applications, thereby preserving raw materials and making considerable energy savings.

In 1990 total aluminium production was around 28 million tons (with over 8 million tons recycled from scrap) and today the total is close to 56 million tons (with close to 18 million tons recycled from scrap). By 2020 metal demand is projected to have increased to around 97 million tons (with around 31 million tons recycled from scrap). Today, around 50% of the scrap is old scrap (i.e. scrap from end-of-life products).

At present, the aluminium industry itself is responsible for around 1% of the man-made greenhouse gas emissions, around 40% of which are the result of the aluminium production process itself (direct emissions) and around 60% resulting from electricity power generation (indirect emissions). The Directors of the International Aluminium Institute (IAI) have therefore established the 'Aluminium for Future Generations' global sustainability initiative, which employs a life cycle approach to address the challenges of climate change, focusing not only on direct emissions and the energy required to produce aluminium products, but also on the energy savings to be made through their use, recycling and reuse.

5.1 Global Stock and Energy Savings by Recycling

Aluminium recycling benefits present and future generations by conserving energy and other natural resources. It saves up to 95% of the energy required for primary aluminium production, thereby avoiding corresponding emissions, including greenhouse gases. Through the use of only around 5% of the originally used energy, this metal can be made available not just once but repeatedly from these material resources for future generations. Improving the overall recycling rate is an essential element in the pursuit of sustainable development.

Recycling of aluminium saves 6kg of bauxite/kg and 14 kWh of electrical energy /kg of primary aluminium. Besides, it keeps the emission levels of greenhouse gases to a low of 5% from the actual emission experienced during primary production. Further, recycling facilitates reduced stress on the use of bauxite and thereby preserving about six lakh tons of bauxite resources every year.

India's metal recycling rate is about 25%. All the activities related to aluminium scrap recovery are limited to unorganised sector, catering mostly to the utensil and casting industries. The proportion of recycled aluminium has been increasing over the years. It is expected that in the years to come, it will reach a figure of about 35-40% of total aluminium consumption. Currently, there is only one recycling unit of Hindalco in organised sector at Taloja with 25,000 tons annual capacity. Although the plant at Taloja was facing challenges due to less availability of scrap, the production from the unit has improved and the plant is now operating at 80% of the rated capacity as against earlier capacity of 60%.

Most recycling units in India operate on outdated, or primitive technology which leads to high levels of pollution and energy consumption. This is an area that needs to be addressed by the Indian aluminium industry. Due recognition of recycling could encourage users of aluminium particularly in transport, housing, packaging and durable sectors to broaden the organised markets for the scrap generated.

5.2 Closed-loop and Open-loop Recycling

A distinction is made between closed-loop recycling and open-loop recycling for including end-of-life recycling in LCA. A closed-loop recycling product system occurs when the materials associated with a product are recycled and used again in the same product at the same level of material quality. The inherent properties are maintained by closed-loop recycling. The recycling of post-consumer aluminium can scrap to make new aluminium cans is an example of a closed-loop recycling system.

Closed-loop recycling also applies when a material is recycled in another product system where its inherent properties are maintained. For example, scrap nickel turbine blades can be blended with carbon steel scrap to make stainless steel, thereby displacing the need to make primary nickel. This type of recycling system has also been referred to as semi closed-loop recycling. An open-loop recycling product system occurs when the materials associated with a product are recycled to a different product system and the material has undergone a change in its inherent properties. Recycling of metals can generally be categorised as closed-loop recycling.

6.0 Structure of Aluminium Metal Recycling Industry

Metal recycling involves the following stages

- collection
- recovery
- refining and remelting
- Energy (primarily fossil fuel-based) is consumed in all of these stages

6.1 Collection

Fuel consumption for collecting and transporting waste materials (including metals) to a material recovery facility is largely dependent on the duration of the collection route. This in turn depends on the source of the waste like city centre or suburban or regional areas – the lower the population density, the greater the transport distance between collection points. Another issue that affects collection energy is the type of collection system, eg. Single-stream (all materials combined) or dual stream (two streams – one for paper fibre and the other for commingled plastic, metal and glass).

6.2 Sorting

Metals are a major fraction of waste, primarily as a fraction from demolition waste, from end-of-life vehicles and from household appliances, and secondly from the municipal waste stream in the form of packaging materials such as cans, foil and containers. Metals from industry and construction have traditionally been recycled as they are generally available in large quantities, whereas recycling of metals in municipal solid waste has mainly increased over the last decade.

Recycling of metals requires elimination of foreign elements and that the metals are sorted into their respective metal type, which takes place at a material recovery facility (MRF). The purpose of the MRF is to sort and upgrade the recovered material to a suitable quality grade for reprocessing. Large clean fractions of steel or aluminium are sent directly from the MRF to recycling. Bulky waste products with a large content of metals are sent to an electrical shredder which divides the large pieces into smaller, cleaner metal and residual fractions that can be further mechanically sorted. The shredded waste is sent to drum magnets where the magnetic fraction is sorted out, followed by an eddy current separator where the aluminium is sorted out. In a third sorting step, the remaining metals (copper, zinc, lead, magnesium, etc.), glass and plastics are sorted out. While a general description of the scrap metal sorting and recovery steps is given above, the actual processing flowsheet and equipment items used depends strongly on the nature/source of the scrap being treated.

6.3 Remelting and Refining

Aluminium recyclers can be divided into two groups - remelters and refiners. Remelters mainly use aluminium scrap which is obtained directly from manufacturers and can be directly remelted. Refiners use "old scrap" aluminium which comes from a variety of sources such as end-of-life vehicles, household goods and MSW. Most of the post-consumer aluminium scrap is processed by refiners. Aluminium scrap refining generally takes place in rotary or reverberatory furnaces. Some typical energy consumption data for steel and aluminium remelting and refining are given in Table 6.

	Energy consumption		Comments	Reference
Steel	1.5	GJ/t steel	Electricity	Norgate and Langberg (2009)
	1.7	GJ/t steel	Electricity	Natural Resources Canada (2007)
	2.2	GJ/t steel	Electricity	Fruehan et al (2000)
Aluminium	8.7	GJ/t aluminium		Anon (1997)
	8.8	GJ/t aluminium	96% gas 3% electricity 1% diesel	Quinkertz et al (2001)
	7.6	GJ/t aluminium		Milford et al (2011)
	7.0	GJ/t aluminium		Kear et al (2000)
	5.6	GJ/t aluminium		Schifo & Radia (2004)

Table 11 Energy consumption for remelting and refining

For aluminium scrap from MSW, such as used beverage cans, it is necessary to pre-treat the aluminium to remove contaminants and de-coat or de-oil the scrap depending on the source. This improves the thermal efficiency of refining and reduces potential emissions from the melting process. The scrap is then loaded into the furnace. The melted aluminium is tapped for either direct casting or sent to another furnace where alloys can be made. In this process the aluminium is also refined to remove the last impurities in the aluminium.

6.4 Refiners and Remelters: Important Players in Recycling

Aluminium scrap is collected and melted everywhere in the world. In many of the countries worldwide there are industrial recycling facilities, but recycling plays a particularly leading role in Europe, North America and Japan. A fully developed aluminium recycling industry, including both refiners and remelters, transforms aluminium scrap into standardised aluminium. Refiners and remelters play integral roles in aluminium recycling but they, in turn, have crucial links with collectors, dismantlers, metal merchants and scrap processors who deal with the collection and treatment of scrap as shown in Figure 21 The metal merchants are also responsible for handling most of the foreign trade in aluminium scrap. Refiners and remelters play vital roles for the downstream industry;

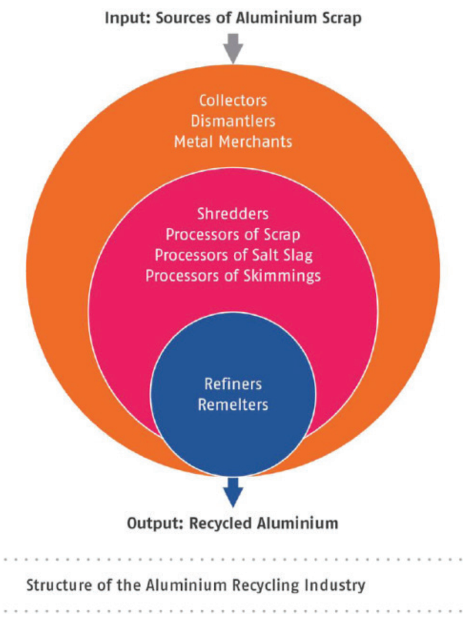


Figure 21: Structure of aluminium recycling industry

In the EU and North America, scrap has been generated in sufficient quantities over the past 70 years to develop an economically strong and technically outstanding aluminium recycling industry. Following the oil shocks and energy cost increases of the 1970s, Japan ceased domestic primary aluminium production and switched to aluminium recycling in the 1980s. In addition to these traditional recycling centres, increasing recycling activities are evident in China, India and Russia.

In the regional overview, Latin America, the Middle East, Oceania and Africa focus on primary aluminium production while recycling plays a minor role, mainly due to lower domestic scrap availability. In addition, much of the aluminium scrap in some of these countries (for example, Australia and Canada) is exported to other regions where a major recycling sector exists. For most countries, there is a well-established market for recycled aluminium with firmly defined distribution chains. Hence, refiners supply foundries with casting alloys and remelters supply rolling mills and extruders with wrought alloys. Alloys are supplied according to official standards and/ or customer specifications.

Typical products made from recycled aluminium include castings, such as cylinder heads, engine blocks, gearboxes and many other automotive and engineering components, on the one hand and extrusion billets or rolling ingots, for the production of profiles, sheets, strips and foil, on the other as shown in Figure 22. Another prominent use for recycled aluminium is in the steel industry, where its use is essential for deoxidation.

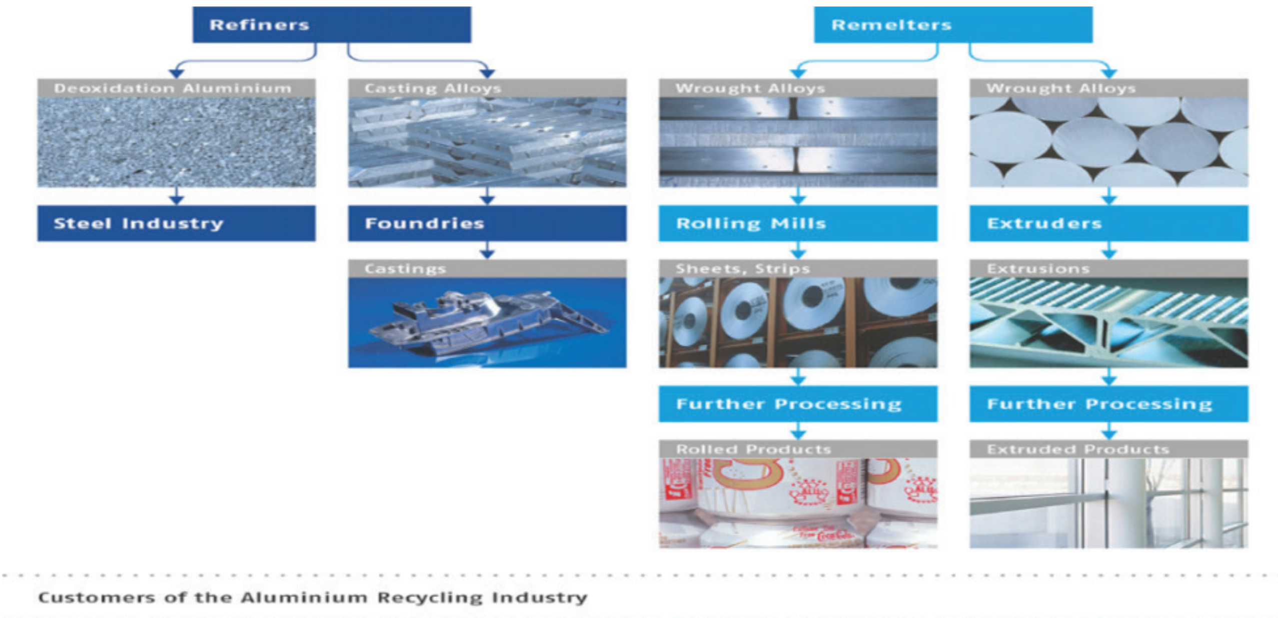


Figure 22: Customers of aluminium recycling industry

6.5 Dross recycling

The worldwide aluminium industry produces nearly five million tonnes of furnace waste each year. Known as dross, the residual waste material is produced from any process in which aluminium is melted, and is left behind after conventional recycling has been carried out. Traditionally, black (which has a much higher salt content) and white dross is disposed of in landfill, costing the industry an estimated £50 million, but tighter regulation and spiralling costs are forcing the industry to consider alternatives. One such solution, which could dramatically reduce landfilling of furnace waste and recover saleable products has been developed by aluminium recycling and manufacturing firm JBM International Ltd.

Primary Aluminium producer normally generates two types of Aluminium dross at their premises. i.e. Lumpy dross and fine powdery form. Lumpy drosses is of ranges from few grams to few kilograms in weight whereas fine powder drosses are between a few microns to millimetre in size.

LUMPY DROSS **FINE POWDER DROSS**

Figure 23: Type of dross

Reasons to Recycle Dross

Developed as part of a major waste minimisation initiative backed by the UK Government and industry, the new treatment method makes it economically viable to treat residual waste left after conventional recycling, offering cost savings and environmental benefits. 'This process offers a means of reducing the amount of residual waste from primary and secondary aluminium manufacturers that ends up in landfill,' says Miles Brough, Managing Director of JBM International Ltd. 'It provides the industry with more choice of what to do with their waste products and because these waste products can be converted in saleable commodities these savings can be saved from the cost of production.'

Wastes incur the costs of processing generate no revenue, satisfy no human need and potentially harm the natural environment. Therefore, as part of a major waste minimisation, the treatment method in the study makes it economically viable to treat residual waste left after conventional recycling or generated at primary production plant, offering cost savings and environmental benefits.

Dross also varies significantly from operation to operation. The characteristics vary depending on furnace practices, skimming techniques, hot processing procedures and skim pan designs. All of these factors affect the metallics and oxides as they separate from each other in this process Mineral processing and metal production generates large volumes of wastes in the form of tailings, residues, slags, ash, fumes, sludges, spent refractories, Aluminium dross and red mud etc. A decision support framework was used to guide information gathering and prioritization of over 20 waste streams. The objective hierarchy for screening of wastes covered key criteria techno-economics, environmental and social/political.

Though the unorganized industry sector may use many primitive technologies, it has not stopped them to be creative to find maximum recovery of aluminium from the dross to the extent of extracting all from the dross to take it to the zero waste. In this context, an alternative research work is to be done. The water treatment agent such alum could be produced using chemical leaching and remaining dross as high alumina referactory castables. The process could achieve zero waste concepts using waste dross material.

FAs the aluminium industry has developed over the past 60 years the value of the aluminium and the view of the oxidation products has changed from one that was thrown away to one that we look to completely recycle. Aluminium melting generates dross. Dross removal carries out free aluminium. Minimizing these two realities has been the charge of companies developing systems for our industry. The last 60 years has marked real progress in these areas and continues move forward successfully. Historically the dross has been handled as hereunder:

- Hand Picking
- Floor Cooling
- Stirring
- Shaker Tables/Vibrators/Stirrers
- Rotary Coolers/Vibrators/Stirrers
- Centrifuge (Focon)
- Inert Gas Dross Cooling (IGDC)
- Hot Dross Pressing
- Cold Mechanical Processing

Secondary Processing

The amount of dross generated at secondary aluminium operations is significantly higher than at primary operations varying, widely depending on the process. White dross is produced from the melting of scrap at the many general recyclers, extruders and mills that process scrap aluminium. This dross is higher in metal content than secondary black drosses and contains little or no flux.

The secondary aluminium industry also generates black dross from the melting of scrap in side well furnaces which contain relatively low levels of aluminium and typically requires some type of mechanical processing from the dross recyclers for efficient recovery of the aluminium. This section highlights the importance and value of developing a comprehensive aluminium dross management program. The first section provided insight into the evolution of dross management and how internally generated dross should be handled. While this is an essential first step, it is also important for an aluminium facility to understand the important role played by the secondary dross processor; it is here that the value of the dross will be ultimately decided. Dross recovery values are primarily the responsibility of the dross generator since good furnace practices and cooling techniques will have a greater effect on overall recoveries than what happens at the secondary processor. While all secondary processors will always promise the highest recoveries, there are many suitable practice and process techniques that can affect the overall quality and recovery of the dross. Dross generators should have the right to inspect and audit their processor to observe their material being processed and feel comfortable that good practice are in effect and that they are getting the true value from their dross and also proper dross management system have been followed handling the remains after recovery of metal. At times, the dross pile at an Aluminium facility is treated as a refuge dump, and it is not uncommon to find floor sweepings and other scrap mixed in with the dross as shown in fig 4. It should be recognized that keeping the material dry, the alloys segregated and free from trash will ensure a better quality of dross and therefore, better recoveries. It is just as important for the dross processor to recognize the importance of material handling and segregation.

If the dross is stored outside and gets wet metal recoveries will be adversely affected. Generally speaking every 1% of moisture will result in 1% of aluminium recovery loss. It is therefore important that the generator be able to walk through the processors facility to ensure material is being stored in an appropriate location.

Future Scope

There is an industry need to keep moving forward in its dross processing technology development. The first step is keeping as much aluminium as possible inside the melting furnace. The next step is keeping as much recycled aluminium in house for use in the facility that generates it and producing by products that are by nature saleable and not a landfill liability. We have moved forward over the past 60 years to understand and keep close to our industry the baby that we use to discard.

International & National Status

The important issue is that after recovery of Aluminium metal from dross to the maximum extent and remaining portion is rejected to the environment by processing agencies for land filling or dumping as waste. Further, this dross still contains Aluminium metal in finer size dross, which may not be recovered by conventional metallurgical processes. The Imperial chemical company treats white dross with sulfuric acid to make Aluminium sulfate for chemical industries. Considerable research is being carried out in this area (59-70). Dross is classified into different grades based on metallic Aluminium content. The lowest grade of dross normally contains around 10-15 % metallic Aluminium. In India conservative estimates of the dross produced is 120,000 tons, three major primary Aluminium producers in India, Nalco, Hindalco and Balco produce around one million tons of primary metal and generate around 25000-35000 tons of dross annually.

Around three forth quantity is disposed off as process rejects for further processing to the downstream industries. After recovery of metal by metallurgical process, remaining reject is dumped in environment by downstream industries, which is a great concern to the ecosystem. There is grading system in some of the industry based on their recoverable metal content. Dross, which contains lowest amount of metallic Aluminium, cannot be processed to recover its metal value economically. Hence, the commercial viability of this grade of dross has become very negligible and it is disposed / sold at a nominal price.

7.0 Recycling Issues: Lifetimes of Metal Products

Primary aluminium producers and the producers of semi-fabricated and fabricated products generally collect and recycle all of the aluminium scrap they generate (new scrap) and therefore the success of a recycling system depends on the degree to which used products are collected at the end of their lives. Collection rates vary depending on the product in question, waste management systems in place and on society's understanding of the value of aluminium scrap and its commitment to conserve that value.

Globally, aluminium achieves among the highest material recycling rates for end of life products, with up to 90% for transport and construction applications. The metal's economic scrap value and ability to be recycled continuously makes the aluminium beverage can the most recycled container in the world, with a global average recycling rate of 60% and a rate of over 90% in some countries.

The finished product enters the use phase and becomes part of the in-use stock of metals. When a product is discarded, it enters the end-of-life (EOL) phase. The life cycle of a metal product is closed if EOL products are entering appropriate recycling chains, which leads to scrap metal in the form of recyclates displacing primary metals. The life cycle is open if EOL products are neither collected for recycling or do not enter those recycling streams that are capable of recycling the particular metal efficiently. Open life cycles occur as a result of products discarded to landfills, products recycled through inappropriate technologies, and metal recycling in which the functionality (ie. the physical and chemical properties) of the EOL metal is lost.

The lifetime of a metal product depends on the nature of the product, and some typical lifetimes for aluminium products are given in Table 7. Product lifetimes also differ widely from country to country. The quantity of a metal available for recycle is not the current level of consumption of that metal, but the sum of the consumption of the metal one product life cycle ago for each of the end-use categories. The long lifetimes for many metal products, together with high growth rates in metal demand in the past has resulted in available old scrap quantities that are typically much smaller than the metal demand in production, leading to recycled contents much smaller than 100%.

Aluminium	Building & construction	40	Norgate et al (2009)
	Consumables	12-15	Norgate et al (2009)
	Electrical	35	Norgate et al (2009)
	Machinery & equipment	20-25	Norgate et al (2009)
	Containers & packaging	0.25-1	Norgate et al (2009)

Table 12: Typical lifetimes (years) of various metal products

7.1 Metal Quality

Commercial recycling systems never create pure material streams as they never achieve 100% material recovery during physical separation (dictated by separation physics) nor achieve 100% material recovery during high temperature metal production (dictated by thermodynamics). Therefore recycled materials always contain some degree of contamination, and this issue is of considerable importance in metal recycling.

Contaminants such as copper in steel and iron and silicon in aluminium, are those elements that are more "noble" than the host metal and, hence, are very difficult (and expensive) to remove. Present strategies include better sorting of metals prior to remelting, diluting contaminants by addition of primary metal and using recycled metal for lower grade applications (eg. wrought products in the case of aluminium).

In the longer term, however, these strategies will need to be supplemented by the development of effective refining processes for removing contaminants. While this will presumably increase the total energy consumption of secondary metal production, it is likely to still compare favourably with primary metal production. The issue of contaminants in aluminium recycling is that the development of products (consumer goods) brings together metals that are not linked in natural resources, and as a consequence, many of these materials are not completely compatible with current processes in the metals production network. The formation of complex residue streams or undesired harmful emissions then inhibits processing and recovery of such products at their end-of-life.

A decision tree model and a matrix have been constructed for several metal and material combinations that might occur in industrial products which is shown in Figure 24. The objective of the decision tree model is to determine whether a given material combination should be avoided or mechanically separated before metallurgical processing, or can be left together because the metallurgical processing is able to handle it. While lightweight metals are increasingly being used in products, the matrix their combination with other materials should be carefully considered, as they are very sensitive to contaminations.

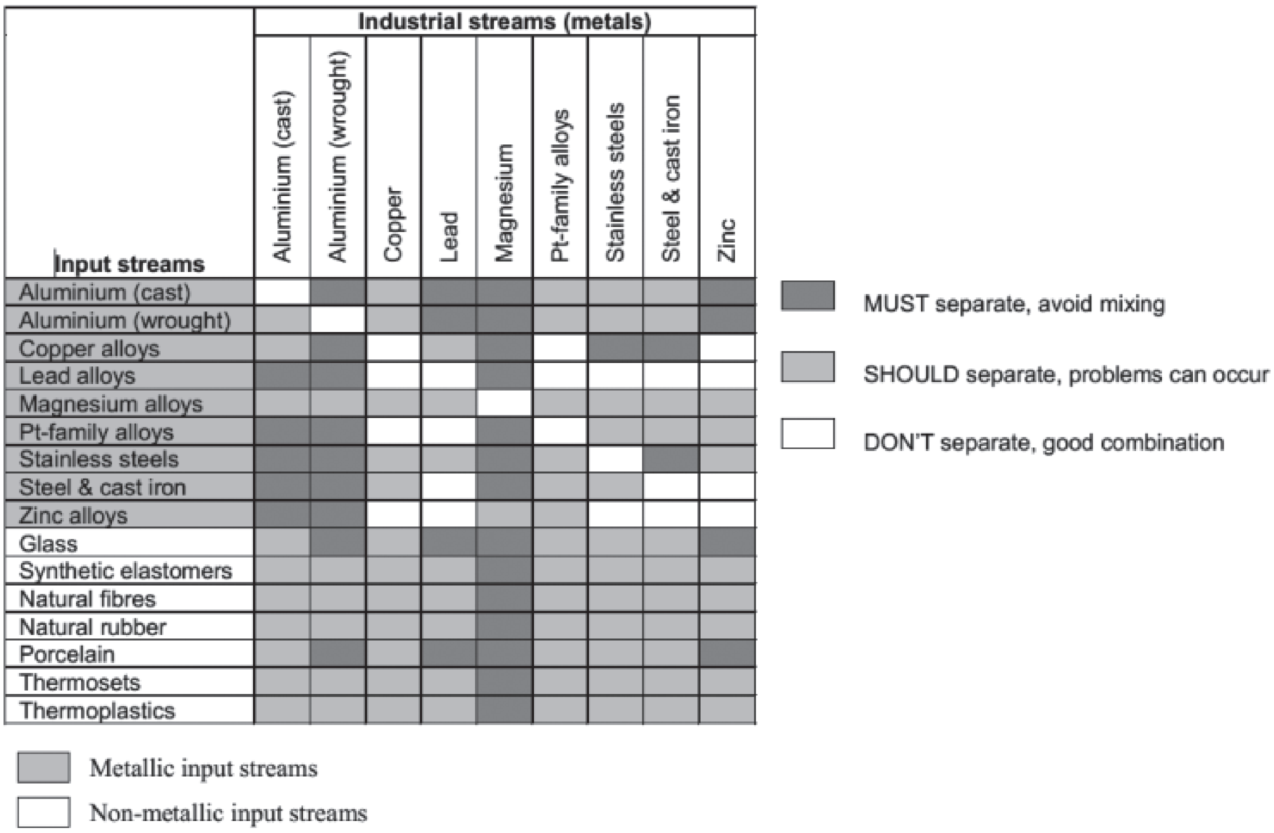


Figure 24: A decision tree model for sorting

7.2 Measuring the Recycling Performance: End-of-Life Recycling of Aluminium

Societies, governments and communities need to work alongside the industry to create effective collecting systems to ensure the constant improvement of recycling rates in all applications sectors. Usually, refiners and remelters report their (gross) metal yield by comparing their outputs of metal ingots with their scrap inputs, as values between 70% and 95%.

In 2005, an aluminium mass balance for the aluminium recycling industry in the EU-15 was carried out by Delft University of Technology, taking into account foreign material (paint, paper, plastic, lubricants etc), at the input side of the scrap and aluminium recycling from skimmings and salt slag. The study has shown that the real metal losses for all scrap melted in the EU-15 are usually less than 2%, i.e. the net metal yield is above 98%. For old scrap, metal losses are between 1% and 5% depending on the scrap type and the furnace technology used.

End-of-life recycling performance and recycled metal content are often misunderstood. From a technical point of view, there is no problem to produce a new aluminium product from the same used product. There are no quality differences between a product entirely made of primary metal and a product made of recycled metal. However, recycled aluminium is used where it is deemed most efficient in economic and ecological terms. Due to the overall limited availability of aluminium scrap, any attempt to increase the recycled content in one particular product would just result in decreasing the recycling content accordingly in another.

It would also certainly result in inefficiency in the global optimisation of the scrap market, as well as wasting transportation energy. The high market value of aluminium means that, if scrap is available, it will be recycled and not stockpiled.

7.3 End-of-Life Product Recycling: the Route to High Quality Products

Transport and building sectors are very high (85% to 95%) and represent more than 50% of finished goods. Between 30% to close to 100% of aluminium cans are found to be collected and recycled, depending on the region. The recycled product may be the same as the original product (e.g. window frame recycled back into a window frame or can to can), but is more often a completely different product (cylinder head recycled into a gearbox).

7.3.1 Transport

Transportation is the most important field of application for aluminium worldwide. In 2007, up to 30% of wrought and casting alloys put on the market were used in cars, commercial vehicles, aircraft, trains, ships, etc. Increasingly, aluminium products are being employed to reduce vehicle weights, without loss of performance, improving safety and reducing greenhouse gas emissions from vehicles' use-phase. In 2002 the average passenger car contained between 100 and 120 kg of aluminium, while in 2006 this figure had increased to between 110 and 140 kg. Forecast show aluminium contents of 120 to 150 kg in 2009 (Ducker Research).

A number of efficient processes are used to recover aluminium scrap from vehicles. Figure 22 show a modern process applied to recycle a typical passenger car. Some aluminium parts, such as wheels and cylinder heads, are removed during the initial dismantling of the vehicle. The car body, including the remaining aluminium, is fed to the shredder in the course of subsequent recycling. After separating the ferrous fraction using magnets, a mixture of plastics, rubber, glass, textiles, high grade steel and nonferrous metals is obtained. This mixed fraction is intended for sink-float separation and eddy current separation and result in the extraction of aluminium scrap.

Another process, developed to sort aluminium scrap metallurgically, utilises laser and spectroscopic technology. Aluminium scrap collected using the various separation procedures is today mainly processed into aluminium casting alloys, which serve as pre-material for the production of castings. Typical applications include engines and gearboxes. Due to the increased use of aluminium wrought alloys in car bodies, a growing volume of wrought alloy scrap is anticipated. Hence, the separate collection of wrought alloys rom cars will be economically viable in the future.

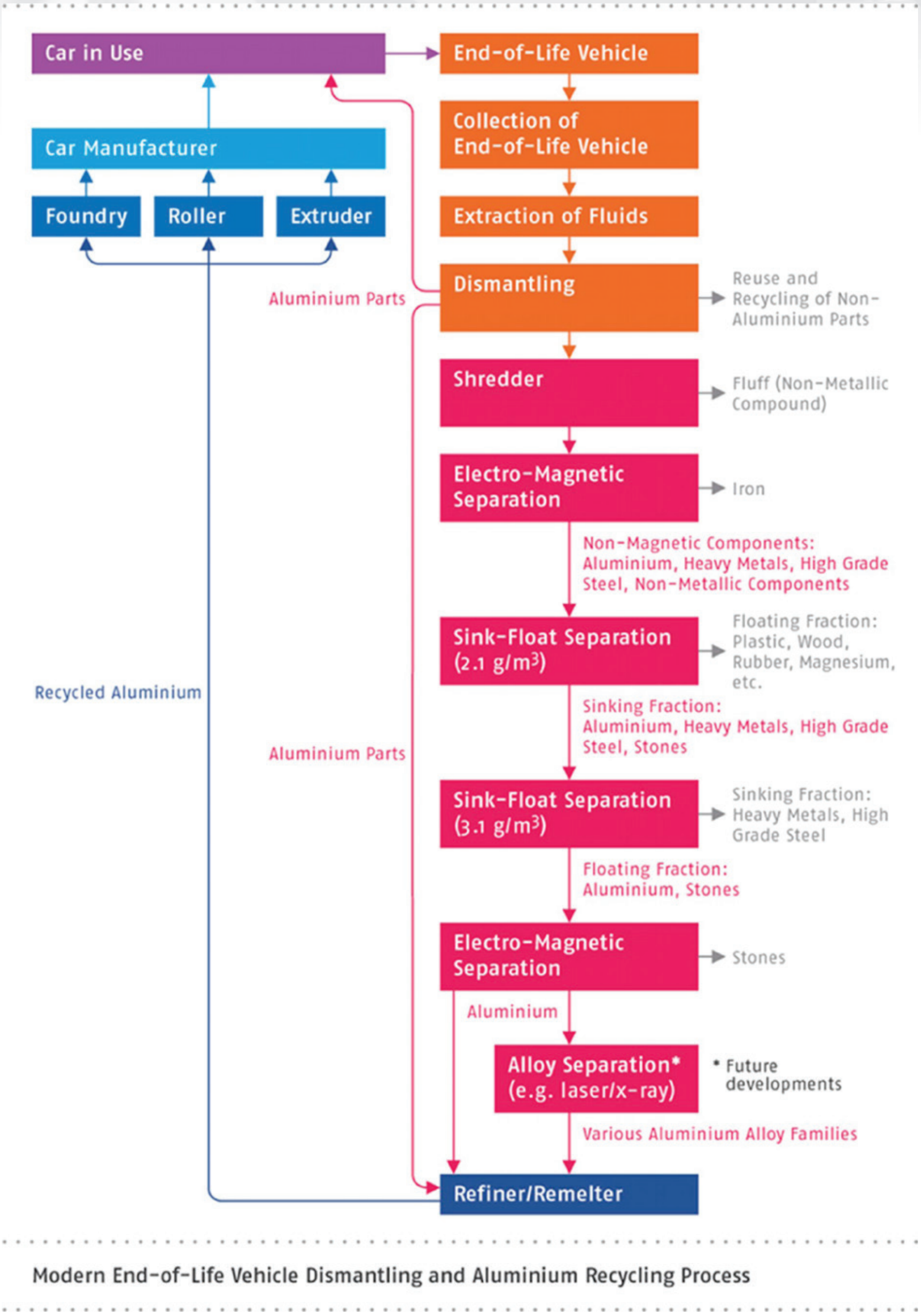


Figure 25: Modern End-of-life vehicle dismantling & aluminium recycling process

Aluminium used in other modes of transportation is collected separately at end-of-life, when commercial vehicles, aircraft, railway coaches, ships, etc. are dismantled. As the aluminium parts are often too large to be directly melted in the furnace, they must first be reduced to small pieces by processes such as shearing. A recent study by the University of Technology of Troyes on behalf of the European Aluminium Association demonstrated a recycling rate of 95% or higher for aluminium in trucks and trailers. Most aluminium-containing ships and railway coaches are still in use, though, because of aluminium's relatively recent history in these applications and its long-lasting performance.

7.3.2 Building

Architects have been aware of aluminium's unique qualities for over one hundred years. As well as being one of the most abundant metals in the world, aluminium's formability, high strength-to-weight ratio, corrosion resistance, and ease of recycling makes it the ideal material for a wide range of building applications. The main uses of aluminium are in the construction of windows, doors and facades, closely followed by roofs and walls. Other structural uses range from a glazed shop front to the superstructure of anything from a shopping centre to a stadium.

Aluminium can also be found in door handles, window catches, staircases, roller shutters and sun-shading systems, heating and air-conditioning systems and more recently in the support structures for solar panels, solar collectors and light shelves. Aluminium's excellent material properties provide the basis for intricate, stable and lightweight structures. These properties ensure that even thin structures do not warp. It also allows a high degree of prefabrication with a variety of finishes before components leave the factory. This reduces the work load at the construction site.

Aluminium's resistance to corrosion is particularly important if a component is installed in an inaccessiblele area. Aluminium is a material that has given the architect the physical means to achieve creative innovations in design. The life cycle analysis of buildings presents some very interesting challenges. Overall the building's design, along with the behaviour of the building's users will have a very large impact on its environmental and energy performance. The typical building will have four major parts to its life cycle; construction, use (mainly heating, lighting and air conditioning), maintenance and end-of-life management. Aluminium collection rates for European buildings are shown in Table 8.

DEMOLITION DATA ON ALL BUILDINGS INVESTIGATED

Case study	Mass of building [tonnes]	Aluminium identified [kg]	Aluminium share [grammes per tonne]	Collection rate [%]
Pau – Elf Aquitaine office building (F)	10 659	6 826	640	92
Le Mans – apartment buildings (F)	9 243	165	18	31
Wuppertal – courthouse (D)	10 188	76 414	7 500	98
Frankfurt – department store (D)	12 000	21 000	1 750	98
Milan – Pirelli factory and offices (I)	142 753	61 384	430	94
Ridderkerk – apartment buildings (NL)	32 700	1 034	32	95
Eindhoven – terraced houses (NL)	37 500	1 853	49	95
Madrid – BNP Paribas bank (E)	23 000	92 000	4 000	95
London – Wembley Stadium (UK)	34 918	213 000	6 100	96
Average collection rate (%) for buildings investigated				95.7

Table 13: Aluminium Collection Rates for European Buildings (source: TU Delft)

In a typical building the "use" phase of the life takes majority of the building's energy requirements while the materials and construction account for a only a small fraction of the building's energy requirements. Choosing the right material for the right application is therefore critical in reducing all the energy requirements over the life cycle of the building. The final phase of a building's life needs to also be considered when making material choices.

Ideally the material will be recycled in an economically and environmentally sustainable way. Usually the least desirable option is landfill. A large amount of waste building materials goes to landfill sites at a cost to both the economy and the environment, others are recycled at cost to the community. In contrast, aluminium is recycled in a way that pays for itself and is sustainable. The collection rate of aluminium in building can be determined by comparing of the mass of aluminium scrap dismantled from an end-of-life building with the mass aluminium identified in this building before starting to demolish it.

In 2004 Delft University of Technology conducted a study into the aluminium content of, and collection rates from, demolished buildings in six European countries, which found that the average collection rate for aluminium was more than 95%. Globally, aluminium enjoys a high collection rate of 85% in the building industry. The global industry is keen to increase collection rates and is working with producers of building applications to enable more efficient collection of scrap from demolished buildings.

Today the global building market uses some 11 million tons of final aluminium products annually. Globally, it is estimated that buildings and their content comprise some 400 million tons of aluminium, which can be extracted and reused by future generations time after time.

7.3.3 Packaging

Aluminium possesses unique barrier and physical properties and is therefore used extensively for the packaging of food, beverages and pharmaceuticals. Even in its thinnest form, aluminium effectively protects contents against the quality-reducing effects of oxygen, light, moisture, micro-organisms and unwanted aromas. Aluminium packaging fits every desired recycling and processing route.

The amount of aluminium packaging effectively recycled depends greatly upon individual national circumstances and the efficiency of the collection schemes, and therefore rates vary from 25% to 85% across the globe. In Europe the collection rate of all aluminium packaging is about 50%.

Two different types of packaging can be distinguished, namely

- rigid and semi-rigid packaging, i.e. food and beverage cans, aerosol cans, closures and menu trayswhich consist mainly of aluminium, and
- flexible packaging, i.e. packaging where a thin aluminium foil is laminated as a barrier material to plastics or cardboard.

For rigid and semi-rigid packaging, in which aluminium beverage cans are the most important representative product, aluminium remelters in particular have developed techniques to recycle old scrap into recycled aluminium ingots, from which wrought products (e.g. can stock) can be fabricated. Rigid and semi-rigid packaging scrap has high aluminium content and therefore a high market value.

The end-of-life route depends on the waste management policy of different countries. If for example a country decides not to separate such material but incinerate it as part of municipal waste, followed by sorting the incineration ash, the aluminium, because of its thickness and physical properties, can be separated and recycled. The collection rates of used beverage cans vary from country to country from 30% to close to 100%, with a global average of close to 70% (includes unregistered collection & recycling in some areas). Sweden and Switzerland collect 91% and 90% of their aluminium beverage cans, respectively. Sweden's success lies in a deposit system whereas in Switzerland a voluntary prepaid recycling charge covers the costs of collection. Brazil is also one of the world leaders in can recycling, with a collection rate of 97%. Every region in Brazil has a recycling market which facilitates easy collection and transportation of end-of-life products. This has encouraged communities to collect and form co-operatives across the country. In Japan a collection rate for used beverage cans of 93% is achieved with a voluntary system. Collecting points include recycle boxes at supermarkets and major shopping centres, volunteer groups and municipality offices.

For flexible packaging, the aluminium barrier often has a low thickness down to 6 microns. This is typically laminated to paper and/or plastic layers that are the mayor components of the packaging. This means that flexible packaging waste has a very low content of aluminium. Nevertheless, aluminium can be extracted from laminates by pyrolysis and thermal plasma techniques. Alternatively, such a packaging is incinerated with a recovery of the combustion heat. Because of its low thickness, the aluminium barrier will be oxidized completely, and the combustion heat of aluminium can be recovered.

The question of whether incineration or recycling is environmentally feasible can only be decided case by-case, while comparing the specific alternatives by life cycle assessments, taking specific local circumstances and other aspects of sustainability into consideration. Generally the energy required for the production of packaging is only a small percentage compared to the total energy used to produce and supply the final product. The aluminium barrier properties in flexible packaging is of special importance as it helps to prevent spoilage of food and pharmaceutical products, for instance, and therefore contributes to the food supply and health of the world's population.

8.0 Aluminium Recycling in India has a Great Future

As India embarks on a growing aluminium consumption trajectory, it must realize that both primary and scrap-recycling industries are essential to the vision of India's Aluminium Policy. Therefore, a fine balance must be maintained for the co-existence of primary and scrap so that it can cater to the future demand, both domestic and foreign.

One of the unique properties of aluminium is recyclability. There are several reasons as to why Primary and scrap are crucial for India's Aluminium story. While, producing Aluminium from recycled scrap produces much less carbon emissions compared to primary metal, Primary aluminium production in terms of value addition is 15 times that of scrap recycling. Also, scrap usage is limited to specific applications based on their alloy composition and is often used along with Primary in manufacturing processes.

A National Material Recycling Policy, shall aim to create generate public awareness to Reduce, Reuse and Recycle to make it a habit of choice. The policy shall provide guidance to enable India to establish an appropriate legislative, administrative and institutional framework for recycling of metals and materials. The Scrap policy shall be formulated to reflect new needs, issues and opportunities with an aim to achieve a target of 85% recycling rate by the year 2025 and enhance job creation opportunities. Scrap usage in India is diffused and not regulated through standards or end-use restrictions with heavy reliance on imports. With growing consumption of aluminium in the country India will reach steady-state value of Aluminium consumption. In this phase, it's the scrap that can be recycled again and again to cater to steady state consumption demand.

Secondary aluminium accounts for 30% of India's overall aluminium consumption of 3.3 million tons per year. In the past six years, secondary aluminium demand has almost doubled to 1.1 million tons, of which some 90% is imported. By 2021, demand is expected to reach 1.6 million tons Figure 26.

In 2016, some 120,000 tons of aluminium scrap was generated in India, with the automotive and power segments together accounting for 75% of the total. India's domestic scrap market may be fast-growing but still has a long way to go. Table 14 show estimated collection recycling rate of old scrap in India. On the positive note, new initiatives are underway to boost recycling including car dismantling etc. These are beginning towards scrap import independency. And India's domestic scrap industry is trying hard to modernise, this can be achieved only with regulatory support.

Year	2015	2016	2017	2030
Bldg & Const	80%	80%	80%	80%
Transportation - Auto & Lt Truck	80%	80%	80%	80%
Transportation - Aerospace	80%	80%	80%	80%
Transport- Truck/Bus/Trailer/ Rail/Marine/Other	80%	80%	80%	80%
Packaging - Cans	87%	87%	87%	87%
Packaging - Other (Foil)	20%	20%	20%	20%
Machinery & Equipment	60%	60%	60%	60%
Electrical - Cable	60%	60%	60%	60%
Electrical - Other	60%	60%	60%	60%
Consumer Durables	60%	60%	60%	60%

Table 14: Estimated collection recycling rate of old scrap in India

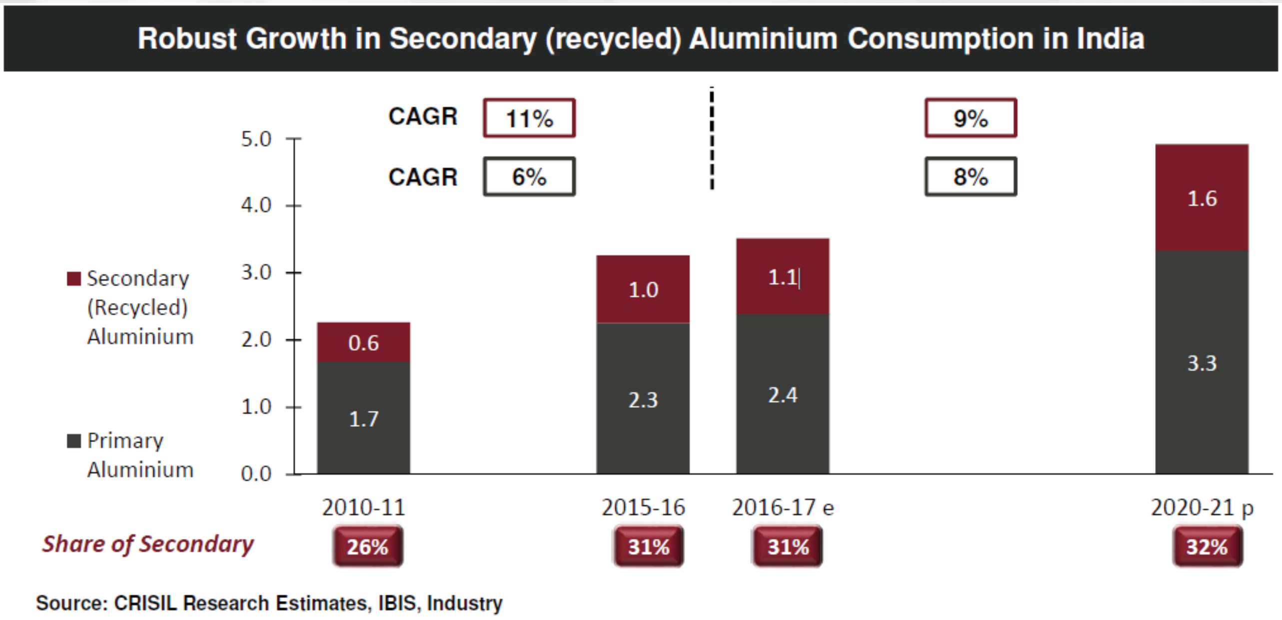


Figure 26: Secondary aluminium consumption in India

Raw Material Scenario

For successful recycling of aluminium scrap, abundant availability of good quality scrap is inevitable. Typical mechanism old scrap collection in the country include

- Unorganised way : **by local collection on daily basis through street vendors**
- Organised: **way By tender / auction with scrap generators**
- Imports

Remelters source scrap aluminium through

- Local : **through local scrap dealers**
- Rate Contract: **by tender / auction with scrap generators**
- Imports

In spite of the above mechanism, regular supply of good quality, graded scrap is not prevalent and local scrap collection of scrap from domestic and household items is done through street vendors who in turn pass it on to local scrap dealers. Wet/Instrumental chemical analysis methods are being adopted by most of the companies for sorting/grading of scrap purchased from the market. Physical inspection method based on visual observation is also adopted. The quantum of scrap imported during 2016 is mentioned in Table 10.

For India, the dynamics of primary and scrap production and consumption will follow two phases. Phase one will see India's consumption of aluminium grow up strongly owing to investments in infrastructure and defense. In the absence of a formalized and standardized scrap recycling policy and industry, our consumption needs would make us unduly rely on foreign imports, despite significant scrap generation and processing potential.

Phase two will witness India reaching some steady-state value of Aluminium consumption. In this phase, it's the scrap that can be recycled again and again to cater to steady state demand. Currently, In India we do not have any formal organized Metals Recycling industry structure. The industry is not highly regulated and there are no specially designated zones/areas for Metals Recycling.

Exporters	Value imported in 2016 (USD thousand)	Quantity imported in 2016	Quantity unit	Unit value (USD/unit)
World	**1,330,645**	**919,376**	**Tons**	**1,447**
Saudi Arabia	182,835	118,886	Tons	1,538
United Kingdom	178,322	129,797	Tons	1,374
UAE	161,048	107,679	Tons	1,496
USA	113,193	76,073	Tons	1,488
Australia	95,255	64,766	Tons	1,471
Netherlands	72,199	51,641	Tons	1,398
South Africa	56,046	41,424	Tons	1,353
Singapore	36,223	24,878	Tons	1,456
Germany	35,698	26,150	Tons	1,365
Kuwait	32,314	21,707	Tons	1,489
Nigeria	29,550	21,843	Tons	1,353
Belgium	24,742	17,813	Tons	1,389
Malaysia	19,170	11,876	Tons	1,614
Bahrain	19,006	13,043	Tons	1,457
Qatar	18,350	12,008	Tons	1,528
New Zealand	18,023	12,237	Tons	1,473
Israel	16,300	11,228	Tons	1,452
Lebanon	13,558	9,670	Tons	1,402
Ghana	12,132	8,932	Tons	1,358
Italy	12,017	8,685	Tons	1,384
Spain	11,059	7,383	Tons	1,498
Benin	10,923	7,962	Tons	1,372
Jordan	9,683	6,355	Tons	1,524
Morocco	9,200	6,606	Tons	1,393
Sources: ITC calculations based on UN COMTRADE statistics.				

Table 15: Waste and scrap of aluminium product imported by India in 2016

Dross Handling In India

Disposal and recycling of dross is worldwide challenge. Secondary industries are responsible for millions of tons of dross/salt slag landfill waste per year. There continues however to be pressure to reduce or eliminate this waste by the aluminium industry in general as we see pressure for sustainable processing. Due to stringent pollution control regulations, the industries are forced to consider the alternative use. Solutions could be the possibility for making some value added products from waste aluminium dross.

There is market potential for Aluminium dross waste as an alternative alumina source for refractory aggregates. The potential benefit of channeling aluminium dross towards refractory material is obvious because dross is a great source of aluminium oxides, thus, it is an alternative source to primary materials.

Increasing domestic and imported scrap will further add to the existing volume to re-melt units. High cost of melt loss, environmental concerns and maximizing metal recoveries shall be key driving factors for Indian Aluminium primaries as well as secondaries to implement better methods, work practices and technology. Metal loss as dross during the melting of Aluminium is and should be a major concern to all Aluminium producers and remelters. Cost reduction, the preservation of metal units and environmental awareness all make limiting dross formation during the melting process a major goal for cast houses and remelt centre.

Dross handling and processing to recover metal is equally important. Few decades ago what was considered normal recovery of 30% of dross weight will not be accepted today. With current technology over 65% will be expected as the minimum return of metal from a given dross weight. All this has been possible as a result of continuous developments in the technology to meet the environmental concerns, energy conservation, profitability and community impact for the long-term sustainability of the industry the triple bottom line concept will be essential.

The rapid pace of this expansion is creating a technology gap, where industries presently used to traditional methods need to change its mind set and invest in the state-of-the-art technology to stay competitive. The present practices of melting, melt handing and dross processing in India have not yet adopted current technology. This technology gap needs to be filled to meet the triple bottom line for a sustainable industry.

UN 3170 designate dangerous goods class 4.3" aluminium smelting by product" in contact with water emit flammable gases. Dross is listed good, too dangerous to be transported. Since there is no organized sector in dross management therefore; the proposed works definitely help the producer of dross in recycling and management of waste and also help in financial and environmental benefits for the company. Project success would open a new source of alum preparation instead of conventional sources (bauxite) and also achieve zero waste concepts, while using waste dross material. Preparation of alum/Castable refractory from waste grade aluminium dross will definitely curtail the expenses towards procurement alum in the company. Non-metallic residues (residual dross) produced during processing of could be used as a source of aluminium oxide in castable refractory. A source of Aluminium oxide (Al2O3) from dross recycling comprises an alternative source to primary materials. Also, less waste is disposed of to landfill.

Global Aluminium Scrap Exporters

The highest recycling percentages can be seen in the construction and transport sector of up to 95% but packaging sector is equally growing due to increased use of foil and cans. It is evident that the countries with higher aluminium consumption would be the countries that would also be largest generator of scrap. Not all countries export their scraps; a large portion of it is recovered domestically to make new aluminium. Since packaging and automotive scraps are recycled and recovered faster, the following countries with more aluminium consumption in these sectors remain the top exporters of scrap.

- **United States**
- **Germany**
- **United Kingdom**
- **France**
- **Saudi Arabia**

United States

More than 36% of **United States'** aluminium metal supply is from recycled metal, and the region is the world's most resource-abundant secondary recovery site because of its long history of aluminium production and consumption. In addition to scrap collected and recycled for producing secondary aluminium for domestic use, nearly 2 million tons of scrap is exported each year, representing one-third of the total global scrap supply. Without scrap recovery the capacity of US aluminium industry would be curtailed drastically as the country has already shut down about 75% of the total primary capacity.

Meanwhile, for the USA, the world's largest aluminium scrap exporter, global scrap shipments were down 12.3% year-on-year in 2015 as reported by Metal Bulletin. According to the recent analysis by **World City of** the latest U.S. Census Bureau data, U.S. exports of aluminium waste and scrap decreased 23% from $2.35 billion to $1.81 billion in 2016 in comparison to 2015.

This is because, after the fall out of primary aluminium industry the U.S. is concentrating more on scrap generation and recovery to produce secondary aluminium. Omni Source Corp., Sims Metal Management, David J. Joseph Co., Commercial Metals Co. are some of the biggest aluminium scraps suppliers in the US.

Germany

Europe accounts for more than 15% of global aluminium consumption and Europe's major aluminium market is Germany, which is home to the world's largest automakers. Germany contributes 25% of total aluminium consumption in Europe, and the development of the global aluminium industry depends significantly on this market. Germany's automotive industry has a high growth potential as it exports cars all over the world catering to the increasing consumption of automotive vehicles.

German aluminium producers and processors produce about 560,000 tons of aluminium. It comprises about 260,000 tons of primary aluminium and 300,000 tons of recycled aluminium.

The aluminium rolling mills account for the largest share of aluminium semis production and the largest customers for rolled aluminium semis are the automotive industry along with packaging and industrial applications. These sectors put together, account for almost three fourth of the total rolled products demand. The automotive industry generates a large amount of aluminium scrap. Other than recovering secondary aluminium from the scrap domestically, the country also exports about 1 million tons of scrap every year.

WMR Recycling, Harita Metals Co, ScholzAlu Stockach GmbH, TSR Recycling GmbH & Co. KG are some of the major scrap suppliers in Germany.

UK

Since 2002, EU has been a continuous net exporter of aluminium scrap year-on-year. On the flip side, high export levels of scrap compromises the development of the recycling industry and the circular economy in Europe. More than 80% of this scrap generated in European Union heads to Asia, with 37% destined for China and 28% to India.

The aluminium scrap generated in the UK is more than the needs of the UK foundry industry. The secondary refiners have therefore developed export markets for their products. There is also a considerable export of aluminium scrap, particularly to China. The remelters are usually connected with the integrated, global aluminium companies and most of the production of rolling slab and extrusion billet is used within their own supply chain. United Kingdom exports about 514,762 tons of scrap annually. The annual production of primary metal in the UK is approximately 200,000 tons and more than double the amount is recovered from recycling aluminium scrap and the extra scrap is exported for recycling in other countries.

France

France is one of the key growth markets in European aluminium industry which grew by 2.4% year on year. The country's aluminium consumption is driven by packaging, building and the automotive sector. The average European car now contains over 130 kgs of aluminium, (about 10% of the weight), and this level is increasing which also boosts the amount of end-of-life aluminium scrap generation from the automotive sector. In the same way packaging and building and construction segment generates substantial amount of scrap. France exports about 400,000 tons of aluminium scrap every year.

Recently, the aluminium scrap export has seen a decline in France. Many scrap dealers in France have reported more than adequate stock levels. A boost in domestic recycling effort can be more productive for the European countries including France.

Saudi Arabia

The Middle East and the GCC is one of the fastest growing aluminium markets in the world. The aluminium recycling market is predominantly export-driven as the downstream industry is yet to develop as a major scrap procurer in the region. The Middle East has a nominal rate of 20 per cent aluminium recycling including smelter re-melting, scrap generation, and secondary re-melting. The major hurdle in the Middle East Aluminium Scrap Market, which results in low rate of recycling is the lack of development of downstream industry. As per Frost & Sullivan estimates, the total Aluminium Scrap generated in the Middle East is estimated to be about 500,000 tons, of which about 360,000 tons are exported to international market destinations.

The Kingdom of Saudi Arabia (KSA) is a major hub for scrap metal recycling followed by the United Arab Emirates (UAE) in the Middle East. Most of the aluminium scraps generated in Saudi Arabia are from consumers, industries, and demolition sites across the country. The country exports about 210,000 tons of aluminium scraps to countries like India, Pakistan, South Korea, Brazil and USA. With the development of new smelters and expansions, more secondary re-melting opportunities will arise in the GCC countries and till then Saudi Arabia would remain a net exporter of aluminium scrap. Country and year wise Global Exports and imports of aluminium scrap are shown in Table 11 & 12.

Global Exports of Aluminum Scrap by Country and Year
(in metric tons)

ISRI Institute of Scrap Recycling Industries, Inc.
Voice of the Recycling Industry™

Top 20 Exporters	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
USA	1,442,272	1,522,021	1,935,165	1,596,601	1,821,190	2,049,151	1,967,664	1,812,917	1,666,019	1,498,303	1,279,788
Germany	732,938	770,065	702,737	753,216	823,810	945,815	976,412	935,339	1,056,231	1,064,372	1,043,968
Canada	417,369	429,765	403,882	365,356	443,996	473,247	482,748	457,277	493,456	499,982	501,550
France	345,107	379,101	342,467	345,308	403,660	428,246	424,881	448,284	482,768	450,827	454,778
United Kingdom	385,292	848,568	874,909	419,972	454,699	440,726	445,390	402,061	452,606	406,070	439,713
Netherlands	334,426	317,877	264,142	200,650	317,038	322,834	378,652	320,523	349,012	360,748	370,527
Belgium	183,412	185,891	177,550	219,804	274,632	320,103	311,159	313,183	285,677	278,763	274,128
Australia	173,865	178,498	177,078	160,948	196,259	189,361	205,016	207,246	228,379	258,970	266,061
Poland	107,210	113,008	122,681	99,522	123,979	150,581	152,463	154,829	180,076	179,880	215,418
Austria	79,390	90,275	87,952	117,949	122,057	105,137	128,587	151,419	173,159	151,625	199,021
Mexico	163,079	179,260	186,510	162,668	183,932	194,355	234,333	169,557	151,152	156,049	180,629
Japan	103,137	108,933	83,776	147,695	98,621	109,443	146,450	157,903	150,737	150,054	174,115
Saudi Arabia	101,894	131,242	111,569	103,413	137,349	149,895	200,558	176,108	189,858	156,296	170,525
United Arab Emirates	43,291	46,171	53,129	90,278	128,798	112,367	143,071	164,251	162,986	139,675	163,981
Italy	50,536	47,153	66,993	88,702	107,155	103,006	103,667	107,060	111,214	144,319	151,977
Switzerland	140,657	139,599	125,769	116,520	132,086	138,643	141,836	149,337	157,500	139,313	146,205
Sweden	67,871	108,115	106,580	89,939	87,491	95,495	106,761	102,955	112,675	102,166	111,549
Spain	43,191	34,104	110,468	46,974	66,976	51,518	90,881	94,856	80,107	89,263	100,021
Denmark	62,112	52,493	63,813	67,853	67,449	67,131	69,974	71,975	79,029	75,502	80,602
Czechia	54,472	61,078	58,438	49,251	71,398	91,192	87,699	57,714	72,423	81,820	77,986
Rest of the World	**1,160,062**	**1,164,287**	**2,199,497**	**952,681**	**1,337,992**	**2,252,639**	**1,514,186**	**1,364,435**	**1,418,872**	**1,434,042**	**1,496,787**
Grand Total	**6,191,581**	**6,907,503**	**8,255,103**	**6,195,302**	**7,400,567**	**8,790,883**	**8,312,391**	**7,819,230**	**8,053,936**	**7,818,040**	**7,899,327**

*Notes
1) Data tables were derived from the UN Comtrade Database (last downloaded on March 23, 2018)
2) Top 20 determined by latest year of complete data
3) Export data was adjusted for the United Arab Emirates

Table 16: Country & year wise global exports of aluminium scrap

Global Imports of Aluminum Scrap by Country and Year
(in metric tons)

ISRI Institute of Scrap Recycling Industries, Inc.
Voice of the Recycling Industry™

Top 20 Importers	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
China	1,765,374	2,090,604	2,154,768	2,626,116	2,854,156	2,685,684	2,592,533	2,504,366	2,305,580	2,086,855	1,917,435
India	247,929	237,194	241,180	297,855	456,333	584,740	709,532	724,101	840,540	882,882	919,376
Germany	597,310	613,081	543,837	362,582	479,416	534,989	577,092	560,691	656,604	790,138	770,140
Rep. of Korea	377,177	467,491	503,154	443,898	545,692	566,953	641,800	711,174	801,211	745,958	715,173
Italy	377,548	448,689	386,459	273,083	376,486	461,302	445,450	456,370	511,986	520,448	517,954
USA	495,527	462,068	476,462	395,212	480,034	545,913	564,447	538,196	536,994	509,848	513,240
Austria	155,586	166,850	170,815	162,155	268,845	282,707	304,271	280,710	285,563	282,557	308,272
Belgium	192,053	192,072	193,475	203,681	221,425	254,967	247,463	219,054	237,096	248,872	275,997
France	206,107	188,814	193,826	215,537	259,420	291,690	266,280	245,937	231,714	215,905	260,759
Poland	52,416	59,519	66,968	66,793	84,850	106,438	107,598	176,509	205,230	238,950	235,391
Spain	107,753	124,093	109,861	67,321	111,942	125,190	155,371	176,445	200,411	205,856	203,673
Netherlands	197,160	204,117	210,203	88,053	184,066	241,081	265,741	220,965	233,610	202,103	185,978
Luxembourg	198,508	196,584	136,806	98,962	128,607	151,237	162,001	165,014	154,961	150,110	142,363
Malaysia	270,015	45,225	56,249	61,754	64,318	79,515	74,988	70,492	88,132	93,747	136,665
Czechia	49,358	63,606	58,686	50,279	61,714	88,951	105,390	83,294	78,491	83,103	125,211
Pakistan	45,969	80,236	59,118	84,872	88,661	90,483	102,437	76,094	105,850	130,775	125,163
United Kingdom	141,469	158,724	149,900	117,673	126,773	110,275	103,224	113,461	168,300	123,124	123,246
Canada	139,489	166,687	163,312	118,266	117,870	121,575	92,098	90,898	102,034	117,890	117,266
Mexico	112,820	112,489	100,475	69,488	126,783	105,363	102,328	89,255	118,549	151,924	113,830
Slovenia	51,596	52,126	51,194	37,315	51,792	52,844	61,462	69,014	77,942	84,186	91,076
Rest of the World	**772,477**	**955,666**	**1,020,837**	**668,410**	**956,239**	**995,670**	**882,814**	**915,381**	**965,009**	**992,748**	**965,013**
Grand Total	**6,553,642**	**7,085,935**	**7,047,583**	**6,509,306**	**8,045,420**	**8,477,565**	**8,564,322**	**8,487,420**	**8,905,809**	**8,857,977**	**8,763,220**

*Notes
1) Data tables were derived from the UN Comtrade Database (last downloaded on March 23, 2018)
2) Top 20 determined by latest year of complete data

Table 17: Country & year wise global imports of aluminium scrap

9.0 Recommendations on Indian Aluminium Recycling

Aluminium as a core industry: Currently, India identifies coal, crude oil, natural gas, refinery products, fertilizers, steel, cement and electricity as its eight core industries. Aluminium contributes to nearly 2% of manufacturing GDP and with projected consumption growth, it is expected that the share (% of manufacturing GDP) to go higher. The industry also has a high direct and an indirect employment multiplier creating close to 800,000 jobs. Therefore, Aluminium industry may be classified as a core industry.

Aluminium as a Strategic Sector: A country's over-reliance on foreign import for essential strategic metals may be detrimental towards the objective of national security. A strong economic power should be able to produce enough high-quality metal to ensure self- reliance in its defence and critical infrastructure needs in order to avoid global volatility in supply and prices.

Export policy for downstream industry: Downstream producers of aluminium need to be encouraged towards high end production and exports of value-added exports of aluminium. This must be in sync with the objective of Make in India with focus on the development of the entire value chain of aluminium production in India.

Zero waste concept for the industry: Aluminium Industry produces more of waste (solid) than primary metal during its making. The waste can be converted in value added products with less efforts and resources. The aluminium industry can very well compensate for all energy and GHG through circular economy route.

Metal Scrap Recycling: Scrap usage in India is diffused and not regulated through standards or end-use restrictions with heavy reliance on imports. The secondary aluminium shall aim to achieve a target of 85% recycling rate by the year 2025 and enhance job creation opportunities.

In order to encourage the domestic industry, the Government policy ought to encourage this industry to become globally competitive for aluminium products. Therefore, the Government policy may include proper duty, tax, subsidy etc.

There is practically no export of aluminium scrap falling under TI 76020010. The total quantity of such export during 2016-17 was 4173 MT, however, no restrictions has been imposed by the Government on the export of aluminium scrap. Government may consider banning the export of aluminium scrap as indigenous supply is very poor.

Metals Recycling industry is Unorganised: In India we do not have any formal organized Metals Recycling industry structure in India. The industry is not highly regarded and there are no specially designated zones/ areas for Metals Recycling. Due recognition of recycling could encourage users of aluminium particularly in transport, housing, packaging and durable sectors to broaden the organised markets for the scrap generated.

Infrastructural Issues: There is no proper scrap collection, segregation, treatment etc facilities. Government may consider zonal scrap collection/segregation/treatment facilities. Also recycling zones may be developed to address above issues including transportation, pollution control etc.

The secondary aluminium industry may be encouraged to save enormous amount of energy and natural resources like bauxite, coal, water, forest cover etc. and will reduce carbon emissions.

The secondary sector cannot depend on indigenous scrap for its sustenance. Locally available scrap is far too less and irregular in supply and the quality is questionable as per international standards. Import of scrap is imperative for the healthy existence and growth of the secondary sector till the time India reaches steady state with regard to indigenous scrap generation.

Scrap disposal system in government owned PSU's and Ordnance factories may be introduced to improve the scrap availability.

Primitive technology usage in the Recycling industry: Most recycling units in India operate on outdated, or primitive technology which leads to high levels of pollution and energy consumption. This is an area that needs to be addressed by the Indian aluminium industry. The present technology used by most of the small-scale operators are primitive, resulting in the loss of the metal to dross and also contamination with undesired elements. Recycling programs may be organised to improvise the awareness pertaining to recycling and associated quality/energy/environment issues.

Imports need to be well regulated to prevent entry of semis in the garb of scrap. Also, aluminium scrap standards like European Union and china shall be evolved improve the quality of recycled metal, reduce the processing cost etc.

Quality Control of Recycled Aluminium products: A serious concern has been raised regarding quality of products manufactured through secondary route (recycled route). It has been observed and verified that quality products maintained through recycled routes do not follow any quality standards as followed by primary producers. Independent agencies/institutions like JNARDDC should be assigned with responsibility of certifying the products made from recycled metals on similar pattern as followed by ARAI for automobile products certification.

Pollution control: Recycling of aluminium may be associated with emission of hazardous gases like chlorine, hydrogen chloride etc., may become significant in large scale operation where the usage of fluxes and chlorine-based degassing agents are used. In long term legislations may be evolved for recycling industry to ensure proper pollution control as well as good health of the labours engaged in these industries.

- **Public Awareness Campaign:** It is recommended to introduce a Public Awareness Campaign on the quality of aluminium being recycled. This can be achieved by the authorised nodal agency like Aluminium Association of India, JNARDDC, MRAI etc.

Glossary

Casting alloys

Aluminium alloys primarily used for the production of castings, i.e. products at or near their finished shape, formed by solidification of the metal in a mould or a die. Casting alloys typically have an alloy concentration of up to 20%, mostly silicon, magnesium and copper. Typical castings are cylinder heads, engine blocks and gearboxes in cars, components used in the mechanical and electrical engineering industries, components for household equipment and many other applications.

Deoxidation aluminium

Aluminium consisting of alloys with a high concentration of metallic aluminium (usually exceeding 95%) used to remove free oxygen from liquid steel. Direct emissions generated by the production process. End-of-life aluminium that has been discarded by its end-user.

Foundry industry

Main customers of refiners. They produce a wide variety of castings which are mostly used in the transport sector.

Indirect emissions

Emissions generated during the production and supply of electricity.

New scrap

Raw material mainly consisting of aluminium and/or aluminium alloys, resulting from the collection and/or treatment of metal that arises during the production, of aluminium products before the aluminium product is sold to the final user. Fabricator and internal scrap are included in the term new scrap.

Old scrap

Raw material mainly consisting of aluminium and/or aluminium alloys, resulting from the collection and/ or treatment of products after use. Primary aluminium Unalloyed aluminium produced from alumina, usually by electrolysis and typically with an aluminium content of 99.7%.

Recycled aluminium

Aluminium ingot obtained from scrap is now referred to as recycled aluminium (formerly secondary aluminium). In this brochure the quantity of recycled aluminium refers to the production of aluminium from traded new and old scrap. Fabricator scrap is excluded.

Recycling

Aluminium collection and subsequent treatment and melting of scrap.

Recycling Rates

Performance indicators of global recycling performance are as follows:

Recycling input rate

Recycled aluminium produced from traded new scrap and old scrap as a percentage of total aluminium (primary and recycled sources) supplied to fabricators.

Overall recycling efficiency rate

Recycled aluminium produced from traded new scrap and old scrap as a percentage of aluminium available from new and old scrap sources. End-of-life recycling efficiency rate Recycled aluminium produced from old scrap as a percentage of aluminium available from old scrap sources.

The end-of-life collection rate

Aluminium collected from old scrap as a percentage of aluminium available for collection from old scrap sources. The end-of-life processing rate Recycled aluminium produced from old scrap as a percentage of aluminium collected from old scrap sources.

Refiner

Producer of casting alloys and deoxidation aluminium from scrap of varying composition. Refiners are able to add alloying elements and remove certain unwanted elements after the melting process.

Remelter

Producer of wrought alloys, usually in the form of extrusion billets and rolling ingots from mainly clean and sorted wrought alloy scrap.

Skimmings

Material composed of a mixture of aluminium, aluminium oxides and gas, which has been removed from the surface of the molten metal or from the bottom and walls of liquid metal containers, e.g. furnaces or transport ladles or transfer channels. This by-product is also termed “dross”.

Salt slag

Residue generated after remelting of aluminium scrap with fluxing salt, consisting of salt in which metallic and non-metallic particles are trapped in amounts that exhaust its fluxing properties. Fluxing salt is used mainly for refining in rotating furnaces in order to:

1. Cover the molten metal to prevent oxidation,
2. Increase the net metal yield,
3. Clean the metal from non-metallic inclusions and dissolved metallic impurities (e.g. calcium and magnesium), and
4. Enhance thermal efficiency in the furnace.

Wrought alloys

Aluminium alloys primarily used for wrought products by hot and/or cold working. Wrought alloys typically have an alloy concentration of up to 10%, mostly manganese, magnesium, silicon, copper and zinc. Typical wrought products are sheet, foil, extruded profiles or forgings.

Scrap specifications ISRI

Tablet	CLEAN ALUMINIUM LITHOGRAPHIC SHEETS To consist of 1000 and/or 3000 series alloys, to be free of paper, plastic, excessively inked sheets, and any other contaminants. Minimum size of 3” (8 cm) in any direction.
Tabloid	NEW, CLEAN ALUMINIUM LITHOGRAPHIC SHEETS To consist of 1000 and/or 3000 series alloys, uncoated, unpainted, to be free of paper, plastic, ink, and any other contaminants. Minimum size of 3” (8 cm) in any direction.
Taboo	MIXED LOW COPPER ALUMINIUM CLIPPINGS AND SOLIDS Shall consist of new, clean, uncoated and unpainted low copper aluminium scrap of two or more alloys with a minimum thickness of 0.015 inches (.38 mm) and to be free of 2000 and 7000 series, hair wire, wire screen, punchings less 1/2 inch (1.25 cm) diameter, dirt, and other non-metallic items. Grease and oil not to total more than 1%. Variations to this specification should be agreed upon prior to shipment between the buyer and seller.
Taint/ Tabor	CLEAN MIXED OLD ALLOY SHEET ALUMINIUM Shall consist of clean old alloy aluminium sheet of two or more alloys, free of foil, venetian blinds, castings, hair wire, screen wire, food or beverage containers, radiator shells, airplane sheet, bottle caps, plastic, dirt, and other non-metallic items. Oil and grease not to total more than 1%. Up to 10% Tale permitted.
Take	NEW ALUMINIUM CAN STOCK Shall consist of new low copper aluminium can stock and clippings, clean, lithographed or not lithographed, and coated with clear lacquer but free of lids with sealers, iron, dirt and other foreign contamination. Oil not to exceed 1%.
Talc	POST-CONSUMER ALUMINIUM CAN SCRAP Shall consist of old aluminium food and/or beverage cans. The material is to be free of other scrap metals, foil, tin cans, plastic bottles, paper, glass, and other non-metallic items. Variations to this specification should be agreed upon prior to shipment between the buyer and seller.
Talcred	SHREDDED ALUMINIUM USED BEVERAGE CAN (UBC) SCRAP Shall have a density of 12 to 17 pounds per cubic foot (193 to 273 kg/m3). Material should contain maximum 5% fines less than 4 mesh (U.S. standard screen size) (6.35 mm). Must be magnetically separated material and free of steel, lead, bottle caps, plastic cans and other plastics, glass, wood, dirt, grease, trash, and other foreign substances. Any free lead is basis for rejection. Any and all aluminium items, other than used beverage cans, are not acceptable. Variations to this specification should be agreed upon prior to shipment between the seller and buyer.
Taldack	DENSIFIED ALUMINIUM USED BEVERAGE CAN (UBC) SCRAP Shall have a biscuit density of 35 to 50 pounds per cubic foot (562 to 802 kg/m3). Each biscuit not to exceed 60 pounds (27.2 kg). Nominal biscuit size ranges from 10” to 13” x 101/4” (25.4 x 33 x 26 cm) to 20” x 61/4” x 9” (50.8 x 15.9 x 22.9 cm). Shall have banding slots in both directions to facilitate bundle banding. All biscuits comprising a bundle must be of uniform size. Size: Bundle range dimensions acceptable are 41” to 44” x 51” (104 to 112 cm) to 54” x 54” (137 x 137 cm) to 56” (142 cm) high. The only acceptable tying method shall be as follows: Using minimum 5/8” (1.6 cm) wide by .020” (.05 cm) thick steel straps, the bundles are to be banded with one vertical band per row and a minimum of two firth (horizontal) bands per bundle. Use of skids and/or support sheets of any material is not acceptable. Must be magnetically separated material and free of steel, lead, bottle caps, plastic cans and other plastic, glass, wood, dirt, grease, trash, and other foreign substances. Any free lead is basis for rejection. Any and all aluminium items, other than used beverage cans, are not acceptable. Items not covered in the specifications, including moisture, and any variations to this specification should be agreed upon prior to shipment between the seller and buyer.

Taldon	BALED ALUMINIUM USED BEVERAGE CAN (UBC) SCRAP Shall have a minimum density of 14 pounds per cubic foot (225 kg/m3), and a maximum density of 17 pounds per cubic foot (273 kg/m3) for unflattened UBC and 22 pounds per cubic foot (353 kg/m3) for flattened UBC. Size: Minimum 30 cubic feet (.85 m3), with bale range dimensions of 24” to 40” (61 to 132 cm) by 30” to 52” (76 to 132 cm) by 40” to 84”(102 to 213 cm). The only acceptable tying method shall be as follows: four to six 5/8” (1.6 cm) x .020” (5 mm) steel bands, or six to ten #13-gauge steel wires (aluminium bands or wires are acceptable in equivalent strength and number). Use of skids and/ or support sheets of any material is not acceptable. Must be magnetically separated material and free of steel, lead, bottle caps, plastic cans and other plastic, glass, wood, dirt, grease, trash, and other foreign substances. Any free lead is basis for rejection. Any and all aluminium items, other than used beverage cans, are not acceptable. Variations to this specification should be agreed upon prior to shipment between the buyer and seller.
Taldork	BRIQUETUED ALUMINIUM USED BEVERAGE CAN (UBC) SCRAP Shall have a briquette density of 50 pounds per cubic foot (800 kg/m3) minimum. Nominal briquette size shall range from 12” to 24” (30.5 x 61 cm) x 12” to 24” (30.5 x 61 cm) in uniform profile with a variable length of 8” (20.3 cm) minimum and 48” (122 cm) maximum. Briquettes shall be bundled or stacked on skids and secured with a minimum of one vertical band per row and a minimum of one girth band per horizontal layer. Briquettes not to overhang pallet. Total package height shall be 48 (122 cm) maximum. Banding shall be at least 5/8” (1.6 cm) wide by .020” (5 mm) thick steel strapping or equivalent strength. The weight of any bundle shall not exceed 4,000 pounds (1.814 mt). Material must be magnetically separated and free of steel, plastic, glass, dirt and all other foreign substances. Any and all aluminium items other than UBC are unacceptable. Any free lead is basis for rejection. Items not covered in the specification, including moisture, and any variations to this specification should be agreed upon prior to shipment between the buyer and seller.
Tale	PAINTED SIDING Shall consist of clean, low copper aluminium siding scrap, painted one or two sides, free of plastic coating, iron, dirt, corrosion, fiber, foam, or fiberglass backing or other non-metallic items.
Talk	ALUMINIUM COPPER RADIATORS Shall consist of clean aluminium and copper radiators, and/or aluminium fins on copper tubing, free of brass tubing, iron and other foreign contamination.
Tall	E.C. ALUMINIUM NODULES Shall consist of clean E.C. aluminium, chopped or shredded, free of screening, hair-wire, iron, copper, insulation and other non-metallic items. Must be free of minus 20 mesh material. Must contain 99.45% aluminium content.
Tally	ALL ALUMINIUM RADIATORS FROM AUTOMOBILES Shall consist of clean aluminium radiators and/or condensers. Should be free of all other types of radiators. All contaminants including iron, plastic, and foam not to exceed 1% of weight. Any deviation to this specification, including oxidation and aluminium content, to be negotiated between buyer and seller.
Talon	NEW PURE ALUMINIUM WIRE AND CABLE Shall consist of new, clean, unalloyed aluminium wire or cable free from hair wire, ACSR, wire screen, iron, insulation and other non-metallic items.
Tann	NEW MIXED ALUMINIUM WIRE AND CABLE Shall consist of new, clean, unalloyed aluminium wire or cable which may contain up to 10% 6000 series wire and cable free from hair wire, wire screen, iron, insulation and other non-metallic items.

Tarry A	CLEAN ALUMINIUM PISTONS Shall consist of clean aluminium pistons to be free from struts, bushings, shafts, iron rings and non-metallic items. Oil and grease not to exceed 2%.
Tarry B	CLEAN ALUMINIUM PISTONS WITH STRUTS Shall consist of clean whole aluminium pistons with struts. Material is to be free from bushings, shafts, iron and non-metallic items. Oil and grease not to exceed 2%.
Tarry C	IRONY ALUMINIUM PISTONS Shall consist of aluminium pistons with non-aluminium attachments to be sold on a recovery basis or by special arrangement between buyer and seller.
Tassel	OLD MIXED ALUMINIUM WIRE AND CABLE Shall consist of old, unalloyed aluminium wire and cable which may contain up to 10% 6000 series wire and cable with not over 1% free oxide or dirt and free from hair wire, wire screen, iron, insulation and other non-metallic items.
Taste	OLD PURE ALUMINIUM WIRE AND CABLE Shall consist of old, unalloyed aluminium wire and cable containing not over 1% free oxide or dirt and free from hair wire, wire screen, iron, insulation and other non-metallic items.
Tata	NEW PRODUCTION ALUMINIUM EXTRUSIONS Shall consist of one alloy (typically 6063). Material may contain “butt ends” from the extrusion process but must be free of any foreign contamination. Anodized material is acceptable. Painted material or alloys other than 6063 must be agreed upon by buyer and seller.
Toto	ALUMINIUM EXTRUSIONS “10/10” Material to consist of new production and old/used 6063 extrusions that may contain up to (but not exceed) 10 percent painted extrusions and 10 percent 6061 alloy extrusions. Must not contain other alloys of aluminium. Material should be free of zinc corners, iron attachments, felt, plastic, paper, card board, thermo break, and dirt and other contaminants.
Tutu	ALUMINIUM EXTRUSION DEALER GRADE Shall consist of old extruded aluminium of one alloy, typically alloy 6063, 6061, or 7075. Material must be free of iron, thermo break, saw chips, zinc corners, dirt, paper, cardboard, and other foreign contamination. Percentages of paint or other alloys to be agreed upon by buyer and seller.
Teens	SEGREGATED ALUMINIUM BORINGS AND TURNINGS Shall consist of aluminium borings and turnings of one specified alloy. Material should be free of oxidation, dirt, free iron, stainless steel, magnesium, oil, flammable liquids, moisture and other non-metallic items. Fines should not exceed 3% through a 20 mesh (U.S. standard) screen.
Telic	MIXED ALUMINIUM BORINGS AND TURNINGS Shall consist of clean, uncorroded aluminium borings and turnings of two or more alloys and subject to deductions for fines in excess of 3% through a 20-mesh screen and dirt, free iron, oil, moisture and all other non-metallic items. Material containing iron in excess of 10% and/or free magnesium or stainless steel or containing highly flammable cutting compounds will not constitute good delivery. To avoid dispute, material should be sold on basis of definite maximum zinc, tin and magnesium content.
Tense	MIXED ALUMINIUM CASTINGS Shall consist of all clean aluminium castings which may contain auto and airplane castings but no ingots, and to be free of iron, brass, dirt and other non-metallic items. Oil and grease not to total more than 2%.

Tepid	AIRCRAFT SHEET ALUMINIUM Should be sold on recovery basis or by special arrangements with purchaser.
Terse	NEW ALUMINIUM FOIL Shall consist of clean, new, pure, uncoated 1000 and/or 3000 and/or 8000 series alloy aluminium foil, free from anodized foil, radar foil and chaff, paper, plastics, or any other non-metallic items. Hydraulically briquetted material and other alloys by agreement between buyer and seller.
Tesla	POST CONSUMER ALUMINIUM FOIL Shall consist of baled old household aluminium foil and formed foil containers of uncoated 1000, 3000 and 8000 series aluminium alloy. Material may be anodized and contain a maximum of 5% organic residue. Material must be free from radar chaff foil, chemically etched foil, laminated foils, iron, paper, plastic and other non-metallic contaminants.
Tetra	NEW COATED ALUMINIUM FOIL Shall consist of new aluminium foil coated or laminated with ink, lacquers, paper, or plastic. Material shall be clean, dry, free of loose plastic, PVC and other non-metallic items. This foil is sold on a metal content basis or by sample as agreed between buyer and seller.
Thigh	ALUMINIUM GRINDINGS Should be sold on recovery basis or by special arrangements with purchaser.
Thirl	ALUMINIUM DROSSES, SPATTERS, SPILLINGS, SKIMMINGS AND SWEEPINGS Should be sold on recovery basis or by special arrangements with purchaser.
Thorn	ALUMINIUM BREAKAGE Shall consist of aluminium with miscellaneous contaminants like iron, dirt, plastic and other types of contaminants. Material can either be sold based on aluminium recovery or content as agreed upon by buyer and seller. Must contain a minimum of 33% aluminium unless otherwise agreed upon by buyer and seller.
Throb	SWEATED ALUMINIUM Shall consist of aluminium scrap which has been sweated or melted into a form or shape such as an ingot, sow or slab for convenience in shipping; to be free from corrosion, dross or any non-aluminium inclusions. Should be sold subject to sample or analysis.
Tooth	SEGREGATED NEW ALUMINIUM ALLOY CLIPPINGS AND SOLIDS Shall consist of new, clean, uncoated and unpainted aluminium scrap of one specified aluminium alloy with a minimum thickness of .015” (.38 mm) and to be free of hair wire, wire screen, dirt and other nonmetallic items. Oil and grease not to total more than 1%. Also free from punchings less than 1/2” (1.27 cm) in size
Tough	MIXED NEW ALUMINIUM ALLOY CLIPPINGS AND SOLIDS Shall consist of new, clean, uncoated and unpainted aluminium scrap of two or more alloys with a minimum thickness of .015” (.38 mm) and to be free of hair wire, wire screen, dirt and other non-metallic items. Oil and grease not to total more than 1%. Also free from punchings less than 1/2” (1.27 cm) in size.
Tread	SEGREGATED NEW ALUMINIUM CASTINGS, FORGINGS AND EXTRUSIONS Shall consist of new, clean, uncoated aluminium castings, forgings, and extrusions of one specified alloy only and to be free from sawings, stainless steel, zinc, iron, dirt, oil, grease and other non-metallic items.

Troma	Aluminium Auto or Truck Wheels Shall consist of clean, single-piece, unplated aluminium wheels of a single specified alloy, free of all inserts, steel, wheel weights, valve stems, tires, grease and oil and other non-metallic items. Variations to this specification should be agreed upon prior to shipment between the buyer and seller.
Trump	ALUMINIUM AUTO CASTINGS Shall consist of all clean automobile aluminium cast ings of sufficient size to be readily identified and to be free from iron, dirt, brass, bushings, and non-metallic items. Oil and grease not to total more than 2%.
Trill	ACSR Aluminium Conductor Steel Reinforced (ACSR) wire is a combination of steel and aluminium wire, of various configurations, with the expected aluminium recovery agreed upon by the buyer and the seller. Material to be free of other wires and cables unless mutually agreed upon.
Twang	IAW Insulated aluminium wire, which may or may not contain other wires or metal shielding, with the expected aluminium recovery agreed upon by the buyer and the seller. The material to be free of other wires and cables unless mutually agreed upon.
Twirl	FRAGMENTIZER AIRCRAFT ALUMINIUM SCRAP (2000 and 7000 series) The material as received must be dry and not to contain more than 2% free zinc, 1% maximum free mag\nesium, and 1.5% maximum free iron and stainless with a maximum of 2% analytical iron. Not to contain more than a total 5% maximum of non-metallics, of which no more than 1% shall be rubber and plastics. To be free of excessively oxidized material. Any variations to be sold by special arrangement between buyer and seller.
Twist	ALUMINIUM AIRPLANE CASTINGS Shall consist of clean aluminium castings from airplanes and to be free from iron, dirt, brass, bushings, and non-metallic items. Oil and grease not to total more than 2%.
Twitch	FLOATED FRAGMENTIZER ALUMINIUM SCRAP (from Automobile Shredders) Derived from wet or dry media separation device, the material must be dry and not contain more than 1% maximum free zinc, 1% maximum free magnesium, and 1% maximum of analytical iron. Not to contain more than a total 2% maximum of non-metallics, of which no more than 1% shall be rubber and plastics. To be free of excessively oxidized material, air bag canisters, or any sealed or pressurized items. Any variation to be sold by special arrangement between buyer and seller.
Tweak	FRAGMENTIZER ALUMINIUM SCRAP (from Automobile Shredders) Derived from either mechanical or hand separation, the material must be dry and not contain more than 4% maximum free zinc, 1% maximum free magnesium, and 1.5% maximum of analytical iron. Not to contain more than a total 5% maximum of non-metallics, of which no more than 1% shall be rubber and plastics. To be free of excessively oxidized material, air bag canisters, or any sealed or pressurized items. Any variation to be sold by special arrangement between buyer and seller.
Twire	BURNT FRAGMENTIZER ALUMINIUM SCRAP (from Automobile Shredders) Incinerated or burned material must be dry and not contain more than X% (% to be agreed upon by buyer and seller) ash from incineration, 4% maximum free zinc, 1% maximum free magnesium, and 1.5% maximum of analytical iron. Not to contain more than a total 5% maximum of non-metallics, of which no more than 1% shall be rubber and plastics. To be free of excessively oxidized material, air bag canisters, or any sealed pressurized items. Any variation to be sold by special arrangement between buyer and seller.

Zorba	SHREDDED NONFERROUS SCRAP (predominantly aluminium) Shall be made up of a combination of the nonferrous metals: aluminium, copper, lead, magnesium, stainless steel, nickel, tin, and zinc, in elemental or alloyed (solid) form. The percentage of each metal within the nonferrous concentrate shall be subject to agreement between buyer and seller. Material generated by eddy current, air separation, flotation, screening, other segregation technique(s), or a combination thereof. Shall have passed one or more magnets to reduce or eliminate free iron and/or large iron attachments. Shall be free of radioactive material, dross, or ash. Material to be bought/sold under this guideline shall be identified as “Zorba” with a number to follow indicating the estimated percentage nonferrous metal content of the material (e.g., “Zorba 90” means the material contains approxmately 90% nonferrous metal content). May also be screened to permit description by specific size ranges. (Refer also to Zorba under Mixed Metals.)

Annexure – 01

BRITISH STANDARD

BS EN 13920-1:2003

Aluminium and aluminium alloys — Scrap —

Part 1: General requirements, sampling and tests

Contents

page

Scope

This European Standard specifies general requirements and guidelines for the delivery and classification of the different categories of aluminium scrap, including quality requirements, sampling and tests.

Special requirements and guidelines for each of the scrap categories are specified in EN 13920-2 to EN 13920-16.

EN 13920 comprises the following parts under the general title “Aluminium and aluminium alloys — Scrap”:

- Part 1: General requirements, sampling and tests
- Part 2: Unalloyed aluminium scrap
- Part 3: Wire and cable scrap
- Part 4: Scrap consisting of one single wrought alloy
- Part 5: Scrap consisting of two or more wrought alloys of the same series
- Part 6: Scrap consisting of two or more wrought alloys
- Part 7: Scrap consisting of castings
- Part 8: Scrap consisting of non-ferrous materials from shredding processes destined to aluminium separation processes
- Part 9: Scrap from aluminium separation processes of non-ferrous shredded materials
- Part 10: Scrap consisting of used aluminium beverage cans
- Part 11: Scrap consisting of aluminium-copper radiators
- Part 12: Turnings consisting of one single alloy
- Part 13: Mixed turnings consisting of two or more alloys
- Part 14: Scrap from post-consumer aluminium packagings
- Part 15: Decoated aluminium scrap from post-consumer aluminium packagings
- Part 16: Scrap consisting of skimmings, drosses, spills and metallics

Annexure – 02

Unclassified ENV/EPOC/WPRPW(2016)2/FINAL

Organisation de Coopération et de Développement Économiques
Organisation for Economic Co-operation and Development 09-Nov-2017

English - Or. English

ENVIRONMENT DIRECTORATE
ENVIRONMENT POLICY COMMITTEE

ENV/EPOC/WPRPW(2016)2/FINAL
Unclassified

Working Party on Resource Productivity and Waste

MAPPING SUPPORT FOR PRIMARY AND SECONDARY METAL PRODUCTION

SUPPORT FOR SECONDARY METAL PRODUCTION

Common forms of support for secondary metal production

137. This section provides a discussion of three common forms of secondary support. The first relates to the use of public funds to provide, or facilitate the private provision of, investment finance for metal recyclers and re-processors. The second involves specific tax provisions, provided through corporate income or other taxes, which confer differential support for these firms. The third relates to policies that serve to increase the supply of scrap emerging from the municipal solid waste stream; landfill taxes, EPR regulations, and the public provision of waste collection and management services are examples.

4.3.1 Finance

138. Targeted public investment schemes are available for material sorting, recycling, and reprocessing firms in a number of countries. Transfers are made in various forms. Non-repayable grants, concessionary debt financing, or loan guarantees are all documented, but the state equity ownership requirements similar to those in the mining sector are uncommon. Most public debt finance is dispensed from the national budget, whereas state or provincial governments are the main source of grants.

139. The provision of public finance confers support for the secondary metal sector in a variety of ways. Where it is provided on concessionary terms, such as in the form of grants or low interest loans, public finance increases individual project profitability by reducing interest repayment costs. In the short run, this is likely to encourage firm entry and increase investment in the sector. Even where it is provided on fully commercial terms, public debt finance may confer support by enabling projects that wouldn't otherwise have been funded on capital markets. There are several market failures or barriers that may restrict investment flows to the sector (see below), and public finance addresses some of these by demonstrating the commercial

viability of a new business model or technology. In the longer run, this "proof of concept" lowers the risk profile of similar projects and facilitates private investment.

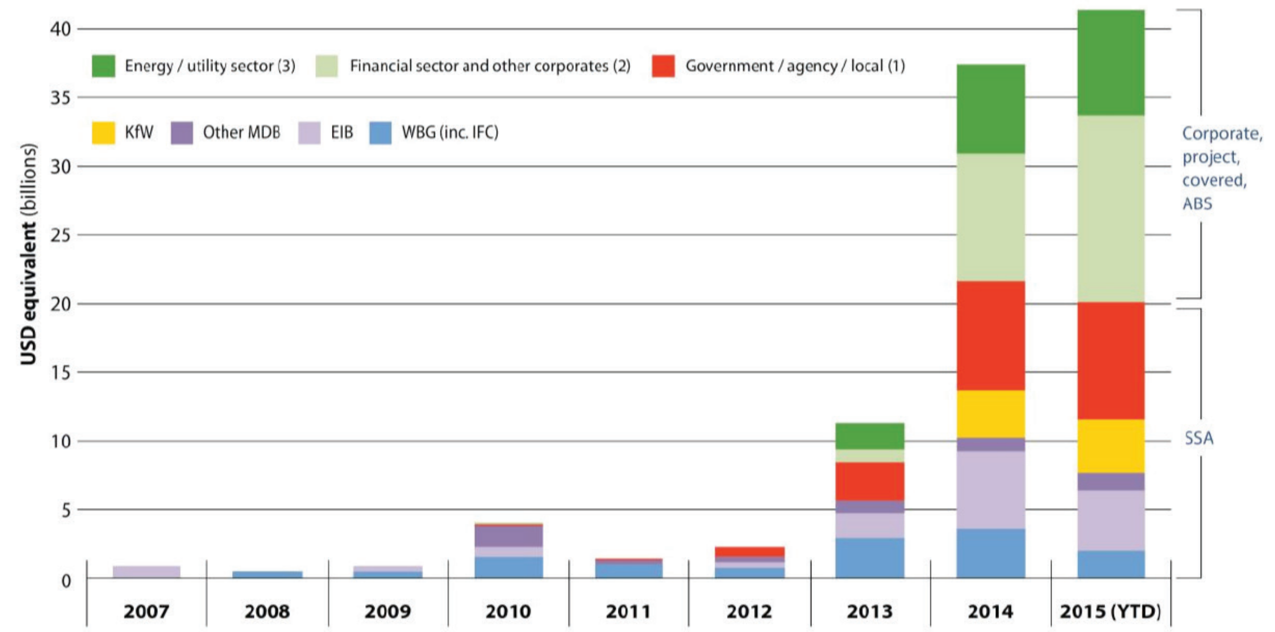
140. The International Solid Waste Association (IWSA) identifies a shortage of investment funds as a key barrier to higher material recovery and recycling rates (IWSA, 2015). Sub-optimal investment flows to the secondary sector may result from several factors. Most obviously, capital, natural resource, energy, water, and waste disposal prices which do not fully reflect their true social costs tend to disproportionately favour primary metals firms. As outlined in Chapter 3, the primary metal production process uses these inputs relatively intensively, and policies which reduce their respective market prices probably serve to decrease the relative profitability of material recycling and re-processing projects.

141. Investment shortages may also result from specific characteristics of the secondary metal business model. For example, certain aspects of the secondary production process may be comparatively novel with respect to those in the primary process. This is particularly relevant for the upgrade phase of secondary production; mechanised sorting technology utilising the differing physical properties of particular waste products are still relatively immature. The additional investment risk associated with any such new or relatively unproven technology can make financing difficult. In addition, geographic separation may make transportation of end of life metallic products between urban centers economically unattractive relative to a network of smaller sorting facilities (EC, 2015). This can generate financing difficulties in situations where private capital seeks investment opportunities of a certain size. Finally, the volatility of scrap metal prices (Blomberg and Soderholm, 2009) introduces additional uncertainty in expected project returns, and can therefore deter investment in secondary sorting or reprocessing capacity.

4.3.1.1 Debt finance

142. Public debt finance for projects in the secondary metal sector tends to be channelled through a range of financial institutions which share the common characteristic of being capitalised (initially at least) with public funds. Examples include national development banks (e.g., Germany's KfW bank group), green investment banks (e.g., the UK's Green Investment Bank), and other types of regional or national level investment bank (e.g., the European Investment Bank).

143. The recent advent of green bonds has increased the amount of investment capital available to these financial institutions. Green bond issuance amounted to USD 36.6 billion in 2014 and USD 40 billion in 2015 (OECD, 2015c), and around half of this was issued by sovereign national or supranational banks, agencies, and institutions (Figure 13). EIB issuances in the first four months of 2016 alone amounted to EUR 2.8 billion (Climate Bonds Initiative, 2016). Although the majority of funds raised by green bonds are earmarked for climate or low-carbon related investments, a proportion may also be available for recycling projects. Notably, the first recycling dedicated bond (EUR 380 million) was issued by French recycling firm Paprec in 2015 (Climate Bonds Initiative, 2015).



Note: SSA: Sub-sovereign, Supranational and Agency, Muni: Municipal; ABS: Asset Backed Securities. (1) includes national development banks, sub-sovereign jurisdictions including municipalities, agencies, and local funding authorities. (2) includes financial sector bonds and all other corporates that are not energy/utility sector, as well as covered, project and ABS not energy/utility related. (3) includes corporate bonds issued by energy/utility companies as well as covered, project and ABS related to energy/utility companies

Green bond issuance by source between 2007 and 2015

144. Within the EU, the European Investment Bank (EIB) Group administers a number of lending programs which are potentially available to firms in the European secondary metals sector. The European Fund for Strategic Investment (EFSI), which was launched in mid-2015, identifies the circular economy as one of several key lending objectives (EIB, 2015). The fund had an initial capitalisation of EUR 61 billion (EIB, 2016), which is used to provide debt finance, equity finance, and loan guarantees with the intention of triggering additional third-party investment. As of May 2016, the EIB had lent EUR 12.8 billion, of which 9% went to firms in the 'environment and resource efficiency sector (EC, 2016). It is unclear what proportion of this accrued to secondary metal firms.

145. The European Investment Bank also manages InnovFin, an EU initiative intended to facilitate access to finance for innovative firms and other entities within Europe (EIB, 2016). The program is expected to make around EUR 24 billion of debt and equity financing available to eligible sectors by 2020. Secondary metal recycling and smelting firms are eligible under the climate action, environment, resource efficiency, and raw materials banner. However, it is again unclear what proportion of loanable funds will accrue to metal firms, let alone those in the secondary sector; many of the raw material specific lending requirements appear to target sustainable or innovative mining technologies.

146. Public green investment banks (GIB's) are a relatively new phenomenon (OECD, 2016d), but also offer finance for material recovery and recycling projects. GIB's are differentiated from public infrastructure funds and other grant making public institutions by their commercial character; debt finance is provided on commercial or near commercial terms. Green investment banks are also different to public investment banks or their international equivalents; the investment focus is exclusively on environmentally related projects. As of December 2015, the OECD had documented thirteen national or sub-national examples of such banks OECD, 2015. The investment focus for many of these institutions was carbon or climate related, but several had also lent to waste management and recycling projects. In the UK, the Green Investment Bank has at least two relevant funds. The Recycling and Waste Fund was created in 2015 with an initial capitalisation of £50

million targeting “smaller-scale recycling and waste projects across the UK” (GIB, 2016). The Waste Resources and Energy Fund was created in 2012 and has financed material recovery facilities, although most funds were directed towards waste to energy plants (GIB, 2016).

4.3.2 Foregone tax revenues

147. Material sorting, recycling, and reprocessing firms are eligible for tax rate reductions, targeted deductions or credits, or special exemptions in a number of countries. These provisions are mostly provided through corporate income tax, although targeted value added tax (VAT) relief is also available in some cases. In addition, environmentally related taxation targeting the by-product “bads” associated with metal production may increase the relative competitiveness of firms in the secondary sector. Although green taxes do not necessarily represent support, they serve to decrease the cost of inputs used relatively intensively in secondary metal production (e.g. scrap) while increasing the cost of inputs used relatively intensively in primary production (e.g. energy).

4.3.2.1 Corporate income tax (CIT) provisions

148. Firms in the secondary metal sector do not benefit from CIT rate reductions or tax holidays to the same extent that mining firms do. No targeted rate reductions are known for recycling firms, although they probably benefit disproportionately (relative to the mining industry) from the availability of reduced CIT rates for small businesses. This is especially the case for commercial scrap collectors, which operate at the top of the scrap metal supply chain; their size is often limited by the flow of end of life scrap from nearby population or industrial centres. Preferential small and medium enterprise corporate income tax rates are available in a range of countries including Australia, Japan, the Netherlands, and Spain (OECD, 2016c).

149. Corporate tax paid by recycling firms is also a function of what definition of earnings is applied. The tax code in many countries allows firms to reduce their taxable income – their tax base – by deducting costs above and beyond what would normally be considered normal business expenses. In the context of the secondary metals industry, the most important provisions relate to tax credits on the value of scrap feedstock, and to accelerated depreciation rules targeted at recycling specific assets. Again, relative to the primary sector, the number of countries applying these provisions is limited.

150. Recycling specific tax credits are available to secondary metal firms in several jurisdictions (KPMG, 2013). Mexico City grants a tax credit to corporations that recycle or reprocess their solid waste. The credits are offered on a sliding scale, from 20% of payroll tax for firms which reprocess between 33% and 44% of their waste, up to 40% for firms which recycle or reprocess more than 60% of their waste. A similar scenario exists in Brazil – secondary metal firms benefit from tax credits on the value of scrap or other intermediate metal feedstock.

151. The OECD database of environmental taxation measures indicates that targeted accelerated depreciation provisions for recycling facilities are available, or potentially available, in France, Ireland, Japan, Netherlands, and the US (OECD, 2016b). For example, the RISE program in the US entitles domestic recycling firms to write-off 50% of an assets value for tax purposes in the first year of operation (KPMG, 2013). It was enacted in 2008 and was extended under the PATH act of 2015. Accelerated depreciation provisions improve project profitability by reducing the assessable tax base early in a project’s life.

4.3.2.2 Value Added Taxes

152. A number of countries provide support for firms in the secondary metal sector through value added taxes (VAT). The most common provision relates to the input tax portion of VAT; recycling firms which acquire metal scrap from VAT exempt or non-registered entities are entitled to claim a deemed input VAT credit. This

credit can then be used to reduce the output tax portion of the VAT the firm is required to pay on behalf of its clients. Deemed input VAT tax credits are particularly important for scrap dealers situated at the top of the secondary metal supply chain. These firms often acquire scrap from VAT non-registered entities such as individuals or publicly owned and operated municipal waste collection organisations. Countries where deemed input VAT tax credits are available include South Korea (KPMG, 2013), South Africa (Saica, 2004), and the United States (IWSA, 2014).

153. VAT-related tax relief is also available for recycling firms in China through targeted partial VAT rebates (KPMG, 2013). Rebate rates vary between 30% and 100% depending on the commodity, but are set at 30% for ferrous scrap.

4.3.3 Induced transfers

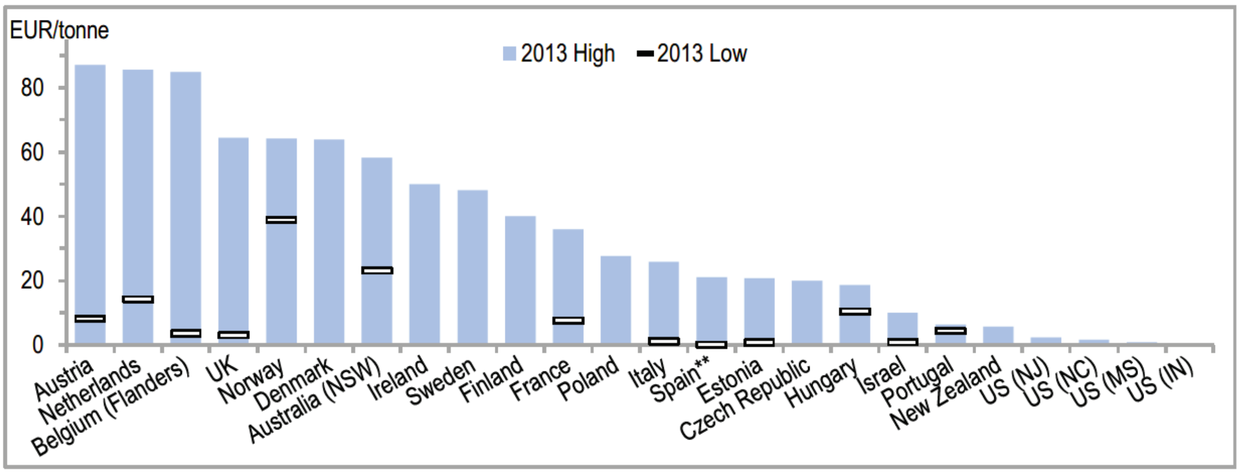
154. Certain waste management policies – landfill taxes and bans, the public provision of separated recycling collection, and EPR requirements among others – divert waste flows away from landfilling and incineration, thereby increasing the quality and availability of scrap feedstock. In many countries, where trade restrictions limit cross border shipments of potentially hazardous materials, this can lead to downward pressure on domestic scrap prices which, in turn, induces a transfer to the secondary metal sector. The easing of pre-existing feedstock supply constraints may generate additional benefits as secondary firms begin to operate at a larger scale.

155. Quantifying the monetary value of induced transfers is difficult, and presents a key barrier to comparing the magnitude of primary and secondary support. In particular, there is often a difference between the net cost of the measure for governments, and the net benefits of the measure for recipients. In the case of landfill taxes, the net cost for governments is actually negative (taxes generate revenues) while the net benefits conferred to recycling firms is difficult to quantify; it depends on how the tax translates into feedstock prices.

156. The regulations that set up induced transfers for the secondary sector are commonly targeted at the MSW stream. In terms of metal, MSW contains considerable potential value even though the absolute amount of contained metal is small relative to that in C&I or C&D waste8. Much of the metallic content is in the form of steel or aluminium packaging, which is both homogenous and composed of relatively simple alloys. Furthermore, the MSW stream is an important source of high value metals and alloys; household appliances and personal electronics contain considerable copper along with a range of other precious and rare elements.

4.3.3.1 Landfill taxes

157. The use of landfill or incineration taxes has become increasingly widespread in OECD countries during the last decade. They are generally assessed by weight, and the relevant tax rate varies across different materials and across sub-national boundaries. Internationally, there is considerable variation in landfill tax rates (Figure 14). From an economic perspective, disposal taxes are broadly justified by pollution externalities. Landfilled waste can produce methane emissions or toxic liquid leachates while incineration may result in local atmospheric pollution. In practice, disposal taxes are often intended to serve other objectives, such as ensuring that public waste management services are fully cost covering; they may not reflect the magnitude of marginal environmental damages.



Source: OECD (2016b), Environmental Policy Instruments Database

Figure 14. Landfill tax rates in OECD countries in 2013

158. Landfill bans on specific materials also exist in a number of countries. In the US, twenty states have banned the disposal of any form of e-waste (Electronic Recyclers International, 2016) while several European countries ban the disposal of waste with a certain organic content (CEWEP, 2012). Switzerland has had a landfill ban in place for municipal solid waste since 2005; all material not recycled is incinerated.

Six other European countries – Austria, Denmark, Germany, the Netherlands, Norway, and Sweden – have landfill bans on certain products (Zerowaste Europe, 2015). In addition, the EU Action Plan for a Circular Economy currently under discussion proposes a ban on landfilling of separately collected waste (EC, 2016).

159. Landfill and incineration taxes or bans discourage waste disposal, which serves to divert the flow of waste towards recovery and recycling activities. This induces a transfer for metal recycling and reprocessing firms which benefit from eased feedstock supply constraints or lower feedstock prices.

160. The value conferred by landfill taxes and bans is difficult to quantify, but to a large extent depends on the availability of other disposal options. Under certain conditions, such as where illegal dumping or incineration is cost effective relative to recycling, the creation of landfill bans or taxes may actually serve to reduce the flow of waste towards the secondary sector. One key result from the theoretical literature is that landfill taxes that do not fully reflect the external cost of disposal may be preferable in situations where illegal dumping is feasible (Fullerton and Kinnaman, 1995). In the European context, several recycling industry lobby groups have expressed reservations about proposed landfill bans (in the EU Action Plan for a Circular Economy). The key concern is that such policies may have unintended and undesirable consequences like increased investment in incineration facilities (Zerowaste Europe, 2015).

161. Finally, landfill taxes on MSW may be ineffective in creating incentives for metal capture. Kerbside waste and recycling collection is provided by local governments, and which facility (material recovery, landfill or incineration) each material type is directed to is generally pre-determined. Landfill taxes are incident upon households and businesses, but do little to incentivise better material sorting when they form part of an annual flat-rate charge (as is often the case currently – see the discussion of municipal waste in section 4.3.3.2). Landfill taxes and bans may be more relevant for the commercial or industrial and construction or demolition waste streams, where firms directly face the cost of waste disposal.

4.3.3.2 Public provision of separate recycling services

162. Local governments in many jurisdictions are required by national or sub-national legislation to organise the collection and disposal of municipal solid waste. These laws generally specify a set of minimum standards

for public waste management, and there is often a requirement for the separate collection of one or more recyclables. In the EU, the Waste Framework Directive requires that, under certain conditions, separated collection of paper, plastic, glass, and metal is provided by 2015. In the United States, disposal bans on certain recyclable materials exist in many states (NERC, 2011).

163. The public provision of separate recycling collection by local government increases the supply and quality of secondary scrap feedstock. Metallic waste that would otherwise be mixed with general household and business refuse, and which would therefore require additional sorting, is already 'clean' upon collection. In some cases, such as for aluminium cans, this means that secondary scrap can be recycled without the need for an intermediate upgrade phase. In other cases, such as where several recyclable fractions are collected together, the limited number of products contained in the waste stream greatly simplifies automated material upgrading. In sum, costs associated with material sorting are reduced for recyclers.

164. Again, the transfer generated for secondary producers is difficult to quantify, and will vary according to whether the net cost of separated recycling collection (for local government) or the net benefits (for recycling firms) is considered. The two numbers generally diverge because a significant proportion of the value contained in clean metal scrap originates not from the provision of separate collection, but from the sorting effort provided by households and small businesses.

165. In practice, the difference between the net cost of service provision and the net benefits conferred through lower scrap prices will depend on how local governments structure waste management services and contracts. For example, if local governments operate waste collection services themselves, and require only that these services be cost-covering, then the benefits conferred to the secondary sector will be greater than the net cost of provision (which would be zero). It is difficult to establish the net cost of a particular local government's separated recycling collection program. This service is often physically undertaken using the same machinery used for general waste collection, and the additional cost of recycling collection may not be disaggregated in public accounts. In addition, although revenues generated by the sale of collected recyclables are usually available, the degree to which recyclables collection is funded by the waste management portion of local taxes is often unclear.

4.3.3.3 Extended Producer Responsibility: product take-back regulations

166. Product take-back is a particular variety of EPR which requires product manufacturers or importers to re-assume some responsibility for their products at the end of their life. This can mean taking physical charge of products through the provision of drop-off locations allowing product return, or taking economic responsibility for the management of end of life products by third party firms. Take-back requirements target a broad range of consumer products and are relevant for the secondary metals sector. Common examples include household appliances and personal electronic devices, all of which are traditionally processed via the municipal-solid-waste system. They may also apply to certain consumer products that are processed beyond the MSW route; end of life vehicles are one such example. Data from the OECD indicate that take-back requirements have grown rapidly during recent decades; they now represent around three quarters of the EPR schemes in existence (OECD, 2016e).

167. When they are well designed, take-back requirements can stimulate additional secondary feedstock supply in a similar way to landfill taxes and the provision of separated recycling. In the short run, and assuming that illegal dumping is not feasible, firms face a choice between product recycling and disposal; theory suggests they will opt for the management option which entails the least cost. The extent to which take-back requirements increase scrap supply depends significantly on the cost of waste disposal in the relevant jurisdiction. Take-back is likely to be less effective where low cost landfill or incineration services are available; producers face little additional cost and simply choose to bury or burn end of life products.

Regulators have attempted to address this issue in two ways. One approach is to marry take back requirements with mandated recycling requirements. A second approach is to ensure that per-unit landfill or incineration charges fully reflect the social cost of waste disposal. This includes the economic cost of constructing and operating waste facilities along with relevant external costs such as leachate contamination of groundwater or methane loss to the atmosphere.

168. In the long run, take back requirements can also create incentives for firms to design products that either contain less material (and are therefore less costly to dispose of) or are less complex (and are therefore more amenable to dismantling and eventual recycling).

5. TRADE RESTRICTIONS ON MINERAL ORES, SCRAP, AND METALS

5.1 Introduction

169. Trade restrictions affecting mineral ores, scrap, and metals can distort competition between primary and secondary metal producers in a similar way to the measures discussed in Chapters 3 and 4. Import restrictions – tariffs or other non-tariff import barriers – can confer support for domestic producers by reducing market access for foreign producers. Export restrictions – taxes, quotas, or bans – increase the domestic supply of the targeted good, with potentially lower prices for domestic firms situated downstream. Both measures can be seen as a form of induced transfer; lower costs for domestic firms enhance their competitiveness relative to foreign counterparts. More generally, the interconnected character of global metal value chains means that support conferred in one jurisdiction may be conveyed globally through trade. This is particularly relevant in the metals sector because of the strong geographic concentration of virgin and anthropogenic metal stocks. Few countries are naturally endowed with the full array of metal resources, and those that are continue to import a range of specific finished metal products.

170. There are three sections in this chapter. The first describes trade flows of primary and secondary materials; it builds on the discussion of global metal production patterns in Chapter 1. The second section draws heavily on the OECD Inventory of Restrictions on Exports of Industrial Raw Materials to highlight the various types of trade restrictions that are currently imposed by different countries. The focus here is on export restrictions, partly because these are relatively widespread and binding in the industrial raw materials sector (OECD, 2014), but also because the highly concentrated nature of global metal supply means they can have significant international impacts when applied by certain countries. The third section provides a description of how export restrictions can confer support for metal producers.

171. Four main messages emerge. First, trade flows of primary mineral ores and concentrates increased at a significantly faster rate than those for metal scrap during the last decade. This may partially reflect limited growth in scrap generation, but may also be due to the effect of policies which restrict cross-border shipments of potentially hazardous materials. Second, restrictions on exports of primary mineral ores, metal scrap and waste, and finished metals are applied by a significant number of countries. This probably partly reflects the fact that WTO disciplines relating to exports are less evolved than those for imports. Third, export restrictions can theoretically increase the competitiveness of domestic downstream producers, who may benefit from reduced feedstock prices. Finally, some of the export restrictions on primary mineral ores and concentrates are applied by countries representing a large share of global supply. Brazil, China, and Indonesia currently apply significant restrictions on exports of certain commodities. This is important because global commodity prices are more likely to be affected in such cases; a restriction applied by one country may therefore influence the competitiveness of primary and secondary metal production in other jurisdictions.

5.2 Trade in mineral ores, scrap, and metals: some stylistic facts

5.2.1 Primary and secondary metal exports: volumes and trends

172. Around 1,550 million tons, or USD 132 billion, of primary ores and concentrates were exported in 2015 (UN COMTRADE, 2016). Iron ore was the most important commodity, accounting for 88% and 47% of total upstream exports by weight and value respectively (Table 7). Copper ores and concentrates and bauxite ores were also important in value terms, representing 29% and 3% of exports. All other primary metal ores account for only 20% of the value of primary exports; ores of zinc (6%), lead (4%), and precious metals (gold, silver, and platinum group) (4%) are the most important of these.

173. The importance of trade in upstream raw materials is made apparent by a comparison between production (USGS) and trade (UN COMTRADE) data. For iron ore, for which these two datasets are broadly

comparable, around 43% of 2013 mine production was exported outside the country of origin. The equivalent figure for other metals is difficult to establish, but likely to be at least as large because China, the world's largest iron ore producer, exports very little of its domestic production.

174. Exports of metal scrap and waste amounted to USD 76 billion in 2015, around half the size of primary exports in value terms. It is unclear what proportion of annual scrap production this represents; reliable data on this is unavailable. Scrap metal exports represented ~58% of the total value of primary upstream exports, but only 6% of the total weight. This implies significantly higher upstream secondary material prices for some metals. For example, aluminium scrap prices were more than an order of magnitude higher than those for bauxite (primary aluminium ore) in 2015. This partly reflects the relatively low per-unit aluminium content of bauxite, but also the relatively high downstream costs of extracting it.

175. Finally, secondary metal trade is dominated by precious metals, aluminium, copper, and steel. All other secondary metals account for only 19% of the value of secondary exports; magnesium (2%), cobalt (2%), tantalum (1%), and manganese (1%) are the most important.

	Fe			Al			Cu			Total	
	Weight	Value	Implied price	Weight	Value	Implied price	Weight	Value	Implied price	Weight	Value
	Mt	USD billion	USD/t	Mt	USD billion	USD/t	Mt	USD billion	USD/t	Mt	USD billion
Ores and concentrates	1,358	62	45	88	3	31	17	38	2,289	1,547	132
Scrap	81	25	312	7	10	1,392	6	14	2,493	98	76
Finished metals		276			105			141			843

Source: UN COMTRADE (2016), UN COMTRADE Database

Table 7. Global trade in metals for 2015

176. Figures 15 and 16 track the evolution of upstream primary (ores and concentrates) and secondary (metal wastes and scrap) exports by weight and value respectively. Between 2000 and 2014, it's clear that the volume of primary material exports increased at a faster rate than that for secondary metal scrap exports. For iron ore, this increase in exports closely tracks production levels (USGS); both increased by a factor of about 2.9 over this period. The nominal value of primary exports also increased at a faster rate than that for secondary exports. Taken together, the trade data indicate a relatively consistent world primary – secondary price ratio; implied prices of both increased by a factor of about 2.7 between 2000 and 2014, although this may mask more nuanced trends for individual metals.

177. Slower growth of metal waste and scrap exports may reflect several factors. Firstly, new sources of metal scrap are limited in a way that new sources of virgin materials aren't; slow growth in metal scrap trade may reflect constraints on the flow of EOL goods and materials from in-use stocks. Alternatively, this trend may come from higher ratios of domestic scrap consumption, possibly due to export restrictions (see Section 5.3).

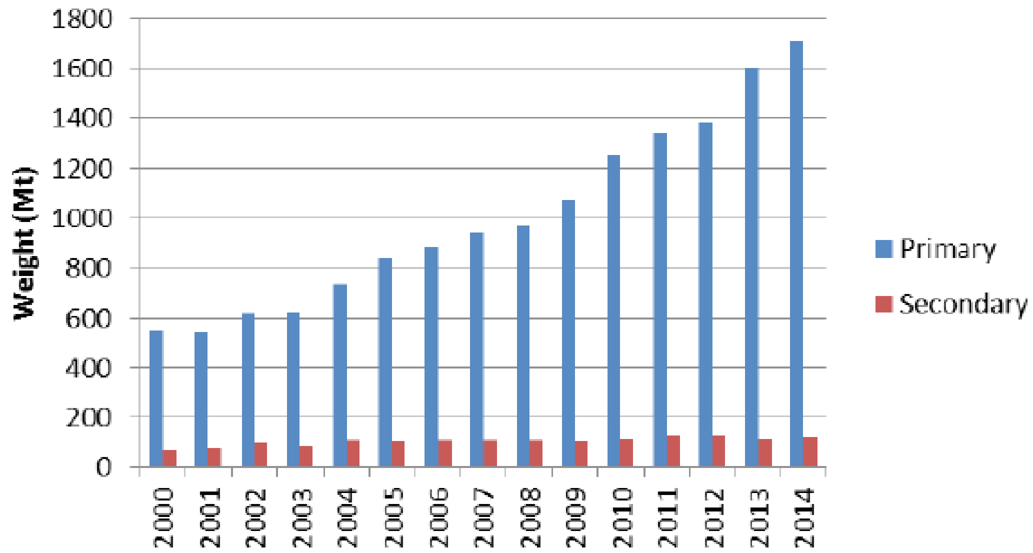
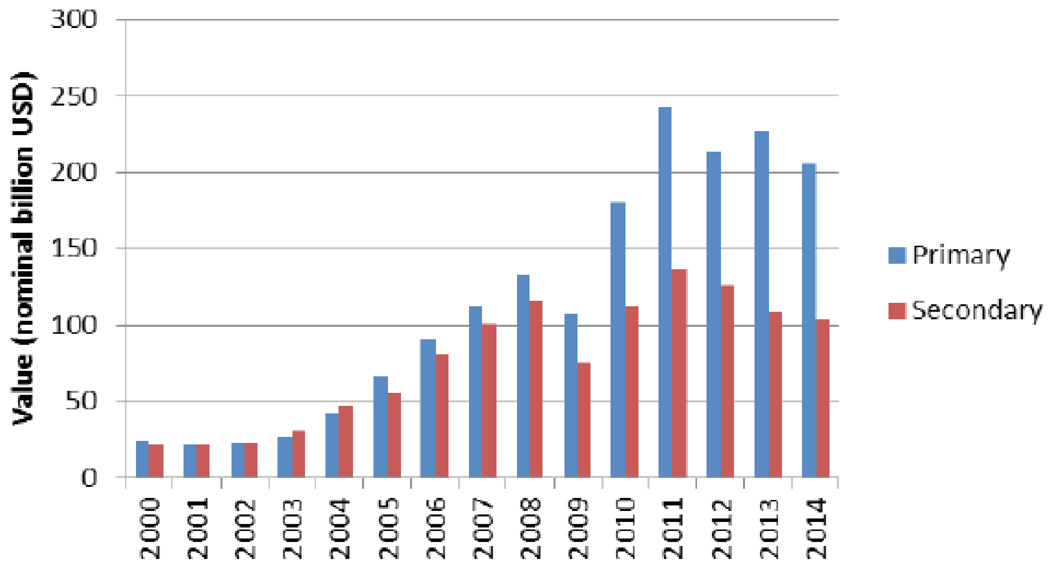


Figure 15. The evolution of upstream primary and secondary material exports by weight

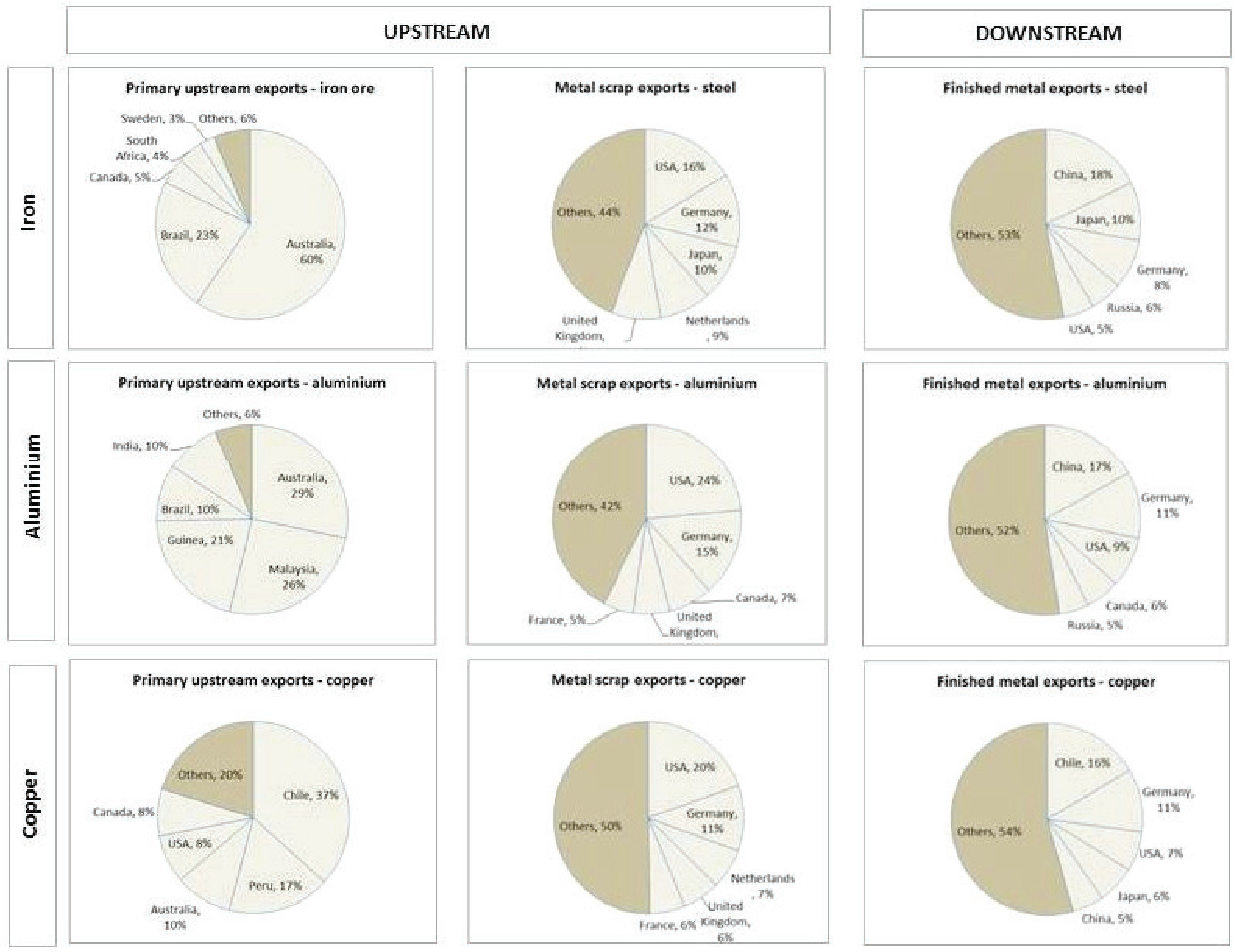


Source: UN COMTRADE (2016), UN COMTRADE Database

Figure 16. The evolution of upstream primary and secondary material exports by nominal value

5.2.2 Primary and secondary metal exports: country and commodity breakdown

178. Figure 17 shows the top five exporters of mineral ores, metal scrap, and finished metals for iron, aluminium, and copper. Exports of most mineral ores and concentrates are dominated by a handful of countries, mostly those endowed with virgin mineral resources. For both iron ore and bauxite, five countries are responsible for ~95% of total exports by value. Australia and Brazil are the largest exporters of both commodities; Malaysia, Guinea, and India are major exporters of bauxite. Copper ore and concentrate exports are slightly less concentrated, with the largest five exporters – Chile, Peru, Australia, Canada, and the United States – accounting for 80% of total value.



Source: UN COMTRADE (2016), UN COMTRADE Database

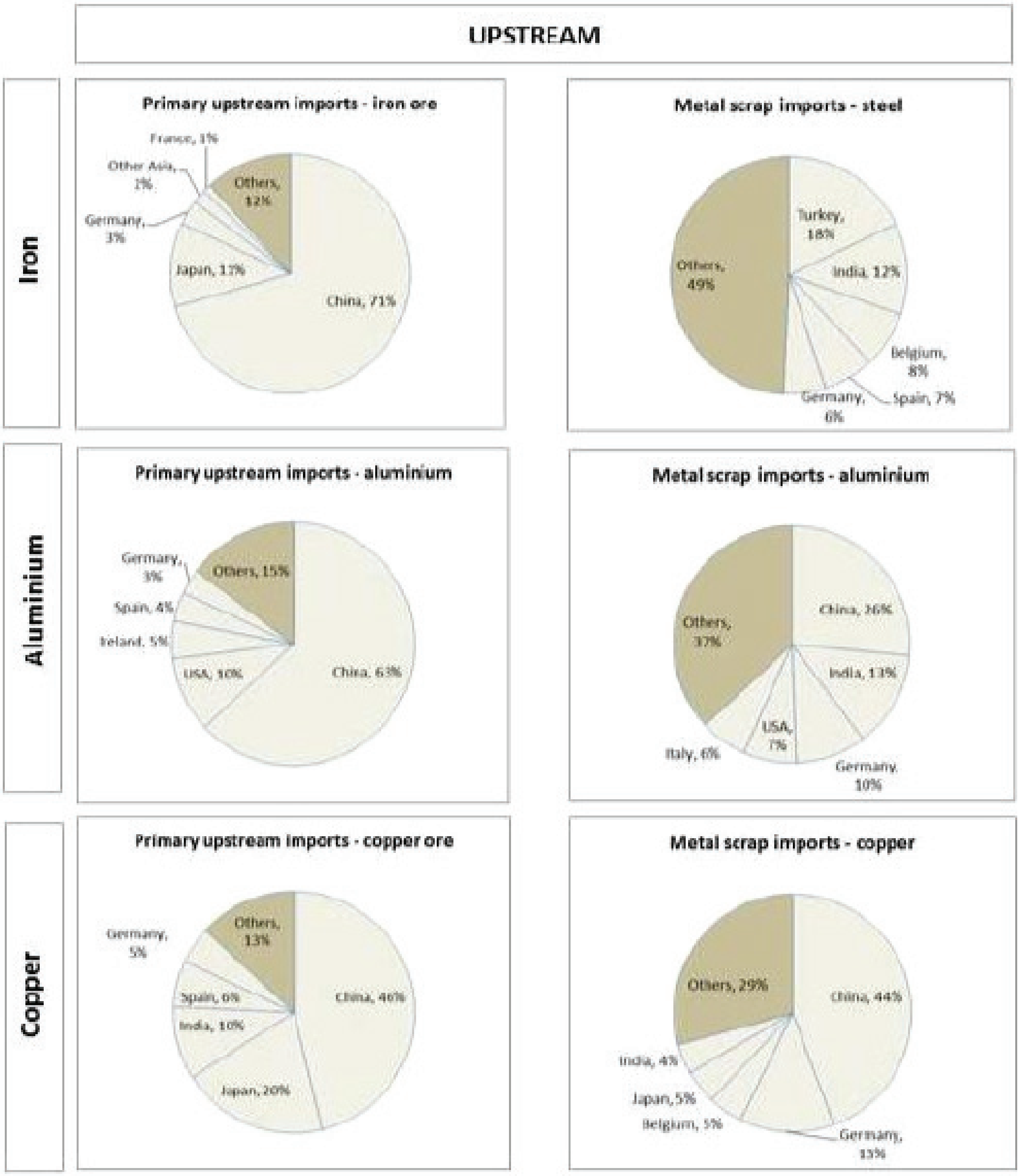
Figure 17. Top five exporters of primary iron ore, bauxite, and copper ore (left), steel, aluminium, and copper scrap (middle), and finished steel, aluminium, and copper metal (right)

179. Other metals for which the production and export of primary ores and concentrates are heavily concentrated include antimony, chromium, cobalt, natural graphite, nickel, niobium, tungsten, and the suite of rare earth elements. Many of these have been identified as 'critical minerals' on the basis of current and future potential supply risk (Coulomb et al. 2015). In 2015, South Africa accounted for 82% and 71% of global cobalt and chromium exports respectively (UN COMTRADE, 2016). Around 70% of tungsten exports (Canada, Russia, Bolivia, and Spain) and nickel exports (Philippines, Australia, USA, and Zimbabwe) originated in four countries. Disaggregated trade data is not available for antimony, chromium, niobium, tantalum, and the REE's, however the highly concentrated character of mine production suggests exports are dominated by a small number of countries. In 2013, China accounted for 75% and 87% of global antimony and REE mine production (USGS, 2016). In the same year, 90% of global niobium extraction took place in Brazil, and 67% of tantalum extraction in the Rwanda and the DRC.

180. Exports of metal waste and scrap are less concentrated than those for primary minerals and concentrates; the largest five scrap exporters account for around 50% of total exports by weight. The key exporters are big industrialised nations where high levels of historic capital accumulation and current consumption result in large present-day domestic scrap metal flows. Canada, France, Germany, Japan, the Netherlands, the United Kingdom, and the United States are the largest exporters of most scrap metals by value.

181. The geographic distribution of finished metal exports is broadly similar to the distribution of production

discussed in Chapter 1. Canada, China, Germany, Japan, Russia, and the United States have considerable domestic smelting and refining capacity and are net exporters of most finished metals. Final metal production often utilises significant quantities of imported feedstock; China, Germany, and Japan are large importers of semi-processed iron, aluminium, and copper ores. On the secondary side, China, Germany, and India are important importers of most metal scraps (Figure 18).



Source: UN COMTRADE (2016), UN COMTRADE Database

Figure 18. Top five importers of primary iron ore, bauxite, and copper ore (left), and steel, aluminium, and copper scrap (right)

5.3 Export Restrictions

182. Restrictions on the export of mineral ores or concentrates and metal waste or scrap exist in a number of countries. The OECD Inventory on Export Restrictions on Industrial Raw Materials (OECD, 2016f) assessed 44 important producer countries and found that 24 had some restriction on the export of primary mineral ores, 29 on the export of metal scrap and waste, and 25 on finished metals or products.

183. Table 8 classifies export restrictions in place in 2014 by measure. There are two apparent patterns. First, there are many more measures affecting metal waste and scrap trade than that for metal ores and concentrates. This is largely because countries which impose restrictions on secondary materials do so across a wider range of commodities than countries imposing restrictions on primary materials. Second, export taxes and licencing requirements are the most common measures used to restrict the export of all three types of material. Export bans and quotas are less commonly used, but represent important export restrictions in several key countries (see below).

	Metal ores and concentrates	Metal waste and scrap	Finished metals
Export Ban	10	97	19
Export Quota	4	15	14
Export Tax	72	265	309
Licencing Requirement	60	209	215
Other restriction	27	43	213
Total	173	629	770

Source: OECD (2016f), OECD Inventory on Export Restrictions

Table 8. Number of countries applying export restrictions: by measure in 2014

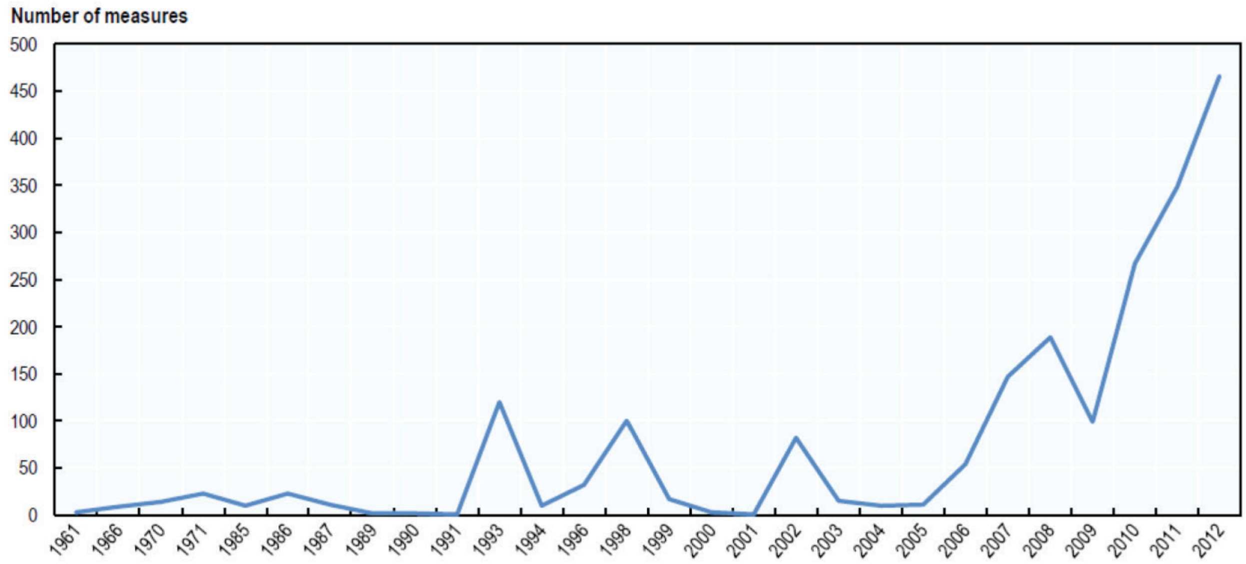
184. Table 9 classifies export restrictions in place in 2014 by which commodity they apply to. At the aggregate global level, there is no particularly commodity focus for export restrictions on primary materials. The same is not true for secondary materials where around one third of documented export restrictions apply to steel scrap.

	Metal ores and concentrates	Metal waste and scrap
Aluminium	7	32
Chromium	8	21
Cobalt	13	21
Copper	18	32
Iron	10	208
Tin	12	24
Titanium	11	21
Tungsten	7	24
Others	87	246
Total	173	629

Source: OECD (2016f), OECD Inventory on Export Restrictions

Table 9. Export restrictions by metal in 2014

85. The number of export restrictions relating to industrial raw materials increased rapidly between 2006 and 2012 (Figure 19), a period characterised by rapidly increasing emerging markets demand for metals. This provides some indication of one motivation behind the creation of many of these measures; as global demand for materials increases, concerns about domestic resource scarcity and resource security also rise. Export restrictions allow governments to conserve mineral resources for domestic consumption. A desire to encourage investment in domestic downstream metal processing facilities may also be an important motivation for certain governments.



Source: OECD (2014), Export Restrictions in Raw Materials Trade

Figure 19. Year of introduction of export restrictions present in 2012

186. Export restrictions affecting upstream primary and secondary feedstock can confer support for domestic downstream sectors. Increased domestic supply puts downward pressure on the price of the targeted product, thereby reducing costs for domestic firms which use it as an intermediate input. In addition, when they are imposed by large exporting countries, export restrictions may place upward pressure on international prices of the targeted good. This increases the cost of intermediate inputs for international downstream firms, thereby increasing the competitiveness of their counterparts in the country imposing the restriction.

187. This section will focus primarily on upstream export restrictions affecting mineral ores and metal scraps. Attention is given primarily to quantitative export restrictions such as taxes, quotas, and bans; other forms of export restriction are addressed in detail in the OECD Export Restrictions database.

5.3.2 Export restrictions on primary minerals and concentrates

188. There were 173 documented restrictions affecting the export of primary minerals and concentrates in 2014. Around 60% of these measures are accounted for by five important mining countries: China, the DRC, India, Indonesia, and Russia. Other significant mineral exporting countries applying one or more primary export restriction include Argentina, Brazil, Guinea, Malaysia, the Philippines, Rwanda, South Africa, and Zambia.

189. Export taxes represented ~40% of primary export restrictions in 2014. The most noteworthy measures are in China, where export tax rates of between 10% and 30% are applied to materials for which China has a very large share of global production. For example, China accounts for 97%, 84% and 37% of global upstream rare earth, tungsten and tin production (USGS, 2016), and levies ad-valorem taxes of 20% to 25% on exports of these commodities.

190. High export tax rates levied in other countries may not distort global prices to the same degree because they affect a smaller share of world trade. These measures nevertheless have important domestic consequences because they place considerable downward pressure on domestic commodity prices. India applies a tax of 30% on iron ore exports, Indonesia a tax of up to 25% on copper concentrate exports, and Zambia a tax of 10% on exports of copper and cobalt ores or concentrates.

191. Low export tax rates in Guinea (0.075%) and the Democratic Republic of the Congo (1%) are noteworthy because they are applied to materials for which these countries represent a very large share of global production and exports. Even slight tax rate increases could lead to significant movements in the relevant global prices. Guinea accounts for 21% of all global bauxite exports. Trade data is poor for the DRC, but it accounts for 49% and 17% of global cobalt and tantalum mine production respectively (USGS, 2016)

5.3.2.2 Export quotas

192. Brazil and China applied quotas to restrict the export of several materials in 2014. The Brazilian quota applied to ores and concentrates of niobium and tantalum, commodities for which Brazil accounted for 90% and 13% of global production respectively (USGS, 2016). It is unclear how binding the quota is. The Chinese quota applied to ores and concentrates of tin, tungsten, molybdenum, and various rare earth elements, materials for which China holds a significant share of global upstream production. The Chinese quota system was abolished in mid-2015 following a WTO ruling.

5.3.2.3 Export bans

193. Indonesia prohibited the export of unprocessed copper, nickel, cobalt, aluminium, and precious metal mineral ores in 2014. The restrictions on aluminium and nickel are especially noteworthy because Indonesia accounts for 20% and 31% of global mine production of these metals (USGS, 2016). Zimbabwe also had an export prohibition on unprocessed chromium exports, but this was lifted in mid-2015.

5.3.3 Export restrictions on secondary scrap and wastes

194. There were 629 documented restrictions affecting exports of metal waste and scrap in 2014. The majority of these are applied by emerging economies; one key distinction with respect to the primary sector is that restrictions are not imposed by large scrap producing or exporting countries. Production data is unavailable for secondary metals, but UN COMTRADE data indicates that 80% of metal waste and scrap exports by value originate in Canada, the EU-28, Japan, or the US – none of which apply any quantitative export restrictions directly to metals9. As such, the impact of secondary export restrictions is likely to be largely limited to domestic markets, where downstream secondary metal processing firms may benefit from lower scrap metal prices.

5.3.2.1 Export taxes

195. Export taxes represented ~42% of secondary export restrictions in 2014. Export tax rates on secondary materials are highest in China, where a rate of 40% is applied to various types of steel scrap, and Russia, where a rate of 40% is applied to copper and aluminium scrap.

196. The average export tax rate on secondary materials across all countries is ~14%, which is very similar to the equivalent figure for primary materials. Few countries apply export taxes to both primary and secondary materials, and there is no obvious pattern of favourable tax treatment in those that do. China and Russia have significantly higher rates for metal waste and scrap, whereas India has higher rates for mineral ores and concentrates.

5.3.2.2 Export quotas

197. Only China and Belarus applied export quotas on metal waste and scrap in 2014. They are applied to scrap of a range of metals including various forms of steel, aluminium, copper, and tungsten. It is unclear how binding these quotas are.

5.3.2.3 Export bans

198. Metal waste and scrap export bans documented in the OECD export restrictions database are restricted to several African countries: Burundi, Ghana, Kenya, Nigeria, and Rwanda. However, export bans targeting end of life consumer products may limit scrap metal trade in other countries. Under European waste regulation, end of life vehicles and certain types of electronic waste are considered to be hazardous waste, and export beyond EU-28 borders is prohibited. This effectively represents an export ban on certain scrap; ELV's are an important source of secondary steel while electronic waste often contains an array of high value metals used in circuitry and batteries.

5.3.4 Effects of export restrictions

199. Export restrictions generally serve to increase domestic supply of the targeted product, which in turn places downward pressure on relevant domestic market prices. In the context of the metals industry, restrictions on exports of primary or secondary raw materials induce a transfer from upstream mining and recycling firms, which face lower output prices, to downstream processing firms, which benefit from lower feedstock costs. The magnitude of support conferred to downstream firms depends largely on the intensity of the tax or quota applied, and the elasticity of downstream feedstock demand. Downstream firms that have spare production capacity or that can adjust their input mix benefit to a greater extent from export restrictions.

200. Export restrictions on primary mineral ores and concentrates and secondary scrap can affect global commodities markets when they are imposed by countries with large export shares. In the context of the metals industry, the concentration of upstream mineral ore and scrap production in a small number of countries (see Chapter 1) means that exporting countries are often large relative to world markets. The data presented in section

5.3.1 indicate that upstream export restrictions imposed by major exporting nations currently apply mostly to primary metals; export restrictions on metal waste and scrap are generally imposed by small exporting nations.

201. When applied by large countries, export restrictions on mineral ores and concentrates reduce global supply sufficiently to place upward pressure on the international market prices of these products. This may increase the cost of primary feedstock for downstream processors located in third party countries, which in turn serves to improve the competitiveness of equivalent firms in the country imposing the measure. In addition, competition between primary and secondary downstream processors in third party countries may be affected; smelters using secondary feedstock may become more competitive as primary feedstock prices increase. The magnitude of support conferred to downstream firms depends largely on: (i) the intensity of the tax or quota that is applied; (ii) the concentration of production and exports of the affected product; and (iii) the prevalence of similar restrictions in other countries.

202. The effect of export restrictions vary according to whether they are considered in the short run or long run. In the short run, upstream export restrictions lower the cost of intermediate feedstock inputs and increase output margins for downstream processing firms. In the longer run, restrictions can incentivise investment in downstream processing capacity and thereby affect the relative primary – secondary share of domestic finished metal production. Technological lock-in may be an important by-product of relatively short-lived export restrictions. Finally, to the extent that they increase global primary metal prices, primary upstream

export restrictions encourage mineral exploration and the development and construction of new mines. One consequence of the Chinese export quota on REE's was increased exploration spending internationally.

203. There are two important caveats relating to the discussion of the support conferred by upstream export restrictions. The first relates to the downward movement in domestic commodity prices as the export restriction binds. Where domestic supply is competitive, this occurs because firms affected by the restriction compete for domestic market share, resulting in a wedge between domestic and international prices. This may not occur to the same extent when domestic supply is dominated by a single, or several, producers; monopolists can continue to charge international prices domestically without being undercut by competitors. The second caveat relates to third party country retaliation in response to the creation of additional export restrictions. The competitiveness gains available in theory to domestic downstream processing firms may not materialise when export restrictions are applied in many countries.

6. POSSIBLE EFFECTS OF SUPPORT FOR METAL PRODUCTION

6.1 Introduction

204. This chapter shifts from identifying different forms of support to describing their likely consequences. It is divided into two parts. The first section focuses on how support distorts competition between firms in the primary and secondary metals sectors. It begins by outlining how a supply side shock (the support measure) in one jurisdiction influences the production decisions of recipient metals firms. It then discusses competition in metals markets and the extent to which modified firm behaviour might translate into primary – secondary market share, both domestically and globally. The second section draws on a number of published life cycle assessments to summarise the environmental consequences of displaced primary (or secondary) production. This discussion is not meant to be exhaustive. Rather, it is intended to highlight the main environmental concerns associated with each stage of the metal's life cycle.

205. The share of primary and secondary production on finished metals markets is the key metric used to discuss the impact of differential support throughout this chapter. Direct competition between the two sectors is mostly restricted to this part of the metal value chain; primary and secondary processing facilities produce finished metal products that are perfect, or near perfect substitutes for each other. The environmental impacts of differential support are also reflected in this metric. All else equal, an increased share of primary metal production implies additional resource extraction (mineral ore, fossil fuel energy, and water) with additional generation of associated by-products (greenhouse gases and residual processing wastes).

206. This chapter is not intended to represent a comprehensive welfare analysis. It also offers no conclusion on the overall welfare impact of government support to the metals sector. The provision of support generates a vast array of benefits and costs for agents operating both within and beyond the metals sector. Many of these impacts are situated in the future; investment decisions made today influence future primary – secondary market share, which has a range of intergenerational environmental implications. Although some support measures clearly target market failures and may therefore be welfare enhancing; others appear to be designed to achieve other objectives such as increased foreign direct investment or domestic job creation. In sum, a full cost benefit analysis is well beyond the scope of this study.

207. Three key messages emerge in this chapter. First, empirical studies indicate that primary and secondary metal processing firms respond to support differently. In particular, the long run elasticity of secondary metal supply with respect to input and output prices appears to be lower than in the primary sector. The apparent unresponsiveness of secondary metals firms to support suggests the existence of barriers to entry; constraints on scrap availability and the volatility of scrap prices are often identified as candidates. One immediate implication is that support measures intended to boost secondary production may have a limited impact for those metals which already have high end of life recovery rates.

208. Second, it is clear that metals value chains span national borders. Targeted sector specific support provided in one jurisdiction modifies domestic primary – secondary market share by encouraging additional production in the recipient sector. It may also influence the production decisions of primary and secondary metals firms in third party countries if global intermediate or finished metal prices are affected. Support provided in large metal exporting countries is therefore particularly worthy of attention.

Third, the life cycle environmental consequences of secondary metal production are significantly lower than those for primary production. The secondary process negates the need for mining, thereby eliminating any associated consequences for local biodiversity, and water and soil quality. Producing metal from scrap also requires considerably less energy than doing so from mineral ores; greenhouse gas emissions are thereby reduced. Secondary production results in fewer waste products than the primary equivalent; mining waste rock and process tailings, both of which can be highly toxic when released into the environment, are not generated. Finally, by utilising metals contained in end of life products as feedstock, secondary production negates the need for these to be disposed of in landfills. Given the above, support measures that serve to boost the share of primary output in total metal production are likely to have negative consequences for overall environmental quality.

6.2 Impact of support at the firm level

209. This section focusses on firm responses to the support measures described in Chapters 3, 4, and 5. The discussion recalls that many of the support measures available in the metals sector are incident on either production inputs or enterprise income. Measures directly affecting output returns or the unit cost of consumption are relatively rare. Support measures which are available at different points in the metal production process may to some extent be transmitted along the value chain.

6.2.1 Measures incident on downstream producers: lowered input prices

210. Primary metal smelters and secondary re-melters use capital, labour, metal feedstock, and energy to produce finished metal products. Support measures which are directly incident on these inputs for final metal producers include accelerated depreciation provisions on capital investment, targeted exemptions from energy related taxes, and the provision of electricity on concessionary terms by state owned utilities. These measures have two main impacts for recipient firms in the short run. Firstly, without any change in firm behaviour, lower per-unit production costs translate into increased per-unit profit margins. Production that was sub-economic without the support measure becomes more viable, and production that was already viable generates increased profits. Secondly, when the support measure relates to variable inputs – those whose levels can be adjusted in the short run – recipient firms may re-optimise their input mix to incorporate more of the subsidised input. This can lead to expanded firm production in the short run if spare capacity is available.

211. In the short run, support measures linked to variable inputs result in higher per-unit profits and the utilisation of any spare production capacity. In the long run, higher profits encourage firm entry and new investment in additional production capacity. Support measures related to fixed inputs, capital being the most obvious example, have a similar long run impact. Concessionary investment finance, grants for capital investment, and tax concessions linked to capital spending all incentivise new investment by increasing anticipated project financial returns. Ultimately, support measures affecting variable and fixed inputs both contribute to a new long run equilibrium involving increased production and lower output prices.

6.2.2 Measures incident on downstream producers: enterprise income

212. Downstream metal processors in some countries benefit from support measures which increase their enterprise income – the aggregate income earned from business activity. These measures are mostly related to foregone tax revenues; specific examples include differential income tax rates – which can be targeted by sector, geographic area, or firm size – and extended tax loss carry forward provisions. Firms respond in a similar way as for measures affecting input prices; per-unit profits increase and previously marginal production may become economic, potentially leading to increased short run production. The key difference in the short run is that firms have less incentive to alter the mix of inputs used in production.

In the longer run, support measures which affect enterprise income will encourage new investment and firm entry in the same way as for other forms of support.

6.2.3 Measures incident elsewhere in metals value chains

213. Downstream metal smelters and refiners also benefit from support which is transmitted from agents operating elsewhere in metal value chains. There are two main mechanisms. First, many government budgetary transfers to the metals industry are received by upstream firms undertaking extraction and upgrading activities. Examples in the primary sector include concessionary mining finance, targeted fuel excise tax exemptions, and concessionary royalty rates. Secondary sector examples include the public provision of separate recycling collection services and public grants or concessionary loans linked to material sorting facilities. Under certain conditions (see below), a proportion of upstream support may be transmitted through the value chain in the form of lower intermediate input prices.

214. Secondly, certain regulatory policies can induce transfers between firms operating in different parts of the metals value chain. Export restrictions on unprocessed raw materials restricts upstream firms' access to international markets; domestic downstream smelting and refining firms potentially benefit from reduced domestic feedstock prices. In the secondary sector, EPR schemes and landfill taxes introduce additional costs for manufacturing and disposal firms, while potentially lowering the cost of intermediate feedstock inputs downstream.

215. Downstream firms respond to indirect support passed through the value chain in a similar way to that described for direct support measures which lower variable input prices. Output and profits are likely to increase in the short run leading to investment in additional production capacity in the long run. Clearly, the size of the downstream firm response depends on both the size of the initial government transfer (or stringency of the policy in the case of regulatory measures), and the degree to which it is transmitted along the value chain. All else equal, higher pass through rates are likely when upstream markets are more competitive, downstream demand is more inelastic, and sectoral value chains are more vertically integrated.

6.2.4 Empirical evidence

6.2.4.1 Firm response in the short run

216. There is a small body of empirical work assessing how smelters and refineries respond to fluctuating input prices. This literature consistently finds that metal processing firms are unresponsive to factor price variability in the short run, both in terms of input demand and output supply. Based on a panel dataset of European primary aluminium smelters, Blomberg (2007) finds that the own price elasticity of electricity demand is -0.027; a 10% decrease in electricity prices only increases demand by 0.3%. Assessments of secondary aluminium plant supply find that output elasticities are low with respect to scrap feedstock prices (-0.10), electricity prices (-0.25) and scrap stocks (0.07) (Blomberg and Hellmer, 2000; Blomberg and Soderholm, 2009). Similar estimates exist for secondary copper facilities; output elasticity with respect to scrap stocks was estimated to be 0.003 by Gomez et al. (2007).

217. These findings suggest that support measures which affect input costs have a limited immediate impact on firm production decisions, and therefore on primary – secondary market share in the short run. Several explanations are commonly given. First, finished metal production is often considered to be characterised by a 'putty-clay technology' (Blomberg, 2007), where factor proportions are optimised ex-ante, and become fixed following plant design and construction. This 'built in' factor mix serves to limit substitution opportunities as input prices fluctuate. Supply constraints for certain inputs may have a similar effect; lower scrap feedstock prices are of little use when scrap availability is limited by the annual flow of EOL scrap from in-use metal stocks. Finally, there may be little opportunity to take advantage of lower factor prices in the short run when plants are already operating at, or close to, capacity.

6.2.4.2 Firm response in the long run

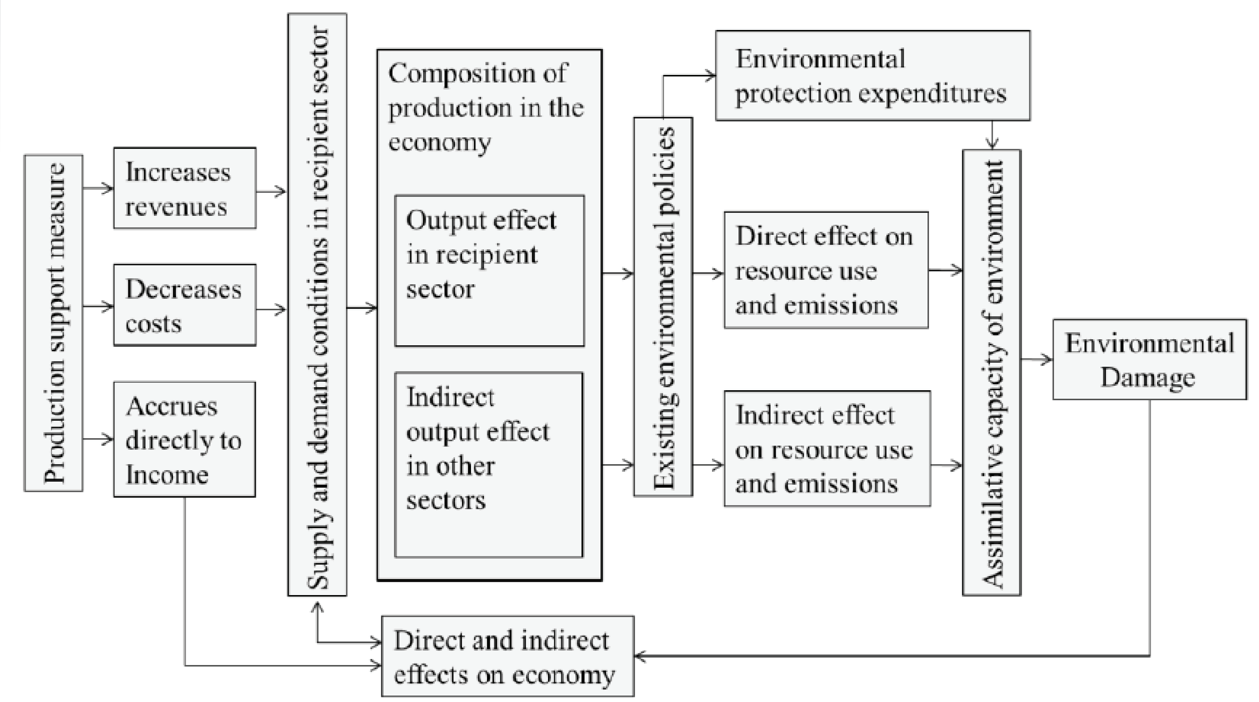
218. Metal production could be expected to be more responsive to the provision of support in the long run; capacity constraints become less binding because production capacity can adjust to new market conditions. There is little data available for the primary sector. One empirical assessment for the finished copper market finds that primary supply is more sensitive to output prices and input (electricity) prices in the long run (Vial, 2004). Fisher et al. (1972) finds a similar result for copper mine production; the elasticity of output with respect to price is significantly larger in the long run.

219. Although the number of studies is limited, empirical assessments of secondary metal sector often find that finished metal supply with respect to both output and input prices is less elastic in the long run (Fisher et al. 1972; Vial, 2004; Valencia, 2005). Blomberg and Soderholm (2009) state that "even though in the long-run expansion of secondary processing capacity is possible, the long-run supply elasticity of secondary aluminium output may not necessarily be higher than the short-run elasticity".

220. One probable explanation relates to constrained availability of secondary scrap metal feedstock. Scrap flows originate from both the in-use stock of capital goods and the use and subsequent disposal of short-lived consumer goods. The size of the former flow is determined by the amount of historic capital investment and the lifetime of these capital goods. The size of the latter is largely a function of aggregate current period consumption. These factors are unrelated to market forces in secondary scrap markets; increased feedstock demand will put upward pressure on material recovery rates, but cannot fundamentally increase the flow of scrap. This becomes especially important where material recovery rates are already high; modelling by UNEP suggests that end of life recovery rates for titanium, chromium, and iron (ie., steel) are around 80%.

6.3 Impact of support on aggregate primary and secondary market share

221. The above discussion outlined how metal re-melting, smelting, and refining firms respond to support. It applied equally to primary and secondary firms, although the potential constraints affecting secondary scrap supply may mean that secondary firms are less sensitive to the provision of support. Similarly, market power in the primary sector may limit the extent to which upstream support is passed through to processing firms. The remainder of this chapter assesses how support might translate into distorted primary and secondary market share at both the domestic and global level, and how this can lead to certain environmental consequences. Figure 20 summarises these relationships.



Source: Adapted from IEA et al. (2010)

Figure 20. The economic and environmental impacts of support

6.3.1 Competition in metals markets

222. Competition between firms in the primary and secondary metals sector takes place mostly at the smelting or refining stage in the metals value chain (see Figure 1). Process plants using feedstock derived from virgin natural resources produce finished products with qualities which are very similar or identical to those produced by plants using scrap feedstock. In general, there is little competition between primary and secondary metal products higher in the value chain. Smelters and refineries are typically optimised to process either primary or secondary feedstock; they have limited capacity to alternate between the two in the short run. There are certain exceptions. Significant quantities of steel scrap are utilised in the primary Blast Oxygen Furnace (BOF) steel production process. Scrap base metal alloys may occasionally be used in integrated processing facilities. In general however, cost efficient finished metal production is facilitated by the use of single feedstock with consistent properties

223. Primary and secondary metal processing facilities produce finished metal products that are perfect, or near perfect substitutes for each other. The Aluminium Association, an industry group in the United States, states that there is “no material difference” between aluminium produced from primary and secondary feedstock; it has the “same physical properties” (Aluminium Association, 2011). For copper, a report from the Centre of European Policy Studies (CEPS) states that “the production of copper from scrap does not affect its properties … secondary copper typically can’t be distinguished from primary” copper (CEPS, 2013). In certain specific situations however, there may be an element of differentiation in finished primary and secondary metal products. Secondary metal is most likely to have inferior properties relative to the primary equivalent when scrap feedstock containing impurities is processed in a re-melting facility. Impurities tend to be incorporated into the finished metal where they result in lower performance characteristics and product differentiation. This is particularly important in high performance applications such as those in the aerospace industry; even small impurities can result in much diminished performance.

224. Finished metal products are bought by a range of agents, including foundries, mills, fabricators, and component manufacturers. Metals markets have become increasingly globally interconnected with the

liberalisation of trade in recent decades. A report by the Centre for European Policy Studies suggests that aluminium and copper markets are developed enough to be considered global (Berg et al. 2013). International prices exist for a number of finished metal products; prices on the London Metals Exchange are an important benchmark and often serve as reference prices for transactions not made through the exchange (Figuerola-Ferretti and Gilbert, 2005; CEPS, 2013). More recently, monthly metal tradevolumes on the Shanghai Futures Exchange (SHFE) have increased substantially (Ferretti et al. 2014); these are frequently used as a reference for Asia based transactions (Sanderson, 2015).

225. Market power held by metal smelting and refining firms is limited for most metals by the increasing interconnectedness of global markets. For aluminium and nickel, Figuerola-Ferretti (2005) states that, the 'prerequisites for oligopolistic co-ordination were gradually removed' following the entry of new fringe producers during the 1980's. Despite this, the largest producers of most finished metals continue to represent a significant share of world production. For steel, aluminium, and finished copper, the largest four producer firms in 2014/2015 represented ~14%, ~25%, and ~27% of world production respectively (see Chapter 1). The largest producer firm for each of these commodities – Arcelor Mittal, UC Rusal, and Codelco – represented ~6%, ~7%, and ~9% of total production.

226. As highlighted in Chapter 1, the share of downstream production held by plants using primary feedstock is in the order of 80% for steel, aluminium, and copper. Although primary – secondary production data disaggregated by firm is unavailable, it is unlikely that significant market power exists within the secondary sector due to its smaller size. Downstream secondary producers are mostly price takers in world markets.

227. In sum, the above set-up is largely consistent with recent theoretical analyses which represent the metals sector in terms of a dominant oligopolistic (primary) sector competing with a smaller secondary sector composed of dominantly price taking firms (Di Vita, 2007; Blomberg and Soderholm, 2009; Boyce, 2012; Zinc et al. 2015).

6.3.2 How support distorts competition between the primary and secondary metal sectors

228. The aggregate impact of government support follows largely from individual firm responses. Short run supply responses may be relatively muted for several reasons, but increased profits or lower investment costs will tend to encourage firm entry, new investment, and increased production in the longer run. Ultimately, expanded aggregate supply will lead to a new long run equilibrium characterised by increased finished metal production and lower market prices. High cost production (both primary and secondary facilities) located domestically and in third party countries will become increasingly uncompetitive as metal prices fall, leading to firm exit or the creation of retaliatory support measures.

229. The extent to which domestic primary – secondary market share is distorted by government support depends on a range of factors. Clearly, the specificity of support is important; measures which accrue exclusively to one sector will serve to increase that sector's production share. The magnitude of support is also critical; firm production decisions will be increasingly distorted as support measures become more generous. In countries where metal is produced exclusively by either the primary or secondary sector, targeted support simply serves to reinforce that sectors dominance. In countries with well-developed primary and secondary metals sectors, differential levels of support will result in modified domestic primary – secondary production share. Two assessments of differential support are known for Canada (Scharf, 1999) and Sweden (Johannson et al. 2014); both conclude that primary support is relatively larger in per-unit terms, but neither study attempts to translate that into market share.

230. One dollar of per-unit support received by the primary and secondary metal sector may not translate into domestic downstream production share in the same way (Zink et al. 2015). As highlighted previously, support received by downstream secondary metal re-melters will have a limited impact on aggregate

secondary production if scrap supply is limited. The volatility of scrap metal prices may also dampen the long run impact of secondary support if incentives to invest in new secondary processing capacity are reduced. In a similar way, different patterns of industrial organisation in primary and secondary metal value chains influence whether support is passed through. The upstream portion of the primary metal value chain is characterised by higher levels of market power than the secondary equivalent. Support received by large mining firms will not necessarily be conveyed further downstream in the form of lower intermediate metal prices.

231. Global primary – secondary market share is important because some externalities associated with metal production have global impacts (e.g., greenhouse gas emissions). Support provided in producer countries can influence primary – secondary market share elsewhere if firms representing a sufficiently large share of world production are recipients (Box 2). Sector specific upstream support available in one large producer country may place enough downward pressure on world feedstock prices to distort downstream primary – secondary competition elsewhere. Alternatively, support received by domestic downstream metal producers in one jurisdiction could depress world finished metal prices enough to render high-cost production located elsewhere sub-economic.

Box 2. International impacts of domestic support

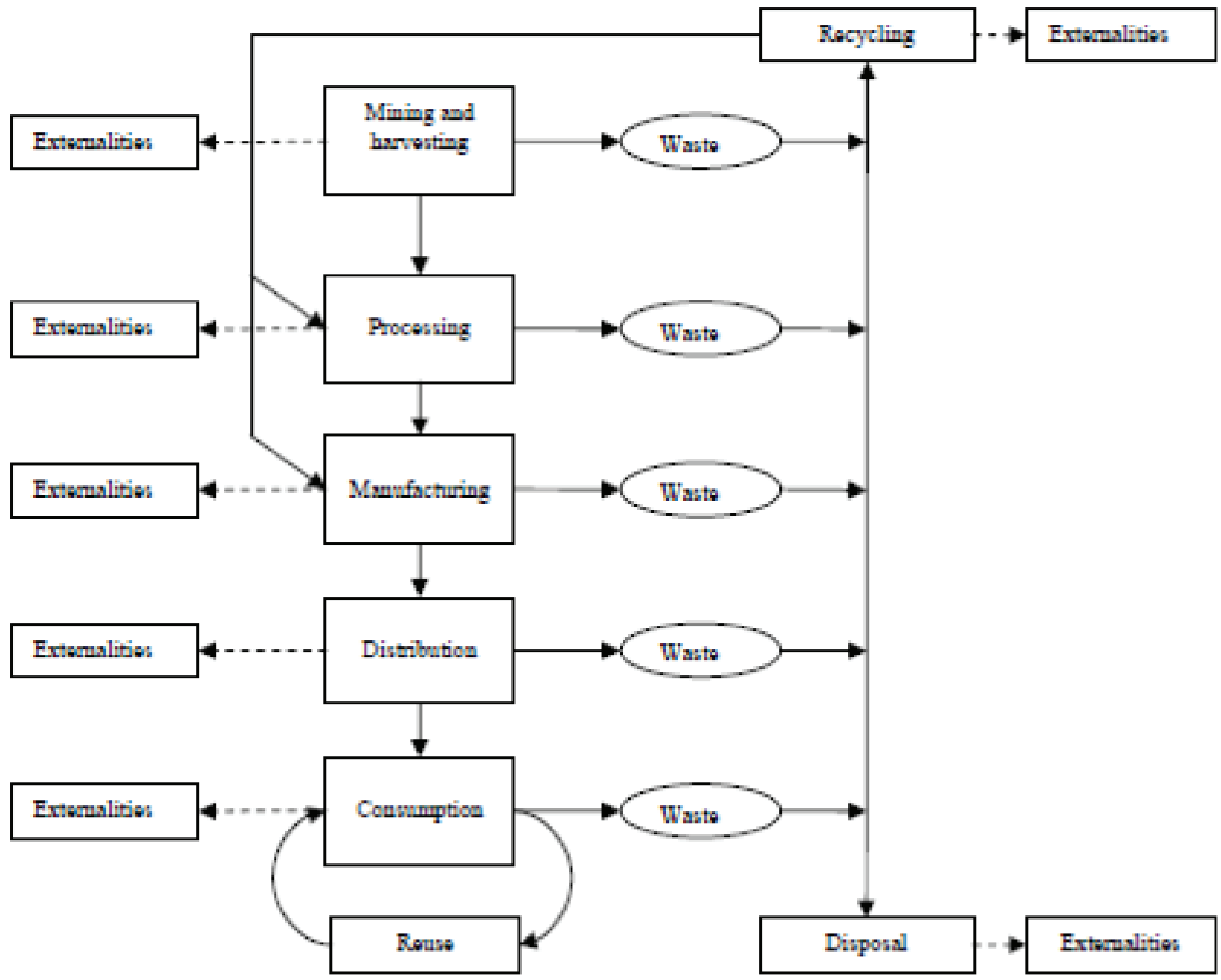
The geographic concentration of upstream mineral ore and scrap production in a small number of countries means that the metals industry is characterised by large trade flows. Metal value chains often span national borders; final metal production in one country may utilise intermediate feedstock that was originally extracted or recovered elsewhere. In 2014, China accounted for almost half of all primary finished aluminium production despite only having 16% of global bauxite mine production (USGS, 2016). Similarly, in the same year, India accounted for 13% of all secondary steel production, despite having limited domestic sources of steel scrap.

The interconnected character of global metal value chains means that support conferred to firms in the metal sector in one jurisdiction may be conveyed globally through trade. The basic transmission mechanism is as follows. Support measures documented in Chapter 3 and Chapter 4 lead to additional domestic metal production, either in the short run as marginal units become economically viable, or in the long run as domestic investment decisions are affected. Assuming a constant export share, higher levels of production translate into increased global supply, which places downward pressure on international commodity prices. This can confer support for downstream metal processors in third party countries which benefit from reduced input costs. The transmission of domestic support may also bias investment decisions made elsewhere; construction of primary smelters or refineries would be favoured if international feedstock prices were lower than they would be otherwise.

The degree to which the transmission of domestic support influences international primary – secondary metal market share is shaped by several factors. Firstly, the magnitude of domestic support is important; all else equal, higher levels of per-unit support will translate into more additional domestic production. Secondly, support conferred in 'large' exporter countries is more likely to be transmitted elsewhere because a greater proportion of global supply is affected. Finally, whether existing domestic production is economically marginal is important; the creation or removal of support measures is less likely to affect the quantity of low cost production than high cost production.

6.4 From market share to life-cycle environmental impacts

232. Support conferred to metals firms can distort the share of primary and secondary production in finished metal markets. This has important environmental consequences because the production of metal from virgin mineral ores generates a broader range of polluting by-products than production from scrap.



Source: Australia Productivity Commission (2006), Waste Management, Productivity Commission Inquiry Report

Figure 21. Life-cycle externalities associated with metal production

Support measures that serve to boost the share of primary output in total metal production are therefore likely to have negative consequences for overall environmental quality.

233. The environmental impacts of metal production have been extensively discussed in a number of cradle-to-grave life cycle assessments (Mudd, 2009; UNEP, 2013; Nuss and Eckelman, 2014), and are presented in Figure 21. The following discussion briefly summarises these impacts across three key parts of the metal lifecycle: extraction, upgrading and processing, and disposal10.

234. Metal production involves an initial upstream phase that is characterised by the extraction of virgin mineral ores in the primary sector and the collection of metallic scrap from various waste streams in the secondary sector. These activities have two main environmental impacts. First, the heavy vehicles and other machinery required for the extraction and transport of raw materials typically run on liquid fossil fuels11, generating greenhouse gas and local particulate emissions as a result. There is little data available on the relative energy and carbon intensities of mining and waste collection. For aluminium, a comparison of studies assessing liquid fuel inputs in bauxite mining (OECD, 2006) and aluminium scrap collection (Quinkertz et al. 2001) suggests that both activities have similar energy requirements per tonne of contained aluminium (around 240 MJ/kg Al).

Energy consumption in mining is small, both relative to the energy required in mineral ore processing (Norgate and Jahanshahi, 2011), and relative to total global energy consumption. On the latter, the IEA indicate that mining accounts for less than 1% of global consumption (IEA, 2016) of local environmental damages that are not encountered in secondary metal production. Surface disturbances associated with mine development, infrastructure construction, and waste dumps can affect large areas, particularly in the case of open pit mining. Further, the exposure of sulphide minerals in mine walls and waste rock dumps can lead to acid mine drainage and increased heavy metal concentrations, with associated consequences for aquatic ecosystems and water supply. Acid mine drainage is often a long-term legacy in mining districts; little can be done to remedy the problem once mineralised materials have been exposed to water and oxygen.

235. Transforming virgin mineral ores and metal scrap into finished metals also generates a range of environmental impacts. Again, the greenhouse gas emissions resulting from energy use are significant. The metals industry is estimated to account for 7.5% of global energy consumption (IEA, 2016), with the vast majority of this originating in upgrading and processing activities (Norgate and Jahanashahi, 2011). As highlighted in Chapter 3, the primary metal production process is highly energy intensive - producing finished metals from mineral ore can require as much as two orders of magnitude more energy than doing so from metal scrap12. This has clear implications for carbon intensity of primary metal production. In addition to the energy requirement, the beneficiation and concentration of virgin mineral ores also requires large volumes of water. This has two main environmental impacts. First, the drawdown or diversion of surface water can lead to water shortages or ecosystem losses, particularly in arid regions. Second, the tailings generated as a by-product often contain high heavy metal concentrations, and can contaminate local groundwater if not properly stored. Environmental damage resulting from tailings spills and smelter or refinery residues are well documented in the mining industry.

236. Finally, the disposal of metals contained in end of life consumer goods or industrial scrap may generate a range of local environmental impacts. Under certain conditions, landfilling of metallic waste may lead to metal leaching and the contamination of local soil and groundwater. This is most likely where landfilled materials contain significant concentrations of arsenic, cadmium, lead, mercury, or other toxic elements; e-waste, pigments, and batteries are potentially important products in this regard (Kiddee et al. 2013). Even metals that are biologically essential may become toxic to certain organisms at high concentrations. Environmental damages associated with waste incineration and landfilling do not directly result from primary or secondary metal production, but are partly a function of primary – secondary sector market share. Any measure that increases the proportion of finished metal produced from scrap will tend to have favourable environmental consequences. Scrap recovery and recycling rates will increase, which simultaneously serves to reduce the extraction of virgin mineral ores and the disposal of potentially toxic metal scrap

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https://www.niti.gov.in/

EU Delegation to India
https://eeas.europa.eu/delegations/india_en

European Union's Resource Efficiency Initiative
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