Draft Report

Reference Report for "Integrated Resource Efficiency Policy" for India

Prepared for
Ministry of Environment, Forests and Climate Change, Government of India

January 2019

The Energy and Resources Institute

...towards global sustainable development

Suggested format for citation

T E R I. 2019

Reference Report for "Integrated Resource Efficiency Policy" Document for India

New Delhi: The Energy and Resources Institute.

[Project Report No. 2017RD03]

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1 Introduction

1.1 Changing Resource Landscape in India

The economic growth and development in India over the last two decades has brought about a decline in poverty rates, increased urbanization and a resulted in a rise in overall demand for various goods and services. This, along with growing population and rising aspirations of a growing middle class is driving the demand for natural resources, exerting pressures on the environment and raising sustainability concerns. Between 2005 and 2012, the middle income class population increased from 300 million to 600 million and is expected to increase by more than 1.5 times by 2025. Urbanization is expected to rise to 50% from its current level of 34% BY 2025[1]. India is likely to be the largest populated country in the world in a decade, with the share of youth expected to reach as high as 35% by 2020 from 20% estimated in 2011.

There is a near consensus – amongst scientists, policymakers and practitioners - that the only possibility for sustainable prosperity in long run is without creating trade-offs between economic growth and environmental sustainability, which though may be a huge challenge due to conflicting priorities.

Enhancing resource efficiency and promoting the use of secondary raw materials has emerged as a strategy for ensuring that the potential trade-off between growth and environmental well-being can be minimized. This strategy has the potential to stabilize raw material supply for industry, reduce pressures on the ecosystem and create many green jobs. Moreover, efficient use of resources often has substantial economic benefits created through reduced costs linked to less extraction for virgin raw material if secondary raw material is made available. Use of environmentally sound technologies and processes can foster resource efficiency, reducing the overall footprint of consumption and production, and mitigating negative side effects on society. The Sustainable Development Goals also recognize the potential of resource efficiency in resolving the short-term trade-offs between growth and environmental sustainability and mention resource efficiency in several places (Refer Box 1).

Box 1: Provisions related to Resource Efficiency in SDGs

The 2030 Agenda for Sustainable Development comprises 17 sustainable development goals or SDGs. The sustainable consumption and production (SCP) agenda, with clear links to resource efficiency, is captured by Goal 12. SDG Goal 12 (Ensure sustainable consumption and production patterns) states:

12.1. Implement the ten-year Framework of Programmes on Sustainable Consumption and Production patterns, all countries taking action, with developed countries taking the lead; 12.2.

[1] https://www.bcg.com/publications/2017/marketing-sales-globalization-new-indian-changing-consumer.aspx

By 2030, achieve the sustainable management and efficient use of natural resources; 12.3. By 2030, halve per capital global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses; 12.4. By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment; 12.5. By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse; 12.6. Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle; 12.7. Promote public procurement practices that are sustainable, in accordance with national policies and priorities; 12.8. By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature.

Several other SDGs include references of relevance to Resource Efficiency. Below a short overview:

Goal 2 (End Hunger, Achieve Food Security and Sustainable Agriculture): 2.4. By 2030 ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.

Goal 6 (Availability and sustainable management of water): 6.3. By 2030, improve water quality ... halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally; 6.4. By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity...

Goal 7 (Access to affordable, reliable and secure energy): 7.2. By 2030, increase substantially the share of renewable energy in the global energy mix. 7.a. By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy ... and promote investment in energy infrastructure and clean energy technology.

Goal 9 (Build resilient infrastructure): 9.4. By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency ... with all countries taking action in accordance with their respective capabilities.

Goal 11 (Cities): 11.1. By 2030, ensure access to adequate, safe and affordable housing and basic services, and upgrade slums; 11.2. By 2030, provide access to safe, affordable, accessible and sustainable transport systems; 11.6. By 2030, reduce adverse per capita environmental impact ... special attention to ... municipal and other waste management.

Though targeted policies on aspects of resource efficiency such as recycling, waste management have been around for some time in most countries, the move is now seen towards designing more comprehensive strategies on Resource efficiency. As explained in detail in chapter 4 later, amongst the pioneers are countries in the European Union (like Germany, Austria, Denmark, etc), Japan and China. The EU, for instance, has adopted a

Circular Economy package in 2015 and China adopted a Circular Economy Law in 2008. The Law is formulated for the purpose of facilitating circular economy, raising resource utilization rate, protecting and improving environment and realizing sustained development. These policies, among other things, outline the importance of mainstreaming RE policy in the overall development policy and how the same can be achieved based on existing policy framework as well as introducing new market based mechanisms. In this regard the role of the public private partnership is critical and has to be mainstreamed that will facilitate investment in adoption and deployment of technologies and improved processes.

In India too, Resource efficiency is gaining traction as a potential strategy to be considered in our policy formulation and in order to foster its spread, the Government of India had earlier set up the India Resource Panel (InRP) in 2015. The objective of the Panel was to advise the Government of India and relevant stakeholders on the potential for enhancing resource efficiency and the productive use of secondary raw materials. In addition, the panel made efforts to raise the issue's importance on the political agenda. In line with global best practices and on the basis of a rigorous policy analysis, the Panel recommended that fostering resource efficiency would be achieved at scale only through enabling policy framework. However, the earlier Indian Resource Panel has been reconstituted as an Advisory Committee to the newly established Resource Efficiency (RE) Cell at the Ministry of Environment Forest and Climate Change. One of the key tasks that the RE Cell has been assigned is the developing an integrated RE policy framework for India, based on the existing work/output of the InRP as well as developing an institutional mechanism that will facilitate, monitor and review the implementation of this framework.

1.2 Past and current trends of material use in India

India consumes about 7.2% of globally extracted raw materials in a year but supports 17% of the global population. The resource extraction per unit area is one of the highest in the world (1,579 tonnes/acre) compared to the global average of 454 tonnes/acre. Material consumption of India has doubled from 2.5 billion tonnes in 1990 to 5 billion tonnes in 2010. India was the third largest consumer of material (5 billion tonnes) after China (21.5 billion tonnes) and USA (6.1 billion tonnes) in 2010, accounting for 7.1 % of global material consumption; 10.6 % of global biomass consumption; 6.6 % of global fossil fuel consumption; 5.8 % of global non-metal mineral consumption; and 2.3 % of global metal consumption (GIZ 2017)[2].

Despite high aggregate consumption levels, per capita consumption in India remains lower than the world average although it has increased from 2.1 tonnes per capita in 1970 to 4.2

[2] http://re.urban-industrial.in/live/hrdpmp/hrdpmaster/igep/content/e64918/e64922/e67075/e67112/DMS_GIZ_IREPeReportApril2017.pdf

tonnes per capita in 2010 – less than half the world average and can increase with income and aspiration (table 1).

Table 1: Consumption of key natural resources

	World	China	USA	India	Japan	Germany	S. Korea
Biomass	18.83	2.94	1.38	2.00	0.15	0.27	0.07
Minerals	29.97	11.12	4.24	1.63	0.56	0.56	0.23
Fossil fuels	12.71	3.12	2.31	0.85	0.49	0.43	0.21
Metals	6.61	1.61	0.52	0.41	0.10	0.04	0.01
Total	68.12	18.82	8.46	4.89	1.29	1.29	0.57
Per capita	10.2	14.2	27.2	4.2	10.2	14.8	15.8

Source: GIZ-TERI-DA-IFEU (2015)[3]; Unit: Billion tonne; & tonnes/capita (2010).

India's material productivity is lower than the global average. India's resource productivity during 1980 and 2009 may have improved by more than three times the global average of 27%, yet it was less than the rates achieved by countries such as China (118%) and Germany (139%). In the use of significant amount of natural resources domestically , the average share of material costs in total production cost has been estimated at more than 70 % vis-à-vis 40 to 50 % in developed economies (EU-NITI, 2017)[4], indicating significant opportunities for improving productivity. The rate of recycling in India is also low (20-25%) when compared to the other developing and developed countries like Europe where the rate of recycling is over 70 %. Further, material recovery at the end of life stage is concentrated in the informal sector, which has implications on the scale of operation, technology choice and product quality of the recovered materials.[5]

1.3 India's Future Trends and trajectories on material demand

Under the assumption of continued economic growth of 8% till 2030 and possible slowing down to 5% thereafter till 2050, and medium growth in population as projected by United Nations, it is estimated that India would require around 2.7 billion tonnes of biomass, 6.5 billion tonnes of minerals, 4.2 billion tonnes of fossil fuels, and 0.8 billion tonnes of metals in

[3] http://www.hrdp-network.com/live/hrdpmp/hrdpmaster/igep/content/e48745/e50194/e58089/ResourceEfficiency_Report_Final.pdf
[4] https://eeas.europa.eu/delegations/india_id/38671/Resource%20Efficiency-%20the%20key%20to%20a%20sustainable%20future
[5] http://re.urban-industrial.in/live/hrdpmp/hrdpmaster/igep/content/e64918/e64922/e67075/e67084/DMS_GIZ_IREP_PolicyBrief.pdf

2030; while the per capita consumption would reach around 9.6 tonnes in that year, which is nearly the current global average. This is presented in figure 1.

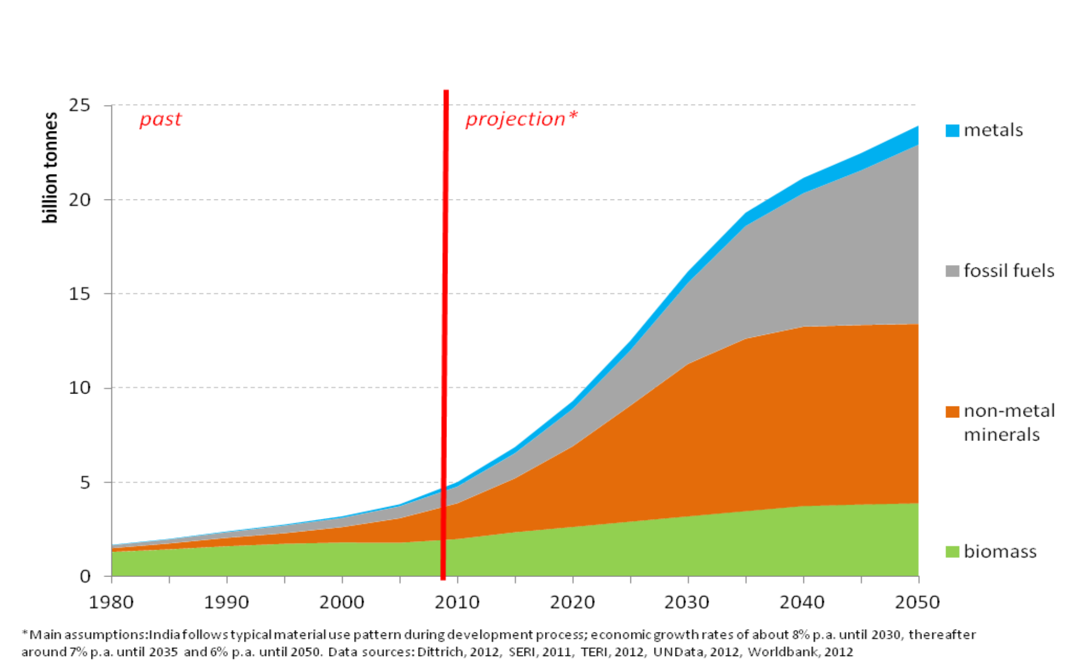


Figure 1: Projection of future material consumption patterns

Source: GIZ-TERI-DA-IFEU (2015)

A quick comparison of material used between 1980 and 2009 vis-à-vis the consumption expected between 2010 and 2030 reveals that India would need 188 billion tonnes of materials (to compare: India extracted between 1990 and 2009 66 billion tonnes); 51 billion tonnes of biomass (1990–2009: 37 billion tonnes); 81.6 billion tonnes of non-metal minerals (18 billion tonnes); 45 billion tonnes of fossil fuels (8 billion tonnes); and 10.5 billion tonnes of metals (2.6 billion tonnes) between 2010 and 2030.

1.4 Consequences of current and future material demand

Meeting the growing demand for materials is a daunting challenge. These challenges include growing costs, shrinking geological availability and risk of material exhaustion/ uncertainty with regard to long-term abundance and finally social license to operate that arise from equity and distributional challenges and the associated uneven and unfair access to natural resources. India is already a net importer of resources, dominated by fossil fuel imports and critical materials. The import dependence increases the vulnerability of the economy to global geo-political and economic risks apart from adversely affecting the trade balance. Table 2 presents India's import dependencies for key resources.

Table 2: India's import dependencies for selected raw materials

Materials	Import Dependency
Molybdenum (Mo)	100%
Cobalt (Co)	100%

Materials	Import Dependency
Nickel (Ni)	100%
Antimony (Sb)	100%
Magnesite (MgCO3)	100%
Rare earths	100%
Lithium (Li)	100%
Phosphate	90%
Copper (Cu)	90%
Fluorite	87%
Silver (Ag)	75%
Lead (Pb)	74%
Oil	70%

Source: GIZ-TERI-DA-IFEU (2015), CEEW-DST (2016)[6], TERI (2018)[7]
Note: Import dependency ration for raw material refers to the extent of dependency on importation in relation to domestic consumption of the raw material

1.4.1 Potential economic challenges

Prices of many resources are under pressure, and continuous depreciation of India rupee, is adding to the cost of manufacturing of many items that require imported materials. India imports more than 80 % of the oil that is processed in the economy for domestic consumption and re-exports. Import dependency is nearly 100 % for majority of the 'most critical' materials such as Co, Mo, Cu, Cr, Ni, Li, Rare earths that find application in high technology industry. It is important to note that if a material is used in relatively smaller quantities, in high value added manufacturing sectors, it can be considered more critical when compared to use of materials in large quantities in a low-value-add manufacturing sector.

In recent months, there has been excess production over demand for selected non-ferrous metals. Hence any short term increase in demand may not have immediate implication on prices but in the medium to long term, it will have impact on the product prices, outflow of foreign exchange reserves (due to increased import) as well as impact on the GDP. In the context of assessing economic challenges, particularly in the non-ferrous material segment, dominated largely by aluminium, copper, zinc, lead, tin and nickel, etc. the inverse duty structure as well as dumping of cheap subsidized goods from China, have become issues of concern. The resulting inflow of semi processed/processed items in India and management of the wastes generated from these products often becomes a challenge because of the absence of adequate availability of relevant information of materials used or their material compositions. Under the new hazardous waste management policy the government has allowed import of metal scrap, paper waste and various categories of electrical and electronic equipment for re-use purpose, without permission from the environment

[6] http://www.dst.gov.in/sites/default/files/CEEW_0.pdf
[7] http://www.teriin.org/policy-brief/towards-resource-efficient-electric-vehicle-sector-india

ministry. When it comes to import of finished products the inflow has substantially increased because of the free trade agreements (FTAs) with ASEAN countries and other countries, which allows duty free imports of finished goods. Such imports also have implications so far waste generation is concerned. The issue of e-waste is already a huge problem in India arising from growing consumerism of electronics product whose key technologies and materials are largely imported. India is estimated to generate around 17 lakh tonnes of e-waste a year (as per estimates of 2014), and it is rising at the rate of 5% per annum.

By the year 2020 domestic scrap generation of non-ferrous metals is expected to touch 6.5 million tonnes, whereas demand would be about 7.9 million tonnes, creating a deficit of 1.4 million tonnes. This will have to be met from imports. The import of scrap is already too high in India and is growing over the years (Refer Figure 2). Estimates suggest that 90% of Al is imported in India. For successful processing of Al scrap, abundant availability of good quality scrap is inevitable. Regular supply of good quality, graded scrap is not prevalent and local scrap collection from domestic and household items is highly fragmented, making it difficult to operate recycling business based on domestic scrap.

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 gap between steel scrap demand and availability is likely to increase from about 5 million tonne to about 9 million tonne by 2021-22. The rising gap and the increased import dependence arise from the fact that India has a highly fragmented, informal reverse logistics mechanism which is not able to create a sustained supply of domestic scrap having enough volume that can make recycling profitable based on scrap feedstock generated within the country.

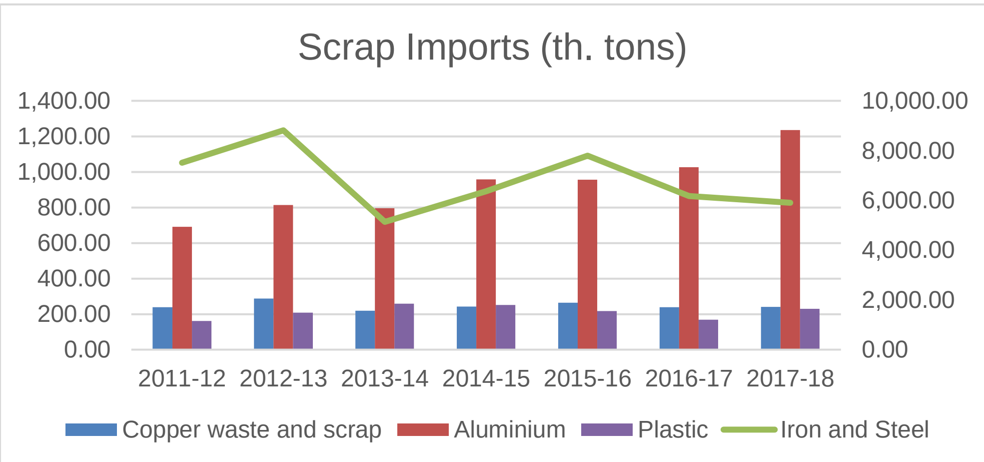


Figure 2: Import of scrap in India: Copper, Aluminium, Plastic and Iron &Steel
Source: DGFT (2018)[8]

[8] http://dgft.gov.in/more/data-statistics/export-import-data-bank

Another issue of economic relevance is India's material productivity which is low when compared with the global average.

1.4.2 Potential Environmental issues

India is gifted with a multitude of biotic and abiotic resources which are unevenly distributed. However, mining of abiotic resources have conflict with the biotic resources. Many of India's mineral reserves lie under dense forests (Refer Figure 3). Around 60% of coal resources, for instance, are located in forests (Ministry of Coal, 2005). Similarly, 61% of current chromite mining leases are in forest areas. It has estimated that the requirement of forest land for coal mining will increase from 22,000 hectares (i.e. 15% of the current total land requirement) to 73,000 hectares (i.e. 25% of the projected total land requirement) by 2025[9]. Increasing mining in forest areas would conflict with India's National Action Plan on Climate Change, in particular with "Green India", which focuses on the preservation and expansion of forests in order to use them as CO_2-sinks.

Mining also leads to significant degradation of land, which is perhaps is one of the most serious environmental externality resulting from the operations. The problem is compounded because of the emphasis on open-cast mining in India, which causes much greater land degradation than underground mining.

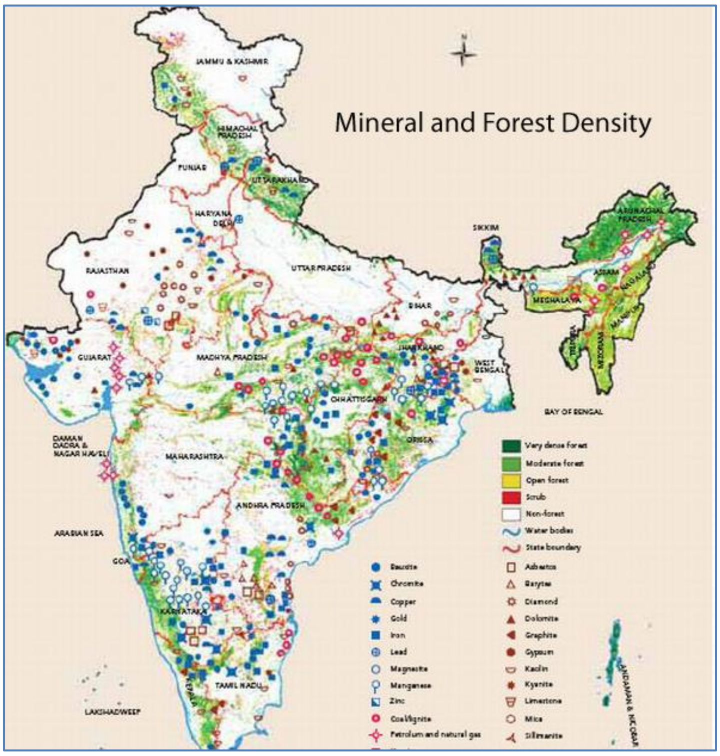


Figure 3: Forest Areas versus Mineral Resources

Source: CSE, 2007[10], IGEP, 2013

[9] http://www.hrdp-network.com/live/hrdpmp/hrdpmaster/igep/content/e48745/e50194/e58089/ResourceEfficiency_Report_Final.pdf
[10] http://www.cse.org.in/mining/pdf/miningpub.pdf

Mining leads to around 32% of total greenhouse gas (GHG) emissions of India (Majumdar, 2009). It involves activities like drilling, blasting, excavation, construction of haul roads, movement of heavy earth moving machinery (HEMM), etc., which results in dust emissions, fugitive emissions of particulate matter and gases such as sulfur dioxide (SOx), nitrogen oxide (NOx), methane, carbon dioxide, carbon monoxide, etc. The release of GHGs compounds the problem of climate change.

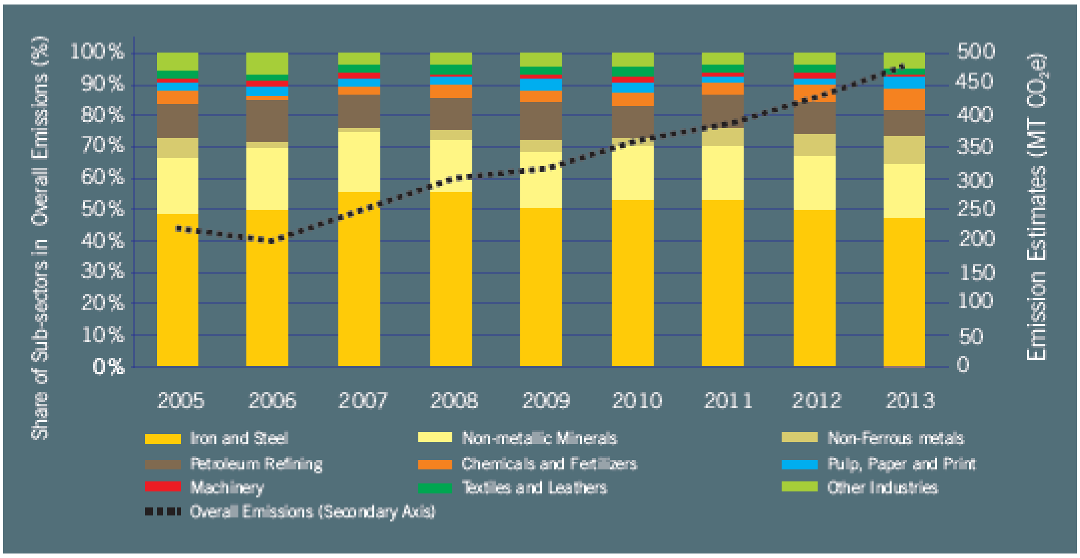


Figure 4: Trend of Greenhouse Gas Emissions by Various Industrial Sub-sectors in India

Source: GHG Platform India (2017)[11]

The manufacturing sector and in particular the iron and steel industry, cement plants, manufacture of sulfuric acid, and smelting of copper, zinc, lead ore, etc. are significant contributors of CO2 and SOx. Iron and steel had the largest share of emissions (38%), followed by non-metallic minerals (predominantly, cement) with a share of 29% in overall GHG emissions by various industrial sectors (Refer Figure 4). Further, GHG emission due to industry energy use has grown upwards at a rate of 10%, rising from ~217 MT in 2005, to ~ 467 MT in 2013.

Mining activities also lead to stress on water resources, whose availability and supply are limited in India. Major hydrological impact of a large and deep open-cast mine is on the groundwater regime of the region, which can result in lowering of the water table. The release of mining waste into local water bodies leads to water pollution, which effects local communities. The Damodar River in Jharkhand and West Bengal, for instance, have been severely polluted due to coal-mining activities. Similarly, mining in the mineral-rich Jaintia Hills district of Meghalaya has created an acute crisis of drinking water as the major rivers in the region have been contaminated and declared unfit for human use.

[11] Available at http://www.ghgplatform-india.org/Images/Publications/GHG%20Trend%20Analysis_2017_07%20Dec'17.pdf

1.4.3 Potential social impacts

With the mining activity, over the years, leading to large-scale destruction of forests, it has led to displacement of millions including many indigenous communities inhabiting the area, and their loss of livelihoods. In a study on the socio-economic impact of mining and mining policies on livelihoods of local populations in the Vindhyan region of Uttar Pradesh, it was found out that mining had a negative impact on adjoining forest, agriculture and was a major cause of pollution. There was direct negative impact on health mainly due to air, water and noise pollutions.[12]

This is a big challenge from human rights perspectives and poses enormous social risk. As reported by Downig (2011), in India the displacement due to mining activities accounted to over 2.55 million people between 1950 and 1990. The displacement which forces entire communities to shift elsewhere is not only limited to losing their homes, but also their land, and livelihoods. The resettlement of displaced communities is mostly in areas without adequate resources and areas close to mining operations full of pollution and contamination. Forced resettlement can be particularly disastrous for indigenous communities who have strong cultural and spiritual ties to the lands and forest of their ancestors and who may find it difficult to survive when these are broken (Singh et al., 2015). In Jharia Coalfields displacement is still a serious issue for their appropriate rehabilitation. In addition, the lack of adequate rehabilitation and resettlement policies, the migrants remain deprived of proper mechanisms to address their basic requirements to improve their livelihoods. Other associated social issues that people face are access to clean drinking water and health[13]. The GHG emissions increase due to mining and have negative impact on the environment, human health and the economy.

This enhancing Resource Efficiency and promoting the use of secondary raw materials (SRM) has emerged as a strategy for ensuring that the potential trade-off between growth and environmental well-being can be minimized. This strategy has the potential to stabilize raw material supply for industry, reduce pressures on the ecosystem and create many green jobs. Moreover, efficient use of resources has substantial economic benefits created through reduced costs linked to less extraction of virgin raw material and the reduced used of energy and process materials.

[12] https://www.niti.gov.in/writereaddata/files/document_publication/Socio-Economic-Impact-Study-of-Mining-and-Mining-Polices.pdf

[13] https://www.researchgate.net/publication/308937912_Environmental_and_social_impacts_of_mining_and_their_mitigation

2 Principles and Objectives

Resource efficiency encompasses a wide variety of technology, process, policy and institutional issues along the various life cycle stages that typically include mining, design, manufacturing, consumption, and end –of –life of products life cycles. In the context of realizing resource efficiency and circular economy, businesses have the opportunity to take the lead while the government can create enabling conditions for facilitating transition. The 6R principles[14] is a key to driving resource efficiency through reduce, reuse, and recycle, re-manufacture, repair and refurbish across different sectors/products and resources, thus necessitating a coordinated approach to strategy and action that brings together different stakeholders across multiple sectors.

Resource efficiency is a key idea which is emerging in political mainstream and has been one of the important discussion points in G20 Agenda, whereby G20 countries are integrating circular economy as part of implementation strategies for Sustainable Development Goals (SDGs). RE is recognized as a key element of Sustainable Development and therefore judicious use of resources will help in achieving SDG -12 on Sustainable Consumption and Production.

Significant improvements of resource efficiency are essential to meet climate goals in a cost-efficient manner. This would happen through both in reduction of greenhouse gas (GHG) emissions by means of mitigation approaches, or securing the sustainability of our food, water, energy and livelihoods through adaptation measures. Appropriate management of natural resources lies at the centre of virtually all viable solutions to climate change. Without significant improvements in resource efficiency, it will be difficult and substantially more expensive to keep average global warming below 2 degrees Celsius.

In line with the developmental imperatives, the focus of developmental policies in India has largely been on fostering economic growth with a special emphasis on poverty eradication. However, with sustained economic growth over the last two decades, it has also become amply clear that the environmental aspects should be mainstreamed into development policy to have sustainable development in the long run. There is a need for resource efficiency policies to address the entire life-cycle of products, as well as the need to align sectoral policies in diverse areas and create synergies between economic growth and environmental sustainability. This report presents the background and structure for developing India's RE policy framework.

[14] Joshi, K., Venkatachalam, A., Jawahir, I.S., 2006, A New Methodology for Transforming 3R Concept into 6R Concept for Improved Product Sustainability, in: Proceedings of the IV Global Conference on Sustainable Product Development and Life Cycle Engineering (Sa˜o Carlos, Brazil),

2.1 Objectives

The specific **objectives** of the policy should be:

- Identify hotspot sectors for resource efficiency in India
- Design and put in place interventions to promote resource efficiency and circular economy in identified areas
- Develop capacity and strengthen research and information systems for promoting resource efficiency and circular economy
- Create an institutional mechanism to achieve the above objectives as well as coordinate and synergize across sectors and tiers of government

2.2 Principles

To meet these objectives, the RE policy based on life cycle thinking should be based on certain principles:

- Promote economic growth that is sustainable and equitable (inter- and intra-generational)
- Create higher value with less material through RE and CE approaches
- Minimise waste creation and loss of embedded resources at the end of life of products
- Ensure security of supply and reduce import dependence for essential materials

3 Measuring Resource Efficiency

3.1 Understanding Resource Efficiency

A systematic transition towards a resource efficient economy implies the need for having quantifiable indicators, supported by a robust Monitoring and Evaluation Framework that can track resource consumption along the value chain of commodities/products and help to learn the associated impacts on the environment. In other words at different stages of the value chain of a product it is important to understand the amount of raw materials that extracted/consumed, the volume of waste that is generated and the output that will fetch revenue in the market. Having such indicators based on sectoral/resource specific data and their periodic assessment will help in tracking and monitoring incremental improvement and how the processes can be made for efficient and productive. While some of these indicators are currently used but they have largely been confined at the industrial or sectoral level for establishing benchmarks and undertake comparative assessment with an objective to achieve certain commercial outcomes. However, larger policy decision and monitoring will not only require customizing these existing indicators but at the same time developing additional indicators that can provide improved understanding and tracking of resource use along the production consumption chain.

Before a detailed overview of the indicators are presented, it is important to define what we understand by the term resource efficiency. A resource (or more commonly raw materials) is defined as a substance or a mixture of substances which have not been subject to any treatment besides detachment from its source. The objective of their extraction is because of its utility value for which it may be consumed directly in the natural form or is further processed to achieve provide desirable utility. If there is an improvement over an existing way a material is extracted, processed, consumed, and recycled, it can be said that we are increasing 'resource efficiency'. European Union defines resource efficiency as *'a means using the Earth's limited resources in a sustainable manner while minimising impacts on the environment. It allows us to create more with less and to deliver greater value with less input'.* UNEP (2009) defines resource efficiency from a life cycle and value chain perspective. This indicates reducing total *environmental impact of the production and consumption of goods and services, from raw material extraction to final use and disposal.*

Interestingly the aspect of resource efficiency can be assessed either using an output-to-input relationship or input-to-output relationship. Resource efficiency can be increased either by minimizing input or maximizing output by keeping the other variable constant. It is the former i.e. output to input relationship that is used as a common way of presenting resource efficiency.

$$\text{Resource Efficiency} = \frac{\textit{benefit (product, function)}}{\textit{input of (natural) resources}}$$

If the same benefit (numerator) is generated by a decreased input of natural resources (denominator), resource efficiency is achieved. Hence it is more of a relative concept than an absolute statement.

Although there can be various ways how resources can be classified, broadly, most literatures have classified them into four broad categories i.e. fossil fuels, biomass, water, metals, and non-metallic minerals. Consumption of resources can be divided in two ways: a physical unit, such as mass, length, area or volume; or in terms of their economic value which can be either reflect economic costs of production or may also include costs of externalities associated with production, consumption and disposal.

As mentioned above, the concept of resource efficiency is based on a life cycle perspective. In other words, there are opportunities for achieving resource efficiency at different stages of the life cycle. In a production consumption system, it is largely the materials that flow across the different life cycle stages and values are added at every stage to provide desired utility. Hence it is important to assess the flow of material resources and the same is achieved through a technique called Material Flow Analysis (MFA). While most of the resources are measured in in tonnes, resources like, land is usually measured in terms of areas (e.g. square metres or square kilometres) and water by its volume (e.g. cubic metres). Typically the time period for each assessment is often a year, although it can be customized depending on the availability of the data in the form of monthly or quarterly assessment for faster evaluation and review of policies and implementation of the interventions.

Undertaking an integrated assessment of a country’s resource consumption is a challenging task. Such challenge may arise from availability of adequate data, issues associated with data disclosure, choice of the tools, and so on. If we briefly try to understand why such framework was established, it can be learnt that such development of framework happened in response to the understanding that many of the most pressing environmental problems were strongly related to the overall scale of resource extraction and use. These material flows comprise the extraction of materials inside the economy and physical imports and exports, their processing, domestic consumption as well as physical exports of semi-finished and products.

Environmental indicators can also be considered but typically, they are not used in economy wide MFAs for reasons arising from adequate availability of data, reliable data. They can however be undertaken for hotspot analysis. The environmental indicators can be divided into two broad categories: those that **measure pressures on the environment** (for example, emissions to air, land and water, or absolute of rate of loss of certain habitat), and those that

measure the state of the environment (for example, air, soil or water quality, or the number of species in the habitat).

It is extremely important to define the boundary conditions particularly when it comes to assessment of environmental indicators. An environmental indicator at the national level may refer to resource use and assessment of environmental consequences resulting from economic activity only in the geographical area under consideration. When it comes to assessing full resource and environmental outcomes associated with resource production and consumption in the geographical area in question, then they are largely represented through the concept of the "footprints". In related environmental and economic literatures, footprints are largely calculated for land (e.g. land required for the production of biomass, extraction of minerals, etc.), water, materials (metals and minerals) and carbon dioxide. In the context of MFA, the assessments are largely confined to use of resource indicators, although environmental assessment through hotspot analysis of products (or even for sectors) can be considered.

Economy wide MFAs, their material/resource balances, and the associated indicators derived from them are tools aiming to provide information on the quantum of materials coming into and leaving a system which can be a society or an economy. They are conceptually based on a simple environment-economy model where the economy is embedded in the surrounding environment and connected through material and energy flows. Terms such as "industrial metabolism" or "societal metabolism" (Ayres 1989; Fischer-Kowalski & Haberl, 1993) have been used to illustrate such flows, and the scale of impact on the environment can be indicated by the size of the "metabolic throughput" (i.e. the amount of materials used or appropriated from the environment and returned back in a different altered form) (Daly, 1992). The material balance principle provides a logical basis for the physical book-keeping of the economy-environment relationship and for the consistent and comprehensive recording of inputs, outputs and material accumulation.

The principles and numerical approaches towards accounting and measuring material flows and their balances more at a national level were developed as early as the 1970s. Research has advanced over the years, as have efforts to standardise approaches and formats. The approaches have experienced revisions, over the last two decades and have also been put to application in several EU member states (Steurer, 1992; Schutz & Bringezu, 1993; German Federal Statistical Office, 1995; Eurostat, 1997). Further countries like Japan and USA too have undertaken such assessment on pilot levels. (Japanese Environmental Agency, 1992 & Wernik et al.,1996). Recent literatures like "Resource Flows: The Material Basis of Industrial Economies" (Adriaanse et al., 1997) and "The Weight of Nations: Material Outflows from Industrial Economies" (WRI, 2000) have also used internationally comparable data based on harmonised approaches. Indicators for materials flows through the economy feature prominently on the political agenda in the context of concepts such as "factor 10" (Schmidt-Bleek, 1994) or "eco-efficiency". The EU Environmental Headline Indicators as well as the

United Nations Indicators for Sustainable Development include a resource use or material consumption indicator based on a materials balance approach. The European Environment Agency (EEA), in its "Environmental Signals 2000" report included a first experimental estimate of Total Material Requirement (TMR) for the EU (EEA, 2000). The OECD as well as the UNEP has created programs and panels on materials flows and resource productivity within the last decade. The European Commission's Directorate General for the Environment collaborates with Eurostat and the EEA to compile and update standardised methodologies and develop environmental headline indicators one of which is based on materials balance (Eurostat, 2001).

A major step towards methodological harmonisation was the publication of Economy-wide Material Flow Accounts and Derived Indicators: A Methodological Guide (Eurostat, 2001). The report Materials Use in the EU-15: Indicators and Analysis (Eurostat 2002), presented the first official MFA dataset for the EU-15 and provided detailed information on accounting methods. Standardised methodologies are updated at regular intervals and guides are made publicly available for practitioners and researchers (for example, see, Eurostat, 2009; 2013; and OECD, 2007). In recent years, this methodology has been used to conduct some initial assessments of materials used in several Asian countries including India (see, UNIDO, 2010; 2011; Singh et al. 2012; IGEP, 2013). A recent report of International Resource Panel titled 'Resource Efficiency: Potential and Economic Implications', has presented a detailed overview of the relevant resource based indicators for MFA as well as key environmental indicators.

3.2 Key indicators for measuring RE

Economy-wide MFA and balances provide an aggregate overview, in tonnes, of annual material inputs and outputs of an economy including inputs from and outputs to the environment and the physical amounts of imports and exports, as well as embodied/upstream flows associated with imports/exports. The net stock change (net accumulation) is equal to the difference between inputs and outputs. Economy-wide MFA and balances constitute the basis from which a variety of material flow based indicators can be derived. A complete material balance for an economy is statistically difficult to achieve since not all material input and output flows are observed in a systematic way; some material flow categories must be estimated. This method can be used to calculate the physical flows of an economy, or just be restricted to certain categories of flows. Two types of system boundaries are recognised: one between the national economy and the natural environment, the other between the national economy and the rest of the world economy.

Extraction of primary materials from and discharge of materials to the national environment are covered, as are material flows to and from the rest of the world (imports and exports). Natural flows into and out of a geographical territory, such as air and precipitation, are excluded. Material flows within the economy are not analysed in economy-wide MFA;

however, they can be calculated in parallel if, say, analysis of a specific industry sector is required. Direct material inputs are defined as all materials that enter the economy for further use in production or consumption processes. The two main categories of raw materials are those that are domestically extracted and those that are imported. Similarly, outputs include outputs to nature/environment and exports. Outputs to the environment are defined as all material flows entering the natural environment, either during or after production or consumption processes. Such outputs include emissions to air and water, waste landfilled, disposal of unused domestic extraction.

In economy-wide MFA and material balance calculations, "hidden" flows are often captured by distinguishing between used and unused extraction. Materials that are extracted but not actually used by the economy may include mining overburden or soil excavation during construction. Such domestic hidden flows are termed "domestic unused extraction". Similarly, researchers may choose to account for unused extraction associated with imports occurring in foreign countries.

It is important to note that MFA is a flow concept, measuring flows of material inputs, outputs and stock changes within the national economy per year. This means that in MFA, stock changes are accounted for but not the quantity of the socio-economic stock itself. Again, individual studies focusing on, say a particular industry or sector, can choose to analyse that sector's stock depending on the scope of the study.

A diagrammatic representation of economy-wide MFA is depicted in Figure 5. The figure includes input and output flows, including unused extraction, as well as the stock. Input materials, whether domestically extracted (DE) or imported, can be further disaggregated into, e.g., fossil fuels, metal ores, industrial minerals, construction minerals and biomass. Each of these broad material groups can be further broken down, e.g., fossil fuels into fuel types, biomass into timber, agricultural harvest, fish catch, etc. Output includes exports as well as domestic processed output (DPO) which includes materials flowing to the environment after being used in the domestic economy.

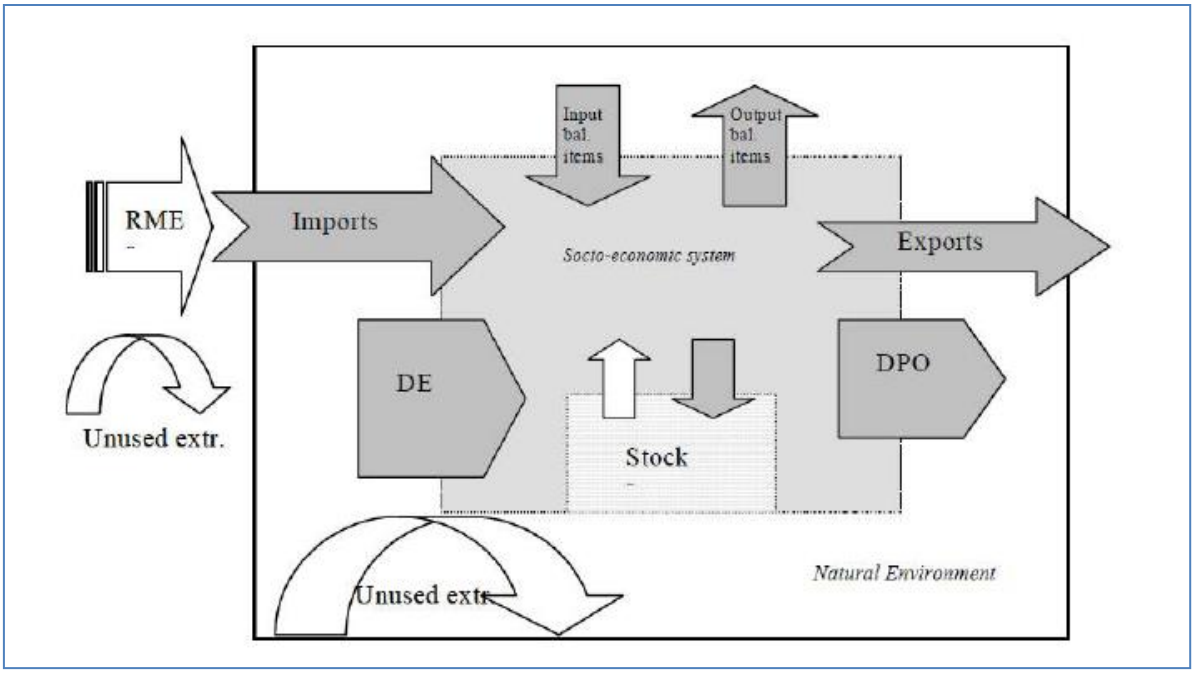


Figure 5: representation of economy-wide MFA

Source: GIZ-TERI-DA 2015

3.2.1 Input Indicators

Based on an extensive review of literatures, a broad list of resource use related indicators that can be used in MFA is presented in figure 6.

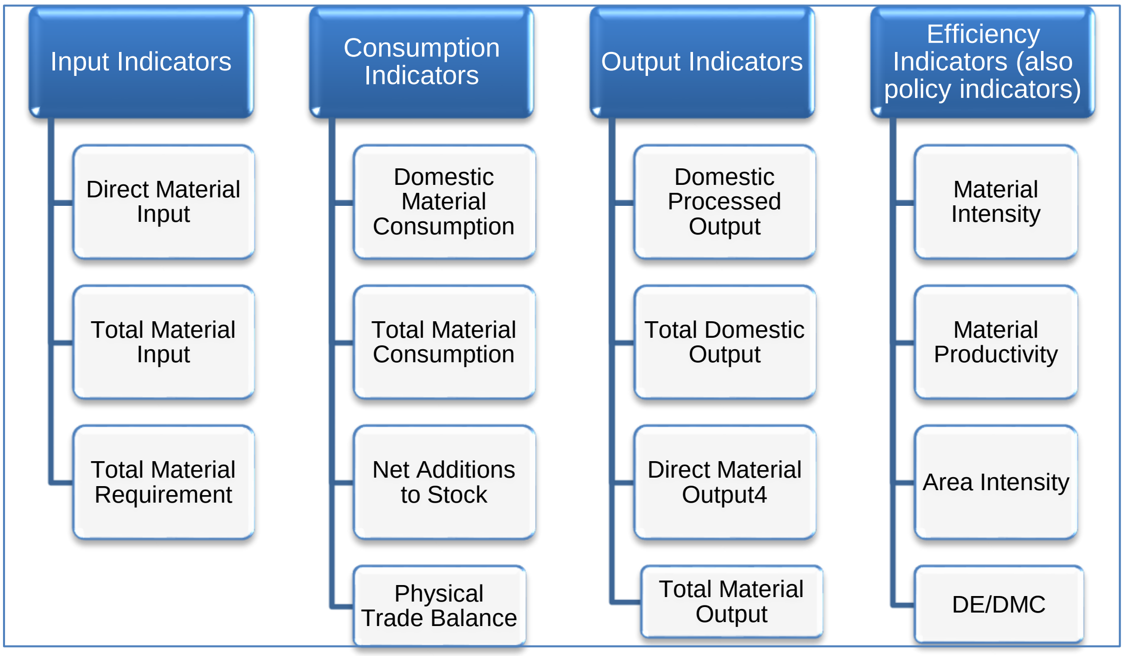


Figure 6: Possible list of indicators across selected stages of the life cycle for measuring RE

Source: **UNEP (2017)[15], IGEP (2013)**

15 http://www.resourcepanel.org/sites/default/files/documents/document/media/resource_efficiency_report_march_2017_web_res.pdf

3.2.2 A brief description of the indictors

3.2.2.1 Input Indicators

Direct Material Input (DMI): measures the direct input of materials for use into the economy, i.e. all materials which are of economic value and are used in production and consumption activities. DMI equals domestic (used) extraction plus imports.

Total Material Input (TMI): includes, in addition to DMI, unused domestic extraction, i.e. materials that are moved by economic activities but that do not serve as input for production or consumption activities.

Total Material Requirement (TMR): includes, in addition to TMI, the (indirect) material flows that are associated to imports but that take place in other countries. It measures the total "material base" of an economy. Adding indirect flows converts imports into their "primary resource extraction equivalent".

3.2.2.2 Consumption Indicators

Domestic Material Consumption (DMC): measures the total amount of material directly used in an economy (i.e. excluding indirect flows). DMC equals DMI minus exports.

Total Material Consumption (TMC): measures the total material use associated with domestic production and consumption activities, including indirect flows imported but less exports and associated indirect flows of exports. TMC equals TMR minus exports and their indirect flows.

Net Additions to Stock (NAS): measures the "physical growth of the economy", i.e. the quantity (weight) of new construction materials used in buildings and infrastructure, and materials incorporated into new durable goods such as cars, machinery and household appliances. Materials are added to the economy's stock each year (gross additions), and old materials are removed from stock as buildings are demolished, and durable goods disposed of (removals).

Physical Trade Balance (PTB): measures the physical trade surplus or deficit of an economy. PTB equals imports minus exports. Physical trade balances may also be included for indirect flows associated to imports and exports.

3.2.2.3 Output Indicators

Domestic Processed Output (DPO): the total weight of materials, extracted from the domestic environment or imported, which have been used in the domestic economy, before flowing to the environment. These flows occur at the processing, manufacturing, use, and final disposal stages of the production-consumption chain. Included in DPO are emissions to air, industrial and household wastes deposited in landfills, material loads in wastewater and materials dispersed into the environment as a result of product use (dissipative flows). Recycled material flows in the economy are not included in DPO.

Total Domestic Output (TDO): the sum of DPO, and disposal of unused extraction. This indicator represents the total quantity of material outputs to the environment caused by economic activity.

Direct Material Output (DMO): the sum of DPO and exports. This indicator represents the total quantity of material leaving the economy after use either towards the environment or towards the rest of the world.

Total Material Output (TMO): measures the total quantity of material leaving the economy. TMO equals TDO plus exports.

3.2.2.4 Efficiency Indicators

Material Intensity is defined as the DMC to GDP ratio. Material Productivity is the inverse of material intensity, thus the GDP to DMC ratio.

Material Productivity is the inverse of material intensity and is ratio of GDP to DMC.

Area Intensity: DE or DMC to total land area ratio: The ratio between material flows and total land area indicates the scale of the physical economy vis-à-vis its natural environment.

DE/DMC: The ratio of domestic extraction to domestic material consumption indicates the dependence of the physical economy on domestic raw material supply. Therefore, the DE to DMC ratio represents "domestic resource dependency" (see Weisz et al., 2006).

3.2.2.5 Use of New Indicators

While the economic system and traditional indicators are concerned with materials directly used, imported or exported, an increased focus on resource efficiency has elevated the importance of in the economy. Capturing indirect flows with consistent empirical data is extremely challenging.

Raw Material Equivalents (RMEs) are increasingly used to count trade flows including the upstream material requirements that were associated with their production. All materials, used to produce the export within the boundaries of domestic extraction used are included in RME calculations. By doing this, the system boundaries are nearly the same as system boundaries of economic accounting. It is important to note that the concept of RME refers only to "used materials"—that is, those material flows that enter economic processes. The other component of these indirect flows, unused extraction, is not included in RME and, despite its ecological relevance, is not considered here. Material inputs included in RME are therefore necessary to produce an output. A certain portion of such inputs, however, is embodied in the final outputs, whereas the rest of the material is dissipated along the production chain or recycled[16]. Consequently, the following indicators are now considered more useful for material flow accounting (Eurostat, 2014):

[16] Munoz et al. ˜ , Raw Material Equivalents of International Trade; Available at https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1530-9290.2009.00154.

Raw Material Input (RMI) in place of DMI: includes domestic extraction and imports plus raw material equivalents of materials associated with the given imports within the system boundaries of domestic extraction used.

Raw Material Consumption (RMC) in place of DMC: similar to DMC but counts imports and exports in raw material equivalents.

3.2.3 Role of these indicators in the Indian context

There is no doubt that there is a growing attention and interest to achieve resource efficiency in developed and developing countries since RE not only create economic opportunities but also have significant environment and social benefits. Given its significant relevance as explained in detailed in chapter 1, there is need to identify methods and framework for measuring the same and monitoring the progress over time. Some of the critical questions that need answers are what indicators should be selected, at what levels, and from where will the data come. Some of the above indicators as mentioned in the previous section may be easy to estimate since there may be relevant data already available in physical units. For example the amount of ores extracted domestically and processed for production of semi finished products like crude metal. At the same time, the quantity of crude metal throughput in processing industries and the materials contained in finished product can be used for measuring various input and output indicators (including estimated volume of waste generated along the value chain).

Accessing data with regard to conversion of ores/concentrates to raw material can be relatively easy since these processes are standardized and the conversion ratios are publicly available. There are however challenges associated with accessing input and output data in various engineering/fabrication and end use products manufacturing industries. Further consumption of indirect resources including water is often unavailable in the public domain. Hence suitable assumptions need to be used atleast in the initial years for estimating various output indicators, including resources wasted or discarded in processing industries before there data collection is made more robust and industries are willing to share estimates of the same. There is a need to create an inventory of information of waste that is generated along the value chain in major sectors/products if not for the entire economy and the state pollution control boards can play and instrumental role in this regard. This inventory template could be created in consultation with the different Line Ministries and Departments and the information collected for this template could be put in the public domain.

Given that India's manufacturing sector is dominated by vast small and medium enterprises, accessing data will prove extremely challenging. These estimates will help in developing efficiency indicators like material intensity and material productivity. In case of use of recycled materials in manufacturing products, the quantum of use of recycled resources will help in estimating the decline in reliance of the primary/virgin materials. The targets against these indicators however need to be introduced over time. While it can be initiated with modest targets for selected sectors that are large and resource intensive, such targets need to be strengthened and their coverage need to widened over time.

Finally consumption of different resources across sectors will help in estimating domestic extraction, imports and exports as well as derived indicators like DMI and DMC. This can further be used in measuring resource efficiency as GDP per DMC. As long as India is self reliant the difference between DMC and RMC will be negligible. It is important to mention that RMC includes domestic consumption and imports. However, overtime, it is recommended that RMC approach is adopted as a key indicator. India has lower RMC than DMC since exports are higher than imports in raw material equivalent terms. Since RMC is an indicator that is used across other countries, hence a gradual transition towards this will help in comparative assessment[17].

With regard to indicators for waste and recycling, it is important to arrive at recycling rates of specific waste fractions like metals or construction based on sectoral, regional and then at the country wide assessments and these can be considered as important mid-point indicator that could be used to measure RE, till more concrete and specific indicators are arrived at. And all the indicators and estimates finally need to be fit in the wider definition of RE as mentioned above.

[17] https://eeas.europa.eu/sites/eeas/files/na_eu_restrategy_nov2017.pdf

4 International RE related policies/strategies - A Review

4.1 Introduction

With motivation to secure material supply and reduce degradation of environment, countries have designed legislative framework for resource efficiency (RE) to guide their country towards resource efficient economic growth. In this chapter, dedicated national resource efficiency policies and strategies as developed by different countries are reviewed.

For Asia-Pacific region, RE strategies of China, Japan and South Korea are reviewed. In Europe, five countries - Austria, Denmark, Finland, Germany and Netherland - have dedicated national strategies for material resource efficiency or circular economy. France has announced Circular Economy Roadmap in 2018 which is to be put before Parliament in 2019. Belgium and United Kingdom have regional resource efficiency strategies. Most countries incorporate material use and resource efficiency in a wide variety of other strategies and policies, including on waste and energy, industrial development and reform programmes, or in national environmental strategies. RE strategies of Austria, Denmark, Finland, Germany and Netherland (Europe) along with overarching European region policy, and United States of America are reviewed.

4.2 International Resource Efficiency Strategies

4.2.1 Asia - Pacific

4.2.1.1 China[18,19]

China has enacted **Circular Economy Promotion Law (2009) and Circular Economy Development Strategy and Immediate Plan of Action (2013)** enabling its transition to resource efficient development. China defines resource efficiency under the concepts of circular economy and 3R (reduce-reuse-recycle) that refers to the reduction of resource consumption and waste generation while reuse and recycling mainly involves wastes. Circular Economy Promotion Law (2009) approaches the ideas of resource efficiency through cleaner production and integrates it into the economic system. It is pursued through pilot projects, policy reform and other activities. The law stipulates no measurable and quantitative targets. Circular Economy Development Strategy and Immediate Plan of Action (2013) establish sector-specific development targets (for Five Year Plans) and detailed guidance for development and safeguard measures for circular economy. The action plan

[18] IINAS, 2013. Elaborating the International Discussion on Resource Efficiency (ENTIRE): Part I: Resource Efficiency Policies in Various Countries Annex Report.
[19] Xin Y., 2016. China's Practice in Improving Resource Efficiency. National Development and Reform Commission of China

sets measures as to carry out demonstration pilots, popularize green consumption, improve policies and systems, carry out examination and assessment, change growth patterns and strengthen structural reform of the supply front.

Circular economy practices are implemented at enterprise, industry and regional level with different objectives carved for actors at each level.

- **Enterprise level -** Cleaner production promoted by integration of higher efficiency methods to reduce the consumption of materials and energy in products and services.
- **Industry level -** Reuse and recycle resources so that resources will circulate fully in the local production system, eco-industrial chains are established, industrial metabolism and symbiosis relationship are formed among enterprises. Government encourages the development of Eco Industrial Parks (EIPs) and has outlined various national guidelines, through the State Environmental Protection Administration (SEPA).
- **Regional level -** Integrate efficient production and consumption systems on a regional scale by understanding material flows in a region and developing efficiency increase measures such as the development of municipal by-product collection, storage, processing, and distribution systems.

Indicators:

- Material - material flow, material intensity, water use intensity
- Energy intensity (amount required per unit of economic output)
- Land use intensity (rural land use/urban land use/managed land use intensity)
- Pollutant related indicator sets (air, water, solid waste, etc.)
- Resource and environment performance index (REPI) - combines data on industrial resource-use and pollution, and measures them against GDP to create national and regional measures
- Input indicators - Direct Material Input (DMI), Total Material Requirement (TMR)
- Output indicators - Domestic Processed Output (DPO)
- Consumption indicators - Domestic Material Consumption (DMC) , Total Material Consumption (TMC)
- Balance indicators - Physical Trade Balance (PTB), Net addition to Stock (NAS)

Policy instruments: Policy instruments mainly include command-control, tax, fiscal, financial, and pricing measures, and focus on upgrading industrial structures, cleaner production, recycling and comprehensive utilisation of waste materials, and exploitation and utilisation of resources and energy. Such instruments include legislation, policy reform, pilot projects, and monitoring and evaluation activities. Certain economic policy instruments are natural resource pricing, environmental fees to reduce externalities, taxation (eg. consumption tax on fuel, large vehicles, plastic bag etc.), public financing etc. Regulatory policy instruments are for example green public procurement, energy efficiency in building and products among others.

Outcomes:

- Resource Productivity (2010 - 2015) increased by more than 15%.
- Energy, Water and Built-up Land Consumption per unit GDP (2010 - 2015) decreased by 13.3%, 24.2% and 22.4%, respectively.
- Resources Recycled (2014) exceeds $ 1.5 trillion with 2.45 hundred million tons recycled resources. Non-ferrous metals and pulp industry sector uses 20% to 50% of raw materials from recyclable resources.

4.2.1.2 Japan [20,21,22]

Japan established a law-setting framework, the **Fundamental Law for Establishing a Sound Material-Cycle Society (2000)** to overcome the challenges with waste and resources. Based on the Fundamental Law, the **Fundamental Plan for Establishing a Sound Material Society (2003)** was first set up. Fundamental Law for Establishing a Sound Material-Cycle Society (2000) aims to ensure material recycling in society, to reduce consumption of natural resources and to reduce environmental burdens. To establish the resource efficiency scheme, the Waste Management Law and Law for Promotion of Effective Utilization of Resources were implemented. Additional regulations covering end-of-life treatment of separate products/materials such as packaging, home appliances (refrigerator, washer, air conditioner and television set), food, construction material and vehicles were also subsequently approved. Fundamental Plan for Establishing a Sound Material-Cycle Society is regularly revised and forms the basis of other national plans.

Indicators:

Three indices at different phases of the material flow are established:

- **Entry -** Material productivity representing effective use of material (how much affluence is produced with less resource)
- **Recycled -** Usage rate of recycled goods representing how much resources input are in cyclically used (reuse and reuse after treatment)
- **Exit -** Final Disposal Amount of final disposal (land-filled waste)

[20] Tanaka I., 2008. Promotion of Resource Efficiency in Japan. ITPS.
[21] Government of Japan, 2010. Establishing a sound material-cycle society. Ministry of Environment, Government of Japan.
[22] Gao L., 2016. An Analysis on Japan's Circular Economy and Its effects on Japan's Economic Development. International Business and Management, 13(2), 1-6.

Additional Supplementary indicators for target setting are:

1. Resource productivity not including resource input of soil and stone
2. Collaboration with the action for low carbon society
    i. amount of reduction by the measures of waste sector to reduce GHGs Emission
    ii. GHGs emission associated with waste sector and fossil fuels to be substituted by waste power generation

Policy instruments: Government supports the activities to form a recycling-oriented society through funds, administrative services, by taking lead to practice green procurement and other actions to promote circular economy. The Japanese central government has established a good partnership with the local governments, enterprises, organizations and citizens. It has developed complete laws and regulations and adopted a variety of effective and comprehensive measures to promote the implementation.

Outcomes:

- Resource productivity at 361,000 yen/ton in year 2007 has increased by 37% from year 2000.
- Recycling rate at 13.5% in 2007 has increased by 3.5% from year 2000.
- Final disposal volume of wastes at 2.7 million tons in 2007 has increased by 53% from year 2000.

4.2.1.3 South Korea[23]

Korea has adopted various policy instruments to transform a linear economy into a circular one. Related policy actions are **Resource Efficiency Programme (REP), Energy Recovery Programme (ERP) and Recycling Technology Programme (RTP).** Resource Efficiency Programme (REP) aims to reduce the amount of resource required to provide products and services. For that purpose REP tries to manage the quantity of raw materials used to convert energy into GDP. It tries to adopt a more efficient production process and/or to recycle resources. The programme is based on the Rational Energy Utilization Act. Energy Recovery Programme (ERP) aims to increase demand and supply of energy from waste. The National Strategy for Green Growth has a target of increasing the share of renewable sources. Recycling Technology Programme (RTP) focuses on developing cutting-edge, converged recycling technology. RTP aims to lower the share of resource-intensive industry in GDP. The Key Green Technology Development and Commercialization Strategies (2009) designed as a road map to develop green (including recycling) technologies. More recent recycling efforts include setting of recycling target rates, the extended producer responsibility list, the

[23] Jin I., 2016. Circular Economy Policy in Korea, in Anbumozhi, V. and J. Kim (eds.),Towards a Circular Economy: Corporate Management and Policy Pathways. ERIA Research Project Report 2014-44, Jakarta: ERIA, 163-184.

shared responsibility of distributors with producers, and the better collection system by local governments.

Outcomes:

- REP - Energy intensity of the economy (2012) dropped 5.5% since 2008.
- Share of energy from non-renewable waste (2012) raised to 1.05% from 0.89% in 2008.
- Green Technology R&D (2009 - 2013) increased at compound annual growth rate of 11.7%.

4.2.2 Europe[24,25,26,27]

A resource-efficient Europe - Flagship initiative under the Europe 2020 Strategy (2011) sets a framework for policies to support policy shift of member countries towards resource efficient and low-carbon economy through long-term strategies in areas such as energy, climate change, research and innovation, industry, transport, agriculture, fisheries and environment policy. The initiative called for a roadmap to define medium and long term objectives and means needed for achieving them. Roadmap to a Resource Efficient Europe (2011) sets out a vision for the structural and technological changes needed up to 2050, with milestones to be reached by 2020 to put Europe on a path to resource efficient and sustainable growth. Closing the loop: **An EU action plan for a Circular Economy (2015)** establishes a concrete and ambitious programme of action, with measures covering the whole cycle - from production and consumption to waste management and the market for secondary raw materials.

Roadmap to a Resource Efficient Europe (2011)

Roadmap sets a vision of resource efficient growth of EU's economy that provides a high standard of living with much lower environmental impacts by 2050. This requires that the stocks of all environmental assets from which the EU benefits or sources its global supplies are secure and managed within their maximum sustainable yields, residual waste is close to zero, ecosystems have been restored and systemic risks to the economy from the environment have been understood and avoided.

Indicators:

Two levels of indicators are provided:

- Lead indicator 'Resource Productivity' - to measure the principal objective of this Roadmap, of improving economic performance while reducing pressure on natural resources;

[24] European Commission, 2011. A resource-efficient Europe - Flagship initiative under the Europe 2020 Strategy.
[25] European Commission, 2011. Roadmap to a Resource Efficient Europe.
[26] European Commission, 2015. Closing the loop - An EU action plan for the Circular Economy.
[27] EEA, 2016. Country profile: More from less - material resource efficiency in Europe. European Environment Agency.

- Series of complementary indicators on key natural resources such as water, land, materials and carbon that will take account of the EU's global consumption of these resources.

Approach:

- Sustainable Consumption and Production
- Turning waste into a resource
- Supporting research and innovation
- Phasing out environmentally harmful subsidies and getting the prices right
- Setting proper value of natural capital and ecosystem services

Key sectors: Food, buildings and mobility

Closing the loop - An EU Action Plan for the Circular Economy (2015)

The Action plan supports the circular economy in each step of the value chain i.e. from production to consumption, repair and remanufacturing, waste management, and secondary raw materials that are fed back into the economy. The actions proposed are to be taken forward in line with better regulation principles, and subject to appropriate consultation and impact assessment.

- **Production** to be approached by better product design, efficient production process and promotion of innovative industrial processes eg. Industrial parks.
- **Consumption** to be approached by improved labelling system, incentives and taxation to reflect environmental costs in product price, waste avoidance by reuse and repair, waste prevention, sharing products or infrastructure, green public procurement.
- **Waste management** to be approached by increased recycling targets, improved waste collection, high quality recycling, reduced landfill target, extended producer responsibility schemes, pay-as-you-throw schemes, waste-to-energy for non-recyclable wastes.
- **From waste to resources - boosting the market for secondary raw materials and water use** to be approached by high quality recycling, setting standards for secondary raw materials, recognition of organic and waste based fetilisers, water efficiency measures, safe and cost effective reuse of treated waste water, promotion of non-toxic material cycles and better tracking of chemicals, facilitation of cross border circulation of secondary raw materials, market (demand) driven initiatives.

Priority areas: Plastics, food, critical raw materials, construction and demolition, biomass and bio-based products.

RE strategy objectives in European countries

The EU is estimated to have adopted more than 200 pieces of environmental legislation since the 1970s. More than a third (38 %) of general policy objectives refer to waste management, including recycling, recovery and a circular economy approach. 17 % of the reported objectives can be regarded as specific to material resource use, while 14 % address economic considerations, and another 14 % refer to managing energy more efficiently and increasing the share of renewables in overall energy consumption. Of reported policy objectives, 12 % focused on the conservation of natural resources such as biodiversity, forests, water, land, and marine resources, which are largely outside the scope of material resources. Societal interests were emphasized by 5 % of the reported policy objectives.

Policy instruments in European countries

Among the policy instruments reported by member countries, economic and financial instruments are reported most often (43%), followed by regulatory (27%) and information-based instruments (17%) in second and third place. Economic and financial instruments typically include taxes and fees, grants, awards, investment or financial support schemes. Regulatory instruments typically include laws or decrees, including bans on the use of certain substances, and design and performance or quality standards, regulations on producer responsibility, among others. Information-based instruments typically include campaigns, eco-audits, training and education, various eco-labels etc.

4.2.2.1 Austria[28]

Austria has a dedicated national resource efficiency strategy **(Resource Efficiency Action Plan - REAP, 2012)**. Building on the **REAP the Reset 2020-Resources.Efficiency. Technologies** initiative has been developed with aim to implement resource efficiency in the areas of environmental technologies, sustainable production and sustainable consumption. Increasing material efficiency is the main focus of measures under REAP. However, increasing energy, water, land-use efficiency and reducing environmental impacts on air and other natural resources is always part of the activities. Resource Efficiency Action Plan - REAP (2012) aims to considerably reduce the consumption of natural resources and realise the benefits for environment, economy and society that can be gained by resource efficiency improvements. It identifies major fields where action is required, sets targets and introduces instruments and measures for a concrete increase in resource efficiency. Fields of action so identified are resource efficient production, public procurement, circular economy and raising awareness.

Priority materials and sectors: Food, construction materials, biomass, fossil fuels, packaging materials, mass metals, production industry, wood industry, industries that use critical materials (mainly the high-value metal industry, car industry, renewable energy industry and electronics industry) and the repair/reuse sector, food and housing.

[28] EEA, 2016. Country profile - Austria: More from less - material resource efficiency in Europe. European Environment Agency, 2016.

Indicators:

REAP defines resource efficiency as the ratio between monetary output and input of natural resource/materials, comprising energy, water, air and land.

- GDP/DMC - gross domestic product generated per unit of domestic material consumption
- domestic material intensity (DMI), domestic material consumption (DMC) and raw material consumption (RMC) of biomass, metals, minerals and fossil fuels

Policy instruments: In most cases the programme is a mix of regulatory, economic, financial and information-based instruments and voluntary agreements. Strong regulatory instruments such as bans should be applied when protection against hazardous substances is needed. Information and motivation/awareness raising are necessary under all circumstances.

4.2.2.2 Denmark[29,30,31,32]

Denmark has resource strategy and plan for waste management **(Denmark Without Waste, Recycle more - Incinerate less, 2013)** and waste prevention strategy **(Denmark Without Waste II, Strategy for Waste Prevention - 2015)** that partly cover the theme of more efficient use of resources. Recently, Denmark has adopted **Strategy for Circular Economy, 2018** aiming to transform society towards sustainable path. Material resource efficiency policies and strategies in Denmark are closely related to considerations regarding job creation/employment, competitiveness as well as ensuring sustainable use of natural resources and reducing environmental impacts. Denmark without waste - recycle more, incinerate less (2013) advocates to incinerate less waste and be better at exploiting the value and resources it contains, reduce environmental impacts from waste, high quality recycling, stronger public-private collaboration in regards to waste management. Denmark without waste II - Strategy for Waste Prevention (2015) advocates prevention of production of waste among companies and consumers. The strategy contains 72 specific initiatives to help prevent waste, spread across five focus areas of food waste, construction and demolition, clothes and textiles, electronics and packaging. Strategy for Circular Economy (2018) sets 15 initiatives for transition to more circular economy - promoting circular business development in SMEs, setting up single point of entry to the authorities, expanding access to finances, supporting digital circular options, incorporating circular economy into product policy, participation in European work on circular standards, circular procurement, focus on total cost of ownership in public procurement, level playing field on waste market,

[29] EEA, 2016. Country profile - Denmark: More from less - material resource efficiency in Europe. European Environment Agency.
[30] The Danish Government, 2013. Denmark without waste: Recycle more - incinerate less.
[31] The Danish Government, 2015. Denmark without waste II - Strategy for Waste Prevention.
[32] The Danish Government, 2018. Strategy for Circular Economy.

liberalising WEEE management, fund for handling regulatory barriers, voluntary sustainability class, selective demolition, more value out of biomass.

Priority materials and sectors: Construction materials (e.g. bricks), wood, electrical and electronic equipment, food, textiles, packaging and food waste, manufacturing, construction & demolition

Indicators:

At sectoral level, indicators include among others Gross Value Added GVA/input (DKK), purchase of input materials (DKK) as %age of turnover (DKK), intensity of energy use (GJ) and waste production (kg) per GVA. These gives detailed information for the different sectors. At national level Denmark also use DMC to measure material resource use in tonnes.

Policy instruments: Mix of policy instruments. Examples include: Taxes and charges in order to for example prevent production of waste, eco-labelling, green public procurement, fund for green business development, eco-innovation program, and task force for increased resource efficiency

4.2.2.3 Finland[33,34]

Finland has a dedicated resource efficiency strategy **(National Material Efficiency Programme 2014)** and several other strategies that are strongly linked to the themes of material efficiency. Material efficiency in production means the sparing use of natural resources, the effective management of secondary flows and wastes, a reduction in the volume of waste and the recycling of materials at different phases of a product's life cycle. National Material Efficiency Programme (2014) with goal of *'sustainable growth through material efficiency'*, aims simultaneously at economic growth, the sensible use of natural resources, and disengagement from harmful environmental effects. The Programme proposes that a research and innovation programme be established to increase knowledge, improve the flow of information and create synergy between different players. From Recycling to a Circular Economy - National Waste Plan to 2023 (2018) has four key areas of construction and demolition waste, biodegradable waste, municipal waste, and waste electrical and electronic equipment.

Priority materials and sectors: water, forests, minerals and other natural products, energy carriers like fossil fuels, and renewable and indigenous energy sources, resources used in construction and the built environment, waste (prevention, recycling, reuse), bio-economy (timber construction, food industry, chemical industry, health sector, service industry, clean-tech business)

[33] EEA, 2016. Country profile - Finland: More from less - material resource efficiency in Europe. European Environment Agency.
[34] The Finnish Environment, Ministry of the Environment, 2018. From Recycling to a Circular Economy - National Waste Plan to 2023.

Indicators: Although compiled, indicators based on material flow accounting (MFA), such as domestic material consumption (DMC) and raw material consumption (RMC) are not currently used for monitoring policy implementation in Finland.

Policy instruments: Regulatory and economic instruments have been seen to be the most effective, eg. energy efficiency measures (promoting energy services and the energy efficiency of equipment, buildings and vehicles; trading in carbon dioxide emissions; obligatory renewable energy targets), promotion of sustainable environmental and energy solutions in public procurement, drinks packaging tax (not applicable to packaging covered by approved returnable deposit systems)

4.2.2.4 Germany[35,36]

Germany has a dedicated strategy for material resource efficiency **(German Resource Efficiency Program - ProgRess 2012, renewed with German Resource Efficiency Program - ProgRess II, 2016)** and several other strategies that are strongly linked to the themes of material efficiency. Current overarching aim is the decoupling of economic growth from raw material use and environmental impacts, through reduced and efficient use of raw materials. German Resource Efficiency Program - II (2016) covers the entire value chain and is aimed at safeguarding a sustainable supply of raw materials, enhancing resource efficiency in production, making consumption more resource-efficient, expanding a resource-efficient circular economy and making use of overarching instruments. It also promotes joint analysis of energy and material efficiency to identify potential synergies and avoid conflicting goals. It is based on four guiding principles:

- joining ecological necessities with economic opportunities, innovation support and social responsibility
- viewing global responsibility as a key focus of our national resource policy
- gradually making economic and production practices in Germany less dependent on primary resources, developing and expanding closed-cycle management
- securing sustainable resource use for the long term by guiding society towards quality growth.

Priority materials and sectors: Energetic and non-energetic raw materials, biomass (energy, industry, chemicals), wood, manufacturing, waste management and recycling, chemicals, agriculture and forestry, building and urban development, information and communication

Indicators: Raw material productivity (GDP/ abiotic Domestic Material Intensity (DMI)), energy productivity (GDP/ total primary energy use), RMC/person (raw material

[35] EEA, 2016. Country profile - Germany: More from less - material resource efficiency in Europe. European Environment Agency.
[36] BMUB, 2016. German Resource Efficiency Programme II. Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB).

consumption per person), total raw material productivity ((GDP+imports)/RMI (including biotic materials)), recycling and recovery indicators.

Policy instruments:

- Regulatory instrument
- Economic and financial instrument (taxes, charges, financial support schemes)
- Information based instrument (award based, Blue Angel Eco-label scheme)

4.2.2.5 Netherlands[37,38]

Netherlands has several policies related to resource efficiency in place such as on waste management, waste prevention, circular economy and green growth. **Circular Economy in the Netherlands by 2050 (2016)** further sets out a course of steps until 2050. The programme From Waste to Resource covers the broad natural resource categories: fossil resources, minerals, metals and renewables (biomass). In a circular economy, cycles are closed and chains designed to be as efficient as possible. Waste and emissions no longer exist, transference to humans and the environment is prevented, and the depletion of resources is no longer an issue. Circular Economy in the Netherlands by 2050 - Government wide program for a circular economy (2016) aims to realise 50% reduction in use of primary raw materials (minerals, fossil and metals). This programme contains the current steps and sets a course for the subsequent steps to be taken on the way to 2050.

Priority materials and sectors: Biomass and food, wood, plastics, manufacturing (electronics, machinery, automotive, energy), construction, consumer goods, disposable health care products, electrical and electronic waste, packaging, textiles, phosphorus, diapers, underground infrastructure materials, mechanical installations in built environment

Indicators: Accounting is based on international standards (concepts, definitions, classifications) and existing statistics.

Policy instruments:

- Regulatory instrument. For example, ban on landfill of all recyclables and incinerable products/materials, producer responsibility legislation, binding declaration-of-waste management fee on flat glass.
- Economic and financial instrument eg. landfill tax, tax deduction for investment in sustainable technologies, subsidies, pay-as-you-throw
- Information based instrument eg. labelling, influence consumer behaviour
- Other eg. voluntary agreements, enforcement agency

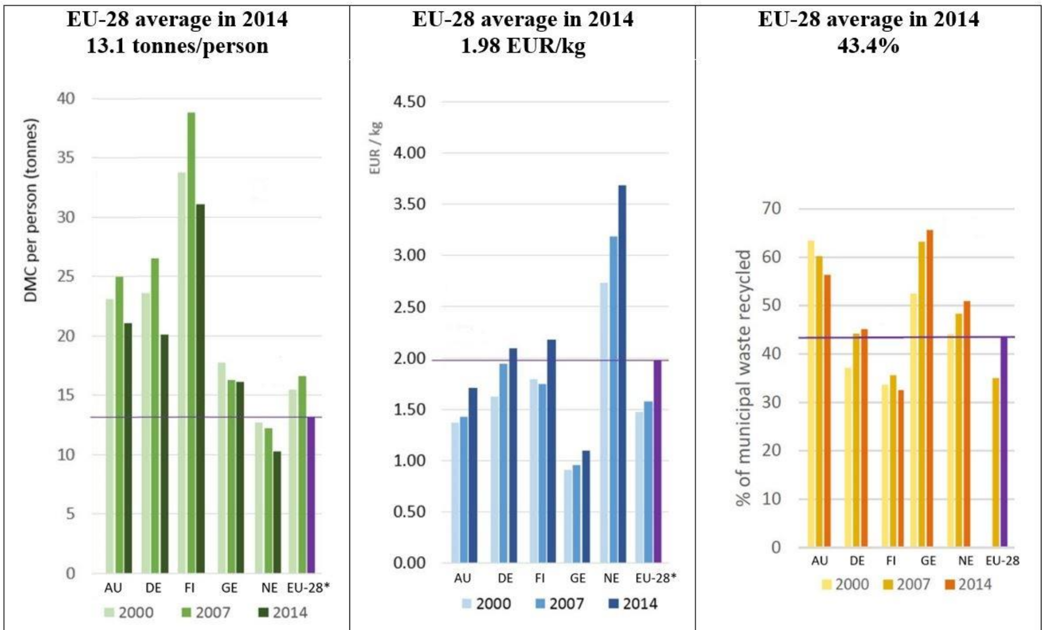
[37] EEA, 2016. Country profile - Netherlands: More from less - material resource efficiency in Europe. European Environment Agency.
[38] The Ministry of Infrastructure and the Environment et al., 2016. A Circular Economy in the Netherlands by 2050 - Government-wide program for a circular economy.

Outcomes:

Table 3: Domestic Material Consumption (DMC), DMC per person and Resource Productivity in year 2014

Indicators	EU-28	Austria	Denmark	Finland	Germany	Netherlands
DMC (million tonnes)	6,640	180	113	170	1,305	173
DMC (% of EU-28 in 2014)	-	2.7 %	1.7 %	2.6 %	19.6 %	2.6 %
EU-28: DMC (2014) is 80 % of DMC (2007)						
DMC per person (tonnes/person)	13.1	21.0	20.1	31.1	16.1	10.3
DMC per person (% of EU-28 in 2014)	-	161 %	154 %	238 %	123 %	79 %
EU-28: DMC per person (2014) is 79 % of DMC per person (2007)						
Resource Productivity (EUR/kg)	1.98	1.71	2.18	1.10	2.10	3.68
Resource Productivity (% of EU-28 in 2014)	-	86 %	110 %	55 %	106 %	186 %
EU-28: Resource Productivity (2014) is 125 % of Resource Productivity (2007)						

Data Source: European Environment Agency, EUROSTAT [10-12, 16, 18, 20, 22]



(a) DMC per person (b) Resource Productivity (c) Recycling rate of municipal wastes

AU - Austria, DE - Denmark, FI - Finland, GE - Germany, NE - Netherlands, EU-28 - EU 28 and participating countries, — EU-28 average in 2014*

Figure 7: (a) DMC per person, (b) Resource Productivity and (c) Recycling of municipal wastes for years 2000 - 2007 - 2014

4.2.3 United States of America[39][40]

The United States of America **has Resource Conservation and Recovery Act (1976),** as a federal law that governs the management and disposal of municipal and industrial waste. One of its main goals is to reduce unsustainable use of materials and resources. The US Environment Protection Agency (EPA) released a framework entitled **Beyond RCRA: Waste and Materials Management in the Year 2020 (2003),** which has been turned into a roadmap to accelerate resource efficiency and materials management for the country. Beyond RCRA: Waste and Materials Management in the Year 2020 (2003) aims to reduce waste and increase the efficient and sustainable use of resources, prevent exposures to humans and ecosystems from the use of hazardous chemicals, and manage wastes and clean up chemical releases in a safe, environmentally sound manner.

Institutionally, USA has a decentralized policy making framework, in which the states and districts develop independent regulations on resource efficiency. Most predominate in the country's resource efficiency initiatives are those related energy efficiency (federal regulations) and waste management (state and municipal jurisdiction).

Priority materials and sectors: agriculture, energy efficiency, cleaner production, public procurement, transport, water, waste

Policy instruments:

- Regulatory instruments eg. nutrient regulation, waste recycling regulation, public procurement, and standards and codes in energy efficiency
- Economic instruments eg. tax incentives (loan guarantees, credits, etc.) to encourage spending in energy efficiency and retrofitting, and recycling enterprises; subsidies for conservation agriculture and organic agriculture
- Awareness instruments eg. awareness programs through state policies, or municipal/ county level, organic agriculture label (at national level)

[39] IINAS, 2013. Elaborating the International Discussion on Resource Efficiency (ENTIRE): Part I: Resource Efficiency Policies in Various Countries Annex Report.
[40] US EPA, 2003. Beyond RCRA: Waste and Materials Management in the Year 2020. United States Environment Protection Agency

4.3 Discussion

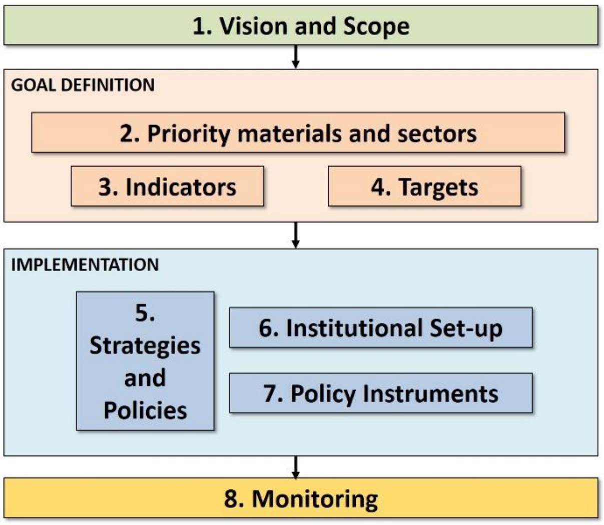


Figure 8: Components of Resource Efficiency Strategy

Based on the review of the international dedicated strategies for resource efficiency, main components of such strategies as identified are shown in Figure 8. Vision and scope outlines the main purpose of the RE strategy. Different priority materials, sectors and consumption categories are identified. Targets and milestones are set which are evaluated on the basis of certain indicators. Different types of strategies and policies backed by institutional set-up and supported by policy instruments help in the implementation of the RE policy. The monitoring of the targets is proposed at regular intervals.

RE strategy or policy sets the **vision and scope** outlining the main purpose of such a strategy. The overarching vision of such the RE strategy is sustainable development envisioned through resource efficient economic growth, resource security, environment protection, restoration of ecosystem and business innovations. The scope typically is to increase the resource or material productivity and may vary from also covering increase in energy, water or land productivity, and reduce the impacts on environment.

Priority materials and sectors typically include food, construction, waste, packaging, transport. Specific priority materials may also be decided eg. water in Finland and China; textile, packaging and electronic equipment in Denmark and Netherlands.

Indicators may be consumption based indicators eg. Domestic Material Consumption absolute and per person (DMC and DMC/person), DMC resource type (biomass, fossil fuels, non-metallic minerals and metal ores), Total Material Consumption (TMC), Total Material Requirement (TMR), Raw material consumption (RMC) of biomass, metals, minerals and fossil fuels or Raw Material Consumption absolute and per person (RMC and RMC/person); Resource Productivity as the ratio between monetary output and input of natural resource/materials, comprising energy, water, air and land eg. Material Productivity (GDP/DMC), Domestic Material Intensity (DMI), Raw material productivity (GDP/ abiotic

DMI), Energy Productivity (GDP/total primary energy use); *Recycling based indicators* eg. share of recycled raw materials used by industry, general waste-related indicators (eg. municipal solid waste generated/treated). Specific indicators may be also be designed.

Different **targets** related to identified priority materials and sectors are specified in the RE strategy. Such targets may be directly related to material use or may also be in form of expenditures to promote efficient use of resources.

Strategies or policies designed to execute the vision of resource efficiency strategy include waste prevention, management and recycling, energy efficiency, green public procurement, eco-labelling, industrial symbiosis and others.

Country specific strategies for resource efficiency given in Table 4 shows that strategies regarding waste prevention, recycling and energy efficiency are most common. Strategies for eco-labelling, green public procurement and green growth are also prevalent for resource efficiency. Specific strategies may also be designed eg. ban or restriction on landfill in Denmark and Germany, food waste in Austria and Germany, bio-economy in Finland and Germany, and Industrial symbiosis (system wherein waste/byproduct/surplus resource generated by an industry are captured and redirected for use as an input into another process by one or more other companies, providing a mutual benefit) in China and Denmark.

Table 4: Country-wise strategies for resource efficiency

Strategies	Asia-Pacific			Europe					USA
	CH	JA	SK	AU	DE	FI	GE	NE	
Waste prevention/management	X	X	X	X	X	X	X	X	X
Recycling	X	X	X	X	X	X	X	X	X
Green Public Procurement	X			X	X	X	X	X	X
Eco-label	X			X	X	X	X	X	X
Green growth/sustainable development	X			X	X	X	X	X	
Ban/restriction on landfill					X		X		
Food waste				X			X		
Biomass/Bio-economy						X	X		
Industrial symbiosis	X				X				
Others (eg. energy, innovation, etc.)	X	X	X	X	X	X	X	X	X

AU - Austria, CH - China, DE - Denmark, FI - Finland, GE - Germany, JA - Japan, NE - Netherlands, SK - South Korea

Institutional set-up for design and implementation of RE strategy is typically addressed by multiple ministries that work closely together on developing policies and regulation. Stakeholders such as regional governments, industry organisations, scientific experts, government funding agencies among others is also involved as part of feedback group.

Policy instruments may be *regulatory instruments* eg. laws, ban (eg. on use of certain substances, on landfill), design and performance or quality standards, producer responsibility, green public procurement etc.; *economic instruments* eg. taxes, fees, grants, awards, returnable deposit system, financial support schemes etc.; *information based instruments* eg. campaigns/awareness, training and education, eco-labels etc. Specific policy instruments may also be designed eg. natural resource pricing, environmental fee to reduce externalities and consumption tax in China; fund for green business development and eco-innovation program in Denmark; binding declaration-of-waste management fee on flat glass, tax deduction for investment in sustainable technologies, pay-as-you-throw and voluntary agreements in Netherlands.

Monitoring of progress is based on pre-decided set of indicators, using simple and effective monitoring framework.

4.4 Conclusion

Review of international RE strategies provides insight on RE strategy design and implementation instruments. Understanding of country’s material requirements, resource constraints and environmental issues forms the basis for setting the scope of any RE strategy. A new RE strategy shall comprise of the identified components with best suited options for different priority sectors as showcased by the countries studied in this review or additional specific options developed as required. This review thus provides for informed understanding of international practices to develop targeted RE strategy.

5 Assessment of Priority Sectors for Enhancing Resource Efficiency and Use of Secondary Raw Materials

5.1 Identification of Priority sectors

India has emerged as a leader in manufacturing sector. The sector in recent times, have not only attracted substantial foreign direct investments, but also engaged a vast pool of talent from India and abroad and as well contributing substantial pie to the total revenue of the exchequer.

The Gross Value Added (GVA) at basic current prices from the manufacturing sector in India grew at a compound annual growth rate (CAGR) of 4.34% during between 2012 and 2018 as per the second advance estimates of annual national income published by the Government of India. In April-June quarter of 2018-19, manufacturing sector's GVA at basic price increased by more than 13%. Under the Make in India initiative, the Government of India aims to increase the share of the manufacturing sector to the gross domestic product (GDP) to 25% by 2022, from 16%, and as well create 100 million new jobs in the next 4 to 5 years.

Industrial manufacturing is a major growth sector for the Indian economy that consists of diverse companies including those engaged in manufacturing of consumer products, machinery and other capital equipment, electrical and metal products, cement, building and construction material, rubber and plastic products and automation technology products, and so on. Apart from availability of skill labour and capital, success, performance and future ambitious goals of the sector lie in dedicated availability of raw materials at affordable prices. It has already been discussed at length in chapter 1 that in the presence of growing uncertainty with regard to availability of materials and price volatility, a sustainable manufacturing will depend heavily on how the sector is able to incorporate the 6 R principles of resource efficiency at their core operations strategy and consumption behaviours.

While there are opportunities of resource efficiency for every sector in an economy, however, the degree of benefits will depend on various factors. Apart from their relative share in the sectoral and national income, the overall benefits of RE particularly in resource intensive sectors will depend substantially on factors like diversity of use of natural resource/raw materials, volume of wastes/scrap generated and recycled, import dependency for raw materials, availability of relevant technologies that can help in material switching or savings, markets for alternative products, etc.

The agriculture sector in India depends heavily on both biotic and abiotic resources. India has world's second largest farm output and has a long way to go to achieve complete food security. Agriculture and allied sectors like forestry and fisheries account more than 12% of the GDP employing 50% of the workforce. India has around 4% of world's fresh water, out of which 80% is used in agriculture. India receives an average of 4,000 billion cubic meters of precipitation every year. However, only 48% of it is used in India's surface and groundwater bodies. A dearth of storage procedure, lack of adequate infrastructure, inappropriate water management has created a situation where only 18-20% of the water is actually used. As per estimates of Central Ground Water Board (CGWB) in 2011, India's total annual repleneshable groundwater resource is around 433 billion cubic meters (BCM) and net annual ground water availability is 398 BCM of which India withdraws 245 BCM (62%) annually. Further, 39% of the wells are showing a decline in groundwater level. Around 1,071 units (in 15 states and 2 union territories) out of 6600 units have been categorized as "over exploited" based on the stage of groundwater withdrawal as well as long term decline in groundwater level[41]. Further India is the second largest consumer of Nitrogen, Phosphate and NPK and the fourth largest consumer of potash making the agriculture sector quite resource intensive although the per hectare consumption may be very low.

A detailed assessment of resource use efficiency potential in India for all sectors including biotic and abiotic resources is an extremely challenging task particularly when it comes to availability of adequate data and information along the value chain of products (sectors). While it is extremely important to undertake such exercise for all economic sectors, selection of hotpsot sectors and their assessment is possibly a better way to initiate the task and explore the efficacy of the existing RE framework in selected sectors. Under the ongoing EU REI project as well as the earlier BMUB supported RE project, the exercise has been confined to selected natural abiotic resources, manufacturing and post-consumer waste sectors with an objective to assess resource usage and material consumption and as well explore efficiency potential selected across critical stages of a typical value chain.

Factors that have been taken into consideration towards selection of hotspot sectors for assessing RE benefits include income share, use of critical raw materials, import dependency and consumption share. Based on this, the following sectors, for which the RE potential was exercised, were shortlisted. These sectors include automotive (including electric mobility), construction, electronics and plastics (including post-consumer usage), steel and aluminium and solar PV. A summary of their contribution to national income, use/generation of various raw materials, import dependency of raw materials (virgin/scrap), is presented in the table 5.

Table 5: Economic contribution of selected sectors in India

Sl. No	Economic Sectors	Share in national income	Selected raw materials	Import dependency
1.	Automobile sector (incl electric vehicles)	7.1%	ICE: Steel, Copper, Aluminium, Zinc, nickel, lead, glass,	Copper (50-60%) Lithium (100%) Co (100%) Aluminium scrap (90%)

[41] http://cgwb.gov.in/Documents/Dynamic-GW-Resources-2011.pdf

Sl. No	Economic Sectors	Share in national income	Selected raw materials	Import dependency
			rubber, various plastics/synthetics E-vehicles: Lithium, Cobalt, Nickel, Rare Earths, various plastics/synthetics, Steel, Copper, Aluminium,	Steel scrap (20%-25%) Lead (75%) Rare Earths (100%)
2.	Chemicals (plastics)	2% (0.5 % - 0.8%)	Crude oil	Oil (80 %)
3.	Construction& Demolition	9%	Cement, Limestone, clay bricks, steel, aluminium, Copper,	Aluminium scrap (90%) Steel scrap (20%-25%), Copper (50-60%)
4.	Electronics (including E-waste)	1.8%	Gold, Silver, Rare Earths, Plastics, Platinum, Copper	Silver (75%), Rare Earths (100%), Gold (90%), Platinum (95%), Copper (50-60%)
5.	Steel	2%	Iron ore, Molybdenum, Nickel, Tugsten	Steel scrap (20%-25%), Molybdenum (100%), Nickel (100%), Tugsten (100%)
6	Aluminium	0.8%	Bauxite, Al Scrap	Aluminium scrap (90%)
7	Solar PV	2.1%	Aluminium, Silver, Copper, Silicon	Aluminium scrap (90%), Silver (75%), Copper (50-60%)

Source: Annual Survey of Industries (2015), NIPFP (2016), MoSPI (2017)

As presented in chapter 1, India's the raw material consumption has increased by many folds in the past few decades and especially of the non renewable resources. The extraction of non renewable has increased by 420% during the period 1970-2010 (Dittrich 2012). Also according to the GIZ-TERI-DA study (2016) that assessed material consumption patterns of India, the absolute consumption of materials of India has increased by 184% between 1980 and 2009. India consumed around 5 billion tonnes of materials in 2010 from which 38% were non metallic minerals and 42% were renewable biomass (IRP 2017). In 2010, India consumed 7.2% of the world's extracted raw material and a prediction of 15 and 25 billion tonnes of raw material requirements has been made by 2030 and 2050 respectively (IGEP 2013).

This increased demand for raw materials not only contributes to the physical and environmental pressure on the available resources of a country but also monetary pressure on the economy. Despite being a resource abundant nation, it imports huge amount of non renewable resources that has impact on foreign exchange reserves. Crude oil, for example, has the maximum share in the total imports (22%) and both this share and its import growth has been increasing every year, widening the trade deficit of the country (Economic Survey

2018). Resource efficiency will not only benefit the government treasury, but also stakeholders along various products and services value chains from importers, producers, consumers and scrap dealers. According to the IGEP Report 2013, the manufacturing sector can save around Rs. 60.8 billion using resource efficiency measures in selected sectors[42]. A FICCI analysis of 2018 reveals that approximately half -a-trillion dollar worth of economic value can be tapped through circular economy model in India by 2030. It was estimated that from urban mining of e-waste in India approximately US $1 billion worth of gold can be extracted. At present, plastic recycling represents a US $2 billion opportunity, where proper waste management can create a total of 14 lakh jobs. In addition, approximately 8 million tons of steel can be extracted from end of life vehicles which is a US $2.7 billion opportunity in itself[43].

Using the selected sectors (as mentioned above), a detailed assessment of material consumption, efficiency potential (based on good Indian and International practices), and suggested policy changes were undertaken. The following sections briefly present these findings. These sections heavily draw inputs from the sectoral studies that have been undertaken by TERI, Adelphi, GiZ. Further NITI Aayog in association with Ministry of Mines, Ministry of Steel, Ministry of Housing and Urban Development and Ministry of Information Technology have developed status papers on achieving RE across sectors like steel, aluminium, e-waste and construction and demolition sectors.

[42] http://www.hrdp-network.com/live/hrdpmp/hrdpmaster/igep/content/e48745/e50194/e58089/ResourceEfficiency_Report_Final.pdf
[43] http://ficci.in/spdocument/22977/FICCI-Circular-Economy.pdf

5.2 Automotive sector

5.2.1 Introduction

Mobility has been intrinsic to human existence. It is crucial for human development as it enables to transcend distances between places either locally, regionally or globally. The automotive industry plays a very important role in providing mobility options through different types of vehicles like passenger cars, light, medium and heavy commercial vehicles, multi utility vehicles such as jeeps, scooters, motorcycles, mopeds, three wheelers, tractors, etc. It is a strong pillar of the global economy and a main driver of macroeconomic growth and technological advancement in both developed and developing countries. This industry in India, comprising of the automobile and auto component manufacturers, is one of the key segments of the economy, having extensive forward and backward linkages with other segments of the economy. With more than 35 automobile companies manufacturing in the country, the industry contributes to more than 7 percent to India's GDP and accounts for 7-8 percent of India's total employed population (GIZ, 2015a). The categories of manufactured items of the Indian automobile industry are categorized in figure 9.

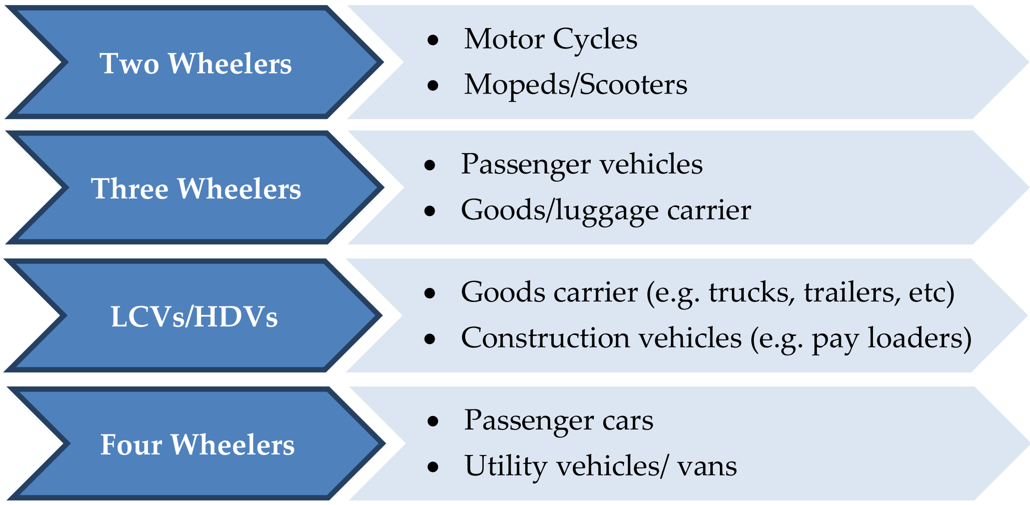


Figure 9: Broad category of automobiles manufactured in India

LCV: *Light Commercial Vehicle, HDV: Heavy Duty Vehicle*

Indian auto industry became the 4th largest in the world with sales increasing to 4.02 million units (excluding two wheelers) in 2017. India also became the 7th largest manufacturer of commercial vehicles in 2017. Key growth drivers include sale and exports of small/city cars, production and sale of multi-utility vehicles (MUVs), two and three-wheelers, a strong after sales market for the component industry, among others.

India's transport sector has predominantly been driven by the growth of Internal Combustion Engine (ICE) based vehicles. The growing middle income class and their rising aspirations, availability of cheaper finances, are some of the key factors that have led to increased demand for personal mobility and proliferation of production and sales of two and four wheelers in recent decades, particularly in major urban centres. As per recent statistics, India's annual vehicle production is over 25 million, and more than 210 million registered vehicles on Indian roads . Around 50 percent of these registered vehicles are in 7 states. With regard to production, two wheelers has the largest share of 79 percent, followed by 14 percent share of passenger vehicles and the remaining 7 percent largely comprising of commercial vehicles that include three wheelers, light commercial vehicles and heavy duty vehicles.

Growing use of internal combustion engine based vehicles, have resulted in to increased consumption of fossil fuels thereby further leading to emission of carbon dioxide and other local pollutants particularly PM 10 and PM 2.5. The transport sector was one of the major contributors to the National GHG emission (2nd largest contributor) and emitted 142 million tonnes of CO2 in the year 2007. The transport sector covered the emissions from road transport, air transport, rail transport and water transport. Road transport, being the dominant mode of transport in the country, emitted 87 percent of the total CO2 equivalent emissions from the transport sector.

One of the ways of decoupling GHG emission from the transport sector is through the introduction of the electric mobility. The government of India has demonstrated a strong commitment in introducing electric mobility in India and announced a very ambitious plan of making India a primarily electric car driven nation by 2030. The government in this regard launched a scheme for the Faster Adoption and Manufacturing of (hybrid &) Electric Vehicles in India (FAME India) under the National Electric Mobility Mission (NEMM) in 2015. The scheme was successful in increasing the share of hybrid and electric passenger vehicles sales from almost zero percent in 2012 to 1.3 percent by 2016. The government plans to introduce 6–7 million electric vehicles (EVs) /hybrid vehicles on Indian roads by the year 2020. In a recent communication by the Ministry of Road Transport and Highways (MoRTH), Government of

India and NITI Aayog, target to increase the share of electric vehicles from its current level of less than 1 percent to nearly 30 percent by 2030 while the share of electric buses could be expected to reach as high as 100 percent. This implies that by 2030, the total number of electric two wheelers to be on Indian roads would be 211 million, while for cars and buses it will be around 34 million and 2.5 million respectively.

Meeting the growing demand of conventional as well as electric vehicles will require a dedicated supply of the materials at affordable prices. Electric vehicles will require many newer materials with enhanced performance over their predecessors, particularly for manufacturing batteries and powertrain. This calls for a detailed assessment on projected demand of different types of the vehicles, and the consequent impact on raw material consumptions. At the same, there will be growing opportunities in improving material consumption including augmenting materials in the value chain through efficient recovery and recycling.

Material demand assessment and efficiency potential in ICE and EV is discussed in the following sections separately followed by a comprehensive framework for promoting resource efficiency in the road transport sector.

5.2.2 Assessing material demand and exploring resource efficiency potential in ICE based vehicles

An ICE based automobile is composed of hundreds of components that are manufactured using various materials like high strength steel, stainless steel, aluminium, rubber, plastics/composites, glass, copper and brass, zinc, lead, fluids and lubricants, and others. All these components can largely be categorized under six heads as presented in figure 10.

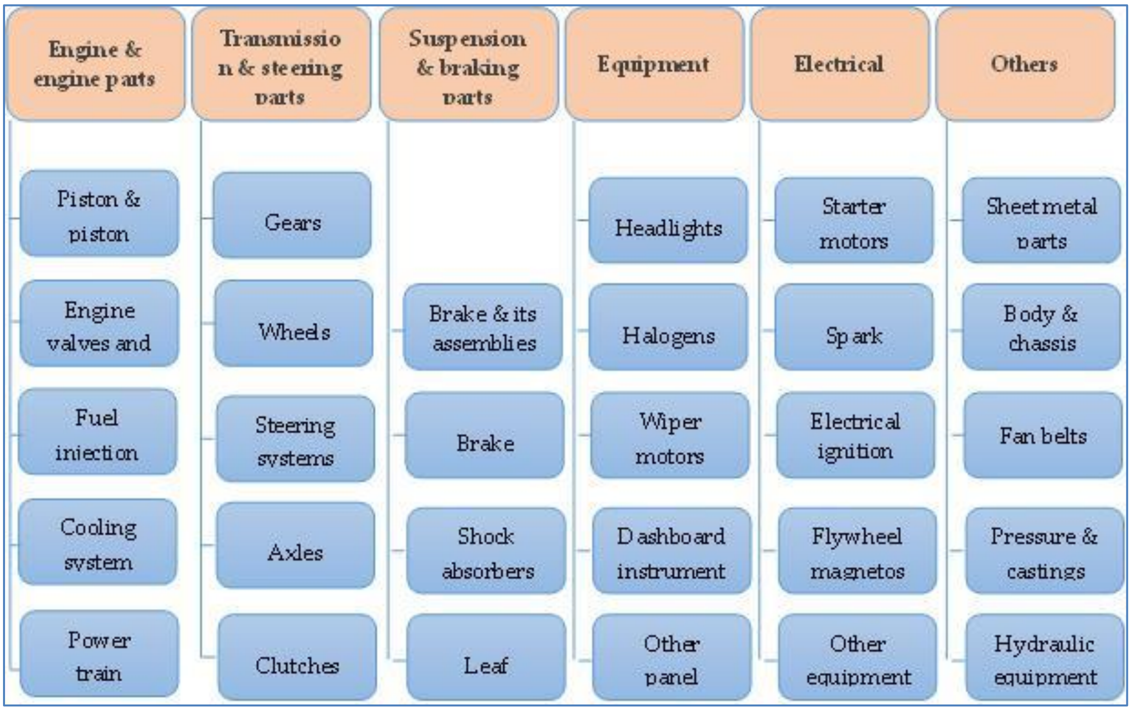


Figure 10: Broad category of assemblies and their subassemblies

Source: Author's compilation

Processing materials and energy are extensively used in manufacturing components and their assembly. The life cycle stages of the automotive sector starts with extraction of the resources, intermediate processing, component manufacturing, assembly of these components by original equipment manufacturers, use phase and the end of life. This is presented in figure 11.

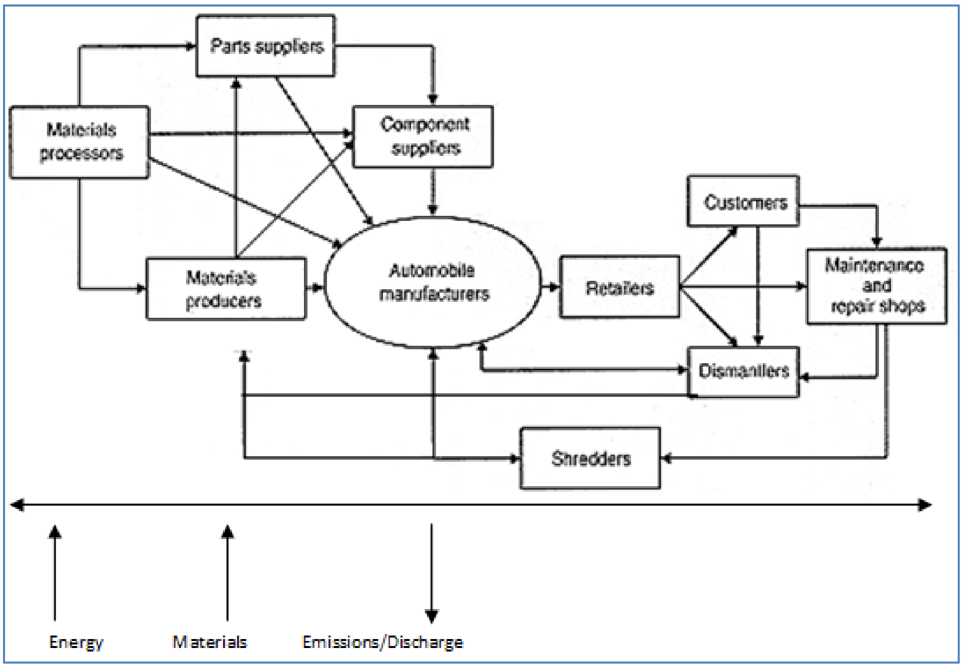


Figure 11: Life cycle stages of the value chain

While there are lot of materials that are consumed in the automotive sector, the material demand assessment is confined to use of direct materials that include iron and steel, aluminium, copper and plastics. These materials contribute to nearly 75 percent of total weight of vehicle. The following section presents a comprehensive assessment of their demand, potential environmental issues associated with manufacturing of these materials and as well the opportunities that exist for recycling particularly from scrap generated from end of life management of vehicles which further can reduce demand of materials from virgin resources as well reduce import dependence of scrap to keep the metal recycling industry running.

5.2.2.1 Consumption of materials automotive sector

5.2.2.1.1 Iron and steel

Steel is the most dominant metal used in production of automobiles (Bhaskar, 2013). It is estimated that that average steel content in an automobile is around 55 percent to 60 percent of the average weight of a vehicle although it may vary depending of the vehicle type (hatchback, sedan, MUVs, LCVs and HDVs), whereas iron accounts for 5 to 7 percent of the total kerb weight. Thus, the total iron and steel share in a weight of a car is estimated to range between 60 and 67 percent.

Key steps associated with steel manufacturing include extraction and treatment of raw ore, iron making, steel making, casting and rolling, and finishing. Steel production is highly energy intensive and involves melting of iron ore at very high temperatures. This not only has implications on local pollutions in the form of emission of particulate matter, sulphur dioxide, ammonia, etc, but also global pollutants that have global warming potential like CO_2 and CH_4. Various factors are responsible for emissions include combustion of fossil fuels, use of electricity, and use of coal and lime as feedstock. Mining of iron ore rock releases dust particles in the air which leads to health hazards such as transient irritation, lung fibrosis, carcinoma, bronchitis, asthma and other lung diseases. Mining workers are exposed to iron dust particulates for long periods and thus have a higher probability of suffering from lung cancer in the long run (PLRARA, 2015). Iron mining is generally carried out by the open cast process which involves operations such as excavation, loading, sizing, crushing and screening, and transportation. These operations generate emission from ore bodies, drilling, blasting and transportation, which deteriorates the ambient air quality within the range of the mining site and surrounding areas. A quick analysis of material embodiment in 1 ton of steel produced from BOF route suggests that the same contain nearly 1.4 tonnes of iron ore, 0.55 tonnes of coking coal, 0.25 tonnes of limestone and 1.9 tonnes of air. By products consist of 0.3 tonnes s of slag, 2.4 tonnes of BF gases, and upto 0.05 tons of dust. Further the estimated CO_2 emission per tonne of crude steel is 2.1 tonne as against 0.6 tonnes emitted from the EAF route. Further when steel enters the automotive sector, there are wastages generated during component manufacturing and fabrication in the form of rejects and scraps from sheet metal cutting, stamping, machining, die casting, etc. It is estimated the automotive industry consumes 11 million tonnes, and with the current trend in vehicle production in India, the estimated consumption of iron and steel will reach between 70 to 80 million tonnes by 2030 which is around 70 to 80 percent of the total steel production capacity in India. The current material productivity is estimated at Rs 885/kg of finished steel consumption.

It is evident from the above estimates that meeting such a demand for steel will require 84 million tonnes of iron ore, 30 million tonnes of coke, 15 million tonnes of limestone, 18 million tonnes of slag and 126 million tonnes of CO_2. In absence of any organized system for scrap/reject collection and processing, India imports nearly 6-7 million TPA of steel scrap leading to drainage of large amount of foreign exchange. Given that India has an estimated 87,31,185 vehicles that have reached the end of life in 2015 and a further 2,18,95,439 vehicles will reach EoL by 2025, India would be able to generate more than 10 million tonne of steel scrap from automotive sector which is more than the current scrap imported by India. The recycling potential along the value chain is presented in figure 12.

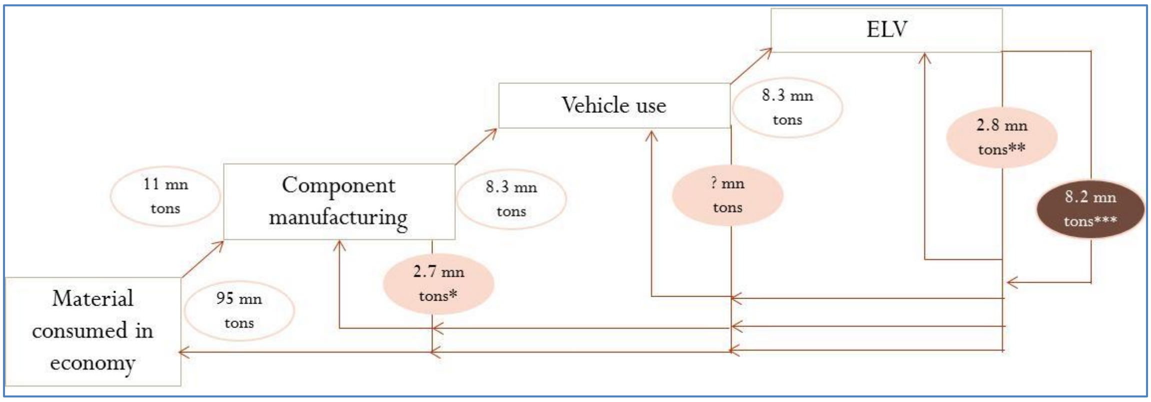


Figure 12: Recycling and saving potential of iron and steel

5.2.2.1.2 Aluminium

In recent years, there has been an increased use of aluminium, magnesium and carbon fibre composites in automobile manufacturing. Aluminium being much lighter than steel and having the same strength, is gradually replacing steel in the automobile industry, which has an overall impact on the cost of the vehicle6. Since the 1970s, the share of aluminium in the overall weight of an average car has been constantly on the rise: from 35 kg in the 1970s, to 152 kg in recent years. Experts project that by 2025, the average aluminium content in a car will reach 250 kg (Richman, 2013). Traditionally, automakers in India have used aluminium for wheels, cylinder blocks, and other engine parts. However, this trend is changing in response to stringent fuel economy standards, and aluminium use has extended to other individual components such as interior decorations, bumper beams, brake components, etc. More recently, aluminium has also been adopted for use in chassis, suspension, and front-end systems. In fact, auto companies are now trying to make the entire car body of aluminium, referred to as 'body-in-white'7. Every 10 percent reduction in weight is expected to improve fuel economy by 5–7 percent (Richman, 2013).

Aluminium has another very useful property, that of being almost twice as effective in absorbing shock compared to steel. For this reason, automakers have long been using aluminium in bumpers. Another reason why an aluminium body is superior to a steel body in terms of safety is because when aluminium parts get bent or deformed, the deformation remains localised to the areas of impact while the rest of the body retains the original shape, ensuring safety for the passenger compartment. Global forecasts suggest that by 2025, the average vehicle will get lighter by 180 kg, in part due to the enhanced application of aluminium on account of closures, body-in-white, bumper, and suspension components. Aluminium is expected to grow to 16 percent of kerb weight by 2025 (Richman, 2013).

With an average share of 8 to 10 percent of the body weight constituting aluminium, the estimated demand for Al will be 11 mn tons by 2030. However, if the share of the Al increases to 15 percent, the demand can be as high as 18 million tonnes from the automotive sector alone. The material productivity is estimated at Rs 9515/kg of refined Al used in the industry.

Aluminium recycling saves huge economic and environmental costs compared with production from virgin ore. Each ton of aluminium recycled uses 95 percent less energy and saves one m^2 of land use, 24 barrels of crude oil equivalent of energy, more than 15 tonnes of water use, eliminates more than 9 tonnes of CO_2 equivalent of GHG, avoids 2.5 tonnes of solid waste. Recycling of aluminium reduces the mining of bauxite ores as well as use of chemicals such as caustic soda, aluminium fluoride and lime.

India imports nearly 0.9 million tonnes of Al scrap per annum. Given that India has an estimated 87,31,185 vehicles that have reached the end of life in 2015 and a further 2,18,95,439 vehicles will reach EoL by 2025, India would be able to generate more than nearly 1.5 million tonne of Al scrap from automotive sector which is more than the current scrap imported by India. The recycling potential along the value chain is presented in figure 13.

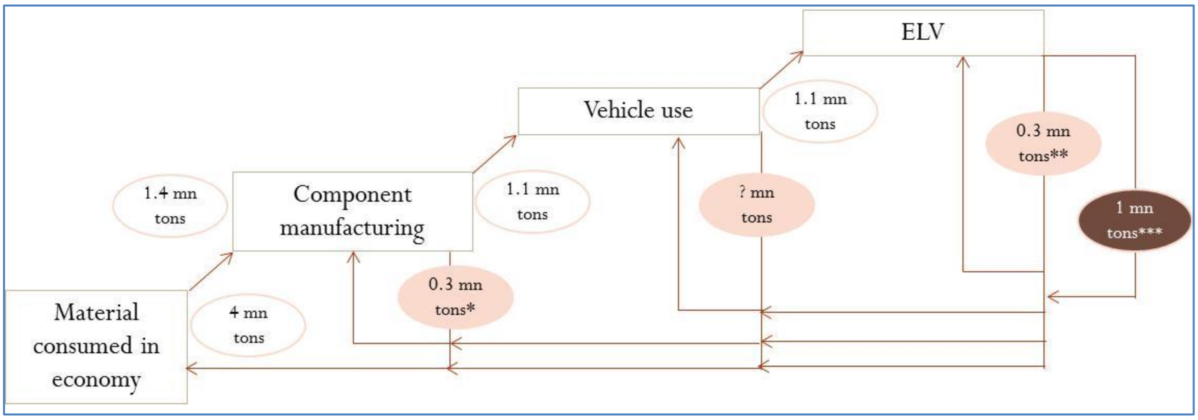


Figure 13: Recycling and saving potential of Aluminium

5.2.2.1.3 Copper

Copper is a multi-purpose material whose properties have assigned it a critical role in the transportation sector for functionality, efficiency, comfort and safety. Automobiles account for the largest share of copper usage in the transportation sector. Trains, ships, and aircraft, in that order, make up the balance. Copper is mostly used for electrical products, followed by heat transfer devices such as radiators and oil coolers, and bronze sleeve bearings. Traditionally, copper usage was distributed about equally among electrical systems (motors, generator/alternators, wiring harnesses), heat transfer systems (radiators, oil coolers, heater cores, and air-conditioning heat exchangers), and mechanical components such as bearings and shifter forks. Beginning in the late 1980s, electrical uses steadily increased, while heat transfer applications were gradually taken over by aluminium. However, despite downsizing and a general reduction in the weight of automotive components, the large increase in the number and complexity of electrical systems has actually led to an increase in copper usage per vehicle (KME, 2013).

Automotive radiators and heaters: Copper's inherent superiority in thermal conductivity, corrosion resistance and strength has made it a preferred primary metal for radiators in cars and trucks. With new technologies, it can be used to make smaller, lighter and stronger copper radiators. However, there was a change in the trend that began in 1978, the year Volkswagen introduced a car equipped with an aluminium radiator. Today, the vast majority of automobile radiators for new cars are made from lighter-weight, lower-cost aluminium alloys, although truck, bus, heavy vehicle, and aftermarket radiators continue to be made from copper and brass. The copper industry remains active in improving copper and brass radiator design, manufacturability, and corrosion resistance.

Automotive wiring: Cars once typically had only three electric motors (for the starter, windshield wiper, and heater/ventilator blower), but modern vehicles contain up to 70 motors for various safety, comfort, and/or convenience features, many of which are now standard equipment. These motors, along with their wiring harnesses and connectors, add significantly to the modern vehicle's copper content.

New automotive applications: The trend toward so-called 'smart' vehicles has increased copper consumption by 40 percent for devices such as antilock-brake systems (ABS), burglar alarms, gyroscopes, collision-avoidance systems, and navigation computers.

Other automotive uses of copper and copper alloys include automotive hydraulic brake tubes, automotive radiators and heat exchangers, and automotive vehicle brake tubing. With technological advancements, the automotive industry has explored the importance of copper in producing more energy efficient, durable and higher quality parts in automobiles.

There are different estimates available for the use of copper in a vehicle. The weight of copper in a vehicle ranges from 15 kg for a small car to 28 kg for a luxury car (KME, 2013), which can correspond to about 1-2 percent of the total vehicle weight. "Hybrid" (ICE-electric) vehicles use almost double the amount of copper (approx. 45 kg) compared to that of traditional ICE vehicles (KME, 2013). Looking at copper use in cars from a different perspective, it has been noted that in 1948, the average family car contained 55 copper wires with a total combined length that averaged 45 metres (150 feet). With improvements in electronics and consumer demand for power accessories in automobiles, today's automobiles contain up to 1,500 copper wires that total about 1.6 km in length (KME, 2013).

India is not self-sufficient in supply of copper ore. Thus, in addition to domestic production of ore and concentrates, India also imports copper concentrates for its smelters for metal production. The domestic demand for copper and its alloys is met through domestic production, recycling of scrap and by imports. The low grade quality of Indian copper ores and nature of ore bodies (narrow width) restrict large scale production from underground mines (IBM, 2012a). Copper scrap import has increased from 39 thousand tonnes to 58 thousand tons by 2010 and 2016. At the same time refined copper import has increased from 18 thousand tonne to 32 thousand tonnes between 2011 and 2015. India continues to import copper concentrate although it has fallen to 1 million tonnes from 2 million tonnes in recent years.

While India's total consumption of copper stands at 0.7 million tonnes, the automotive sector contributes to more than 0.1 to 0.15 million tonnes. It is estimated that the consumption will reach about 1.6 million tonnes by 2030. This is more than the current total production of copper in India.

Recycling rate of copper is very low in India compared to other nations. For example In U.S., the amount of copper recycled is almost the same as is mined per year, approximately 75 percent of used copper except wire production that requires newly refined copper comes from recycling. About 50 percent of the copper used in Europe comes from recycling. India has high recyclability potential and automotive sector of copper particularly from radiators from retired cars. Based on the estimated volume of vehicles that have reach the end of life as well as those that will reach EoL, the estimated volume of copper scrap can be more than 0.23 million tonnes which is more than that current import of scrap as well as the materials which is consumed in the automotive sector. The material productivity is estimated at Rs 63400/kg of copper consumed in the sector. The recycling potential along the value chain of copper is presented in figure 14.

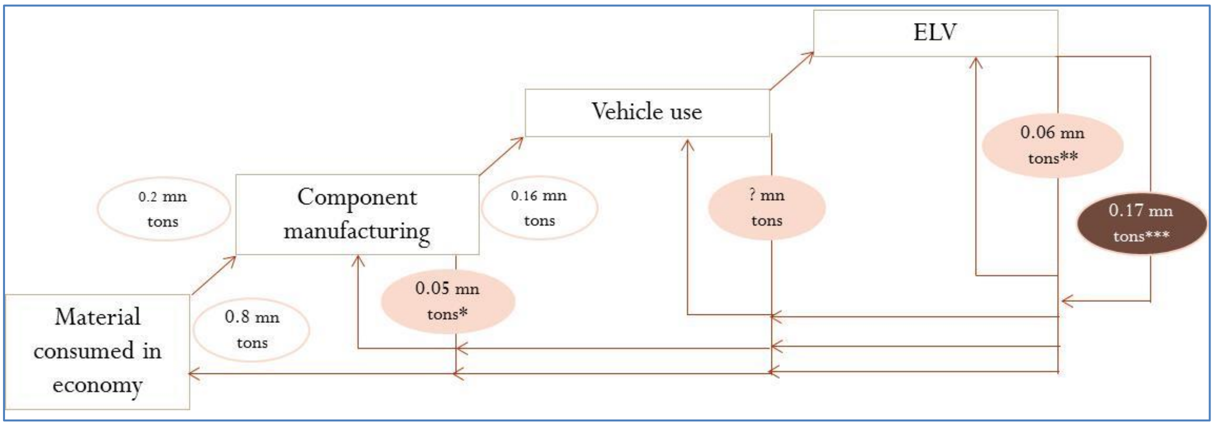


Figure 14: Recycling and saving potential of Copper

5.2.3 Assessing material demand and exploring resource efficiency potential in electric vehicles

An electric vehicle uses a lot of newer materials compared to their ICE vehicles counterpart. While the body of an electric vehicle is mostly made up of steel, but with an aim to make these vehicles lighter in weight, many light weighting materials are also used that include aluminium, plastics, synthetics and rubber among other materials. The drive motor system is an essential part of EVs as it converts the electrical energy into mechanical energy. This consists of an electric motor, invertor, convertor, power distribution unit (PDU), and charger. The traction batteries are those that are used for the propulsion of any type of electric vehicle are mostly nickel-metal hydride (NiMH) or Lithium Ion (LIB) type. Since Lithium is the lightest solid element and possesses the highest oxidation potential, it carries higher energy density compared to the standard lead acid and NiMH batteries, thus making it the preferred material among battery manufacturers. The essential components that have been considered for assessing material consumption in an electric four wheeler is presented in figure 15.

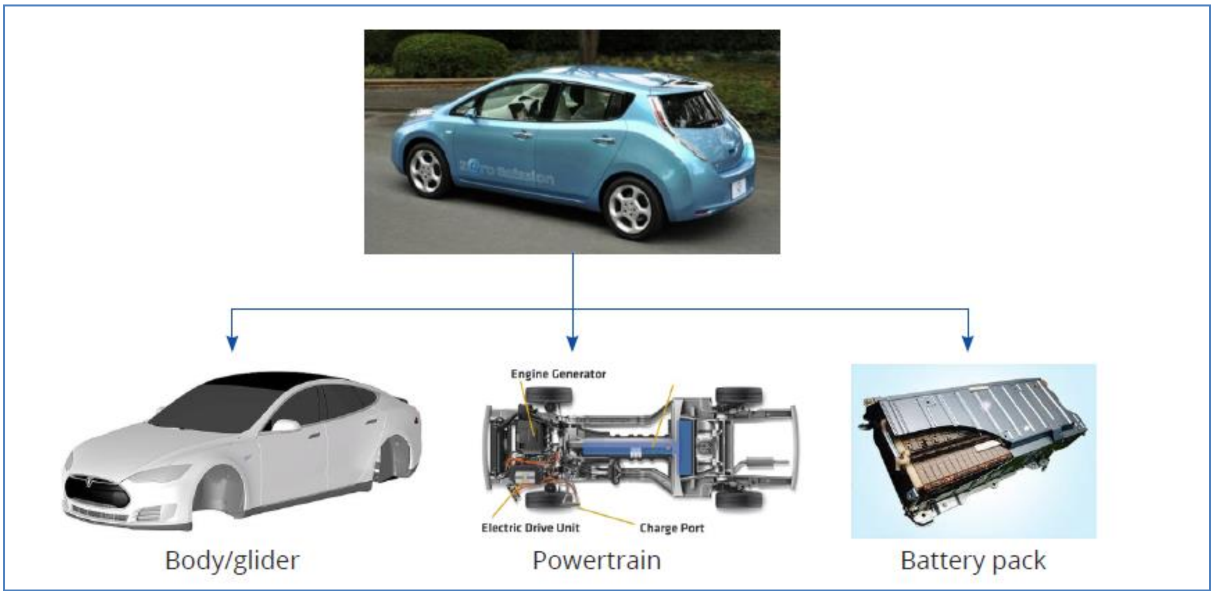


Figure 15: Key components of electric vehicle

The following sections briefly describe the functions of these key components, and the materials that go into manufacturing these components. Due to limited penetration of electric four wheelers in India, manufacturing of these components in India is almost negligible currently and hence, the material requirement for manufacturing these components have been largely based on literature review as well as interactions with selected industry and subject matter experts. With the number of EVs manufactured domestically to rise in the coming decades, the production and hence consumption of materials will peak up significantly in India.

5.2.3.1 Traction battery and materials

Battery forms the source of power for electric vehicles. Lithium ion batteries have emerged has the key element for manufacturing batteries. These batteries use metal compound powders coated on aluminium foil as key cathode materials. These may include Lithium cobalt oxide ($LiCoO_2$), Lithium manganese oxide ($LiMn2O_4$), or Aluminium doped $LiCoO_2$. $LiCoO_2$ has one of the highest energy density and are used in modern electronic devices. The battery consists of a cobalt oxide cathode and a graphite carbon anode. However, these batteries have relatively lower life and low thermal stability and limited load capabilities (specific power).

Li-manganese may have less specific energy than Li-cobalt however design flexibility can help in improved battery life, specific power or high capacity. Further this chemistry is cheaper than some of the other options currently available. Lithium nickel manganese cobalt oxide ($LiNiMnCoO_2$ or NMC) is a very good cathode material. However, due to high cost of cobalt, manufacturers are moving away from cobalt systems toward nickel cathodes. Nickel-based systems have higher energy density, lower cost, and longer cycle life than the cobalt-based cells but they have a slightly lower voltage. Finally, $LiFePO_4$ (LFP) forms one of the key cathode materials which are commercially available. These types of batteries have good safety with enhanced life, although the specific energy is relatively less compared to other chemistries and self- discharging may be high.

Manufacturers of lithium batteries largely use graphite coated on copper foil as the key anode material. There are however some application of amorphous carbon or lithium titanate as cathode materials. However, the latter is mostly used for stationary applications due to its low specific energy. Newer materials with higher capacities in the form of composites like C/Si, Si alloys, and non-Si alloys are at research phase stages. Lithium hexafluorophosphate (LiPF6) is mostly used as the conducting salt in the battery. Newer salts are being explored to improve electrical conductivity in the batteries. Finally the battery and thermal management is indeed complex. The system is responsible for continuously monitoring the performance of the battery and accordingly adjusting it to match the usage and the ambient condition. Further there are electronic components of the battery pack that may include switches, contactors and fuses that contain copper, aluminium and other materials. For a four wheeler in the hatchback segment, the battery and associated components on an average weigh in the range of 100 kg to 130 kg.

The share of materials by weight in traction batteries is presented in the figure 16.

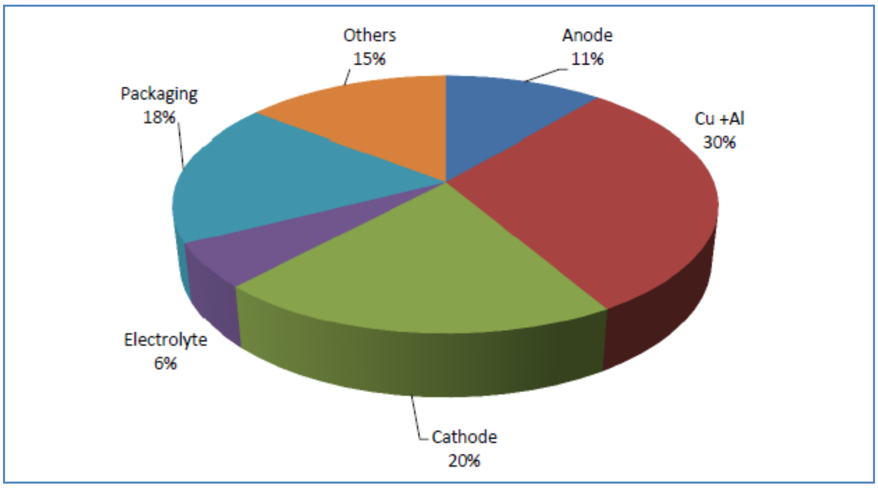


Figure 16: Material composition of traction batteries (by weight percentage)

5.2.3.2 Electric Drive Motors

The electric drive train is another major component in an electric vehicle. It converts the electrical energy into mechanical energy. Challenges and issues associated with its manufacturing include material availability and ensuring of cost competiveness (particularly for rare earth elements). This can be addressed through material selection, product design, optimal functional efficiency, etc. There are continuous efforts in improving electric motors using newer materials that do not compromise with operational efficiency. Some of the alternate technologies that have been tested include reduced NdFeB (Neodyium iron boron) magnet, ferrite permanent magnet, copper rotor induction, wound rotor synchronous, switched reluctance motor. Table 6 presents efficiency parameters of these different types of motors.

Table 6: Electric motor technologies having limited or no use of rare earths

Motor technology	Reduced NdFeB magnet	Ferrite permanent magnet	Copper rotor induction	Wound rotor synchronous	Switched reluctance Motor
Peak power	80 kW	80 kW	50 kW	50 kW	75 kW
Peak efficiency	98%	96%	96%	96%	97%
Active material cost per kW	$2.78/kW	$1.93/kW	$2.88/kW	$2.88/kW	$1.57/kW
Torque density	15 Nm/kg	11 Nm/kg	10 Nm/kg	10 Nm/kg	15 Nm/kg

However, the real challenge remains in terms of accessing relevant information with regard to material specificity, weights and even sometime performances. Regarding the material composition, electric motors mostly consist of aluminium, cast iron, copper, steel and NdFeB magnets since till date permanent magnet motor is the most common propulsion types in EVs.

NdFeB magnets contain about 30 percent of rare earth elements, mainly neodymium and dysprosium with small amounts of terbium and praseodymium. Magnets applied in synchronous motors often consist of up to 10 percent of dysprosium, which helps in improving coercivety and temperature tolerance.

Apart from the motor, the other key components (presented in figure 3) include inverter, converter, PDU and charger. The inverter converts the direct current (DC) of the battery to alternating current (AC) for electric motor operation. The DC voltage converter supplies power for on-board electrical system using low voltages. However, certain EV concepts have been developed that provide additional DC converter which converts the battery voltage to a higher voltage before converting it into AC for the electric motor using a downstream inverter. The power electronics also have printed circuit boards with other control electronics equipment. Typically a vehicle with 20 kW of power is estimated to weigh between 40 to 60 kg.

The share of materials by weight in electric drive motors is presented in the figure 17.

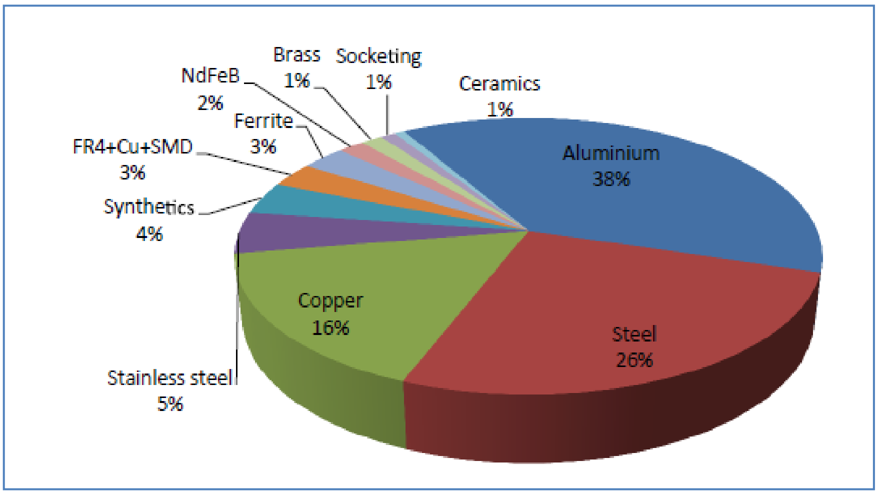


Figure 17: Material composition of electric drive motors (by weight percentage)

5.2.3.3 Glider

Steel has remained a major material for the body of an automobile because of its structural integrity and ability to maintain dimensional geometry throughout the manufacturing process. In response to increasing demands for more fuel efficient cars, the past ten years have seen changes in the composition of materials used in automobiles. Most of the original equipment manufacturers (OEMs) are developing multi-material strategies for building body in ICE vehicles and the same thinking is applicable for EVs. Companies are using a mix of ferrous and non-ferrous metals and plastics. Uses of iron and steel have come down over the years and have been replaced by plastics and aluminium.

The decline in steel used in automobiles is partly due to the use of better and more compact steel components in recent years, particularly the use of high strength steel plate (High-Tensile Steel). Its use is rapidly increasing as a means to reduce car body weight; in some types of automobiles, high tensile steel constitutes more than 50 percent of the car body weight. Aluminium and plastics are also valuable materials that are used in the body, not only for their lighter weight, but also because of their inherent corrosion resistance. Tesla Model S body and chassis are manufactured mostly using aluminium. Being lightweight material, it helps in maximizing the range of the battery beyond that of other EVs. The total amount of aluminium used in the car is 190 kg that constitutes to somewhere 8 to 10 percent of the vehicle weight.

The share of materials by weight in gliders is presented in figure 18.

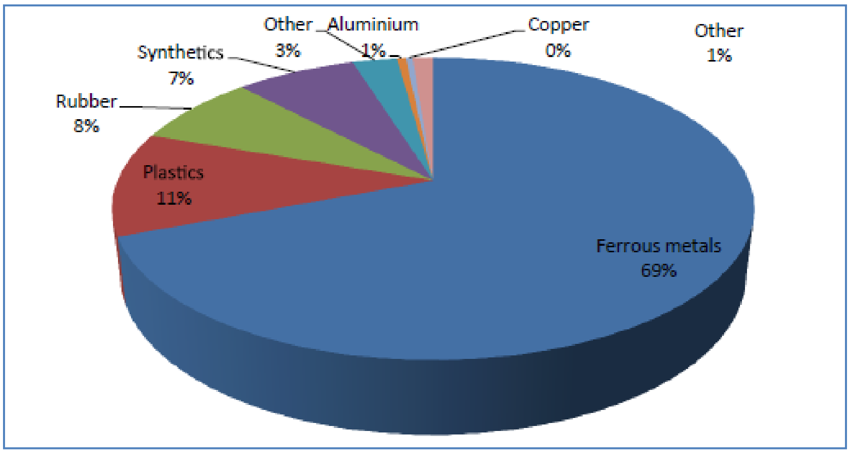


Figure 18: Material composition of glider (by weight percentage)

5.2.3.4 Estimated consumption of materials for manufacturing electric cars in India

The estimated material consumption is based on the projected production of the electric cars in India. Assuming that 70 percent of the vehicles are in the hatchback segment, the annual production of electric cars (hatchback) will increase from its estimated current value of 30000 to almost 10 million by 2030, with a cumulative registration of 24 million by 2030. The reason for considering hatchback is to ensure equivalence with the drive train power and the battery capacity as considered for the exercise and described in above. This big change in manufacturing electric cars will drive up the consumption of different materials. Since the volume of production of electric vehicles that run on lithium batteries are currently limited, the demand for related materials is currently insignificant. However, consumption of materials by 2030 will increase significantly from its current level of 0.03 million tons to 11 million tons. Ferrous metals will contribute to 53 percent of the total estimated demand, followed by 17.4 percent of plastics and synthetics, 2.5 percent of aluminium and 7.2 percent of copper. Figure 18 presents the materials that will be required to meet the cumulative demand for manufacturing nearly 24 million vehicles (hatchback) by 2030.

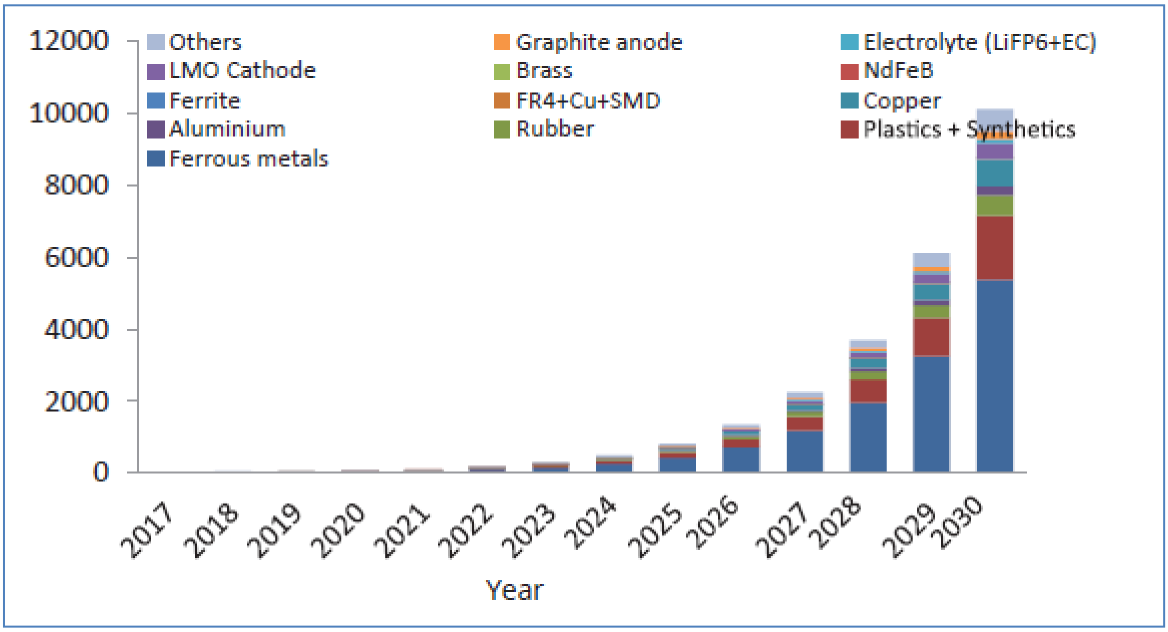


Figure 19: Material requirement for various four wheel electric cars (hatchback) in India till 2030 (thousand tons)

With no change in material composition in three major components (i.e. glider, drive train and battery pack) of electric vehicles, the estimated demand for ferrous metals would increase from 0.016 million tons to 5.3 million tons. Estimated increase in consumption of plastics and synthetics would be nearly 1.8 million tons, while the increase in copper would be around 0.8 million tons by 2030. Requirement of neodymium, iron, boron fused permanent magnets would increase from 28 tons to almost 9000 tons, while lithium based cathode and electrolyte salts would increase from 2000 tons to 525000 tons.

5.2.3.5 Need for adopting resource efficiency in the EV sector

Many critical materials that are used in manufacturing EVs are mostly imported by India. For example rare earth materials for non-defence applications are currently imported to India in finished form. Rare earths are present in different minerals and are recovered as by-products from phosphate rock and from spent uranium leaching9. Indian Rare Earths Ltd (IREL), a public sector enterprise, under the administrative control of Department of Atomic Energy (DAE) has been processing monazite and has also recently set up a plant in Odisha for processing 10,000 tonnes of monazite per annum. However, this is largely used for defence application. India mostly imports rare earths as monazite which is the principal source of rare earths in India, contains uranium and thorium which are prescribed substances and controlled under Atomic Energy Act, 1962.

Between 2009 and 2017, India's import of rare earth has increased nearly four times from INR 0.7 billion (Euro 8.5 million) to INR 2.4 billion (Euro 33 million). In terms of quantity, the average imports in recent years are reported to be around 400 to 500 tons11. Absence of adequate recovery and inefficient recycling, combined with lack of use of newer/substitutable materials will lead to increased imports. The estimated demand of rare earth magnets for manufacturing motors in electric cars (hatchback), assuming no change in technology and efficiency of motors, will be approximately 9000 tons by 2030. This is approximately 150 times the current import of the rare earths by India. Further, the estimated import demand will increase further if its application in other forms of electric vehicles (e.g. two-wheelers, buses, etc.) is also taken into consideration. Given that majority of the rare earths are produced in China, recent imposition of mining quota and consolidation in mining operations, it is predicted that there will be lesser supply flexibility and mounting pressure on prices. This development in the international market of rare earths will significantly increase the import cost and has the potential to nullify the anticipated benefit arising from reduced import of crude oil.

Further the environmental footprint of rare earth extraction is quite high. Studies have confirmed that that the extraction and refinement of oxides of rare earth has serious environmental consequences. Research based on life cycle assessments (LCA) in automotive industry conclude that permanent magnets NdFeB may be substantially damaging when compared to other materials commonly used in electrical equipments. NdFeB magnets may be responsible for as high as 25 percent of the material processing related GHG emissions, although their share of weight in motors may be very less.

Lithium has emerged as a key resource that goes into manufacturing batteries in electric vehicles. For lithium batteries in electric vehicles, as presented in the previous sections, cathode materials largely include minerals such as aluminium, cobalt, lithium, manganese, and nickel, with anode made up of graphite. Primary availability of many of the materials, that go into manufacturing batteries, like lithium, cobalt, nickel, copper used in conductors, cables, and busbars is limited. Value of import of lithium (e.g. Lihtium oxide, hydroxide, carbonates and pure metal) has increased from INR 2 billion (Euro 25 million) to nearly INR 15 billion (Euro 188 million) between 2010 and 2017, increasing at a compound annual growth rate of 30 percent. Import of cobalt has also increased in recent years12. While import of cobalt ore and concentrates have fallen over the years, India's import of cobalt salts and materials like cobalt oxides and hydroxides, commercial cobalt oxides, and other articles of cobalt has more than doubled between 2010 and 2016. Specifically, India's import of processed cobalt salts and materials increased from INR 0.5 billion (Euro 6.2 million) to INR 1.1 billion (Euro 13.8 million), between 2011 and 2018.

Although certain studies reveal that there are enough lithium resources available globally to meet the growing requirement and in particularly for the energy storage sector, the challenges that remain for India is largely with regard to trade supply chain, availability at affordable prices and its many competing applications among others. Further, India, has not made any substantial efforts to ramp up domestic availability of these scarce minerals. There are also investments risks foreseen, possibly due to absence of long-term policies.

Thus India is highly import dependent for these minerals and at times has had to struggle to acquire lithium and cobalt assets abroad, along with other resources, to ensure security of their future supply. China has taken a lead in the race towards acquiring assets of these mineral resources, similar to the way it did through investment abroad in oil and gas sectors.

5.2.3.6 Resource efficiency opportunities in the EV sector

5.2.3.6.1 Neodymium Iron Boron magnets and electric traction motors

Neodymium is a member of the family of materials known as Light Rare Earth Elements (LREE). These magnets offer such high levels of performance owing to their very high Maximum Energy Product compared to other magnetic materials. The key ingredient allowing NdFeB magnets to operate at high ambient temperatures is Dysprosium; a Heavy Rare Earth Element (HRE) which is added to NdFeB in order to increase the high temperature coercivity (ability to withstand demagnetisation) of the magnets above 100 °C. Although the performance benefits of these NdFeB permanent magnets are undisputed, but there are concerns over the availability, supply and the prices of these rare earth materials. However it has been established that the traction motors without NdFeB materials would have significantly lower costs.

Reducing the use of NdFeB magnets would have significant environmental benefits too as they are responsible for 25 percent of the material related greenhouse gas emissions, despite being less than 5 percent of the motor by mass (Widmer, J. et.al 2015). It is therefore worthwhile to consider the alternatives replacing or minimizing the used of rare earth permanent magnets.

Hitachi Metals have developed magnets with reduced Dysprosium content as compared to conventional NdFeB materials, and without a reduction in their high temperature coercivity. These magnets are manufactured using a new process, which involves the diffusion of Dysprosium into the magnet material in place of direct alloying. Other interventions are targeted towards reducing the grain size in the magnets to nanoscale with the expectation that this will significantly increase the Maximum Energy Product of the material.

5.2.3.6.2 *Induction motors with no permanent magnetic materials*

Induction motors contain no permanent magnetic materials, instead they operate by inducing electrical currents in conductors in the motor's rotor; these currents in turn give rise to a magnetic field in the rotor and hence produce torque. Further when switched off, these motors are inert, producing no electrical voltage or current, no losses and no cogging torque. However, induction machines incur losses in their rotor conductors, which can result in total rotor losses typically two to three times higher than in a permanent magnet based motor. High rotor losses are not desirable as the rotating rotor is much more difficult to cool than the stationary stator. In practice these high losses mean not just that this type of electrical machine may be less efficient than other options but also that in operation it may quickly become overheated. However, these motors are able to produce high levels of performance using modern and appropriate vector control techniques as was in the case by Tesla motors.

Tesla Motor Corporation uses copper rotor cage in their electric vehicles as opposed to commonly used aluminium. This motor technology had proved to be highly successful for Tesla in recent. However with Model 3 Tesla has made a significant change to use a permanent-magnet electric motor instead of the AC induction motor it has used so far.

5.2.3.6.3 *Using recycled material/ secondary resources for manufacturing lithium ion batteries*

Based on a life cycle analysis of Lithium Cobalt Oxide based Lithium ion battery reveals a 70% reduction in energy consumption when lithium ion cell is produced from recycled cobalt vis-à-vis virgin raw material. However, recycled lithium is more expensive than extracted lithium and currently it may not be attractive to retrieve lithium from used batteries. This will not be the case in the future, when recycled lithium will represent the largest cumulative source. Although experts do not consider a scenario of lithium depletion17, the question of emancipation from suppliers remains crucial.

5.2.3.6.4 Next Generation Batteries/Innovation in Battery Chemistries

With the aim of returning Japanese manufacturers to the forefront of automotive battery technology, the four heavyweight Japanese companies -Toyota, Nissan, Honda and Panasonic have teamed up for a new research and development program to develop solid-state batteries. The Consortium for Lithium Ion Battery Technology and Evaluation Center, or "Libtec," is being supported by a $14 million support grant from Japan's Ministry of Economy, Trade and Industry.

Solid-state battery technology is increasingly seen as the next big development in the EV sector. While lithium-ion batteries use liquid electrolytes, solid-state batteries employ a solid form of this key component, making the new batteries easier to manufacture and safer, as they do not leak. They also have fewer components, cost less, and provide higher energy than the lithium-ion batteries -- the current choice for electrics and hybrids. Libtec consortium's end goal is to jointly develop net battery technology that could support 800-km runs between charges by 2030. The shorter-term goal is to create a 550-km range pack. That's well above the range of most of today's EVs, and is around the capacity of Tesla's Model S 100D, which has a massive, heavy and costly 100-kWh pack.

Solid state lithium ion technology has a real promise but this is clearly a moving target. Meanwhile other companies like BMW have also started investing in developing their own solid state designs. The company claims to have achieved a breakthrough by incorporating a high-capacity lithium metal anode in lithium batteries – creating a solid-state cell with an energy capacity "2-3X higher" than conventional lithium-ion.

5.2.3.6.5 Design of EVs

At the design stages it becomes essential to design for an elongated use phase that not only delays the death of the vehicle but allows the reuse of parts which are in working condition (and do not create any safety issues). Moreover designing for greater dismantling on effective disposal, will enhance the recovery of parts which could be used for remanufacturing of vehicles. In case of any failure to meet the recovery target, manufacturers will have to consider redesigning of the vehicle to enable easier and efficient dismantling. Also having a design of vehicles which is receptive to using recycled/secondary raw material will reduce the chances of downcycling. This should be accompanied by focusing on high-efficiency engines and lightweight materials which take less energy to accelerate the vehicle.

5.2.3.6.6 Better EV powertrain integration

Efficient powertrain integration calls for moving many parts of the power electronics closer together and integrating into fewer modules. As OEMs continue their hunt for design efficiency, mainstreaming powertrain integration offers substantial potential in terms of raw material savings and in increasing efficiency. A good indicator for the increased level of integration is the design of the electric cables connecting the main EV powertrain components (i.e., battery, e-motor, power electronics, and thermal management modules). For instance if we look at the weight and total number of parts for these cables across OEMs and their EV models, we observe a decrease in both cable weight and number of parts in the OEMs' latest models compared to the earlier vehicles, reflecting a higher integration of more recent EV powertrain systems.

5.2.3.6.7 End of Life management of EVs

Recycling and Reusing Worn Cathodes to Make New Lithium Ion Batteries

Less than five percent of used lithium ion batteries are recycled today and with EV sales picking up, it implies that overtime we will face huge stocks of end-of-life batteries and given the finite amount of resource available it becomes essential to invest into technologies aimed at extending the use life of components and recovering the embedded materials. Further with prices of lithium, cobalt and nickel having risen significantly in recent times, recovering these expensive materials could lower battery costs. As a lithium ion battery wears out, the cathode material loses some of its lithium atoms. The cathode's atomic structure also changes such that it's less capable of moving ions in and out. University of California has developed an energy-efficient recycling process that restores used cathodes from spent lithium ion batteries and making them work sufficiently good enough to restore the storage capacity, charging time and batter lifetime to their original levels. The process involves harvesting the degraded cathode particles from a used battery and then boiling and heat treating them. Efforts are geared towards making new batteries using the regenerated cathodes. The new recycling process uses 5.9 megajoules of energy to restore one kilogram of cathode material whereas several other lithium ion battery cathode recycling processes consumes at least twice that energy. Currently the researchers are working towards refining this process so that it can be used to recycle any type of lithium ion battery cathode material, in addition to lithium cobalt oxide and lithium NMC with the goal to make this a general recycling process for all cathodes.

Copper recycling from End-of-life Electric Vehicles

Copper is in high demand for infrastructure development in emerging economies and will be one of the key materials in manufacturing of electric motors for hybrid, PHEV and EV powertrains, given the increase in the proportion of electronics in the next generation of vehicles vis-à-vis conventional ICE based vehicles. Toyota Motor Corporation along with a number of partner firms in Japan, have developed what it claims to be the world's first technology to recycle copper in wiring harnesses. According to the company, the new recycling process is able to produce copper with a purity level of 99.96 percent from the wiring found in automobiles and after stringent quality checks, the retrieved copper was successfully reintroduced into the vehicle production process. Toyota estimates as much as 1000 tons of copper can be produced annually using the new recycling process.

5.2.4 Towards an enabling framework for promoting resource efficiency in automotive sector in India

In the last decade, India has experienced one of the highest motorisation growth where more than 200 million motorised vehicles where registered by 2015. Central Pollution Control Board has estimated that more than 8.7 million vehicles had reached the End of Life Vehicles ELV) status in 2015, and by 2025, the number of ELVs is estimated to reach over 21 million. Further, the recent ban on diesel vehicles by the National Green Tribunal implies that more vehicles will soon end up as ELVs. The current situation experiences these vehicles usually ending up reaching the unorganised sector for dismantling. Auto components are either refurbished or sent for recycling. Efficiency of material recovery is very low since people who are involved in these activities are not trained. While some aspects of ELV recycling are addressed by the vehicular and environmental policies as well as in the waste management rules, there are other aspects that are yet to be covered by existing laws. CPCB has recently issued guidelines to regulate the sector in an environmentally friendly manner, recommending a system of "shared responsibility" involving all stakeholders—the government, manufacturers, recyclers, dealers, insurers and consumers. The guidelines also state that if large quantities of metal and other materials present in ELVs are salvaged or recycled, it can once again be used by various sectors, thus reducing the demand for virgin raw materials. While these are guidelines, the system will not work unless and until there is proper way of understanding how to define end of life vehicles, possibly an incentive that need to be provided in the form of paying the last ELV owner a salvaging price and as well as introducing take back system as a part of the extended producer responsibility framework. Automotive Industry Standard (AIS), 129, defines ELV as a vehicle which, at the discretion of its last owner, is ready to be scrapped. But since the scrapping allowance is minimal, many vehicle owners do not discard their vehicles when the government timeline expires. They, instead, sell their vehicles in rural areas or to the second-hand dealers. India had earlier proposed a vehicle scrappage policy that sought to do away commercial vehicles that are more than 20 years old however; the same is yet to be finalized. However, there have not been many deliberations on the private vehicles.

It is important to make the customer aware of the danger—environmental, legal or related to misuse—of using the services of the unorganised sector, and provide them world-class services at their doorsteps. Also, the very definition of ELVs in India leaves a fundamental impediment—defining the average life of a vehicle. For instance, in countries such as Taiwan, China and Singapore the average life of a vehicle is 10 years or in terms of the kilometres driven, whichever comes first. This needs to be incorporated in the regulatory framework for accurate assessment of a vehicle.

On the supply side, there are many challenges—high investment costs for establishing reverse logistics networks; the cost of the quality assurance test equipment; or, the fact that some products may not have been designed to be dismantled easily for reuse. These factors can fail the business case for reuse, remanufacture and recycling. There is also an urgent need to formulate rules which mandate automobile manufacturers to frame the Standard Operating Procedures (SOPs) to dismantle every model and type of vehicle, which would encourage them to reconsider the material while making new automobiles.

The SOPs could then be shared with the semi-formal sector, which would enhance the efficiency in the recycling process. Streamlining the unorganised sector is extremely important. AIS 129 standards need to be incorporated in the regulatory framework to ensure compliance by the unorganised sector, where most of the recycling is done. But the material recovery rate in this sector is low, and compliance with AIS 129 will help enhace material use efficiency.

Further, the non-availability of facilities such as the National Automotive Testing and R&D Infrastructure Project in each hub does not serve the requirements of small and medium-sized auto component manufacturers. Such centres are critical to train personnel who could then dismantle scientifically, thereby leading to better resource recovery. Before the government implements the National Electric Mobility Mission 2020, it needs to set up high-grade recycling units to recover lithium, cobalt and other metals used in traction batteries, which is important from an ecological point of view.

Vital ingredients need to be developed to make this business model a viable one. First, the setting up of collection centres, which would collect vehicles from owners and carry out the deregistration process. Second, the setting up of de-pollution centres to remove hazardous materials from the vehicles. It will also be their responsibility to safely dispose the harmful materials.

Third, shredding centres should be set up, which would segregate materials for recycling. Automotive shredder residue should be sent to incineration plants for energy recovery. Lastly, vehicles about to be scrapped often have reusable parts. These parts can be separated at the de-pollution units and could be sold to retailers or to used-part dealers. Importantly, a mechanism needs to be put in place that offers the right economic incentives to garner the support of both consumers and manufacturers for the effective management of ELVs in India.

5.3 Plastic Packaging Sector

5.3.1 The Plastics Industry (with special reference to plastic packaging)

The most common forms of plastic polymers on the market include Polyethylene erephthalate (PET), High density polyethylene (HDPE), Low densit polyethylene (LDPE), Polyvinyl chloride (PVC), Polypropylene (PP) and Polystyrene (PS). Further types of polymers may include resins and multimaterials like Acrylonitrile butadiene styrene (ABS), Polyphenylene oxide (PPO), Polycarbonate (PC), linear low-density polyethylene (LLDPE) or Polybutylene terephalate (PBT), amongst others. There are a multitude of end use applications for these polymers which vary considerably across different national contexts and are swiftly replacing traditional materials due to their flexibility and unique set of properties.

India's plastics industry is characterised by a relatively high level of market concentration in upstream processes vis-à-vis low levels of concentration in downstream processes. With regards to upstream processes, industrial manufacturers control the market for supply of polymers alongside 200 equipment manufacturers which cater to roughly 30,000 plastic processing units. Further downstream, collection and recycling are mainly dominated by the informal sector with about 1.5 million workers in total, catering to around 4,000 informal and 3,500 informal recycling units (Federation of Indian Chambers of Commerce and Industry 2017). Hence, downstream processes tend to be dominated by micro-, small and medium sized enterprises which specialise on certain end-use applications and processing technologies for injection moulding, extrusion, blow moulding or others. A simplified illustration of Indian plastics industry is presented in figure 20.

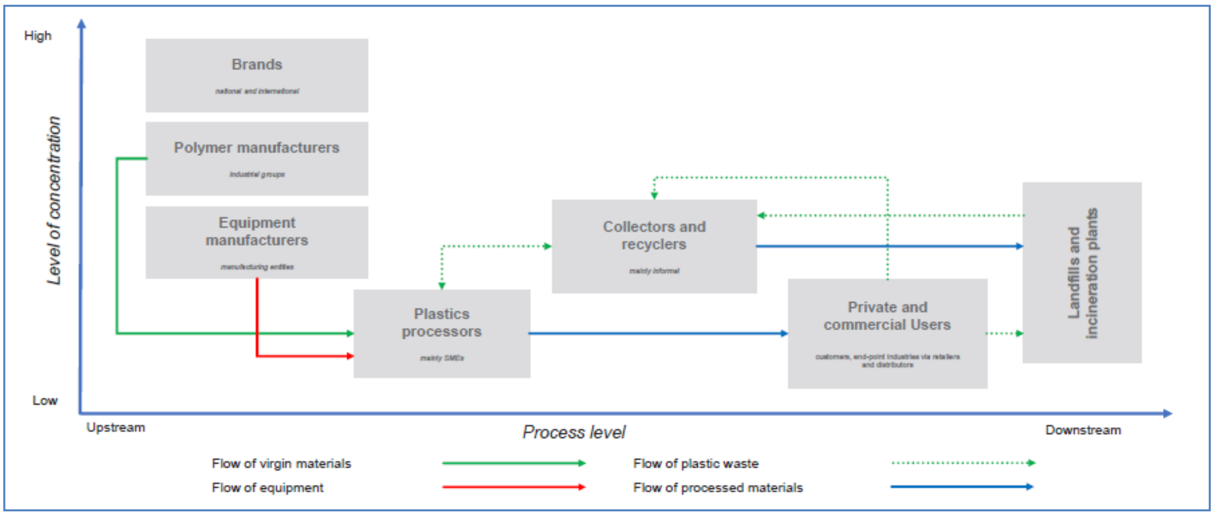


Figure 20: Value chain of plastic packaging industry in India

Source: EU-REI 2018

Economically, plastic packaging is particularly important for the segment of Fast Moving Consumer Good (FMCG). According to FICCI, more than 95% of the total number of biscuits, dried processed food items, hair care products and more than 85% of dairy products, baked goods, laundry and skin care sold in India used plastic packaging as a material of choice in 2014 (Federation of Indian Chambers of Commerce and Industry 2016). Through recent years, the plastic packaging industry has undergone a gradual shift from rigid to flexible packaging due to its visual appeal, low price and high durability. Flexible packaging consists of either monolayer or multilayer films. These mainly include PE, PP, PET and PVC but may also consist of a thin foil of aluminium which is sandwiched or laminated in a structure of paper and/or plastic layers. According to the Central Pollution Control Board (CPCB), multilayer packaging refers to "any material used or to be used for packaging and having at least one layer of plastic as the main ingredients in combination with one or more layers of materials such as paper, paper board, polymeric materials, metalized layers or aluminium foil, either in the form of a laminate or co-extruded structure.

In sync with polymer manufacturing capacities, analyses show that processing capacities have increased by a compound annual growth rate (CAGR) of 10% between 2010 and 2015 and are expected to continue at CAGR of 10.5% for the subsequent five years, thus reaching an annual production volume of 22 million tonnes by the end of the decade. Due to growing domestic sales potential, India is emerging as one of the key markets for plastics processing and polymer conversion worldwide. The trade balance of the Indian polymer market suggests that, due to enduring growth, India's polymer production capacities are increasingly catering to international demand. Overall however, India maintains a trade deficit in plastics, especially relying on imports of PE and PVC. Major trade partners for imports of plastics include (valued by current monetary value) China (15.66%), South Korea (10.33%), United States (7.71%), Thailand (7.14%) and Japan (6.32%). With regards to exports of plastics, major trade partners are the United States (12.64%), United Arab Emirates (5.09%), Germany (4.18%), China (3.83%) and Bangladesh (3.7%). Hence, India's trade balance for plastics stood at USD 14.3 billion imports versus USD 7.6 billion exports, amounting to net imports (trade deficit) to the tune of USD 6.7 billion.

With 11 kg per capita1, India's consumption of plastics is less than half of the world's average (28 kg per capita) and almost six times lower than in Europe (65 kg per capita). This can be attributed to a combination of factors, such India's large population coupled with low penetration levels of plastic products in rural areas. While low per capita consumption appears desirable from a purely environmental point of view, it also highlights the enormous growth potential which has been addressed in more detail above. Given that India is home to a population of about 1.3 billion people, total plastic consumption can be estimated 14.5 million tonnes in 2016 (World Bank Group 2017). Looking at the growth trends illustrated above, this appears to be roughly in line with figures provided by the Central Pollution Control Board (CPCB) which estimated annual plastics consumption of 12 million tonnes and 8 million tonnes for 2012 and 2008 respectively (Central Pollution Control Board 2014; Central Pollution Control Board 2013). Demand of polymer types in India is presented in table 7 below.

Table 7: Type of polymers used in India

Type of polymer	Share (relative) in percent	Share (absolute) in million tonnes
Polyethylene (PE)	43	6.235
Polyvinyl chloride (PVC)	28	4.06
Polypropylene (PP)	24	3.48
Poly styrene (PS)	3	0.435
Others	2	0.29

Source: EU-REI 2018

End use application of plastics in different sector is presented in figure 21.

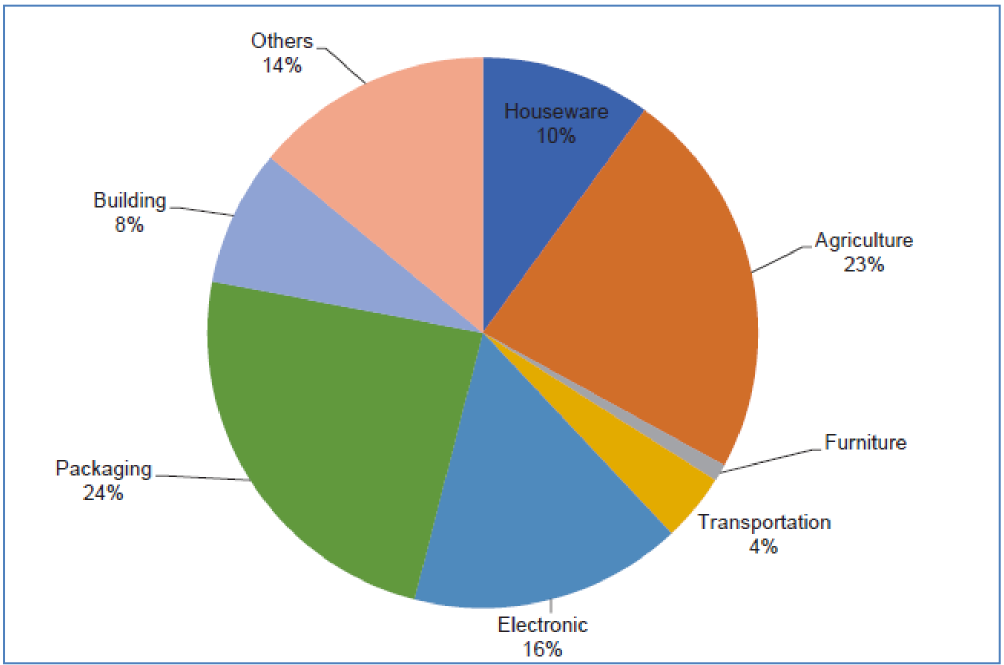


Figure 21: End use application in different sector in India

Source: EU-REI 2018

As can be seen the packaging industry is the largest consumer of polymers in India. According to analyses by the Federation of Indian Chambers of Commerce and Industry (2016) for the packaging segment in 2016, PE and PP accounted for around 33% and 29% of polymer usage respectively, followed by PET (17%), PVC (7%) and others (14%).

Estimates for recovery rates (collection and recycling) vary widely across the existing body of literature. For plastic waste in general (applications across all sectors), CPCB estimates that 94% of all plastics put on the Indian market are recyclable (CPCB 2018) and collection efficiency reached 80.29% in 2014 (Bhattacharya et al 2018). According to CPCB's annual report for 2016, India generates 1.6 million tonnes of plastic waste every year. However, comparing this figure to an annual consumption rate of 14.5 million tonnes and the growth of Indian production capacities raises doubts regarding the validity of these statistics. The difference between both numbers may go either unaccounted for or is added to the country's growing stock of plastic waste (Venkatesh et al 2018).

For recycling, large discrepancies arise amongst the reviewed sources, ranging from 28.4% (ibid.) to 42% of plastic waste was recycled in 2014 (Banerjee et al. 2013). Even higher numbers are reported by Atulesh (2011) who estimates a recycling rate of 60%. For materials with established post-consumer value chains (e.g. PET bottles), recycling rates are reported to come close to 70% (Linnenkoper 2017). However, more robust estimates for the overall amount of plastic packaging collected or recycled or processed via thermal recovery remains unknown at this point in time.

While it is unclear which of these figures are most accurate, relatively high collection and recycling rates could be attributed to the strong presence of workers from the informal sector. Till date, major parts of the downstream processes for management of plastic (packaging) waste - including collection and recycling – remains in the hand of micro, small and medium-sized enterprises (MSMEs) from the informal economy (e.g. Kabadiwallas). To some estimates, the informal sector is responsible for close to 70% of plastic waste collection; as for recycling volumes, only 4% of generated plastic waste is processed by formal recyclers, whereas 96% is recycled in the informal sector (WBCSD 2016).

5.3.2 Plastic Packaging in EU

In the European Union some 60 million tonnes of plastic were produced in 2016, the majority of which was applied in the packaging industry. In total, 12.7 million tonnes of plastic packaging waste were collected in 2016. Recycling rates are increasing in all the member states: from 2006 to 2016 plastic waste recycling has increased by almost 80% (PlasticsEurope 2018). This development can be attributed to a complex and constantly evolving legal framework set by the EU and adapted and applied by its member states.

The EU Circular Economy Action Plan identified plastics as a key priority and the Commission committed itself to "prepare a strategy addressing the challenges posed by plastics throughout the value chain and taking into account their entire life-cycle" (European Commission 2018a). Subsequently, the European Strategy for Plastics in a Circular Economy was published in 2018, aiming towards a transformation of the design, production, and use and recycling of plastics and plastic products with key commitments for action (EUROPEN 2018). The strategy focuses on investment in innovative solutions and concrete measures to achieve the vision of a more sustainable plastic economy, with benefits for all member states.

To harmonize national efforts for plastic management the EU Packaging and Packaging Waste Directive (Directive 94/62/EC or PPW Directive) was first introduced in 1994 with the objective of reducing the environmental impacts of (plastic) packaging waste and to facilitate trade of packaging and packaged goods within the EU. Legal obligations for member states in terms of recovery and recycling targets were set. The latest amendment took place due to the adoption of the new legislative proposal on waste (see above) which set new ambitious recycling targets for packaging waste (including plastics) for 2025 and 2030.

5.3.3 Extended Producer Responsibility for Plastic Waste Management

With the introduction of the new Plastic Waste Management, EPR has become a central tool within the Indian waste policy landscape. If we look at the EPR schemes for plastic packaging in the EU, By now, 26 of the 28 EU member states have some form of EPR scheme for packaging waste in place (Watkins Emma et al. 2017), with first implementation efforts starting as early as the 1990s. These schemes vary greatly in terms of set-up, financial performance and responsibilities of producers. While the Austrian EPR scheme finances 100% of collection and net treatment costs, the UK system merely covers 10% of the costs for managing household plastic waste. This fact also attributes to the relatively low fees in the UK (6.7 €/tonne put on the market) compared to other countries like Austria (129 €/tonne put on the market) or Switzerland (64 €/ tonne put on the market). The analysis further highlights that recycling rates are relatively equal across the EU member states (i.e. in the UK 61%; Germany 75%; France 67%; Netherland 72%; and Austria 67%) regardless of the widely differing fees, implying that EPR schemes do not need to be costly for producers in order to be effective (Monier Vèronique et al. 2014).

5.3.4 Case study of Netherlands

As part of the implementation of the Dutch EPR system and the Packaging Decree, a framework agreement has been signed by national government, the packaging industry and the Association of Dutch Municipalities (VNG). According to this agreement, producers pay a packaging waste management contribution to a centralised packaging waste fund (Afvalfonds Verpakkingen). The fund compensates municipalities for collecting separated packaging waste from households, thus ensuring separate collection of paper and cardboard, glass, plastics and beverage cartons. In addition, the EPR scheme is supported by sector innovation plans which stipulate objectives for improving the sustainability of packaging chain. These plans are set out by producers and importers themselves, thus fixating the responsibility even more firmly at their end. Monitoring and enforcement of the EPR scheme is ensured by agreements with Human Environment and Transport Inspectorate (ILT), the Ministry of Infrastructure and the Environment, and Rijkswaterstaat Environment (RWS) (Kennisinstituut Duurzaam Verpakken 2015).

5.3.5 Case study of France

In 1992, a collective EPR scheme for household packaging waste was introduced in France. Operating under the name of CITEO (previously Eco-Emballages), it covers all companies, producers and importers responsible for placing packaged products on the French market and seeks to encourage separate collection and reduction of waste at the source. French legislation sets an ambitious recycling target of 75% for all packaging materials put on the market. By joining CITEO, producers finance the additional cost of separate collection which is carried out by local authorities. These Advance Recycling Fees (ARFs) are calculated based on the number of sales of packaging units placed on the market (before 2016) and their weight per material. In 2012, eco-modulation of fees was introduced, providing boni or mali in order to encourage eco-design and separate collection and reduce the amount of non-recyclable packaging (for more details, please refer to the textbox below. In 2016, a packaging recycling rate of 68% was reported, representing 3.3 million tonnes in total and a steep increase from 18% (816,000 tonnes) shortly after the formation of the PRO in 1993. Since then, 50,000 companies participate in recycling and sorting initiatives implemented by local authorities. Since 1993, collected ARFs represent a combined value of EUR 8 billion whereas in 2016 alone, contributions were valued at EUR 654 million for a total of 4.9 million tonnes of post-consumer packaging collected. The average contribution per tonne collected can thus be estimated at EUR 133 annually, implying a slight decrease over time from EUR 140 per tonne in 2012 (Watkins Emma et al. 2017).

5.3.6 Implementation of EPR for plastic waste management in India

Various implementation challenges remain which can hamper the effectiveness of EPR in India. For one, monitoring and enforcement systems remain yet to be fully implemented so that policy makers can review the effectiveness of sub-national level implementation and allocate resources accordingly.

The wide-spread adoption of secondary raw materials will fall short unless EPR schemes are complemented by policy instruments which increase their market penetration at a pan-Indian scale. Typical instruments which facilitate this process are standards for secondary raw materials (SRM). Standards are technical documents that provide requirements, specifications, guidelines or characteristics to ensure that materials, products, processes and services fulfil their purpose. Hence, they play a crucial role in creating a level playing field and create economic benefits by reducing transaction costs in competitive market environments. In India, standards are issued by the Bureau of Indian Standards (BIS) which represents a statutory organisation under the Indian Standards Act from 1986. Interviewed experts repeatedly suggested that a major barrier to using recycled materials is the lack of demand for SRM. This can in part be attributed to a high degree of uncertainty from the viewpoint of manufacturers regarding the technical performance of recycled materials, resulting in fear of production downtimes due to potential complications in the manufacturing process. By developing and facilitating the adoption of standards, this uncertainty can be minimised and manufacturers could be encouraged to substitute virgin feedstock with recycled materials in their production processes. Looking at existing standards in India as well as examples from the EU, one can differentiate between process-related and product-related standards. Process-related standards define criteria for activities carried out along (e.g.) the waste management value chain, including collection of products at the end of life, storage and logistics as well as final treatment. In principle, such standards could also define the steps for integration of informal workers in plastic packaging waste. Product-related standards seek to define the material quality of end products (e.g. recyclates from plastics) by stipulating the degree of purity or prohibiting the use of certain additives.

Specific examples for European standards (e.g. WEEELABEX, CENELEC and CEN) on plastic (packaging) waste.

As of today, the development of standards on SRM in India has not been taken up by the BIS in a comprehensive manner. In the field of environmental protection, a number of standards exist which mainly pertain to environmental management systems, lifecycle assessment methodologies, the development and use of eco-labels as well as greenhouse gas emissions. A first step for standards on production and utilisation of SRM could be the development of a roadmap for standards on RE and CE under the leadership of BIS. Such document would outline thrust areas, technical priorities, materials of high concern and the way forward for the BIS' technical committee. With a Seconded European Standardisation Expert in India (SESEI) being present in India, there also appears to be a valuable window of opportunity for Indo-European collaboration in this field.

5.3.7 Recommendations on EPR for plastic waste management, it is recommended to

- Explore strengths and weaknesses of different implementation mechanics for EPR schemes at a pan-Indian scale;
- Elaborate minimum requirements for EPR schemes in India to streamline implementation processes and create administrative synergies;
- Promote large-scale formalisation of the informal economy through dedicated guidelines and tailor made capacity building programmes;
- Support the implementation of EPR by developing standards in the field of resource efficiency and circular economy;
- Develop and apply Green Public Procurement criteria for circular and resource efficient materials; and strengthen capacities of CPCB and SPCBs in order to monitor and evaluate the implementation of Plastic Waste Management Rules.
- Looking at the implementation of EPR in the plastic (packaging) sector, governmental authorities may consider to mandate step-wise introduction of minimum recycled contents in plastic (packaging) across selected target sectors; evaluate the inclusion of collection targets into Plastic Waste Management Rules to ensure full accountability of producers;
- Foster uptake of innovative and resource efficient processing technologies and inclusive business models which integrate the informal sector; and
- Explore mechanisms which promote the introduction of certification schemes in the field of CE and RE for high-priority packaging products.

Together, these recommendations can contribute to the implementation of EPR schemes in India and increase resource efficiency on a larger scale. The study concludes by highlighting potential for Indo-European collaboration in the area of resource efficiency and circular economy, e.g. by launching a producer responsibility partnership and jointly working towards the implementation of collection, transport and treatment standards.

5.4 Construction and Demolition Sector

5.4.1 Introduction

India has experienced unprecedented growth in urbanization in recent decades. More than 30 percent of India's population is already living in urban areas and. An estimate of the UN State of the World Population report, more than 40 percent of the population will be living in urban areas by 2030. By 2050, India, along with China, Indonesia, Nigeria, and the United States, will lead the world's urban population surge by 2050. The immediate outcome of urbanization is demand for basic infrastructure requirement that is housing. However, there is simultaneous demand for other infrastructure facilities particularly roads, commercial establishments, public services.

With a current contribution of 8% to India's GDP, the sector is the second largest in terms of employment generation after agriculture. India's construction sector is projected to grow at a rate of 7-8 percent over the next 10 years and likely to become the world's third largest by the middle of the next decade. It is estimated that almost 70 percent of buildings supposed to exist by 2030 are yet to be built. Such demand for infrastructure will rely heavily on raw materials like sand (for concrete and mortar), soil (mostly for clay bricks), stone (for aggregates) and limestone (for cement).

The key challenge will be to make materials available in a manner that takes into consideration exhaustible nature of these resources and as well as address ecological impacts associated with their extraction and processing. It is critical to understand the resource flows and introduce interventions that can reduce environmental stress and associated conflicts. Resource efficiency holds the key which helps in conserving resources and recycling raw materials to meet India's future demand of resources, while at the same time reduce costs and thus strengthening the competitiveness of industries. As one of the largest consumer of resources in the country today, the construction sector needs to urgently emphasise issues of resource efficiency.

5.4.2 Life cycle stages of the C&D sector

In order to study the opportunities of RE in the sector, it is critical to understand the important stages of the life cycle in the sector and as well identify hotspot stages that promises high RE potential. This is presented in figure 22.

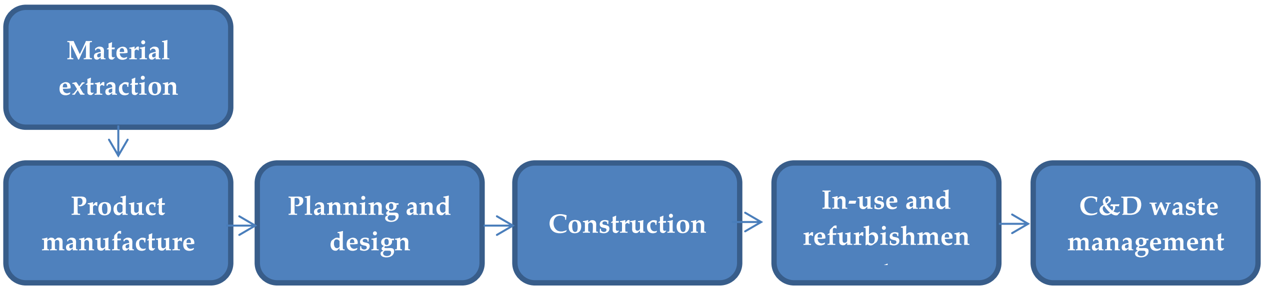


Figure 22: The construction value chain

Stages like component manufacturing, planning and design and C&D waste management is extremely crucial for making construction sector resource efficient. This is because companies need to make manufacturing of sustainable products from recycled materials, ensure through planning and design that resource efficient materials are used. Further, dependence on virgin materials needs to be gradually reduced and enhanced reuse of the construction and demolition wastes needs to be adopted. An estimate from and earlier TIFAC study reveals that on an average India generates around 12-15 million tonnes per annum. This has increased to nearly 100 million tonnes as estimated by MoHUA. Wastes and rejects are also generated during construction of new buildings. However, material recovery from demolition of old infrastructure has much higher potential. To illustrate, new construction and repair may lead to waste generate in the range of 45 to 50 kg/ sq. m, however, demolition can lead to waste generation of 425 kg/m2. The estimated consumption of construction materials in India is very high. For example, India's annual consumption of sand is estimated at 750 million tonnes, while 350 million m3 of soil is used mostly for manufacturing of clay fired bricks. Annually 2 billion tonnes of stones are used for making aggregates. Further 242 limestone million tonnes is consumed in cement plants to manufacture 297 million tonnes of cement a year. A substantial share of the new demand can be met using the waste of the existing stock.

The following sections present a brief analysis of the materials that are extensively used in the C&D sector, the potential environmental issues associated with mining of some materials and as well the opportunities that exist for recycling of C&D waste.

5.4.2.1 Sand

Sand is a very important resource for the construction industry as it is used for making concrete and brick. Sand is found in rivers (flood plain and river bed), around lakes and reservoirs, agricultural fields, and coastal and marine locations. However, river sand is the preferred over other sources mostly because it has high silica content that makes it inert, hard and durable. It is estimated that the demand for sand will double in the next few years reaching almost 1500 million tonnes. The rivers in Eastern and Northern India are perennial under this system and carry a huge load of silt. The sand is of good quality and therefore rivers in this system are exploited heavily for sand extraction.

In the presence of the serious environmental issues with regard to sand mining coupled with high future demand, there is a need for alternatives of sand. Ecological impacts related to sand mining, including change in instream floral and faunal habitat arising from increase in river gradient, suspended load, sediment deposition, increased turbidity, change in temperature, etc. There have been instances of harmful impacts of sand mining. Sand mining along the Yamuna River has led to shifting of the river flow by almost 0.5 kms towards manmade embankments which was a part of the floods plains of the river Yamuna. The cause of the shift was illegal sand mining up to the depth of 20 feet (which is almost double the legal limit) within 30 metres of the embankment. Figure 22 depicts Material flow of sand in India.

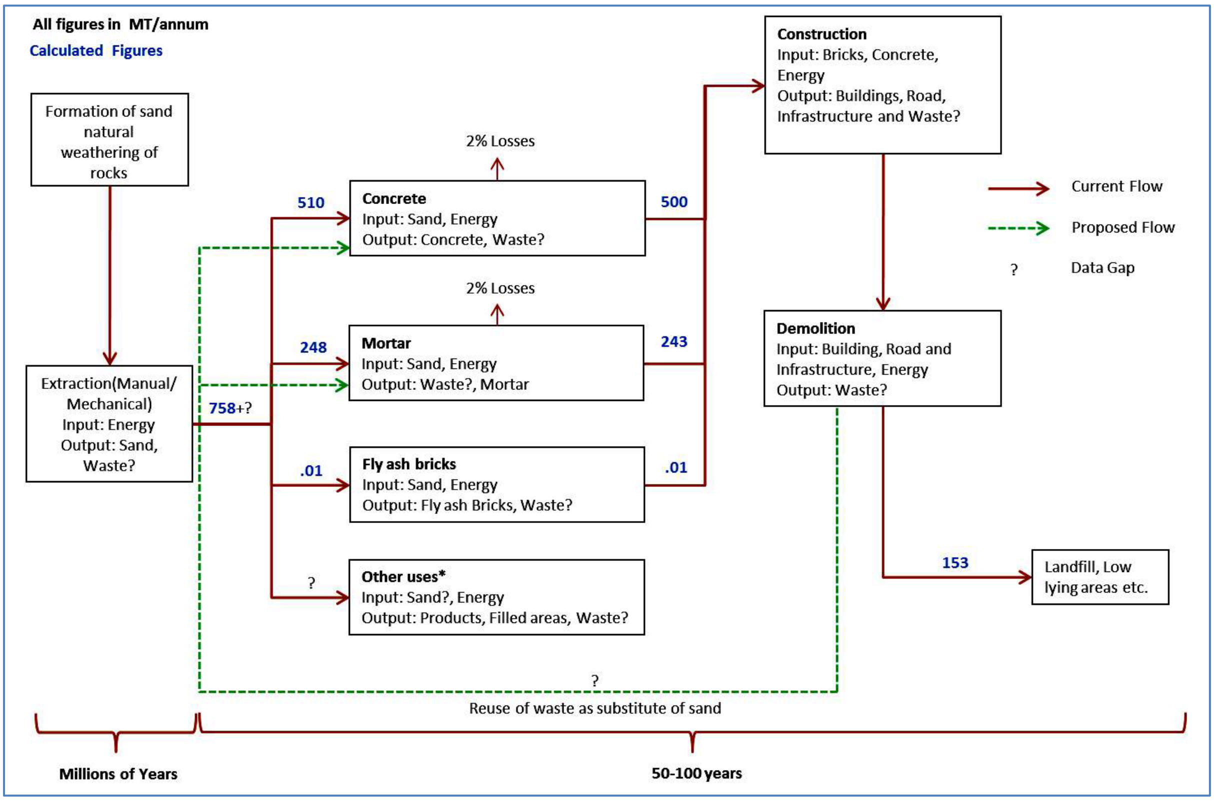


Figure 23: Material flow of sand in India

The process of sand mining requires obtaining permit from the state government as well as payment of royalties on the sand sold to the market. However, there are concerns with regard to adherence to the procedures. Further royalty for sand varies from Rs 0 to Rs 93 in different States. There is a significant variation in the royalty rates across states and the bulk density used for conversion of units of royalty is also different in different States. Seldom is mining carried out in an organized manner, frequently skirting the law.

This calls for better rationalization of the sand royalty rates.

5.4.3 Enabling RE transition in the C&D sector

The responsibilities for managing the C&D waste rests with the local bodies and is a big challenge. The C&D Waste Management Handling (Rules) 2016 mentions that 'every waste generator shall be responsible for collection, segregation of concrete, soil and others and storage of construction and demolition waste generated separately, deposit at collection centre so made by the local body or handover it to the authorised processing facilities….In most cases there are no proper designation of sites for collection of these wastes and hence they are dumped. Further, no advance communications are provided to the local bodies regarding such activities. The rules mentions giving incentives for use of material made out of the wastes. The Rules also specify that all government construction projects, at all levels, should utilise between 10% and 20% of C&D recycled products (aggregates, kerb stones, paver blocks, tiles and manufactured sand). There are very few cases where notifications have been issued regarding provision of incentives for development of products. Consumers have little or no understanding about the collection points from where the debris can be collected and transported to processing sites.

5.4.3.1 Penalising illegal dumping of C&D waste

It is extremely critical to identify designated areas where consumers responsible for demolition can dump the C&D waste are notified. To prevent illegal dumping at other places pilot level monitoring at the ward level needs to be periodically undertaken and violators should be penalized. This will act as deterrence for other generators to illegal dump waste and will further motivate the generator to transfer the waste at the notified collection points. This will help in creating volumes thereby receiving more interests from waste processors to establish decentralised waste processing units. The number of operating C&D waste processing plants is extremely small when compared to other countries. For example, Germany has one of the largest C&D waste processing plants (220), while UK, Netherlands and Belgium have estimated 120, 70, and 60 plants respectively[44]. Given the potential of C&D waste which is expected to be generated in the coming years, there is tremendous potential for such plants to come up making different products and catering to different needs in the C&D sector.

5.4.3.2 Creating fund for incentivizing recycled products

Given that, ULBs often suffer from financial resource constraints, providing incentives for products developed and sold from C&D waste, is an issue of concern. The C&D waste rules mandates provision for giving incentives for use of material made out of construction and demolition waste in the construction activity including in non-structural concrete, paving blocks, lower layers of road pavements, colony and rural roads Property taxes need to be rationalized periodically and funds can be allocated not only for incentivizing product development from recycled C&D waste but also possibly supporting demonstration projects. Further funds need to be created based on the payments received from waste generators for collection, transportation, processing and their disposal as notified by the concerned authorities. The state's support is also important for those ULBs that are yet to be

[44] http://164.100.228.143:8080/sbm/content/writereaddata/C&D%20Waste_Ready_Reckoner_BMTPC_SBM.pdf

financially self-sustaining. As a part of the mandated public procurement of materials made from C&D waste, the ULBs need to explore avenues how the target at prescribed in the C&D waste can be best achieved. For example there are opportunities for using these products for recreational purposes (parks, etc), for roads and pavements and filling of pits, and as well in constructing buildings. This is possible when there are short medium and long terms planning of construction activities undertaken in advance.

5.4.3.3 Fast tracking product certification

Although there is significant market potential of products manufactured from recycled C&D, yet their uptake has been a concern due to the apparent lack of confidence among potential buyers. Certification is an important way to improve market acceptance of products like tiles, paver blocks, and manufactured bricks. The role of BIS here is extremely critical by way of adopting faster certification of products that are launched and commercialised. In 2016, BIS revised 383 standards to allow specific uses of recycled coarse and fine aggregates with certain condition. Although National Building Code of India (2005) also allowed the use of recycled aggregates in certain applications. For example, upto 30 percent of natural crushed coarse aggregate can be replaced by the recycled concrete aggregate which can further increased to 50 percent for pavements and other specific application. ULBs need to maintain a list of authorised sellers of these products and whose details can be provided in e-market place for the larger benefit of the consumers.

5.4.3.4 Technical support to new entrepreneurs

Another hurdle faced in the effective use of secondary material streams like C&D waste is the availability and accessibility to appropriate technologies. There is often a knowledge gap about information on technology and service providers, business potential and challenges and success stories for setting up a facility. Furthermore, if such technologies are imported, as is often the case, there may not be adequate in-house capacity to operate, manage and troubleshooting. This lack of technical support often deters entrepreneurs from engaging in waste management ventures. Technical support to new entrepreneurs from the current processing units will encourage more entrepreneurs to engage in processing of C&D waste. Further JVs will also help address issues associated technology access and transfer and bring in better knowhow from other countries.

5.4.3.5 Monitor implementation of C&D Waste

While the State Pollution Control Boards (SPCBs)/ Committees are supposed to monitor the implementation of C&D Waste Rules and submit annual report to CPCB, however, the progress on the same is clear as these details are not shared publicly. There should be proper reporting mechanism and time frame should be implemented (e.g 3 to 5 years) by when there is strict adherence and any violations can draw possible penal action.

5.4.3.6 Enhancing public awareness

The awareness of the consumers is very low when it comes to their role in ensuring proper implementation of the C&D waste rules in India. The rule suggests that ULBs need to create a sustained system of information, education and communication for construction and demolition waste through collaboration with expert institutions and civil societies and also disseminate through their own website. Such engagement is currently missing. The local bodies themselves need to organize camps for awareness building workshops for the office bearers of the resident welfare associations (RWAs) as well as commercial establishment associations, builder associations, etc.

5.5 Electrical and Electronic Equipment Sector

5.5.1 Introduction

The productivity of human beings has increased manifold from being able to communicate using electronic devices to mechanisation of daily chores like washing clothes. Globally, almost half of the population is now connected over the internet and is online1 (Baldé et al, 2017)). Industries have adopted electronics to enhance safety in work processes which had risks involved for humans. Automobiles have become safer due to the enhanced use of electronics. In the evolving landscape of the engineering and construction sector, electronics is playing a major role. Advanced software, construction-focussed hardware and analytical capabilities are ensuring state of the art improvements in enhancing productivity of materials as well as workers on a real time basis. Safety monitoring on site using electronic equipment has led to faster tracking and reporting of safety incidents. Quality control has increased the efficiency and accuracy of implementation of projects reducing costs and increasing productivity. This has led to increase in material use for Electrical and Electronic Equipment (EEE) production over this time period.

By 2020, the demand of electronic products in India is expected to reach nearly $400 billion with a CAGR of 41% during 2016-2020. Domestic production is expected to grow at CAGR of 27% to reach $104 billion given the Government of India (GOI) push towards manufacturing through its Make in India Initiative and Digital India missions. The growth rate has nearly tripled from 2010-2016 period when CAGR was at 9.6%. In 2016, India was the fifth largest producer of e-waste in the world after the United States, China, Japan and Germany, and according to the Global E-waste Monitor 2017 estimates, it generated nearly 2 million metric tons of e-waste in 2016. With a multitude of electronics which have now become a part of daily life, the consumption of metals and materials like plastics has seen a boom. The resource use per capita shows a significant difference in developed and developing countries. The quantum of waste generated follows a similar pattern as well. According to the Global e-waste monitor, the estimated value of raw materials which can be mined from e-waste stood at 55 billion euros of which mobile phones alone was to the extent of 9.5 billion euros.

The EEE sector is characterised by a relatively high level of market concentration in upstream processes versus a low level of market concentrations in downstream processes. Upstream, dominant players include brands (both international and domestic), component manufacturers and technology providers. They cater to private and commercial end users. Downstream, the informal sector is estimated to handle around 95% of electronic and electrical products at the end of life.

Key challenges which exist for manufacturing are development of skills and inclusion of the informal workers into the formal chain which will allow to address resource security concerns. Furthermore, it is important to note that the work of the informal sector leads to serious health and environmental hazards. This endangers livelihood security and has socioeconomic consequences. It is therefore important to foster adoption of technology which will not only mitigate negative impacts of e-waste recycling but also enhance resource recovery leading to higher incomes, availability for resources for manufacturing and mitigate the environmental and health impacts of hazardous substances.

Across the world, resource efficiency considerations are now been advocated in the design of products (eg, Fairfone) which are used in these industries. This will lead to reduction in environment footprint of producers. Regions like to EU have drafted laws which aim to enhance resource efficiency and circular economy through not only better product design but also enabling product and material recycling. A few of these regulations include the Restriction of Hazardous Substances Directive (RoHS), the Basel Convention, and the Waste Electrical and Electronic Equipment Directive (WEEE) which are enabling frameworks for resource efficiency and circular economy.

Resource efficiency and Circular economy are at the heart of the solutions which can provide the necessary fillip to key Government of India missions and ensure the next wave of growth in the country. The movement towards a circular and resource efficient design than the traditional linear model of produce, use and dispose has the scope of business savings for businesses. The FICCI Circular Economy Report, 2017 clearly outlines that the business opportunity for extracting gold from e-waste is to the tune of $0.7 - $1 billion. Furthermore, 1 ton of ore has an extractable reserve of about 1.4 gms of gold while a ton of mobile phone PCBs can produce about 1.5 kgs. As stated earlier, according to the Global e-waste monitor, the estimated value of raw materials which can be mined from e-waste stood at 55 billion euros.

5.5.2 Waste management in the EEE sector

EEE products have a lifecycle where end of life disposal is critical not only because they are hazardous in nature and affect human health and environment but also because they are a source of secondary materials which can easily be channelized back into the production process. This can lead to livelihood generation and growth.

While collection rates in the informal sector are comparatively high, processing techniques are associated with economic, social and environmental costs, such as loss of valuable raw materials due to low extraction rates in the informal sector; massive environmental pollution and has dire impacts on health of the local population. Figure 24 depicts Value chain of Indian EEE industry in India.

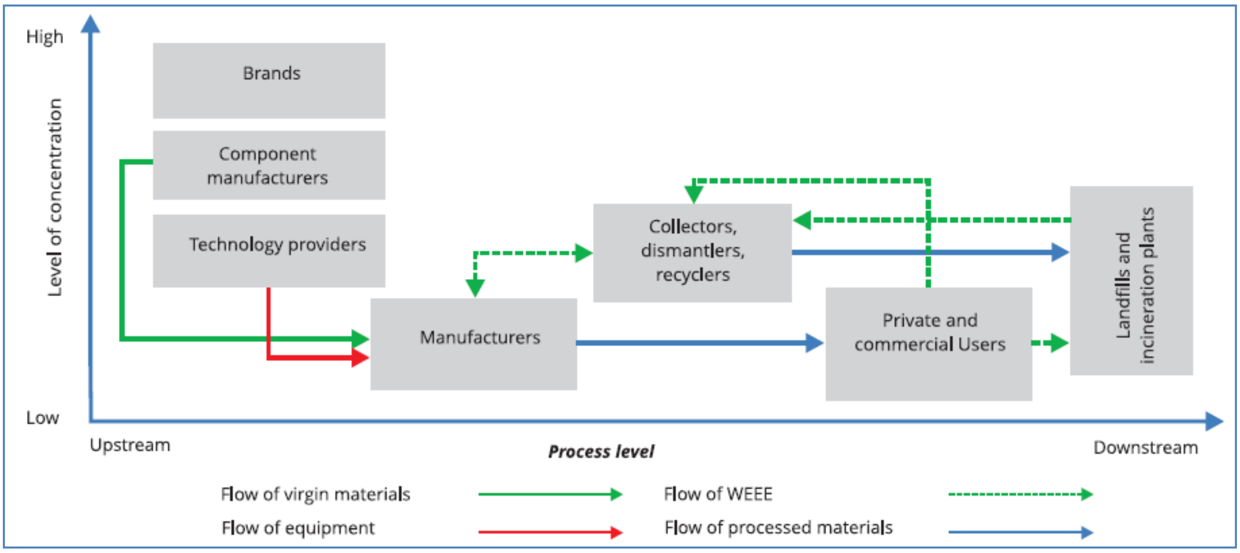


Figure 24: Value chain of Indian EEE industry in India

Source: EU-REI 2018

In contrast, formal recycling facilities are still rare and have not yet scaled up sufficiently in order to recycle e-waste in considerable numbers. In part, this can be attributed to significant differences in cost structures. Whereas formal recyclers face higher fix costs for maintenance of machinery, environmental protocols and administrative procedures, informal recyclers compete at the expense of decent EHS conditions and are thus able to provide higher prices of collected EEE. Hence, formal recyclers continuously struggle to collect e-waste on a sufficiently large scale to mainstream their operations. According to Sinha et al. (2010), the first stages of informal waste processing involve cannibalisation of functioning parts which can be reused for refurbishment of components and products by applying manual labour. Subsequently, all defunct parts are shifted to dismantlers where individual products or components (e.g. monitors, keyboards or CPUs) are further dismantled and broken down to individual components using bare hands and basic tools such as hammers and screwdrivers. Printed wiring boards (PWBs) are placed directly above blowtorches and heaters to loosen solders and remove the components by heat. Often times, these processes are carried out in unventilated rooms without adhering to basic concern for occupational health and safety measures.

Components which have been segregated in such a way are then sorted by their material composition and shifted for material recovery (i.e. extracting of valuable and precious metals). A prominent technique is the use of acid baths for recovery of copper from PWBs. In addition, flame retardant plastics are processed by using crushers, flakers and extruders to create new materials and products. Cathode ray tubes (CRTs) containing dangerous concentrations of phosphorus and mercury are handled without any protective gear whatsoever and broken with hammers in an open environment to separate glass. By openly burning the PVC cladding of cables, additional copper is extracted and sold for further processing.

Overall, the Indian EEE industry is forecasted to expand considerably during the next years with local production growing at more than 16% CAGR between 2012 and 2020. Major EEE categories include consumer electronics (including mobile phones, TVs, refrigerators, ACs etc.), industrial electronics (automation systems, process control etc.) as well as electronic components (Printed Circuit Boards, semiconductors, capacitors etc.); together, these are responsible for 73.5% of the market share.

Figure 25 presents the Break-up of market shares by different EEE categories.

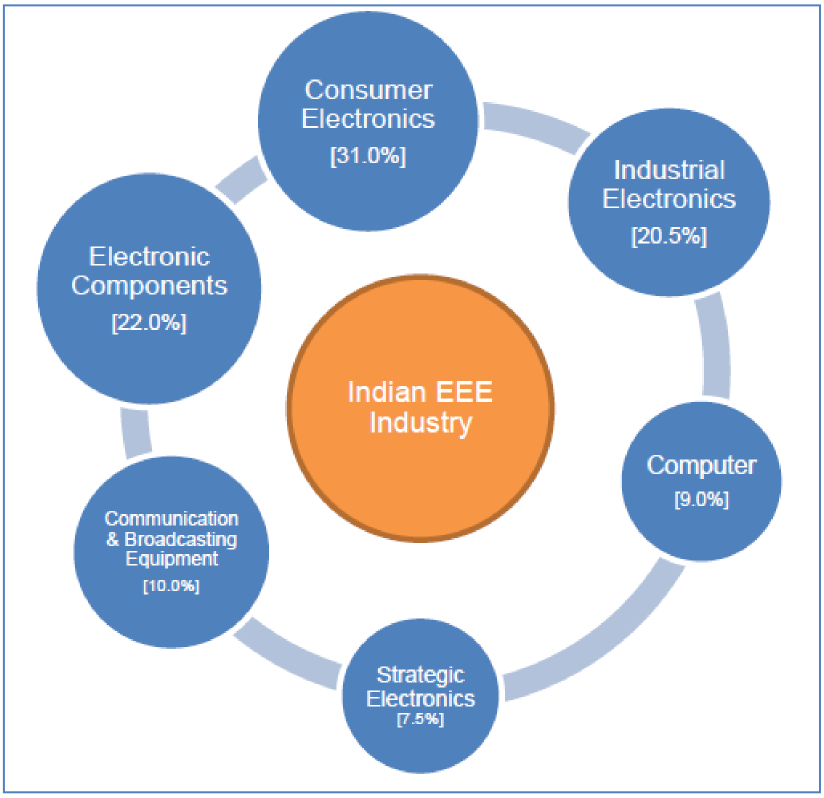


Figure 25: Break-up of market shares by different EEE categories

Source: EU-REI 2018

Within the second strongest market segment – consumer electronics – more than 40% of the market share can be attributed to TVs (36%), set-top-boxes (14%) and AV players (3%) combined, thus highlighting the growing importance of India's middle-income class as an aspirational consumer segment with a strong interest in home electronics and entertainment systems.

India represents the fifth largest producer of e-waste globally and generates approximately 1.85 million tons of WEEE annually (ASSOCHAM India 2017). Other estimates range from 1.64 (United Nations University 2014) to 1.7 million tons a year (Toxics Link 2015). Most recent estimates are in the range of 2 million tons generated every year (IANS 2018; Baldè et al. 2017). According to ASSOCHAM India (2017), the amount of e-waste is growing at CAGR 30% and will reach a staggering 5.2 million tons per year by 2020. As for the generation by state, Maharashtra ranks highest, Tamil Nadu and Andhra Pradesh. With regards to city-wise generation of e-waste, it is estimated that about 24% of India's e-waste is generated in Mumbai, followed by Delhi (21.20%) and Bangalore (10.10%). Top ten city-wise generation of e-waste in % is presented in figure 26.

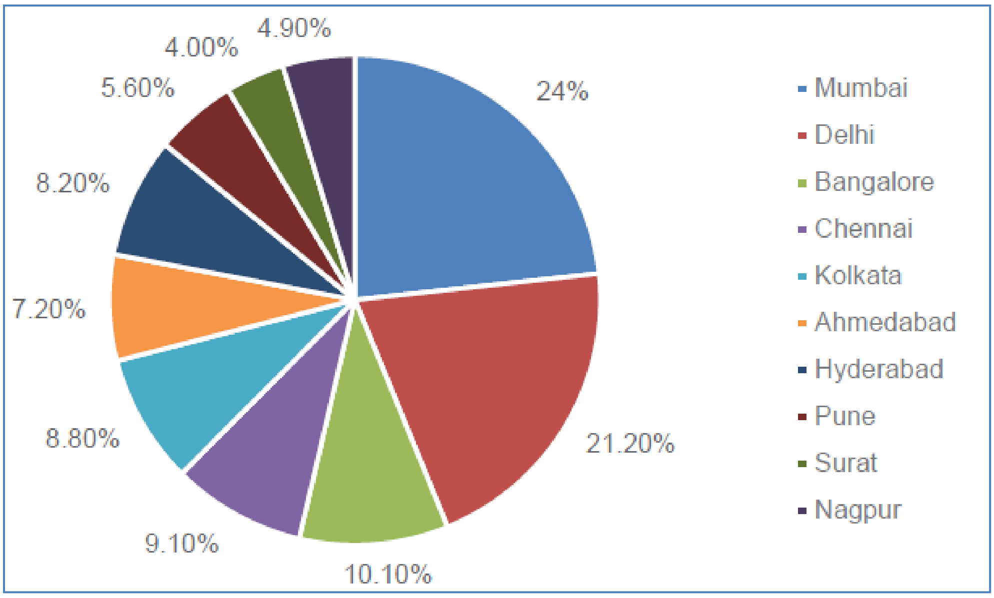


Figure 26: Top ten city-wise generation of e-waste in %

Source: EU-REI 2018

In order to ensure that India moves towards resource efficiency, it is pertinent that the recycling opportunity be grabbed. Recycling leads to not only recovery of materials and metals from waste which can be channelized into the production process but also ensures energy savings while recovering from secondary materials than production of metals from primary sources like ore[45]. Furthermore, it is important to ensure that a design centric approach is followed so that dismantling and recycling for recovery of materials is made easier. This will not only reduce recovery costs but also enhance demand for secondary raw materials but pushing down their prices.

5.5.3 E-waste Management Policy in India

E-waste management frameworks in India have developed over the years from different rules on the subject of waste. Key observations with respect to the framework for e-waste management rules in India are:

- The producers role has been clearly articulated under the Extended Producers Responsibility whereas a target has been fixed for each year for collection of the quantum of e-waste produced in the country. This is a step towards making India resource secure by promoting proper disposal of e-waste and its collection which can ensure that secondary materials can flow back into the production stream.

[45] 2 https://www.recupel.be/en/why-recycle/7-reasons-why-urban-mining-is-overtaking-classical-mining/

- The bulk consumers of e-waste have been mandated to ensure that they dispose the ewaste in an environmentally sound manner to a recycler and maintain records of the same to be produced as and when requested by the respective SPCB or PCC
- The refurbishers have to register themselves with the SPCB or PCC in order to carry on with their livelihood of repair of electronic and electrical items so that any waste generated is disposed of in an environmentally sound manner to the recycler of dismantler of e-waste
- Producers can set-up Producers Responsibility Organisation (PRO) which can manage collection and safe disposal of e-waste as per the targets stated in the e-waste management rules, 2016
- Provisions of legislations were not sacrosanct and hence the same has been revised a few times to make it more robust and fool-proof.

However, many challenges continue to face the e waste management in India. These are depicted in Figure 27.

Figure 27: Challenges of e-waste management in the Indian context

Source: Niti Aayog Strategy Paper for Secondary Materials Management for promoting Resource Efficiency (RE) and Circular Economy (CE) in Electrical and Electronic Equipment Sector[46]

5.5.4 Components of the Secondary Materials Strategy

Development of a strategy to enhance secondary material availability in India will play an important role in addressing the challenges faced in managing e waste. There can be different components of this strategy which will need to be preceded by identification and engagement of stakeholders. These components include:

[46] Available at https://www.niti.gov.in/writereaddata/files/E-WasteStrategy.pdf

Culture of Circularity: Capitalising on the Traditional Values of Reuse, Repair and Refurbishment in the Indian society and Economy- India has traditionally been a society which has produce limited quantum of waste. The culture of reuse and repair lead to the creation of jobs and ensured elongation of life of materials and resources. The economies of scale have predominantly taken over the narrative around resource use leaving principles of circularity and resource efficiency in the background.

Informal Sector: Upgradation of Skills of Informal Sector through Provisions for Utilisation of Indigenous Technology and Capacity Development- The informal sector in India is the backbone of recycling and resource recovery, thereby contributing towards development of a circular economy. However, owing to lack of economic prowess and access to technology, the ways and means employed are often archaic in nature leading to low yield of resources and creation of waste. Most of the times, the methods employed have added risks to human health and environment. The problem is further accentuated with lack of capacity development for this sector which leads to lower levels of resource efficiency from the work that is done around recycling of waste

Challenges with the Informal Sector- The informal actors have very limited knowledge on the path they need to pursue towards formality because they are either illiterate and are scared of the paper work involved, or they have a perception that the work that they do and the material that they access is mostly perceived of as stolen from somewhere. Formalisation of the informal sector will be extremely important and for this it is important to do research to understand the key concerns and needs of the informal sector which can lead them on the path towards formalisation. Further, capacity building of the informal sector will need to be done to ensure that they understand the advantages of formalising and help others in their sector to formalise.

Integration of the Informal Sector: Moving towards Formalisation – The informal sector recycles material at an efficiency rate between 20 to 30 percent. Provision of technology to these informal actors who are willing to formalise will allow benefits in the socio-economic and environmental space. There are some elements which have been identified in context of the key needs to this sector. These include need to provide access to land where they are able to engage in their livelihood which will not lead to any damage to nature, access to infrastructure which will allow them to engage in their livelihood in ways and means which will comply with the law, and access to finance so that they are able to invest in infrastructure and work within the legal framework.

Technological Development: Assessment of Technical and Technological Solutions Available in India and Globally- The Ministry of Electronics and Information Technology has developed indigenous technology at C-MET and Central Institute of Plastics Engineering & Technology (CIPET) for recovery of precious metals and plastics from e-waste respectively. After laboratory scale experiments, these technologies have now been upscaled to industry level use. These indigenously developed technologies provide solutions for recycling of complex materials which otherwise had to be exported to countries where state of the art technologies have been developed and large-scale investments made to source and recycle materials from different parts of the world. One such facility which recycles precious metals from e-waste is Umicore in Belgium which is one of the largest such facilities in the world today. Benchmarking of the technologies which are in use in the informal sector as well as the best available technologies shows the huge gap which exists when it comes to recycling complex materials embedded in e-waste. Furthermore, when it comes to recycling of precious metals the efficiency of recycling and extraction of metals in the informal sector lags behind from the other two options that are available.

Extended Producer Responsibility[47] and its Role in proliferation of best available technologies- Recyclers can now access more material because producers are channelizing the same to them to meet their EPR obligations. This allows them to now operate at full capacity and also invest in technology which will help them to recycle all fractions of e-waste in the country. In the present scenario, the entire chain marked inside the box operates in the informal domain. Policy interventions, through which technology is made available, will have the benefit of formalising the informal sector and enhance resource security. Strengthening EPR compliance will enhance access to secondary materials which will make economic sense for the recycler to then recycle the material rather than sell it in the informal sector or export the same. This intervention will create an enabling mechanism for development of a recycling industry in the country with benefits of access to resources on one hand and creation of jobs on the other.

5.5.5 Action Plan

Successful envisioning of a strategy will require engagement and integration of multiple stakeholders in the value chain. It is important that action agendas be identified along-with the implementing agencies for ensuring time-bound implementation of strategies with identified stakeholders. The informal sector has been at the heart of recycling of WEEE in India for the last two decades and it is crucial that there is development of recycling technology for mitigating the hazardous effects of environment and human health is as important as its development for new electronics products.

Informal Sector Integration in the E-Waste Management Ecosystem to Strengthen Implementation of EPR regime - The integration of the informal sector would be the key to ensure that collection costs can be brought down to sustainable levels. The informal sector, through its network of aggregators, dismantlers, recyclers has been able to develop an ecosystem which has been able to sustain multiple actors across different geographies in the country. These actors have also been able to develop competitive advantages for themselves in terms of specific areas of expertise which they cater to when it comes to handling different

[47] The e-waste management and handling rules, 2012, had introduced the concept of extended producer responsibility.

material flows for end-of- life electronics.[48] It is important to recognise these material flows and value chains which will then allow for development of key strategies which would allow for integration of the informal sector in a formal value chain.

From a resource efficiency perspective, it makes sense to design interventions which are targeted at the informal sector helping them work in safe and healthy environment, enhance their ability to higher recovery of metals from e waste and develop facilities to take care of environmental impacts of recycling and dismantling e-waste and have provision of personal protective equipment for occupational safety. The likely chain in the material flow will enhance missions like Make in India, provide skilled livelihoods to informal actors thereby enhancing the efficacy of the Skill India Mission and also reduce the environmental impact of improper e-waste recycling thereby positively impacting the Swacch Bharat Mission.

Industrial Clusters – Twin Approaches - Integration of the informal sector can be done in 2 possible ways. Since end of life electronics falls in the category which is environmentally polluting, it is important that the work be done in industrial clusters such that effluents can be properly managed and environmental risks can be mitigated. Furthermore, a monitoring mechanism in such clusters helps to mitigate human health risks as well. It is however, important to understand the kind of interventions which are available and the risks and rewards attached to these approaches. The 2 possible ways to set-up industrial clusters are

- Co-locating the e-waste management industrial cluster in a manufacturing cluster
- Locating e-waste management cluster in hubs where the informal actors have been working

Capacity Building Programmes including Awareness Programmes for all Stakeholders and Actors '- Government has launched many initiatives for building capacity of the stakeholders. These included an awareness initiative in 2015 by Ministry of Electronics and Information Technology and organizing workshops and activities in various cities, with participants from schools, colleges, resident welfare societies (RWA), manufacturers, informal operators and government officials. However, capacity building should also be done by the industry. Since awareness building is an area of compliance under the waste rules, it is important that the government uses such programmes to develop institutions which can lead these efforts and innovate to create large scale. These institutions can be funded through different sources including the public and the private sector. For stakeholders, who need to create awareness as part of compliance, a separate body can be set-up which can manage funds meant for awareness and capacity building. The institutions who would like to work in this area can apply for grants which will allow the body to evaluate such proposals and choose the best possible ones. This will also allow for

[48] OECD: (https://www.oecd.org/environment/waste/Session_2-Part_1-EPR-Role-of-Informal-Sector-Sandip_Chatterjee.pdf

replication of best possible efforts since the learnings from different programmes would be evaluated by this body and chosen as best practices.

Standardisation and Research & Development (R&D) - There is a need to ensure that a RE scheme is devised which encompasses the use of secondary materials in products to ensure that they are resource efficient and producers put circular economy principles into practice in the production process. The scheme should also address the development of R&D infrastructure in the country which provides cost effective recycling technologies for WEEE and also considers the rapid technological and material composition changes in the EEE. Although India is not majorly manufacturing products and components in the country so the application of Eco-Design or Design for Environment principles is difficult to accomplish through initiatives in India. Usually the components used for assembling the final products are compliant with the national and international regulations or standards. Thus, to enhance RE, the scheme can focus on strengthening R&D advancements to create a platform for applied research in this direction.

The use of secondary materials can be guided through a standardisation of technologies which are being used for extraction of the material during the recycling process. This will ensure voluntary certification by recyclers as the demand for secondary materials increases and will also provide a fillip to the precious metal recycling sector in India, thereby promoting the Make in India mission

5.5.6 Recommendations and Action Agenda

The key elements of the Action agenda include:

- Estimating the quantum of e-waste generated in the country which can help understand the scale of the problem to estimate infrastructure required to solve the same
- Gaps in Research & Development for technology development on recycling and to address rapid technological advancement in EEE
- Outreach and advocacy with all stakeholders to ensure that the environment and health hazards are communicated for formalising of disposal mechanisms Mapping of value chains which will enable to understand stakeholders and draw specific action plans towards formalisation
- Capacity building of monitoring and implementation agencies at the state level so that the rules are enforced across stakeholders
- Infrastructure for e-waste recycling in the country which can disrupt movement of e-waste in the informal sector and incentivise them to formalisation
- Product design guidelines which can help make products and materials easier to dismantle and recycle thereby enhancing resource recovery

- Standards for recycling to enable use of best available technologies to mitigate the environmental and health impacts of unsafe recycling in the informal sector

5.6 Steel

5.6.1 Introduction

India's steel industry, since independence, has played a very important role in achieving infrastructure growth and economic development. India has emerged as the third largest steel producer, and may soon become the second largest producer surpassing Japan (NITI 2019). Steel industry is estimated to contribute nearly 2 percent India's income as well providing employment to 25 lakh people, directly or indirectly. The stainless-steel industry is a very niche subsector contributes both in meeting domestic requirement as well as exporting the special steels. India is also the second largest stainless-steel producer. However challenges remain in terms of meeting domestic requirement for key sectors particularly automobile, electrical, aviation, engineering and machineries resulting in substantial imports in recent years.

India has witnessed 6.2 percent growth in steel production capacity and has reached more than 100 MT thereby making India the third largest steel producer. Year wise increase in production, total consumption and per capita consumption of steel is presented in figure 28.

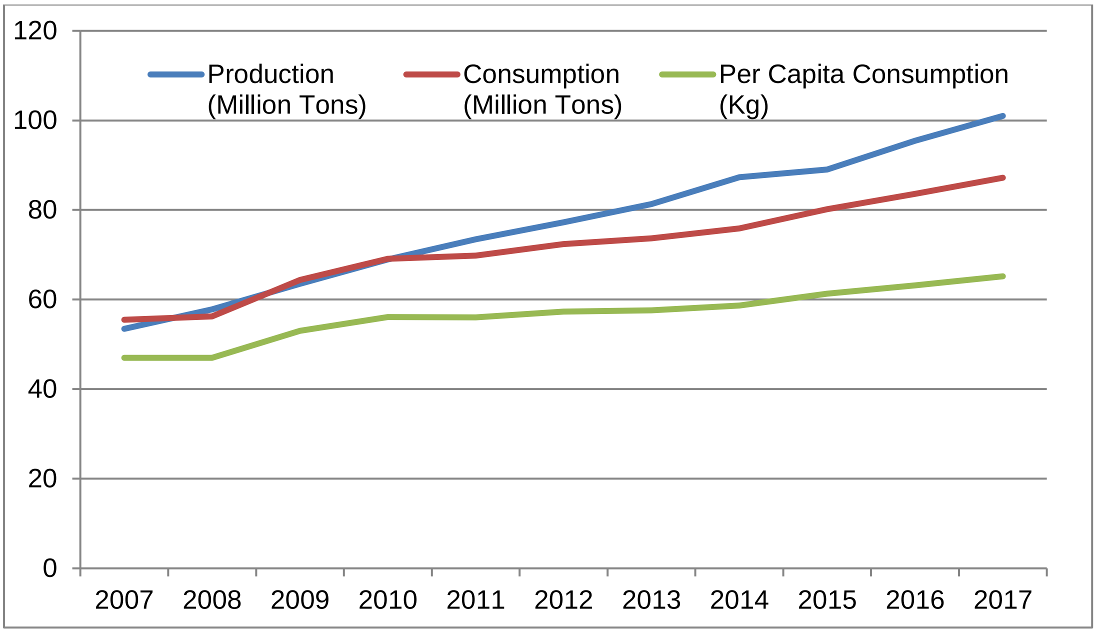


Figure 28: Change in production and consumption of steel in India

Source: https://www.niti.gov.in/writereaddata/files/RE_Steel_Scrap_Slag-FinalR4-28092018.pdf

Steel manufacturing output of India is expected to increase to 128.6 (million tons) MT by 2021, accelerating the country's share of global steel production from 5.4 per cent in 2017 to 7.7 percent by 2021. A sector wise break up in steel consumption reveals that construction industry has the largest share of 35 percent followed by infrastructure development 20 percent and automobiles 12 percent. Given the fact that majority of the construction and infrastructure is expected to come up in the coming years, and human aspirations will drive vehicular ownerships, the potential growth of steel consumption is very high. Figure 29 presents the sector wise steel consumption in India.

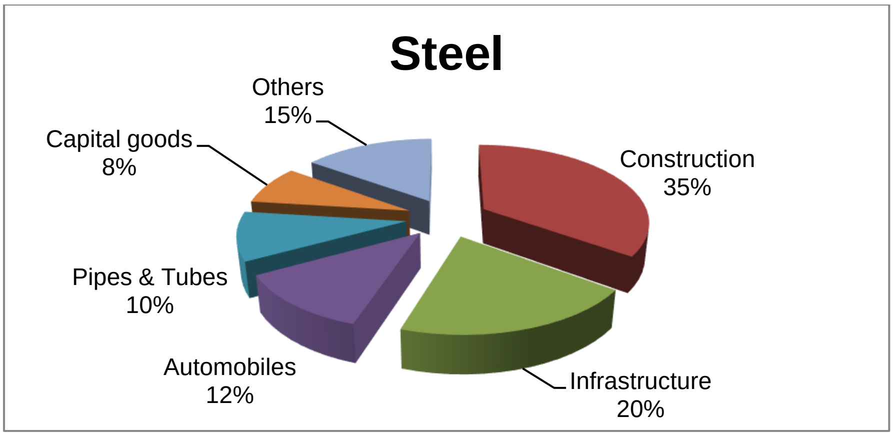


Figure 29: Sector wise steel consumption India

Estimates by the ministry of steel reveal that India's steel consumption can grow by an average of 6.3 percent and reach 140 MT in the next five years. This will increase per capita steel consumption from 65 kg in 2017 to approximately 96 kg by 2023 and 160 Kg by 2030. 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.

Stainless steel production too has increased in recent years, largely to meet demand for their use in special application in critical technologies, products and defence application. Production has increased from 2.4 MT in 2009-10 to 2.9 MT in 2013-14. Consumption of stainless steel during this also 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. The per capita stainless consumption is very low when compared to world average. India's estimated per capita stainless consumption is 2 kg as against the world average of 6 kg, indicating that there are substantial opportunities for growth in the sector. The present demand of around 5 MT is likely to double by 2030. This implies that the overall requirement of stainless and alloy steel may be between 12-14 MT by 2030.

5.6.2 Steel manufacturing processes and implications on material consumption

Steel manufacturing is extremely resource intensive. The Blast Furnace (BF) process of steel making is the predominant technology used in steel making that uses iron ore and coking coal as the key raw materials. Electric / Induction Furnace route of steel making use scrap as the key raw materials. The installed capacity and production from different routes is presented in table 8.

Table 8: Installed capacity and production of steel from different routes[49]

Route	Installed Capacity (MT)	Production (MT)
Iron/DRI		
BF	81	74
DRI	50	31
Crude Steel		
BOF	55	47
EAF	40	26
IF	42	29

The production of crude steel from BF-BOF route contributes around 45 percent of India's steelmaking capacity while the remaining 55 percent 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. An estimate by the Ministry of steel reveal that there are approximately 42 Electric Arc Furnances, 1126 Induction Furnaces and more than 300 sponge iron producers, and around 1157 small and medium sized steel rerolling mills spread across India. India's MSME steel sector contributes around 30 percent of the total steel production. Figure 30, presents a typical process flow of steel making.

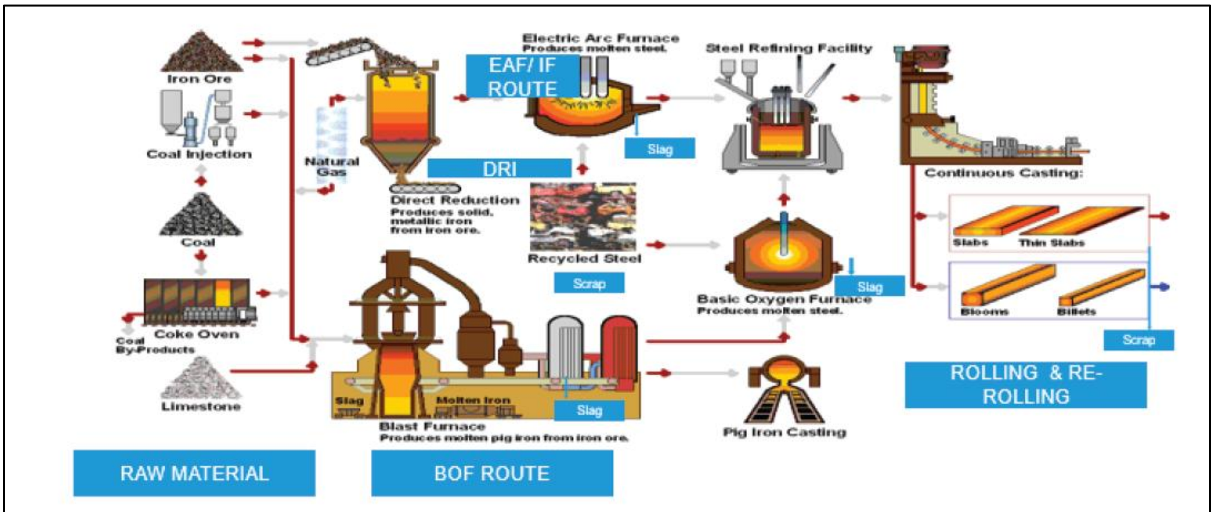


Figure 30: Steel making process in India

As mentioned above, most of the steel produced in India follow the BF-BOF route. While BF converts ore into in liquid metal or pig iron (when solidified). Coking coal used in BF along with iron ore acts as a reducing agent as well as providing the required thermal energy. The product is further purified through BOF process to produce steel. Natural gas needs to be

[49] https://www.niti.gov.in/writereaddata/files/RE_Steel_Scrap_Slag-FinalR4-28092018.pdf

explored an alternate fuel in BF operation, which can help in reducing consumption of coke. India is heavily import dependant on coke and this replacement can be very cost effective while reducing reduces SOx and CO2 emissions and as well improving output efficiency in BF. Two co-products that are generated during iron and steel making are BF and BOF slags. This is a growing challenge for the steel industry when it comes to their management particularly BOF slag. They are discussed in greater details in the following sections. BOF normally uses oxygen in the process along with lime, limestone and dolomite. The liquid steel produced is further refined (called secondary refining), and cast into ingots, slabs, blooms or billets. India's integrated steel plants in the 80s introduced continuous casting that not only reduced wastage but also cost and energy. A quick analysis of material embodiment in 1 ton of steel produced from BOF route suggests that the same contain nearly 1.4 tonnes of iron ore, 0.55 tonnes of coking coal, 0.25 tonnes of limestone and 1.9 tonnes of air. By products consist of 0.3 tonnes of slag, 2.4 tonnes of BF gases, and upto 0.05 tons of dust. Further the estimated CO2 emission per tonne of crude steel is 2.1 tonne.

This implies that by 2030, to produce around 300 MT of steel from the BF route having the same share of 75 percent in the total steel production, India will require 315 MT of iron ore per annum, 123 MT of coking coal, 60 MT of limestone. Further the annual generation of BF and BoF slag is estimated at 67 MT. This has significant implications on emission too where the total CO2 emission can be as high as 472 MT. While India may be self-sufficient with regard to iron ore yet their access and extraction has serious environmental implications. Further rising prices and import volume will hit our foreign reserves.

Electric Arc Furnaces is another steel making technology which varies in size from small units of 4-5-ton capacity to as large as furnaces of 250-ton capacity. Some of the producer's have 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. While the share of steel making using the EAF route is only 20 percent in India, the same in US and EU is as high as 64 percent and 40 percent respectively. This implies the growing utilization of scrap for steel production in these regions.

Induction furnace is another route that 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. However the process lacks ability to refine steel.

5.6.3 Exploring Resource Efficiency Potential in steel sector in India

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. 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 producers 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.

5.6.3.1 Scrap Recycling

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

Recycling of one ton of scrap saves 1.4 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 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. 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 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 in the country in the form of “obsolete scrap”.

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 center, 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 fulfill 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 source 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 Faridabad, Haryana to tap this additional source of scrap, mostly automobiles and white goods in National Capital Region.

5.6.3.2 Slag utlization

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, aluminum, 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 CO2 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 kilometers 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.

5.6.4 Towards a resource efficient steel sector in India

5.6.4.1 Steel Recycling Strategy

India need to explore 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).

5.6.4.2 Steel Slag Utilization

With increasing steel production, significant efforts have been made to develop the slag processing technologies to enable its utilization. While BF slag is mainly used for cement production, steelmaking slags can be used for road construction, hydraulic engineering, as fertilizer etc. 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. 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. 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.

5.6.4.3 Capacity development

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.

5.7 Aluminium

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

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

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

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

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

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

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

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

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

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

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

5.8 Solar Photo Voltaic Sector

5.8.1 Introduction

With a total installed electricity generation capacity of 344 GW in 2018, which is significantly higher than the peak demand of 173 GW, India is still characterized by low per capita level energy consumption (670 kgoe and at 1075 KWh/year). India being a rising economy, it has been predicted that in future the energy demand, GDP and population would further increase significantly. As a part of India's pledge to the Paris Agreement India would contribute 40 percent of the installed capacity from renewables.

Geographically located near the tropics, India is well endowed with natural and renewable sources such as solar, wind, biomass, small hydro and the like. Renewable energies hold a lot of potential in the context of energy security and decarbonization of the economy. It offers a plausible option to steer the energy system in the direction of sustainability by catering to energy requirements in an environmentally benign way. Consequently, renewables have become a high priority in the energy policy strategies at the national level.

Renewables, particularly wind and solar, have been given tremendous thrust by the Government of India (GoI) in the recent years. In 2010, India launched the renewable energy program- 'Jawaharlal Nehru National Solar Mission (JNNSM)', with an objective of deploying 20,000 MW of solar power by 2022, and revision in this target was made to 100,000 MW of which 60000 MW has to be grid connected and 40000 MW has to be rooftop solar. This will require supply and use of newer materials for manufacturing different solar PV technologies while maintaining cost competiveness in the sector and in this regard resource efficiency will be a key to achieving these objectives. Further, India Energy Security Scenarios 2047 of the NITI Aayog show a possibility of achieving a high of 479 GW of solar PV by 20473. This signifies the potential for the solar photovoltaic power sector to contribute to India's energy security. To capture the benefits of renewable energy, it would require large scale manufacturing and wider adoption of solar photovoltaic.

To achieve the 100 GW target of electricity generation from solar under the National Solar Mission (NSM), the GoI has initiated a large number of policy measures with emphasis on reduction in cost and increase in efficiency. A significant reduction in cost of solar has been achieved in the recent years through tariff based competitive bidding process with a lowest tariff of INR 2.44 per unit for solar. For transparent bidding and facilitation for procurement of solar and wind power, the government has notified the competitive bidding guidelines in 2017.To promote renewables in the states having greater resource potential and to create a pan-India renewable power market, the GoI has waived the Inter State Transmission System charges and losses for inter-state sale of solar and wind power for projects to be commissioned by 2022. This would facilitate transmission of excess power generated to the resource poor states without additional financial burden. Consequently, Green Energy

Corridor projects seeking creation of grid infrastructure for renewable power evacuation and for reshaping grid for future requirements, are being implemented by eight renewable rich States, and these will set up about 9400 circuit km transmission lines and Substations of total capacity of approx. 19000 MVA by 2020.

To reinforce government's commitment towards renewables the GoI has notified Renewable Purchase Obligation (RPO) trajectory upto the year 2019 and the process of further extending it upto the year 2022 is being pursued. Furthermore, Renewable Generation Obligation (RGO) has also been introduced by the GoI towards mainstreaming renewables by encouraging coal based thermal power generators to diversify into renewable energy portfolio.

The Government started a scheme in 2014 for setting up of 25 Solar Parks, which will be able to accommodate over 20 GW of solar power projects. The target for Solar Parks has been enhanced from 20 GW to 40 GW and 41 Solar Parks in 21 States with aggregate capacity of over 26 GW have already been sanctioned. To encourage participation by private parties and central public sector undertakings in setting up Solar Parks, the GoI has announced the New Solar Park policy.

To provide a stimulus to domestic manufacturing of solar cells, efforts have been made to create an ecosystem. Expression of interest for setting up solar PV manufacturing capacities linked with assured off take of 20 GW has been issued. For setting up of renewable energy-based power generation projects and for financial and/or technical collaboration foreign investors can enter into joint venture with an Indian partner. Hundred Percent foreign investment as equity qualifies for automatic approval and foreign investors are being encouraged to set-up renewable energy-based power generation projects on build-own-operate basis. Accordingly, during last four years, over US$ 42 billion investment has been made in renewable energy in India. To boost end-to-end manufacturing of solar equipment - polysilicon, wafers, cells and panels, Viability Gap Funding (VGF) in the form of a financial subsidy is being offered to companies setting up integrated manufacturing facilities. To enable the manufacturers to compete on an even level with their global counterparts, government may soon announce a domestic solar manufacturing policy. The policy, being prepared by the Department of Industrial Policy and Promotion in association with the MNRE, is in pursuant with the Make in India policy of the government of India which recognizes solar manufacturing as an industry having "strategic importance".

5.8.2 Different PV Technologies

Given that renewable energy, and in particular solar energy, has significant sustainable development implications, the country has tremendous scope of generating solar energy due to its geographical location. Large scale solar deployment will not only help in reducing the cost of power generation in the country and helping promote energy access, but the promotion of research and development in the context and the related technology transfer can enhance domestic manufacturing capability of components and products.

Silicon is the leading technology in making solar cells. However, due to high cost, considerable amount of research has been undertaken on newer generation thin film low cost technology. Three materials that have been given much attention under thin film technology are amorphous silicon, CdS/CdTe andCIS. Other materials that find application include copper, silver, iron, plastics, etc. There are further research towards development of third and fourth generation technologies using polymer or organic as solar cell materials. Polymer materials have many advantages like they are low cost, light weight and environmental friendly. A brief description of the technologies is presented in figure 31.

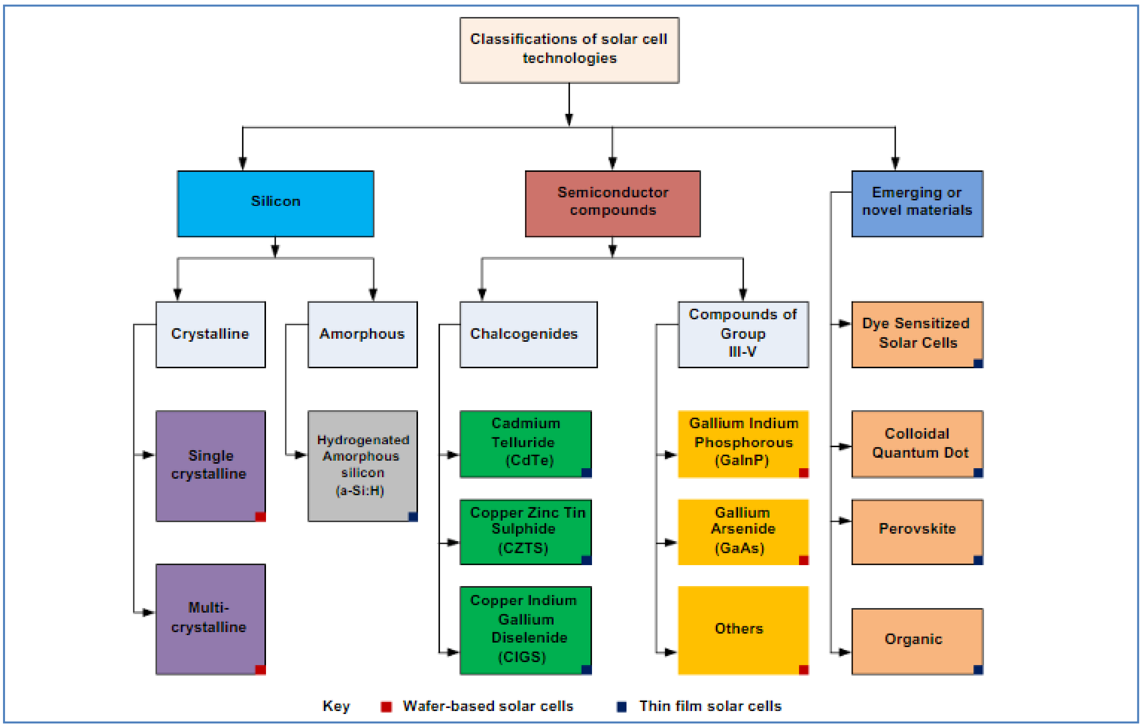


Figure 31: Classification of solar cells based on the primary active material.

Source:
https://www.researchgate.net/publication/317569861_Perovskite_solar_cells_An_integrated_hybrid_lifecycle_assessment_and_review_in_comparison_with_other_photovoltaic_technologies

5.8.3 Crystalline silicon

This is one of the most widely used technologies for building solar panels. The three prominent forms of modules within this include:

- Monocrystalline
- Multi-crystalline
- Amorphous Silicon (a-Si)

The monocrystalline silicon modules exhibit higher conversion efficiency while the multi-crystalline modules are comparatively cheaper and more resistant to degradation due to irradiation. Even though amorphous silicon modules are made up of non-hazardous materials, that make their disposal less problematic, the low efficiency rates and absence of materials of high value have led to the discontinuation of a-Si products. The dominance of crystalline silicon in world markets is primarily due to its reliability and longer service life. However, the main task at hand is improving the efficiency and effectiveness of resources consumed through a reduction in materials, and automation of manufacturing to name a few.

5.8.4 Semiconductor Compound

The semiconductor compounds can be categorized into the following two types:

5.8.4.1 Cadmium Telluride (CdTe)

This technology is the second most widely used solar PV technology. The main selling point of this is that it can capture energy at shorter wavelengths unlike silicon panels. Their manufacturing costs are low and there is an abundance of cadmium telluride as it is a byproduct of a commonly used industrial element – zinc. A major drawback of this is that cadmium is a toxic material. While it is not harmful for humans presently, disposing off degraded CdTe panels will prove to be problematic. Further, the efficiency levels of CdTe panels is not at par with those of silicon panels.

5.8.4.2 Copper Indium Gallium Selenide (CIGS)

In case of CIGS, high light absorption is used as a semiconductor. Variation in the ratios of different elements in the semiconductor such as gallium, selenium and indium help adjust the light spectrum. They pose a significant competition to silicon panels in terms of efficiency. On the down side, CIGS too contain the toxic element cadmium. However, its presence is lower in CIGS as opposed to CdTe panels. The high production costs of CIGS panels acts as a barrier for them to compete in the market with the other technologies.

5.8.5 Concentrator photovoltaics and other technologies

5.8.5.1 Organic solar panels

It has the potential to supply electricity at cheaper rate than electricity generated from other solar technologies. Different absorbers can be used to build organic photovoltaic (OPV) devices. Some of the benefits include- low manufacturing costs, ample availability of building materials etc.

OPV cells are of two types-

- Small molecule

- Polymer based

5.8.5.2 Hybrid panels

Hybrid Photovoltaic/Thermal (PV/T) solar system is one of the most popular methods for cooling the photovoltaic panels. The hybrid system consists of a solar photovoltaic panels combined with a cooling system. The cooling agent, i.e., water or air, is circulated around the PV panels for cooling the solar cells, such that the warm water or air leaving the panels may be used for domestic applications such as domestic heating.

5.8.5.3 CPV solar panels

Concentrator photovoltaic (CPV) (also known as Concentration Photovoltaic) is a photovoltaic technology that generates electricity from sunlight. In contrast to conventional photovoltaic systems, this technology uses lenses and curved mirrors to focus sunlight onto small, but highly efficient, multijunction (MJ) solar cells. In addition, CPV systems often use solar trackers and sometimes a cooling system to further increase their efficiency.

5.8.5.4 Dye- sensitized solar panels

The dye-sensitized solar cells (DSC) provides a technically and economically credible alternative concept to present day p–n junction photovoltaic devices. In contrast to the conventional systems where the semiconductor assumes both the task of light absorption and charge carrier transport, the two functions are separated here. Light is absorbed by a sensitizer, which is anchored to the surface of a wide band semiconductor. Charge separation takes place at the interface via photo-induced electron injection from the dye into the conduction band of the solid. Carriers are transported in the conduction band of the semiconductor to the charge collector.

When making a choice between crystalline and thin films technology there are pros and cons for both. On one hand, crystalline technology has higher efficiency and requires less roof area (in terms of number of panels to be installed) to generate the same amount of power. They also tend to work better in warmer conditions than thin film technology. On the other hand, crystalline PVs have higher initial costs and in case of partial shading, some of the silicone cells may stop generating electrons and the efficiency of the panel will reduce13. Thin film PVs have shorter payback and are not as susceptible to shading issues as crystalline PVs. However, in comparison to crystalline technology, thin films require more land (i.e. more panels need to be installed) for reaching the same capacity level due to its relative lower efficiency. Moreover, their service life is usually shorter than that of crystalline technology. On an average the thin films have a life of around ten years while that of the crystalline technology can be 25 years.

5.8.6 Life cycle stage of PV sector and estimated material consumption

For the purpose of analysis, the assessment focuses on multi-crystalline solar PV technology for estimating material requirement. This largely accounts for more than 80 percent of the total installations of solar PV in India are multi crystalline silicon technology.

The material consumption across various life cycle stages is for multi-crystalline solar PV technology is presented in figure 32.

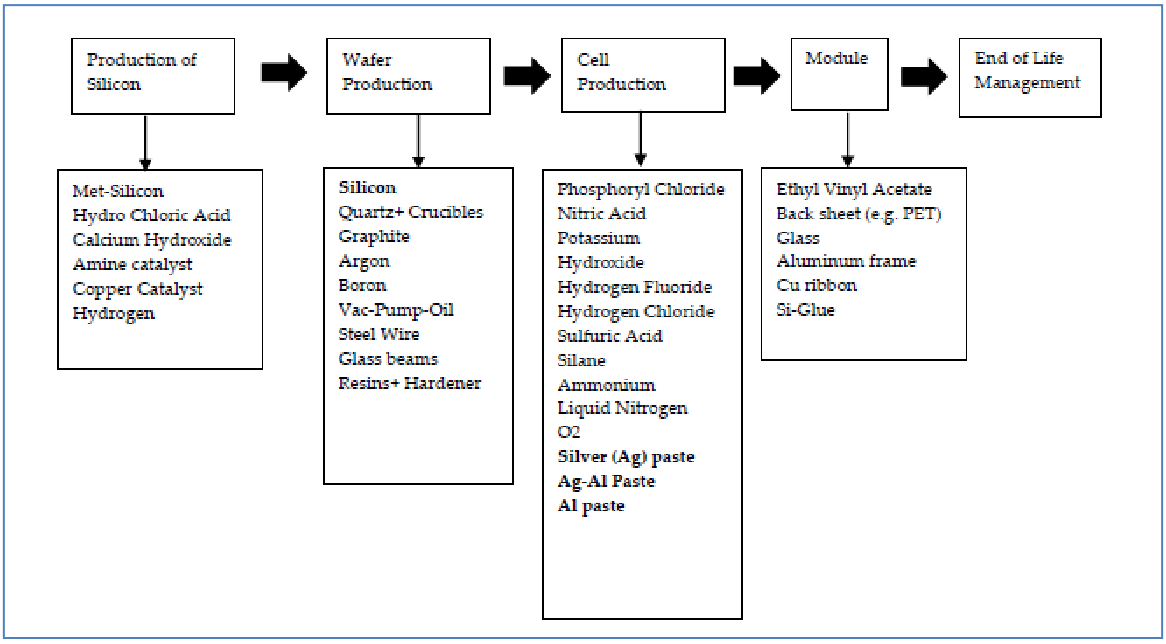


Figure 32: Key materials that are used in manufacturing silicon solar PV

Key materials that are used in manufacturing silicon crystalline solar PV are silicon, glass, silver, aluminium and copper. Typically, crystalline silicon solar PV contains 70 percent of glass while aluminium, silicon and silver account for 18 percent, 3.65 percent and 0.053 percent of total weight. Ethylene-vinyl acetate (EVA) encapsulation takes up 5.1 percent of the share while the back sheet represents 1.5 percent (Latunussa, et.al. 2016). This is presented in figure 33.

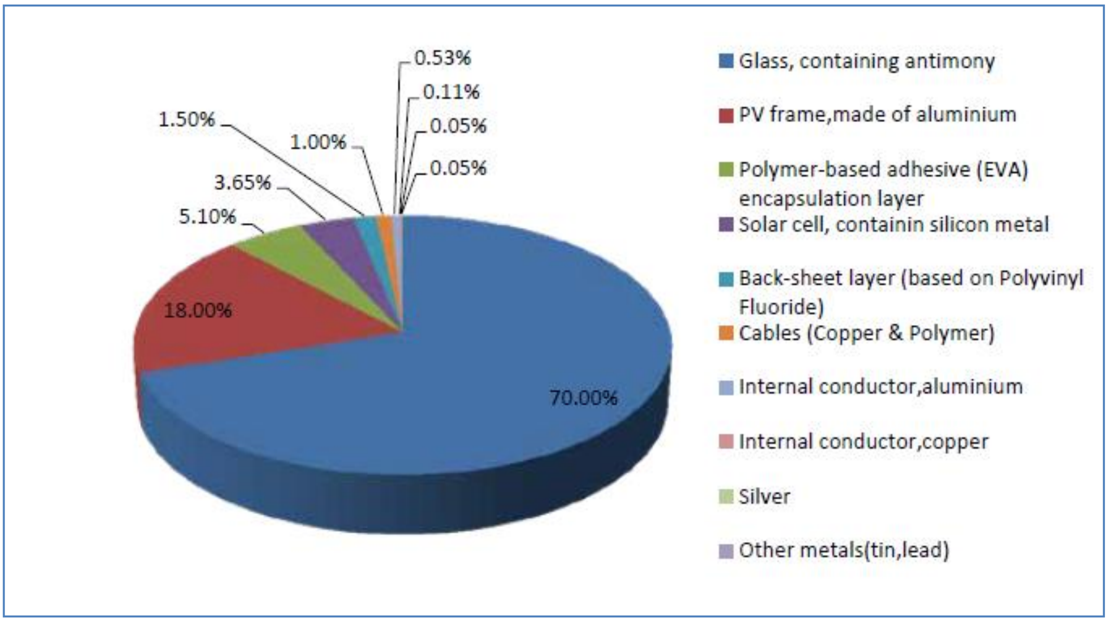


Figure 33: Material composition in a crystalline solar PV (by percentage weight)

Source: https://www.scribd.com/document/360791571/1-s2-0-S0927024816001227-main

Under an ambitious solar energy deployment scenario of nearly 170 GW by 2030, total estimated demand for materials will increase from almost 0.7 million tonnes to 12 million tonnes between 2015 and 2030. The demand for glass will reach 7million tonnes in 2030 from 0.4 million tonnes in 2015. Aluminium consumption is estimated to be more than 1.7 million tonnes from its current level of 0.1 million tonnes. Silver use will increase from 0.2 million tonnes to 3.8 million tonnes by 2030, while poly-silicon consumption estimated to reach 0.7 million tonnes. This is presented in figure 34.

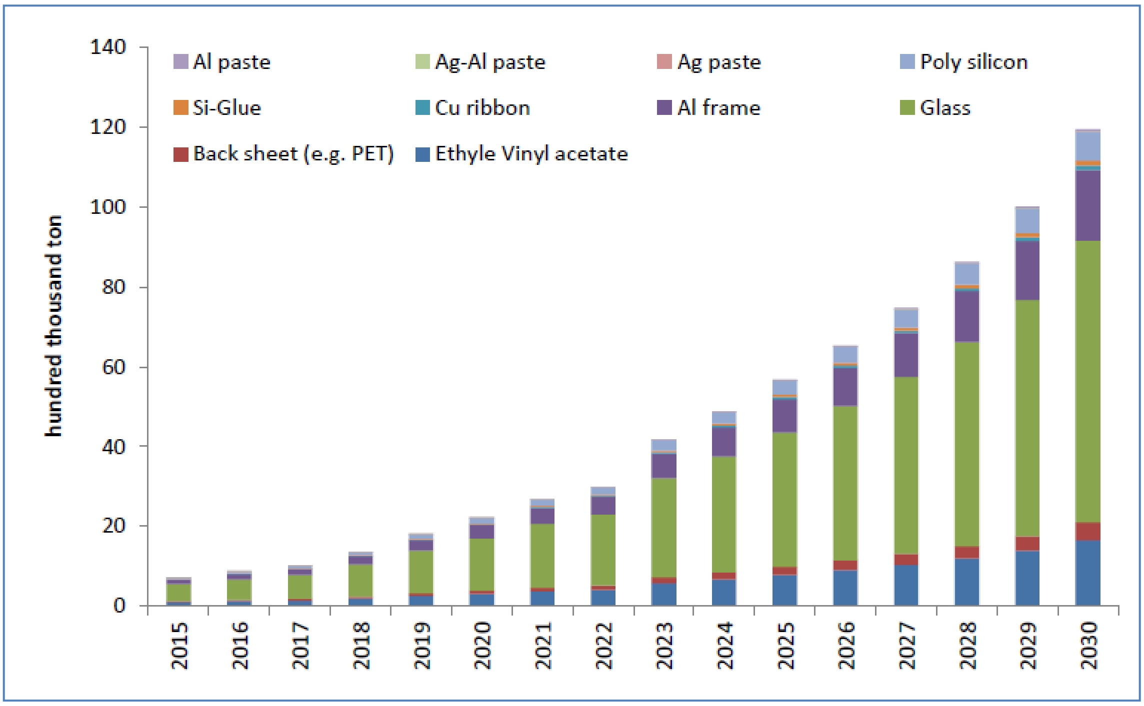


Figure 34: Estimated requirement of materials for manufacturing crystalline solar PV in India

The PV sector however has the potential to create unprecedented opportunities for resource savings along the value chain. Process innovation will reduce primary demand of resources. Further efficient recovery of wastes generated at different stages of the life cycle and recycling can help in material security for the sector. Before India becomes a leading manufacturing hub of solar PVs, it is extremely important that an ecosystem is developed that can promote efficiency across the life cycle stages. The resource efficiency opportunities are presented in figure 35.

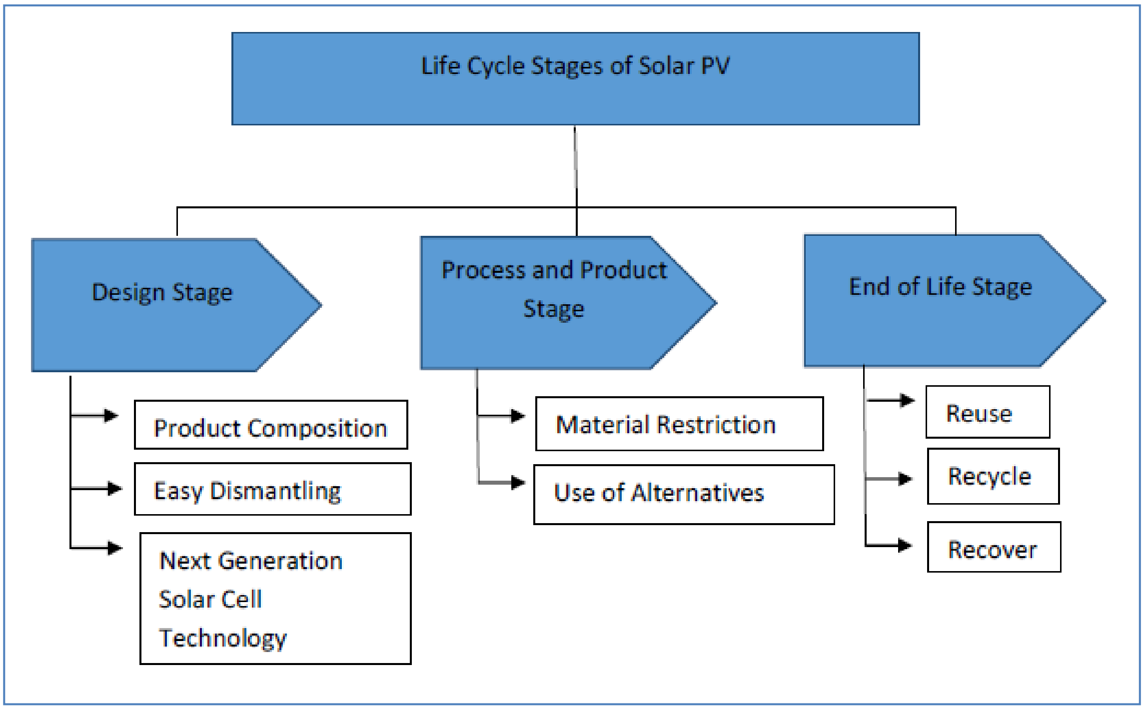


Figure 35: Resource efficiency opportunities across selected life cycle stages of solar PV.

Given the scale of deployment of solar power that is being discussed in India, dedicated availability and affordability of materials among others are some of the critical factors for the success of the ambitious program in India. The PV industry is not immune from such issues. For example, India depends heavily on imports of the materials particularly silver and copper and any change in prices will have impacts on these products. There are also significant rooms for improvement of material usage during manufacturing and assembly of solar panels. Further, many of panels that have been installed will be reaching their end of life in a decade and will pose new environmental challenges. However the PV waste also has the potential to create for value generation for recycling businesses

In the context of PV cells, resource efficiency can be achieved by reducing kerf-loss with the use of Diamond Wire Sawing (DWS) technology, reducing the consumption of silver by substituting it with copper and other alloyed materials, reducing the thickness of front glass and introducing frameless modules to decrease aluminium consumption. The standard slurry based silicon wafering technology leads to significant amount of kerf loss. In order to remedy this, Diamond Wire Sawing technology is introduced, which will help reduce the consumption of silicon by 15 percent, as a result of improved cutting. According to the

ITRPV Report between 2015 and 2030, it is expected that the production process will shift from 100 percent to 5 percent slurry based technology. The estimated weight of silver used is 170 mg/cell as was the practice in 2015. Silver is a key material in manufacturing PV. The median consumption of silver for the year 2017 has come down to 100 mg/cell and is 90 mg/cell for 2018. It is expected that by 2030 the weight will be reduced further to 50mg/cell. Copper (or other alloys), being relatively less expensive materials are expected to be used as substitutes for silver. At present, modules having aluminium frames are dominating the market. It is expected that frameless modules will have a market share of approximately 28 percent by 2030. The share of frameless modules was very low at 2 percent in 2015 as reported in ITRPV report and emerged from stakeholder. With increased deployment, there will more production of frameless module and reported to reach 28 percent by 2030. Hence, 72 percent of the installations will have use of aluminium frames. Further plastic frames are also likely to emerge as alternate framing materials.

Comparison of two scenarios, viz. the baseline and in the presence resource efficiency reveals that an estimated 12 million tons of material will be demanded under the baseline scenario, as compared to the 8.2 million tons if interventions, are practised. The latter provides an efficiency of more than 30 percent by 2030 when compared to baseline scenario (Figure 36).

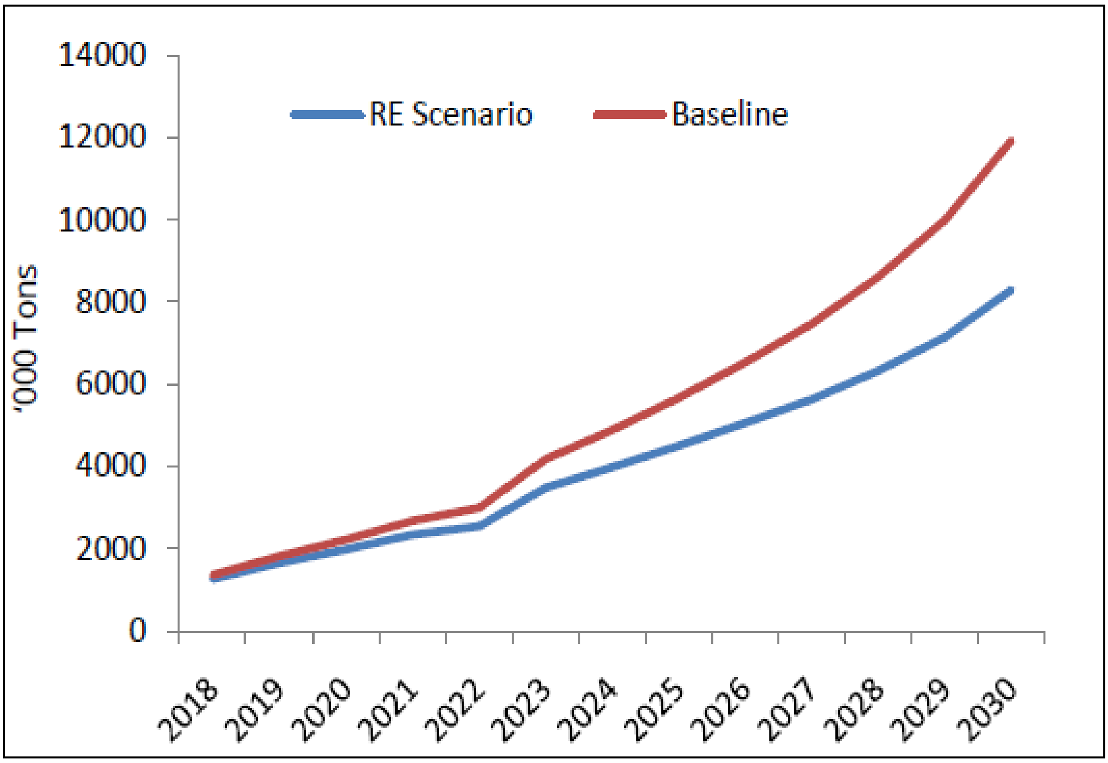


Figure 36: Comparison of material consumption under Baseline and Resource Efficient Scenario

5.9 Policies Promoting Resource Use Efficiency

Regulation has a very important role to play to promoting resource efficiency. They can incentivize development of break-through technologies and processes including use of use of recycled materials, and creating standards and thereby creating demand for secondary raw materials. The developed countries across the world have given a serious thought to the resource efficiency aspect of the solar PV sector, particularly the end of life management of the solar PV modules. Infact solar PV recycling is gradually becoming a prominent industry with potential to earn significant profits. The following sections briefly presents selected policy good practices for that matter.

The Case of European Union

The Extended Producer Responsibility (EPR) route of the European Union for that matter has been the heart of the regulatory approach to promoting circularity in the sector. Producers supplying products to EU markets are responsible for managing the end of life phase of solar panels regardless of where the manufacturing process is taking place . The waste electrical and electronic equipment (WEEE) directive mandates labeling to be carried out by the producers. Further buyers have to be informed of the designated centers where the panels are to be disposed-off and are not to be mixed with other waste materials. The revised waste legislation sets new recycling targets and redefines mandatory EPR schemes. Further, suppliers are newly required to inform the European Chemicals Agency (ECHA) about the presence of substances of very high concern (SVHC) in their products.

The mandate for setting the end of waste criteria was put in place for the purpose of encouraging recycling, reducing the consumption of natural resources and reducing the volume of waste sent for disposal. This has been ensured by the creation of a legal framework and the removal of any unnecessary administrative burden. The criteria is not applicable on all wastes but only on certain waste streams for which the criteria can be developed and adopted, while remaining within the purview of the Waste Framework Directive (EU 2016). For example, copper being a scarce resource, the EU wide end of waste criteria for copper scrap is likely to provide improvement in functioning of internal market, clear difference between high and low quality copper scrap and as well reduction in administrative burdens pertaining to shipment and transportation of scrap materials. Further, the European Standard EN 12861:1991 specifies the characteristics for copper and copper alloy scrap for direct melting. It specifies details regarding the moisture, composition, metal content, metal yield and test procedures. The requirements regarding the metal content and yield also mention the effectiveness of any pre-treatment that takes place and puts limits on the possibilities of diluting the scrap by using other waste material

The Case of Japan

Japan does not have a specific regulatory framework to manage end of life PV panels. Japanese Government has been working with organizations like the New Energy and

Industrial Technology Development Organization (NEDO) and other private companies such as NPC Group for developing technologies for recycling solar panels. However Japan introduced the 'Promotion of Effective Utilization of Resources Law was enacted in 2000 and came into force in 2001. Establishing a sound material cycle system was the central objective of the law. This was achieved by:

- Encouraging recycling of goods and resources through collection and recycling of used products by businesses.
- Reducing waste generation through longer use life of products
- Implementation of measures for reusing materials recovered from used products.

Recently the Japan Photovoltaic Energy Association (JPEA) voluntarily issued guidelines, which are not enforceable yet strongly recommended to the industry, on 'proper disposal' of used solar modules.

The Case of Germany

Rules governing the collection and recycling of panels have been implemented in Germany ever since the revised WEEE directive was incorporated into German Law in 2015. The National Register for Waste Electrical Equipment regulates the country's e waste. Shiftung EAR (national registrar for waste electronic equipment) was founded by producers to act as their clearing house, when WEEE was introduced for the first time. Functions performed by Shiftung EAR include the following, registration of producers suppling electrical or electronic equipment to German markets, assessment of collective producer guarantee systems, coordination of provisioning of containers for public exchange facilities and take back of waste at the public waste disposal authorities, collecting data regarding the electrical and electronic equipment supplied in the market etc. A financial guarantee has to be provided by the producers against each new panel that is sold. Depending upon the financing approach selected by the producer, the guarantee is calculated. There is a provision for separate collection and treatment of PV panels at the municipalities.

5.9.1 Developing a Roadmap For A Low Carbon Resource Efficient Solar PV Sector In India

Given that India has seen modest growth in solar capacity only in recent years, that too using mostly imported modules, there has not been much thinking of management of solar PV wastes not only during production and installation phase, but also at the disposal stage. In other words, the solar PV modules in the country are far away from reaching their end of life and therefore their recycling in terms of policy and regulatory measures has still not been considered by the Government, as it is perceived that the repercussions of waste from used PV modules are not glaring presently. However, with increased installations, the projected installation of solar generation capacity can reach 100 GW by 2022, and hence there will be increased volume of PV waste that would be generated. To promote the solar cell manufacturing, India has already initiated dialogue on the policy front with the announcement of a draft concept note on Solar PV manufacturing scheme to build up manufacturing capacity of solar PV modules, cells, wafers/ ingots and polysilicon in India. The concept mentions about a "direct financial support" of Rs 11,000 crore and a 'technology upgradation fund', for solar cells and module manufacturing.

An estimate by IRENA (2016) the cumulative PV waste generated in India was between 1000- 2500 metric tons in 2016 which will probably rise to 50,000-320,000 metric tons by 2030, and further culminating into 4.4-7.5 million metric tons by 2050 as a result of country's solar targets. The ramping up of solar power generation, should address the prospect of used panels that would flood the landfills while leaching toxic waste into the environment. There is a significant thrust on domestic manufacturing under the "Make in India' campaign. Hence systemic value chain based resource management thinking now will help India in the long term to manage the expected growing value of waste from the sector thus enhancing material security.

Review of literatures and discussion with experts has revealed that product standardization and labeling is one of the first steps to promote resource efficiency in the sector. For that matter, the industry, academia and government institutions concerned, need to come together for realizing the same. Financial support through subsidies, incentives need to be explored to encourage responsible product design. Setting up modest target of use of recycled materials in their new products, followed by gradual rise in the target can help in achieving resource efficiency in the sector. Market for such products can be created through possible rebates for new installation of products using recycled raw materials recovered through PV recycling processes.

Setting up a proper solar panel recycling infrastructure that can manage the large volumes of PV modules that will be disposed in near future, will facilitate increased scientific dismantling of panels. They should be supported by cost effective business model of reverse logistics where the role of EPR is extremely important. Dealers network for buy back of end of life solar rooftop panels holds the key while for large scale projects developers in association with original equipment manufacturers need to come together for the same. The cost of take back arrangement need to be specified within the total cost of installation. Enforcement mechanism for such contracts should be designed by the Government in their tenders/schemes or PPA agreements. Awareness generation through showcasing innovation and good practices and exploring potential for upscaling of the new technologies for end of life solar PV need to be undertaken hand in hand with other initiatives.

Easy financing instruments need to be explored by banking and non banking financial institutions for promoting investment in formal recycling set ups. A cluster based approach could be considered bringing different players and thus minimizing risk and these activities can be undertaken close to where PV manufacturing takes place thus facilitating in creating a suitable ecosystem.

6 Existing Policies in India: A Life Cycle Analysis

The utilisation of resources involves their flow from one life-cycle stage to another, and it begins from mining to designing, followed by manufacturing, consumption and ultimately end-of-life management (disposal or recycling). These different stages of the life cycle can be interpreted as a nexus of economic and social activities which occur in such a way that there is impact of one stage of the life cycle on the other and impact on the use of natural resources. For example, use of technologies for mining raw materials can have an impact on the quality/grade of raw material extracted and used for further processing. Extraction of higher quality raw material can help avoid necessary resource consuming processing steps in the ensuing stages of the life cycle. The ways in which products are designed and/or used have an impact on their life time and will play a role in determining the extent of reusability, reparability, recyclability and cost of safe disposal. The various ways of end of life treatment have significant impacts on the quality and usability of the materials (secondary raw materials) originating from those activities, and thus on resources needed for safe disposal or reuse in different forms. The possibility to substitute primary with secondary materials is determined by the quality and usability of the recovered secondary raw material.

Devising a national level initiative for resource efficiency and secondary resource management in India must have scope for achieving the objectives across different stages of the life-cycle and ensure that all the stakeholders get involved at respective stages. In addition, a life-cycle approach is not material or sector-specific and it provides scope for initiatives across different sectors. It enables highlighting the relevant policies and facilitates stakeholders, particularly the government departments, to create an enabling policy environment for achieving resource efficiency. The life-cycle approach is also in line with the idea of closing the loops and reducing dependency on virgin raw material by creating alternate sources of resources through reuse and recycling. The approach also enables introducing consistency in policies, targeting different lifecycle stages so that resource efficiency gains at one stage are not lost due to inefficiencies at other stages. The life-cycle approach is also in line with the idea of closing the loops and reducing dependency on virgin raw material by creating alternate sources of resources through reuse and recycling.

Major economies like China, Japan, Germany, USA (to name a few), have chalked out strategies of not only integrating resource efficiency policies under a unified framework or program, but also adopting value chain/life cycle thinking for addressing efficiency gaps and facilitating stakeholders engagement. Designing novel policies along the life cycle stages can create an enabling framework for achieving resource efficiency, thereby addressing larger goal of circular economy. Although the Indian government does not have a life cycle approach to promote resource efficiency, it has adopted various policy initiatives to promote the sustainable use of resources that can address issues along different life cycle stages. Life cycle approach is not sector specific and it provides scope for initiatives across different sectors.

One of the most notable policies that India introduced a decade ago that articulated the spirit of sustainable development was the National Environment Policy (NEP) of 2006. It mentions that only such development is sustainable, which respects ecological constraints and the imperatives of social justice. The NEP highlights the consensus around the sustainable development concept through three foundational aspirations (NEP, 2006):

i. that human beings should enjoy a decent quality of life;

ii. that human beings should become capable of recognizing the finiteness of the biosphere;

iii. neither the aspiration of a good life, nor the recognition of the limits of the biophysical world should preclude the search for greater justice in the world.

The NEP 2006 also asserts that the most viable basis of environmental conservation is to ensure that people gain better livelihoods from the act of conservation of natural resources than from environmental degradation (MoEF&CC 2011).

India's environmental protection is based on the provision in Indian Constitution as a directive principle of state policy. India's regulation has played a role very important role in the context of promoting eco-innovation. As a part of the 32nd Amendment Act of the parliament, in 1976, an obligation on the part of the state and citizens was introduced for protecting and improving environment. Government of India also introduced policies that were largely based on command and control strategies in the form of emission standards, water quality standards, etc. and in certain cases were linked to fines and penalties. While there are certain advantages of command and control strategies, yet one of the disadvantages associated with this regulatory framework is the high cost of information. In certain situations, the regulator has to rely completely on information from the polluter/emitter, either in terms of emission loads or associated costs of control. As a result, the polluter/emitter may distort critical deciding information to the regulator. However, over the last couple of decades, India has gradually moved from a command and control type of regulation towards use of economic instruments for addressing resource use and environmental challenges. For example, India's policy statement for abatement of pollution, by the then Ministry of Environment and Forest, aimed at giving 'industries and consumers clear signals about the cost of using environmental and natural resources. It mentioned that 'economic instruments will be investigated to encourage the shift from curative to preventive measures, internalise the costs of pollution and conserve natural resources'. It expected that the market based price mechanisms would influence consumer and producer behaviours to avoid excessive use of natural resources.

India has deployed various policies for resource efficiency which include financial support for research and development, eco-mark/eco-labelling, standards, public procurement, tradable permits and certificates and self-regulation, etc. Even rationalization of unwarranted benefits in the subsidy reform played in instrumental role towards sustainable consumption of resources and promoting resource efficiency.

Table 9 provides an overview of some of the key national policies of India which have elements or aspects related to material use and efficiency to promote more judicious and sustainable use of natural resources.

Table 9: Overview of Key National Policies in context of Resource Efficiency

Existing policy of Government of India	Life cycle stage	Resource efficiency aspect	Further potential /opportunities for enhancing resource efficiency-
National Environment Policy 2006	All stages	Emphasises the high potential of waste as a resource, containing valuable materials that can be efficiently extracted and utilised back in the economy; Outlined plans for protecting environmentally sensitive zones, water conservation measures, wildlife protection and protection of wetlands.	Need for a unifying framework that brings together these different sources of secondary raw material for effective closed-loop recycling.
National Mineral Policy (2008)	Raw material extraction/mining	Includes zero-waste mining as a national goal and emphasises the need to upgrade mining technology to ensure efficient extraction and utilisation of the entire run-of-mines	Extraction of associated metals (Tin, Cobalt, Lithium, Germanium, Gallium, Indium, Niobium, Beryllium. Tantalum, Tungsten, Bismuth, and Selenium) along with major metals like Copper, Lead and Zinc needs to be emphasised as a resource efficiency measure.
National Steel Policy (2017)	Raw material extraction/mining	Highlights the need for actions to increase availability of ferrous scrap, technological efficiency, raise availability of washed coking coal to reduce import dependence on it to 65% by 2030-31 (from 85% at present); adoption of energy efficient technologies in the micro, small and medium enterprise steel sector, to improve overall productivity and reduce energy intensity	Needs to address absence of systems for large scale scrap collection in an organized manner, lack of coordination, 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.
National Manufacturing Policy (2011)	Production	Notes that the growth of the manufacturing sector has to be made sustainable, particularly ensuring environmental sustainability through green technologies, energy efficiency, and optimal utilization of natural resources and restoration of damaged /degraded eco-systems; Established the Technology Acquisition and Development Fund for acquisition of appropriate technologies including environment friendly technologies; creation of a patent pool; and development of domestic manufacturing of equipment used for controlling pollution and reducing energy consumption.	Promote comparative advantage of resource efficient industrial sectors as well as the advancement of RE technologies; Potential instruments that the policy could look at include market-based instruments to promote the efficient use of material inputs through indirect taxation, recycling fees, the removal of harmful subsidies, access to finance, environmental taxes, provision of eco-efficient infrastructure, the introduction of industry-based standards and eco-labels, the harnessing of resource-efficient technologies, legal and regulatory frameworks, etc.

Existing policy of Government of India	Life cycle stage	Resource efficiency aspect	Further potential /opportunities for enhancing resource efficiency-
National Industrial Policy 2017	Production	Establishment of a circular economy; ensure minimal/zero waste from industrial activities; Introduced the concept of National Investment and Manufacturing Zones (NIMZs) which are greenfield industrial townships	Promote comparative advantage of resource efficient industrial sectors as well as the advancement of RE technologies; Potential instruments that the policy could look at include market-based instruments to promote the efficient use of material inputs through indirect taxation, recycling fees, the removal of harmful subsidies, access to finance, environmental taxes, provision of eco-efficient infrastructure, the introduction of industry-based standards and eco-labels, the harnessing of resource-efficient technologies, legal and regulatory frameworks, etc.; Waste management should be a key element of the policy as it would contribute to acquiring low cost raw materials for industrial development
National Design Policy (2007)	Design	Provides overall guidelines for quality assurance of products and their economic and industrial competitiveness	Can include issues related to RE and SRM, which would also reflect their potential environmental impact.
National Housing and Habitat Policy, 2007 and and the Pradhan Mantri Awas Yojana (PMAY), 2015	Design and Production	Emphasize on developing appropriate ecological design standards for building components, materials and construction methods; PMAY has a technology submission to promote the use of innovative housing designs and typologies that are modern, green and cost-effective for faster and quality construction of houses	Increase emphasis of use of secondary raw material and minimize waste generation
Draft National Policy on Electronics 2018 (NPE 2018)	All stages	Promote research, innovation and support to industry for green processes and sustainable e-Waste management, including safe disposal of e-Waste in an environment friendly manner, development of e-Waste recycling industry and adoption of best practices in e-Waste management.	Promote inventorization of e-waste by developing a specific methodology; R&D investment in establishment of testing facilities or laboratories and build capacity of stakeholders to streamline end of life management of the products
National Mission on Sustainable Agriculture, 2010	Production	Conservation of natural resources and strengthening resource efficiency are identified as objectives to be addressed through interventions on water use efficiency; pest management; improved farm practices; nutrient management, appropriate R&D. Linkages to other National Missions on Water, Green India, Enhanced Energy Efficiency, Solar power and Strategic Knowledge on Climate Change are emphasized	Need to increase the importance of bio-fertilizers, improved farm practices, organic farming and commitment to agro-ecological approach, which is the most climate efficient farming (IAASTD, 2011)

Source: Author's Compilation

Recent years have seen resource efficiency gaining salience, as reflected through initiatives like Zero Effect - Zero Defect, Swachh Bharat Mission, end of life stage policies to tackle all types of waste ranging from hazardous waste to municipal waste, plastic, construction and demolition to e-waste, etc. However, an overarching strategy needs to be developed that would help encourage and help realize the benefits from prioritizing materials and sectors for short-term, medium-term and long term action, and developing appropriate strategies that are integrated across multiple sectors. One step in the direction taken was the Resource Efficiency Strategy that was prepared by the NITI Aayog, the policy think tank of the Government of India along with EU Delegation to India in 2017. This strategy paper was developed based on the recommendations of the Indian Resource Panel (InRP) — an advisory body under the Ministry of Environment, Forest and Climate Change (MoEFCC) — through the support of Indo-German bilateral cooperation, to assess resource-related issues facing India and advice the government on a comprehensive strategy for RE.

The following sections briefly describe key policies of the government that have been formulated keeping the larger goal of resource efficiency in India, though also help address multiple other sustainability objectives.

6.1 Key policies across life cycle stages

For achieving economy wide benefits of RE & SRM it is crucial that policies across life-cycle stages consider RE & SRM issues. The existing policies and programs of Government of India have already included several aspects related to RE& SRM with ample opportunities and options to include additional RE & SRM measures. Introducing life-cycle approach in RE & SRM related policy making across ministries and exploring inter-linkages will help India utilise resources more efficiently and unlock the potential of secondary resources.

6.1.1 Enabling resource efficient mining practices

Improvement in resource efficiency at the mining stage can lead to substantial savings not only in the mining sector but also to the economy and would contribute to environmental protection and economic development. Inefficient extraction is leading to wastage of resources deployed in mining activities as certain percentage of the extractable mineral in left in the mine and there is limited or no extraction of associated minerals. Enhancement of resource efficiency in this sector would mean improved mining practices leading to minimal wastage, beneficiation, better transportation, as well as reduce environmental and social conflicts.

For this, the mining policies and framework need to put adequate emphasis on specific minerals in particular to enhance efficiency in their extraction including those that are important for the important economic sectors of the country. Increased use of secondary raw materials can also enhance the supply of raw materials- for example, making use of the by-products from mining and use of mining waste as raw material for construction or in other industries like cement manufacturing.

We discuss here the key policies of the government of India that have RE implications along the extraction stage of the life cycle.

6.1.1.1 National Mineral Policy (2008)

The national mineral policy of 2008 highlights the importance of resource conservation and making zero waste mining as the national goal and emphasises the need to upgrade mining technology to ensure efficient extraction and utilisation of the entire run-of-mines. The policy suggests value addition through latest technique of beneficiation, calibration, blending, sizing, concentration, pelletisation, purification and general customising of product. Extraction of associated metals (Tin, Cobalt, Lithium, Germanium, Gallium, Indium, Niobium, Beryllium. Tantalum, Tungsten, Bismuth, and Selenium) along with major metals like Copper, Lead and Zinc needs to be emphasised as a resource efficiency measure. This becomes extremely important in the case of strategic minerals such as Molybdenum and Selenium from Copper ore, Cadmium and Germanium from Zinc ore, and Gallium and Vanadium from Use of equipment and machinery will improve efficiency, productivity and economics of mining.

The policy also suggests strengthening research by technical organizations under the ministry of mines particularly with regard to mineral beneficiation. It acknowledges the environmental issues with regard to mining and further suggests ways of prevention and mitigation of adverse environmental effects including orderly and systematic closure of mines[50].

6.1.1.2 Draft National Mineral Policy, 2018[51]

The policy outlines a vision for the mining industry that specifically mentions environmentally sustainable mining. Furthermore, it articulates that supply of raw materials will be augmented by developing processes for recovery of metals through recycling. It even mentions that research and development efforts will be made to improve operational efficiency and by-product recovery in mining

6.1.1.3 Sustainable Development Framework for Mining Sector in India, 2011

As per the recommendations of the Hooda committee for the development of the Sustainable Development Framework of the mining sector, the ministry of mines published the same in 2011[52], which highlighted the importance of environmental and social sensitivities during granting of mining leases. The Framework includes incorporating environmental and social sensitivities in decisions on mining leases, strategic assessment in

[50] http://steel.gov.in/sites/default/files/88753b05_NMP2008%5B1%5D.pdf
[51] https://mines.gov.in/writereaddata/UploadFile/draftnationalmineralpolicy2018.pdf
[52] https://mines.gov.in/writereaddata/UploadFile/SDF_Overview_more.pdf

key mining regions, managing impacts at the mine level through sound management systems and addressing land, resettlement and other social impacts. It also notes that the mine closure and post-closure mining operations must prepare, manage and progressively work on a process for eventual mine closure along with assurance and reporting (Ministry of Mines, 2011). However, It must also clearly lay down the process for fund disbursement by the District Mineral Foundation so that accrued funds contribute to the long term social and economic development of the communities affected by mining. The framework envisions mining to be *"financially viable; socially responsible; environmentally, technically and scientifically sound; with a long term view of development; uses mineral resources optimally; and ensures sustainable post-closure land uses".*

6.1.1.4 Minerals and Mining Development Regulatory Act (MMDR), 2016

The MMDR Act, apart from setting other guidelines, particularly recommends evaluation and implementation of sustainable development frameworks for the sector. It empowers the central Government to issue directions with regard to reduction of wastes, and adoption of waste management practices and promotion of recycling of materials, mitigation of adverse environmental impacts on ground water, air, noise and land, as well as minimizing impacts on bio-diversity, flora, fauna and habitat. Further it empowers the government to formulate strategies for restoration and reclamation activities that would help in optimal use of mined out land resource. Other relevant policies in this context will include Sustainable Sand Mining Management Guideline (2016), and Star Rating System for Mining industries in India as well (MoM, 2017).

6.1.1.4.1 Further Opportunities

Fostering certification and international standards helps in enhancing accountability in mining industry. For example, the Extractive Industries Transparency Initiative (EITI) has developed a standard for the mining industry that ensures transparency on how a country's natural resources are governed. This ranges from how the rights are issued, to the way resources are monetised plus its benefit for the citizens and the economy. The transparency issues have implications for resource efficiency in the sector as well (EITI, 2016a)

Guidelines for best available technology and processes for mining along with promoting research and development is needed to achieve the potential of RE in Mining Sector in India. The expertise available with IBM and the National Mineral Development Corporation (NMDC) would help the Bureau of Indian Standards (BIS) to develop standards for sustainable mining. These standards/benchmarks may separately be developed for existing mines, new mines and closed mines.

A disclosure process should be created by the mining companies or the IBM that provides stakeholders with relevant and timely information, and allows issues to be raised in engagement forums. There should be an intensive use of geo-spatial and geo-scientific information at mine level for assessment, planning, management and monitoring of the mining sector. Developing information and tools for businesses to help them make resource efficiency savings could also be supported.

A Star Rating Scheme for responsible mining based on the social and environmental impact of mining activities has been developed by IBM. This scheme could also explore including RE related aspects in the Star Rating for promoting RE technology and practices in the country (Ministry of Mines, 2016)

6.1.2 Enabling resource efficiency in during product design phase

Designing environmentally benign products is key to achieving sustainable consumption and production goal of SDGs and has considerable implications on the raw material input requirements and end-of-life material recovery. Resource efficiency at design phase can be in the form of improving durability and lifespan of products, use of sustainable/recycled materials, product labelling for better understanding of reusability and recyclability potential, easier repair and/or recycling of the product, focus on less packaging material etc.

Integrated life cycle assessments of existing products should be conducted to identify the opportunities of making newer products sustainable through proper product development and design. It is equally important that such products have necessary certification or labels that would increase their market acceptability, and enhanced credibility.

6.1.2.1.1 National Design Policy, 2007

Given the strategic importance of design for product competitiveness, the Department of Industrial Policy and Promotion (DIPP), Government of India came out with the National Design Policy, with an objective to promote a *"design enabled Indian industry" which could impact both the national economy and the quality of life in a positive manner*[53]. The policy, among other things, aims to promote a brand image for Indian designs by awarding India Design Mark on designs which satisfy key design criteria like originality, innovation, aesthetic appeal, user-centricity, ergonomic features, safety and Eco-friendliness. India Design Mark was introduced as a design standard that recognizes good design which symbolizes excellence in form, function, quality, safety, sustainability and innovation and communicates that the product is usable, durable, aesthetically appealing & socially responsible, which essentially are some of the important characteristics of sustainable products (DIPP 2017).

6.1.2.2 Science, Technology and Innovation Policy, 2013

The key objective of the policy is to enhance sustainable and inclusive growth based on science, technology and innovation. The policy aims to enhance employment generation through R&D in science and technology. A major aspiration of the policy is *'fostering resource-optimized, cost effective innovations, across size and technology domains'. A focus of the*

[53] http://dipp.nic.in/sites/default/files/national_design_policy%20%20%20eng%201.pdf

policy is on 'providing incentives for commercialization of innovations with focus on green manufacturing[54]*'* (DST 2013).

The Technology Development and Transfer Division (TDT) of the Department of Science and Technology, Ministry of Science and Technology supports research and development (R&D) and market development for 19 Waste Management Technologies. It is possible to extend similar programs for sectoral RE related R&D with additional funding to TDT division (Ministry of Science and Technology, 2016)

6.1.2.3 Bureau of Indian Standards Act, 2016

The Government of India introduced the Bureau of Indian standards (BIS) Act 2016, in 2017 that repealed existing Bureau of Indian Standards Act, 1986. The BIS certification cover a wide range of products across different sectors like textiles, and plant machinery to building materials including paints and chemicals, plastics and their products including packaging and their impact on the environment. The Act provides additional powers to the Government where it can issue compulsory certificates for any article or goods from a scheduled industry, process, system or service that may be considered important in the public interest or for the protection of human, animal or plant health, safety of the environment, including prevention of unfair trade practices/ national security[55]. BIS recognizes environment friendly products through its labelling scheme Eco-Mark. The Scheme provides certification of consumer products that meet certain environmental specifications (including quality standards) for these products as required in the Indian conditions[56] (BIS 2016).

Under the Environment (Protection) Rules, 1986, the Central Pollution Control Board has developed national standards for effluents and emissions for industries under the statutory powers of the Water (Prevention and Control) Act, 1974 and Air (Prevention and Control of Pollution) Act, 1981. Additionally, it is required to develop standards for design of products which could target RE and promote SRM. Conceptualisation of the 'design' through the lifecycle of a product that ensures manufacturing utilising least resources, ease of refurbishing, dismantling, recycling etc. continues to be a recent development in the Indian manufacturing sector, as most products are designed considering the utilisation phase with limited consideration of resource use during manufacturing or post-consumption waste disposal issues. Priority is given to maintaining and increasing production levels, with the design being thought of as short-term investment (Zbicinski et al., 2006).

Design policies will need to be incorporated in manufacturing policies itself to enable companies and firms to undertake life-cycle environmental impact assessments of production and product designs, with emphasis on resource efficiency and promotion of the use of secondary raw materials. Voluntary standards, like Green Reporting Initiative and

[54] http://www.dst.gov.in/sites/default/files/STI%20Policy%202013-English.pdf
[55] http://pib.nic.in/newsite/PrintRelease.aspx?relid=171705
[56] http://www.bis.org.in/cert/echo_mark_scheme.htm

ISO 14062: 200211 should be encouraged to develop and strengthen design initiatives for improving resource efficiency and promoting use of secondary raw materials.

Box 2: Best practice example for a changed product design

A research study conducted by École Polytechnique Fédérale de Lausanne (EPFL), Indian Institute of Technology-Madras, Indian Institute of Technology-Delhi, and Technology and Action for Rural Advancement (TARA), New Delhi, designed a new type of cement that is based on a blend of limestone and calcined clay. As the processes of producing the cement have to be adapted to support this new product design as well, this example has also an aspect that has to be implemented in the production stage.

Box 3: Learning from the Success of Energy Efficiency Program in India

Energy Efficiency Programmes have had significant success in India.These programs were accepted by the people primarily due to the accrued economic benefits. While energy efficiency is directly related to the expenditure to be incurred on energy by the user of the product, resource efficiency and use of secondary raw materials could go beyond the economic gains, and have a positive social and environmental impact. It is crucial that resource cost savings are shared between the different stakeholders through design of appropriate tax and incentive structure. It is also possible to setup an Indian Bureau of Resource Management based on the experience of setting up BEE that works in close coordination with BIS and other related government bodies to mainstream RE and SRM issues.

6.1.3 Enabling resource efficiency in Production/Manufacturing India

Over the years India's manufacturing sector has emerged as a key economic sector. RE in production/manufacturing may include reduced waste in production process, substitution of more environmentally harmful materials by less harmful ones, reduced input materials in production via better organisation of processing in a more efficient way, etc. Within manufacturing, sectors like automobiles, cement, IT, electronics and electrical equipment, etc. have sector specific promotion policies, but they mostly lack any focus on RE and SRM goals.

The guiding policy document towards bringing transformation in the sector has been the National Manufacturing Policy of 2011. To address the renewed commitments of the government on 'Make in India', 'Digital India', and 'Skill India', the earlier National Manufacturing Policy has been modified and would soon be made available. Apart from increasing income and employment, the policy aimed at enhancing global competitiveness of India's manufacturing sector, increase domestic value addition and strengthen technological depth that supports environmental sustainability.

6.1.3.1.1 National Manufacturing Policy, 2011

The national manufacturing policy was introduced in 2011, in order to increase India's manufacturing share in the national income. The policy identifies the importance of green manufacturing and provides incentives for acquiring technologies that are environmentally friendly and thereby controlling consumption of key resources like water and energy (PIB 2011).

6.1.3.1.2 National Policy on Electronics, 2012

The policy aims at making India a globally competitive electronics manufacturing hub that can meet India's growing demand as well as that of other countries. It aims to streamline implementation of e-waste rules in the industry including facilitation of extended producers responsibility under the e-waste (Management and Handling) Rules of 2011 (MEITY, 2017).

6.1.3.1.3 National Manufacturing Competitiveness Program, 2014

The National Manufacturing Competiveness Program (NMCP) was launched by Ministry of Micro, Small & Medium Enterprises in 2014, with an aim to enhance the competitiveness of MSME sector. The MSME sector forms of the backbone of the India's manufacturing sector and effective policies will go a long way in bringing resource efficiency in the sector. This may be achieved by reducing the manufacturing costs through better space utilisation, scientific inventory management, improved process flows, reduced engineering time, etc. The target is to achieve "Zero Effect, Zero Defect Models" by aligning schemes like Lean Manufacturing Competitiveness Scheme, Quality Management Standards (QMS) and Quality Technology Tools (QTT), Technology and Quality Upgradation (TEQUP) schemes, etc. (PIB, 2015).

Key schemes under the NMCP presented in table 9.

Table 10: Various schemes under National Manufacturing Competitiveness Program

Sl. No	Name of the Scheme	Brief Description
1	Credit Linked Capital Subsidy for Technology Upgradation	The scheme provides 15 percent subsidy for additional investment up to INR 10 million for technology upgradation by MSMEs.
2	ISO 9000/ISO 14001 Certification Reimbursement	The scheme provides incentives to those MSMEs/ancillary undertakings that have acquired ISO 9000/ISO 14001/HACCP certification. The scheme is enlarged so as to include reimbursement of expenses in the acquisition of ISO 14001 certification.
3	Marketing Support/Assistance to MSMEs	Adoption of international numbering standards used in Bar-Coding/E-commerce applications

Sl. No	Name of the Scheme	Brief Description
4	Lean Manufacturing Competitiveness for MSMEs	Financial assistance is provided for implementation of lean manufacturing techniques, primarily the cost of lean manufacturing consultant (80 percent by government of India and 20 percent by beneficiaries).
5	Design Clinic for Design Expertise to MSMEs	Funding support of (1) INR 60,000 per seminar and 75 percent subject to a maximum of INR 0.37 million per workshop, (2) To facilitate MSMEs to develop new Design strategies and or design related products and services through project interventions and consultancy.
6	Technology and Quality Upgradation Support to MSMEs	The scheme advocates the use of energy efficient technologies (EETs) in manufacturing units so as to reduce the cost of production and adopt clean development mechanism.
7	Entrepreneurial and Managerial Development of MSMEs through Incubators	It provides early stage funding to nurture innovative business ideas (new indigenous technology, processes, products, procedures, etc.) that could be commercialized in a year. The scheme provides financial assistance for setting up business incubators.
8	Enabling Manufacturing Sector to be Competitive through QMS&QTT	The scheme endeavours to sensitize and encourage MSEs to understand and adopt latest Quality Management Standards (QMS) and Quality Technology Tools (QTT).

Source: Ministry of Micro, Small and Medium Enterprises (2017)

6.1.3.2 Charter on 'Corporate Responsibility for Environmental Protection, 2016

The Charter on "Corporate Responsibility for Environmental Protection (CREP)" was launched in 2003 with sole objective of going beyond the traditional compliance as governed by regulatory norms, for the purpose of prevention & control of pollution through various measures including waste minimization, in-plant process control & adoption of clean technologies[57] (MoEF&CC 2003). The charter includes various measures such as waste minimisation, in-plant process control and adoption of clean technologies. Abiding by these standards could have significant positive impact on RE and SRM. However, it would additionally require appropriate accompanying measures like dissemination of information regarding RE and SRM approaches along with awareness generation in partnership with industry bodies and chambers of commerce.

6.1.3.2.1 Financial Support to MSMEs in ZED Certification Scheme, 2017

This is based on the government's objective of promoting Zero Defect Zero Effect (ZED) across all manufacturing and service sector industries with a specific emphasis on the MSME. This includes production mechanisms wherein products have no defects as well as the production process has zero adverse environmental and ecological effects. The ZED rating scheme is a pan India drive for creating awareness in MSME clusters about the

[57] http://www.cpcb.nic.in/divisionsofheadoffice/pci3/Important_projects.pdf

benefits of the zero defect manufacturing and how enterprises can quickly adopt theme through financial assistance. The increased productivity and reduced wastages would then substantially increase India's vast MSME sector in the global production chains. Figure 34 shows India's ZED rating process.

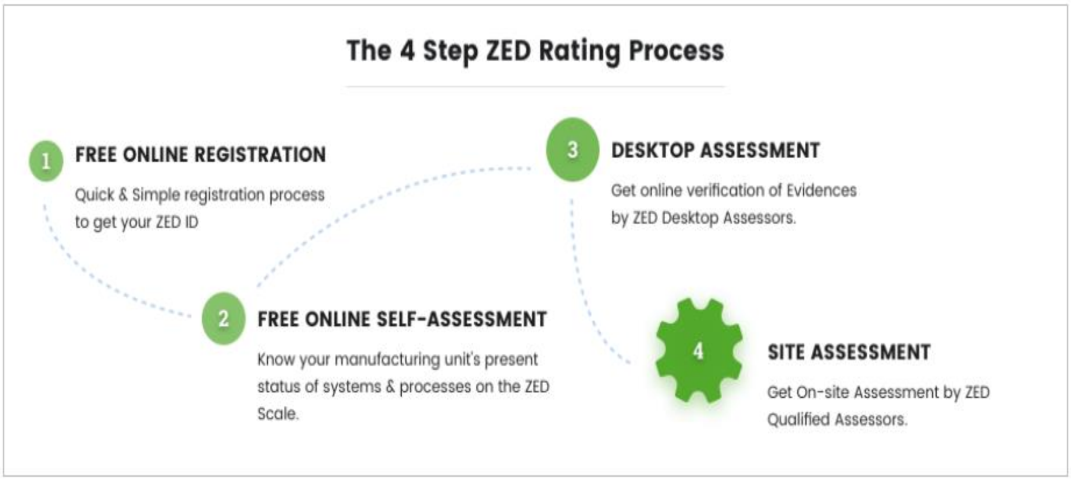


Figure 37: The Four Step Rating Process

Source: Ministry of Micro, Small and Medium Enterprises (2017)

6.1.3.3 National Steel Policy, 2017

India's New Steel Policy of 2017, inter alia, emphasises on the need for having a development path that respects environmental friendliness, resource conservation, and product quality, which when implemented over time, will make India a world leader in steel Industry. The policy also emphasises the increased importance of the presence of industries on mineral beneficiation and agglomeration as well as innovative transportation mechanism that will reduce wastage, pollution and *de-congest transportation infrastructure in mining area* (MoS, 2017).

The Standards prepared by the Bureau of Indian Standards (BIS) have significant uptake amongst manufacturers. For example, IS 455:2015 Portland Slag Cement – Specification (Fifth Revision) allows for use of slag as raw material to compensate for lime. Similarly, IS 1489 (Part 1): 2015 Portland Pozzolona Cement —Specification Part 1 Fly Ash Based (Fourth Revision) allows for use of fly ash in place of lime in specified proportions. There is a need for more such standards for promoting RE and SRM across sectors.

6.1.3.4 Draft National Policy on Electronics 2018

The policy aims to promote research, innovation and support to industry for green processes and sustainable e-Waste management, including safe disposal of e-Waste in an environment friendly manner, development of e-Waste recycling industry and adoption of best practices in e-Waste management

6.1.3.4.1 *Further Opportunities*

Setting up of recycling units in the industrial corridors could be promoted through designing appropriate incentives. Industrial infrastructure promotion policies like the Delhi-Mumbai Industrial Corridor (DMIC) and "Smart Cities" are already considering the issue of solid waste management and recycling. The recently revised e-waste Rules mandate that space should be allocated for the recycling of e-waste in every industrial park or zone by the state government. This provision would promote the practices of industrial symbiosis in the industrial clusters by channelizing the waste from one firm as a resource for another.

Measures can be formulated to promote the use of more resource efficient technologies or organisational solutions, optimally in a sector specific way. This can encompass e.g. R&D, standards, active dissemination of resource efficient technologies, organisational solutions in relevant targets groups and incentives for the implementation of environmental management systems.

Waste related information should be provides to different stakeholders. The inclusion of raising awareness on e-waste under the Digital India mission is another example of promoting SRM in India. While the Digital India mission promotes the manufacturing and consumption of IT in India, the inclusion of e-waste awareness demonstrate that policies for promoting manufacturing can also promote recycling as an industrial activity.

6.1.4 Enabling resource efficiency at the consumption phase

Resource efficiency at the consumption phase has a lot to offer in terms of material savings. In recent years, the Government has introduced new policies and as well modified earlier policies with a larger objective to promote sustainable consumption and production.

6.1.4.1.1 *Labelling schemes*

Eco mark 1991

Eco-mark is one of India's earliest voluntary labelling schemes for identifying environment friendly products. The scheme, launched in 1991, by the then Ministry of Environment and Forests, and is administered by the Bureau of Indian Standards (BIS). The scheme defines an environmentally friendly product which is made, used or disposed of in a way that significantly reduces environmental impacts. The definition considers a cradle-to-grave approach that includes raw material extraction, production and disposal.

Bureau of Energy Efficiency- Star Labelling Program, 2006

The energy efficiency product labelling scheme was launched in 2006 with an objective to provide consumers informed choice about purchase decisions thereby saving their electricity bills. The scheme is expected to bring a substantial energy savings in the residential and commercial buildings in the medium and long run. Key appliances that are covered under the scheme include room air conditioners (Fixed Speed), ceiling fans, colour television, computer, refrigerators, distribution transformers, domestic gas stoves, frost free refrigerators, general purpose industrial motor, pumps, stationary type water heater, submersible pump set, , washing machine, ballast, solid state inverter, office automation products, diesel engine driven, diesel generator set, led lamps, room air conditioners (variable speed), chiller, variable refrigerant flow, agricultural pumpsets, microwave oven, etc (BEE 2017).

Biofuel Programme, 2009

To meet the increasing energy needs of the country and to provide Energy Security, National Policy on Biofuels was announced in December 2009. The major goals of the policy are Development and utilization of indigenous non-food feed stocks raised on degraded or waste lands, thrust on research and development on cultivation, processing and production of biofuels and a blending mandate of 20 percent Ethanol and Bio-diesel by 2017. The objective of biofuel programme is to support R&D, Pilot plant/Demonstration projects leading to commercial development of 2nd Generation biofuels. The Ministry of New and Renewable Energy (MNRE) supports R & D projects for development of technologies for production of biofuels through Biogas, Pyrolysis and Gasification, besides promoting deployment of technologies for pilot and full-scale projects on biofuels in general (MNRE 2009).

Renewable Energy Certification, 2010

India's Electricity Act, 2003, and the various policies under the Act, as well as the National Action Plan on Climate Change (NAPCC) provide a clear roadmap for increasing the share of renewable energy in the total generation capacity in the country. Indian states having abundant renewable energy can produce excess electricity and sell it to those states where the renewable energy potential is less. In 2010, the Central Electricity Regulatory Commission (CERC) introduced Renewable Energy Certificates (REC) program so that distribution companies can meet RPO targets while incentivizing green energy generation. These RECs can be traded or exchanged where renewable energy generators can sell these certificates to buyers i.e. those states that are deficient. This provides win-win opportunities where renewable energy generators are incentivized to produce more renewable energy and timely settlement helps in supporting their overall cash flows (Renewable Energy Certificate Registry of India 2010).

Perform Achieve and Trade (PAT) Scheme, 2012

In order to energy efficiency in energy intensive industries in India, government introduced the Perform Achieve Trade (PAT), a market-based trading scheme under the National Mission on Enhanced Energy Efficiency (NMEEE) and administered by the BEE. Specific targets have been assigned for energy consumption in designated industries. Based on the efficiency gained by the designated consumers, these industries can trade energy efficient certificates in energy-intensive sectors The scheme is implemented in three phases (i) the first phase ran from 2012-2015 that covered 478 facilities and included eight manufacturing sectors, viz. aluminium, cement, chor-alkali, fertilizer, iron and steel, pulp and paper, textiles and thermal power plants. These industries account for approximately 60 percent of India's total primary energy consumption (BEE 2015).

Auto Fuel Policy, 2015

In 2002, an expert Committee on Auto Fuel Policy, was formed for laying out the road map regarding vehicle emissions and fuel norms. The aim is to promote fuel economy and is being done through levy of differential tax on two wheelers and passenger cars/jeeps (MoEF, 2011). In 2015, Auto Fuel Policy and Vision for 2025 was introduced that would promote improved fuel quality as well as stricter emission norms for the sector (MoPNG 2015).

National Electric Mobility Mission Plan, 2015

India introduced National Electric Mobility Mission Plan 2020 that is expected to bring paradigm shift in the automotive and transportation sector. It envisages introducing 6–7 million battery operated electric/hybrid vehicles on Indian roads by 2020. Promotion of electric vehicles not only has environmental benefits but also will help India in saving foreign exchange in importing crude oil. India currently imports 70 percent of crude from other oil exporting countries. In order to promote faster adoption of electric vehicles Government of India is preparing to offer incentives in cities having population more than one million. This initiative is a part of FAME (Faster Adoption and Manufacturing of Hybrid and Electric Vehicles) India scheme that aims to promote multimodal public electric mobility. Almost all the global auto players have planned to launch electric vehicles in the coming years (DHI 2017).

6.1.5 Enabling resource efficiency through efficient disposal of wastes/end of life products

6.1.5.1.1 Waste management Rules

The objective of waste rules is to protect the environment, natural resources and human health and ensure a sound management of these waste streams by specifying rules for segregation at source, collection and transportation, storage and processing for secured disposal. The enforcement of these rules is carried out by the State Pollution Control Boards, the Central Pollution Control Board as well as by the Urban Local Bodies (especially regarding the management of C&D waste).

Batteries (Management and Handling) Amendment Rules, 2010

The rules of 2001 were amended in 2010 to include provision for sale of batteries through registered dealers, assigning responsibilities to bulk consumers etc. Rules apply to manufacturer, importer, re-conditioner, assembler, dealer, recycler, auctioneer, bulk consumer and consumer, to ensure collection, recycling, transportation and sale of batteries (MoEF&CC, 2010).

Solid Waste Management Rules, 2016

The government of India in 2016 notified the new Solid Waste Management Rules (SWM), 2016, thereby replacing the earlier Rules, established 16 years ago. 2000. The new rule explicitly mandates source segregation of waste for creating opportunities to value addition and promote recovery, reuse and recycle. The local bodies have been assigned power to levy 'user charges', or impose 'Spot Fine' for littering and non-segregation. The industrial estate/SEZ/industrial park developers need to allocate at least 5 percent of the total project area for resources recovery from wastes and build recycling facility. The policy calls for increased production of compost and mandates the department of fertiliser for increased marketing of these products. Further, it emphasise promotion of waste to energy plant. The urban local bodies need to create infrastructure for segregation as well as easy access to waste pickers and recyclers for collection of segregated waste (MoEF&CC 2016).

Construction and Demolition Waste Management Rules, 2016

The government of India notified the construction and demolition waste management rule in 2016. The rule assigns responsibility to waste generators for their storage and at collection centre as provided by local bodies or to be handed over to authorised processing facilities. The rule suggests administrative and other logistic supports from the State Governments to the business in the C& D Waste Management Sectors (MoEF&CC 2016).

E-Waste Management Rules (2016) & Amendment 2018[58]

The E-Waste Management Rules, 2016 & Amendment, 2018 mandates the collection of e-waste generated during manufacture of any to be channelized for recycling or disposal. The rules direct the producers under EPR to collect and channelize e-waste of a set target to an authorised dismantler or recycler or Treatment, Storage and Disposal Facility (TSDF). Manufacturers and producers can implement EPR individually or collectively through a Producer Responsibility Organization. EPR plan submitted to the SPCB permits producers to place products in the market. Compliance to the EPR is only through self-declaration.

It is important however to raise the consumer awareness about the impact of electronic product manufacture, and e waste generation and management. Further, government or market-based incentives for consumers need to be established to encourage them to dispose their e waste appropriately

Plastic Waste Management Rules, 2016

[58] http://www.moef.gov.in/sites/default/files/EWM%20Rules%202016%20english%2023.03.2016.pdf

Government notified the Plastic Waste Management Rules in 2016 that will bring responsibilities in collection back system of plastic wastes, use of plastic waste for road construction as per Indian Road Congress guidelines or energy recovery, or waste to oil etc. for gainful utilization of waste (MoEF&CC 2016).

Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016

The rule emphasises on the recovery and reuse of materials from hazardous and other waste materials generated from a process thereby ensuring a sound management of all hazardous and other waste materials (MoEF&CC 2016).

6.1.5.1.2 Fly Ash Utilization Policy 1999

The notification on fly ash utilization was first issued in the year 1999 and since then, the fly ash utilization in the country has increased to almost 60 percent. Recently, MoEF&CC ministry revised some of the norms to diversify its application/use across other sectors, and mandating power generating companies to provide fly ash free of cost to consumers within 300 kms. It also mandated cement industries, that are operating within a radius of 300 kms of a coal based thermal power plant, to use fly ash for cement manufacturing as per BIS. The cost of transportation of fly ash is to be borne collectively by the thermal power plant and the industry concerned (MoEF&CC 1999).

6.1.5.1.3 CPWD Guidelines for Sustainable Habitat

These guidelines have a section on Guidelines on Reuse and Recycling of Construction and Demolition Waste. Recognizing the shortage of naturally available aggregates for construction of buildings, the guidelines outline that reduction of this demand is possible only with the reusing or recycling of construction and demolition waste generated from the construction activities. Hence, the construction sector must accept the use of C& D waste wherever feasible, which will lead to a significant saving in virgin raw material and consequent reduction in waste disposal.[59]

6.1.5.1.4 Reduction in GST on waste products 2017

Recently the GST Council significantly reduced the rates on electronic waste from 28 percent to 5 percent while for plastic wastes as well as other waste or scrap of glass and rubber waste, the rates have been reduced from 18 per cent to 5 per cent.

Further Opportunities

The waste rules need to consider developing business models that lead to better implementation, mobilization of financial resources for waste management through Extended Producer Responsibility (EPR) and Polluter Pays Principle. Also, there is a need for a unifying framework that brings together different sources of secondary raw materials

[59] https://cpwd.gov.in/Publication/Guideleines_Sustainable_Habitat.pdf

for effective closed-loop recycling. Further, building the technical capacity of the informal sector and creating mechanisms for financial support to improve efficiency levels and sustainability aspects of their work will help achieve greater resource efficiency.

There is an urgent need to formalise the informal sector by organising them in cooperatives or jointly owned private enterprises, so that they can access technology and funding to improve their operations and ensure safe environment and health for the people employed in the informal sector. Therefore, the positive aspects of informal sectors could be built upon to develop business models that augment the livelihood generation potential. For instance, the informal sector's expertise and ability in terms of collecting e-waste or other wastes directly from households and segregation can be supported through a web-platform which could be operated by a formal sector enterprise. Informal sector units can form cooperatives or private companies that enable them to participate formally in waste management related tenders while ensuring that safety procedures and employment benefits are provided to the workers engaged in the formal set-up

There is a need to bring in standards and guidelines for the recycling and remanufacturing industries to enable them to operate in a scientific and environmentally sound manner and also increase the credibility and acceptability of their products.

7 Resource Efficiency Policy Framework for India

7.1 Perspectives for designing Resource Efficiency (RE) policies

It is important that a policy framework for resource efficiency considers three main perspectives to design the planned policy instruments/approaches: the stages of lifecycle (mining and extraction of resources, design, production, consumption and end of life), selected hotspot sectors (such as mobility, renewable energy, construction, waste categories), selected categories of material resources that are considered as priority materials (such as rare earths, iron and steel, aluminium, copper etc). Further, policy instruments/approaches to address resource efficiency could cut across individual sectors, materials or life-cycle stages.

The first perspective related to the stages of life cycle has been discussed in the previous chapter. The life-cycle approach is also in line with the idea of closing the loops and reducing dependency on virgin raw material by creating alternate sources of resources along the life cycle stage through reuse and recycling.

The second perspective on sectoral prioritization for bringing about resource efficiency improvements will need to identify resource use challenges, and policy measures for addressing these challenges for the key industrial and strategic sectors of the Indian economy. Mainstreaming resource efficiency measures in sectoral policy documents will help retain focus on the need to secure a sustainable supply of resources, the aim of using resources more efficiently, the economic, and social gains to be made from efficiency, and the need to protect the environment.

Since different sectors use several materials to produce a particular set of products, the third perspective to be looked at for designing RE policies is the use of critical and/or priority materials. These differences between the materials constitute the rationale according to which the material specific formulation of measures may seem promising in increasing resource efficiency to the highest extent possible. Such measures may include the promotion of recycling cycles and markets for secondary products of individual materials, the targeted substitution of critical materials by less critical materials or R&D for the development of materials fulfilling certain conditions to allow for a specific product function or property.

Resource efficiency can be optimized along the life cycle stages of these materials and the products in which these are used as inputs. The physical and chemical properties of the materials will determine the scope of applicable processing technologies, of the realisation of specific product solutions as well as their features and functionalities.

Lastly, though the policy measures have to be adapted to specific characteristics of their diverse subjects, policy instruments/approaches could also be of a cross-cutting nature when their applicability or their potential impact are taken into account. Such policy approaches can have an impact on all stages of the life cycle and to a vast array of different materials and sectors. These would include- collection, interpretation and publication of statistical data and other information; development and standardisation of methods to assess resource efficiency in companies and for products; promotion of R&D and innovation in and together with enterprises, the creation of public awareness for resource conservation, the introduction of resource related issues in the education system, support for municipal and regional bodies in resource efficiency politics and last but not the least -the engagement in international discussions and policy processes dealing with resource efficiency.

Resource efficiency should be embedded into the policies and processes of the government and it should work to ensure the effective implementation of the resource efficiency initiatives in the country. The compartmentalisation of policies that may happen due to the institutional structure, can prove to be an obstacle to the implementation of resource efficiency which needs to address many different actors, sectors and materials. A coherent framework of action and policy coordination would help to achieve further progress in this area.

Recent years have seen resource efficiency gaining salience, as reflected through initiatives like Zero Effect - Zero Defect, Swachh Bharat Mission, end of life stage policies to tackle all types of waste ranging from hazardous waste to municipal waste, plastic, construction and demolition to e-waste, etc. However, an overarching strategy needs to be developed that would help encourage and help realize the benefits from prioritizing materials and sectors for short-term, medium-term and long term action, and developing appropriate strategies that are integrated across multiple sectors.

As a step in the direction, in 2017, a Resource Efficiency Strategy was prepared by the NITI Aayog along with EU Delegation to India, the policy think tank of the government of India. This strategy paper was developed based on the recommendations of the Indian Resource Panel (InRP) — an advisory body under the Ministry of Environment, Forest and Climate Change (MoEFCC) — through the support of Indo-German bilateral cooperation, to assess resource-related issues facing India and advice the government on a comprehensive strategy for RE.

Sectoral and material resource assessment studies have also been conducted over the last two years. The sectors and materials were prioritized based on the:

1. Economic importance of the material based on its usage across different sectors
2. Sectors that are high in economic importance
3. Environmental impact due to extraction and production of resources
4. Supply risks of materials determined through

a. Limited geological availability and criticality
b. High import dependency for critical resources
c. Geopolitical constraints

7.2 Policy Instruments for RE for India

7.2.1 Economic instruments

It is fundamental to 'get the prices right' through internalising environmental costs and implementing the polluter-pays principle. Economic instruments, sometimes also referred to as market-based instruments can help in this direction and also have the potential to take into account issues of equity and competitiveness concerns in its design. It is widely recognized across the world that economic instruments play a significant role in helping transform economies to become greener and should be based on a sound life-cycle basis to support real resource efficiency. There should be use of consistent definitions and methodologies along with improvements in monitoring and evaluation.

Economic instruments typically include fiscal instruments in the form of taxes, charges, subsidies, incentives and budget allocations, marketable permits, deposit-refund systems and performance bonds. These instruments can also help generate revenue for environmental and social purposes besides shifting behaviour towards resource efficient activities and stimulating investment in cleaner and resource efficient technologies, grants, and various investment or financial support programmes.

Taxes must incorporate the cost of externalities and better reflect the effects of extraction and value creation. Tax instruments to promote resource efficiency range from taxes on extraction (though rarely applied) to taxes and fees on generating hazardous waste.

Value-added taxes should be levied on value-added activities like mining, construction, and manufacturing, and not on value preserving activities such as reuse, repair and remanufacture. The effect of GST on secondary raw materials and products made using these should also be analysed and harmonised with the resource efficiency goals as well as those mandated through the various waste management rules in order to make sure that their use is not discouraged and leads to their greater market adoption.

> In Sweden, a tax on natural gravel was introduced in 1996 with an aim to promote the use of crushed rock and recycled materials, such as concrete, and thereby address the shortage / limited supply of supply of natural gravel in parts of the country. The tax encouraged substitution with other materials.

Tax exemptions for components and sub-components made using recycled material in the product value chains can help promote RE from the supply side, whereas tax sops for eco-labelled products that would encourage consumers to purchase those products, based on informed decision choices will help promote RE from the demand side.

Targeted tax and other financial incentives for manufacturers of green building products made from secondary raw materials such as those made from C&D waste, industrial slag, mining and quarrying waste, timber scrap, low-carbon cement, etc can help to make these products more competitive since higher prices are often the biggest obstacle for adoption of green products by users. Subsidies or tax holidays could be provided to businesses engaged in providing remanufactured/refurbished/recycled products and related services

Economic instruments are often contrasted to regulatory or "command and control" policy approaches that determine pollution reduction targets and define allowable control technologies via laws or regulations. In reality, however, command and control policy and economic instruments frequently operate together. A government may set limits on permitted pollution levels for a region or a country in order to meet a certain health or environment objective. Here the market-oriented approaches such as tradable permits can then be used to allocate the allowable emissions in an efficient manner. Tax incentive structure including tax breaks could be designed to incentivise and reward those manufacturers who want to invest in clean technology

For the waste sector, the commonly prevalent incentives to address the critical problem of waste management in India includes: 1) taxes and fees; 2) recycling credit and other forms of subsidies; 3) deposit-refund; and 4) standards and performance bond or environmental guarantee fund. Some taxes or levies targeted at a specific type of waste, such as plastic packaging have received lot of attention in recent years thanks to the successful use of levies in many countries.

Landfill taxes, particularly those levied based on volume of waste reaching the landfill, can encourage the reduction of waste and are easy to implement. Their effectiveness, however, depends on the tax rate per tonne of waste and on the existence of adequate monitoring and enforcement measures providing control on types and volumes of waste streams. It is also important to ensure that the tax does not result in increased illegal dumping rather than encouraging 3Rs (reduce, reuse, recycle). Pay-as-you-throw (PAYT) is another way of discouraging waste generation. Precaution against illegal waste dumping or misuse of recycling facilities is therefore needed. Full financing of the waste management infrastructure has to be assured and sufficient awareness-raising is necessary. PAYT has been shown to have a positive impact on recycling. Over time, it will be extremely important to move towards zero landfill. For this, it will be important to dis-incentivize landfilling itself by imposing high tipping fees, especially for bulk generators of waste, thereby encouraging the optimal use of material and redirecting of waste to appropriate channels for recovery.

For promoting use of cleaner technologies, the Technology Acquisition and Development Fund (TADF) under the National Manufacturing Policy Standards in India, being implemented by the Department of Industrial Policy & Promotion (DIPP) is helping Micro, Small & Medium Enterprises (MSMEs) to acquire clean and green technology at affordable cost across their sector. The fund will support manufacturing of pollution control equipment and reducing energy and water consumption through subsidies.

Further, Tax exemptions may be provided to companies that are able to meet the "Best Available Technologies Not Entailing Excessive Costs" (BATNEEC) standards. These standards could include explicit RE and SRM criteria and be developed by Central Pollution Control Board (CPCB). The need to rationalize the tax regime on extraction of critical virgin raw materials to make secondary raw materials price-competitive and for businesses entering remanufacturing, refurbishing and recycling sectors has been highlighted.

Box 4: Advanced Recycling Fee and Proper E-waste Disposal– How it Works

The ARF works as a tool that makes both consumers and manufacturers participate in the recycling process. It provides incentives to recycling companies to set up more units, and employ environment-friendly recycling methods to process e-waste. In fact the funds received from ARF can give e-waste recycling a much needed push with respect to innovation and development of better solutions to handle e-waste – something that is quite essential. This could enable establishment of recycling plants that make use of innovative and disruptive technologies to recover resources like precious metals and rare earth elements from electronic waste and dispose e-waste toxins responsibly – thereby not only saving the environment from the polluting effects of harmful elements in e-waste, but also ensuring recovery and reuse of rapidly depleting resources.

The ARF can also be used to set up consumer e-waste collection networks, establish transportation systems and reverse logistics capabilities to allow for collection of end-of-life electronics from consumers and divert it to proper recycling channels. Such an approach could prove effective as a means of ensuring that more consumer e-waste is disposed in an environmentally responsible manner rather than ending up in landfills or in the improper e-waste processing setups.

Integrating the end of life management costs in to product pricing can be an important way to encourage sound management of end of life products. One economic instrument to do this is the Advance recycling fees (ARF). ARF is basically a tax that consumers (or even manufacturers) are required to pay when they purchase (or sell) a product. It generates revenues that fund the otherwise non-profit activity of recycling end-of-life, discarded products such as electronic and electrical waste. The motive behind this tax is to get consumers (and/or producers) to contribute towards the recycling industry and consequently provide them with better ways for disposing (or managing) the used products responsibly.

Another example is that of the Deposit refund system (for recycling). In India, the instrument is in use for lead acid batteries in Delhi and NCR. The instrument is relevant for the Automobile and Energy (inverters and emergency systems) sector and is aimed to address the end of life management of lead acid batteries and deal with the hazardous substances such as lead Under this policy instrument, a discount is given to consumers on purchasing new batteries and returning used batteries to retailers for recycling. This instrument could be extended to other parts of the country and cover other battery types such LiFe, NiCd, and NiMH.

Economic instruments are part of a wider system of governance and regulation, complicating the task of defining specific impacts of the instrument both qualitatively and through modelling. This highlights the fact that instruments rarely work in isolation. They work within in a legislative, cultural and market framework that also has a major bearing on their effectiveness. Ensuring this framework is coherent and supports the instrument objectives is important to achieve improvements in resource efficiency. Where this supporting framework is less coherent, with contradictory or competing goals, or loopholes or gaps in the system, then the intended resource efficiency effects can be weakened or lost.

Monitoring and data relating to market based instruments is typically weak. Quantities can sometimes only be derived from tax revenue data and with this being subject to aggregation, confidentiality and other issues, its usefulness for assessing impact is reduced. For instruments with a solely revenue raising objective this may be sufficient, but for policies with resource efficiency objectives this lack of follow-up and understanding is a weakness in successfully implementing policy.

7.2.2 Regulatory instruments

Regulatory instruments would include laws or decrees on a variety of themes related to materials, including bans on the use of certain substances, and design and performance or quality standards. In context of RE, these typically include laws or regulations that stipulate efficiency standards, ban certain products and practices, and mandate application of certain "best available technologies". In India, there are many existing policies influencing resource use at different lifecycle stages starting from extraction/mining to designing, followed by manufacturing, consumption and ultimately final disposal/end-of-life management (disposal or recycling). However, their design, emphasis, integration or implementation is often suboptimal in terms of achieving RE goals. At the mining stage, the National Mineral Policy already includes zero-waste mining as a national goal and emphasizes the need to upgrade mining technology. What is additionally needed is to promote extraction of associated metals (Tin, Cobalt, Lithium, Germanium, Gallium, Indium, etc.) along with major metals like Copper, Lead and Zinc to enhance resource efficiency in the sector. Just as the Steel Policy aims to increase extraction rate from present 93.5% to 98%, there is a need to increase efficiency in extraction of other minerals to reduce mining and associated environmental impacts.

The Government needs to look into more closely integrating resource conservation concepts into relevant legislations. By elaborating, enhancing and supplementing existing provisions and instruments, the concept of resource efficiency can be taken up at a broader base, leading to more efficient and economic resource use. A coherent and future-ready legal framework for the circular economy needs to be developed with adequate focus on enhancing implementation of product responsibility in waste management laws and ensuring product recycling across sectors and for different materials.

Standards, developed by specialized standard setting organisations, have been widely used to promote quality in manufacture and performance of products. However, standards to promote environmental goals, especially resource efficiency, are relatively new. Standards for recycled materials now exist in many countries; but it is being recognized that there are opportunities to expand the use of standards in the upstream stages of the lifecycle, e.g. at the design phase. Simple quality standards for the use of secondary materials should be prioritised, followed by more complex standards targeting resource efficiency in the design phase gradually over time. Where formal standards do not exist or maybe developed in the future, industry-wide benchmarks can play a similar role and industry associations, together with other stakeholders, can play a key role in developing and propagating their adoption.

Bureau of Indian Standards (BIS) has been the universally recognized and trusted professional standard setting organization with a wide range of standards for quality and performance of manufactured products. In recent years, BIS standards have been developed for recycled products that can be used to promote resource efficiency in the economy. Some of the most prominent examples include standards for use of fly ash in concrete (IS 3812) and bricks (IS 12894). In 2016, BIS also amended the IS 383 standard to allow for the use of recycled aggregates from construction and demolition waste in concrete production. The fly ash standards have been instrumental in promoting the use of fly ash; in 2014, 57.6% of fly ash produced in India was utilized. It is expected that the standard permitting use of recycled aggregates in concrete will have a similarly significant impact. It would also be helpful if the BIS codes are supported by preferential procurement of products made from secondary materials. For this, public tenders that include quotas for locally sourced materials or give bonus points for their use could be designed.

BIS standards can have an immediate impact on market acceptance of new resource efficient products. In addition to taking up standard development for resource efficiency on a priority basis, in coordination with stakeholders, BIS can consider ways to speed up the lengthy standard setting process. One option would be to look for standards developed internationally and adapt them to the Indian context that addresses local challenges. Another option, as seen in the recycled aggregates example, would be to amend existing standards rather than creating new ones, since this can be a much shorter and simpler process. Initially, simpler standards for the use of secondary materials may be prioritized, while more complex standards targeting resource efficiency in the design phase may be taken up gradually over time. Where formal standards do not exist or may be developed in the future, industry-wide benchmarks can play a similar role and industry associations, together with other stakeholders, can play a key role in developing and propagating their adoption.

In 2015, the Government of India launched the automotive industry standard for scientific dismantling and recycling of used vehicles that have reached the end of their life.[60] The Government can speed up the adoption of many Green technologies by using levers like PPP models (e.g. such a model is proposed for development electric and hybrid transportation), creating a dedicated Green Fund to invest in emerging technologies, setting up Green science parks which promote collaboration between businesses, research institutions and universities and providing fiscal incentives for the early adopters

Sectoral assessment for Aluminium has highlighted the need for quality control of recycled aluminium products and consequently the need for product standards for recycled Al to be strengthened and enhanced in consultation with the bulk consumers.

Standards are also needed for collection, logistics and treatment to form essential parts of the monitoring and enforcement frameworks of the Plastic and E –waste management rules.

National Housing and Habitat Policy, 2007 and the Pradhan Mantri Awas Yojana (PMAY), 2015 emphasizes on developing appropriate ecological design standards for building components, materials and construction methods encourage resource efficiency.

There is also a need to promote voluntary standards, like Green Reporting Initiative and ISO 14062:200212 to develop and strengthen design initiatives for improving RE and promoting use of SRM across sectors.

Environmental liability is another regulatory instrument that could be used to promote RE. This instrument makes the "polluter" pay for remediating the damage he has caused and is one of the forms of implementing the "polluter-pays" principle. The liability imposed creates a cost for causing harm, and provides a direct incentive not to pollute and to reduce corporate environmental risks (Comm.2000, GTZ 1995, von Seth/Ott 2000).

In context of resource efficiency, the instrument becomes important when trying to address gradual pollution caused by hazardous substances or waste coming into the environment from identifiable sources. In a joint-and-several liability scheme, producers of a certain product or product group agree to jointly accept the liabilities for waste collection and recycling for a specific product or product group.

[60] Draft Automotive Industry Standard for End-of-Life Vehicles. Automotive Research Association of India. Retrieved from: https://araiindia.com/hmr/Control/AIS/811201443718PM3_Draft_AIS-129_F4_Aug_2014_ELV.pdf

If we take the example of solar PV sector, solar PV manufacturer's legal liability for product end-of-life, combined with electrical and electronic equipment (EEE) dedicated collection, recovery and recycling targets, and minimum treatment requirements can help in end of life management of solar PV.

It is also important to develop more balanced compliance monitoring and compliance promotion programs, particularly for the SMEs

7.2.3 Information based instruments

Information-based instruments typically include communication and information campaigns, technical support schemes and eco-audits, training and education, or various eco-labels.

Eco-labelling, i.e. certification of the desirable environmental attribute or performance of a product or service, is a useful information based policy instrument that harnesses the buying power of conscious consumers, including public and institutional purchasers, to promote the acceptance and consumption, and hence the production, of greener products. Eco-labelling has been a widely used policy instrument in numerous countries for several decades, and its success was largely dependent on the degree of consumer consciousness and motivation. The pioneering German Blue Angel eco-label was introduced in 1977, which was followed by several countries introducing eco-labelling schemes in the following decades. Up to 544 eco-labelling schemes covering 197 countries were operating in 2012 (Gruere, 2013).

In 1991, India launched its own eco-labelling scheme called "EcoMark" which is unique because it considers both environmental and quality criteria; product quality has to be certified by the Bureau of Indian Standards (BIS) in addition to an environmental attribute certification. Criteria have been developed for 16 product categories, with the approved products being awarded the "earthen pot" EcoMark label (CPCB, 2016a). However, the EcoMark scheme has not become very popular even after over two decades with only a few dozen products being certified so far. Experts have cited several reasons for this lack of success including low public awareness and complicated certification process (Mehta, 2007). It is important that the scheme is rejuvenated with a reorganised structure comprising multiple stakeholders and should expand into new product categories, especially focusing on products that use secondary /recycled raw material/resources. The standard setting and criteria development should take into account international best practices, using life cycle assessment tools wherever applicable and using guidance from ISO standards. The certification process should be simplified and streamlined, possibly with the involvement of third-party accreditation agencies, to make it more appealing to manufacturers. Testing and certification capacities are often lacking for many environmental attributes, and these capabilities need to be built up all over the country before an eco-labelling scheme can be successful. A rejuvenated EcoMark scheme can focus on a few chosen categories initially for which the criteria, market, and testing facilities already exist and gradually expand into other categories. Further, in the Indian market, where public consciousness is relatively low, completely voluntary eco-labels like EcoMark are unlikely to be successful on their own without supportive policies such as public procurement mandates, at least in the initial stages

It is important to highlight here the successful example of the energy efficiency labelling for appliances by the Bureau of Energy Efficiency (BEE) , which has also been relatively successful. Launched in 2006, the scheme identifies appliance categories contributing to the highest energy consumption and sets minimum standards for their energy efficiency. The BEE energy label has seen widespread use and its impact has been further enhanced by public procurement programmes that mandate the purchase of efficient appliances. While BEE has continued to refine the programme over time, experts have called for a more participatory approach involving non-governmental experts to improve transparency, accountability, promotion and adoption, monitoring and evaluation, and capacity building (Jairaj et al., 2016). Instructively, eco-labelling schemes that have been successful to varying degrees in India have been supported by some sort of government mandate.

Green rating systems also are an example of information based instrument. One example in the Indian context is the GRIHA (Green Rating for Integrated Habitat Assessment) rating system for green buildings modelled after the internationally famous LEED (Leadership in Energy and Environmental Design) rating system. Since 2007, the GRIHA rating system has been adopted as the national rating system for green buildings by the Government of India. While GRIHA is a comprehensive and well reputed rating system that is being updated continually, its actual impact on the building market is limited only to a handful of eco-conscious developers. However, in recent years, its impact has improved somewhat with both central and state governments making GRIHA rating mandatory for all new government construction projects.

Consideration should be given to establishing a forum and network for resource efficiency and eco-innovation in India in order to share best practice. Further, co-operation between policymakers, statistical offices and research institutes responsible for producing resource efficiency indicators should be prioritised.

The European Union uses indicators for material use and material efficiency (resource productivity) for its resource efficiency roadmap, which is one of the building blocks of Europe's resource efficiency flagship initiative and part of the Europe 2020 strategy. EU Member countries report material flow data biannually to the European Statistical Office (Eurostat) which compiles Europe's material flow data and makes the data accessible through its website.

The resource panel of the United Nations has promoted the development of a global data base on raw material utilisation and issued a report on global utilisation (UNEP, 2016). It provides information on the DMC, physical trade balance and material intensity as well as raw material equivalents for a selection of countries. While the DMC indicators are based on the SEEA's harmonised methodology, raw material equivalents are calculated based on a multi-regional input-output model that distinguishes between 60 production groups and 40 countries or world regions.

The collection, interpretation and publication of statistical data and other information can be an important information based instrument for promoting RE.

Creating a data inventory by different Government Ministries and Departments could prove to be an important way to address the information gap for policy formulation. As a starting point, a data inventory template could be prepared which could be used by the Ministries and Departments to initiate the collection and reporting of RE relevant data and indicators to for measuring resource efficiency of the economy, sectors and materials depending on its priorities.

7.2.4 Public procurement

Governments and public authorities, apart from their role in policy, regulation, administration and monitoring, also exercise a significant leverage on the market as a large consumer of goods and services in an economy. Consequently, preferential public procurement can have a significant impact on market transformation towards desirable products and services. Preferential procurement by large organisations, public or private, can be used to bolster the market demand of goods and services deemed serving a desirable environmental and/or social goal. Preferential public procurement has been frequently used as a policy tool to promote various social objectives in different countries including supporting vulnerable small-scale industries, protecting human rights in the supply chain, improving energy efficiency, reducing environmental impact, etc.

The inclusion of environmental requirements in the procurement process is defined as Green Public Procurement (GPP). Specifically, GPP is 'the approach by which public authorities integrate environmental criteria into all stages of their procurement process, thus encouraging the spread of environmental technologies and the development of environmentally sound products, by seeking and choosing outcomes and solutions that have the least possible impact on the environment throughout their whole life cycle' (Michelsen and de Boer, 2009). GPP has been extensively used, especially in OECD countries, to support green production and bring about market transformation towards environmentally preferable products through large scale purchases.

In India, public procurement accounts for almost 30% of GDP, wielding substantial purchasing power to the government. It is governed by rules and instructions contained in the General Financial Rules and the Delegation of Financial Powers Rules (DFPR), apart from ministry/department specific purchase procedures for particular ministries and the

Directorate General of Supplies and Disposal (DGS&D). Some states like Karnataka, Kerala, Rajasthan and Tamil Nadu also have their own public procurement policies. Historically, preferential procurement in India has sought to achieve social goals such as protection of vulnerable industries (e.g., jute), or promotion of handicrafts from disadvantaged areas/communities, etc. (TERI, 2013).

The Indian Public Procurement Bill introduced in Parliament in 2012 seeks to regulate procurement by Ministries/Departments of the Central Government and its attached/subordinate offices, Central Public Sector Enterprises (CPSEs), autonomous and statutory bodies controlled by the Central Government and other procuring entities with the objectives of ensuring transparency, accountability and probity in the procurement process, fair and equitable treatment of bidders, promoting competition, enhancing efficiency and economy, safeguarding integrity in the procurement process and enhancing public confidence in public procurement. The bill, which did not become a law, was comprehensive in many respects, but did not specifically include GPP. Therefore, a single law governing public procurement at the central government level still does not exist.

Green purchasing is thus about influencing the market. By promoting and using GPP, public authorities can provide industry with real incentives for developing green materials, technologies and products. GPP is therefore a strong stimulus for eco-innovation. However, the possibility to use GPP as a pro-active policy tool for promoting innovative resource efficient products and services needs to be realized. Most of the times, the short term decisions are made to comply with procurement law and the criteria adopted for existing products and services on the market, while innovative product-service system solutions are not stimulated. It is therefore important to set objectives for both short and long term, which are defined, agreed upon and understood by the government.

The government has attempted to promote GPP through the EcoMark eco-labelling scheme; however, the market uptake was not satisfactory. Some public sector organisations such as the Indian Railways, Bharat Heavy Electricals Limited (BHEL), National Thermal Power Corporation (NTPC), and Indian Oil Corporation have engaged in GPP schemes independently with a major focus on energy conserving equipment (TERI, 2013). CII has launched a certification scheme called Green Products or GreenPro to promote products that are green. So far, more than 100 products (mainly related to construction) have been certified. The green criteria used however are not well defined, not easily verifiable and many times ambiguous.

In June 2017, the Government of India issued Public Procurement (Preference to Make in India), Order 2017 as part of its policy to encourage 'Make in India' and promote manufacturing and production of goods and services in India with a view to enhancing income and employment. Subject to the provisions of this Order and to any specific instructions issued by the Nodal Ministry or in pursuance of this Order, purchase preference shall be given to local suppliers in all procurements undertaken by procuring entities in the manner specified. As per the order the minimum local content shall ordinarily be 50%. The Nodal Ministry may prescribe a higher or lower %age in respect of any particular item and may also prescribe the manner of calculation of local content. The margin of purchase preference shall be 20%. Ministries /Departments and the Boards of Directors of Government companies may issue such clarifications and instructions as may be necessary for the removal of any difficulties arising in the implementation of this Order.

A comprehensive and well-designed national level SPP policy can be a key instrument to promote resource efficiency in the economy in addition to helping meet many other environmental goals. The RE Status paper by NitiAayog (2018) suggests that a national policy on SPP and its action plan should:

- Establish product standards (including refurbished and recycled goods) for priority products and services
- Introduce certification and labelling schemes that will cover low carbon considerations
- Introduce economic instruments (incentives and disincentives)
- Develop and launch pilot programs at PSUs like the Indian Railways and SMART cities
- Prepare training materials and toolkits for capacity building of procurement officers
- Develop and launch consumer awareness programs

However, it is important that we start with a small range of products first, for which the market is already reasonably well established, and then gradually expand as the policy matures. Further, experience from other countries shows that an independent entity should develop criteria and standards and oversee certification and eco-labelling of products (including refurbished and recycled products). In addition, a list of products and manufacturers of approved green products must be maintained by such an entity. This makes it simpler for each government agency to engage in green procurement without the need to undertake complex assessments with inadequate expertise.

The government could consider including provisions for preferential procurement of for Indian made, resource efficient products and eco-labelled products in public procurement through Green Procurement Policies. Mandatory targets for green procurement help to achieve the desired level of performance; these targets can be graduated and made more ambitious over time depending on the maturity of the program and the market for green products.

7.3 Other instruments

7.3.1 Creation of markets for recycled products

If the country has to meet its objective of turning waste into resources, it would certainly require the holistic transformation of the waste management sector into a secondary resource recovery sector, coupled with its integration with the manufacturing sector, which at the moment continues to rely heavily on virgin resources. There will also need to design an extended (regional, national or international) markets of recyclables. The design of a policy instrument that aims to increase recycling of a certain material should take into consideration whether there is a well-established and functional international recycling market in place or not.

So for materials where such a market exists, policy instruments should primarily focus on increasing the collection for recycling. The collected recyclables can then be assumed to substitute the demand of virgin materials in the market (regional, national or international) where the two commodities (virgin/recycled) compete.

However there is a significant risk of high search and transaction costs associated with recyclable materials in secondary markets, related to incomplete information (Nicolli et al. (2012)). Effective communication between users and suppliers of recycled materials may be lacking. There could also be a lack of information concerning the quality and properties of potentially recyclable or reusable materials and products, which can act as a barrier to the successful completion of a transaction between seller of recycled product and potential user of the same. Moreover, the provided information quite often is asymmetric, in the sense that the supplier holds a negotiating advantage by knowing more about the quality or properties of the material or product than the potential buyer does. In such cases, a broad range of policy instruments can be used in order to support the markets (Finnveden et al. (2013)). This would include establishment of harmonised quality standards for recycled materials and/or certification schemes, information provision on the content of materials in products, before these turn up as waste for recycling, and support for establishing information hubs or hiring middlemen who could act as waste brokers.

Direct inter-firm reuse of waste is the cornerstone of the phenomenon termed industrial symbiosis (IS), where a group of firms in relative geographic proximity cooperate on resource management issues. Support to industrial symbiosis networks by removing institutional barriers for increased recycling of industrial by-products and wastes will prove to be very helpful. For this, industrial parks and clusters[61] that can focus on economic

[61] National Manufacturing Policy of India (2011) had introduced the concept of National Investment and Manufacturing Zones (NIMZs) which are greenfield industrial townships. In addition, there are five industrial corridors under development including Delhi Mumbai Industrial Corridor (DMIC), Bengaluru Mumbai Economic Corridor (BMEC), Amritsar Kolkata Industrial Corridor (AKIC), etc. China has developed 94 Eco-Industrial Parks focused on minimizing waste generation and improving the overall eco-efficiency of the park by applying principles such as industrial symbiosis, clean production, green supply chain management and centralized pollution abatement. There is a need to set-up such Eco-Industrial Parks and Recycling Industrial

viability and profits but are also geared towards increasing resource symbiosis and closing the resource loop by enabling utilisation of waste of one sector or industry as secondary raw material in another. This is also likely to result in cost savings. In addition, there is a need to provide subsidized land and other support for setting up recycling units in all industrial areas near large towns and cities to prevent dangerous recycling in cities or in far-off isolated areas that limit access to waste as well as recovered materials.

Box 5: Naroda by-product exchange network – An example of eco-industrial development in India

The Naroda industrial estate houses approximately 700 companies in a 30 km2 region in Ahmedabad, Gujarat. In December 1998, research funded by the German Ministry for Education and Research surveyed 477 of the industries in Naroda to suggest potentially beneficial industrial symbiosis initiatives (Lowe, 2001). These included: (i) converting spent acid with high concentrations of H_2SO_4 to commercial grade $FeSO_4$, (ii) selling sun dried chemical gypsum to cement manufacturers, replacing the need for disposal, (iii) reducing the hazardous content of iron sludge produced by dye manufacturing industries, so that it could be used by brick manufacturers, in addition to reducing the amount of iron sludge being produced, and (iv) converting approximately 100 t per month of industrial food waste to biogas (vonHauff and Wilderer, 2000). More than a decade later, however, activities other than a common effluent treatment plant are still in the planning stages. A planned pilot project would create a 'waste exchange bank' to facilitate the future exchange of residuals across companies (Gopichandran, 2008; Express News Service, 2009). It is important that the activities planned should be pushed towards implementation to be able to realize the expected resource efficiency benefits.

7.3.2 Creation of RE Business models'

RE business models must lead to value creation or profit for enterprises so that more and more companies are motivated to get involved. While some business models may be viable based on market prices there could be a need for government support through direct subsidies, mandatory public procurement, public support for consultation, networking and dissemination of solutions as well as regulation to accelerate adoption of certain technologies and/or practices. Governments can provide support through hard measures like financial incentives, tax rebates, subsidy, and low interest rate loans or through soft measures including mandatory green public procurement, generating consumer pressure through awareness campaigns by the government, through rewards and recognitions for implementing desired measures related to RE or public support by information services and promotion of exchange of stakeholders. Also, provisions like Viability Gap Funding (VGF)

Parks in India as well. As a step towards it, pilot projects may be taken up where feasible in existing industrial parks that already promote some degree of collaboration between industries, for example, parks with Common Effluent Treatment Plants (CETPs).

can help businesses meet the high initial cost in their attempt to overcome the barriers and become competitive over time by building scale and upgradation of technology. Additionally, business models that are based on sharing services as opposed to owning resources can further aid the shift towards a RE economy.

Different types of RE business models exist:

- **RE products:** Sale of products that are resource efficient or help users achieve RE. For example, C&D waste aggregates replacing natural building materials. French start-up Eco2Distrib installs electronic vending machine to sell liquid products through dispenser leading to saving of packaging.
- **RE services:** Services like waste management, consulting for saving resources and payment per use model for products. For example car sharing, End of Life Vehicle management etc.
- **Cost reduction based business models:** RE measures leading to cost savings. For example: Bosch uses electrowinning process to recover copper from plating solution waste.
- **Customer value Creation Based Business Model:** Catering to environmentally conscious consumers. For example Dell produces new products using e-waste and is preferred by conscious consumers.
- **Quality Improvements and "First Mover" advantages** in terms of complying with new environmental regulations is also possible through implementing RE initiatives.

Barriers to RE business models include limited awareness or knowledge about available RE technologies and suppliers, lack of financial resources or limited return on investment compared to other investment opportunities, lack of government support in form of subsides, tax incentives, etc. and lastly lack of internal motivation. Policy can address this awareness gap by providing sectoral, even process-specific information and support to convince businesses that conscious resource management does not only reduce the burden on the environment, but that it can reduce cost of production by reducing material and energy costs and thus create competitive advantages for the company.

7.3.3 Integrating the informal sector with the formal sector

Informal sector makes a significant contribution to the overall economy and society by reducing the cost of waste management and recycling. They constitute nearly 1% of urban population and belong to the lowest social strata. With substantial increase in volume of waste across dispersed streams, a RE strategy should recognize their role and build upon the comparative advantages of the informal sector (in collection, segregation and dismantling) with an aim to mainstreaming and formalising it. Towards this end, the informal sector could be organised into cooperatives, jointly owned private enterprises to aid their access to technology and funding for improving their operations, ensuring safe working environment and health for the workers employed in the sector. This will enable them to participate formally in waste management related tenders while ensuring that benefits from SRM accrue to the workers resulting in increased earning potential. From a material recovery perspective, the loss of value and quality of metals and critical mineral resources due to inefficient and unskilled handling could be minimised. Quality metal scrap would be more in demand, especially as resources become more scarce, and this will enable them to fetch better prices and augment livelihood options. Other kinds of business models could also be developed that build on the positive aspects and overcome inefficiencies. For instance, the informal sector's expertise and ability in terms of collecting e-waste or other wastes directly from household and segregation can be supported through a web-platform which could be operated by a formal sector enterprise. Therefore, integration of informal sector towards efficient and quality raw material recovery should be made an important element for an Indian RE and SRM strategy.

7.3.4 Research and Development (R&D) and educational initiatives

R&D includes basic research, applied research and experimental development conducted by governmental departments, universities, research institutes, private companies, and non-governmental research bodies, in many cases forming the first stage of the development and application of new technologies and organisational innovations (SciDev.net, 2006).

R&D support should be oriented towards producing resource efficient solutions and the development of resource-efficient products and services. R&D to improve process efficiency and for introducing new processes that generate less waste is extremely important. For example, as R&D and technological advances continue with a maturing solar industry, the composition of panels is expected to require less raw material. Currently two-thirds of globally manufactured PV panels are crystalline silicon (c-Si), which are typically composed of more than 90% glass, polymer and aluminium, which are classified as non-hazardous waste. However, the same panels also include hazardous materials such as silver, tin and lead traces. Thin-film panels, by comparison, are over 98% non-hazardous glass, polymer and aluminium, combined with around 2% copper and zinc (potentially hazardous) and semiconductor or other hazardous materials including indium, gallium, selenium, cadmium, tellurium and lead. Hazardous materials are typically subject to rigorous treatment requirements with specific classifications depending on the jurisdiction. By 2030, given current trends in R&D and panel efficiency, the raw material inputs for c-Si and thin film technologies could be reduced significantly. This would decrease the use of hazardous and rare materials in the production process and consequently improve the recyclability and resource recovery potential of end-of-life panels.

The Department of Science and Technology, Ministry of Science and Technology, Government of India is promoting R&D related to waste management and there is a need to further enhance funding specifically for RE and Secondary Raw Materials (SRM) related R&D. The Technology Development and Transfer Division (TDT) of the Department of

Science and Technology, Ministry of Science and Technology supports research and development (R&D) and market development for 19 Waste Management Technologies. It is possible to extend similar programs for sectoral RE related R&D with additional funding to TDT division (Ministry of Science and Technology, 2016).

In context of waste, R&D is also important to develop sound methodologies to carry out the inventorization and characterization of major waste streams.

A lot of research is taking place in India and worldwide concentrating on substitutes in the cement industry and energy efficient production. This research needs further support in the future and identified RE innovations need a favoured access into the market.

Infrastructure support to carry out R&D activities then becomes crucial. For this support could be provided in different forms including land for R&D centres, financial support to buy technologies that enable R&D and setting up of knowledge platforms for sharing knowledge. In 2011, NATRiP facility, which is an automotive dismantling centre - Global Auto Research Centre (GARC), under the National Automotive Testing and R&D Infrastructure Project (NATRiP) at Oragadam, near Chennai was set up by the Ministry of Heavy Industries (MoHI) , Government of India and Society of Indian Automobile Manufacturers (SIAM). This centre is expected to engage in scientific dismantling and improve resource recovery, management of hazardous waste and encouraging use of secondary raw materials by the OEMs.

Education about RE technologies and solutions can play an important role in bringing about the needed behavioural change. Through education, people can become much more aware than at present of the fundamental role of the environment and its resources in underpinning economic activity and human welfare. Industrial training networks should be supported where appropriate in order to deliver the required courses and skill sets needed for a resource efficient and low-carbon economy.

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