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Ministry of Steel
Government of India

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NITI Aayog

STRATEGY ON RESOURCE EFFICIENCY IN STEEL SECTOR

JANUARY 2019

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 Steel Sector.

Steel is a key component of infrastructure development and is one of the core infrastructure industries. India is the third largest steel producer in the world. Steel industry contributes around 2% to India's GDP and employs around 25 lakhs people directly or indirectly. As a material Steel can be recycled to the same quality with no downgrading. Steel recycling uses 74% less energy, 90% less virgin materials and 40% less water. It also produces 76% fewer water pollutants, 86% fewer air pollutants and 97% less mining waste. Thus, Resource efficiency in steel sector will contribute significantly to sustainable consumption and production which is a standalone goal in the 2030 Agenda for Sustainable Development as well as Climate Change adaptation and mitigation targets under Paris agreement. As India embarks on a growing steel consumption trajectory, it must realize that both primary and scrap-recycling industries are essential to the vision of India's Steel Policy.

It is with this background that a strategy has been proposed in the report containing 8 recommendations (under headings Steel Scrap Recycling and Steel Slag Utilisation), which is expected to provide impetus to scrap based Steel Industry, increase its competitiveness as well as circularize the production process. It will also go a long way in reducing CO_2 emissions significantly.

I would like to thank Ms Ruchika Chaudhry Govil, Nodal Officer, Ministry of Mines, and Dr Mukesh Kumar, Director, SRTMI, 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 Steel 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 steel sector 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
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Executive Summary

Resource efficiency or resource productivity, is the ratio between a given benefit or result and the natural resource use required for it. Resource efficiency is closely linked to the concept of "circular economy", which has gained prominence as a policy goal for sustainable development in recent years. Circular economy implies reusing waste back into the production cycle to produce new products and uses instead of wasting such materials with embedded resources. Therefore, steps to achieve a circular economy are an important part of resource efficiency.

A transition towards Resource Efficiency is expected to contribute to a more sustainable economic growth and to create new jobs. Resource efficiency in steel sector plays an important role as its main product i.e steel can be recycled even after its end of life into usable products as well as other waste or by-products developed during production of steel, known as slag or flue gases can be used in several applications. Achieving full potential of Resource Efficiency w.r.t steel scrap processing and by-products development based on slag in India would require significant innovating efforts ranging from the adoption of the state-of-the-art technologies and equipment, logistic support, new business models etc. This cannot be achieved by incremental evolution within the existing systems. It will require rather holistic and possibly radical change of the existing production and consumption systems. This may require a coherent policy framework addressing issues like financing, capacity building, supply chain management, logistic etc.

NITI Aayog has developed a comprehensive and balanced strategy guideline paper on resource efficiency, outlining future policy directions that should propagate shifting away from the waste-centric approach towards a more holistic approach combining more resource efficient production and consumption approaches. The implementation of Resource Efficiency based projects is expected to contribute to a more sustainable & economic growth besides opening new avenues for employment.

This document exclusively deals with the need of resource efficiency in the steel sector, adoption of which shall help in improving performance in the field of energy, environment and efficiency in the sector besides making industry globally competitive. Steel is an alloy of iron and carbon, and other alloying elements, which, because of its wide range of properties and low cost, is one of the most important material in the modern world used for innumerable applications, e.g. buildings, infrastructure, transport, household appliances, automobiles, ships, machines, defence etc. Indian steel industry is the third largest steel producer in the world and going by production trend in 2018, is likely to emerge as the second largest producer soon. The Indian steel industry enjoys huge advantage of high-grade iron ore and coal reserves but technological interventions are required to make effective utilization of the same to become globally competitive.

Today, the Indian steel industry contributes around 2% of the country's GDP and employs about 25 lakh people directly or indirectly. However, the per capita steel consumption in India is much below the world average but increasing continuously. The per capita steel consumption is likely to be increased from existing level of 68 kg to 160-180 kg by 2030-31. To ensure sustainable development of the steel sector and to meet continuously growing demand of steel from the domestic sources, National Steel Policy 2017 (NSP-2017) has been issued. This will require increasing steelmaking capacity from present level of 125 million tons per annum (MTPA) to 300 MTPA by 2030-31. The creation of additional capacity for fulfilling the anticipated demand will require significant capital investment of about Rs. 10 lakh Crore by 2030-31 and will also increase employment in the range of 36 Lakhs by 2030-31 from the current level of 25 Lakhs i.e around 1 million additional work-forces through direct & indirect opportunities.

The increased demand of steel will mainly be driven by the new initiatives taken by the Government of

India in various sectors like Infrastructure, Housing, Transport, Capital Equipment & product manufacturing , Defence, Aviation etc under schemes like Make in India , Smart City, Affordable Housing for all etc., The choice of technology for this level production will require careful consideration for effective and efficient utilization of domestic resources with minimum damage to environment.

> Humans are using technology in ways that are affecting nature adversely. The cost of doing so is heavy. For the future of mankind, we do not have to struggle against nature but find a symbiotic path with it.
>
> *Hon'ble Prime Minister Sh. Narendra Modi at World Government Summit in Dubai, 11th Feb 2018*

Steelmaking process are generally classified under two heads, namely, Blast Furnace-Basic Oxygen Furnace (BF-BOF) route and Electric Arc Furnace (EAF) and /or Induction Furnace (IF) route. The BF-BOF route (primary sector) caters to around 45% of India's steelmaking capacity, while the remaining 55% is processed through the EAF and IF route, mostly in MSME sector (called as secondary or mini steel sector). The main raw material for steel making are Iron Ore and / or Steel Scrap. However, use of intermediate product called sponge iron, mainly in EAF/IF route, is very common and have been adopted widely. Today, India is the largest producer of sponge/direct reduced iron (DRI).

Steel scrap is a recyclable material left- over from steel manufacture or fabrication or at end of life of the product. Recycling is the process of converting such material into reusable new material. Steel scrap is essentially of three types:

- *home/in-house scrap* which is generated inside the steel plant and recycled in steelmaking,
- *new scrap or prompt scrap* which is generated during processing of steel product at customers end, such as forming of auto components, machining of tools, fabrication of structures/equipment, processing of white goods etc. These are collected and used in the MSME or secondary sector.
- The third type is known as *end of life cycle scrap or obsolete scrap*.

A huge reserve of obsolete scrap is available which, if properly utilized, will lead to significant availability of scrap in the country and will boost the growth of steel manufacturing through MSME (secondary sector). However, in absence of any organized system, India is forced to import nearly 6-7 million TPA of steel scrap leading to drainage of large amount of foreign exchange. There is a need of clear-cut guidelines to be issued in the form of policy so that the MSME sector can grow meeting all environmental norms and adopting the best available technologies for sustainable development.

Recycling of one ton of scrap saves 1.1 ton of iron ore, 06-0.7 T of coking coal and around 0.2-0.3 T of fluxes. Besides, specific energy consumption is also reduced drastically as the requirement of energy for production of steel through primary and secondary routes 14 MJ/Kg and 11.7 MJ/ Kg respectively. Thus, it leads to savings in energy by 16-17%. It also reduces the water consumption and GHG emission by 40% and 58% respectively. Thus, the use of scrap as a main source of raw material for steel making enhance the sustainability of the steel sector and also results into significant conservation of natural resources.

> Recycling of one ton of scrap saves 1.1 ton of iron ore, 06-0.7 T of coking coal and around 0.2-0.3 T of fluxes. Specific energy consumption for production of steel through primary and secondary routes is 14 MJ/Kg and 11.7 MJ/ Kg respectively. Thus, it leads to savings in energy by 16-17%. It also reduces the water consumption and GHG emission by 40% and 58% respectively.

Global ferrous scrap availability stood at ~775 MT in 2017, out of which 630 MT were recycled by the steel and foundry casting industries. As per World Scrap Association (WSA) estimates, global ferrous scrap availability will reach 1 billion tons by 2030. Scrap consumption is driven by the price differential between scrap and hot metal, and tend to correlate closely with the prices of iron ore and coking coal. Steelmakers make trade-off based on this input prices as well as the global trends in terms of availability and demand of ferrous scrap.

The production of steel through EAF/IF route is expected to increase substantially because of various inherent advantages the sector enjoys like low energy consumption, ease of establishing, availability of raw material etc. The gap between demand and availability for steel scrap is likely to increase from 5 MT presently to 9 MT by 2021-22. During this period, the total availability of steel scrap is likely to rise from ~ 30 MT to ~ 46 MT. As steel scrap recycling industry grows, multi-pronged interventions will be required with regard to policy framework across the value chain to conduct the operations of the process with efficient and effective management of resources. It is therefore necessary to formulate a policy for scrap generation and processing, keeping in view the huge untapped resources available the country in the form of "obsolete scrap".

Ferrous Scrap being the primary raw material for EAF/IF based steel production, the policy must envisages a framework to facilitate and promote establishment of metal scrapping centres to ensure scientific processing & recycling of ferrous scrap generated from various sources and a variety of products.

Various strategies need to be enforced to make scrap recycling to grow as full-fledged organized industry with the state of art facilities and economies of scale. Currently, the major limitations of this sector are absence of systems for large scale scrap collection in an organized manner, lack of coordination between scrap collectors and steel producer, prevailing import duties, absence of regulatory framework etc. In addition, the skilled manpower and state of art facilities for collection, segregation, shredding, transporting etc. need to be created. The economics of the scrap recycling business will determine how much obsolete scrap will actually be available for steel production. Government support may be required to actively nurture this industry through hand holding with the promoters by way of technological support, streamlining regulatory requirement, developing a mechanism for fair price mechanism between OEM and scrap processing centre, land acquisition and tax structures. Interventions also may be required to accord status either under "Industry Status" or "Infrastructure Status" to scrap recycling sector to enable promoters to arrange for capital requirement and also ensure statutory compliance w.r.t safety, health and environmental norms. Higher scrap usage will promote larger volume of production of steel through EAFs, leading to a cleaner and greener industry.

The potential for revenue generation in steel scrap industry is of the order of Rs. 2000 crore/million ton per annum of steel scrap processed. This will require skilling people in new trades as well as bringing focus on new innovative ideas/researches in the MSME sector. Some of the institutes such as National Institute of Secondary Steel technology (NISST), Biju Patnaik National Steel Institute (BPNSI) etc may fulfil this gap by formulating the courses needed for the steel scrap recycling sector.

The need of a policy to scrap the vehicles older than 15-20 years is also being discussed but formal policy is yet to be announced. This is mainly because old vehicles are considered as fuel inefficient and found to be one of the main sources of pollution and CO2 emission in the cities. If implemented, this will lead to generation of additional 20-25 MT of additional scrap in the next five years or so. This may require numbers of auto shredding and scrap recycling plants in the country. MSTC Limited and Mahindra Accelo are already setting up India's first vehicle shredder of 1.2 lakh TPA capacity. It is reported that the major steel player viz Tata Steel is also planning a similar unit in Gurugram, Haryana to tap this additional source of scrap, mostly automobiles and white goods in National Capital Region.

During steel making, all the unwanted elements present in the raw materials are removed as **"Slag"** by use of various fluxes so that maximum recovery of Iron is ensured. Iron & steel making processes thus generate huge amount of slag which is basically a non-metallic product consisting of calcium silicates and ferrites, combined with fused oxides of iron, aluminium, manganese, magnesium, calcium, phosphorous etc. Iron making slags, known as Blast Furnace (BF) slag are predominantly utilized in the cement making, but the steel making slags, both from BOF (also called as LD Converter) as well as EAF/IF furnaces have limited usages.

Thus, a major portion is dumped in open areas which occupy a large area in any plant. Sustainable use of slag shall contribute to natural resource saving and CO_2 emission reduction and also provide ecological advantage.

Steel slags are partially consumed at steelworks itself but has other applications also like in cement, as road/highways, building material, fertilizer, and as waste in landfills. However, in India, the importance of steel slag utilization is yet to be fully realized and implemented. There is an urgent need to utilize this by-product effectively by promoting researches as well as adopting already proven technologies.

Steel slag has a great potential as a replacement for natural aggregates in road construction. Steel slag processing has been developed to enable its use as product acceptable by the construction industry. Steel slag aggregate meets all important physical characteristics of aggregates laid down in Ministry of Road Transport and Highways (MoRTH) specification for Road and Bridge Work 2001 for preparation of bituminous concrete mixes. Currently, use of steel slag as aggregate is limited within few hundred kilometres around the steel plant, mainly due to the logistics issues. Although, field trials have been conducted for assessing the suitability of processed weathered BOF slag for use as rail track ballast, but due to presence of lime the safe utilization could not be established till date. Pilot scale study has been conducted for "Development of process for steam maturing of BOF slag" so that the issues of lime can be addressed and acceptability of slag as an aggregate or rail ballast can be improved. Besides, steel slag can be used for amending acidic soils for soil neutralization and as source of growing agents. India is having nearly 40% of arable land as acidic and thus steel slag can be the best and cheapest source for such soil to correct the acidity as well as improve the crop productivity. This necessitates conducting field level trials to develop steel slag-based cost-effective eco-friendly fertilizers for sustainable agriculture and inclusive growth

This strategy paper discusses the opportunities and strategies needed for effective utilization of steel scrap and slag in a cost-effective manner i.e. Resource Efficiency to improve sustainability of the sector as well as to promote the concept of circular economy. Action agenda also has been suggested to implement the measures required to make scrap recycling and steel slag utilization a sustainable, energy efficient and environment friendly sector.

1.0 Background

Resource efficiency or resource productivity is the ratio between a given benefit or result and the natural resource use required for it. Resource efficiency is closely linked to the concept of *"circular economy"*, which has also gained prominence as a policy goal for sustainable development in recent years. Circular economy implies reusing waste back into the production cycle to produce new products instead of wasting such materials with embedded resources. Therefore, steps to achieve a circular economy are an important part of resource efficiency.

Steel is one of the most important material in the modern world and is used for innumerable applications right from safety pins to bridges, transmission towers, automobiles, defence etc. Historically, all nations during their industrialization phase have been backed by a strong domestic steel industry. The crude steel production in India has increased considerably in the last 5 years reaching to highest ever production of 103 million tons in 2017-18 against 81.694 million tons in 2013-14.[1]

India is the third largest steel producers in the world, and on-going production trend in 2018, is likely to emerge as the second largest producer soon, surpassing Japan. Today, the Indian steel industry contributes approximately 2% to the country's GDP and employs about 25 lakh people, directly or indirectly. The contribution of alloy steel industry and stainless-steel industry is also significant and it is contributing both in meeting domestic requirement as well as exporting the special steel and products to numbers of countries. Today, India is the second largest stainless-steel producer in the world but lacking in meeting domestic requirement of special steels for sectors like automobile, electrical, aviation, capital equipment etc and thus a large amount of such special steels is being imported.

The Indian steel industry enjoys advantage of availability of high-grade iron ore but non-availability of adequate quantity and quality of coking coal is one of the main reasons of its non-competitiveness. Although, India is having large reserve of coking coal but due to mining issues and lack of technological expertise / availability of suitable technology for coal washing, most of the requirement is met by import. In addition, India is having a strong MSME sector, highly trained manpower and a relatively low labour cost which can boost growth of the steel sector in future. There are numbers of other factors such as significant increase in Government's spending on infrastructure and manufacturing sector, increase in per capita income, ease of doing business, human resources for steel sector which had necessitated formulation of the new National Steel Policy 2017 (NSP2017) to leverage the full potential of growing domestic demand for economic growth.

The main objectives of NSP2017 are as follows:

1. Build a globally competitive industry
2. Increase per Capita Steel Consumption to 160 Kgs by 2030-31
3. To domestically meet entire demand of high-grade automotive steel, electrical steel, special steels and alloys for strategic applications by 2030-31
4. Increase domestic availability of washed coking coal so as to reduce import dependence on coking coal from ~85% to ~65% by 2030-31
5. To have a wider presence globally in value added/ high grade steel
6. Encourage industry to be a world leader in energy efficient steel production in an environmentally sustainable manner.

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7. Establish domestic industry as a cost-effective and quality steel producer
8. Introducing the concept of life cycle cost while evaluating projects instead of upfront cost
9. Attain global standards in Industrial Safety and Health
10. To substantially reduce the carbon foot-print of the steel industry.

In 2017-18, nearly 47 million tons of steel was produced by BOF route and around 56 million tons by EAF/IF route i.e. MSME sector (Secondary / Mini) has contributed around 55% of the total steel production in the country[2]. large portion of input metal used by this segment comprises steel scrap from different sources, in addition to sponge iron / directly reduced iron (DRI) produced from iron ore using non-coking coal. In order to move towards greener technologies, most of the developed countries are switching over to scrap-based steel production instead of iron ore based production. In Indian context, the importance of MSME sector becomes very significant as the generation of scrap is likely to be increased significantly and utilization of the same in making steel will help in minimizing greenhouse gas emission as well as conservation of natural resources. Thus, during ramp up of steelmaking capacity 300 MTPA by 2030-31, steel scrap requirement is poised to be increased significantly. This strategy paper aims provide general guidelines for scrap generation and processing, keeping in view the huge untapped resources available in the country in the form of "obsolete scrap".

A sustainable circular economy is one in which society reduces the burden on nature by ensuring resources remain in use for as long as possible. Once the maximum value has been extracted, the resources are then recovered and reused, remanufactured, or recycled to create new products. Society's needs for things such as food, housing, transportation and energy, can be met without the production of waste.

Steel is fundamental to the circular economy. Not only can steel products be reused and remanufactured, steel is also a permanent material which can be recycled over and over again without losing its properties.

World Steel Association

Globally, steel containers, cans, automobiles, appliances and construction materials contribute the major chunk of recycled materials. Steel doesn't lose its inherent physical properties during recycling process. The recycling process drastically reduces the energy, additives & fluxes requirement compared to its production from iron ore. Basic Oxygen Furnace (BOF) steelmaking also uses approximately 15-20% recycled steel but the same is mainly "home scrap" generated during processing of crude steel into the finished products. EAF/If route supported by downstream refining process consumes most of the scrap in addition to DRI. The Quality of steelmaking through EAF/IF route depends on quality and quantity of recycled steel and DRI and may steel may contain slightly higher residual elements, depending on the scrap used. But now a days, large technological advances have been made and almost similar quality of steel as of BOF is produced by EAF/IF route also. Thus, the steel produces by EAF/IF route is being widely accepted in various applications, such as automobile & engineering industry, structural, beams, rebars and other products.

Iron & steel making processes generate slag, quantity of which depends upon the input raw material quality and process requirements. Based on production data of crude steel and pig iron, it is observed that in 2017-18, nearly 27 million ton of BF slag, 8 million Tons of BOF slag, 2.5 million tons of EAF slag and around 1-1.5 million tons of IF slag was generated. Blast Furnace slag is predominantly utilized in the cement making and more than 85% of the same is being used. There are some plants which are not having easy access to the cement plants and thus finding it difficult to make 100% utilization of the same. But, looking into the availability of limestone and trend to replace more limestone with BF slag, most of the slags will find effective uses as an alternate raw material for cement industry. The same is not applicable for the steel

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slag whether produced by BoF/LD route or EAF/ IF route. Although, some quantity is being used in road construction but majority is used in land filling / dumped in the plant and thus not finding much economical usages. In order to achieve a sustainable steel production, it is essential that higher volume of steel slag, to be generated with increasing steel production in the country, is beneficially utilized and fully consumed in an environmentally friendly manner. Sustainable use of slag shall contribute to the conservation of natural resource and reduction in CO2 emission besides ecological advantage due to less storage requirement. The need for saving natural resources and energy makes it essential to enhance reuse of steel slag in various by-products form. Extensive researches are being made globally and new techniques / applications are getting developed for effective utilization of steel slag and turning the same into valuable products. Globally, Steel slag is used in multiple ways e.g. as a raw material for cement manufacture, a road base course material, concrete, soil amelioration in agriculture etc. However, in India, the importance of steel slag utilization is yet to be fully realized and implemented.

Achieving full potential of Resource Efficiency in steel sector w.r.t steel scrap processing and slag utilization in India would require significant innovation efforts ranging from the adoption of latest technology and equipment, logistic support, new business models etc. This cannot be achieved by incremental evolution within the existing systems. It will require rather holistic and possibly radical change of the existing production and consumption systems. To support the transition to a Resource Efficiency w.r.t. steel scrap processing and steel slag utilization, a coherent policy framework and major policy innovation will be needed which can address all technical and non-technical issues including financing, capacity building, supply chain management etc.

This strategy paper highlights the steel scrap and steel slag scenario in India. Recommendations have been made to implement the measures required to make scrap recycling and slag utilization a sustainable, energy efficient and environment process and to set parameters for sustainable and resource efficient growth of steel sector as recognised in Steel Policy.

2.0 Steel Demand & Supply Scenario

2.1 Global Demand and Supply

Steel is a critical industry worldwide, and steel products are a heavily traded commodity. In recent years, market changes, shifts in import and export levels, and weakness in the global demand for steel have negatively impacted steel industries across the world. Along with shifting trade patterns, world benchmark steel prices were trending downward. Although, steel industry had faced major challenges from 2011 to 2014 due to multiple reasons, 2015 was also a period of decline for the steel industry, as weak global demand caused declines in other indicators. The positive sign of improvement started towards late 2015 and still continuing.

During 2017-18, the global steel consumption registered a growth of 2.8%, driven by strong demand from China. Going forward, 2018 may witness a relatively muted growth of 1.6% y-o-y due to slower demand projection in China. The global crude steel production during 2017-18 registered a 5.3% growth to 1691 MT, out of which China's contribution has been 832 MT[3]. India remains one of the fastest growing markets, with crude steel production rising 6.2% y-o-y, reaching 103 MT and propelling India to the third largest steel producer in the world. Steel production in European Union (EU) and North America registered a growth of 4.8% and 4.1% respectively. The crude steel production and consumption data is the last 10 years is shown in Table 2.1 which clearly shows that although there is not much increase in average per capita consumption globally but the production has increased considerably from 1330 million tons in 2007 to 1689 million tons in 2017, mainly due to increase consumption in the developing countries.

Year	Production (Million Tons)	Consumption (Million Tons)	Per Capita Consumption (Kg.)
2007	1348.108	1330.937	202.2
2008	1343.429	1336.598	200.6
2009	1238.755	1233.734	182.9
2010	1433.433	1409.997	206.5
2011	1538.003	1414.000	204.6
2012	1560.131	1442.000	206.2
2013	1650.354	1541.500	217.9
2014	1669.450	1545.800	216.0
2015	1620.001	1500.700	207.3
2016	1627.004	1516.000	207.1
2017	1689.000	1587.400	214.5

Table 2.1: World Crude Steel Production vs. Consumption[3]

The combination of weaker Chinese demand and large gap between current production and available capacity may lead to higher exports from China during 2018 and beyond. As per the 13th Five Year Plan for its steel industry released by the Chinese government, by 2020, the government expects apparent demand in China to decline to 650-700 MT vs production of 750-800 MT. This suggests the government expects steel exports to remain flat at current levels of about 100 MTPA.

3 World Steel Association

Demand in Japan, South Korea, EU, USA is expected to remain stable in the near future. Thus, there may not be much increased in steel consumption in these countries and the demand may grow only from the developing countries.

2.2 India's Future Demand

The past three years have been challenging for the domestic steel industry on account of a global supply glut. During this period, global prices declined by approximately 35%. Imports of finished steel in 2014-15 increased by 71% and another 26% in 2015-16 y-o-y. The sector also saw significant financial stress, with NPAs amounting to 37% of loan outstanding as on March 2016.

In spite of all constraints, steel production and consumption continued to grow and per capita consumption has increased from 47 Kg in 2007 to in excess of 65 Kg in 2017 as shown below in Table 2.2. Overall economic growth, and more specifically accelerated spend infrastructure sector including roads, railways and ship building, anticipated growth in defence sector and the automobile sector are expected to create significant demand for steel in the country. In addition to this, favourable demographics, improvement various socio-economic indicators, increasing penetration of steel rural areas, and increased usage of steel in bridges, crash barriers are also expected to contribute positively to steel demand. The focus on the Make in India initiative is overall expected to give a fresh boost to steel consumption.

India's steel production grew 6.2% y-o-y to 101 MT in 2017 in line with the ongoing expansion in steel making capacities and ramping of production by steel majors such as, SAIL, TATA Steel and JSW. This led to India becoming the second largest steel producer in the world in the first quarter of 2018, surpassing Japan. During 2017, steel consumption grew by around 5.2%.

Year	Production (Million Tons)	Consumption (Million Tons)	Per Capita Consumption (Kg)
2007	53.468	55.491	47.0
2008	57.791	56.209	47.0
2009	63.527	64.360	53.0
2010	68.976	69.082	56.1*
2011	73.471	69.80	56.00
2012	77.264	72.40	57.3
2013	81.299	73.70	57.6
2014	87.292	75.9	58.7
2015	89.026	80.20	61.3
2016	95.477	83.60	63.2
2017	101.0	87.20	65.2

Table 2.2: India Crude Steel Production vs. Consumption

As a result of the above, the steel consumption is likely to grow by an average of 6.3% and reach 140 MT by 2023. This will lead to an increase in per capita consumption of steel from 65 kg in 2017 to approximately 97 kg by 2023 and finally around 160 Kg by 2030.

Alloy / Stainless Steel Demand in India

The production capacity available with stainless steel (SS) industry is close to 4 million TPA. The production process adopted are primarily through EAF-AOD-VD/VOD and IF (Induction Furnace)-AOD-VD/VOD routes, share roughly being 50 % each. Feed materials used is entirely SS scrap for IF route. In the case of EAF-AOD-VD/VOD route, MS scrap along with Fe-Cr, nickel etc., or SS scrap or both in combination are used.

The domestic production and consumption of SS during 2009-10 and 2013-14 are shown in Table- 2.3. The domestic production increased from 2.4 MT in 2009-10 to 2.9 MT in 2013-14. The consumption of SS during this period increased from 2.5 MT to 3.1 MT. In 2017-18, Stainless steel production in the country touched 3.6 MT, registering an annual growth rate of around 10 per cent. Going by India's GDP growth rate, and the fact that our per capita consumption of stainless steel is 2 kg as against the world average of 6 kg, it is evident that stainless steel has ample scope for growth.

Stainless steel is increasingly being consumed to produce clean energy. Desalination, which will pave the way through future water crises, is based on stainless steel. Flue-gas desulfurization, or FGD, a process that removes sulfur dioxide from exhausts, is also impossible without stainless steel due to requirement of corrosion resistance and longer life. Stainless Steel is also gaining ground in nuclear power, railway, infrastructure etc. It is expected that the demand may be doubled by 2030.

Year	Production	Consumption	Import
2009-10	2.4	2.5	0.1
2013-14	2.9	3.1	0.2

Table 2.3: Stainless Steel Production and Consumption in India

Alloy and special steels, in particular, are strategic materials needed in smaller quantities essentially for intricate and sophisticated applications where improved mechanical properties, high strength characteristics, high resistance to heat, wear and corrosion, excellent surface finish are called for. The demand for alloy steel is mainly arising from strategic sector like Oil & gas besides automobile and transport. The present demand of around 5 million tonnes is also likely to be doubled by 2030. Thus, the overall requirement of stainless and alloy steel may be between 12-14 million Tons by 2030.

3.0 Steel Manufacturing

3.1 Steel Manufacturing Alternatives

Steelmaking can be classified under two heads, namely, BF-BOF (Blast Furnace – Basic Oxygen Furnace) route and Electric / Induction Furnace route. Iron Ore is is used as primary source of raw material in BF-BOF route where as in EAF/IF route the raw materials are Steel scrap, Sponge Iron and to some extent Pig Iron. The installed capacity and production from different route in 2017-18 in million tons was as follows[4]:

Route	Installed Capacity, MT	Production, MT
Iron/ DRI		
BF	80.556	73.744
DRI	49.617	30.511
Crude Steel		
BOF	55.267	47.489
EAF	40.242	26.421
IF	42.466	29.221

The production of crude steel from BF-BOF route contributes around 45 % of India's steelmaking capacity while the remaining 55 % is processed through the electric route. India is also the largest producer of sponge iron with the installed capacity of around 49 MT but the utilization is quite low, which is also a feed material for the electric route of steelmaking, in addition to scrap.

BF-BOF remains the main route in countries where the required raw materials are available. Production of high-end flat products (for automotive, Oil & Gas, Lifting & Excavation segments etc.) is more convenient through this route. Historically, as countries have matured, share of EAF has increased, due to environmental concerns. As the demand of steel is increasing continuously in India, it is expected that EAF contribution shall remain in the same ratio but the installed capacity shall increase considerably.

3.2 Major Indian Steel Producers

Broadly there are two types of producers in India, namely, major steel producers and MSME (secondary/ mini) steel producers. Integrated/ major steel plants have facilities to convert iron ore into hot metal and further process the hot metal into steel. The liquid steel is cast into slabs, billets and blooms and these are further processed into finished products such as hot rolled coil, cold rolled coil, structural, wire rods, rails, bars etc. Currently the major integrated steel players in India include SAIL, Tata Steel, JSW, RINL, JSPL, Essar Steel, Bhushan Steel Ltd (recently taken over by Tata steel)., Bhushan Steel & Power Ltd. etc. The capacity of each plant of major players is in excess of 1 million and at several location it is having unto 12 million tons at single location.

Secondary (MSME) steel producers use scrap or sponge iron/direct reduced iron (DRI) or hot briquetted iron (HBI). This sector comprises mainly electric arc furnaces (EAF) and induction furnaces (IF) units, apart from steel processing units such as hot rolling, cold rolling and rerolling units. Sponge iron and merchant pig iron producers are also included in the secondary (MSME) steel producer category. There are approximately

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313 sponge iron producers, 42EAFs, 1126IFs, and around 1157 small and medium sized steel rerolling mills (SRRMs) scattered over the country. They are usually found in clusters, with each cluster having about 50-400 units. Collectively, the MSME steel sector produces around 30MT of finished steel, which is close to 34% of India's steel production. It has been estimated that the sector employs directly and indirectly, around 400,000 people. A general overview of Steel making in India is shown in Figure 1.

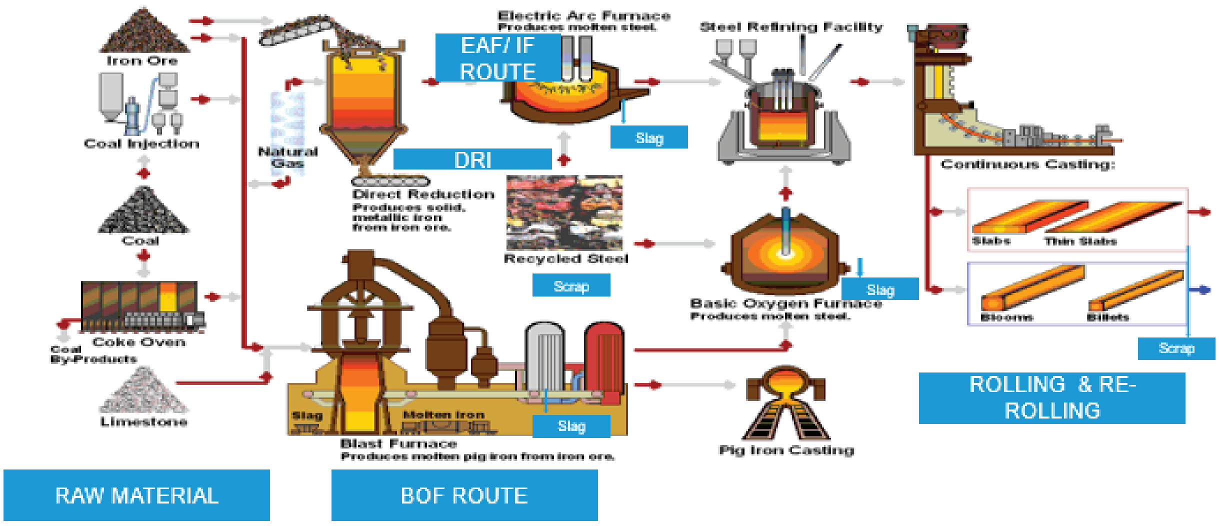


Figure 1: Overview of Steel Making in India

3.3 Steel Production Processes

Blast Furnace (BF)–Basic Oxygen Furnace (BOF):

Most of the major steel producers operate through the BF-BOF route. Blast furnaces convert iron ore into hot metal (when further processed in liquid stage to steel) or pig iron (when solidified). The fuel used in the BF is coke, which has a dual role: it provides the required thermal energy and also acts as a reducer. Product of BF contains high amount of carbon, silicon and other impurities. The hot metal from BF is transferred into a BOF vessel where its carbon, silicon and other impurities are oxidized or removed through slag separation. Main inputs in BF are iron ore, sinter/pellet and coke. Further, natural gas can be injected as a supplement fuel in BF operation, to reduce the consumption of coke. It reduces NOx, SOx and CO_2 emissions and improves productivity of BF.

BOF normally uses oxygen in the process along with lime, limestone and dolomite. The liquid steel produced is further refined (called secondary refining), if required, and cast into ingots, slabs, blooms or billets.

Continuous casting, introduced in Indian integrated steel plants in early 80s, has gradually replaced traditional ingot casting route, and today almost 90% of the steel is continuously cast into slabs/ blooms/ billets, leading to significant savings in cost and energy.

Electric Arc Furnace:

Industrial EAFs vary in size from small units of 4-5-ton capacity used to as large as furnaces of 250-ton capacity. Some of the producer's hve modified their furnaces to a new design called New Oxygen Electric Arc Furnaces, where advantage of oxygen lancing is utilized to increase the productivity and reduce the energy consumption. The power required to melt a ton of steel in EAF is approximately 440 KWh. The furnace can be operated with 100% scrap as input metal along with lime and dolomite, which are slag formers. This greatly reduces the energy required to make steel when compared with primary steelmaking using iron ore. EAFs are extremely flexible and if required hot metal from BF or direct reduced iron can be used as furnace feed.

Induction furnace (IF):

A large tonnage of mild steel is made through IF route in India. Induction furnace works on the principle of electromagnetic induction. Initially IFs were used for melting stainless steel scrap. Since mid-eighties, these furnaces are used for mild steel production also. IF is one of the most cost-effective technique but the process lack in refining the steel. Thus, most of the players uses downstream facilities like Ladle Refining Furnace (LRF) to get the desired chemical composition.

3.4 Alternate Technologies

The following steel making options are also available and being used globally, including India mainly to reduce the impact on environment and carbon footprint. Although, such process is cleaner way of producing steel and uses Iron Ore as main raw materials, but non-availability of natural gas/ alternate gas has impeded the growth of such technologies.

Corex:

This is a relatively new process developed by South Korea for production of hot metal using iron ore/pellets and non-coking coal. The process differs from the conventional blast furnace route. Here, low grade coal can be directly used for ore reduction and melting, eliminating the need for coke making units. The use of lump ore or pellets also eliminates the need of sinter plants. The operation is carried out in two reactors, namely, the reduction shaft and the melter-gasifier.

The first two Corex plants were introduced at JSW in 1999 and 2001 respectively and are operating successfully since then. Later in 2011, two more Corex plants were relocated from Korea to Essar Steel, Hazira. This plant is facing problem due to non-availability of natural gas based on which the plant was designed.

Direct Reduced Iron (DRI):

The DRI process of producing steel is intrinsically more energy efficient than BF route because it operates at lower temperature. The DRI units are either coal based or gas based. The energy efficiency of coal-based plants is lower than gas-based plants and the emission level is significantly higher. Currently, India produces approximately 60% of steel through scrap and DRI, which help in reducing emission level compared to BF-BOF route. Natural gas is utilized as reductant in gas based DRI plants.

The main product of BOF/EAF /IF are steel but during production several by-products (or waste) and flue gases are also produced. The flue gases are properly treated for recovery of heat energy and thus the same is not covered in this strategic resource efficiency document. However, other by-product viz Slag (excluding by-product of coke making plants) has been covered separately in this document in Chapter 5.0.

It is expected that the stringent environmental requirement and continuous pressure on reduction of CO2 emission to avert climate change may lead to development of cleaner technologies in time to come. However, based on the present projections, it is expected that the share of EAF shall increase considerably as can be seen from Figure 2.0 below:

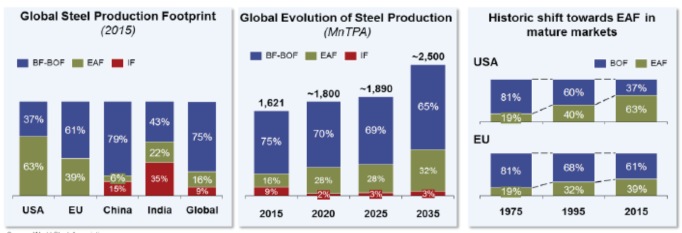


Figure 2: Global evolution of steel-making route[5]

5 Source: Tata steel

4.0 Steel Scrap & Life Cycle

4.1 Scrap Definition & Classification

India's steel production touched nearly 100 Million Tonnes mark in 2017 with major contribution from Secondary Sector. Steel is a material most conducive for circular economy as it can be used, reused and recycled infinitely. Steel produced today is scrap for tomorrow and thus again becomes a resource. Steel scrap comes from several different sources and it varies both in respect of physical and chemical properties. The age of a scrap consignment can vary from one day to over 100 years old. The properties depend on where the scrap comes from and when it was produced. Different grades of steel are produced for variety of applications. It therefore becomes essential that the scrap is segregated generally by composition and size or grade suitable for melting, in order for the recycling process to be as effective as possible.

Depending on its origin of generation, steel scrap is classified in to three main categories

(i) Home/In-house scrap,

(ii) New scrap, or prompt scrap, and

(iii) Old scrap or obsolete/end of life cycle scrap.

Home/In-house scrap is the internally generated scrap during the manufacturing of steel products in the steel plants. This form of scrap rarely leaves the steel plant production area. Instead, it is returned to the steelmaking furnace on site and melted again. This scrap has known physical properties and chemical composition. Technological advancements have significantly reduced the generation of home scrap. The generation of home scrap in various plants in the country from 2009 -13-14 is shown in table 4.1 and consumption in the same period in Table 4.2.

'000 tonnes

Name of the Company	2009-10	2010-11	2011-12	2012-13	2013-14
SAIL	1200	1210	1140	1140	1260
Tata Steel	400	410	440	550	610
RINL	230	230	230	210	245
Essar Steel	450	450	490	505	410
JSW	690	830	870	980	1150
JSPL	125	125	240	230	175
BSPL	30	35	40	50	65
Bhushan Steel Ltd.	20	70	65	70	70
Total	**2845**	**3360**	**3515**	**3700**	**3985**

Table 4.1: Year-wise Generation of Home Scrap by ISPs: 2009-10 to 2013-14.

'000 tonnes

Name of the Company	2009-10	2010-11	2011-12	2012-13	2013-14
SAIL	1000	1010	950	950	1010
Tata Steel	400	410	440	550	610
RINL	230	230	230	210	245
Essar Steel	450	450	490	505	410
JSW	690	830	870	980	1150
JSPL	125	125	240	230	175
BSPL	30	35	40	50	65
Bhushan Steel Ltd.	20	70	65	70	70
Total	**2645**	**3160**	**3325**	**3510**	**3735**

Source : JPC Report – Indian Scrap Market, 2015

Table 4.2: Year-wise Consumption of Steel Scrap by ISPs during 2009-10 to 2013-14.

New scrap (also called **prompt** or **industrial scrap**) is generated from manufacturing units which are involved in the fabricating and making of steel products, such as forming of auto components, white goods, machining, tool and equipment manufacture. Scrap accumulates when steel is cut, drawn, extruded, or machined. It is usually transported quickly back to steel plants for re-melting. The supply of new scrap is a function of industrial activity. When activity is high, more quantity of new scrap is generated. The chemical composition and physical characteristics of new scrap is well known. This scrap is typically clean, meaning that it is not mixed with other materials.

Old scrap, also known as **obsolete scrap,** is the steel that has been discarded when steel products (e.g. automobiles, appliances, machinery, buildings, bridges, ships, cans, railway coaches and wagons etc.) have served their useful life. Old machinery and equipment are auctioned by railways, defence, port authorities etc. The first option of buyers of such equipment and machineries are to recondition them and sell at higher price. The second option is to dismantle them and sell as spare parts for maintenance of equipment in use. The third and last option is selling as metal scrap. Similarly, old vehicles need to be scrapped after completion of its service life. However, in India, after serving the life in large cities, such vehicles are usually relocated to Tier–II and Tier-III cities and small towns where demand for such vehicles exists. Presently, no policy exists towards scrapping of vehicles and this needs immediate attention of Govt. of India as older the vehicles, greater is the pollution level. Old scrap is often contaminated, depending on its origin and the collection systems. Since the old scrap is the material that has been in use for years, chemical composition and physical characteristics are not usually well known. It is also often mixed with other trash. Due to these reasons, old scrap is not easy to recycle. It requires cleaning, sorting, removal of coatings, and other preparation like pressing, crushing, shearing, shredding etc. Prior to use. Obsolete scrap may contain radiation source with associated environmental and health risks. These low intensity radioactive sources may trickle into scrap from wastes disposed by research laboratories, scientific gauges, industries, hospitals etc. Although, adequate safeguards have been made at port handling imported scrap to ensure detection of radioactive material in imported ferrous scrap but the similar measures shall be required for the scrap processing industry also.

4.2 ITC/HSIC Code Classification

Steel scrap is covered in ITC/HS {Indian Trade Clarification (ITC) based on Harmonized System (HS) of Coding} Code 7204. It was adopted in India for import-export operations. There are no internationally accepted standards for Scrap but some guidelines issued by the following agencies are used globally.

- Bureau of International recycling (BIR)
- EU 27 Steel Scrap Specifications- Shredded E40
- Institute of Scrap recycling Industries, Inc (ISRI) specifications
- Japan ferrous Raw Material Association

4.3 Global Steel Scrap Scenario

> Global ferrous scrap availability stood at about 750 million tons in 2017, out of which 630 million tons were recycled by the steel and foundry casting industries. As per estimates of WSA, global ferrous scrap availability is expected to reach 1 billion tons in 2030 and 1.3 billion tons in 2050, growing more than 500 million tons within the next 30 years

After more than a decade of consistent growth, global demand for steel scrap started declining in 2014. This was due to both the slowdown in overall steel demand and a drop in the global production share of the EAF route – the primary destination for scrap in steelmaking. While steel production grew 4.3 percent per year since 2000, scrap annual growth has averaged 3.1 percent. The slower global growth of steel scrap was also due to a large extent to China's rising share of the global steelmaking sector. In 2000, China accounted for 15 percent of global crude steel production, while in 2017 it represented almost 50 percent. Over the past two decades, China has dominated both steel demand and production. As a developing economy, it has limited domestic supply of obsolete scrap. Additionally, with most of the installed assets using BOF technology, China has largely relied on primary raw materials – namely iron ore and coking coal. As the country's share of global steel production grew, its low dependence on scrap pushed down scrap's overall share in global steel production from 40 percent in 2000 to 34 percent in 2015.

It is expected that the share of EAF will increase over the next 20 years due to China's large-scale adoption of the EAF-route, consequent to closure of its obsolete plants owing to poor quality and environmental considerations.

Based on the world steel recycling in figures 2012-2016 report, the scrap / crude steel production ratio in 2015 is as given in the following Table 4.3:

Country	Scrap Consumption in 2015 MT	Steel Scrap / Crude Steel Production in 2015 %
Turkey	24.0	76.4
Korea	30.0	42.9
Japan	33.5	31.9
USA	56.5	71.7
China	83.3	10.4
EU-27	91.0	54.5
India	33.5	37.5
Rest of the world	203.2	73.5
Total	**555.0**	

Table 4.3: Scrap / Crude Steel Production Ratio in 2015

Global ferrous scrap availability stood at about 750 million tons in 2017, out of which 630 million tons were recycled by the steel and foundry casting industries. As per estimates of WSA, global ferrous scrap availability is expected to reach 1 billion tons in 2030 and 1.3 billion tons in 2050, growing more than 500 million tons within the next 30 years.

Current global ferrous scrap consumption is ~580 MTPA with EU, China, USA and Japan driving half of the world scrap consumption. Scrap consumption in China has increased to ~19% in 2017.

Scrap consumption is also driven by the price differential between scrap and the hot metal. Scrap prices tend to correlate closely with the prices of iron ore and coking coal used {to produce hot metal (pig iron)} as scrap is essentially a substitute for them. Steelmakers make trade-offs based on these inputs' relative prices.

In US, around 65% of its steel production is through recycled scrap. In Europe, more than 90% of used steel products are recycled to produce new steel. About 40% of crude steel within EU27 is produced by the scrap + EAF route. There is a potential to increase gradually this rate up to 50% in the next 20 years due to larger available quantities and better control of scrap qualities. Scrap usage in Vietnam is also increasing. In first three months of 2018, Vietnam imported 1.31 million tons of scrap, up 68.7% year on year basis. It imported a total of 4.74 million tons of ferrous scrap in 2017, up 21.5% from 3.9 million tons a year earlier.

4.4 Indian Scenario

Scrap is the main raw material for the MSME (Secondary/Mini) steel sector in India. The steel production through the secondary route is expected to increase substantially, driven by growing demand of steel resulting in increase of per capita steel consumption. The Projected demand –supply gap of steel scrap up to 2022 is given in Table 4.4 below.

(Thousand Tonnes)

Year	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22
	(Actual)	(P)	(P)	(P)	(P)	(P)	(P)	(P)	(P)
A. Projected Demand									
ISPs	3,735	3,996	4,276	4,576	4,896	5,239	5,605	5,998	6,417
EAF Units	856	899	944	991	1,040	1,092	1,147	1,204	1,265
IF Units	13,994	15,184	16,474	17,874	19,394	21,042	22,831	24,772	26,877
Secondary Re-rollers (Long Products)	1,945	2,052	2,165	2,284	2,410	2,543	2,682	2,830	2,986
Iron & Steel Foundries	8,341	8,841	9,372	9,934	10,530	11,162	11,832	12,541	13,294
SS Industry	2,828	2,997	3,177	3,368	3,570	3,784	4,011	4,252	4,507
Total Demand	**31,699**	**33,969**	**36,408**	**39,027**	**41,840**	**44,862**	**48,108**	**51,597**	**55,346**
B. Projected Availability									
Home Scrap	10,047	10,733	11,469	12,259	12,858	13,769	14,748	15,801	16,932
New Scrap	8,759	9,423	10,143	10,924	11,772	12,694	13,697	14,788	15,976
Old Scrap	8,054	8,577	9,134	9,727	10,359	11,033	11,749	12,513	13,326
Total Availability	**26,860**	**28,733**	**30,746**	**32,910**	**34,989**	**37,496**	**40,194**	**43,102**	**46,234**
C. Demand Availability Gap (A-B)	**4,839**	**5,236**	**5,662**	**6,117**	**6,851**	**7,366**	**7,914**	**8,495**	**9,112**

Table 4.4 : Projected Demand Availability Gap of Steel Scrap 2013-14 to 2021-22

It may be seen that the gap between steel scrap demand and availability is likely to increase from about 5 MT presently to about 9 MT by 2021-22. During this period, the total availability will rise from ~27 MT to ~46 MT as shown in Figure 3. It shows that the projected trend of domestic demand of steel scrap till 2030 is likely to increase at the rate of 4-6% whereas the availability may grow at a rate of 6-8% and thus the import may continue to reduce.

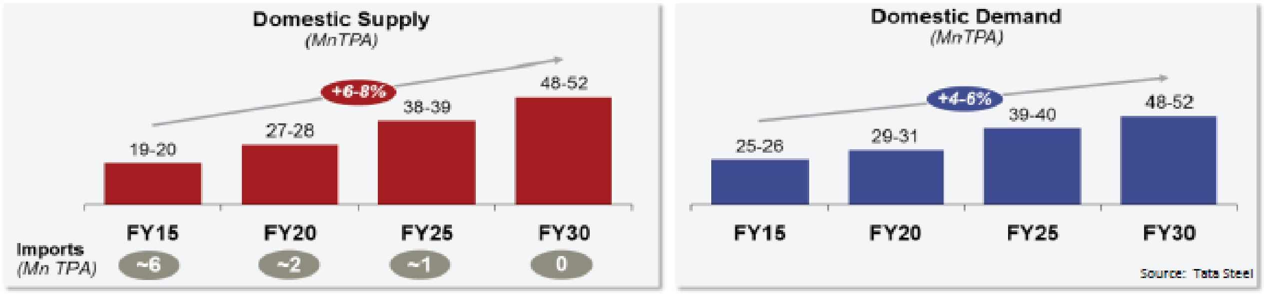


Figure 3: Indian Demand & Supply Evolution for Ferrous Scrap

4.5 Sorting and Preparation of Steel Scrap

Steel scrap recycling shall be the main driver of circular economy in the steel sector in future as large quantity of steel scrap is going to be generated due to upgradation/ renovation/ demolition of old structures, buildings etc. There is need of strategic planning and evaluating risks associated so that the recycling industry can be established in an environmental friendly and sustainable mode. The cycle envisaged for circular economy in steel sector is depicted in Figure 4.

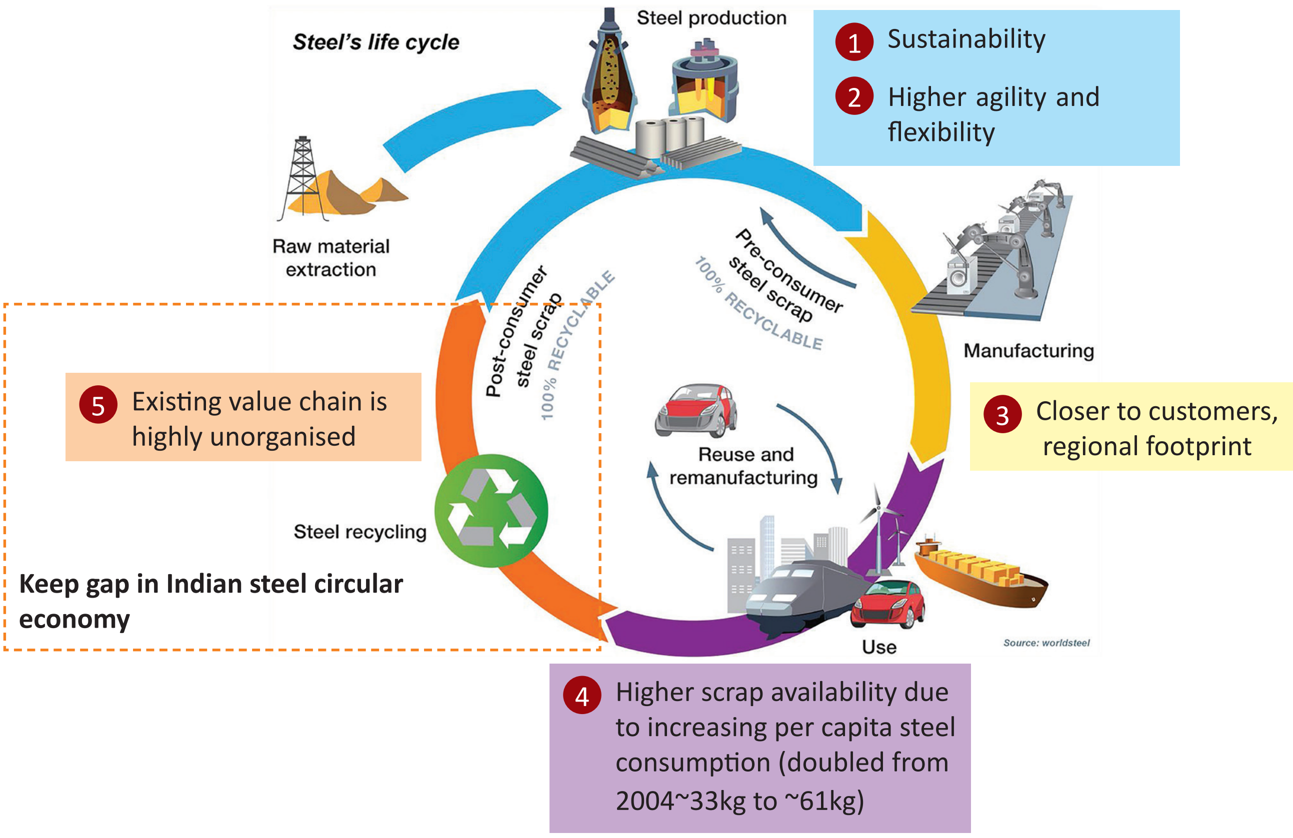


Figure 4: Circular Economy for Steel

It shows the circular economic cycle right from raw material i.e mining, steel production and utilization , scrap generation, and finally recycling of these finished products back to steel manufacturing after its life cycle.

The steps involved in managing and transporting scrap efficiently before actual melting are referred to as Scrap Processing. The large number of sources and forms of steel scrap requires the use of numerous scrap sorting and preparation processes to remove the contaminants and/or recover other valuable materials (i.e. non-ferrous metals) and sizing/compacting prior to entering the steelmaking process.

Home scrap hardly need any preparation except that the larger pieces of the scrap may have to be cut to make the size suitable for its charging in the steelmaking furnace. Same is also true for substantial quantity of the new scrap. However, some of the new scrap may need processing. The methodology to be adopted for collecting and processing in an organized manner is shown in Figure 5.

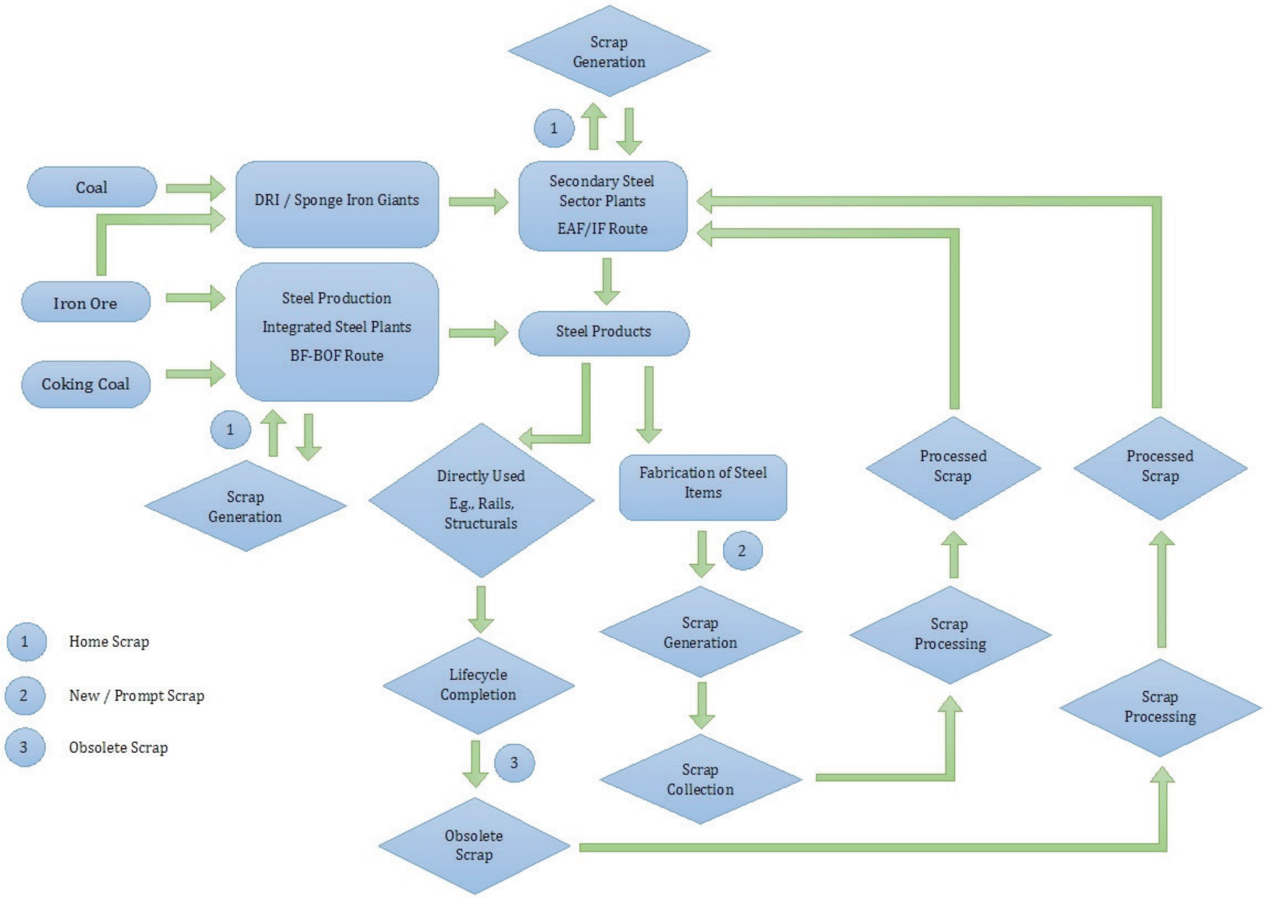


Figure 5: Flowchart of Scrap Recycling Methodology

Large items such as ships, automobiles, appliances, railway coaches and wagons, structural steel etc. need to be cut to allow them to be charged into the steelmaking furnace. This can be done using shears, hand-held cutting torches, crushers or shredders. Manual sorting is done for removal of undesirable components from the scrap by hand. It is most suitable when miscellaneous attachments are to be removed from the scrap (i.e. radiators from scrapped automobiles, plastic and tanks from radiators etc.). The separation of metallic from non-metallic is also often accomplished manually.

Scrap processing normally involves following processes – Baling, Shearing, Shredding and Briquetting. Baling means compacting large volume of scrap into denser form in the form of bales which becomes easy to handle, store and transport. Shearing machines are used to shear or cut metal scrap which is large or bulky in size, to make the scrap ready for directly feeding the furnaces or to remove any unwanted fittings or other parts from the scrap metal not accepted by the shredder. Shredding means tearing and fragmenting huge volume of scrap into smaller portions. Briquetting is used for scrap metal which is in the form of small chips or turnings. A briquetting machine extracts extra fluid from the scrap and converts them into briquettes which can be then easily transported and fed in the melting unit.

Magnetic separation is used when a large quantity of ferrous scrap is to be separated from other materials. Eddy current separation process is used sometime to separate non-ferrous metals. The process generally follows the primary magnetic separation process, and it exploits the electrical conductivity of non-magnetic metals.

Several steel products are being used with coating of other metal on them, e.g. galvanized sheets, tin plate etc. Steel scrap generated from such coated products is stripped of the coating material before it is processed in the steelmaking furnaces. There are currently a number of processes used in industry for de-coating of the steel scrap viz., dezincing, detinning, de-copperization (later not very common).

Incineration process is sometime used for the removal of the combustible materials including oil, grease, paints, lubricants and adhesives. There shall be a need to develop some Integrated Waste management approach to see that none of the residue after scrap processing is left out and all other wastes like non-ferrous, plastic, oil, electronic etc are being processed as per relevant rules, guidelines and policy issued by the concerned ministries/ department.

4.6 Justification/Rationale for Steel Recycling

India is poised to become the second largest steel producer in 2018 – 19. It has plans to increase its steelmaking capacity to 300MT by 2030. As India moves from developing economy towards developed economy, it will witness a steady increase in availability of obsolete scrap from products completing their end of life cycle in various industries and sectors. Similar to China, the availability of scrap in India will also see a sharp increase primarily from "obsolete scrap". Concurrently, with "Make in India" program, the country will also see a steady rise in manufacturing and increased availability of prompt scrap. This will lead to a higher growth trajectory of steel production through the EAF route as compared to the conventional BOF route. Further to meet the stringent environmental norms w.r.t energy and carbon foot print as per Paris Agreement on Climate Change, use of EAF /IF may increase over BF/BOF route.

Adopting the philosophy for maximizing scrap processing shall result help in the following:

- Adopting principle of 6R's i.e Reduce, Reuse, Recycle, Recover, Redesign and Remanufacture and thus improving global competitiveness
- Reduction in the energy intensity / ton of steel aims to fulfil commitment in COP21
- Optimum utilization of natural resources
- Focus on recovery of energy (heat, gas)
- Adoption of Energy efficient & Environmental friendly technologies
- Benchmarking of secondary / MSME and prioritization of investments
- Moving towards Zero Discharge Zero Waste and Zero Harm regime

In addition to above, making steel from scrap conserves iron ore, coal and limestone. As per the World Steel Association, the integrated steelmaking route based on the BF-BOF, uses about 1,400 kg of iron ore, 800 kg of coal, 300 kg of limestone, and 120 kg of recycled steel to produce 1,000 kg of crude steel. EAF route, on average, uses 880 kg of recycled steel combined with varying amounts of other sources (DRI/HBI, hot metal), 16 kg of coal and 64 kg of limestone, to produce 1,000 kg of crude steel. On an average, production of 1 ton of steel from scrap conserves an estimated 1,030 kg of iron ore, 580 kg of coal, and 50 kg of limestone. Steel scrap recycling also saves the energy.

Figure 6 shows the benefits of EAF route over BOF-BF route in terms of carbon emission, energy consumption and resource consumption.

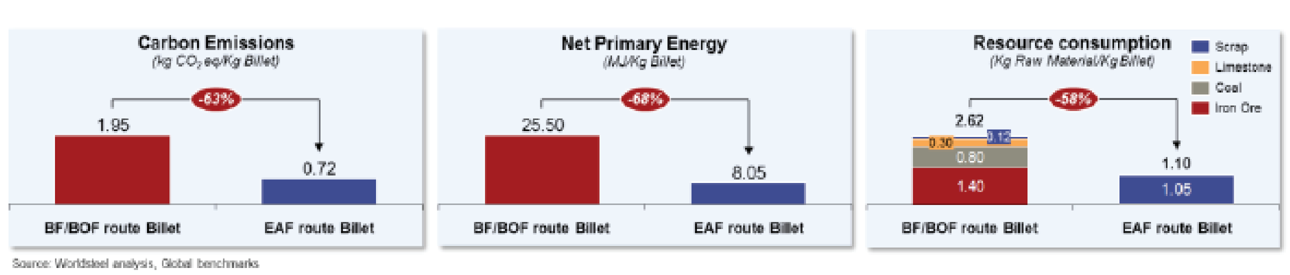


Figure 6: Comparison of BF-BOF Vs EAF routes on sustainability considerations

Steel scrap is a strategic and sought-after raw material for the steel industry. Increased consumption of scrap shall reduce the need for additional resource extraction and hence the environmental impact. However, scrap recycling need to be made more environmental friendly.

The recycling of steel enables preservation of scarce natural resources as it will require less energy to process than the manufacture of steel using virgin raw materials. Recycling emits less carbon dioxide and other harmful gases. More importantly, is economic also and allows manufacturing businesses to reduce their production cost.

4.7 Current Practice

Home scrap is normally utilized in the in-house melting units, though some of the scrap which can be rolled, is sold as re-rollable scrap to Re-rolling Mills. New scrap, generated by automobile, auto ancillary industry, white goods, household appliances, steel fabricators, construction sector, tube makers etc., is normally sold by the generating units to actual end users. Old scrap is handled through small traders, who in term depend on Kabaddis, who go door to door for collecting the scrap. Various institutions often auction the obsolete scrap which is also collected by small traders.

4.8 Need for Change

Regulations are mainly required for collection and processing of obsolete scrap, and making this sector more organized, ensuring quality, safety and environmental friendly operation of scrap handling shredding units.

4.9 Opportunities for Employment Creation

As steel scrap recycling industry grows, it will require skilled employees to carry out numerous operations of scrap recycling process. Annual potential of revenue generation in steel scrap industry is of the order of Rs. 2000 Cr / million tonne of steel scrap processed. Recycling will create a good number of jobs in the country. Currently it is largely an unorganised sector, as most of the people involved are operating independently. Larger is the industry, more chances of organized job creation. Consolidation of the industry consequently, will generate a demand for well-trained and qualified personnel, capable of executing multitask work with high efficiency.

Steel scrap recycling involves a range of activities, such as scrap collection, transportation, sorting, logistics, etc. Recycling companies will have to employ workers to deal with every of these activities separately.

Figure 7 shows the value chain created through use of steel scrap in secondary steel sector.

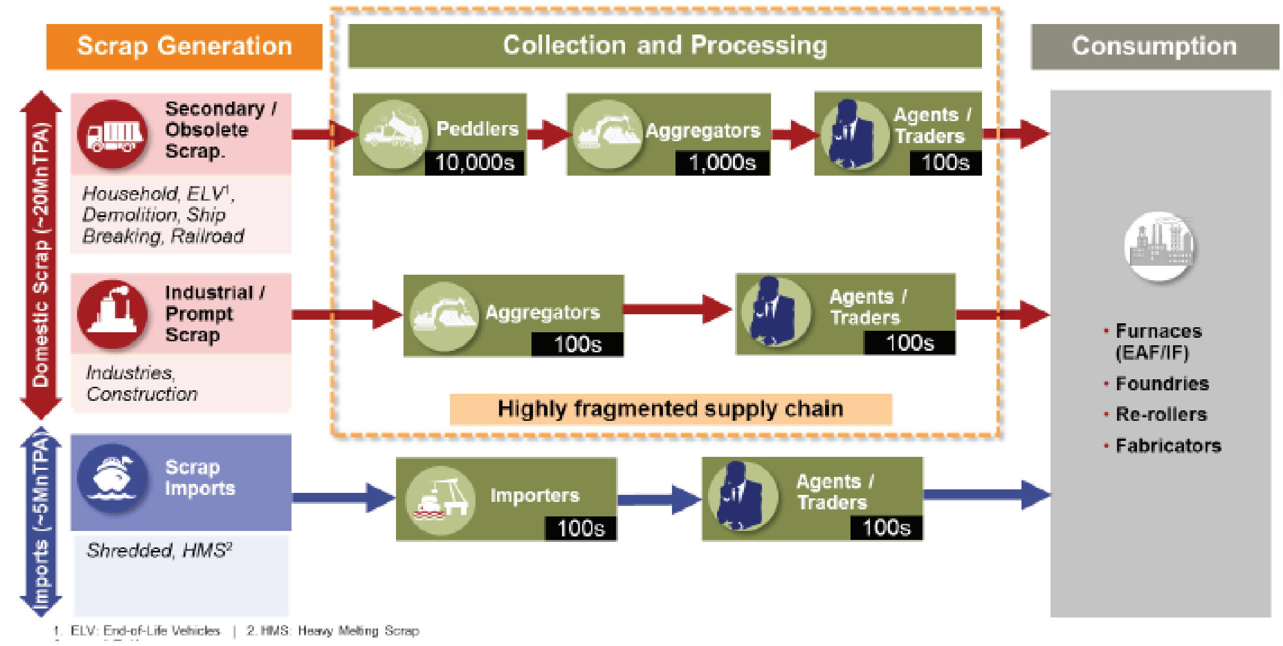


Figure 7: Current Indian scrap value chain

4.10 Training for scrap recycling jobs

Most of the jobs in scrap recycling will require hands-on experience, therefore steel scrap recycling enterprises have to provide for appropriate trainings, especially considering the jobs dealing with state-of-the-art equipment. However, small duration courses can be designed by institutes like NISST, BPNIST for imparting theoretical knowledge, quality control etc.

4.11 Independent metal scrap collectors

Alongside with scrap collection and recycling companies, independent scrap collectors can emerge as self-entrepreneur, who collect scrap by themselves and then sell it to recyclers. Government may consider issuing license for their business. They may be useful in collecting steel scrap from local scrap-dealers, cities, towns, rural areas etc. and providing to big processors.

4.12 Scrap Industry and Investment Opportunity

Steel Ministry is targeting an increase in the usage of steel scrap. A new scrap policy needs to formulated to address all the issues from local scrap collectors to processing centres including role of OEM, Government and other department / ministries. A policy to scrap vehicles which are more than 15-20 years old is also need to be framed. Auto-shredding and vehicle-recycling plants are being established. Scrap-based steel production capacity is expected to be increased. Around 30-40 million tonnes more steel is expected to be produced from scrap by 2030. Obsolete scrap from old vehicles will comprise a major chunk of the additional scrap, in view of the fact that roughly 20- 25 MT of scrap will be generated.

MSTC and Indian conglomerate Mahindra Accelo are establishing India's first vehicle shredder, with a capacity of 100,000-300,000 tpy of vehicles. It will generate the shredded-grade scrap which India currently has to import from Europe and the United States. Tata Steel is also planning to set up a scrap processing unit in Gurgaon to tap the high consumption of automobiles and white goods in the National Capital Region. These initiatives provide a good opportunity for investment in India's quest to become self-sufficient in ferrous scrap.

5.0 Recycling of Steel Slag

5.1 Slag Classification

On producing steel, other wanted and unwanted materials are produced. The main challenge is to make the unwanted by-products into wanted and economic value-added products. The unwanted materials/ elements present in the raw materials i.e Iron ore, Coke & Fluxes etc in the form of Silica, Sulphur, Phosphorous, Alumina, etc. need to be removed during the smelting and refining stages Majority of the unwanted elements are taken out the form “Slag” from Blast Furnace, Basic Oxygen Furnace (BOF) converter, Electric Arc Furnaces or Induction Furnaces. Thus, steel plant slag is a solid industrial waste generated from steel industries production of steel. Blast Furnace & Steel Slag are valuable by-products and thus must be used as a substitute of natural resources within the same legal framework as both can serve the same purpose. Substituting natural resources with by-products made out of such waste materials shall avoid duplication of energy use in the production phase and thus shall contribute in developing the green economy.

Blast Furnace & Steel Slag are valuable by-products and thus must be used as a substitute of natural resources within the same legal framework as both can serve the same purpose. Substituting natural resources with by-products avoids duplication of energy use in the production phase and contribute in developing green economy

Physio-chemical and mineralogical characteristics of steel slags are different depending upon the type of process used i.e. BF slag, LD Slag, EAF Slag or IF slag. Even though the chemical composition of steel slag imitates that of cement, the type of mineral phases and their quantities in steel slag are very different. The lack of verification property in steel slag restricts its usage in cement making. Majority of the Blast Furnace slag produced is suitable for cement industry due to high percentage of lime and other constituents beneficial for cement industry and thus are being used extensively in the cement industry. The slags produced through different routes can be classified as follows:

Blast Furnace Slag

BF slag is generated during the process of iron making in a blast furnace. When it is removed from the blast furnace, the slag is molten and is at a temperature of approximately 1,500 ^{0}C. BF slag can be cooled in different ways to form any of several types of BF slag products, as follows:

Air cooled BF slag (ACBFS): Molten BFS is allowed to flow from the blast furnace into open air pits located beside the furnaces where the material is quenched with water applied by sprays to facilitate cooling. Alternatively, molten slag is dumped in the open yard where it is allowed to cool naturally. Once sufficiently cooled, it results in a crystalline, rock-like air-cooled slag and is referred to as rock slag. ACBFS is dug and transported to a nearby crushing and screening (aggregate) plant, where it is processed into aggregates. However open-air cooling requires large areas of land. On the other hand, land availability is getting scarce day by day and pollution control board also has been impressing upon to avoid dumping of slag in open land.

Granulated Blast Furnace Slag (GBS or GBFS): In modern blast furnaces, molten slag is directly converted into fine granules in the BF shop complex itself and dumping in open yard is avoided. Granulated BFS (GBFS) can be used for manufacture of slag cement, ground granulated blast furnace slag (GGBFS) or fine aggregates for concrete making along with cement (OPC). The granulated blast furnace is dried and finely ground to produce Ground granulated Blast furnace slag (GGBFS).

Physical properties of air-cooled blast furnace slag (ACBFS) by and large matches with other natural rock materials used as coarse & fine aggregate and hence, it can be and is used as substitute to natural aggregates in all types of roads. Granulated ground BF slag is also used as substitute to natural sand for use in civil construction. In addition, BF Slag is also used in embankment, land fill etc.

LD or Steel Slag

Basic oxygen steelmaking (BOF), also known as Linz–Donawitz Steel making slag is cooled in a cooling yard by air cooling and moderate water sprinkling. However, this method requires a considerable amount of time to cool the hot slag down to a workable temperature and demands the allocation of a spacious land / yard which is also discouraged by authorities like MoEF&CC/ CPCB etc. For operational safety, a number of more efficient cooling processes have been put into practical use. They include:

- Air granulation process, whereby a high-pressure air is blown onto the molten slag to solidify and granulate the slag while it is being cooled.
- ISC (Instantaneous slag chill) process, whereby the hot slag is first poured into a steel box for accelerated cooling/solidification and then subjected to water sprinkling and immersion cooling;
- Water granulation, whereby the molten slag is poured into a special drum and cooled rapidly by sprinkling water over the slag.

5.2 Slag Generation

The Steel industry in India is producing about 24 million tonnes of blast furnace slag and 12 million tonnes of steel slag annually. It is expected that the BF slag generation may reach around 45-50 million tons and & BOF slag around 15-20 million tons per year by 2030. This can meet large requirement of cement industry as well road and agricultural need. Besides, EAF and IF slag, generation also will increase to more than 10 million tons per year from the present level of around 5 million TPY by 2030. In the past, utilization of steel slag was very low except some mixing in the sintering which has resulted in accumulation of large quantities of steel slags in every plant. It is estimated that more than 30-40 million Tons of steel slag may be lying in various steel plants. The typical slag generation and its utilization across the globe is shown in Figure 8.

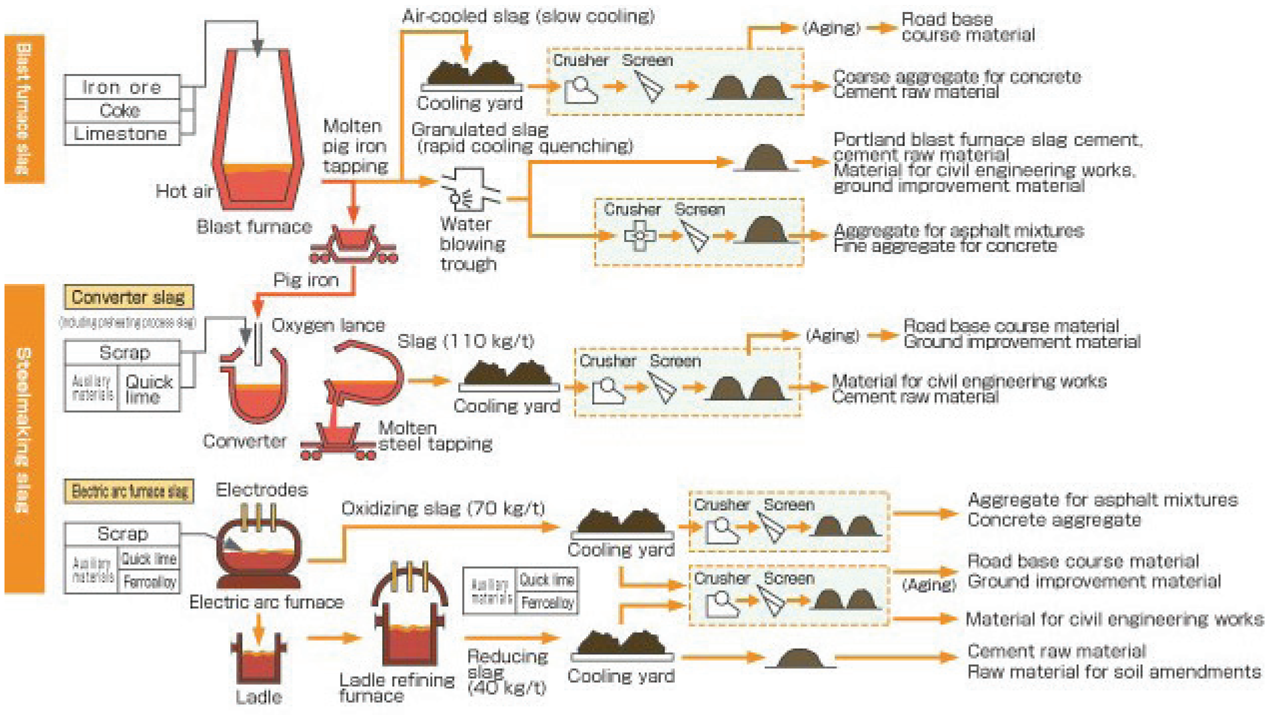


Figure 8: Typical Slag Generation and Utilisation

In addition to the slag, dust and sludge is also generated in various process, quantity of the varies from place to place depending upon the technology adopted. The average generation of slag, sludge and dust from various process route on global basis are shown in Figure 9 below:

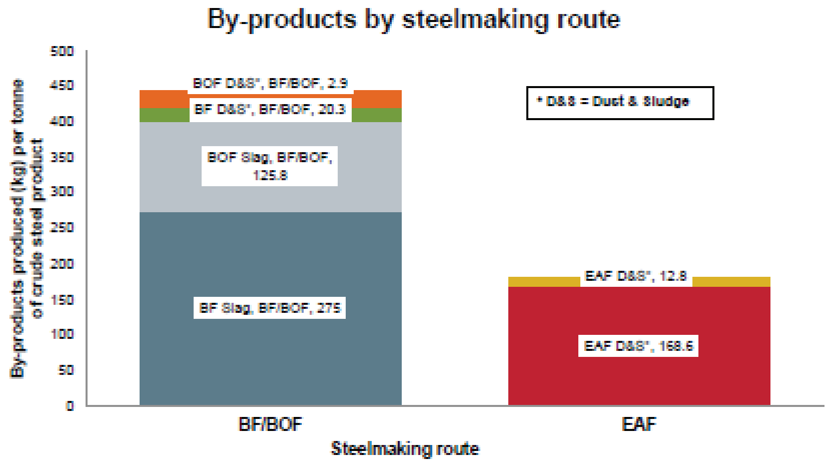
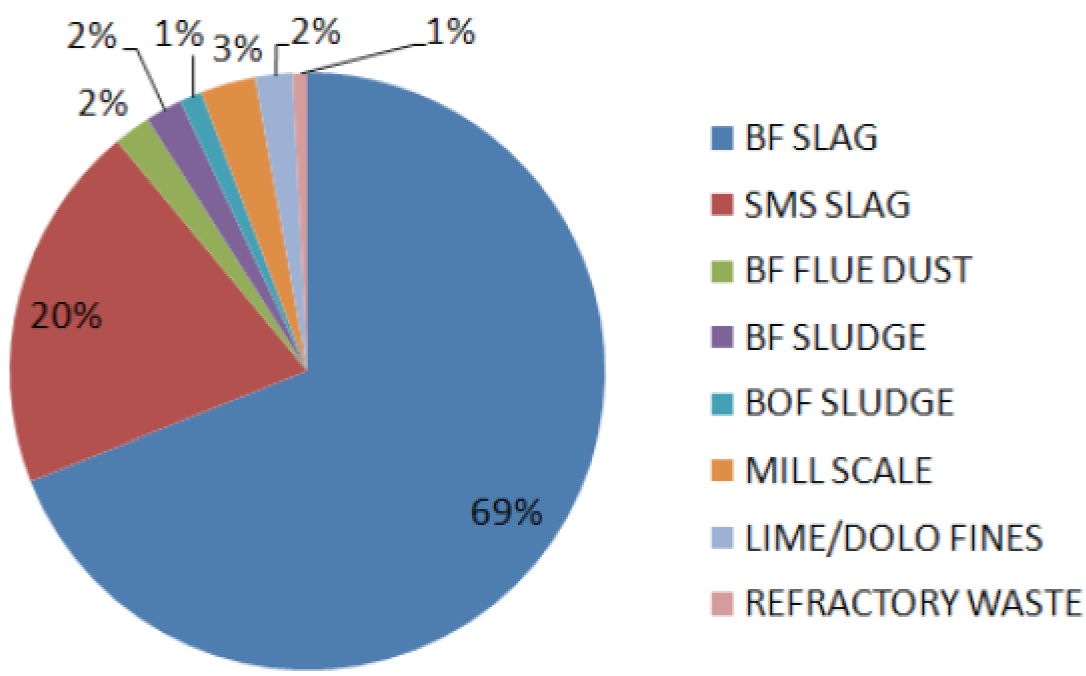


Figure 9: Steel Slag Generation-Global Scenario

Source: World Steel association

However, in India the slag, dust and sludge generation in BF & BOF route is much higher as shown in Figure 10 below:



BF Slag : 375- 400 Kg/TCS ; BOF/SMS Slag : 120-140 kg/TCS;
Dust/Sludge: 50-60 Kg/TCS

Figure 10: Steel Slag Generation in India

Most of the steel producers are taking steps to control the generation of slag and has achieved significant improvement in the past but majority of the units are yet to achieve benchmark performance.

5.3 Slag Properties and Utilization

The typical chemical analysis of BF, BOF and EAF slag is as follows:

Slag	Unit	Cao	SiO_2	MgO	MnO	Fe	Al_2O_3	P_2O_5
Blast Furnace	%	40-45	30-35	5-7	<1	<1	15-12	<1
Steel Slag (LD)	%	45-48	13-16	5-10	<5	15-17	1-3	1-3
EAF Slag	%	25-35	15-17	3-5	<1	20-25	6-4	<0.5

The composition of steel slag varies with the furnace type, steel grades and pre-treatment method. However, the main constituent remains SiO_2, CaO, Fe_2O_3, FeO, Al_2O_3, MgO, MnO and P_2O_5. In steel slag the most important mineral phases are dicalcium silicate (C2S), tricalcium silicate (C_3S), RO phase (CaO – FeO – MnO - MgO solid solution), tetra-calcium aluminoferrite (C4AF), olivine (fayalite (Fe_2SiO_4), few have kirschsteinite ($CaFeSiO_4$) compositions), merwinite and free lime.

Granulated blast furnace slag is extensively used in the manufacture of slag cement (up to 70 % addition is permitted as per IS-455). Ground granulated BFS, is used as a substitute of cement in ready mix concrete.

Different type of slags have different applications depending upon chemical analysis. Granulated blast furnace slag is a latent hydraulic material and is glassy in character. Its glass content varies from 90 to 95 percent[6]. Although, majority of the Blast Furnace Slag is fully utilized in the Cement Industry but the use of BOF steel slag and EAF slag is still a major issue. The other uses of steel slags are in Road Construction, Sand, Insulation wool, and Agriculture. The amount of LD/BoF slag generated is about 170-200kg/t of hot metal produced in Indian integrated steel plants. Out of this only 25% is being reused in India compared to 70-100% in other countries and that too also internally for road project and for sintering and iron-making through recycling.

Steelmaking slag contains metallic iron (5-10% by weight), which is derived from the refining process. Therefore, the slag is adjusted to the customer-specified grain size through a process of crushing and magnetic classification. The metallic are recycled in the process of steel making.

BOF slag also contains free lime which expand in contact with moisture/ water. This restricts its use in various applications. Thus, the steelmaking slag is subjected to the ageing treatment process, namely, normal ageing treatment, (whereby the hydration reaction is allowed to take place by natural rainfall on the yard), and accelerated ageing treatment / steam ageing treatment, (whereby the hydration reaction is induced to complete in a shorter period of time). It is imperative that the free lime content in steel slag from BOF and EAF is brought down to acceptable levels for use of steel slag as aggregate in civil construction. Currently, integrated steel plants in India are planning installation of such facility for weathering.

Steel slag is also traditionally used in road construction, in Rail Ballast, as Soil stabilizer (Silica and phosphorous supplement), as performance improver in cement making, Raw material in clinker manufacture replacing lime stones.

In BOF slags major phases present are dicalcium ferrite, calcium aluminate, wustite, dicalcium silicate, tricalcium silicate, free CaO and MgO etc. EAF slag, due to lower lime content, is stable and can be used in ashphalt. Secondary steel refining slag dis-integrates into a powder due to instability of its constituents,

5 (http://www.cpcb.nic.in)

causing dust emission. There is an additional use of steel slag which is being explored widely across the globe, mainly for supplementing soil nutrients as well as soil remediation of acidic soil. Miscellaneous uses of steel slags and limitation are as follows:

Utilization as Aggregates

Highway construction in India has posed a great demand of natural aggregate for road construction. Natural resources, traditionally utilized in road construction, are depleting fast and causing serious environmental threat, Steel slag has a great potential as a replacement for natural aggregates in road construction.

Steel slag is similar to stone aggregates in strength, but its volumetric instability in contact with water hinders its application in construction as aggregates. As mentioned earlier, steel slag mostly is dumped after recovering metallic and is exposed to rain and sun for natural ageing and stabilization, which is slow process and time consuming and restricts its usage.

The reason for volumetric expansion and structural instability of steel slag in construction is the presence of free lime (CaO) and magnesium oxide (MgO) in its mineralogy, which form low density hydroxides in the presence of water. The hydroxides react with atmospheric CO_2 and form carbonates, with increase in volume. The swelling nature of steel slag is undesirable in civil engineering application.

Some of the steel plants have already installed facilities for artificial ageing so that free lime can be bound quickly. Process has been developed accelerating the steel slag ageing process using steam. Steam percolates through the minute pores in the slag lumps and hydrates the expansive free lime and MgO phases, making them stable.

Steel slag aggregate meets all important physical characteristics of aggregates laid down in MoRTH specification for Road and Bridge Work 2001 for preparation of bituminous concrete mixes. The high bearing capacity of steel slag aggregates can be used advantageously on week subgrades and in heavy traffic applications. However, in absence of inclusion of steel aggregates in IRC manual, the acceptability is low but in rural roads the usages are on the rise.

Transportation is another issue which restricts the utilization of Steel aggregates over long distances. Field trials were conducted for assessing the suitability of processed weathered BOF slag for use as rail track ballast along a stretch of 55 m near the Ispat Nagar Railway Yard at Bokaro. It is expected that in future the acceptability of steel aggregates shall improve.

Utilization in Agriculture

In India, about more than 35 million Ha of land is affected by acidity. Low cost additives are needed which can improve soil health and reduce cost of farming. Steel slag for reclamation of acidic mine land is an excellent use for this material. Application rates to neutralize total potential acidity of mine land are high and reapplication of lime may not be technically or economically feasible. It has been studied that, steel slags were as effective as limestone in neutralizing. Germination was successful in all treatments with limestone and slag.

Steel slag can be used for amending acid soils for soil neutralization and as source of growing agents. It can improve soil structure and reduce frungal infection. Silicates in slag minerals are useful for plant nutrition and soil quality. Silicates provide beneficial effect on plant health and soil structure, increase the phosphorus mobility in the soil and the efficiency of phosphate fertilization.

Steel LD slag can also be used in fertilizers for agricultural applications. The efforts have been made in Tata steel that LD slag after grinding to 300 mesh, can be used as a soil conditioner in paddy field, tea gardens etc. Nippon KokanKk Corporation (NKK) in Japan has developed a process to produce eco-friendly slow release potassium silicate fertilizer from the slag which generated during the desiliconisation process of hot metal at steel mill.

By undertaking planned research in agricultural on use of slag based fertilizers and by products, dependency on imported fertilizers like NPK or Potash or Phosphate can be minimized by using slag as it is or after mixing with sugar industry waste (press mud or spent wash), cow dunk or animal waste generated from Gobar Dhan Yojna or by mixing with some of the minerals like Glauconite, recently discovered in Uttar Pradesh

Some studies show that according to soil type and agricultural use by adding a concentration of LD slag between 1.5 and 5.0t/ha, it is possible to achieve increase in soil pH and improve the soil quality and also productivity. The experimental works were carried out using pulverized LD slag for growing different vegetables and crops like tomato, potato, onion, spinach and wheat in acidic soil. Steel slag contains fertilizer components CaO, SiO2, and MgO. In addition to these three components, it also contains components such as FeO, MnO, and P_2O_5, so it has been used for a broad range of agricultural purposes

Studies were carried out by some of the Indian Agricultural Universities like Orissa University of Agriculture and Technology, Bhubaneshwar, in the laboratory as well as in the field for assessing use of BOF slag as acid soil ameliorant. On site trials showed higher yield of crops and decrease in acidity of soil. However, impact of heavy metals like chromium could not be established.

Steel slag is having economic as well as ecological advantages and is a vital resource. The cement production in India was 270 MT in 2013-14, and the same is expected to be increased to 400 MT by 2020. While for making one tonne of cement about 1.5 T lime stone is required and with about 10% replacement of limestone with BF slag creates a market for 60 MT BF slag /year, thus providing an additional possibility for 100% reuse of BF slag and also a drastic reduction of CO_2 emissions will be a bonus with reduced limestone mining also.[7]

Similarly, acid soils occur in the high rainfall areas covers around 25 million hectares of land with a pH below 5.5 and 23 million hectares of land with a pH between 5.6 and 6.5 (Out of 142 million ha of arable land in India) spreading over 24 states of the country. Productivity of such soils are mainly constrained due to low base saturation and other acidity-induced soil plant nutritional and fertility problems. The utilization of steel slag can address the above issues to a large extent without utilizing costly fertilizers / soil additives.

5 (https://www.ieindia.org).

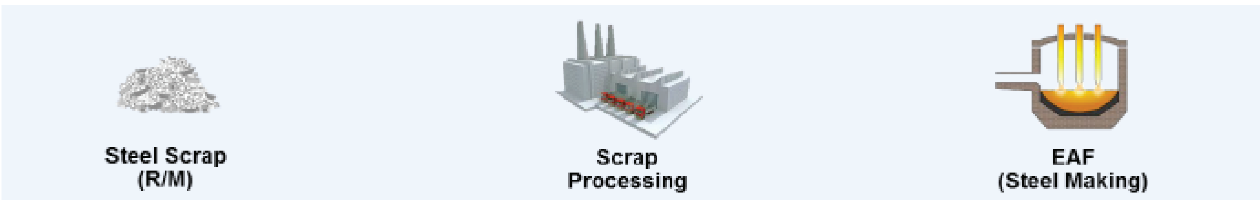
6.0 Strategy for Recycling

As the availability of obsolete scrap continues to grow, the recycling industry will need to expand and become more efficient in order to handle the larger volumes as well as improve profitability. How India can benefit from the rising volume of obsolete scrap, will depend largely on the evolving economics of the recycling industry.

Small collectors gather discarded items containing steel from neighborhoods and local industry. Distributors sort, dismantle, and bale this scrap using simple processing equipment. Professional scrap companies then sort and process the scrap into standardized products for sale to steel mills. For some specialized obsolete goods, such as cars and ships, only experienced scrap companies can conduct collection and processing.

The supply of obsolete scrap is determined by both availability and how much it can be profitably collected and processed. While the former is a function of the amount of steel historically used in the economy, the latter largely depends on the economics of collecting, processing, and transporting scrap. The main costs involved in recycling obsolete scrap are labour and the energy used in processing, and expense for the transport of scrap from steel consumers to collection and processing sites and then to steel mills. The economics of the scrap recycling business will determine how much obsolete scrap will actually be available for steel production.

As the government is increasingly concerned about the environmental impact of industrial economy, there is a need to put more incentives in place for scrap-intensive EAF/IF, which has a potentially lower environmental footprint. Figure 11 shows the major limitations the secondary steel sector is facing today, in terms of scrap usage due to various factors such as, unorganized scrap collection, lack of incentives to the scrap collectors, prevailing import duties, absence of regulatory frameworks, need for skilled manpower, land acquisition and state of art facilities.



- No formal system for scrap collection
- No social security/social status for scrap collectors
- Highly fragmented market
- Limited statutory compliances
- Limited traceability & accountability of scrap
- Limited adherence to policies on waste management

- Not assigned industry status → No regulatory framework
- Value loss due to sub-optimal processing
- No organized players
- Low concern for quality → Limited investment in equipment & capability building
- Limited adherence to policies on safe dismantling of obsolete goods
- No infrastructure for safe disposal of waste materials

- Difficulty in acquiring land
- High power consumption
- Voluminous material → High cost of transportation
- Inconsistent supply of quality steel scrap
- High dependence on imports for quality, processed scrap
- The IFs produce low quality steel & are polluting in nature

Figure 11: Limitation of Steel Production Using Scrap in India

With good iron ore availability in India, manufacturers may favour hot metal-based technologies for creating new capacity over scrap based technology, if desired scrap quality, quantity, and easy availability is not assured.

With proper guidelines and regulation, the scrap recycling industry has huge potential to benefit the economy. Unlike coking coal, which is largely imported, scrap recycling would feed domestic economic activity. Higher scrap usage will help building a cleaner economy. Future policies may be more stringent for polluting coke making plants, sinter plants, and blast furnaces, and provide further incentives for choosing EAF over BOF. However, most of the electricity that powers EAF plants currently comes from coal burning, which is also harmful to the environment. Perhaps the biggest challenge for the scrap industry lies in our ability and willingness to make the EAF technology easy to adopt and operate. Enhancing proportion of EAF will require slower capacity enhancement of BOF and enhanced investments in EAF capacity. EAF mills have higher production flexibility and have typically lower maintenance capex. However, BOF based plants could apply new technologies to increase the amount scrap used in the converter by injecting additional thermal or chemical energy into the furnace. As more investment shifts to either EAF or an increase of scrap use in BOF, the scrap industry will benefit from the increase in demand.

The recycling industry itself will need to be more efficient. Most of the scrap will continue to be concentrated around big cities, providing large volumes of material within a short radius. Scrap companies will need to plan higher operational efficiency through more sophisticated technology, higher labour productivity, and more streamlined logistics. Figure 12 shows the current and the proposed road map starting from scrap collection to steel production. The interventions required at different stages namely, scrap collection, aggregation, logistics, and creation of scrap processing centres and finally steel production through EAF route is outlined. As operating costs come down and revenues grow, the threshold price for economical scrap collection shall drop, putting the scrap industry in a better position to compete with iron ore and coking coal-based plants.

Figure 12: Current and Proposed Road Map for Scrap Collection, Processing and Steel Production

6.1 Need for Recycling Policy

National Steel Policy 2017 projects 300 MT crude steel capacity by 2030-31. There has been a gradual emergence of scrap-DRI based electric steel making in India, and in 2016, IF and EAF routes together accounted for around 57% of crude steel production in the country. Scrap is an important feed material for EAF/IF based steelmaking. However, due to wide-scale adoption of continuous casting technology in steel plants and un-organized recycling of scrap in the country, the domestic availability of good quality scrap is limited and the country has to resort to imports. Import of scrap is also associated with risks of volatility in global prices as well as forex rates.

As such, a proper recycling strategy would need to be in place for monitoring and regulating the metals recycling sector in India across the value chain through formal collection, processing and recycling of scrap in an organized, safe and environmentally efficient manner. This would result in natural resource and energy conservation, reduction in GHG emission as well as enhancement of domestic availability of good quality processed scrap for production of quality steel and thereby reducing dependency on imports.

Interventions are required to accord Industry / infrastructure status to the hitherto unorganized scrap recycling sector so as to ensure statutory compliance with respect to safety, health and environmental norms in collection and processing of scrap. Conferring industry status / infrastructure to metal recycling sector shall help in increasing financing options. This shall result in encouraging innovative projects on waste avoidance, waste minimization, collection and processing of recyclable material to authorized recyclers willing to setup facilities across the nation as a part of Swacch Bharat Abhiyan.

Scrap processing units would need to be located strategically to optimize transportation cost of input and output material and achieve cost competitiveness with respect to global prices which also exhibit fluctuating trend.

6.2 Challenges in Recycling

Following challenges, which adversely impact the areas of scrap metal supply, industry growth, pollution, quality, safety, revenue and transparency in different steps of steel scrap recycling, necessitate having a comprehensive recycling policy:

1. Generation

- i. Lack of definite guidelines for scrap classification (in line with ISRI or equivalent classification)
- ii. No definite criteria of defining “End of Life of Equipment” or “ End of life Vehicle”
- iii. Rationalization of tax and duty structure
- iv. Quality of domestic scrap

2. Collection/Processing

- i. Logistic issues as high transport cost may act as a deterrent for scrap movement within the country
- ii. Lack of regulations to handle contaminated waste and other hazardous items arising out of scrapping and shredding.
- iii. Lack of E-Procurement of scrap and standardization of procurement policy for various government related departments / institutions.
- iv. Absence of safety gears during dismantling and sorting of scrap
- v. Lack of uniform standard and specifications for usage across industries

vi. Lack of storage guidelines for hazardous waste, non-ferrous and non-metallic waste

vii. Lack of organized recycling zones and associated infrastructure

3. Usage

i. Charging of polluted and undesirable scrap in furnace

ii. Lack of enforcement to manage poisonous fumes during melting

iii. Lack of implementation of safety standards in melting process

iv. Lack of Promotional schemes for firms for R &D on recycling process to develop better technologies / equipment

4. Disposal

i. Scrap residue sold to agent without verifying authorization certificate

ii. Lack of authorized disposal sites (landfills) in all the major cities of country

iii. Water and other waste generated during melting

6.3 Benefits of Developing the Steel Scrap Processing Sector

1. Domestic recovery of scrap will ensure reduction in scrap and metal imports, thereby reducing trade deficits.
2. Metal scrap recycling will lead to natural resource conservation and energy savings.
3. Processing metal scrap in an organized, safe and environmentally efficient manner.
4. Promotion of a formal collection and shredding mechanism for end of life products that are sources of metal scrap.
5. Generation of new sources of revenue and employment for the government.
6. Contribution and promotion of the Swachh Bharat Abhiyan by developing recycling zones.
7. Establishing mechanism such as e-auctions, defined payment systems for monitoring and regulating the metals recycling sector in India across the value chain.

6.4 Regulatory Needs

Regulations are essential for steel scrap recycling industry to ensure that the steel scrap is free from hazardous material, inflammable or explosive, dirt or pollutants which may contain or emit dangerous substances, chemicals waste classified as hazardous, radioactive material, carcinogenic substances, sulphur etc. Steel scrap should also be free from non-metallic materials like dirt, glass, concrete, and insulation, combustible non-metallic material such as wood, grease, oil, other lubricants, plastic, rubber, fabric and organic substances. Restriction is also required for contents of non-ferrous metals like copper, brass, aluminum, lead, chromium, nickel, cobalt etc. There has to be guidelines about maximum weight of scrap pieces for suitability in handling and charging.

Steel scrap processing will involve a number of activities like sorting, loading/unloading etc. Use of appropriate safety appliances need to be made compulsory for all the personnel engaged, large number of which is likely to be contract workers.

All scrap that come for processing should be subjected to required quality checks. After processing, indicative chemical analysis should be known, and existence of contaminants or hazardous elements must be determined for quality, safety and regulatory compliance.

Employees in facilities that recycle metal scrap are exposed to a range of safety hazards associated with material handling methods, hazards associated with the metals themselves (as dust or fumes), and with the hazardous substances used to process or recover these metals.

6.5 Standards and BIS

Ferrous scrap is sorted and processed into various grades for recycling. Broad grading of scrap as per BIS 2549: 1994 (Code for Classification of Processed Ferrous Scrap) is as follows:

- Shredded scrap
- Heavy Melting Scrap (HMS) No. 1
- Heavy Melting Scrap (HMS) No. 2
- Light Melting Scrap – Bundles
- Re-rollable scrap
- Turnings and borings
- Iron Scrap
- Stainless steel Scrap

Specifications exists for steel scrap specifying type (heavy melting scrap, shredded, steel turnings), composition restriction etc. in other countries also (e.g. EU-27 Steel Scrap Specification). Some companies have their own specification for procurement of steel scrap (e.g., Scrap Specification, Slovakia Steel Mills a.s., ArcelorMittal Dofasco Hamilton Scrap Specification etc.)

6.6 Capacity Building

The performance of Primary as well as Secondary Steel Sector need to be benchmarked to remain globally competitive. Presently, the steel sector is facing lot of challenges, both technological as well as financial. Immediate technological intervention is necessary so that productivity, energy consumption, raw material consumption etc. are at par with global peers to remain competitive. In view of its potential of energy saving, natural resource conservation, and environmental benefits, capacity building is required by involving institutes of reputes like IITs, NITs, NISST, BPNIS etc. Integrated steel plants can produce steel grades which require low residuals and which should be free from trace and tramp elements, while other grades can be produced in secondary sector utilizing mainly steel scrap, the availability of which shall continue to increase in the country.

There is need for skill development for scrap recycling, energy efficiency, quality control, and other associated areas in the secondary steel industry. Biju Patnaik National Institute of Steel (BPNIS) was earlier envisaged for undertaking special courses related with Iron & Steel Industry but the same is yet to start such courses. Although, large numbers of initiatives were taken by NISST in the past and encouraged secondary sectors to adopt energy efficient and environmental friendly technologies with support from UNDP but more focus may have to be accorded on skill development and specialized training that may be required for this emerging sector. In addition, some new Centre of Excellence have been created in various IITs for steel technology and these centres can also promote higher level of research as well as to meet any future specialized requirement of human resource. Similarly, some centre of excellence for waste management in steel industry may be helpful in addressing the issues of technology gap required for this new but important sector so that zero waste concept can be adopted.

This may require wider consultation with existing institutes as well as long term need planning so that such institutes may undertake long term researches also to meet future requirement of the sector. The courses may cover degree/diploma courses and training modules for theoretical and practical knowledge, especially considering the jobs dealing with state-of-the-art equipment, short term specialized refresher courses, utilizing expertise available in-house, industry and academic institutes.

6.7 Regional Distribution

As steel scrap is generated all over the country (though volume may vary from state to state), there is a need to create designated zones and areas for recycling of steel in the major industrial areas or on the outskirts of major cities where large generation of steel scrap is expected. Setting-up of steel shredding facility needs to be encouraged.

6.8 Vehicle Scrapping Policy

There is a need for Vehicle Scrapping Policy. Although a strategy paper on need of such policy and guidelines have already been issued by the MoEF & CC but till date no formal policy has been issued. The implementation of policy, as and when issued will result in setting up of more and more shredding facility and also increased availability of shredded scrap for MSME (secondary) sector. The scrap so generated may require guidelines for classification of scraps so that high alloy and special scrap can be utilized for producing special materials in cost effective manner.

6.9 Environmental Threats and Suggested Measures

Minimum environmental standards are required to be introduced for scrap metal facilities across the industry. The environmental concerns are greatest where end-of-life vehicles and/or white goods are to be processed. Some important issues here are:

- Practices for storage and handling of oils, grease, fuel, solvent, batteries and degreasers, particularly at small auto dismantlers.
- Presence of hydrocarbons, metals, heavy metals and polychlorinated biphenyls (PCBs) could result in soil and groundwater contamination, as well as water pollution
- Inadequate draining of fuel, oil and other liquids from end-of-life vehicles
- Improper hard base, covered areas and inappropriate storm water infrastructure to prevent fuel, oil and grease and other potentially contaminating materials from coming into contact with soil and waters
- Storage of waste tyres, which are a fire risk and are the perfect environment for mosquitoes to breed
- Noise and air pollution, particularly at larger facilities where hammer mills / shredders are being used. Hand held tools are used for dismantling end-of-life vehicles at smaller scale, equipment, such as oxy cutters and balers, are utilized at larger scale adding to noise and air pollution, and an increased risk of fire.
- Poor practices for the management of liquids, such as fuel, oils and grease (including draining fluid from end-of-life vehicles at small auto dismantlers), and a lack of appropriate covered areas, hardstands, storm-water and drainage controls are generally the major environmental risks on site. This can lead to the contamination of soil and water both on and off site. Chemical and oil storage on site and hot works (the use of equipment, such as oxy cutters) can also increase the risk of fires starting at these facilities.

These environmental concerns can have possible human health impacts on site workers and residents in neighboring communities. Minimum environmental standards need to be created to ensure that any environmental and human health risks are minimized.

For merchant scrap, there is a need of well-established market with scrap metals being bought and sold in accordance with agreed rules regarding environment friendly processing and quality.

7.0 Implementation Frame-work

7.1 Integrated Steel Recycling & Slag Utilization approach

Presently, steel scrap recycling is an unorganized business and thus effective coordination will be required among scrap generators , collectors, traders, processors, original equipment manufacturers and end users for ensuring efficient and economic recycling, providing the processed scrap of required quality (size, chemistry) in time to user industry. The facility shall require to be equipped with depollution system, preferably with zero discharge system, and dismantling by making use of best available technology for processing the end of life goods and other scraps. The centers shall have to comply with relevant health and safety legislation/ regulation and environmental norms as laid down by MoEF / CPCB / SPCB for such operations. All these aspects need to be covered in the Steel Scrap policy which relevant department may consider to issue in future.

Similarly, utilization of steel slag in various applications shall require close coordination between research bodies, manufacturer and other consumer where slag can act as an alternate raw material. Also, fertilizer industry may require to be associated in developing alternate fertilizers using steel slag as the main material.

7.2 State Government's Role

As both the new opportunities i.e. steel recycling and slag utilization may require some local rules and monitoring mechanism, role of the state governments shall be very crucial. In the case of slag utilization in agriculture, state government and research bodies may have to work with farmers also so that myths, if any can be removed and suitable recommendation depending upon the soil requirement can be made available to the farmers. To monitor adherence to safety and environment related measures in steel scrap and steel slag collection and processing may require new guidelines. For making these sectors more organized, concerned operators have to follow applicable guidelines, laws and rules framed by the central as well as the State Government.

Further, logistics may be one of the main challenges for safe and cost-effective system for inbound unprocessed products/scrap and outbound processed scraps to the melting shops. Thus, scrapping centres (Collection cum dismantling centre and recycling centre) need to be supported by adequate logistic facility and hence the State Government intervention / role will be important in identifying areas for setting up such centres as per respective industrial policy of the state. The implementation of effective logistic framework shall prevent pilferage and facilitate containerised transport in an environment friendly manner taking into consideration of the local societal issues.

The setting up of these centres near highways, industrial corridors, railway sidings and in the close proximity to Sagarmala project shall help in development of multi-modal logistics parks. As the industry evolves over time, setting up of ECO parks/recycling zones having the scrapping/ recycling centres along with the user secondary steel sector industry shall help in boosting the economic activities around these centres besides generating large employment opportunities in the state.

7.3 Implementation Agency & Its Role

It is recommended that some centralised authorized agencies may be constituted which can deal with all types of waste (ferrous and non – ferrous scrap and slag, electronic waste, plastics, rubber, etc.) in the country. This agency shall be responsible for formulating policies and guidelines, implementing, monitoring all aspects related to collection, handling, processing and recycling of all types of wastes in the country to achieve resource efficiency targets based on the best practices used across the globe. It will have regular interaction with the all the stake holders for overcoming difficulties including with the states. It will also facilitate in adoption of latest technology and equipment for efficient recycling operations and encouraging R&D work in the relevant areas by engaging institutes of repute in the country as well as abroad. The suggested action plans are given in action agenda below.

Action Agenda: Central Agency

Category	Recommendation	Action Agenda	Implementing Agency	Timelines
Institutional	Constitution of Centralized authorized agency	To be constituted to deal with all types of waste (ferrous and non – ferrous scrap and slag, electronic waste, plastics, rubber, etc.) in the country. It will formulate, implement and monitor all aspects related to collection, handling, processing and recycling of all types of wastes in the country to achieve Resource Efficiency targets. It will have regular interaction with the all stake holders for overcoming difficulties.	NITI Aayog / Ministry of Commerce & Industries	Jan. 2019 – Dec. 2019

Action Agenda: Steel Scrap Recycling

Category	Recommendation	Action Agenda	Implementing Agency	Timelines
Institutional	Dedicated “Resource Efficiency Group” in Steel Companies	Dedicated department in steel industries to look into all aspects related to Resource Efficiency, including new technology, new market, new products etc.	Ministry of Steel, Steel Industries	Oct. 2018 - Dec. 2018
Institutional	Fixing Resource Efficiency improvement target and monitoring	Production Efficiency to be included in the MoU being signed by PSUs with Government. Raw material consumption/ recycling can be MoU parameter and adequate marks can be assigned for this purpose. Accordingly, MoU guidelines can be amended.	SRTMI / ISA, Min. of Steel, PSUs.	Oct. 2018-March 2019
Institutional	Encouraging R&D for Resource Efficiency in Steel Sector	Data regarding R&D Expenditure, Ongoing R&D Efforts on Resource Efficiency, R&D Programs and Funds required for further work on Resource Efficiency, Identification of R&D/academic institutes for undertaking R&D on Resource Efficiency	SRTMI, R&D Dept. of Steel Companies	Oct. 2018-March 2019
Institutional	Policy formulation for “Ease of doing business” related to scrap recycling	Faster granting of required clearances for setting up industrial units for scrap collection and processing, and availability of low cost capital	Min. of Steel, Min. of Commerce & Industries, Min. of Finance, Min. of Env.	April 2019-Dec. 2019
Institutional	Skill development in steel processing technology	NISST, BPNIS, INSDAG, and initiating Programs on Resource Efficiency in Steel Sector	Min. of Steel, SRTMI	Oct. 2018 – Sept. 2019

Action Agenda: Recycling of Steel Slag

Category	Recommendation	Action Agenda	Implementing Agency	Timelines
Institutional	Preparing guidelines for best available techniques for processing and utilizing steel making slags	Preparing a comprehensive document providing detailed guidelines for efficient handling, treating and processing of steel slag and its utilization for various applications.	Ministry of Steel, SRTMI, BIS, Steel Industry.	Oct. 2018 - Dec. 2018
Institutional	Determination of physico-chemical characteristics of Indian steel making slags for assessment of their applicability for various applications.	Collection of representative steel slag samples from various processes and different plants, physico-chemical characterization for various possible applications.	NML, RDCIS, Steel Industry, Ministry of Agriculture	Jan. 2019 - Dec. 2019
Institutional	Expertise development in the area of steel slag processing and utilization	To set up specialized group in steel plants and R&D units, dedicated to overlooking matters related to steel slag handling, collection, processing and efficient utilization	Steel industry, SRTMI, Min. of Steel, Ministry of Agriculture	Oct. 2018 - Dec. 2018
Institutional	Evolving utilization strategy for over 5 MT of naturally weathered BOF slag available in steel plants in the country	Exploring avenues of utilization of available weathered BOF slag in steel plants in the country for beneficial use in road construction and agriculture in near- by places	Steel industry, CRRI, IRC State Governments, Min. of Steel, MOEF &CC.	Oct. 2018 - Dec. 2018
Institutional	Efficient processing of steel slag	Setting up modern facilities for collection, crushing, screening, processing of steel slag near the dump site inside the plant boundary	Steel Industry, FSNL, MECON, Min. of Steel.	

8.0 Research & Development

8.1 Need for R&D in Steel Scrap Recycling

As Steel Scrap Recycling through mechanized and organized structure and utilization of steel slags in various applications will be a new emerging sector, there may be a need of R&D programs to address issues generated during subsequent stages. Following are the likely areas that may require R&D support:

- To streamline eco-cycle for steel in order to lower energy usage, reduce carbon dioxide emissions and efficient utilisation of natural resources.
- For removal of trace and tramp elements from obsolete scrap
- Environmental friendly technology for scrap processing
- Development of efficient technology for sorting, quality assessment.
- To generate new knowledge about how we can increase the yield of iron and alloying elements.
- To enhance resource efficient steel production and recycling

8.2 R&D in Steel Slag Utilization

R&D work need to be undertaken towards understanding and eliminating adverse side effects, if any, of use of steel slags in agriculture in order to achieve an effective and sustainable recycling. Steel slag can supply nutrients, but should not have any negative side effects on the environment and on the human, animals and plants.

Also, R&D efforts need to be made to develop alternate uses of EAF, IF and LD slag like aggregates, sand etc besides developing technologies for recovery of heat of slag.

8.3 Role of Academic Institution

Academic institutions undertake research programs for developing process technology to preferentially remove undesirable elements from steel melt while melting steel for a particular grade in EAF/IF. Some element may be useful to enhance specific attribute in steel grade being produced, while it may be harmful and undesirable in some other grade. Some fundamental research may be required to address the issues of different types of scraps generated from various sources.

9.0 Conclusions & Recommendations

9.1 Steel Scrap Recycling

India need to venture into systematic and efficient scrap processing as it prepares for an era when proportion of BF-BOF based steel making using coking coal and iron ore diminishes and scrap based EAF/IF processes becomes preferred choice. Steel scrap processing so far has been largely an unorganized sector, with no control over quality. Modern scrap processing facility need to be planned which will source, separate, shred and process scrap that can be used as preferred input for quality steel production. More scrap processing units to be set up so that import volumes may be minimized.

In the short-term import of ferrous scrap will continue as it will take some time for India to bring on the steel scrap processing plants. For steel output to grow according to the plan, India's EAF output will have to rise by at least 16.85 million tpy, which can actually be achieved by full utilization of the existing EAF and induction furnace capacities. The utilization rate in 2016 was 74%. If existing mills raise their capacities, they will need more scrap and therefore will have to turn to more imports.

Scrap requirement by Indian EAFs can be reduced if direct reduced iron (DRI) is available and can be economically utilized. Many Indian induction furnaces have used 75-80% DRI in the steelmaking charge.

In future, more scrap should be used as DRI technology, though more environment friendly than BF, does create pollution.

Indian steel makers in MSME (secondary) sectors shall require greater supply of good quality scrap. Generally, it will be economic and less polluting to consume scrap nearer to places where it is generated. Therefore, Scrap Processing Units need to be set up near the centres/clusters of scrap consumers (i.e. EAF/IF Plants).

Comprehensive Steel Scrap Recycling Policy need to be formulated which can address following:

1. Efficient collection, segregation and processing of steel scrap with adequate quality control.
2. Strict adherence to necessary safety measures, use of radiation detection equipment (particularly if scrap has been sourced from laboratories/hospitals).
3. Formation of Zonal Scrap Collection and Processing Sectors in the country, so that processing is done nearer to generation centres or near the end users.
4. Revisiting the existing BIS specifications pertaining to steel scrap.

9.2 Steel Slag Utilization

With increasing steel production, significant efforts have been made to develop the slag processing technologies to enable its utilization.

1. While BF slag is mainly used for cement production, steelmaking slags can be used for road construction, hydraulic engineering, as fertilizer etc.
2. In integrated steel plants, there is significant generation of LD (or BOF) slag. India has about 55 million t capacity of steel production through BOF route, where slag generation is about 150-175 kg/t of steel.
3. BOF slag contains Ca, S, Fe, Si, P, Mg etc. which may be useful for plant growth. It is useful for acidic soils as it gives pH around 8 when mixed with water. Calcium helps in formation of fertile soil and

improves disease resistance. It also helps in absorption of other nutrients by roots. Sulphur is required for amino acids, proteins etc. Iron is essential for plants' growth. Silica helps in improving the growth and stress defence mechanism of plants. Phosphorus is a vital component in the process of converting sun's energy into food, fibre and oil. Tata steel has demonstrated the use of BOF slag as soil conditioner.

4. Steel slag aggregates exhibit a number of favourable mechanical properties, including very high stability and good soundness. If properly selected, processed, aged and tested, can be used as granular base for roads. Volume stability is the key aspect for using steel slag as a construction material.

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