CIRCULAR ECONOMY: INCLUSION FRAMEWORK OF ALUMINIUM SCRAP IN THE INDIAN MATERIAL FLOW PROCESS

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ABSTRACT

The rapid growth in industrialization and urbanization as much as contributing to India's growth story is also causing enormous negative environmental externalities. The sustainability of the industrial economy can be ensured only if the issues of resource constraints, energy inefficiency and waste management are addressed. A circular economy model helps in mitigating the negative environmental externalities and also sustaining the growth of the economy. This study aims to analyze the inclusion of aluminium scrap in the Indian material flow process as part of the transition of aluminium production towards circular economy. The production forecasting of aluminium for the years 2010 to 2030 is undertaken using a modified IPAT model and then the total scrap ratio of production for the same years is obtained. According to the forecasts, India's production of aluminium will increase from 1.3 million MT in 2010 to 5.6 million MT in 2020 and 6.6 million MT in 2030. Scrap ratio of aluminium production increases from 0.34 in 2010 to 0.44 in 2020 but decreases to 0.37 in 2030. India relies heavily on imported scrap to meet its production requirements, using only domestic depreciated aluminium scrap in calculation reduces the scrap ratio to 0.05 in 2010 and 0.06 in 2030.

Key words: Circular Economy, Extraction, Material flow, metal, Aluminium

1. INTRODUCTION

India is on a high pedestal growth trajectory. As per recent IMF estimates, it is one of the fastest growing major economy in the world (WEO, 2017).The rapid growth in industrialization and urbanization as much as contributing to India's growth story is also causing enormous negative environmental externalities. Mining and metal industry is the beginning of value chain of major industrial processes. For resource rich countries like India, mining and metal industry is the source of resources to meet domestic requirements and also international demands. India is the third largest producer in iron and steel, fifth largest producer in bauxite. The environmental impacts of mining activities seem inevitable starting from the exploration process lasting till after mine closure. The impacts vary depending on the scale and techniques used such as open cast overall affecting air quality, land-use sustenance and causing groundwater and surface water contamination, noise pollution. (Kitula AGN, 2006; Azcue,2012). There is also huge amounts of waste generated in the entire value chain and also after end of life of the finished products. The energy consumption of industrial sector alone accounts for 37% of the total primary energy consumption. (Energy Balance Statistics, 2012). The emissions from this sector account for 80 % of India's total emissions. The sustainability of the industrial economy can be ensured only if these issues of resource constraints, energy inefficiency and waste management are addressed. The current system of linear model where resources are extracted, processed, used for production of finished products, which are eventually discarded after end use has to transform to a circular model where end of life products are brought back into the value chain by restoration and recycling in order to move towards sustainability.

1.1 CIRCULAR ECONOMY

Circular economy is an industrial system that is restorative and regenerative by design. It replaces the 'end of life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems and business models. (Ellen MacArthur Foundation, 2013)

There are several definitions and interpretations of circular economy. The overall concept of circular economy is to ensure that the resources are efficiently used and waste is completely eliminated. This can be done by using less primary resources by promoting restoration and recycling and use of renewable energy sources; maintaining high value of material and products throughout their life cycle by improving product design , changing utilization patterns by shift in consumption patterns (Rizos et al; 2017).

The benefits of this model are not just in mitigating the negative environmental externalities but also in sustaining the growth of the economy. A circular economy development path could create a net trade benefit of 40 lakh crore in 2030 thereby enabling cost savings by 11% of current GDP in 2030 (Ghisellini et al., 2016). Thus although challenges remain in knowledge and adoption there are huge opportunities for India to transition towards circular economy

1.2 OBJECTIVE OF THE STUDY

Aluminium, an infinitely recyclable material due to its unique physical and chemical properties provides more scope for the move from ‘take make dispose’ linear model to a circular economy model. Hence this study aims to analyze the inclusion of aluminium scrap in the Indian material flow process as part of the transition of aluminium production towards circular economy.

2.0 LITERATURE REVIEW

Chen et al, 2015 in their study analyzed the copper flows in United States for the years 1975 to 2012 using a four stage substance flow analysis. Substance flow analysis is an assessment of the anthropogenic metal cycle of a substance. The four stage framework includes transformational flows , trade flows , recycling flows and loss flows. This analysis helped the authors find out the scrap utilization scenario in production, scrap trade over the years.

Refined copper includes primary copper and secondary copper. Primary copper is extracted from the ore, secondary copper is obtained from manufacturing and fabrication stages of copper and old scrap from used copper products. Output of secondary refined copper fell 90 % from 1986 to 2012 while primary remained stable ratio decreases from 27.33 % to 3.94 % in 2012. Reasons for their decrease also are discussed as environmental pressure, market interests, government regulations on hazardous waste and others which make primary product cheaper. Refined copper dominates imports and scrap dominates exports. Amount of exported old scrap increased drastically In 1975, the total exported old scrap was only 130.829 Gg. In 2012, the amount of exported old scrap increased 8.13 times compared to that of 1975. Due to environmental degradation and increased regulations for secondary processing, it is cheaper for US with primary product The study highlighted the reduced usage of old copper scrap for production in United States although the recycling rate of copper has increased 40 percent from 1965 to 2012. This scrap is mostly exported. The reasons for this reduced usage were discussed as environmental pressure and cheaper refined copper available at imports.

This paper closely follows Xuan and Yue (2016). In this paper, the authors have forecasted the production of steel for the years 2010 to 2030 using a modified IPAT model and calculated the scrap ratio for the same years in order to estimate the availability of steel scrap for production. The results show that production will increase to 901 million tonnes and scrap ratio will also increase to 0.366.

Xuan et al (2016) investigated the influence of imported steel scrap used for steel production on future resource and energy consumption and emissions using a subsystem input output model and scenario analysis. Three scenarios have been assumed for which the energy consumption and emissions have been discussed. The baseline scenario is production of steel based only on domestic depreciated scrap, the second scenario is production of steel based on low imported scrap usage, the third scenario is high imported scrap usage for production of steel.

The results show that third scenario has higher energy saving potential of about 10082 PJ compared to other two scenarios. There is also resource efficiency with the third scenario since China imports 78.5 percent of the domestic iron ore demand. The emissions are reduced by 60 % with the third scenario. Hence the shift from iron ore based steel to scrap based steel is essential. Sevigne – Itoiz et al (2014) studied the environmental consequences of recycling old scrap in a global market using dynamic Material Flow Analysis and consequential Life Cycle Assessment. The study was carried out for Spain as representative of Europe. The dynamic MFA of aluminium flows was done for the years 1995 to 2010. The analysis showed that as old scrap was collected and exported, the export flows contributed to more reduction of greenhouse gas emissions.

3.0 METHODOLOGY

The methodology of this paper closely follows Xuan and Yue(2016)

The production forecasting of aluminium for the years 2010 to 2030 is undertaken and then the total scrap ratio for the same years is obtained in order to understand the scrap utilization scenario in Indian aluminium industry.

3.1 **Method**

a) Aluminium Production forecasting for 2010 to 2030

The production of aluminium in India is estimated and forecasted using a modified IPAT model

The IPAT model also known as Kaya identical equation is used to estimate carbon emissions as product of various factors. Here we use a modified IPAT model to forecast aluminium production since it takes into consideration the growth, environment, social and policy factors in its estimation process.

The modified IPAT model is as follows

$$Q = P\left(\frac{G}{P}\right)\left(\frac{E}{G}\right)\left(\frac{C}{E}\right).k\ .w = P\ .Aec\ .k\ .w \qquad (3.1a)$$

where **Q** represents total aluminium production in the year t , **P** represents population in the year t , $\left(\frac{G}{P}\right)$ represents GDP per capita for the year t , $\left(\frac{E}{G}\right)$ represents energy intensity per unit of GDP (e) , $\left(\frac{C}{E}\right)$ represents carbon emissions per unit of energy consumed (c) , **k** represents technological progress coefficient , **w** represents share of carbon emissions of aluminium production in total national emissions.

b) Scrap ratio calculation for the years 2010 to 2030

Scrap ratio is the depreciated aluminium scrap recycled in aluminium industry for use in aluminium production. It includes domestic scrap and imported scrap**.**

The scrap ratio for the year t is calculated as follows

$$S_t = \rho_t + e_t = \frac{m_t M_{t-\Delta t} + E_t}{P_t} \quad \textbf{(3.1b)}$$

S_t is total scrap ratio for the year t, ρ_t is domestic depreciated scrap ratio , e_t is imported scrap ratio for the year t

Δt is average lifespan of aluminium products , m_t is recycling rate of domestic depreciated scrap , $M_{t-\Delta t}$ is aluminium consumption in particular region Δt years ago , E_t is amount of imported scrap for the year t , P_t is total aluminium *production for the year t

The domestic depreciated scrap ratio for the year t is calculated by multiplying the recycling rate of domestic depreciated scrap and aluminium consumption in the year $t - \Delta t$ and dividing by the total aluminium production in that year t. Similarly imported scrap ratio of aluminium production is calculated by dividing amount of imported aluminium scrap in the year t by total aluminium production in that year t.

3.2 **Data source**

The data for the variables used in this study is taken from secondary sources. The population, GDP per capita , energy intensity per unit of GDP, carbon emissions per unit of energy consumed values for the years 2010 to 2015 are taken from World Bank database of World Development Indicators. The world technological progress coefficient is assumed from the paper Xuan and Yue (2016). The share of carbon emissions of aluminium production in total national emissions is taken from India Greenhouse Gas Emissions Report, 2007.

The recycling rate of domestic depreciated scrap for India is taken from India Mineral Yearbook.

The aluminium consumption for the years is sourced from NITI Report on Metals Industry, India. The amount of imported scrap for the years 2010 to 2015 is taken from Export Import Databank of Ministry of Commerce, India. The total aluminium production for the years 2010 to 2030 are the values obtained using forecasting.

4.0 **RESULTS AND DISCUSSION**

4.1 **ALUMINIUM PRODUCTION FORECASTING**

The production of aluminium for the years 2010 to 2030 has been calculated and forecasted using the modified IPAT model given in Equation 3.1a.

The calculated and predicted values are depicted in Table 1.

According to forecast results, Indian aluminium production would increase from 1.3 million tonnes in 2010 to 6.6 million tonnes in 2030. Compared with statistical data of aluminium production the forecast will have only as error percent of 0.19 with respect to the year 2010.

4.2 **SCRAP RATIO: 2010 – 2030**

The scrap ratio of aluminium production is estimated and forecasted for the years 2010 to 2030 using the Equation 3.1b. The calculated and predicted values are depicted in Table 2. India's recycling rate of domestic depreciated scrap is very low, about 20 percent. (India Bureau of Mines). The average lifespan of aluminium products is 20 years (KK Chatterjee, 2007). India relies heavily on import of aluminium scrap to meet its production requirements. India was the second highest importer of aluminium scrap in the year 2015 after China.(Institute of Scrap Recycling Industries). The scrap ratio calculated is found to be 0.340 or 30 percent for the year 2010 and fluctuates around the same rate 0.4 or 40 percent for the year 2030. So the amount of aluminium scrap used for production of 1.6 million MT in 2010 is 0.55 million MT.

4.3 **SCENARIO ANALYSIS**

4.3.1 Domestic scrap only exists

When there is no import of aluminium scrap allowed, and only domestic aluminium scrap exists, the scrap ratio of aluminium production is found to be very low.

Table 1 : Aluminum Production forecasting for 2010 to 2030

Year	Population	GDP PER CAPITA (IN THOUSAND DOLLARS PER PERSON)	ENERGY INTENSITY PER UNIT OF GDP Tcoe	CO2 EMISSIONS PER UNIT OF ENERGY CONSUMED	k TECHNOLOGICAL PROGRESS	w SHARE OF CO2 EMISSIONS OF Aluminum IN TOTAL	ALUMINIUM PRODUCTION (MT)
2010	1230984504	1.3457	0.5627	1.4	1	0.001	1304985
2011	1247446011	1.4614	0.5627	1.5	0.991	0.001	1524869
2012	1263589639	1.4475	0.5743	1.6	0.982	0.001	1650421
2013	1279498874	1.4562	0.5951	1.6	0.973	0.001	1726170
2014	1295291543	1.5768	0.6061	1.7	0.965	0.001	2030788
2015	1311050527	1.5983	0.61594	1.77	0.956	0.001	2183973
2016	1327287778	1.64277	0.62786	1.84	0.947	0.001	2385466
2017	1343281376	1.6889	0.63978	1.91	0.939	0.001	2603310
2018	1359274975	1.7352	0.6517	1.98	0.93	0.001	2830472
2019	1375268573	1.7814	0.66362	2.05	0.922	0.001	3073020
2020	1391262171	1.8276	0.67554	2.12	0.914	0.001	3328444
2021	1407255770	1.873	0.68746	2.19	0.905	0.001	3593023
2022	1423249368	1.9201	0.69938	2.26	0.897	0.001	3874584
2023	1439242967	1.9663	0.7113	2.33	0.889	0.001	4169713
2024	1455236565	2.0125	0.72322	2.4	0.881	0.001	4478619
2025	1471230164	2.0588	0.73514	2.47	0.873	0.001	4801501

2026	1487223762	2.1050	0.74706	2.54	0.865	0.001	5138543
2027	1503217361	2.1512	0.75898	2.61	0.858	0.001	5496320
2028	1519210959	2.1974	0.7709	2.68	0.85	0.001	5862666
2029	1535204558	2.2437	0.78282	2.75	0.842	0.001	6243659
2030	1551198156	2.2899	0.79474	2.82	0.835	0.001	6647384

Table 2 : Scrap ratio of aluminium production for 2010 to 2030

Year	**m- RECYCLING RATE OF DOMESTIC SCRAP %**	**M – ALUMINIUM CONSUMPTION Δt YEARS AGO**	**E -- AMOUNT OF SCRAP IMPORTED FOR THE YEAR t**	**P – TOTAL ALUMINIUM PRODUCTION FORECASTED FOR THE YEAR t (MT)**	**SCRAP RATIO**	**TOTAL AMOUNT OF SCRAP USED IN PRODUCTION (Mt)**
2010	0.2	423000	466386.25	1619455	0.340	550614.7
2011	0.2	457000	622988.69	1667634	0.428	713747.4
2012	0.2	400000	726535.44	1757319	0.458	804852.1
2013	0.2	424000	718942.25	1723100	0.466	802964.6
2014	0.2	455000	866431.5	2031835	0.471	956994.3
2015	0.25	461000	866734.5	2183973	0.449	980603.9
2016	0.25	478000	983784.0873	2385466	0.462	1102085
2017	0.25	481000	1061626.273	2603310	0.453	1179299
2018	0.25	488000	1139468.458	2830472	0.445	1259560

2019	0.25	494500	1217310.644	3073020	0.436	1339837
2020	0.25	505250	1295152.829	3328444	0.427	1421246
2021	0.25	570320	1372995.014	3593023	0.421	1512663
2022	0.25	579120	1450837.2	3874584	0.411	1592454
2023	0.25	542680	1528679.385	4169713	0.399	1663715
2024	0.25	681995	1606521.571	4478619	0.396	1773533
2025	0.25	1000127	1684363.756	4801501	0.402	1930203
2026	0.25	1118621	1762205.942	5138543	0.397	2040002
2027	0.25	1273531	1840048.127	5496320	0.392	2154557
2028	0.25	1301730	1917890.312	5862666	0.380	2227813
2029	0.25	1532239	1995732.498	6243659	0.382	2385078
2030	0.25	1707831	2073574.683	6647384	0.376	2499416

Table 3 : Scenario : Domestic scrap only

YEAR	SCRAP RATIO WITH DOMESTIC SCRAP ONLY	SCRAP RATIO WITH IMPORTED SCRAP
2010	0.05	0.340
2011	0.05	0.428
2012	0.04	0.458
2013	0.04	0.466
2014	0.04	0.471
2015	0.05	0.449
2016	0.05	0.462
2017	0.04	0.453
2018	0.04	0.445
2019	0.04	0.436
2020	0.03	0.427
2021	0.03	0.421
2022	0.037	0.411
2023	0.03	0.399
2024	0.03	0.396
2025	0.05	0.402
2026	0.05	0.397
2027	0.05	0.392
2028	0.05	0.380
2029	0.06	0.382
2030	0.06	0.376

CONCLUSION

In this study, we analyzed the scenario of Indian aluminium production and inclusion of scrap in production by forecasting for the years 2010 to 2030. The forecast results show that India's production of aluminium will increase from 1.3 million MT in 2010 to 5.6 million MT in 2020 and 6.6 million MT in 2030. The increasing growth in aluminium demand can be attributed as a reason. The scrap ratio was obtained by calculating for the years 2010 to 2015 and predicting for the years 2016 to 2030. The results show that scrap ratio of aluminium production increases from 0.34 in 2010 to 0.44 in 2020 but decreases to 0.37 in 2030. The scenario analysis shows that using only domestic scrap reduces the scrap ratio to 0.05 in 2010 and 0.06 in 2030. Thus India relies heavily on imported scrap to meet its production requirements. The utilization of scrap in production is one of the circular economy processes and India has to increase its recycling rate and enable transition to a sustainable circular economy model.

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