REFERENCE REPORT FOR "NATIONAL **RESOURCE EFFICIENCY** POLICY" FOR INDIA

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

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The sectoral analysis in this report draws heavily upon inputs from the Indian Resource Efficiency Programme, developed by the Indian Resource Panel (InRP) in 2017, and assessments that have been undertaken through the EU-REI for the sectors on automobiles, solar PVs, electronics, and plastics during 2017–18. The assessments on electronics and plastics have been undertaken by adelphi, while sectoral assessments on automobiles and solar PVs have been undertaken by TERI. Sectoral inputs have also been taken from the status papers on achieving resource efficiency across four sectors – steel, aluminium, e-waste and construction and demolition which were commissioned in 2018 by the NITI Aayog in association with Ministry of Mines (and in particular Jawaharlal Nehru Aluminium Research Development and Design Centre), Ministry of Steel, Ministry of Housing and Urban Development and Ministry of Information Technology.

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Foreword

The focus of developmental policies in India has largely been on fostering economic growth with a special emphasis on poverty eradication. However, over the last two decades, it has also become amply clear that growing constraints in availability of land, energy, biomass and other natural resources, as well as environmental degradation pose grave threats to the achievement of this goal. It is also been clear that there are physical and financial limits which constrain the import of some of these resources. However, on the other hand, the demand for these resources could continue to increase exponentially with the current paradigm of resource-led economic development. Consequently, it is essential that resource efficiency, together with a circular economy, which promotes reuse, recycling and mining of wastes, are embedded in our development paradigm.

This is not as difficult as it seems. Over the past fifteen years or so, the country has effectively enhanced energy-use efficiency, both by adopting increasingly energy efficient products, such as air conditioners and LED bulbs, but also by utilizing waste energy, especially through heat recovery processes. This experience has taught us that with government – led policies, the private sector, consumers, and corporations, can bend the resource-use curve downwards.

Resource efficiency directly contributes to mitigation of climate change targets, and in most cases without having medium or long term effects. Besides the global and national benefits, resource efficiency also delivers strong consumer benefits- monetary as well as cultural.

We believe that it is now time to address resource efficiency for metals and minerals and existing and new policy instruments is orchestrated within a comprehensive policy framework in order to infuse signals and incentives that promote material resource efficiency. The framework should also have a built in system for monitoring and review and where necessary, revision.

This reference report outlines the broad contours of the need for resource efficiency, as well as suggestions for promoting resource efficiency for India. The report draws on a vast corpus of work which has focussed on the need and scope of resource use efficiency in various sectors and the policies and practices that can promote resource efficiency in the economy. It was therefore prepared with extensive consultation including the members of the Resource Efficiency Cell at the Ministry of Environment, Forests and Climate Change, Government of India and other government departments and relevant ministries to seek their inputs and suggestions. Subject and sectoral experts, stakeholder groups including those representing important hotspot sectors, have also shared their feedback on the draft report which has been incorporated in the final version.

I hope that this report helps us move forward to a strong data-based national debate on resource efficiency and to the formulation of a National Resource Efficiency Policy.

Dr Ajay Mathur
Director General,TERI

Executive Summary

Enhancing resource efficiency (RE) and promoting the use of secondary raw materials have 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, which in turn translates into reduced price spikes due to supply constraints or disruptions resulting in substantial economic benefits. These include reduced costs linked to less extraction of virgin raw material, if secondary raw material is made available, and there is improved corporate performance and competitiveness. New industries can be created including those in the recycling sector as well as through innovative design and manufacturing.

In terms of social benefits, reduced extraction pressures due to adoption of resource efficient strategies have the potential to reduce conflict and displacement in mining areas along with improving health and welfare of local communities. Resource efficiency has enormous potential for job creation, not only in the recycling sectors, but also high skilled jobs in innovative design and manufacturing. The resource efficient strategies also contribute towards preserving resources for future generations.

Resource efficiency measures will lead to better management of waste, creating cleaner cities and rivers. There is direct and indirect positive impact on energy conservation and efficiency. Use of resource efficient technologies and processes can help reduce the overall footprint of consumption and production, and mitigate negative side effects on society.

The Sustainable Development Goals (SDGs) also recognize the potential of resource efficiency in resolving the short-term trade-offs between growth and environmental sustainability and mentions resource efficiency in several places. The SDG 12 which is on ensuring sustainable consumption and production patterns reflects resource efficiency specifically in terms of substantially reducing waste generation through prevention, reduction, recycling, and reuse. Seven other goals (Goals 3, 4, 8, 9, 11, 12 and 17) also directly refer to resource efficiency or sustainable use of resources. Action to implement SDGs will necessarily be at national and sub-national levels and there needs to be a comprehensive integration of resource concerns in policy, planning and implementation. Resource efficiency has also been one of the important discussion points in G20 Agenda, whereby G20 countries are integrating circular economy as part of their implementation strategies for SDGs. India is a signatory to the Global Development Agenda -2030 of the United Nations (UN).

In 2015, the Government of India set up the India Resource Panel (InRP) to mainstream resource efficiency in policy formulation and foster its spread. The objective of the panel was to advise the government and relevant stakeholders on the potential for enhancing resource efficiency and the productive use of secondary raw materials. Additionally, to further emphasize on the importance of RE, the panel urged the topic to be added in the government's 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 large scale only through enabling policy framework. In June 2018, the InRP was reconstituted as an Advisory Committee to the newly established RE Cell at the Ministry of Environment Forest and Climate Change (MoEF&CC). One of the key tasks that the RE Cell has been assigned is developing an integrated national resource efficiency policy framework for India, based on the existing work / output of the InRP and sectoral assessments undertaken by Niti Aayog and the EU-REI project.

This Reference document presents the background and structure for drafting India's national RE policy. The document compiles the various sectoral assessments that have been undertaken along with providing an understanding of the changing resource landscape in India, the need for RE, and the possible indicators for measurement. The sectoral assessments focus on the economic relevance of the sectors, current resource consumption in these sectors, followed by identification of resource efficiency opportunities and the possible strategies to tap these opportunities to enhance resource efficiency in the sectors. The reference document clearly recognizes that 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. Finally, the document also presents a discussion on the elements that should constitute this policy framework for India and the various action areas that need to be taken up for fostering resource efficiency in the country.

Chapter 1 looks at the changing resource landscape in India, highlighting the current and future material demand and sustainability consequences related to this demand. Rapid urbanization in recent decades, doubling of per capita income, and the rising middle class population has led to increased resource consumption. Though the per capita consumption of resources in India is low compared to the global average, India is the second largest material consumer in the world (at nearly 7.4 billion tonnes) and there is substantial growth anticipated in the future. The key challenge will be to make materials available in a manner that takes into consideration exhaustible nature of these resources and 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 for helping conserve resources and recycle raw materials to meet India's future demand, while at the same time reduce costs, thus strengthening the competitiveness of industries.

Mining leads to huge loss of forest cover, generates pressure on the water table, destroys biodiversity, damages the natural ecosystem, causes land degradation due to topsoil erosion, forms sinkholes and induces land subsidence; further, there is increase in emissions. Iron and steel had the largest share of emissions at 38 per cent, followed by non-metallic minerals (predominantly, cement) with a share of 29 per cent in the overall industrial emissions.

Mining operations also leads to displacement of millions, including many indigenous communities inhabiting the area, loss of livelihoods and adverse health implications.

In line with the developmental imperatives, the focus of India's developmental policies 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 become amply clear that the environmental aspects should be mainstreamed into development policy to have sustainable development in the long run. **Chapter 2** describes the principles and objectives that should be considered for formulating the resource efficiency policy in India. The specific objectives of the policy include generating savings in primary / virgin raw material, substituting its use with secondary / recycled raw materials, identifying hotspot sectors for design interventions, capacity building, and strengthening research and information systems and creating an institutional mechanism to achieve these objectives as well as coordinate and synergize across sectors and tiers of government. To meet these objectives, the principles for resource efficiency policy should include promoting economic growth that is sustainable and equitable (inter- and intra- generational), reducing primary resource consumption to 'sustainable' levels in keeping with achieving the Sustainable Development Goals and staying within the planetary boundaries, creating higher value with less material through resource efficient and circular approaches, minimizing waste creation and loss of embedded resources at the end of life of products and ensuring security of supply and reducing import dependence for essential materials.

Chapter 3 presents a discussion on measuring resource efficiency. UNEP (2009) defines resource efficiency as reducing total environmental impact of the production and consumption of goods and services, from raw material extraction to final use and disposal. The European Union defines resource efficiency as a means of using the earth's limited resources in a sustainable manner while minimizing impacts on the environment. It allows us to create more with less and to deliver greater value with less input. The aspect of resource efficiency can be assessed either using an output-to-input relationship or input-to-output relationship, though the former is used more extensively. While material productivity can be assessed at the final output level, however, such assessment can be undertaken at different stages of the value chain. At times, assessments are undertaken in industries but that is more confined to internal benchmarking purposes. In terms of indicators, these may be consumption-based indicators, e.g. 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, e.g. Material Productivity (GDP / DMC), Domestic Material Intensity (DMI), Raw Material Productivity (GDP/ abiotic DMI), Energy Productivity (GDP / total primary energy use); Recycling-based indicators, e.g. share of recycled raw materials used by industry, general waste-related indicators (e.g. municipal solid waste generated / treated). Specific indicators may also be designed.

Choice of the indicator will also depend on the availability of data to measure the same, and assumptions may have to be made (at least in the initial years) on estimating these. It is suggested that to move towards a more comprehensive data collection beginning should be with an inventory of waste that is generated along the value chain in major sectors / products if not for the entire economy be created 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.

Chapter 4 presents an overview of the resource efficiency policy frameworks existing across the world. The overview found out that five countries in Europe – 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 presented in 2019. Belgium and United Kingdom too 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. Resource efficiency strategy of USA is also reviewed along with resource efficiency policy for Asia-Pacific region – China, Japan, and South Korea. The international review suggested that countries focus on different priority materials, sectors, and consumption categories; and their targets and milestones are set which are evaluated on the basis of certain indicators. Different types of strategies and policies backed by institutional setup and supported by policy instruments help in the implementation of the resource efficiency policy. The monitoring of the targets is proposed at regular intervals. Resource efficiency strategy or policy sets the vision and scope outlining the main purpose of such a strategy. The overarching vision of such a resource efficiency 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 although it may vary from covering increase in energy, water or land productivity, to reduced impacts on environment. Priority sectors typically include food, construction, waste, packaging, and transport.

Chapter 5 presents a detailed assessment of resource use efficiency potential in India for selected priority sectors and materials in India. Covering 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 hotspot sectors and their assessment is possibly a better way to initiate the task and explore the efficacy of the existing resource efficiency aspects in selected sectors. These sectors included automotive (including electric mobility), construction, electronics and plastics (including post-consumer usage), steel and aluminium, and solar PV.

The automotive sector is extremely important, considering that mobility is intrinsic to human existence. Total material demand in the sector is expected to increase from 14 million tonnes to 100 million tonnes during 2015–2030. Specifically, the estimated demand for iron and steel in 2030 is 80 million tonnes, aluminium is 11 million tonnes, plastics and composites is 8.3 million tonnes, copper is 1.6 million tonnes, and zinc and nickel is 0.6 million tonnes. There is significant potential for improving resource efficiency in the sector through greater recovery of secondary materials from end-of-life vehicles (ELVs) (target based / materials based), promotion of auto cluster based recycling, improved design to incorporate sustainable materials, training and capacity development (particularly for tier 3 or 4 manufacturers and informal sector) and implementation of extended producer responsibility (EPR). The electric vehicles (EVs) particularly present many more opportunities for resource efficiency. These include battery recycling and efficient powertrain integration. Many critical materials that are used in manufacturing EVs are mostly imported by India. Also 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 lightweighting materials are also used that include aluminium, plastics, synthetics, and rubber among other materials; and there is significant potential to recover these. Targets could be set on automobile companies to increase use of recycled materials (say to 25 per cent of the kerb weight by 2030) and on dismantlers for percentage recovery of materials in relation to the body weight of the vehicle, resulting in higher recovery of secondary raw materials.

The sectoral analysis on the plastic packaging shows that the sector is the largest consumer of polymers in the country and economically, plastic packaging is particularly important for the segment of Fast Moving Consumer Good (FMCG). Total consumption of plastics in India amounts to some 14.5 million tonnes every year with a wide range of single-use applications (e.g. packaging films, carry bags). With the introduction of the new Plastic Waste Management Rules in India, EPR has become a central tool within the Indian waste policy landscape. However, various implementation challenges remain which can hamper the effectiveness of EPR in India. 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. To support the implementation of EPR in the plastic (packaging) sector, governmental authorities may consider mandating stepwise 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. Further, uptake of innovative and resource efficient processing technologies and inclusive business models which integrate the informal sector, and exploring mechanisms which promote the introduction of certification schemes in the field of circular economy and resource efficiency for high priority packaging products can be helpful. It is suggested to set targets for recycling on producers of packaged materials and producers of plastics. India has a current estimated average recycling rate of 60 per cent for Polyethylene Terephthalate (PET), which could be increased to 100 per cent. Further, it has been s proposed that recyclable waste be banned from landfills by 2035 (that would include plastics, metals, glass, paper, cardboard, and biodegradable waste).

India's construction sector is projected to grow at a rate of 7 – 8 per cent 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 per cent of buildings supposed to exist by 2030 are yet to be built. Realizing this 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). Focus should be on increasing the use of more sustainable resources as building materials, such as the locally sourced resources and vernacular architecture concepts along with using demolition waste and recycled products as building materials. Codes and standards should be formulated to ensure products meet quality standards and that will develop user confidence in the product. BIS codes should be supported by preferential procurement of products made from secondary materials. Public tenders that include quotas for locally sourced materials or bonus points for their use could be floated. There should be greater use of indicator frameworks and green rating schemes that enable comparability between building concepts with regards to their environmental impact. In terms of targets, it is proposed that municipalities in Tier 1 and Tier 2 cities start inventorizing construction and demolition (C&D) waste data by 2022 and rate of recycling for C&D waste reaches 50 per cent by 2025 and 75 per cent by 2030. There could also be a target of 30 per cent for the public procurement of materials from recycled materials for civil construction by 2025.

The productivity of human beings has increased manifold from being able to communicate using electrical and electronic equipment (EEE) to mechanization of daily chores. This has led to increase in material use for EEE production. By 2020, the demand of electronic products in India is expected to reach nearly $400 billion with a compound annual growth rate (CAGR) of 41 per cent during 2016–2020. Domestic production is expected to grow at CAGR of 27 per cent to reach $104 billion if the Government of India (GOI) thrusts manufacturing through its Make in India initiative and Digital India missions. With 95 per cent of the e-waste being handled by the informal sector, it becomes extremely important to integrate them with the formal set up for managing e-waste. Policy interventions, through which technology is made available, will have the benefit of formalizing the informal sector and enhancing 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. Benchmarking of the technologies which are in use in the informal sector as well as the best available technologies show the huge gap which exists when it comes to recycling complex materials embedded in e-waste. Further, with the end-of-life electronics falling mostly in the category which is environmentally polluting, it is important that the work is done in industrial clusters so that effluents can be properly managed and environmental risks can be mitigated. A monitoring mechanism in such clusters can be setup as that will help to mitigate human health risks. There can be two possible ways to setup industrial clusters co-locating the e-waste management industrial cluster in a manufacturing cluster, and locating e-waste management cluster in hubs where the informal actors have been working. As regards targets for the EEE sector, while MoEF&CC has identified targets for e-waste collection, it is important there is penal mechanism built in the existing system soon (by 2020) to punish those not meeting the targets.

Since independence, India's steel industry has played a very important role in achieving the country's infrastructure growth and economic development. The steel sector shows a consumption level that is likely to grow by an average of 6.3 per cent and reach 140 metric tonnes by 2023. This will lead to an increase in per capita consumption of steel from 65 kg in 2017 to approximately 97 kg by 2023 and finally around 160 kg by 2030. India has emerged as the third largest steel producer and may soon become the second largest producer surpassing Japan. Steel industry is estimated to contribute nearly 2 per cent to India's income and provide employment to 25 lakh people, directly or indirectly. The stainless steel industry is a very niche subsector that 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 of steel for key sectors, particularly automobile, electrical, aviation, engineering, and machineries resulting in substantial imports in recent years.

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 Arc Furnace (EAF) route of steelmaking use scrap as key raw materials. A gradual shift is being witnessed in steel production from BF route to EAF route. As a result, the projected trend of domestic demand of steel scrap till 2030 is likely to increase between 4–6 per cent whereas the availability may grow between 6–8 per cent, thus reducing import. 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 and its other waste or by-products formed during production of steel, known as slag or flue gases can be used in several applications. Achieving full potential of resource efficiency with respect to steel scrap processing and by-products development based on slag in India would require significant innovative efforts ranging from the adoption of 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, logistics, etc. Further, India should increase its efforts to end import of steel scrap (by 2030) and meet all its requirement of steel from domestic scrap. Quality index-based pricing mechanism should be introduced to facilitate continuous and smooth scrap supply to recyclers by 2022 and standards for scrap can be established by independent agencies that can assess and certify scrap and link it to the indexed price.

After steel, aluminium is the second most used metal in the world with an annual consumption of 88 million tonnes (including scrap). Aluminium consumption in India at 2.5 kg/capita is much below the global average of 11 kg/ capita. To reach the global average of 11 kg/capita, India will require an additional annual consumption of 16 million tonnes, thus making it the second largest consumer in the world (absolute terms). 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. Compared with the production of primary aluminium, recycling of aluminium products needs as little as 5 per cent of the energy and emits only 5 per cent of the greenhouse gas. 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. 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. Currently, there is no proper scrap collection, segregation, treatment, etc. facilities. The government may consider zonal scrap collection / segregation / treatment facilities. Also recycling zones may be developed to address issues including transportation, pollution control, etc. A serious concern has been raised regarding quality of products manufactured through secondary route (recycled route); and in order to address this concern, product standards for recycled aluminium needs to be strengthened and enhanced, in consultation with the bulk consumers. By 2030, India should aim to generate 50 per cent of the total aluminium scrap domestically; and for this the targeted recycling rate to be achieved could be set at 80 per cent by 2025 and 90 per cent by 2030.

Renewables, particularly wind and solar, have been given tremendous thrust by the Government of India 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 megawatt of solar power by 2022, and revision in this target was made to 100,000 megawatt, of which 60000 megawatt has to be grid connected and 40000 megawatt has to be rooftop solar. This will require supply and use of newer materials for manufacturing different solar PV technologies while maintaining cost competitiveness in the sector and resource efficiency will be the 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 2047[3]. 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.

The PV sector 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. Cutting and wafering of silicon ingots, based on diamond and kerf loss, reducing / avoiding use of certain chemicals and metals such as silver, hydrogen fluoride, lead, etc. and increased use of less pure and / or recycled chemicals, designing of modules that are easy to dismantle and repaired; replacing aluminium frames with frameless modules, etc. encouraging manufacturers of solar PV systems to use recycled raw material; and setting up a proper solar panel recycling infrastructure can be important steps in this direction. In terms of targets for the sector, at least four major authorized dismantling facilities could be established by 2025 and the target could be increased to eight by 2030. There should also be a target on recovery of materials from discarded PVs (in a phased manner towards 85 per cent).

Chapter 6 presents the analysis of policies existing in India along the life cycle stages. 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 life cycle stages so that resource efficiency gains at one stage are not lost due to inefficiencies at other stages. The existing policies and programs of the government have already included several aspects related to resource efficiency and secondary resource management (RE & SRM) with ample opportunities and options to include additional RE & SRM measures.

In **Chapter 7**, discussion is brought about on the possible policy instruments that could be used to foster resource efficiency across life cycle stages and for different sectors and materials. Economic / market based instruments, such as taxes and subsidies, fees and user charges, environmental financing and certificate trading could be used. India is already using some of these instruments, such as the Deposit refund system (for recycling) for lead acid batteries in Delhi and NCR, and Technology Acquisition and Development Fund

(TADF) under the National Manufacturing Policy Standards in India, is being implemented by the Department of Industrial Policy & Promotion (DIPP) which is helping Micro, Small & Medium Enterprises (MSMEs) to acquire clean and green technology at affordable cost across their sector. The second type of instruments includes the regulatory instruments, such as norms and standards, environmental liability, and environmental control and enforcement. The 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). National Housing and Habitat Policy, 2007 and the Pradhan Mantri Awas Yojana (PMAY), 2015 emphasize on developing appropriate ecological design standards for building components, materials, and construction methods to encourage resource efficiency. Information-based instruments typically include communication and information campaigns, technical support schemes and eco-audits, training and education, or various eco-labels. Existing examples of these instruments are the EcoMark scheme and the GRIHA rating for green buildings.

Public Procurement is another instrument that can be widely used for promoting resource efficiency in the country by transforming the market towards desirable products and services. In India, where public procurement accounts for almost 30 per cent of GDP, wielding substantial purchasing power to the government. The government has attempted to promote green public procurement through the EcoMark eco-labelling scheme; however, the market uptake was not satisfactory. The government could consider including provisions for preferential procurement of India 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. Circular procurement through take-back options and third-party arrangements could be made and public tenders could include resource efficiency related quotas and bonus points.

Besides the use of different policy instruments, certain action areas also need to be emphasized to foster resource efficiency in the country.

Business models should be created that are based on different aspects of resource efficiency. These may require support initially through viability gap funding, mandatory public procurement, networking and dissemination of solutions in tandem with regulation to accelerate adoption of certain technologies and / or practices. However, with time the economics of the model would make them sustainable.

Resource efficiency strategy should recognize the role of the informal sector in waste management and build upon their comparative advantages (in collection, segregation, and dismantling) with an aim to mainstreaming and formalizing it. They could be organized 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. 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 minimized by empowering the informal sector through dissemination of low-cost technology and capacity development.

Different kinds of business models could also be developed that build on the positive aspects of the ways of operation of the informal sector and overcome the existing inefficiencies of the waste management system. For instance, the expertise of the informal sector 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, creating another channel for informal-formal integration.

The R & D support should be oriented towards producing resource efficient solutions and the development of resource-efficient products and services. There should be R&D to improve process efficiency and introduction of new processes that can reduce the material inputs and / or generate less waste which is extremely important. R&D to develop innovative technologies to substitute critical raw materials in key industrial sectors, such as automotive, renewables, and construction is needed. The scarcity of critical raw materials, together with their economic importance, makes it necessary to explore new avenues towards substitution in order to reduce the consumption of natural resources and decrease the relative dependence upon imports. 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 resource efficiency related innovations need a favoured access into the market.

There is a need for standardized use of terms, collection of information using standardized methods and indicators in order to facilitate aggregation of raw material consumption and estimate the availability of secondary raw material. It is recommended that standards are developed for the use of the main terms as well as data categories and methods for data collection. In this context, dynamic forecasting models that are currently under development can be made use of and these will permit targeted analysis and assessment of volumes and types of waste and the percentage available as a source of secondary raw materials that can help substitute away the virgin raw material in the future. The sources of waste and the condition in which it is available will determine how to exploit the resource potential embedded in the waste and how to establish high quality recycling and recovery pathways.

A robust awareness generation campaign and marketing strategy (along with labels and standards) is required by involving the consumer bodies, government, and these campaigns towards knowledge dissemination by showcasing benefits that directly and indirectly accrue to consumers as a result of lower environmental impact of the resource efficient products. These should be done across different media platforms, like television, radio, newspaper, internet and social media.

Lastly, but most importantly, in order to ensure wider adoption and enforcement of resource efficiency policy in India in a coordinated, integrated and harmonized manner, there is a need for an overarching authority with relevant legal, administrative, and financial powers. Section 3.3 of the Environment Protection Act refers that 'The Central Government may, if it considers it necessary or expedient so to do for the purposes of this Act, by order, published in the Official Gazette, constitute an authority or authorities by such name or names …' The allocation of business rules mandates the establishment of any such authority such as a Central Resource Efficiency Authority (CREA) under the MoEF&CC. It is proposed to create such an authority with clearly defined functions and an implementation plan. Key functions of such an authority would include establishing targets for resource efficiency, setting standards and guidelines for resource efficient products (jointly with BIS), facilitating public procurement of resource efficient products , providing certifications to resource efficient products and services, maintaining database of resource use across various sectors and life cycle stages of products and materials and serving as a storehouse of best practices and business models and supporting line ministries to develop and implement their sectoral plans. The authority would support collaborations between different stakeholders including think tanks, industry associations and chambers, for promoting resource efficiency projects with a focus on enabling their replication and upscaling and engage in capacity development, besides overseeing, administering and reviewing the implementation of resource efficiency policy that is formulated for India.

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 has resulted in a rise in overall demand for various goods and services. This along with increasing 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 of 2005 levels by 2025. Urbanization is expected to rise to 50 per cent from its current level of 34 per cent by 2025[1] and the share of youth is expected to reach 35 per cent by 2020 from its share of 20 per cent estimated in 2011.

This changing demographics has led to rapid increase in demand for consumer durables. The penetration of refrigerators in the country has approximately doubled over the past decade to reach 30 per cent in 2015–16. Further, the share of households owning a television has increased 20 per cent to reach 66 per cent, while 20 per cent of households own an air conditioner or cooler. Construction, infrastructure, transport, and electrical and electronics equipment (EEE)[2] sectors is expected to experience phenomenal growth. Demand for personal mobility is expected to triple by 2030 which eventually can make India the third largest market in the world after China and US. India's construction sector is projected to grow at a rate of 7–8 per cent over the next 10 years and likely to become the world's third largest by the middle of the next decade. The Indian EEE industry is forecasted to expand considerably during the next years with local production growing at more than 16 per cent CAGR between 2012 and 2020.

Meeting the demand for products and services require an adequate availability and affordable supply of natural resources and this can lead to resource use pressures and result in environmental degradation, thereby raising sustainability concerns. There is a near consensus – amongst scientists, policymakers, and practitioners – that the only possibility for sustainable prosperity in the long run is creating no trade-offs between economic growth and environmental sustainability, which may be a huge challenge due to conflicting priorities.

Enhancing resource efficiency (RE) and promoting the use of secondary raw materials has emerged as a strategy for ensuring that the potential trade-off between growth and

[1] Details available at www.bcg.com/publications/2017/marketing-sales-globalization-new-indian-changing-consumer.aspx, last accessed on 9 April 2019

[2] 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 per cent of the market share

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 (SDGs) 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 to Box 1. 1).

Further, the action to implement SDGs is happening at national and sub-national levels, but there is a need for comprehensive integration of resource concerns in policy, planning, and implementation.

Box 1.1: Provisions related to resource efficiency in SDGs

The 2030 Agenda for sustainable development comprises 17 SDGs. The sustainable consumption and production (SCP) agenda, with clear links to resource efficiency, is captured by Goal 12. SDG 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: 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. Given below is 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, amongst the pioneers are countries in the European Union (like Germany, Austria, Denmark, France, etc.), and other countries like Japan and China. The European Union, for instance, has adopted a circular economy package in 2015 and China adopted a Circular Economy Promotion 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 (GoI) had earlier set up the India Resource Panel (InRP) in 2015. The objective of the panel was to advise the government 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 its 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 a large scale only through enabling policy framework. In June 2018, the Indian Resource Panel was reconstituted as an Advisory Committee to the newly established RE Cell at the Ministry of Environment, Forests and Climate Change (MoEF&CC). One of the key tasks that the RE Cell has been assigned is developing an integrated national RE policy framework for India, based on the existing work/output of the

InRP and sectoral assessments undertaken by Niti Aayog and the EU-REI project. The policy framework will also suggest the institutional mechanism that will facilitate, monitor, and review the implementation of this framework.

This report presents the background and structure for developing India's RE policy framework.

1.2 Past and current trends of material use in India

India consumes about 7.2 per cent of globally extracted raw materials in a year but supports 17 per cent of the global population. The resource extraction per unit area is one of the highest in the world (1579 tonnes/acre) compared to the global average of 454 tonnes/acre. Material consumption in India has increased from 1.18 billion tonnes in 1970 to more than 7 billion tonnes in 2017. The compound annual growth rate (CAGR) in domestic material consumption has increased at a modest rate of 3 per cent between 1970 and 2000. However, since the beginning of this millennium the estimated CAGR has nearly doubled, making India the second largest consumer of materials (at 7.42 billion tonnes) after China (35.19 billion tonnes). The trend in material consumption is presented in Figure 1.1.

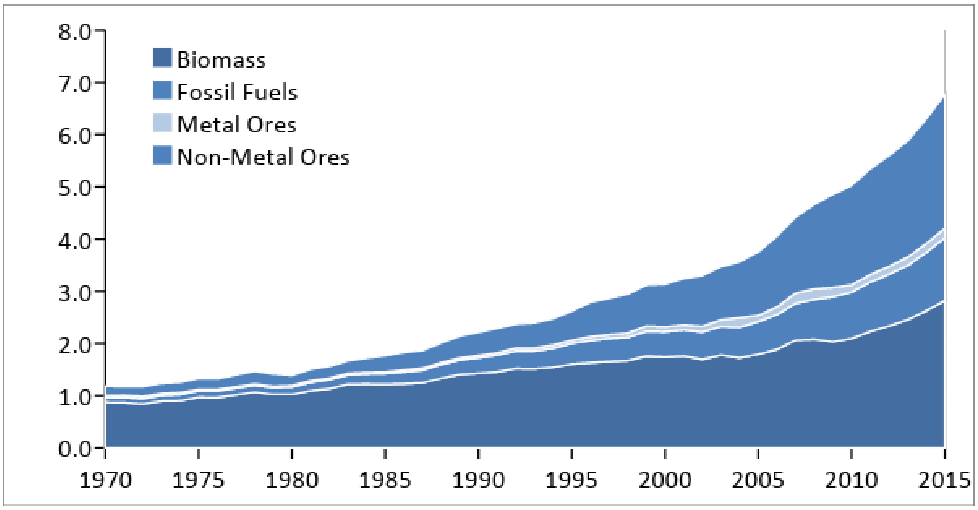

Figure 1.1: India's trend in material consumption (Billion tonnes)

Source: Details available at www.materialflows.net/visualisation-centre/, last accessed on 9 April 2019

Despite high aggregate consumption levels, per capita consumption in India remains lower than the world average although it has increased from 2.1 tonnes/capita in 1970 to 5.67 tonnes/capita in 2017 – less than half the world average (12.44 tonnes) and can increase with income and aspiration . India's material productivity is lower than the global average. India's resource productivity during 1970 and 2015 may have improved, however it has been less than the rates achieved by Japan (301) and China (311) (Table 1.1).

Table 1.1: Material consumption and productivity in selected countries

	China	Germany	India	Japan	United States of America	World
Total material consumption (billion tonnes)	35.19	1.21	7.42	1.14	6.58	91.88
Per capita consumption (tonnes/capita)	25.19	14.75	5.67	8.92	20.58	12.44
Material productivity (percentage improvement between 1970 and 2015)	311	287	256	301	276	115

Source: Details available at http://www.materialflows.net/visualisation-centre/, last accessed on 9 April 2019

Less productive utilization of resources has consequences in increased demand for virgin resources, high environmental burden, increased costs of production, etc. India's average material cost in total production cost is estimated at more than 70 per cent vis-à-vis 40–50 per cent in developed economies (EU-NITI, 2017). The rate of recycling in India is also low (20–25 per cent) when compared to other major economies like Japan, China and Germany. . Further, the current process of augmenting secondary materials in production chains is highly inefficient, largely because they are handled by the informal sector. Limited technology know-how and access to finance and technology are factors that impede in improving productivity in the informal sector.

1.3 India's future trends and trajectories on material demand

Under the assumption of continued economic growth of 8 per cent till 2030 and possible slowing down to 5 per cent 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 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 1.2.

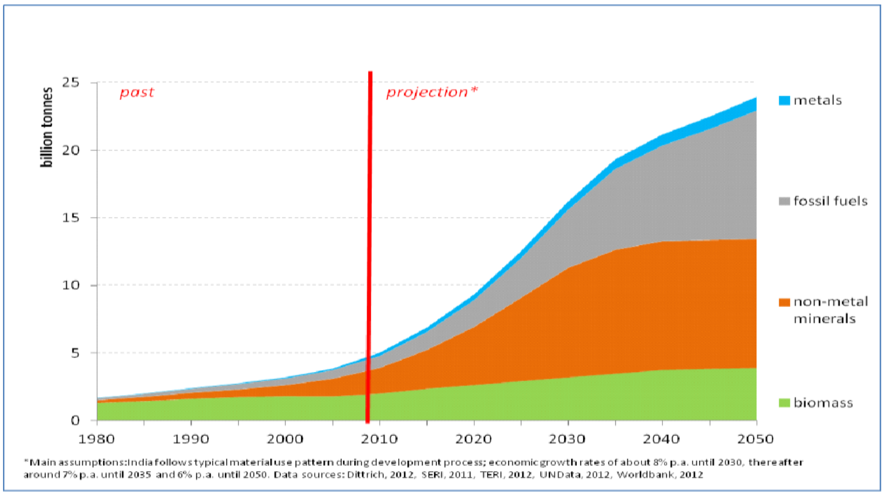

Figure 1.2: Projection of future material consumption patterns

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 licence 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 geopolitical and economic risks apart from adversely affecting the trade balance. Table 1.2 presents India's import dependencies for key resources.

Table 1.2: India's import dependencies for selected raw materials

Material	Import dependency (in %)
Molybdenum (Mo)	100
Cobalt (Co)	100
Nickel (Ni)	100
Antimony (Sb)	100
Magnesite ($MgCO_3$)	100
Rare earths	100
Lithium (Li)	100
Phosphate	90

Material	Import dependency (in %)
Copper (Cu)	90
Fluorite	87
Silver (Ag)	75
Lead (Pb)	74
Oil	70

Source: GIZ-TERI-DA-IFEU (2015), CEEW-DST (2016)[3], TERI (2018)[4]

Note: Import dependency ratio for raw material refers to the extent of dependency on imports 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 Indian rupee, is adding to the cost of manufacturing of many items that require imported materials. India imports more than 80 per cent of the oil that is processed in the economy for domestic consumption and re-exports. Import dependency is nearly 100 per cent 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 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 inverted duty structure and 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 Rules, the government has allowed import of metal scrap, paper waste , and various categories of electrical and electronic equipment for reuse purpose, without permission from the Ministry of Environment, Forests and Climate Change.

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 allow

[3] Details available at www.dst.gov .in/sites/default/files/CEEW_0.pdf, last accessed on 9 April 2019

[4] Details available at www.teriin.org/policy-brief/towards-resource-efficient-electric-vehicle-sector-india, last accessed on 9 April 2019

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 cent 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 to Figure 1.3). Estimates suggest that 90 per cent of aluminium is imported in India. For successful processing of aluminium 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 micro small and medium enterprises (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 tonnes to about 9 million tonnes 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.

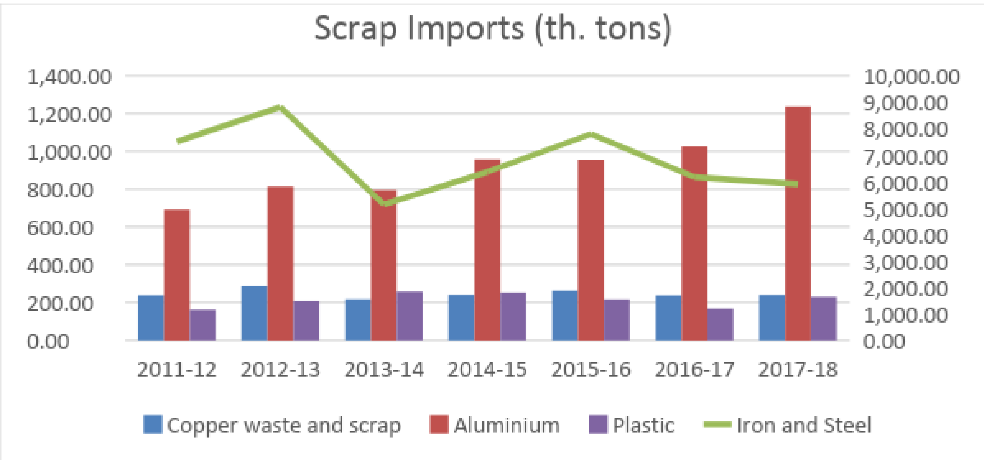

Figure 1.3: Import of scrap in India: copper, aluminium, plastic, and iron and steel

Source: DGFT (2018)[5]

[5] Details available at www.dgft.gov.in/more/data-statistics/export-import-data-bank, last accessed on 9 April 2019

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 has conflict with the biotic resources. Many of India's mineral reserves lie under dense forests (refer to Figure 1.4). Around 60 per cent of coal reserves are located in forests (Ministry of Coal, 2005). Similarly, 61 per cent 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 per cent of the current total land requirement) to 73,000 hectares (i.e. 25 per cent of the projected total land requirement) by 2025[6]. Increasing mining in forest areas would conflict with India's National Action Plan on Climate Change (NAPCC), 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 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.

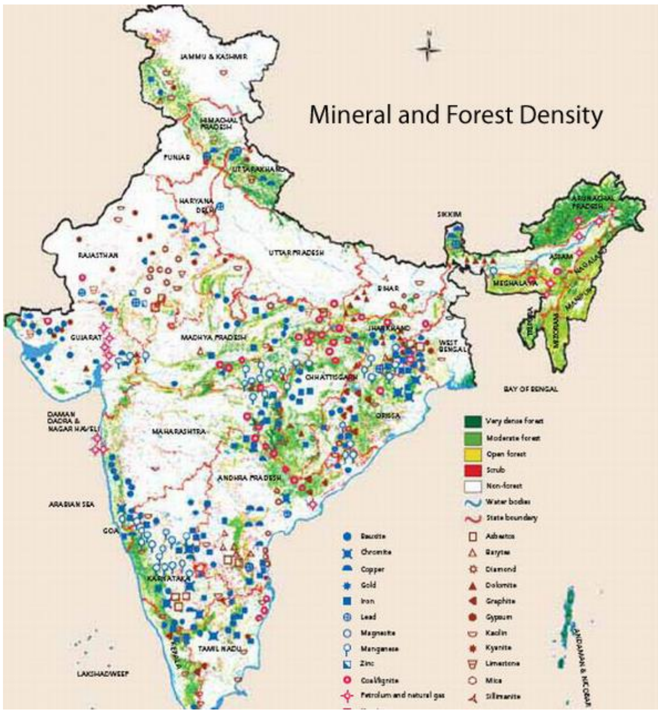

Figure 1.4: Forest areas versus mineral resources
Source: CSE, 2007[7], IGEP, 2013

Mining leads to around 32 per cent 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

[6] Details available at www.hrdp-network.com/live/hrdpmp/hrdpmaster/igep/content/e48745/e50194/e58089/ResourceEfficiency_Report_Final.pdf, last accessed on 9 April 2019

[7] Details available at www.cse.org.in/mining/pdf/miningpub.pdf, last accessed on 9 April 2019

dust emissions, fugitive emissions of particulate matter, and gases, such as sulphur dioxide (SO_2), nitrogen oxide (NO_x), methane, carbon dioxide, carbon monoxide, etc. The release of GHGs compounds the problem of climate change.

The manufacturing sector and in particular the iron and steel industry, cement plants, manufacture of sulphuric acid, and smelting of copper, zinc, lead ore, etc. are significant contributors of CO_2 and SO_x. Iron and steel had the largest share of emissions (38 per cent), followed by non-metallic minerals (predominantly, cement) with a share of 29 per cent in overall GHG emissions by various industrial sectors (refer to Figure 1.5). Further, GHG emission due to industry energy use has grown upwards at a rate of 10 per cent, rising from ~217 tonnes in 2005, to ~ 467 tonnes in 2013.

Mining activities also lead to stress on water resources, the availability and supply of which is limited in India. The 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 waterbodies leads to water pollution, which affects local communities. The Damodar River in Jharkhand and West Bengal has 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.

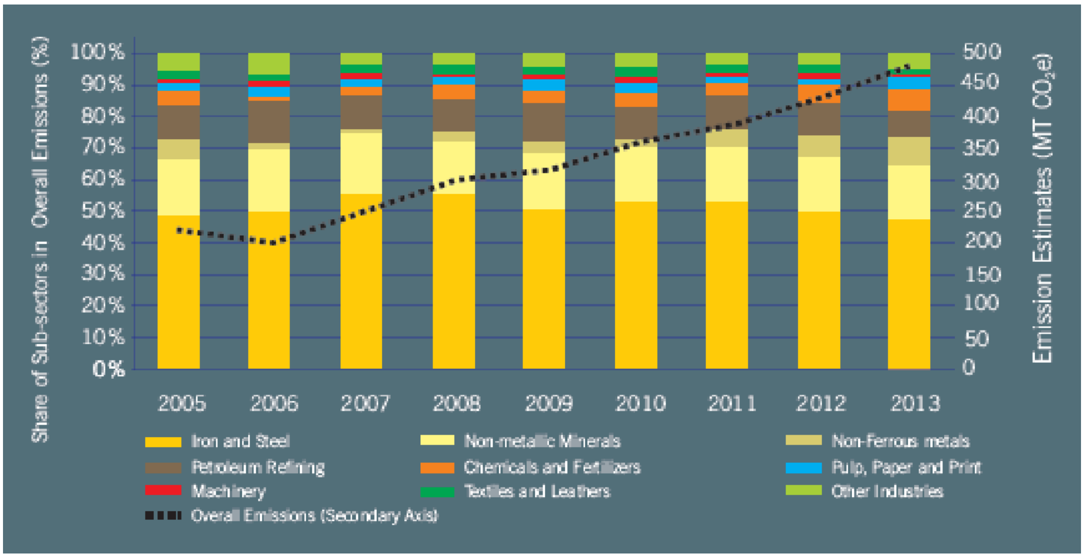

Figure 1.5: Trend of greenhouse gas emissions by various industrial sub-sectors in India
Source: GHG Platform India (2017)[8]

[8] Details available at www.ghgplatform-india.org/Images/Publications/GHG%20Trend%20Analysis_2017_07%20Dec'17.pdf , last accessed on 9 April 2019

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 the livelihoods of local populations in the Vindhyan region of Uttar Pradesh, it was found that mining had a negative impact on the 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.[9]

This is a big challenge from human rights perspectives and poses enormous social risk. As reported by Downing (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 is affected by pollution and contamination. Forced resettlement can be particularly disastrous for indigenous communities who have strong cultural and spiritual ties to the lands and forests 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.[10] The GHG emissions increase due to mining and have negative impact on the environment, human health, and the economy.

Thus enhancing RE and promoting the use of secondary resource management (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.

[9] Details available at www.niti.gov.in/writereaddata/files/document_publication/Socio-Economic-Impact-Study-of-Mining-and-Mining-Polices.pdf , last accessed on 9 April 2019

[10] Details available at www.researchgate.net/publication/308937912_Environmental_and_social_impacts_of_mining_and_their_mitigation, last accessed on 9 April 2019

1.5 Why national resource efficiency policy for India

1.5.1 Need for a comprehensive policy framework

A resource efficient strategy and promoting use of secondary raw materials will encompass wide variety of technology, process, policy, and institutional issues along the various stages of product life cycles and across multiple resource groups, necessitating a coordinated approach to strategy and action that brings together different stakeholders across multiple sectors.

A comprehensive enabling framework may be needed as individual policy instruments tend to focus on certain aspects of the transition to a resource efficient and circular economy and the effect of an instrument might be offset by the effect of another, or there could be burden shifting happening from one resource / sector to another. Thus, it is important that policy instruments be orchestrated within a comprehensive policy statement in order to infuse a common approach to the various sectoral and cross-sectoral, including fiscal, regulatory, information based, approaches to resource efficiency. The framework should also have a built-in system for monitoring and reviewing, and revision, whenever.

Also many policy instruments generate a co-benefit of resource efficiency besides generating other environmental and social benefits. It is important to mainstream the use of these instruments across sectors.

1.5.2 Current gaps in resource efficiency agenda

What is essentially missing currently in India is life cycle thinking towards addressing the larger resource efficiency agenda. The life cycle approach is in line with the idea of closing the loops and reducing dependency on virgin raw material by creating an alternate source of resources through reuse and recycling. At every stage along the life cycle, policies of resource use and resource efficiency can be implemented. Programmes and policies already focus on energy efficiency or environmental issues but do not directly address RE or secondary raw materials.

India has deployed various policies and interventions addressing other environmental and social objectives but at the same time having implications on resource efficiency. These include taxes and subsidy (including rationalization of unwarranted benefits in the subsidy reform), financial support for research and development, eco-mark/eco-labelling, industry standards, public procurement, tradable permits and certificates and self-regulation. Also many policy interventions have focused on end-of-life stage and that too mostly on recycling, while the other stages of the life cycle have not been given the due importance.

1.5.3 Formulating national resource efficiency policy

- The national resource efficiency policy is intended to be a guide to action for stakeholders including different government departments and ministries, civil society organizations, consumers, and informal sector
- The policy will integrate the three main perspectives: 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), and selected categories of material resources that are considered as priority materials (such as rare earth, iron and steel, aluminium, copper, etc.). Also, looks at instruments cut across individual sectors, materials or life cycle stages
- The policy also will suggest an institutional structure for the country to take forward the resource efficiency agenda, and highlight the importance of partnerships of different stakeholders for efficient harnessing of resources and promoting resource use and environmental sustainability
- The policy does not displace, but builds on the earlier policies by bringing in an integrated thinking to help explore interlinkages
- Though resources can be broadly defined to include both biotic and abiotic resources as well as ecosystem services including air, water, forests, land, minerals, fossil fuels, etc., the larger scope of national resource efficiency policy will be to develop a policy landscape for achieving sustainable consumption and production for abiotic resources, specifically non-energy minerals. The rationale for this is that policies on most of these other resources already exist to some extent, and improving mineral resource efficiency is an extremely urgent task given the current and projected explosive growth rates in material demand arising out of India's growth. In future, the policy hopes to expand its scope of interest to a broader set of resources
- The preparation of this policy will integrate inputs and suggestions from different line ministries and government departments, subject and sectoral experts, stakeholder groups
- The policy will also seek to stimulate partnerships of different stakeholders, i.e. public agencies, local communities, academic and scientific institutions, the investment community, and international development partners, in harnessing their respective resources and strengths for resource efficiency.

2 Principles and objectives

Resource efficiency (RE) encompasses a wide variety of technologies, processes, policies, and institutional issues along the life cycle stages that typically include stages of mining/raw material extraction, design, manufacturing, consumption, and disposal/end-of-life. In the context of realizing RE and circular economy, businesses have the opportunity to take the lead while the government can create enabling conditions for facilitating the transition. The 6R principles[11] 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 and meeting many other goals too.

Significant improvements in RE are essential to meet climate goals in a cost-efficient manner. This would happen through both 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 RE, it will be difficult and substantially more expensive to keep average global warming below 2°C.

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 clear that the environmental aspects should be mainstreamed into development policy to have sustainable development in the long run. There is a need for RE policy instruments to address the entire life cycle of products, and a 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.

2.1 Objectives

The specific objectives of the national resource efficiency policy for India should be:

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[11] 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 (São Carlos, Brazil)

- Savings in primary / virgin raw material by increasing efficiency in use in the sense of reduction in their use per unit of economic output, to minimize adverse environmental impacts and substituting its use with secondary/recycled raw materials
- Identify hotspot sectors for promoting resource efficiency in India and design interventions to promote resource efficiency and circular economy in identified sectors
- Develop capacity and strengthen research and information systems for promoting resource efficiency and circular economy
- Create an institutional mechanism to achieve the above objectives through coordination and synergy across sectors and tiers of government

2.2 Principles

To meet these objectives, the national resource efficiency policy for India should be based on certain principles:

- Promote economic growth that is sustainable and equitable (inter- and intra-generational)
- Reduce primary resource consumption to 'sustainable' levels, in keeping with achieving the SDGs and staying within the planetary boundaries
- Create higher value with less material through resource efficient and circular approaches
- Minimize 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 efficiency and productivity. While some of these indicators are currently used, they have largely been confined at the industrial or sectoral level for establishing benchmarks and undertaking comparative assessment with an objective of achieving 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 while 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 categories – 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. Therefore, 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 tonnes, resources like, land is usually measured in terms of area (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 (e.g, 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, and 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.

3.2 Key indicators for measuring resource efficiency

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:

(i) between the national economy and the natural environment, and

(ii) 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 3.1. 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.

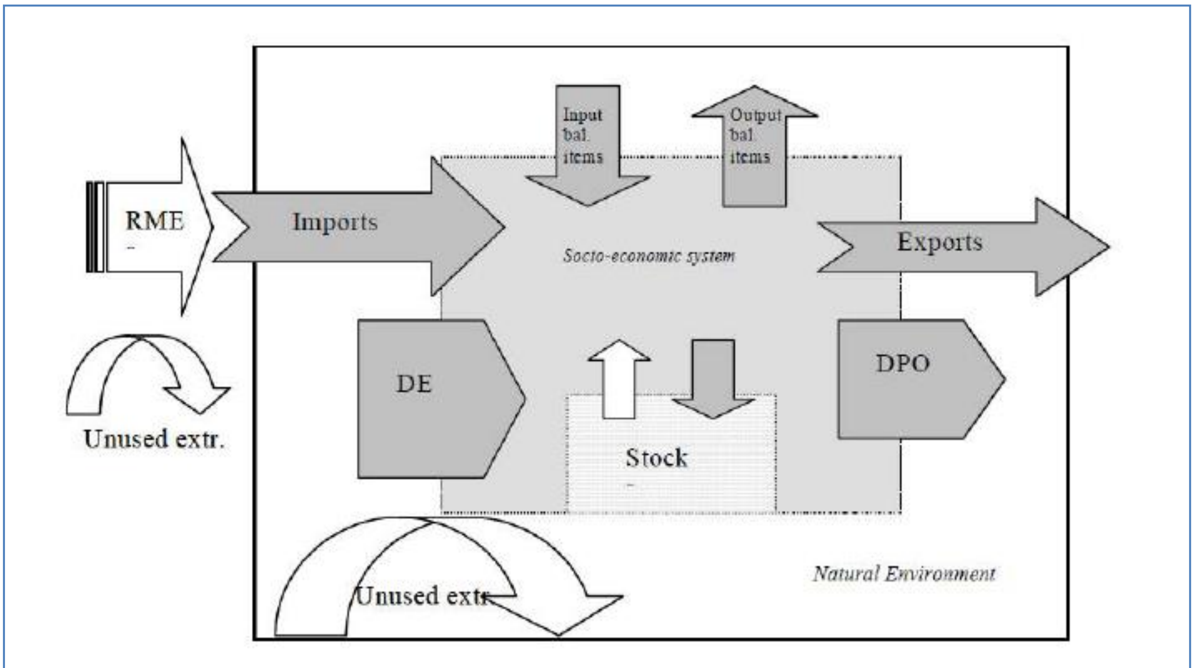

Figure 3.1: Representation of economy-wide MFA
Source: GIZ-TERI-DA-IFEU (2015)

3.2.1 Resource use indicators

Based on an extensive review of literature, a broad list of resource use related indicators that can be used in MFA is presented in Figure 3.2

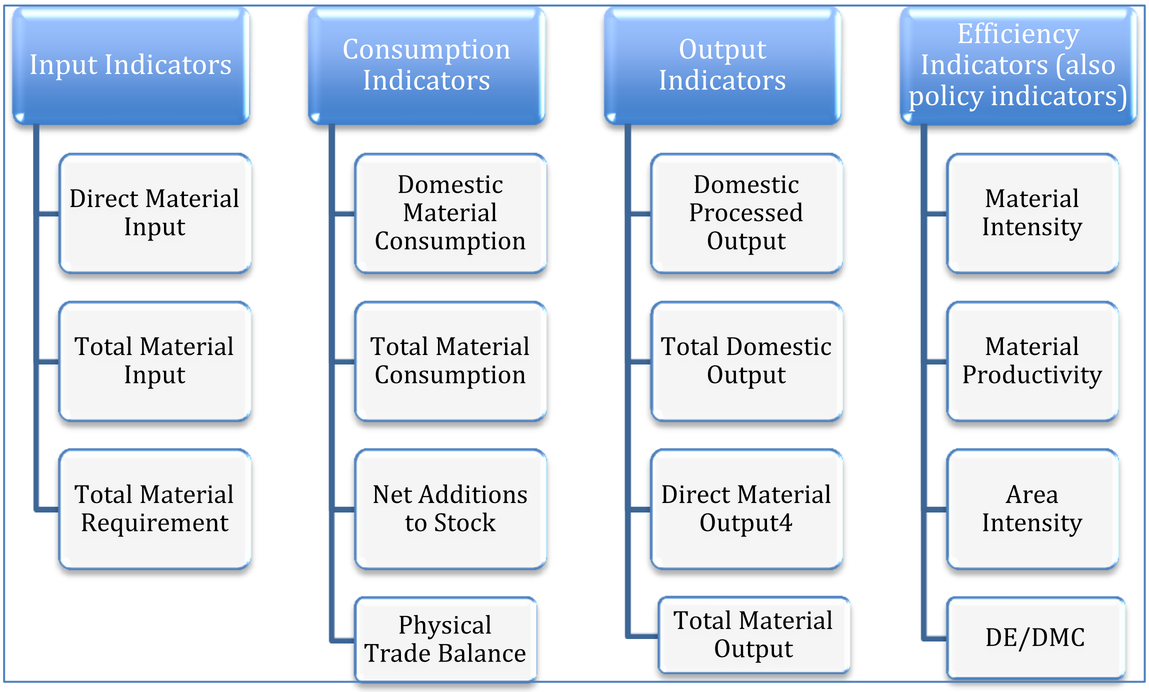

Figure 3.2: Possible list of indicators across selected stages of the life cycle for measuring RE
Source: UNEP (2017)[12], IGEP (2013)

3.2.2 A brief description of the indicators

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'

[12] Details available at http://www.resourcepanel.org/sites/default/files/documents/document/media/resource_efficiency_report_march_2017_web_res.pdf, last accessed on 9 April, 2019

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' (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 it 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' – i.e. 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 is recycled. [13] Consequently, the following indicators are now considered more useful for material flow accounting (Eurostat 2014):

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 RE in developed and developing countries since it not only creates 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

[13] Details available at www. onlinelibrary.wiley.com/doi/pdf/10.1111/j.1530-9290.2009.00154, last accessed on 9 April, 2019

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 at least 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 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.[14]

[14] Details available at www. eeas.europa.eu/sites/eeas/files/na_eu_restrategy_nov2017.pdf, last accessed on 9 April, 2019

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.

4 International resource efficiency-related policies/strategies: a review*

4.1 Introduction

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

In the Asia-Pacific region, China, Japan, and South Korea have a dedicated national policy for resource efficiency. In Europe, five countries—Austria, Denmark, Finland, Germany, and the Netherlands—have dedicated national strategies for material resource efficiency or circular economy. France has announced the Circular Economy Roadmap in 2018 which is to be placed before the Parliament in 2019. Belgium and United Kingdom have regional resource efficiency strategies. Many European 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. The United States of America (USA) has federal law for waste management with one of the goals to reduce unsustainable use of materials and resources.

The RE strategies of Austria, China, Denmark, Finland, Germany, Japan, the Netherlands, South Korea, and USA along with overarching RE policy for the European region are reviewed in this chapter.

4.2 International resource efficiency strategies

4.2.1 Asia-Pacific

4.2.1.1 China[15],[16]

China has enacted the 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 3Rs (reduce-reuse-recycle) that refers to the reduction of resource

* **Bhawna Singh and Kushal Vashist, Ministry of Environment, Forests and Climate Change, Government of India**

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

consumption and waste generation while reuse and recycling mainly involves waste. The 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. However there are no targets identified for the economy. The 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 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 the enterprise, industry, and regional levels with different objectives carved for actors at each level, as enumerated

- **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, and industrial metabolism and symbiosis relationship are formed among enterprises. The 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 gross domestic product (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 (e.g. 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 per cent.
- Energy, Water and Built-up Land Consumption per unit GDP (2010–2015) decreased by 13.3 per cent, 24.2 per cent, and 22.4 per cent, respectively.
- Quantity of resources recycled in 2014 was 2.45 hundred million tonnes valued at US $ 1.5 trillion resources recycled (2014) exceeds $1.5 trillion with 2.45 hundred million tonne recycled resources. Non-ferrous metals and the pulp industry sector use 20 per cent to 50 per cent of raw materials from recyclable resources.

4.2.1.2 Japan[17],[18],[19]

Japan established a law-setting framework, the Fundamental Law for Establishing a Sound Material-Cycle Society (2000) to overcome the challenges associated with waste and resources. Based on the Fundamental Law, the Fundamental Plan for Establishing a Sound Material Society (2003) was first set up. The Fundamental Law for Establishing a Sound Material-Cycle Society (2000) aims to ensure material recycling in society, reduce consumption of natural resources, and reduce environmental burdens. In order 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. The Fundamental Plan for Establishing a Sound Material-Cycle Society is regularly revised and forms the basis of other national plans.

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[17] Tanaka I., 2008. Promotion of Resource Efficiency in Japan. ITPS

[18] Government of Japan, 2010. Establishing a sound material-cycle society. Ministry of Environment, Government of Japan.

[19] 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.

Indicators:

Three indices at different phases of the material flow have been 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 (landfilled waste)

Additional supplementary indicators for target setting are enumerated as follows:

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 greenhouse gas (GHG) emissions
   ii. GHG emissions associated with the waste sector and fossil fuels to be substituted by waste power generation

Policy instruments: The 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 implementation.

Outcomes:

- Resource productivity at 361,000 yen/tonne in 2007 has increased by 37 per cent from 2000.
- Recycling rate at 13.5 per cent in 2007 has increased by 3.5 per cent from 2000.
- Final disposal volume of wastes at 2.7 million tonne in 2007 has increased by 53 per cent since 2000.

4.2.1.3 South Korea[20]

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). REP aims to reduce the amount of resource required to provide products and services. For this purpose, REP tries to manage the quantity of raw materials used to convert energy into GDP. It tries to adopt a

[20] 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.

more efficient production process and/or to recycle resources. The programme is based on the Rational Energy Utilization Act. ERP aims to increase the demand and supply of energy from waste. The National Strategy for Green Growth has a target of increasing the share of renewable sources.

RTP focuses on developing cutting-edge, converged recycling technology and 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 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 per cent since 2008.
- Share of energy from non-renewable waste (2012) rose to 1.05 per cent from 0.89 per cent in 2008.
- Green Technology R&D (2009 - 2013) increased at compound annual growth rate of 11.7 per cent.

4.2.2 Europe[21,22,23,24]

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 the means required for achieving them. The 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 achieved by 2020 in order 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.

<u>Roadmap to a Resource Efficient Europe (2011)</u>

The 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

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

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;
- 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, that is, 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, such as 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, and 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, and 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 fertilisers, 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, and 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 per cent) of general policy objectives refer to waste management, including recycling, recovery and a circular economy approach. Around 17 per cent of the reported objectives can be regarded as specific to material resource use, while 14 per cent address economic considerations, and another 14 per cent refer to managing energy more efficiently and increasing the share of renewables in overall energy consumption. Of reported policy objectives, 12 per cent 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 per cent 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 per cent), followed by regulatory (27 per cent) and information- based instruments (17 per cent) 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[25]

Austria has a dedicated national resource efficiency strategy (Resource Efficiency Action Plan 2012). Building on the REAP, the Reset 2020-Resources.Efficiency. Technologies

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

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. The fields of action so identified are resource efficient production, public procurement, circular economy, and raising awareness.

Priority materials and sectors: Food, construction material, biomass, fossil fuels, packaging material, 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, and food and housing.

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 (DMC)
- domestic material intensity (DMI), 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 dissemination and raising motivation/awareness are necessary under all circumstances.

4.2.2.2 Denmark[26],[27],[28],[29]

Denmark has a resource strategy and plan for waste manageme**nt (Denmark Without Waste, Recycle more - Incinerate less, 2013) and waste prevention strategy (Denmark Without Waste II, Strategy for Waste Prevention - 2015)** that partly covers the theme of more efficient use of resources. Recently, Denmark has adopted the Strategy for Circular Economy, 2018, aiming to transform society towards the sustainable path. Material resource efficiency policies and strategies in Denmark are closely related to considerations regarding

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

job creation/employment and competitiveness as well as ensuring sustainable use of natural resources and reducing environmental impacts. Denmark without waste is the Government's presentation of a new approach to waste management in the country. waste - recycle more, incinerate less (2013) It 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 with regard 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 a more circular economy - promoting circular business development in small and medium enterprises (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, liberalizing waste electrical and electronic equipment (WEEE) management, fund for handling regulatory barriers, voluntary sustainability class, selective demolition, and deriving 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, and construction & demolition.

Indicators:

At the sectoral level, indicators include, among others, gross value added (GVA)/input (DKK), purchase of input materials (DKK) as percentage of turnover (DKK), intensity of energy use (GJ) and waste production (kg) per GVA; these provide detailed information for the different sectors. At the national level, Denmark also uses DMC to measure material resource use in tonnes.

Policy instruments: A mix of policy instruments are in use, such astaxes and charges in order to prevent production of waste, eco-labelling, green public procurement, fund for green business development, eco-innovation programme, and task force for increased resource efficiency.

4.2.2.3 Finland[30],[31]

Finland has a dedicated resource efficiency strategy **(National Material Efficiency Programme 2014)** and several other strategies strongly linked to the theme of material efficiency. Material efficiency in production means the sparing use of natural resources, the

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

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.

The National Material Efficiency Programme (2014) with the goal of *'sustainable growth through material efficiency'* simultaneously aims at economic growth, 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)

4.2.2.4 Germany[32],[33]

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. The 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, enumerated as follows:

- 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 and developing and expanding closed-cycle management
- securing sustainable resource use for the long term by guiding society towards quality growth.

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

[33] BMUB, 2016. German Resource Efficiency Programme II. Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB).

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, and information and communication.

Indicators: Raw material productivity (GDP/ abiotic Domestic Material Intensity (DMI)), energy productivity (GDP/ total primary energy use), RMC/person (raw material consumption per person), total raw material productivity (GDP + imports)/RMI (including biotic materials), recycling and recovery indicators.

Policy instruments:

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

4.2.2.5 The Netherlands [34],[35]

The Netherlands has several resource efficiency policies in place such as those on waste management, waste prevention, circular economy, and green growth. The **Circular Economy in the Netherlands by 2050 (2016)** further sets out a course of action 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 the chains designed need 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—a government-wide programme for a circular economy (2016) aims to realise 50 per cent reduction in the use of primary raw materials (minerals, fossils, 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 the built environment.

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

[34] EEA, 2016. Country profile - Netherlands: More from less - material resource efficiency in Europe. European Environment Agency.
[35] 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.

Policy instruments:

- Regulatory instruments such as, the 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 instruments, such as landfill tax, tax deduction for investment in sustainable technologies, subsidies, pay-as-you-throw
- Information-based instruments, such as labelling and influencing the consumer behaviour
- Others, such as voluntary agreements, enforcement agency

Outcomes:

Table 4.1: Domestic material consumption (DMC), DMC per person and resource productivity in 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)						

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

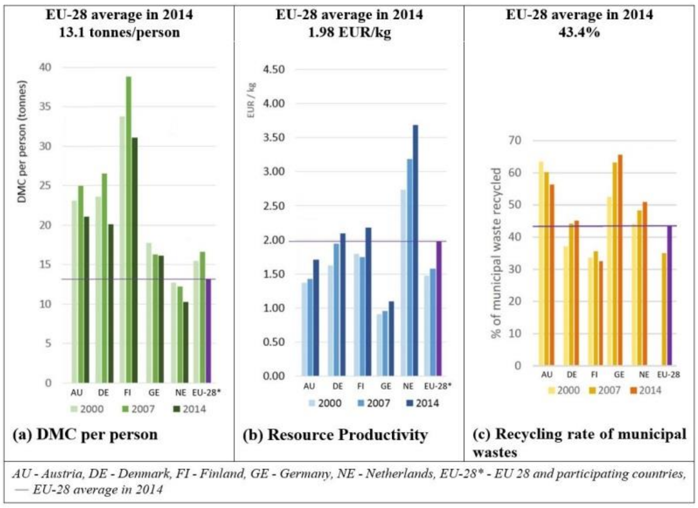

Figure 4.1: (a) DMC per person, (b) Resource productivity and (c) Recycling of municipal wastes for years 2000 - 2007 – 2014

4.2.3 United States of America[36],[37]

The **Resource Conservation and Recovery Act (1976)**, a federal law of the USA, 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, and environmentally-sound manner.

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

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

Policy instruments:

- Regulatory instruments, such as nutrient regulation, waste recycling regulation, public procurement, and standards and codes in energy efficiency
- Economic instruments, such as 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, such as awareness programmes through state policies or municipal/county level, organic agriculture label (at the national level)

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[36] IINAS, 2013. Elaborating the International Discussion on Resource Efficiency (ENTIRE): Part I: Resource Efficiency Policies in Various Countries Annex Report.

[37] US EPA, 2003. Beyond RCRA: Waste and Materials Management in the Year 2020. United States Environment Protection Agency

4.3 Discussion

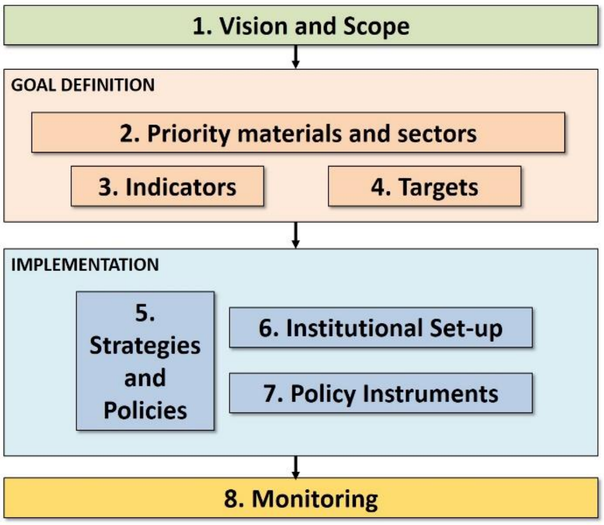

Figure 4.2: Components of RE strategy

Based on the review of the international dedicated strategies for resource efficiency, the main components of such strategies as identified are shown in Figure 4.2. The vision and scope outlines the main purpose of the RE strategy. Different priority materials, sectors, and consumption categories have been identified. Further, targets and milestones evaluated on the basis of certain pre-defined 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 a resource efficiency 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 covering increase in energy, water or land productivity to reducing the impacts on the environment.

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

Indicators may be consumption based, such as DMC 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 RMC 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, such as Material Productivity (GDP/DMC), Domestic Material Intensity (DMI), Raw material productivity (GDP/ abiotic DMI), Energy Productivity (GDP/total primary energy use); recycling-based indicators, for instance, the share of recycled raw materials used by industry, general waste-related indicators (such as municipal solid waste generated/treated).

Different **targets** related to identified priority materials and sectors are specified in the resource efficiency strategy. Such targets may be directly related to material use or may also be in the form of expenditure 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 as displayed in Table 4.2 show 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, such as the ban or restriction on landfills 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 4.2: 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 – the 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 organizations, scientific experts, government funding agencies, among others, are also involved as part of the feedback group.

Policy instruments may be *regulatory instruments*, such as laws and bans (for instance on the use of certain substances and landfills), design and performance or quality standards, producer responsibility, green public procurement, etc.; *economic instruments*, such as taxes, fees, grants, awards, returnable deposit system, financial support schemes, etc.; *information-based instruments*, such as campaigns/awareness drives, training and education initiatives, eco-labels, etc. Specific policy instruments may also be designed, for instance, natural resource pricing, environmental fee to reduce externalities and consumption tax in China; fund for green business development and the eco-innovation programme 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 the Netherlands.

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

4.4 Conclusion

Review of international resource efficiency strategies provides insight on RE strategy design and implementation instruments. Understanding of a 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 an informed understanding of international practices to develop a targeted RE strategy.

5 Assessing Resource Efficiency Potential in Priority Sectors in India

5.1 Identification of priority sectors

While there are opportunities of resource efficiency for every sector in an economy, however, the degree of benefits will depend on number of factors. These include (i) relative sectoral share and the share in the national income; (ii) diversity of use of natural resource/raw materials; (iii) volume of wastes/scrap generated and recycled; (iv) import dependency for raw materials; (v) access and use of efficient processes and technologies that can help in material switching or savings; (vi) markets for alternative products, etc. This reference document explores the resource efficiency potential and opportunities in selected priority sectors in India with a focus on abiotic material resources (non-energy minerals) to help India move towards achieving the larger sustainable consumption and production goal. As highlighted in Chapter 1, the focus on abiotic material resources does not undermine the importance of resource efficiency in biotic resources, such as water, land and soil, air, and biomass, which experience substantial exploitation and degradation due to growing anthropogenic activities and require equal importance in the context of achieving sustainable consumption and production.

As mentioned earlier, India is already a net importer of resources (in value terms), dominated by fossil fuel imports and critical materials (CEEW, 2016). India imports more than 80 per cent of oil requirement, more than 70 per cent of coking coal, and nearly 100 per cent of 'most critical' materials. To keep up with the pace of growing demand for various goods and services, domestic extraction of abiotic resources has also increased and resulted in significant environmental degradation.

Waste generation is an eventual outcome of growing consumerism. Among different wastes being generated annually, e-waste and plastic waste need special mention. The e-waste sector is further complicated by the fact that it lacks proper use of technologies and handling processes that makes it unsafe and inefficient when it comes to extraction of materials. As per estimates, India generates around 2 million tonnes of e-waste per year, and it is rising at the rate of 5 per cent per annum. If managed efficiently, such wastes can help in recovering tonnes of valuable materials that can potentially replace costly imports of precious materials and reduce the pressure on domestic virgin resources. Plastic pollution has reached unprecedented levels in recent years. Only 60 per cent of the total plastic waste is being recycled. While reduced consumption is the best principle, other interventions in the form of reuse as well as recycling for alternate product development will go a long way in managing wastes.

Further, there is a need to improve the processing of waste materials, such as steel and aluminium, for ensuring production of quality secondary raw material which can then be fed back into the manufacturing sector. As rapid urbanization continues, one of the most critical urban challenges is the management of waste where purposeful interventions have the potential to support transformational circular economies and build the foundation for sustainable communities.

The factors that have been taken into consideration towards selection of hotspot sectors for assessing resource efficiency benefits, potential, and opportunities include share of the sector in national income, use of critical raw materials by the sector, and import dependency of raw material (virgin/scrap) (Refer Table 5.1). These sectors include automotive (including electric mobility), construction, electronics, plastics, steel, aluminium, and solar PV.

Table 5.1: Economic contribution of selected sectors in India

Sl. No	Economic sectors	Share in national income	Selected raw materials	Imports
1.	Automobile sector (incl. electric vehicles)	7.1%	ICE: Steel, copper, aluminium, zinc, nickel, lead, glass, rubber, various plastics/synthetics E-vehicles: Lithium, cobalt, nickel, rare earths, various plastics/synthetics, steel, copper, aluminium,	Copper (50%–60%) Lithium (100%) Co (100%) Aluminium scrap (90%) 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: MoSPI (2015), NIPFP (2016), MoSPI (2017)

For the selected sectors, a detailed assessment of material consumption, efficiency potential (based on Indian and international best practices), ongoing initiatives with implications on resource efficiency and suggestions on policy interventions was undertaken. The following section briefly presents these findings.

It is important to acknowledge here that these sections draw heavily upon inputs from the sectoral studies that have been undertaken by TERI, Adelphi, GIZ and Development Alternatives (DA) for the sectors on automobiles, solar PV, electronics, plastics, E-waste and C&D waste. Further, the NITI Aayog in association with Ministry of Mines, Ministry of Steel, Ministry of Housing and Urban Development, and Ministry of Information Technology, Government of India, have developed status papers on achieving resource efficiency across four sectors—steel, aluminium, e-waste, and construction and demolition; the findings from these status papers have formed the basis for the relevant sections in this chapter on these four sectors.

5.2 Automotive sector

5.2.1 Introduction

The automotive industry plays a very important role in providing mobility options to the people in the country through different types of vehicles, such as passenger cars, light, medium and heavy commercial vehicles, multi utility vehicles, such as jeeps, scooters, motorcycles, mopeds, three wheelers, tractors, etc.

India's automotive sector forms 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 manufacturing companies in the country, the industry contributes to more than 7 per cent to India's gross domestic product (GDP) and accounts for 7–8 per cent of India's total employed population. The categories of manufactured items of the Indian automobile industry are categorized in Figure 5.1.

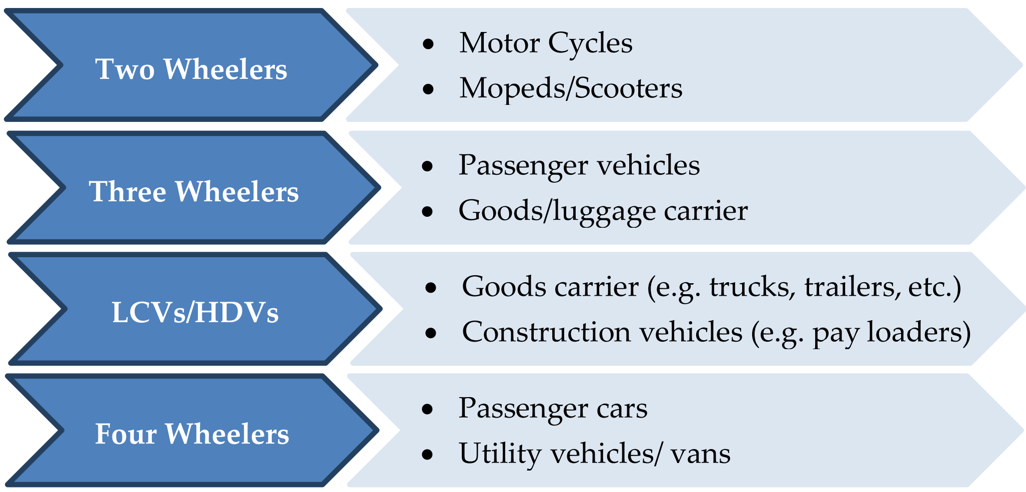

Figure 5.1: Broad category of automobiles manufactured in India
LCV: *Light Commercial Vehicle, HDV: Heavy Duty Vehicle*

The Indian auto industry became the fourth largest in the world with sales increasing to 4.02 million units (excluding two wheelers) in 2017 (IBEF 2017). India also became the seventh largest manufacturer of commercial vehicles in 2017. The 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 mobility sector has predominantly been driven by the growth of internal combustion engine (ICE)-based vehicles. The growing middle income class and their rising aspirations and availability of cheaper finance, are some of the key factors that have led to increased demand for personal mobility and proliferation of production and sale 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 there are more than 210 million registered vehicles on Indian roads. Around 50 per cent of these registered vehicles are positioned in 7 states of the country. With regard to production, two wheelers has the largest share of 79 per cent, followed by 14 per cent share of passenger vehicles and the remaining 7 per cent largely comprising of commercial vehicles that include three wheelers, light commercial vehicles, and heavy duty vehicles.

The growing use of ICE-based vehicles has resulted in an increased consumption of fossil fuels leading to emission of carbon dioxide (CO_2) and other local pollutants. 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 per cent of the total CO_2 equivalent emissions from the transport sector.

One of the ways of decoupling GHG emission from the transport sector is switching to cleaner fuels and electricity. In fact, the Government of India has demonstrated a strong commitment in introducing electric mobility in India and announced an 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 per cent in 2012 to 1.3 per cent 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, there is a target to increase the share of electric vehicles from its current level of less than 1 per cent to nearly 30 per cent by 2030 while the share of electric buses could be expected to reach as high as 100 per cent. This implies that by 2030, the estimated number of electric two wheelers on Indian roads would be an estimated 211 million, while electric cars and buses will be around 34 million and 2.5 million, respectively.

Meeting the growing demand for conventional as well as electric vehicles will require a dedicated supply of the raw materials at affordable prices. Electric vehicles will require many newer materials with enhanced performance over their predecessors, particularly for manufacturing its components, such as batteries and powertrain. This calls for a detailed assessment of the projected demand of different types of the vehicles and the consequent impact on raw material requirements. At the same time, 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 suggestions on action areas to promote resource efficiency in mobility by road.

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

An ICE- driven automobile consists of hundreds of components that are manufactured using various materials including high strength steel, stainless steel, aluminium, rubber, plastics/composites, glass, copper and brass, zinc, lead, fluids and lubricants, and others. All these components can be broadly categorized under six heads as presented in Figure 5.2.

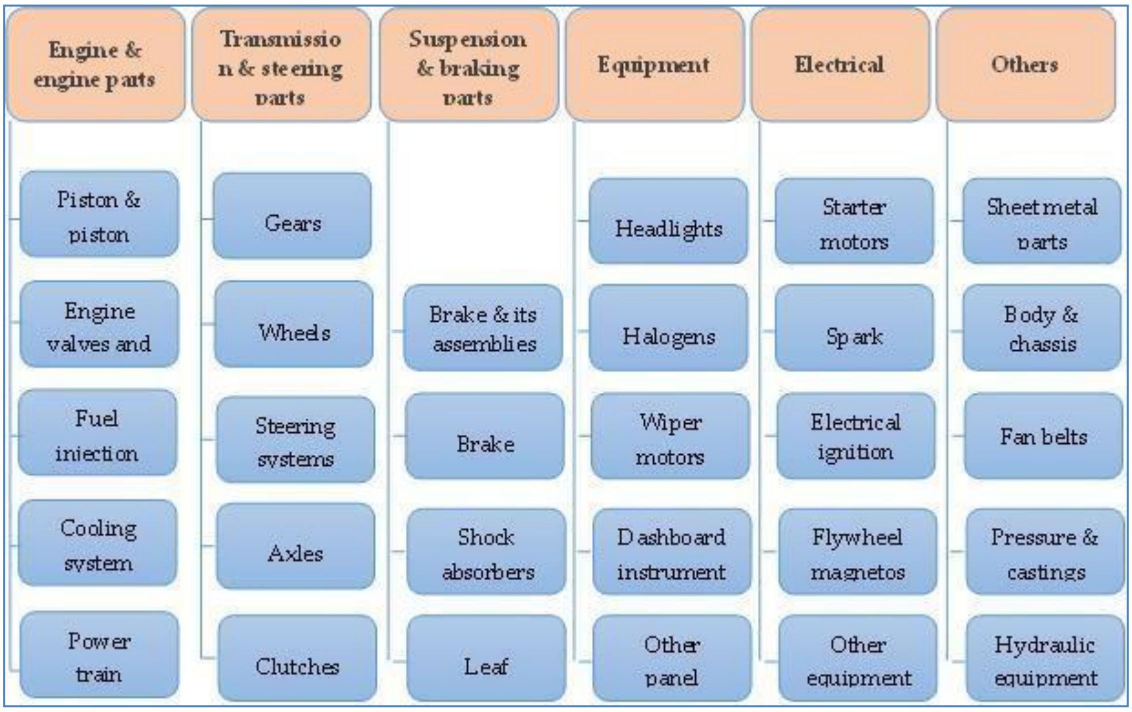

Figure 5.2: Broad category of assemblies and their sub-assemblies

Source: Authors' 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 stage. This is presented in Figure 5.3.

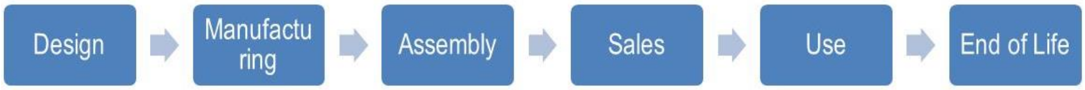

Figure 5.3: Life cycle stages of the value chain

While many materials are consumed in the automotive sector, for the purpose of this exercise, material demand assessment has been confined to use of direct materials that include iron and steel, aluminium, copper, and plastics. These materials contribute to nearly 75 to 80 per cent of the total weight of the vehicle. The following section presents a comprehensive assessment of their demand, potential environmental issues associated with mining and manufacturing of materials as well as resource efficiency opportunities along with selected life cycle stages.

5.2.2.1 Consumption of materials in automotive sector (ICE) and resource efficiency opportunities

5.2.2.1.1 Iron and steel

Steel is the most dominant metal used in production of automobiles. It is estimated that the average steel content in an automobile is around 55 to 60 per cent 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 per cent of the total kerb weight. Thus, the total iron and steel share in a weight of a car is estimated to range between 60 per cent and 67 per cent.

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 pollution in the form of emission of particulate matter, sulphur dioxide, ammonia, etc., but also global pollutants that have global warming potential, such as CO_2 and methane (CH_4). Various factors 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. 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.

Box 5.1: Material embodiment in steel

A quick analysis of material embodiment in 1 tonne 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 tonnes of dust. Further, the estimated CO_2 emission per tonne of crude steel is 2.1 tonnes as against 0.6 tonnes emitted from the EAF route.

Source: Author compilation

Further when steel enters the automotive sector, wastage is 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 of steel and with the current trend in vehicle production in India, the estimated consumption of iron and steel will reach between 70 and 80 million tonnes by 2030. The current material productivity is estimated at Rs 885/kg of finished steel consumption.

It is evident from the above estimates 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 emit 126 million tonnes of CO_2.

In the absence of any organized system for scrap/reject collection and processing, India imports nearly 6–7 million tonnes per annum of steel scrap. Given that India has an estimated 87,31,185 vehicles that have reached the end of life in 2015–16 and a further 2,18,95,439 vehicles will reach end of life by 2025 (CPCB 2017), India would be able to generate more than 10 million tonnes of steel scrap only from the automotive sector which is more than the current scrap imported by India. This, however, excludes the opportunity from recycling steel lost during material processing, which, if included will add another 1–2 million tonnes. The recycling potential along the value chain is presented in Figure 5.4.

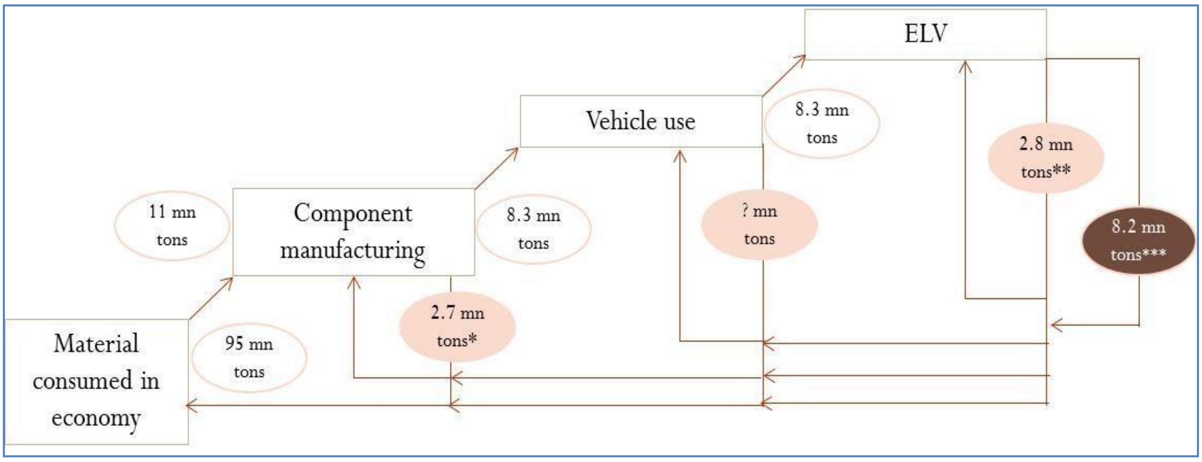

Figure 5.4: Recycling and saving potential of iron and steel
Source: GIZ-TERI-DA-IFEU-VDI (2016)

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, is gradually replacing the former in the automobile industry for various applications. This also has an overall impact on the weight and cost of the vehicle. Since the 1970s, the share of aluminium in the overall weight of a 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'.

Every 10 per cent reduction in weight is expected to improve fuel economy by 5 to 7 per cent (Richman, 2013). 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 per cent of kerb weight by 2025 (Richman, 2013).

With an average share of 8 to 10 per cent of the body weight constituting aluminium, the estimated demand for Al will be 11 million tonnes by 2030. However, if the share of the Al increases to 15 per cent, 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.

Box 5.2: Aluminium recycling

Aluminium recycling saves huge economic and environmental costs compared to production from virgin ore. Each ton of aluminium recycled uses 95 per cent 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 greenhouse gas (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.

Source: NITI 2019 - Aluminium

India imports nearly 0.9 to 1 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 21,895,439 vehicles will reach end of life 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 5.5.

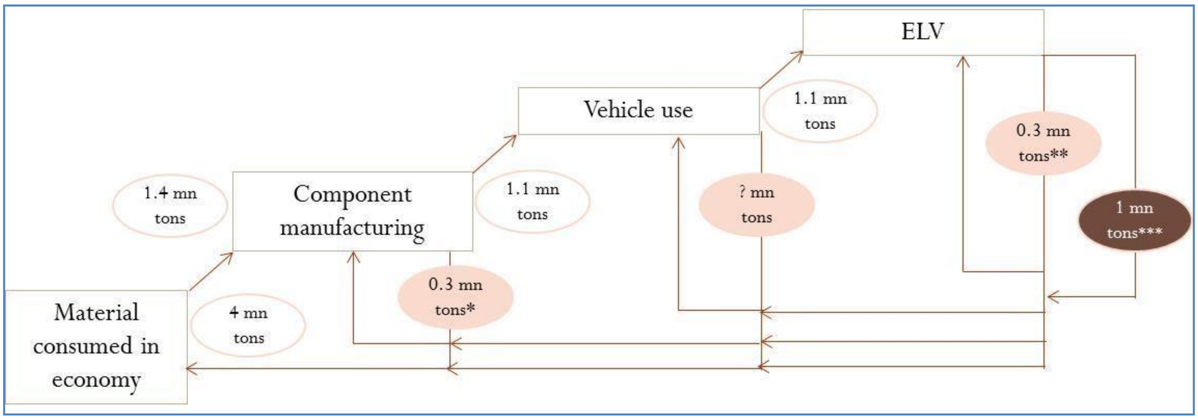

Figure 5.5: Recycling and saving potential of aluminium
Source: GIZ-TERI-DA-IFEU-VDI (2016)

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 and 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.

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 towards so-called 'smart' vehicles has increased copper consumption by 40 per cent 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 high 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 per cent 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 m (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 the supply of copper ore and so in addition to domestic production of ore and concentrates, the country 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, 2012). Copper scrap import has increased from 39000 tonnes to 58000 tonnes between 2010 and 2016 and the refined copper import has increased from 18000 tonnes to 32000 tonnes between 2011 and 2015. India continues to import copper concentrate although the quantity has fallen to 1 million tonnes from 2 million tonnes in recent years (DGFT 2019).

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 which is more than the current total production of copper in India.

The recycling rate of copper is very low in India compared to other nations. For example, in the US, the amount of copper recycled is almost the same as that is mined per year, approximately 75 per cent of used copper except wire production that requires newly refined copper comes from recycling. About 50 per cent of the copper used in Europe comes from recycling. India has high recyclability potential in the automotive sector of copper particularly from radiators from retired cars. Based on the estimated volume of vehicles that have reached the end of life as well as those that will reach end of life, the estimated volume of copper scrap recovered can be more than 0.23 million tonnes. The material productivity is estimated at Rs 63,400/kg of copper consumed in the sector. The recycling potential along the value chain of copper is presented in Figure 5.6.

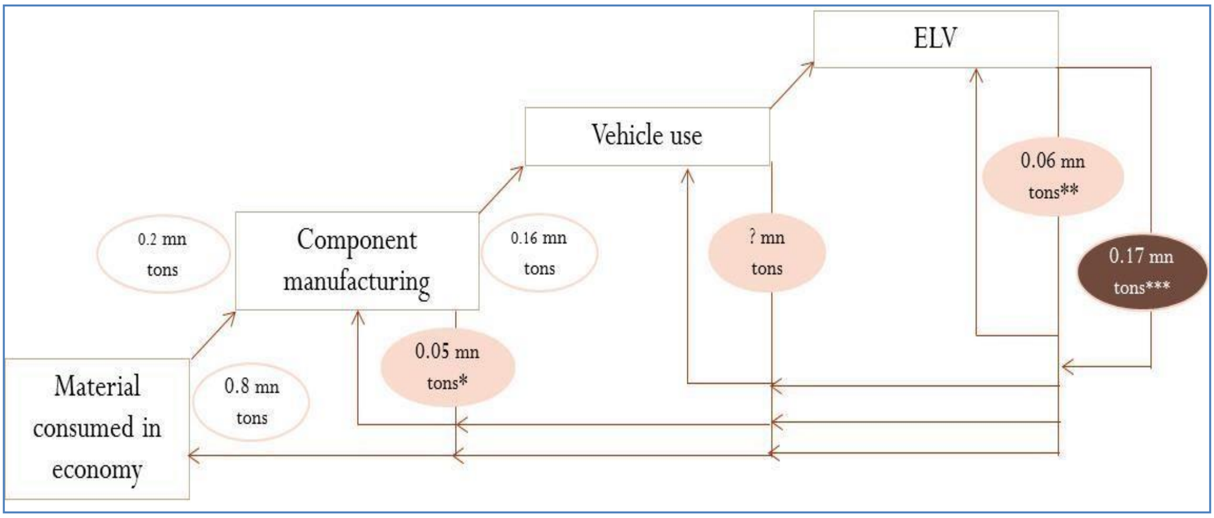

Figure 5.6: Recycling and saving potential of copper
Source: GIZ-TERI-DA-IFEU-VDI (2016)

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 vehicle 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-weighing materials are also used, such as aluminium, plastics, synthetics, and rubber, among other materials. The drive motor system is an essential part of electric vehicles 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 are presented in Figure 5.7.

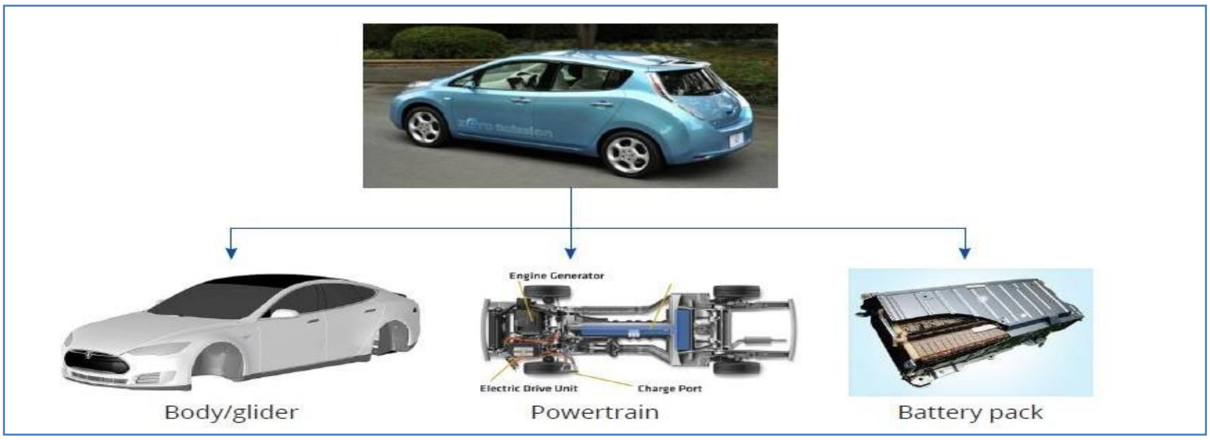

Figure 5.7: Key components of electric vehicle

The following sections briefly describe the functions of these key components and the materials that go into manufacturing of 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 electric vehicles, 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. The lithium-ion batteries have emerged as 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 ($LiMn_2O_4$) 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 a relatively lower life and low thermal stability and limited load capabilities (specific power).

Li-manganese may have less specific energy than Li-cobalt, however the 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 have better safety performance with enhanced life although the specific energy is relatively less compared to other chemistries combinations 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 ($LiPF_6$) 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, the electronic components of the battery pack 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 (Elwert, *et. al.* (2016).

The share of materials by weight in traction batteries is presented in Figure 5.8.

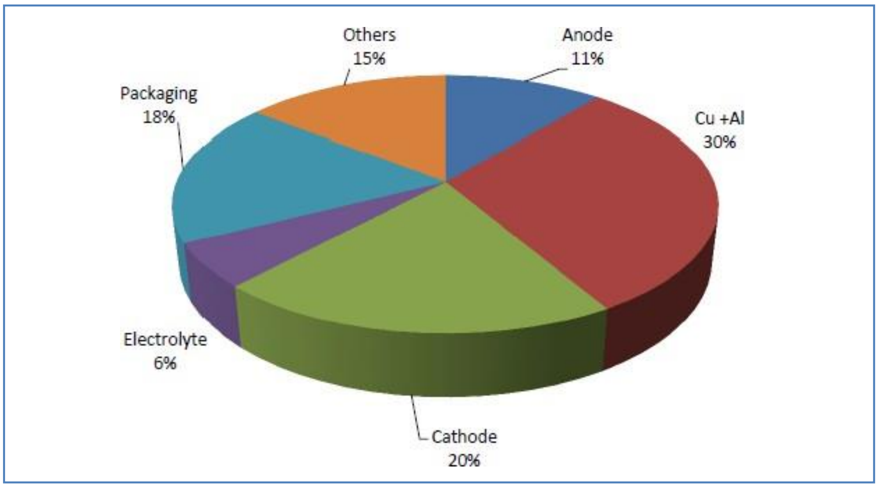

Figure 5.8: Material composition of traction batteries (by weight percentage)
Source: EU-REI 2018 (TERI- EV)

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 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 5.2 presents the efficiency parameters of the different types of motors.

Table 5.2: 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

Source: Widmer *et.al* (2015)

However, the real challenge remains in terms of accessing relevant information with regard to material specificity, weights, and at times, the 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 electric vehicles. NdFeB magnets contain about 30 per cent 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 per cent of dysprosium which helps in improving coercivity and temperature tolerance.

Apart from the motor, the other key components 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 electric vehicle 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 Figure 5.9.

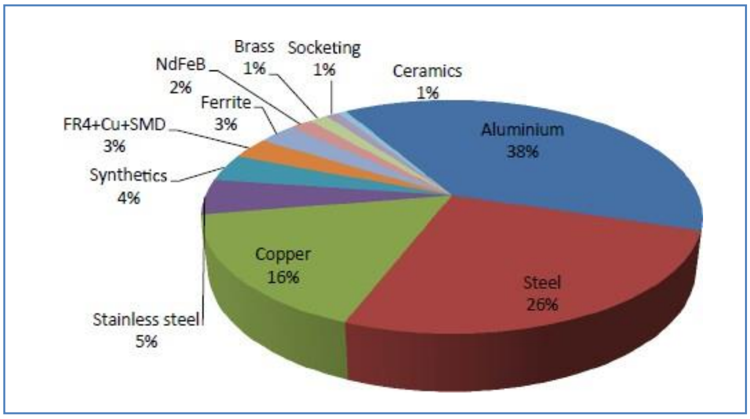

Figure 5.9: Material composition of electric drive motors (by weight percentage)
Source: EU-REI 2018 (TERI-EV)

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. The usage of iron and steel has come down over the years and has 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 per cent 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 a lightweight material, it helps in maximizing the range of the battery beyond those of other electric vehicles. The total amount of aluminium used in the car is 190 kg that constitutes to around 8 to 10 per cent of the vehicle weight. The share of materials by weight in gliders is presented in Figure 5.10.

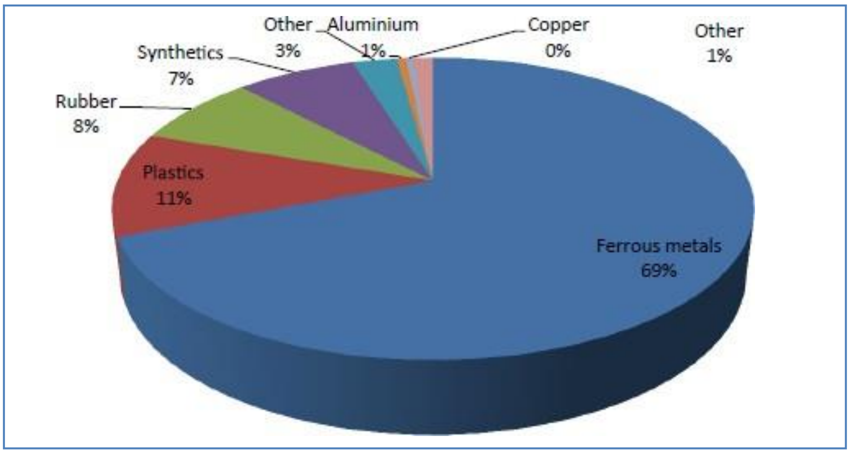

Figure 5.10: Material composition of glider (by weight percentage**)**
Source: EU-REI 2018 (TERI-EV)

5.2.3.4 Consumption of materials in electric vehicles (EV) and resource efficiency opportunities

The estimated material consumption is based on the projected production of the electric cars in India. Assuming that 70 per cent 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. This big change in manufacturing electric cars will increase 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 tonnes to 11 million tonnes. Ferrous metals will contribute to 53 per cent of the total estimated demand, followed by 17.4 per cent of plastics and synthetics, 2.5 per cent of aluminium and 7.2 per cent of copper. Figure 5.11 presents the materials that will be required to meet the cumulative demand for manufacturing nearly 24 million vehicles (hatchback) by 2030.

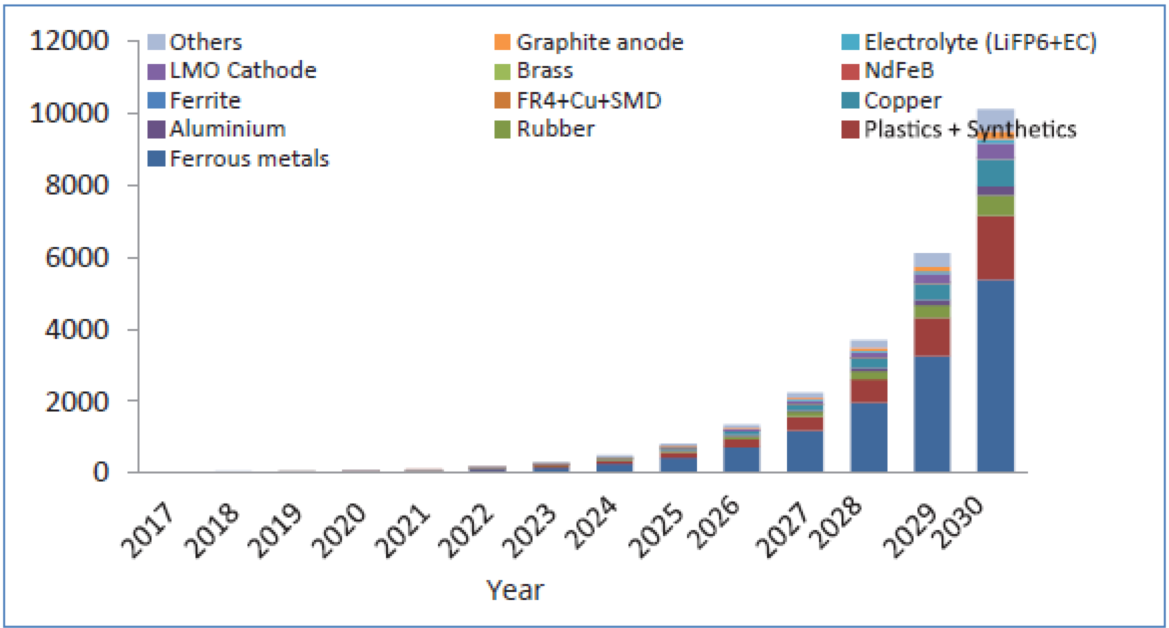

Figure 5.11: Material requirement for various four wheel electric cars (hatchback) in India till 2030 ('000 tonnes)
Source: EU-REI 2018 (TERI-EV)

With no change in material composition in three major components (that is, glider, drive train, and battery pack) of electric vehicles, the estimated demand for ferrous metals would increase from 0.016 million tonnes to 5.3 million tonnes. The estimated increase in consumption of plastics and synthetics would be nearly 1.8 million tonnes while the increase in copper would be around 0.8 million tonnes by 2030. Requirement of neodymium, iron, boron-fused permanent magnets would increase from 28 tonnes to almost 9000 tonnes while lithium-based cathode and electrolyte salts would increase from 2000 tonnes to 525,000 tonnes.

5.2.3.4.1 Developing magnets without rare earth materials

Neodymium is a member of the family of materials known as light rare earth elements (LREE). These magnets offer 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 demagnetization) of the magnets above 100 °C. Although the performance benefits of these NdFeB permanent magnets are undisputed, there are concerns over the availability, supply, and the prices of these rare earth materials. The high cost rare earth materials can be replaced by either recycled materials or low cost lanthanum and cerium. Reducing the use of NdFeB magnets would also entail significant environmental benefits as they are responsible for 25 per cent of the material related greenhouse gas emissions, despite being less than 5 per cent of the motor by mass (Widmer, J. *et.al* 2015).

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

The life cycle analysis of Lithium Cobalt Oxide based Lithium ion battery reveals a 70 per cent 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.

5.2.3.4.3 *Next Generation Batteries/Innovation in Battery Chemistries*

Solid-state battery technology is increasingly seen as the next big development in the electric vehicle 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. Solid state lithium ion technology has a real promise but this is clearly a moving target. Meanwhile other companies, such as 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.

5.2.3.4.4 *Design of EVs*

At the design stage, it becomes essential to have an extended use phase that not only delays the end of life 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 for 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, a design of vehicles which is receptive to using recycled/secondary raw material will reduce the chances of down cycling of recovered material from end of life vehicles. This should be accompanied by focusing on high-efficiency engines and lightweight materials which take less energy to accelerate the vehicle.

5.2.3.4.5 *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 to design for efficiency, mainstreaming powertrain integration offers substantial potential in terms of raw material savings and increasing efficiency. A good indicator for the increased level of integration is the design of the electric cables connecting the main electric vehicle powertrain components (that is, 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.

5.2.3.4.6 *End of Life management of EVs*

Recycling and reusing worn cathodes to make new lithium ion batteries

Less than 5 per cent of used lithium ion batteries are recycled today and with EV sales picking up, it implies that over time there will be substantial 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* useful life of components and recovering the embedded materials. However, there are energy-efficient recycling process that restore used cathodes from spent lithium ion batteries and make them work sufficiently good enough to restore the storage capacity, charging time, and battery 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.

Copper recycling from end-of-life electric vehicles

The Toyota Motor Corporation along with a number of partner firms in Japan, has 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 per cent 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 tonnes of copper to be produced annually using this recycling process.

5.2.4 Action areas

- Developing a sustainable and commercially viable EoL vehicle policy: CPCB had issued guidelines to regulate the sector in an environment-friendly manner, recommending a system of 'shared responsibility' involving all stakeholders—including government, manufacturers, dealers, insurers, consumers, and recyclers.[38] 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. India had earlier proposed a vehicle scrappage policy that sought to do away with commercial vehicles more than 20 years old. However, the same is yet to be finalized. The EoL vehicle policy should cover in its scope both the commercial and private vehicles and mandate the EoL to undergo proper deregistration, scientific dismantling, and material recycling. The policy should also propose clear and transparent ways to define ELVs. With this background, the suggested key elements of EoL vehicle policy should include:
    - Defining ELVs based on age, mileage, and emission criterion
    - Setting up of collection centres. (*Role of EPR in this regard is extremely crucial in identification of PROs, improving capacity building, sharing relevant technical knowhow amongst dismantlers).*
    - Exploring role of advance recycling fees and institutional mechanism
    - Setting up shredding centres that engage in segregation of materials for recycling. Automotive shredder residue (ASR) should be sent to incineration plants for energy recovery.
- Original equipment manufacturers need to develop guidelines/standard operating procedures (SOPs) to dismantle model and type of vehicle, which can prevent damage to components and encourage reuse of parts through proper channels. There should be labelling of components for easier identification of materials for proper segregation and downcycling.
- There is a need to encourage material substitution and promote use of recycled materials in new ICE and electric vehicle fleets. This could possibly start through setting up of modest targets for use of recycled materials for specific categories and their coverage can gradually be increased over time based on discussion with agencies including SIAM and ACMA.

5.3 Plastic sector

5.3.1 The plastic industry (with special reference to plastic packaging)

Synthetic polymers, also known as plastics, have transformed our lives in the last few decades. India's production of polymers has increased from nearly 5.7 million tonnes in 2009–10 to 9.16 million tonnes in 2016–17 that grew at a compound annual growth rate of

[38] Details available at cpcb.nic.in/openpdffile.php?id=TGF0ZXN0RmlsZS9MYXRlc3RfMTEzX0RyYWZ0X0d1aWRlbGluZXNfRUxWLTFfLnBkZg==; last accessed on April 8, 2019.

7.03 per cent. On the other hand, consumption has increased from nearly 7 million tonnes to 13 million tonnes posting a CAGR of 8.46 per cent where the consumption gap is largely met through imports. Table 5.3 presents the trend in production capacity, utilization factor, and exports and imports of polymer in India.

Table 5.3: Trend in production capacity, utilization factor, and exports and imports of polymer in India

	2009	2010	2011	2012	2013	2014	2015	2016
Capacity ('000 tonnes)	7,030	8,306	8,351	8,761	8,905	8,905	9,768	9,839
Production ('000 tonnes)	5,695	6,343	7,250	7,509	7,876	7,558	8,839	9,163
Capacity Utilization (%)	81	76.4	86.8	85.7	88.4	84.9	90.5	93.1
Imports ('000 tonnes)	2,160	2,500	2,435	3,180	3,125	3,737	4,214	4,452
Exports ('000 tonnes)	658	822	1,163	1,113	1,188	903	998	912

Source: Details available at
https://chemicals.nic.in/sites/default/files/Chemical%20and%20Petrochemical%20Statistics%20at%20a%20Glance%20-2017_0.pdf

Key polymers manufactured in India include (i) High density polyethylene (HDPE), (ii) Polyvinyl chloride (PVC), (iii) Polyethylene Terephthalate (PET), (iv) Low density polyethylene (LDPE), (v) Polypropylene (PP), and (vi) Polystyrene (PS). The trend in production of major polymers is presented in Figure 5.12.

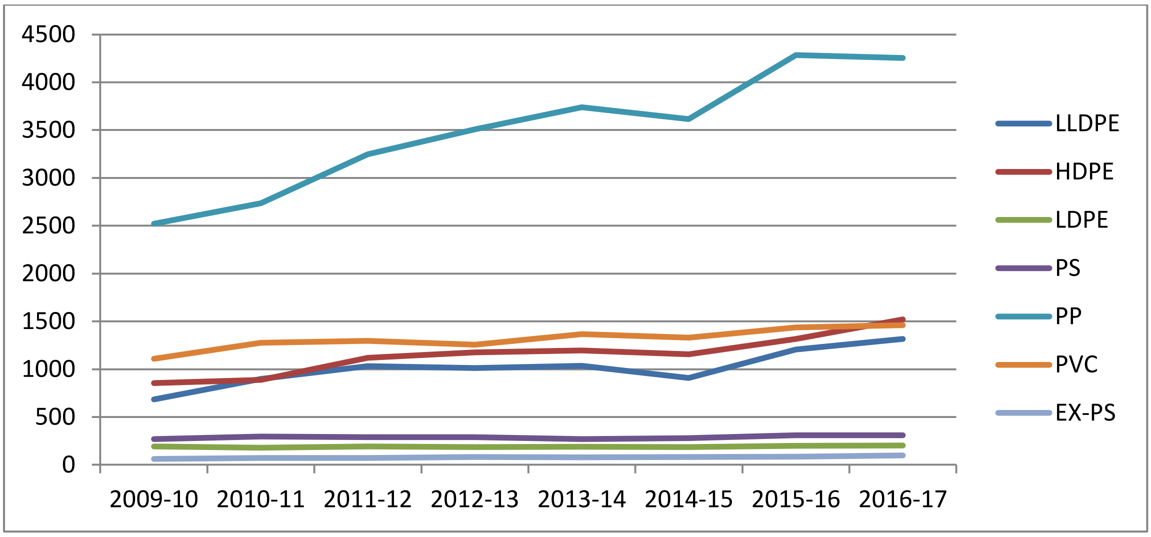

Figure 5.12: Trend in production of key polymers in India ('000 tonnes)

Source: Details available at
https://chemicals.nic.in/sites/default/files/Chemical%20and%20Petrochemical%20Statistics%20at%20a%20Glance%20-2017_0.pdf

The growth in production of PP has outpaced all other polymers. Between 2009 and 2016, production of PP has increased from almost 2.5 million tonnes to nearly 4.3 million tonnes. PP finds use in a variety of applications that include packaging, plastic parts for various industries including the automotive industry, consumer durables, and textiles.

India has also been catering to the demand for plastics in the international markets through exports. However, these exports have not been able to match the growing volume of imports and as a result, India maintains a trade deficit in the sector, especially relying heavily on imports of PE and PVC, mainly from China, South Korea, United States, and Japan. With regards to exports of plastics, major trade partners are the United States, United Arab Emirates, Germany, China, and Bangladesh.

The market structure is quite diverse for plastics manufacturing value chain (Figure 5.13). There is relatively lesser number of players in the upstream sector, which is dominated by 15 larger industrial groups. Industrial manufacturers control the market for supply of polymers alongside 200 equipment manufacturers which cater to roughly 30,000 plastic processing units. The end of life management of various plastics items is undertaken in the informal sector with an estimated 1.5 million workers involved (Federation of Indian Chambers of Commerce and Industry 2017).

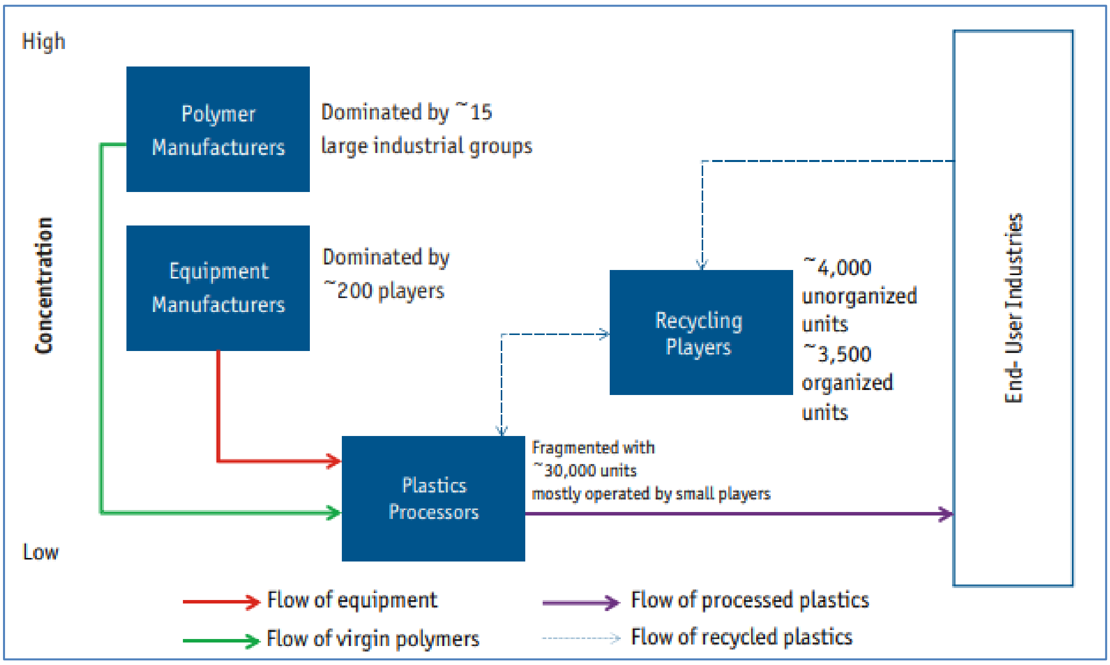

Figure 5.13: Value chain of plastic packaging industry in India

Source: Details available at http://ficci.in/spdocument/20872/report-Plastic-infrastructure-2017-ficci.pdf, based on CRISIL, Plastindia Foundation, Kanvic, TSMG Analysis

The polymers are used in a variety of sectors that include textiles, home furnishings, agriculture, packaging, infrastructure, healthcare, furniture, automobiles, electronics and telecommunication, construction, etc. As observed from Figure 5.14, packaging has the largest share (24%) in total domestic consumption followed by agriculture (23%), household items (including home furnishings: 10%), etc. The packaging segment reveals that PE and PP accounted for around 33% and 29% of polymer usage, respectively, followed by PET (17%), PVC (7%), and others (14%).

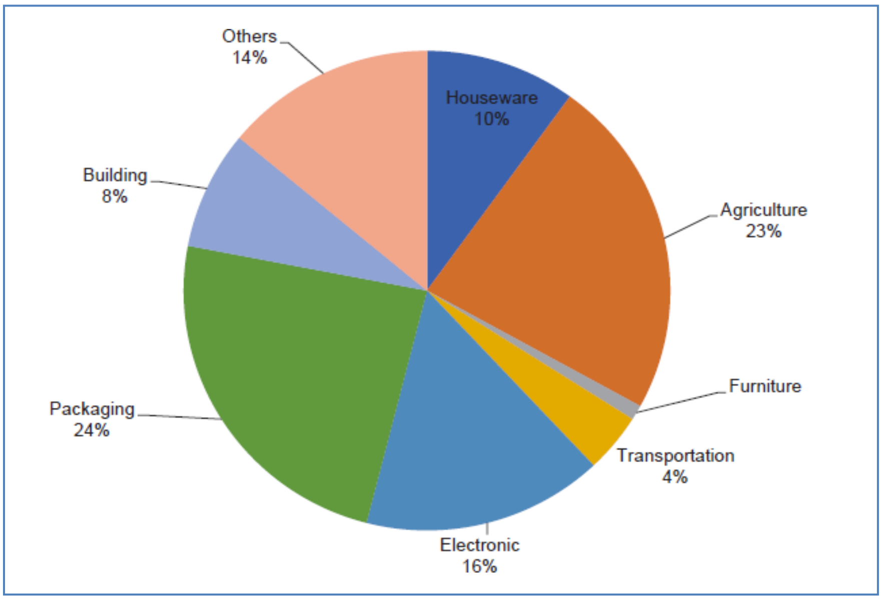

Figure 5.14: End-use application in different sectors in India

Source: EU-REI 2018 (adelphi -EPR)

Assessment by FICCI (2016) reveals that plastics is a preferred packaging material for most items consumed on a daily basis. This includes food items like biscuits and dried processed food, hair care products, cosmetics, etc. Packaging quality and form has changed rapidly in India in recent years, becoming more flexible and light, which has also made it cost effective, durable, and easy for transportation. Such packaging is either monolayer or multilayer films and may also contain a thin foil of aluminium — assigning it durability and extending shelf life of the items.

The average plastic consumption of 10 kg per capita in India (based on apparent consumption and population estimates of 2016) is significantly lower than the global average (28 kg per capita) and almost one-sixth of that of Europe (65 kg per capita) and one eleventh of the US (109 kg). Even countries such as China and Brazil have much higher consumption levels of 38 and 32 kg per capita, respectively. Apart from large population base, cheaper packaging and use of alternate packaging items especially in rural areas are often reported factors that make per person consumption relatively low in India. However, there is the enormous growth potential in the future for plastic consumption.

Box 5.3: Demographics and plastic consumption

> If India's population increases to 1.5 billion by 2030, and the average per capita consumption reaches 28 kg by 2025, from its current level of 10 kg, then the annual apparent consumption of plastics will increase to 56 million tonnes by 2030 from its current level of 13 million tonnes. This reflects almost a four times increase in consumption from its current level.

5.3.2 Plastic waste management: current practice

CPCB estimates reveal that India generates around 15,342 tonnes of plastic waste per day. Plastic contributes to nearly 8 per cent of the total solid waste, with Delhi leading the list of producers followed by Kolkata and Ahmedabad. The major challenge, however, is segregation and re-aggregation of plastic waste streams such as packaging waste, including laminated plastic. Efficient recycling is one of the preferred ways to deal with plastic wastes. However, there are concerns about the current practices of recycling which is mostly an informal sector activity. Further, there are issues associated with heterogeneous properties of unsegregated and littered plastic wastes. These wastes are often found to litter across various locations in urban areas, resulting in an unpleasant landscape, choking of drains, and release of GHGs from landfills at times leading to fire. Concerns have also been raised with regard to estimates on the volume of plastic waste generation that may not reflect the actual situation.

In order to address the growing problem of plastic waste disposal, the erstwhile MoEF&CC introduced the Plastic Waste Management Rules (PWR), 2011, under the Environment Protection Act, 1986. Amongst other things, it established a framework that assigned responsibilities for plastic waste management to the urban local body (ULB) and setting up of state-level monitoring committees. The issue of carry bags was addressed in the policy by setting minimum standards for the thickness and a mandate for retailers to charge fees for the same (TERI 2018). The earlier rules were succeeded by the Plastic Waste Management Rules, 2016 that made the rule more comprehensive. One of the most interesting features was the introduction of the extended producer responsibility (EPR) which is yet to experience an effective implementation. Further, the new rule also mandates the establishment of a centralized registration system where brand owners and producers operating in more than two states need to register with the CPCB, while the earlier rule required vendors, to register with the respective urban local body by paying an annual fee of Rs 48,000.

There is quite a large variation in estimates of recycling of plastic wastes. These range from 28 per cent to 42 per cent (Banerjee *et al.* 2013). Even higher numbers are reported by Atulesh (2011) who estimates a recycling rate of 60 per cent. For materials (e.g., PET bottles), recycling rates are reported to come close to 60 per cent. 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.

Although there has been a substantial progress in addressing the growing challenge of plastic waste management, yet there are opportunities for further improvement particularly when it comes to the implementation of rules. Before proposing the action areas, it is important to learn from some of the effective practices from other countries.

5.3.3 Plastic packaging in EU

EU has established a robust mechanism to deal with the growing volume of plastic waste in the country. The region produced around 49 million tonnes of plastics and generated around 25.8 million tonnes of plastic waste. Further, 15.8 million tonnes of plastic packaging waste is generated. On an average, 42 per cent of plastic packaging waste was recycled in 2016. In eight EU Member States, more than half of the plastic packaging waste generated was recycled in 2016. EU's Circular Economy Action Plan did identify plastics as a key priority and is committed to deal with challenges posed by plastics throughout the value chain and taking into account their entire life-cycle. European Strategy for Plastics in a Circular Economy was published in 2018 that aimed at bringing a radical transformation in plastic design, production, usage, and their recycling (EU 2018). One of the unique measures adopted is the integration of chemical industry with plastics recyclers to help them find wider and higher value applications for their output. Further legal obligations for member states in terms of recovery and recycling targets have also been set.

5.3.4 Extended producer responsibility for plastic waste management

Extended producer responsibility (EPR) scheme has been introduced in 26 of the 28 EU member states (Watkins Emma *et al.* 2017), with first implementation efforts starting as early as the 1990s. The schemes vary greatly in terms of set-up, financial performance, and responsibilities of producers. Schemes from selected countries are presented below:

- Austrian EPR scheme finances 100 per cent of collection and net treatment costs.
- UK system covers 10 per cent of the costs for managing household plastic waste.
- Italian National Packaging Consortium was formed in order to support compliance with the EU Directive on Packaging and Packaging Waste. The current average rate for plastic is €188.00/tonne).
- Fost Plus, a Belgian producer responsibility organization, was founded in 1994 as a voluntary initiative of the private sector. It is accredited in Belgium for the collection and recycling of household packaging waste. Green Dot tariffs applied by Fost Plus are differentiated by packaging material such as ‘drink carton’ or ‘PET bottle’. The latest rates for HDPE/PETs is €210/tonne.
- In France, there is a collective EPR scheme for household packaging waste, called Eco-Emballages (now CITEO). It encourages selective waste collection and thereby reducing packaging waste and also create interface between various stakeholders according to environmental criteria, rewarding good sorting practices and eco-design, and penalizing packaging which hampers recycling. CITEO has been delivering solutions and business. Producers need to ensure effective managing of end-of-life of the products that are placed in the French market by them. The companies are initially supposed to finance extra costs of selective collection and when the 75 per cent packaging recycling targets are met, the costs come down to 80 per cent of the net costs. Local authorities are responsible for managing waste.[39] In 2012, fees charged to producers have been moderated to its 50,000 client enterprises. In 2016, the packaging waste recycling rate increased to 68 per cent from its level of 18 per cent reported in 1993. 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.

In case of the Netherlands, a part of the Dutch EPR system and the Packaging Decree, the government has signed agreement with the packaging industry as well with the Association of Dutch Municipalities. A centralized packaging waste fund is created where producers are supposed to contribute. The proceeds of the funds are used to compensate urban local bodies (ULBs) to meet the expenses incurred in collecting separated packaging waste. At the

[39] Details available at ieep.eu/uploads/articles/attachments/95369718-a733-473b-aa6b-153c1341f581/EPR%20and%20plastics%20report%20IEEP%209%20Nov%202017%20final.pdf?v=63677462324 ; last accessed on 9 April, 2019.

same time, EPR scheme supports innovation plans and design to support the objective of improving sustainability of packaging value chain. Such 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 selected ministries.

5.3.5 Action Areas

- There is need for the municipalities to design plans in accordance with the Plastic Management rules to ensure scientific management of plastic waste. Producers and brand owners need to partner with municipalities to ensure developing the implementation plan of their EPR mandates.
- A local/state level packaging waste fund needs to be created where producers will contribute to compensate urban local bodies to meet the expenses incurred in collecting and segregating packaging waste.
- To enable sourcing back of plastic packaging waste, joint ventures could be designed between companies/not-for-profit (e.g., PROs) entities that can support municipalities.
- Strengthening of ward-wise material recovery facilities, coupled with the EPR implementation, and integration with the recycled products industry would accelerate India towards a circular economy.
- Innovative packaging product design and development will help to create opportunities across various sectors. For example,
    - Development of high-performance and value-added recycled products either commodity-wise or with commingled plastics require the development of innovative solutions which focus on increased mechanical properties (at par with virgin plastic) that are tailor-made to meet the special needs, such as recycled fire-retardant plastics, hydrophobic coatings, and so on. These products can cater to the building sector, furniture industry, packaging, and automobile industry.
    - Amongst the other sustainable alternatives for plastic waste management, co-processing of plastic in cement kilns offers a sound, environmentally-viable mechanism to process non-recyclable, combustible plastic waste.
    - Integration of mixed plastic waste with bitumen is becoming an attractive and accessible option for municipalities owing to the unsegregated nature of waste, improved quality of roads, and pothole filling.
- At a more macro level, there is a need to handhold the industry and academia for the development of innovative products, providing support for the establishment of product standardization processes in association with BIS and creation of certification labs that can help better facilitate the assessment of quality and performance of the developed recycled packaging material.

5.4 Construction and demolition sector

5.4.1 Introduction

India has experienced unprecedented growth in urbanization in recent decades. More than 30 per cent of India's population is already living in urban areas and an estimate of the UN State of the World Population report says that more than 40 per cent 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 related to housing. However, there is simultaneous demand for other infrastructure facilities particularly roads, commercial establishments, and public services.

With a current contribution of 8 per cent to India's GDP, the construction sector is the second largest in terms of employment generation after agriculture and is projected to grow at a rate of 7 per cent–8 per cent 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 per cent of buildings supposed to exist by 2030 are yet to be built. Meeting this demand for infrastructure will rely heavily on availability of 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 as well as address the 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 strengthen the competitiveness of industries. As one of the largest consumer of resources in the country today, the construction sector needs to urgently emphasize and integrate resource efficiency in its processes and inputs.

5.4.2 Materials in construction and demolition sector and resource efficiency opportunities

In order to study the opportunities of resource efficiency in the sector, it is critical to understand the important stages of the life cycle in the sector and also identify hotspot stages that promise high efficiency potential. The value chain of the construction sector is presented in Figure 5.15.

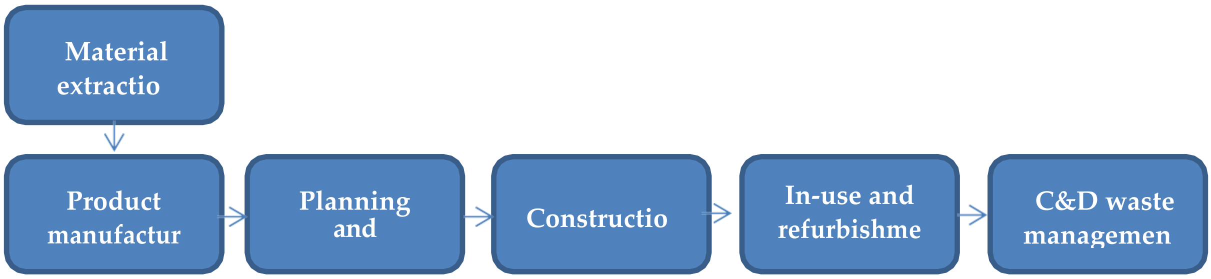

Figure 5.15: The construction value chain

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, and ensure through planning and design that resource efficient materials are used. Further, dependence on virgin materials needs to be gradually reduced through substituting its use by construction and demolition wastes. An estimate from an earlier TIFAC study suggested that on an average India generates around 12–15 million tonnes of C&D waste per annum. This has increased to nearly 100 million tonnes as estimated by MoHUA recently. 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 generation in the range of 45–50 kg/m^2. However, demolition can lead to waste generation of 425 kg/m^2. 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 m^3 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 of infrastructure (EU-REI 2018 (adelphi –C&D).

Among various materials that are used in the construction sector sand needs special mention and assessment. 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 option 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 to identify and use alternatives of sand. Ecological impacts related to sand mining, include 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 km towards manmade embankments which was a part of the flood plains of the Yamuna River. 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 5.16 depicts material flow of sand in India.

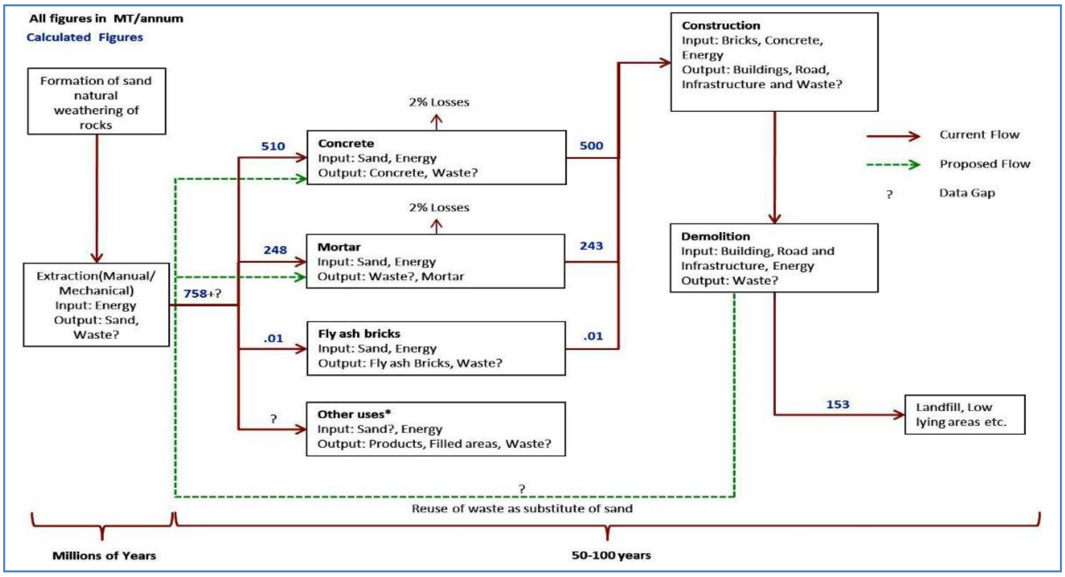

Figure 5.16: Material flow of sand in India
Source: GIZ-TERI-DA-IFEU-VDI (2016)

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 these procedures. Further, royalty for sand varies from Rs 0 to Rs 93 in different states and the bulk density used for conversion of units of royalty is also dissimilar 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.

Construction activities will push up demand for stones largely used as coarse aggregates. Granite and basalt are common choices for such application. Although India is estimated to have a deposit of more than 120 billion tonnes of granite, yet their extraction and crushing have serious environmental consequences. Basalt deposits is covered across an area of 0.6 million sq.km. Mining process of these stones require, drilling, blasting, processing and transportation, that has serious impacts on air quality. Further, extraction of these resources has serious land use implications. Not only it leads to land degradation, but also becomes a major source of conflict over traditional land usage. Degradation mostly arises from soil contamination as well as removal of top soil. Sludge generated during granite washing and processing leads to siltation at processing sites. Their processing is energy intensive too. Using recycled aggregates as alternate material such as those derived from C&D waste, will help in reducing dependence on virgin resources.
Limestone, a key ingredient for manufacturing cement, has seen increased consumption in recent times with growing demand for infrastructure. Although, India has substantial reserves of limestone (15 billion tonnes), yet there are serious environmental and social issues associated with limestone extraction which is similar to those of sand mining. Out of the available resources of nearly 175 billion tonnes of cement grade limestone, nearly 30 percent falls under forest coastal zone and regulated areas. This will make accessing limestone all the more challenging in the future and further reiterates the fact that there is a need to shift to alternate materials for cement production. There is greater requirement for blending fly ash and appropriate industrial and mining wastes that eventually can reduce demand for limestone consumption particularly in cement manufacturing.

5.4.3 Action areas

The responsibilities for managing the C&D waste rests with the local bodies and this is a big challenge for them. The C&D Waste Management Handling (Rules), 2016 mentions that 'every waste generators shall be responsible for collection, segregation of concrete, soil and others and storage of construction and demolition waste generated separately, deposit at collection centres so made by the local body or handover it to the authorized processing facilities. In most cases, there is 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 mention giving incentives for use of material made out of the wastes. The Rules also specify that all government construction projects, at all levels, should utilize between 10 per cent and 20 per cent 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 made out of wastes. Consumers have little or no understanding about the collection points from where the debris can be collected and transported to processing sites. With this background, the suggested action areas include:

- *Setting up designated areas for collection of C&D waste and penalizing illegal dumping*: It is extremely critical to identify designated areas where consumers responsible for managing the waste from the demolition activity they have undertaken to dump the C&D waste are notified. To prevent illegal dumping at non-designated 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 illegally dump waste and will further motivate the generator to transfer the waste to the notified collection points.
- The collection of wastes at designated collection points will create volumes thereby incentivizing waste processors to establish decentralized waste processing units. This opportunity should be tapped. Currently, in India 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 number of C&D waste processing plants (220), while the UK, the Netherlands and Belgium have estimated 120, 70, and 60 plants, respectively. Given the potential C&D waste 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.
- *Creating fund for incentivizing buying of 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. For this, property taxes could be rationalized periodically to reward/incentivize the use of secondary raw material. Funds can be allocated not only for incentivizing product development from recycled C&D waste but also possibly supporting demonstration projects. 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 financially self-sustaining.

- As a part of the mandated public procurement of materials made from C&D waste, the ULBs need to explore avenues on setting targets for the use of C&D waste. For example, there are opportunities for using these products for recreational purposes (parks, etc.), for roads and pavements and filling of pits, and also in constructing buildings. This is possible when there is short-, medium-, and long-term planning of construction activities integrating such use being undertaken in advance.
- *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 amongst potential buyers. Certification is an important way to improve market acceptance of products such as tiles, paver blocks, and manufactured bricks. The role of BIS is extremely critical here by way of adopting faster certification of products that are launched and commercialized. In 2016, BIS revised 383 standards to allow specific uses of recycled coarse and fine aggregates with certain conditions. The National Building Code of India (2005) also allowed the use of recycled aggregates in certain applications. For example, up to 30 per cent of natural crushed coarse aggregate can be replaced by the recycled concrete aggregate and this can further be increased to 50 per cent for pavements and other specific applications. ULBs need to maintain a list of authorized sellers of these products and whose details can be provided in e-market place for the larger benefit of the consumers.
- *Technical support to new entrepreneurs*: Another hurdle faced in the effective use of secondary material streams like C&D waste is the availability of 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 for 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 with technology access and transfer and bring in better knowhow from other countries.
- *Monitoring 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, the progress on the same is not clear as these details are not shared publicly. To address this lack of clarity, there should be proper reporting mechanism and time frame (e.g., 3–5 years) for enforcing strict adherence with any violations drawing possible penal action.
- *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 on C&D waste through collaboration with expert institutions and civil society organizations and disseminate the same 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, and others.

5.5 Electronic waste sector in India

5.5.1 Introduction

India has emerged as a major market for electrical and electronic products. From an estimated market of $69.6 billion in 2012, the electronics market is estimated to reach $400 billion by 2022, although certain studies have revealed that such size may be achieved as early as 2020. Conducive policy environment in the sector has attracted strong investments in the form of green field investment and mergers and acquisition. Government of India's push towards manufacturing through Make in India and Digital India Mission need special mention in the context as they have promoted research and development and production across product categories, such as telecom, television, computers, lighting, and so on.

India's Electrical and Electronic Equipment (EEE) industry is expected to grow considerably during the coming 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.). The recent trend in production of different products is presented in Figure 5.17.

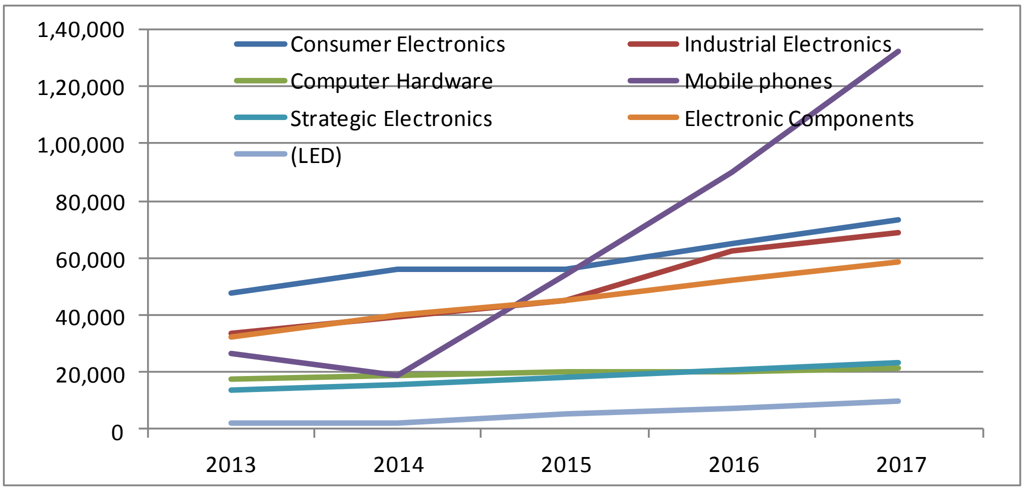

Figure 5.17: Production of electronics sector (in rupees crore)

Source: Details available at https://www.meity.gov.in/writereaddata/files/Annual_Report_2017%E2%80%9318.pdf, last accessed on 9 April 2019

In terms of the market share of these products, mobiles phone has the largest share of 34 per cent, followed by consumer electronics (19%) and industrial electronics (18%). Electronic components (including semiconductors) have a market share of 15 per cent, while computer hardware and strategic electronics have a market share of 6 per cent each (Figure 5.18).

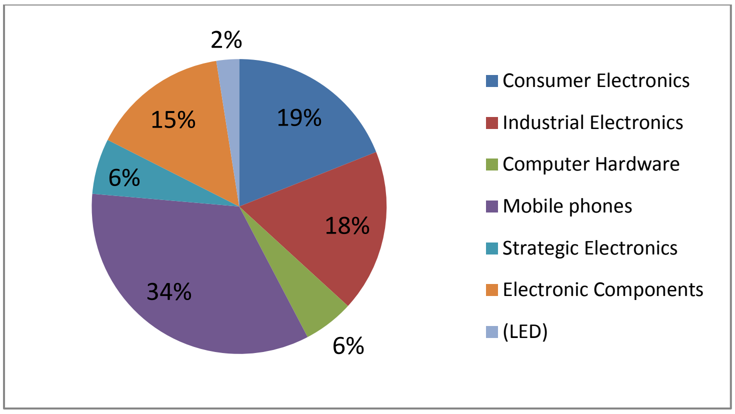

Figure 5.18: Market shares of the different electronic products based on 2017 estimates

Source: Details available at https://www.meity.gov.in/writereaddata/files/Annual_Report_2017%E2%80%9318.pdf, last accessed on 9 April 2019

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

5.5.2 E-waste generation and management issues in India

One of the immediate outcomes of the recent upsurge in the electrical and electronic sector is the growing volume of waste generation. 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 tonnes of e-waste in 2016. However, the e-waste sector has the potential to generate up to 300,000 jobs, and can generate revenue over $3 billion per annum. According to ASSOCHAM India (2017), the amount of e-waste is growing at CAGR 30% and will reach more than 5 million tonnes per year by the end of this decade. Maharashtra ranks highest in terms of e-waste generation, followed by Delhi (21.20%) and Bengaluru (10.10%). This is presented in Figure 5.19.

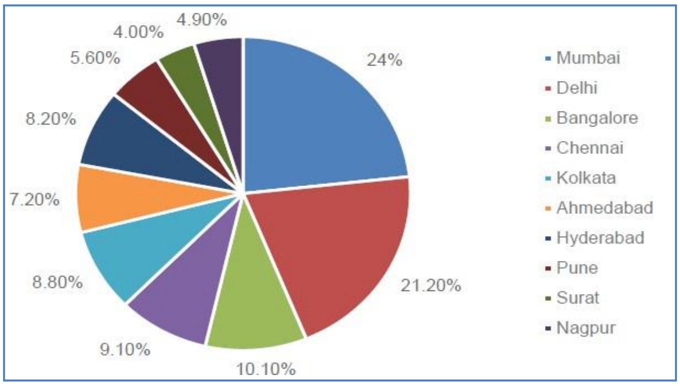

Figure 5.19: Top ten city-wise generation of e-waste in per cent

Source: EU-REI 2018 (adelphi - EPR)

There are many challenges associated with current management of e-waste. Since majority of the e-waste is handled in the informal sector the rate of recovery is very poor, leading to substantial loss in valuable resources. Since they operate in small scales the cost of recovery sometimes is very high. 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. Hazardous substances, their occurrences and impacts on human health and environment is presented in Table 5.4.

Table 5.4: Hazardous substances, their occurrences and impacts on human health and environment

e-Waste components	Toxic metals	Limit, ppm	Disease caused by the exposure to above permissible limit
Ceramic capacitors, switches, batteries	Ag^a	5.0	Excessive amount causing blue pigments on body, damages brain, lung, liver, kidney
Gallium arsenide is used in light emitting	As^b	5.0	Chronic effect and causes skin disease and lung cancer and impaired nerve signaling.
Electron tube, lubricant, fluorescent lamp, CRT gun	Ba^b	< 100	Causes brain swelling, muscle weakness, damage to the heart
Power supply boxes, motherboard	Be^b	0.75	Causes lung cancer, beryllicosis, skin disease, carcinogens
PCBs, casing, PVC cables	Br^b	0.1	Thyroid gland damage, hormonal issues, skin disorder, DNA damages, hearing loss
PCBs, battery, CRTs, semiconductors, infrared detectors, printer ink, toners	Cd^b	1.0	Pose a risk of irreversible impacts on human health particularly the kidney
Printed circuit boards (PCBs)	CN^b	< 0.5	Cyanide poisoning, > 2.5 ppm may cause to coma and death
Plastic computer hosing, cabling, hard discs, as a colorant in pigments,	$Cr(VI)^b$	5.0	Toxic in the environment, causing DNA damage and permanent eye impairment
Batteries, LCD, switches, backlight bulbs or lamps	Hg^b	0.2	Damages brain, kidney and foetuses
Mobile, telephone, batteries	Li^a	< 10d	Diarrhea, vomiting, drowsiness, muscular weakness
Batteries, semiconductor, CRT, PCB	Ni^a	20.0	Causes allergic reaction, bronchitis, reduces lung function, lung cancers
Transistor, LED lead-acid battery, solder, CRT, PCBs, florescent tubes	Pb^c	5.0	Damages brain, nervous system, kidney, and reproductive system, causes acute and chronic effects on human health
CRT glass, plastic computer housing and a solder alloy	Sb^b	< 0.5	Carcinogen, causing stomach pain, vomiting, diarrhea and stomach ulcer
Fax machine, photoelectric cells	Se^b	1.0	High concentration causes selenosis
CRT, batteries	Sr^c	1.5	Somatic as well the genetic changes due to this cancer in bone, nose, lungs, skin
Batteries, luminous substances	Zn^b	250.0	nausea, vomiting, pain, cramps and diarrhea
Cooling units and insulation foam	$CFCs^b$	< 1.0 for 8 h/day	Impacts on the ozone layer which can lead to greater incidence of skin cancer
Transformer, capacitor, condensers	$PCBs^b$	5.0	PCB causes cancer in animals and can lead to liver damage in human
Monitors, keyboard, cabling and plastic computer housing	PVC^b	0.03	Hazardous and toxic air contaminants, release of HCl causes respiratory Problems

Source: Details available at www.iosrjournals.org/iosr-jestft/papers/Vol12-%20Issue%2011/Version-1/B1211010816.pdf, last accessed on 9 April 2019

Discarded electronic items contain many materials that can fetch high value. Such materials include iron, aluminium, gold, nickel, silver, platinum, etc. An indicative list of material composition in selected electronic products is presented in Table 5.5. 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 billion–$1 billion. Furthermore, 1 tonne of ore has an extractable reserve of about 1.4 g of gold while a tonne of mobile phone PCBs can produce about 1.5 kg.

Table 5.5: Indicative list of material composition in selected electronic products

S.No	E-Waste	Weight (%)					Weight (ppm)		
		Fe	Cu	Al	Pb	Ni	Ag	Au	Pd
1	TV board scrap	28	10	10	1	0.3	280	20	10
2	PC board scrap	7	20	5	1.5	1	1000	250	110
3	Mobile phone scrap	5	13	1	0.3	0.1	1380	350	210
4	Portable audio scrap	23	21	1	0.14	0.03	150	10	44
5	DVD player scrap	62	5	2	0.1	0.05	115	15	4
6	Calculator scrap	4	3	5	0.1	0.5	260	50	5
7	PC main boar scrap	4.5	14.3	2.8	2.2	1.1	639	566	124
8	Printed circuit board scrap	12	10	7	1.2	0.85	280	110	NR
9	TV scrap (CRTs removed)	NR	3.4	1.2	0.2	0.038	20	<10	<10
10	Electronic scrap	8.3	8.5	0.71	3.15	2.0	29	12	NR
11	Pc scrap	20	7	14	6	0.85	189	16	3
12	Typical electronic scrap	8	20	2	2.	2	2000	1000	50
13	E-scrap sample	37.4	18.2	19	1.6	NR	6	12	NR
14	E-scrap sample	27.3	16.4	11.0	1.4	NR	210	150	20
15	Printed circuit board	5.3	26.8	1.9	NR	0.14	3300	80	NR
16	e – scrap (1972 sample)	26.2	18.6	NR	NR	NR	1800	220	30
17	E-waste mixture	36	4.1	4.9	0.29	1.0	NR	NR	NR

Source: Details available at www.iosrjournals.org/iosr-jestft/papers/Vol12-%20Issue%2011/Version-1/B1211010816.pdf , last accessed on 9 April 2019

According to Sinha *et al.* (2010), the first stage includes cannibalization of functioning parts which can be reused. The defunct parts are shifted to dismantlers where individual products or components are further dismantled and broken down to individual components manually using very crude processes. Printed circuit boards are melted to loosen solders. Since such processes are undertaken in closed chambers, the process becomes extremely hazardous and raises occupational health and safety concerns. 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 PCBs. 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.

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.

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. Producer role has been clearly defined under the EPR where targets have been fixed for each year for the quantum of e-waste to be collected. This is an innovative step towards making India resource secure by promoting proper disposal of e-waste and ensuring effective recovery of materials. The bulk consumers of e-waste have been mandated to ensure that they dispose the e-waste in an environmentally sound manner. The refurbishers need 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 or dismantler of e-waste. Producers can set up Producers Responsibility Organization (PRO) which can manage collection and safe disposal of e-waste as per the targets stated in the e-waste management rules, 2016. However, many challenges continue to exist for the e-waste management in India including those that arise from ineffective implementation of current policies, awareness issues, high costs due to poor scale effect, absence of documentation, and fragment reverse logistics.

5.5.4 Action areas

The informal sector has been at the heart of recycling of WEEE in India for the last two decades and the 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 for managing e-waste in the country. It is crucial that the sector is integrated with the formal recycling set-up and provided access to recycling technology that mitigates the hazardous effects of environment and human health. The integration of the informal sector would be the key to ensure that collection costs are also brought down to sustainable levels. With this background, the suggested action areas for improving resource efficiency in the e-waste sector include:

- EPR is an effective instrument that can help in making available best technologies to the recyclers. 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 and they need to be promoted as a part of the EPR. Licensing such technologies at very low cost to informal sector with appropriate training will not only help in creating markets for such new technologies but also help in improved recovery of materials and better working conditions. The fact that EPR can play an important role in providing finances that is needed for efficient and sustainable recycling could be implemented through setting up the advanced recycling fees (ARF) on EEE products. Such fees can be collected at the state level which can be used to finance technology licensing cost to the informal sector.
- 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. There is a need to gradually introduce penal system in case of non-compliance and the financial resources thus collected can be used for providing access of recycling technologies to the informal sector. While it is a good step adopted in preventing export of high valued e-wastes to other countries, recyclers from other countries should also be encouraged in establishing recycling facilities in India.
- Provide support to the informal sector in the form of 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 their livelihood in ways and means which will comply with the law, and access to finance so that they are able to invest in equipment and infrastructure and work within the legal framework. Business models that can lead to technology provision to the informal sector need to be developed.

- Integration of the informal sector with the formal sector should be promoted. Two of the ways to do this are: (i) through locating their work in industrial clusters such that effluents can be properly managed and environmental risks can be mitigated; and (ii) through creating a monitoring mechanism in such clusters to mitigate the human health risks as well. The industrial clusters for e-waste management can be set up either by co-locating the e-waste management industrial cluster in a manufacturing cluster, or by locating e-waste management cluster in hubs where the informal actors have been working.
- Manufacturers of EEE products need to put circular economy principles into practice in the production process and for this availability of secondary raw materials is the most crucial factor. The availability can be encouraged through 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, standardization of technologies being used for extraction of the secondary material during the recycling process, and facilitating voluntary certification by recyclers as the demand for secondary materials increases. This will also provide a fillip to the precious metal recycling sector in India, thereby promoting the Make in India mission.

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 witnessed 6.2 per cent growth in steel production capacity and has reached more than 100 MT thereby making India the third largest steel producer and may move up its position soon to be the second largest, surpassing Japan (NITI 2019 Steel). Steel industry is estimated to contribute nearly 2 per cent share to India's national income as well as provide employment to 25 lakh people, directly or indirectly. The stainless steel industry is a very niche subsector that contributes both in meeting domestic requirement as well as exporting the special steels. India is also the second largest stainless steel producer in the world.

Year-wise increase in production, total consumption, and per capita consumption of steel is presented in Figure 5.20.

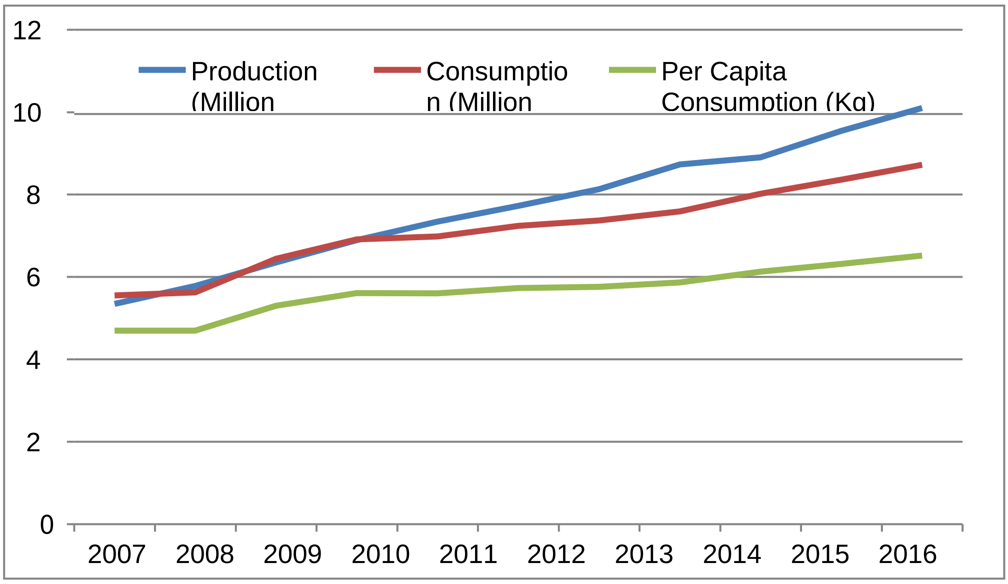

Figure 5.20: Change in production and consumption of steel in India

Source: Details available at www.niti.gov.in/writereaddata/files/RE_Steel_Scrap_Slag-FinalR4-28092018.pdf, last accessed on 9 April 2019

Steel manufacturing output of India is expected to increase to 128.6 (million tonnes) MT by 2021, accelerating the country's share of global steel production from 5.4 per cent in 2017 to 7.7 per cent by 2021. A sector-wise break-up in steel consumption reveals that construction industry has the largest share of 35 per cent followed by infrastructure development (20%) and automobiles (12%). 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 growth of steel consumption has a very high potential. Figure 5.21 presents the sector-wise steel consumption in India.

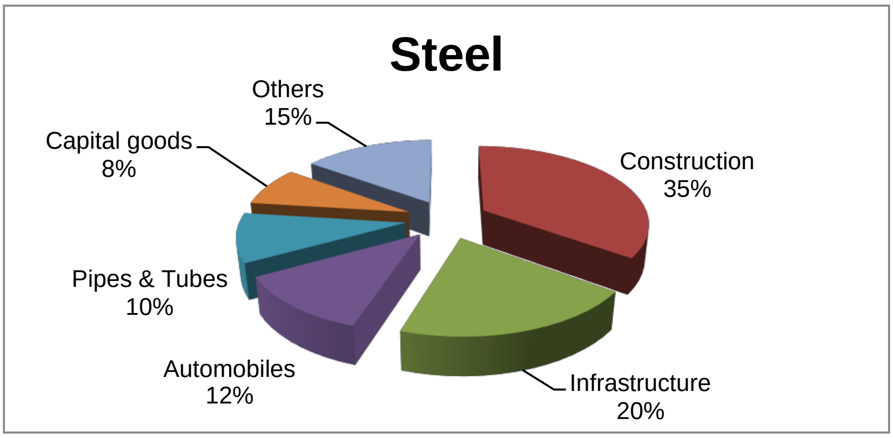

Figure 5.21: Sector-wise steel consumption in India

Estimates by the Ministry of Steel reveal that India's per capita steel consumption will increase 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 tonnes 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 lakh by 2030–31 from the current level of 25 lakh, i.e., around 1 million additional work-forces through direct and 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 period also 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 MT and 14 MT by 2030.

However, challenges remain in terms of meeting domestic requirement of steel in the key sectors particularly automobile, electrical, aviation, engineering, and machineries resulting in substantial imports in recent years.

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 steelmaking 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 5.6.

Table 5.6: Installed capacity and production of steel from different routes[40]

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

[40] Details available at www.niti.gov.in/writereaddata/files/RE_Steel_Scrap_Slag-FinalR4-28092018.pdf, last accessed on 9 April 2019

The production of crude steel from BF-BOF route contributes around 45 per cent of India's steelmaking capacity while the remaining 55 per cent 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 reveals that there are approximately 42 electric arc furnaces; 1,126 induction furnaces; and more than 300 sponge iron producers; and around 1,157 small- and medium-sized steel rerolling mills spread across India. India's MSME steel sector contributes around 30 per cent of the total steel production. Figure 5.22 presents a typical process flow of steelmaking.

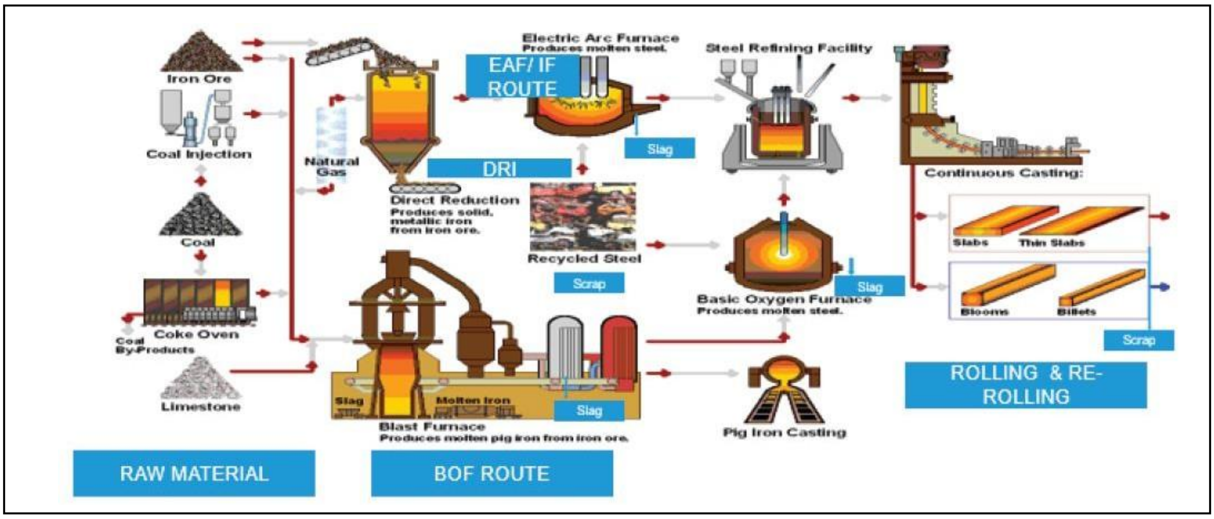

Figure 5.22: Steelmaking process in India

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 and also provides the required thermal energy. The product is further purified through BOF process to produce steel. Natural gas needs to be explored as an alternate fuel in BF operation, which can help in reducing consumption of coke. India is heavily import dependent on coke and this replacement can be very cost effective while reducing SO_x and CO_2 emissions and also 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. These 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 1980s introduced continuous casting that not only reduced wastage but also cost and energy. A quick analysis of material embodiment in 1 tonne of steel produced from BOF route suggests that the same contains nearly 1.4 tonnes of iron ore, 0.55 tonnes of coking coal, 0.25 tonnes of limestone, and 1.9 tonnes of air. Byproducts consist of 0.3 tonnes of slag, 2.4 tonnes of BF gases, and up to 0.05 tonnes of dust. Further, the estimated CO_2 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 per cent in the total steel production, India will require 315 MT of iron ore per annum, 123 MT of coking coal, and 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 CO_2 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 furnace is another steelmaking technology which varies in size from small units of 4–5-tonne capacity to as large as furnaces of 250-tonne capacity. Some of the producers 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 tonne of steel in EAF is approximately 440 kWh. The furnace can be operated with 100 per cent 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 steelmaking using the EAF route is only 20 per cent in India, the same in the US and EU is as high as 64 per cent and 40 per cent, 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 the mid-1980s, 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 the 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, such as financing, capacity building, supply chain management, logistics, 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 producer of steel 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 made out of steel. 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 the 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 involved in steel manufacturing can grow meeting all environmental norms and adopting the best available technologies for sustainable development. Improving scrap processing will help in (i) Adopting the principle of 6R's, i.e., Reduce, Reuse, Recycle, Recover, Redesign, and Remanufacture and thus improving global competitiveness; (ii) Reduction in the energy intensity/tonne of steel aims to fulfil commitment in COP21; (iii) Optimum utilization of natural resources; (iv) Focus on recovery of energy (heat, gas); (iv) Adoption of energy efficient and environment-friendly technologies; (v) Benchmarking of secondary/MSME and prioritization of investments; (vi) Moving towards Zero Discharge Zero Waste and Zero Harm regime.

Recycling of one tonne of scrap saves 1.4 tonne 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 per cent to 17 per cent. It also reduces the water consumption and GHG emission by 40 per cent and 58 per cent, respectively. Thus, the use of scrap as a main source of raw material for steelmaking enhances the sustainability of the steel sector and also results in 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 the World Scrap Association (WSA) estimates, global ferrous scrap availability will reach 1 billion tonnes by 2030. Scrap consumption is driven by the price differential between scrap and hot metal, and tends to correlate closely with the prices of iron ore and coking coal. Steelmakers make trade-off based on this input price 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, such as 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 state-of-the-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-the-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 fair price mechanism between OEM and scrap processing centre, land acquisition, and tax structures.

Interventions also may be required to accord status either under 'Industry Status' or 'Infrastructure Status' to scrap recycling sector to enable promoters to arrange for capital requirement and also ensure statutory compliance w.r.t safety, health, and environmental norms. Higher scrap usage will promote larger volume of production of steel through EAFs, leading to a cleaner and greener industry.

The potential for revenue generation in steel scrap industry is of the order of Rs. 2,000 crore/ million tonne 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 the National Institute of Secondary Steel technology (NISST), Biju Patnaik National Steel Institute (BPNSI), etc., may fulfil this gap by formulating the academic and research courses for the capacity development 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 announcement is still awaited. This is mainly because old vehicles are considered as fuel inefficient and found to be one of the main source of pollution and CO_2 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 numerous 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 the National Capital Region.

5.6.3.2 Slag utilization

During steelmaking, all the unwanted elements present in the raw materials are removed as 'slag' by use of various fluxes so that maximum recovery of iron is ensured. Iron & steel making processes thus generate huge amount of slag which is basically a non-metallic product consisting of calcium silicates and ferrites, combined with fused oxides of iron, aluminium, manganese, magnesium, calcium, phosphorous, etc. Iron making slags, known as blast furnace (BF) slag are predominantly utilized in the cement making, but the steel making slags, both from BOF (also known as LD Converter) as well as EAF/IF furnaces have limited usages. Thus, a major portion is dumped in open areas which occupy a large area in any plant. Sustainable use of slag shall contribute to natural resource saving and CO_2 emission reduction and also provide ecological advantage.

Steel slags are partially consumed at steelworks itself but has other applications also like in cement, as road/highways, building material, fertilizer, and as waste in landfills. However, in India, the importance of steel slag utilization is yet to be fully realized and implemented. There is an urgent need to identify more avenues for utilizing this by-product effectively. R&D and adoption of already proven technologies can help in this regard.

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 the Ministry of Road Transport and Highways (MoRTH) specification for Road and Bridge Work 2001 for preparation of bituminous concrete mixes. Currently, use of steel slag as aggregate is limited within few hundred kilometres around the steel plant, mainly due to the logistics issues. Although, field trials have been conducted for assessing the suitability of processed weathered BOF slag for use as rail track ballast, but due to the 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 a source of growing agents. India has nearly 40 per cent 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 Action areas

- *Steel recycling strategy*: India needs to explore into systematic and efficient scrap processing as it prepares for an era when proportion of BF-BOF based steelmaking using coking coal and iron ore diminishes and scrap based EAF/IF processes becomes the preferred choice.
    - Steel scrap processing so far has been largely an unorganized sector, with no control over quality. Modern scrap processing facility needs 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 need 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 tonnes per year, which can actually be achieved by full utilization of the existing EAF and induction furnace capacities. The utilization rate in 2016 was 74 per cent. 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 per cent to 80 per cent 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).

▪ *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, and so on. 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 the 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 exhibits a number of favourable mechanical properties, including very high stability and good soundness. If properly selected, processed, aged and tested, it can be used as granular base for roads. Volume stability is the key aspect for using steel slag as a construction material.

▪ *Technological intervention*: The performance of primary as well as secondary steel sector needs 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, such as 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.

- *Capacity development*: There is a 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 environment-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 centres 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, creating dedicated centres 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 Solar photovoltaic sector

5.7.1 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 1,075 kWh/year), but the energy demand is expected to rise in the future along the increasing trends of GDP and population. As a part of India's pledge to the Paris Agreement, India would have 40 per cent of its 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 60,000 MW has to be grid connected and 40,000 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 2047. 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 Rs 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. These states will set up about 9,400 circuit km transmission lines and substations of total capacity of approx. 19,000 MVA by 2020.

To reinforce government's commitment towards renewables, the GoI has notified Renewable Purchase Obligation (RPO) trajectory up to the year 2019 and the process of further extending it up to 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 per cent 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 the last four years, over $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 GoI, which recognizes solar manufacturing as an industry having 'strategic importance'.

5.7.2 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 is further research towards the 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 environment-friendly. A brief description of the technologies is presented in Figure 5.23.

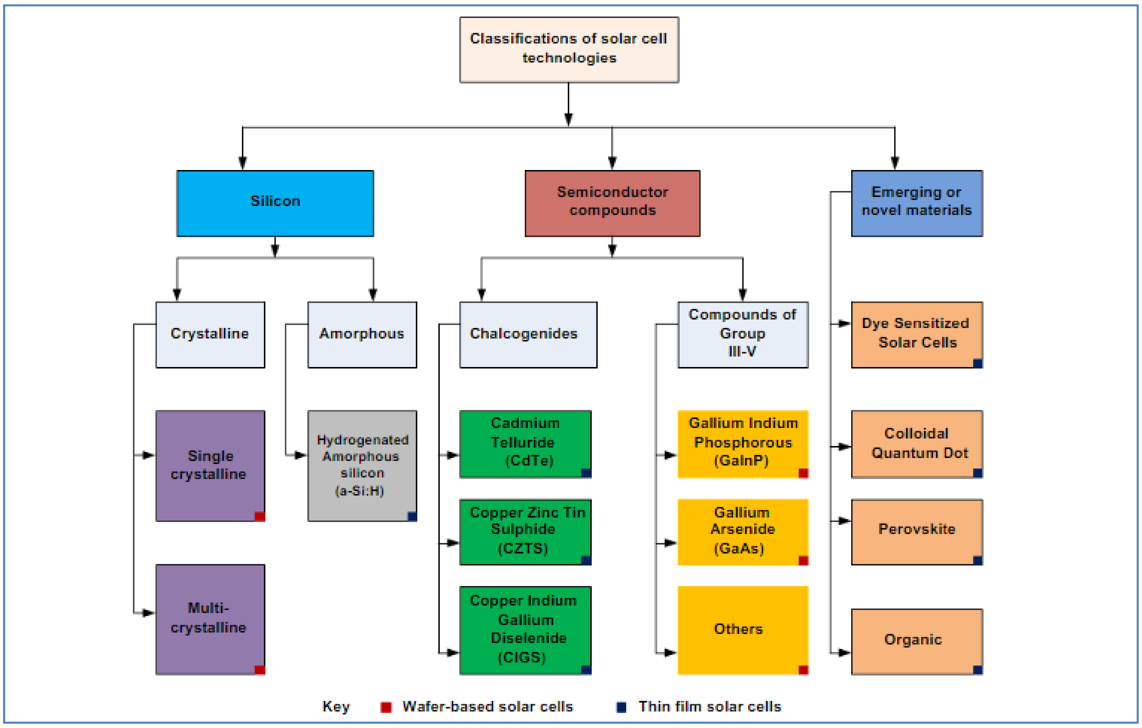

Figure 5.23: Classification of solar cells based on the primary active material

Source: Details available at https://www.researchgate.net/publication/317569861_Perovskite_solar_cells_An_integrated_hybrid_lifecycle_ass essment_and_review_in_comparison_with_other_photovoltaic_technologies, last accessed on 9 April 2019

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.

Semiconductor compound

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

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 of degraded CdTe panels will prove to be problematic. Further, the efficiency levels of CdTe panels is not at par with those of silicon panels.

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 downside, 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.

Concentrator photovoltaics and other technologies

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

Hybrid panels

Hybrid photovoltaic/thermal (PV/T) solar system is one of the most popular methods for cooling the PV panels. The hybrid system consists of solar PV 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.

Concentrator photovoltaic 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.

Dye-sensitized solar panels

The dye-sensitized solar cells (DSC) provide 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 reduce 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.

5.7.3 Material consumption and exploring resource efficiency potential

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

The material consumption across various life cycle stages for multi-crystalline solar PV technology is presented in Figure 5.24.

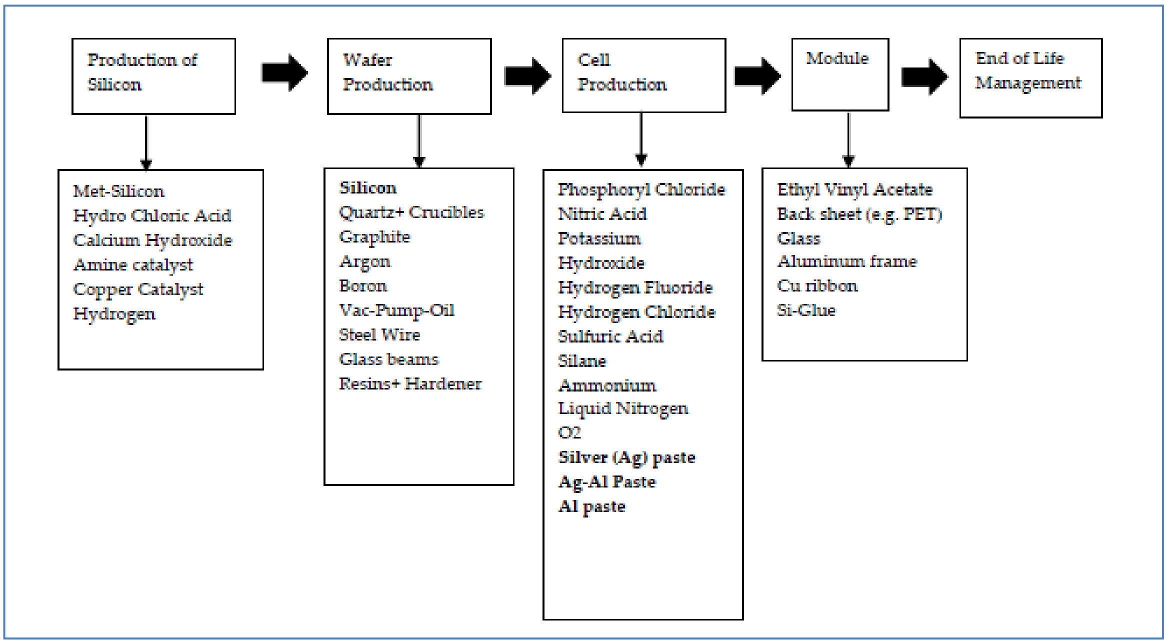

Figure 5.24: Key materials that are used in manufacturing silicon solar PV

Source: EU-REI 2018 (TERI- 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 per cent of glass while aluminium, silicon, and silver account for 18 per cent, 3.65 per cent, and 0.053 per cent, respectively, of total weight. Ethylene-vinyl acetate (EVA) encapsulation takes up 5.1 per cent of the share while the back sheet represents 1.5 per cent (Latunussa, *et al*. 2016). This is presented in Figure 5.25.

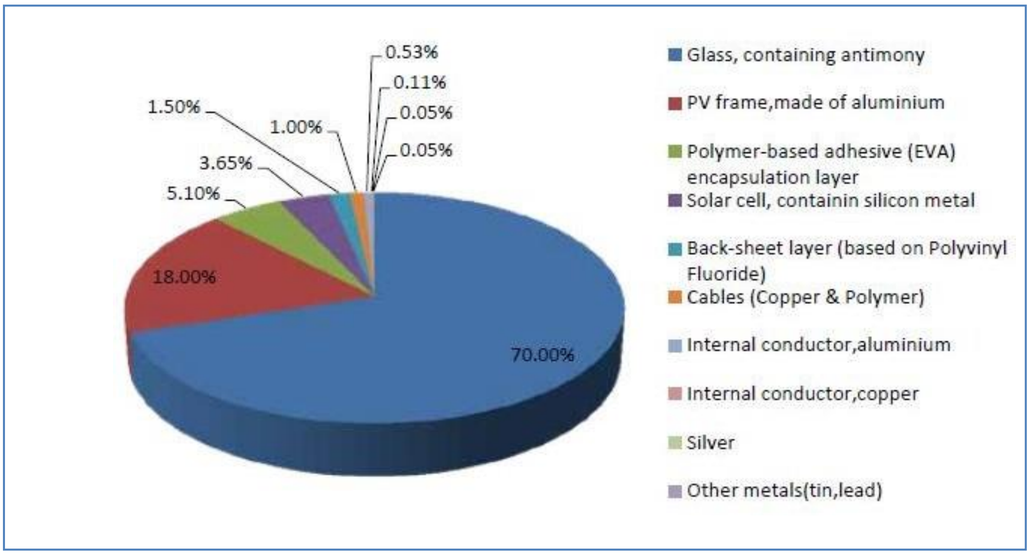

Figure 5.25: Material composition in a crystalline solar PV (by percentage weight)

Source: Details available at https://www.scribd.com/document/360791571/1-s2-0-S0927024816001227-main, last accessed on 9 April 2019

Under an ambitious solar energy deployment scenario of nearly 170 GW by 2030, the 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 7 million tonnes in 2030 from 0.4 million tonnes in 2015. The 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 polysilicon consumption is estimated to reach 0.7 million tonnes. This is presented in Figure 5.26.

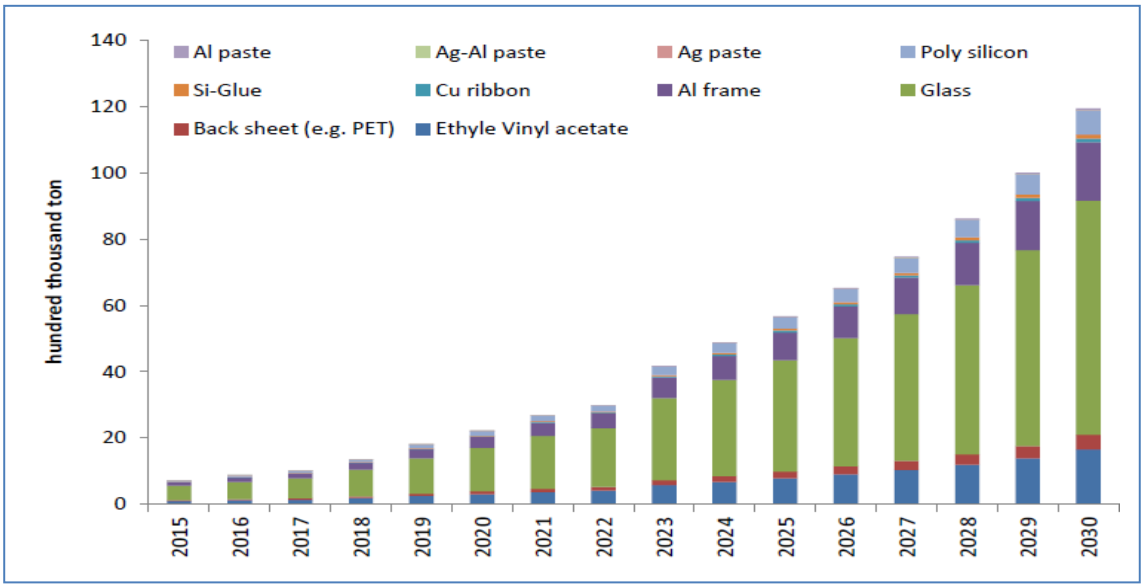

Figure 5.26: Estimated requirement of materials for manufacturing crystalline solar PV in India
Source: EU-REI 2018 (TERI-PV)

The PV sector, however, has the potential to create unprecedented opportunities for resource savings along the value chain. Process innovation will reduce the primary demand for 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 which promotes efficiency across the life cycle stages. The resource efficiency opportunities are presented in Figure 5.27.

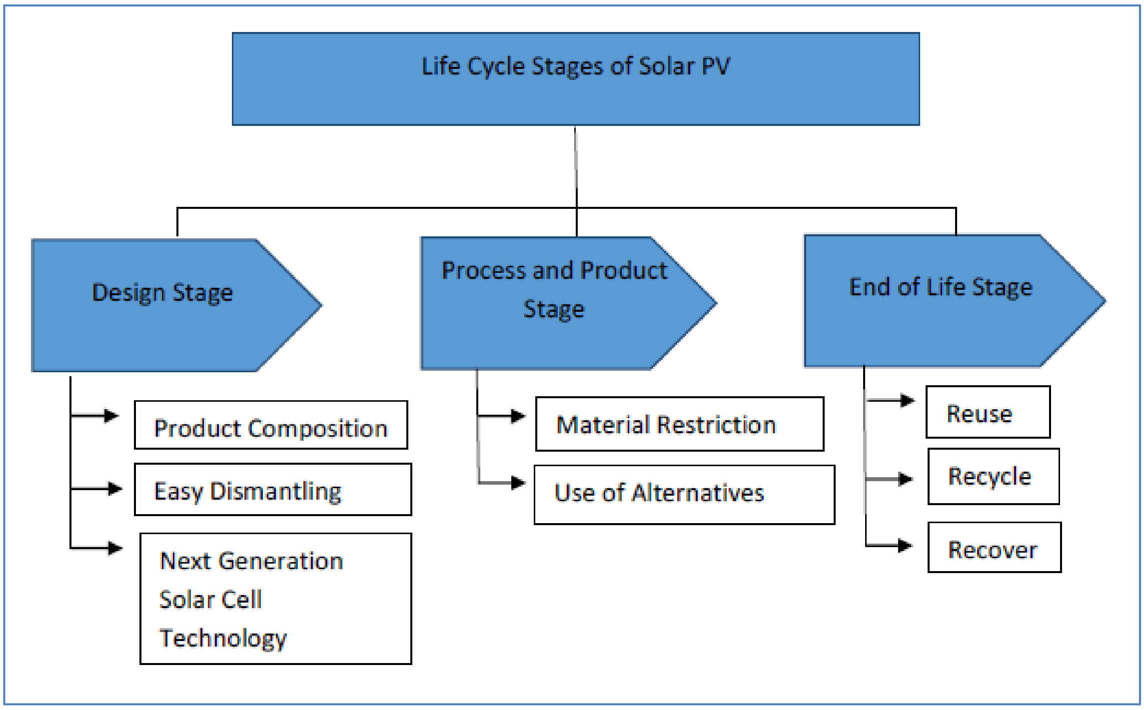

Figure 5.27: Resource efficiency opportunities across selected life cycle stages of solar PV
Source: EU-REI 2018 (TERI- PV)

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 on which the success of the ambitious programme depend. The PV industry is not immune from such issues. For example, the country depends heavily on imports of the materials, particularly silver and copper, and any change in prices will have impacts on these products. There is also significant room for improvement of material usage during manufacturing and assembly of solar panels. Further, many of the panels that have been installed will be reaching their end-of-life in a decade and pose new environmental challenges. However, the PV waste also has the potential to create opportunities 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, and 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, DWS technology is introduced which will help reduce the consumption of silicon by 15 per cent, as a result of improved cutting. According to the International Technology Roadmap for Photovoltaic (ITRPV) Report, between 2015 and 2030, it is expected that the production process will shift from 100 per cent to 5 per cent slurry-based technology As per the practice in 2015, the estimated weight of silver used was 170 mg/cell. Silver is a key material in manufacturing PV. The median consumption of silver for 2017 has come down to 100 mg/cell and in 2018 it was 90 mg/cell. It is expected that by 2030 the weight will be reduced further to 50 mg/cell. Copper (or other alloys), being relatively a less expensive material, is expected to be used as a substitute 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 per cent by 2030. The share of frameless modules was very low at 2 per cent in 2015 as reported in the ITRPV Report and emerged from stakeholder. With increased deployment, the production of frameless module will be more and is expected to reach 28 per cent by 2030. Hence, 72 per cent 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. baseline and resource efficiency, reveals that an estimated 12 million tonnes of material will be demanded under the former, as compared to the 8.2 million tonnes if interventions are practiced. The latter will provide an efficiency of more than 30 per cent by 2030 when compared to the baseline scenario (Figure 5.28).

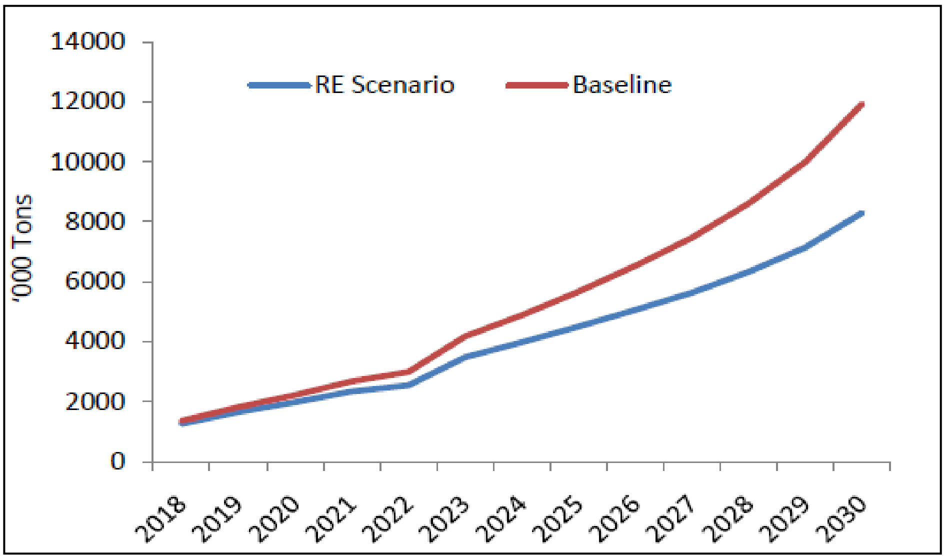

Figure 5.28: Comparison of material consumption under baseline and resource efficient scenarios
Source: EU-REI 2018 (TERI- PV)

5.7.4 Policies promoting resource use efficiency

Regulation has a very important role to play in promoting resource efficiency. It can incentivize development of break-through technologies and processes including the use of recycled materials and creating standards, and thereby create a demand for secondary raw materials. 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. In fact, solar PV recycling is gradually becoming a prominent industry with the potential to earn significant profits.

5.7.4.1 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 labelling to be carried out by the producers. Further, buyers have to be informed of the designated centres 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 the mandatory EPR schemes. Further, suppliers are 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, and reducing the consumption of natural resources and 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 are not applicable on all wastes but only on certain waste streams for which they can be developed and adopted, while remaining within the purview of the Waste Framework Directive (EU 2016). For example, copper is a scarce resource. As a result, the EU wide end of waste criterion for copper scrap is likely to provide improvement in functioning of internal market, clear difference between high and low quality copper scrap, and 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.

5.7.4.2 The case of Japan

Japan does not have a specific regulatory framework to manage end-of-life PV panels. The 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', enacted in 2000, which 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 of life of products; and

- implementation of measures for reusing materials recovered from used products. Recently, the Japan Photovoltaic Energy Association (JPEA) voluntarily issued guidelines, which, though not enforceable, are strongly recommended to the industry, on 'proper disposal' of used solar modules.

5.7.4.3 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. Stiftung EAR (the 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 Stiftung EAR include the following: registration of producers supplying 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.

5.7.5 Action areas

Given that India has seen modest growth in solar capacity only in recent years, that too using mostly imported modules, not much thought has been put into the management of solar PV wastes, whether it is during the time of production, installation or at the disposal stage. In other words, the solar PV modules in the country are far away from reaching their end-of-life and it is perceived that the repercussions of waste from used PV modules are not glaring presently, so their recycling in terms of policy and regulatory measures has still not been considered by the government. However, with increased installations, the projected installation of solar generation capacity can reach 100 GW by 2022, and, hence, the volume of PV waste generated will increase. To promote 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 creating a 'technology upgradation fund' for solar cells and module manufacturing.

According to an estimate by IRENA (2016), the cumulative PV waste generated in India was between 1000–2500 tonnes in 2016, which will probably rise to 50,000–320,000 tonnes by 2030 and further culminate to 4.4–7.5 million tonnes by 2050 as a result of the 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, particularly given the significant thrust on domestic manufacturing under the 'Make in India' campaign. Given this background, the suggested action areas include the following:

- Adopting systemic value chain based resource management thinking that it will help the country to manage the expected growing value of waste from the sector in the long term; thus, enhancing material security.
- Product standardization and labelling are the initial steps for promoting resource efficiency in the sector. For that matter, the industry, academia and government institutions concerned need to come together to realize the same and learn from the experience of other countries across the world.
- Financial support through subsidies and 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. The market for such products can be created through possible rebates for new installation of products using recycled raw materials recovered through the PV recycling processes.
- Setting up a proper solar panel recycling infrastructure that can manage the large volumes of PV modules which will be disposed in the near future and facilitate increased scientific dismantling of panels.
- This 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. The cost of take-back arrangement needs 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 setups. A cluster-based approach could be considered in bringing different players and, thus, minimizing the risk. These activities can be undertaken close to where PV manufacturing takes place, thus, facilitating in creating a suitable ecosystem.

5.8 Aluminium

India has emerged as a global leader in aluminium production in recent years. It is the fourth largest producer of bauxite which is the key resource in manufacturing aluminium.

India produces more than 3.3 million tonnes of aluminium per year and the average annual growth rate in production of aluminium has been estimated at 11% in recent years. Consumption of aluminium is growing at a CAGR of 3% since 2012–13 onwards. Between 2012 and 2017, the annual consumption of aluminium has increased from 2.85 million tonnes to 3.6 million tonnes. Given that aluminium consumption in India is very low (at 2.5 kg/capita), compared to the global average of 11 kg/capita, the sector has promising opportunities for future growth (NITI 2019: Aluminium).

Aluminium finds application across various sectors. In India, the electrical and electronics sector is the largest consumer of aluminium accounting for nearly 37% of the domestic consumption followed by transportation at 26%, construction at 11%, and consumer durables at estimated 8%. The power sector will drive future demand significantly as investments from state distribution companies and central government schemes, amounting to Rs 4.3 trillion, are being planned over the next five years. As nearly 70% of India's infrastructure is yet to come up, there will be increase in industrial development, rapid urbanization, and infrastructure development, which will drive the future consumption of aluminium in this sector. Further, building of Smart Cities coupled with construction of modern spaces will encourage environment-friendly construction where aluminium can play a key role in making facades, curtain walling, structural glazings, roofing, and cladding applications (NITI 2019: Aluminium).

However, there are substantial resource use related issues (including environment damage) associated with primary aluminium production from the bauxite route. The environmental issues of bauxite mining include air, water, and soil pollution due to bauxite dust; leaching of bauxite into water sources resulting in reduced soil fertility as well as affecting agricultural food products and aquatic life. The occupational exposure to bauxite affects the health of miners, and has negative consequences, such as increased respiratory symptoms, contamination of drinking water, other potential health risks from ingestion of bauxite and heavy metals including noise-induced hearing loss and mental stress, on the health of surrounding communities. Aluminium production depends heavily on conventional energy. Nearly, one third of smelting cost accounts for power required for electrolysis process. Use of conventional electricity (coal based) is associated with carbon emissions, which makes it a double whammy. While producing 1 tonne of primary aluminium, simultaneously about 8–10 tonne of by-products are produced, in the form of bauxite residue (Red Mud), fly ash, spent pot liner (SPL), dross, etc.

5.8.3 Action areas

Aluminium is a very important material for the economy and will play a crucial role in sustainable growth of various economic sectors. There are many opportunities where resource use efficiency can be adopted and promoted in the sector across various stages of the life cycle of the aluminium sector, right from raw material extraction to end- of-life management of materials. The suggested action areas include the following:

- Classification of aluminium as a core sector, similar to the emphasis given on steel by the Ministry of Steel, to further help in enabling production of high-quality metal with the provision of critical infrastructure to avoid global volatility in supply and prices.
- Since the sector generates substantial waste during aluminium production, there is a potential to convert these wastes into value-added products by setting targets on resource recovery and reuse of wastes by various primary metal producers.
- Since domestic scrap usage is diffused and not regulated without any standards or end-use restrictions, there is heavy dependence on imported scrap. Reduce the import dependence by increasing the recovery of secondary aluminium and for this a target of 85% recycling rate by 2025 could be set.
- Incentivize the availability of domestic scrap by various economic instruments. These include export taxes, export quotas, and even export bans or punitive tax rate if the recycler resorts to trade in scrap without processing or adding value. This is, particularly, important when the recyclers have the potential to generate feedstock at lower prices.
- There is a need for direct and indirect support measures to enhance recycling of aluminium and make domestic aluminium scrap available. The direct measures may be in the form of exemption on duties (and GST) on scraps and capital subsidies (including import duty exemption) on technologies for efficient recycling. Indirect supports may include providing land and exemptions for companies on allowing land resources to be used for recycling. Recycling specific tax credits are available to secondary metal firms in several jurisdictions and can be explored in India. In the long run, support measures which affect enterprise income and profit will encourage new investment and firm entry.
- Product take-back is one of the ways to exercise the extended producer responsibility and would enable product manufacturers or importers to re-assume some responsibility for their products at the end of their life. This can mean taking physical charge of products through the provision of drop-off locations allowing product return or taking economic responsibility for the management of end-of-life products through third party firms. India already has an EPR policy in place and this needs to be exercised in various sectors that will help in generating aluminium scrap volume.
- There is a need for adoption of practices that can promote organized metals recycling industry structure in India. The industry is not highly regarded and there are no specially designated zones/areas for metals recycling. Due recognition of recycling could encourage users of aluminium, particularly in transport, housing, packaging and durable sectors to broaden the organized markets for the scrap generated.

- Recycled aluminium products should follow standards for better quality control and be certified.
- It is recommended to introduce a public awareness campaign on the quality of aluminium being recycled. This can be initiated by authorized nodal agencies such as Aluminium Association of India, Jawaharlal Nehru Aluminium Research Development and Design Centre, Material Recycling Association of India.

6 Existing policies in India: a life cycle analysis

Utilization of resources involves their flow from one life cycle stage to another, beginning from mining of resources to designing of products and services, followed by manufacturing, use and consumption, and, ultimately, end-of-life (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. 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 in avoiding 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 the cost of safe disposal. The various ways of end-of-life treatment have significant impacts on the quality and usability of the recovered secondary raw materials, and, thus, on resources needed for safe disposal or reuse in different forms. The possibility to substituting 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 and facilitates stakeholders, particularly government departments, in creating an enabling 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 recover, recycle, and reuse. The approach also enables introducing consistency in policies, targeting different life cycle stages so that resource efficiency gains at one stage are not lost due to inefficiencies at other stages.

As discussed in Chapter 4, major economies such as China, Japan, Germany, the USA (to name a few), have chalked out strategies for not only integrating resource efficiency policies under a unified framework or programme, but also adopting value chain/life cycle thinking for addressing efficiency gaps and facilitating stakeholder engagement. Designing novel policy instruments along the life cycle stages can create an enabling framework for achieving resource efficiency and creating a circular economy. Although, the Indian government does not have a life cycle approach to promote resource efficiency, it has adopted various policy interventions to promote sustainable use of resources that can address resource efficiency issues along different life cycle stages.

One of the most notable policies that India introduced a decade ago, which also articulated the spirit of sustainable development, was the National Environment Policy (NEP) of 2006. It mentions that only such a 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 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 the environment. The 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 the same is that the regulations are associated with a high cost of information. In certain situations, the regulator has to rely completely on information from the polluter/emitter, in terms of either 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 the 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, internalize the costs of pollution and resource exploitation, 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.

Looking at the aspect of resource efficiency, it is evident that the key national policies of India have elements or aspects related to material use and efficiency to promote more judicious and sustainable use of natural resources. Table 6.1 provides an overview of some of the key national policies in the context of resource efficiency.

Table 6.1: 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	Emphasizes the high potential of waste as a resource, containing valuable materials that can be efficiently extracted and utilized 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 emphasizes the need to upgrade mining technology to ensure efficient extraction and utilization 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 such as copper, lead and zinc need to be emphasized 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 the 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 and 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; establishes 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.
National Industrial Policy 2017	Production	Establishment of a circular economy; ensure minimal/zero waste from industrial activities; introduce 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 resource-efficient 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,

Existing policy of Government of India	Life cycle stage	Resource efficiency aspect	Further potential /opportunities for enhancing resource efficiency
			provision of eco-efficient infrastructure, introduction of industry-based standards and eco-labels, 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	Emphasizes 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	Promotes 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

The recent years have seen resource efficiency gaining salience, as reflected through various government initiatives such as 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 waste to e-waste, etc. However, an overarching strategy could help encourage and realize the benefits from prioritizing materials and sectors for short-term, medium-term and long-term actions, and developing appropriate strategies that are integrated across multiple sectors. In 2017, NITI Aayog, the policy think tank of the Government of India, along with the EU delegation to India prepared the resource efficiency strategy for the country.[41] 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 resource efficiency.

The following sections provide an analysis along life cycle stages of policies in India which have implications for various aspects of resource efficiency besides addressing multiple other sustainability objectives. Introducing life cycle approach in resource efficiency and secondary raw material management related policy making across ministries and exploring inter-linkages will help India utilize resources more efficiently and unlock the potential of secondary resources.

6.1 Key policies across life cycle stages

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 is 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 reduced 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 crucial 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 such as cement manufacturing.

We discuss here the key policies of the Government of India that have resource efficiency 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 emphasizes the need to upgrade mining technology to ensure efficient extraction and utilization of the entire run-of-mines. The

[41] Details available at http://niti.gov.in/writereaddata/files/document_publication/Strategy%20Paper%20on%20Resource%20Efficiency.pdf, last accessed on 8 April 2019

policy suggests value addition through latest technique of beneficiation, calibration, blending, sizing, concentration, pelletization, purification, and general customizing of product. Extraction of associated metals (tin, cobalt, lithium, germanium, gallium, indium, niobium, beryllium, tantalum, tungsten, bismuth, and selenium) along with major metals such as copper, lead and zinc needs to be emphasized 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.

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.[42]

6.1.1.2 Draft National Mineral Policy, 2018[43]

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, which was published by the Ministry of Mines in 2011,[44] the importance of environmental and social sensitivities during granting of mining leases was clearly highlighted. The framework includes incorporating environmental and social sensitivities in decisions on mining leases, strategic assessment in 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 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

[42] Details available at http://steel.gov.in/sites/default/files/88753b05_NMP2008%5B1%5D.pdf, last accessed on 9 April 2019
[43] Details available at https://mines.gov.in/writereaddata/UploadFile/draftnationalmineralpolicy2018.pdf, last accessed on 8 April 2019
[44] Details available at https://mines.gov.in/writereaddata/UploadFile/SDF_Overview_more.pdf, last accessed on 8 April 2019

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, 2016

The Minerals and Mining Development Regulatory (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 the context of resource efficiency include Sustainable Sand Mining Management Guideline (2016), and star rating system for mining industries in India (MoM, 2017). 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 resource efficiency related aspects in the star rating for promoting resource efficient technology and practices in the country (Ministry of Mines, 2016)

6.1.1.5 Further opportunities

Fostering certification and international standards help in enhancing accountability in the 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 monetized 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 are needed to achieve the potential of resource efficiency in the 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.

6.1.2 Enabling resource efficiency during product design

Designing environmentally benign products is the 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 enhance credibility.

6.1.2.1 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 of promoting a 'design enabled Indian industry' *which could impact both the national economy and the quality of life in a positive manner*.[45] 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 such as originality, innovation, aesthetic appeal, user-centricity, ergonomic features, safety, and eco-friendliness. The 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 and 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 policy is on 'providing incentives for commercialization of innovations with the focus on green manufacturing'*[46] (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

[45] Details available at http://dipp.nic.in/sites/default/files/national_design_policy%20%20%20eng%201.pdf, last accessed on 8 April 2019

[46] Details available at http://www.dst.gov.in/sites/default/files/STI%20Policy%202013-English.pdf, last accessed on 8 April 2019

extend similar programmes for sectoral resource efficient-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 the previous Bureau of Indian Standards Act, 1986. The BIS certification covers 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.[47] The 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[48] (BIS 2016).

Conceptualization of the 'design' through the life cycle of a product that ensures manufacturing utilizing 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 utilization 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 a 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 ISO 14062: 200211, should be encouraged to develop and strengthen design initiatives for improving resource efficiency and promoting use of secondary raw materials.

[47] Details available at http://pib.nic.in/newsite/PrintRelease.aspx?relid=171705, last accessed on 8 April 2019
[48] Details available at http://www.bis.org.in/cert/echo_mark_scheme.htm, last accessed on 8 April 2019

Box 6.1: 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 6.2: Learning from the success of energy efficiency programme in India

Energy efficiency programmes have had significant success in India. These programmes 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 authority 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

Over the years, India's manufacturing sector has emerged as a key economic sector. Resource efficiency 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 organization of processing in a more efficient way, etc. Within manufacturing, sectors such as automobiles, cement, IT, electronics and electrical equipment, have sector specific promotion policies, but they mostly lack any focus on resource efficiency 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, increasing domestic value addition and strengthening technological depth that supports environmental sustainability.

6.1.3.1 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 such as water and energy (PIB 2011).

6.1.3.2 National Policy on Electronics, 2012

The policy aims at making India a globally competitive electronics manufacturing hub that can meet the country'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).

6.1.3.3 National Manufacturing Competitiveness Programme, 2014

The National Manufacturing Competitiveness Programme (NMCP) was launched by the Ministry of Micro, Small & Medium Enterprises in 2014, with an aim to enhance the competitiveness of the sector. The MSME sector forms the backbone of 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 utilization, scientific inventory management, improved process flows, reduced engineering time, etc. The target is to achieve 'Zero Effect, Zero Defect Models' by aligning schemes such as Lean Manufacturing Competitiveness Scheme, Quality Management Standards (QMS) and Quality Technology Tools (QTT), Technology and Quality Upgradation (TEQUP) schemes, etc. (PIB 2015).

The key schemes under the NMCP are presented in Table 6.2.

Table 6.2: Various schemes under National Manufacturing Competitiveness Programme

Sl. No	Name of the scheme	Brief description
1	Credit Linked Capital Subsidy for Technology Upgradation	The scheme provides 15% per cent subsidy for additional investment up to Rs 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
4	Lean Manufacturing Competitiveness for MSMEs	Financial assistance is provided for implementation of lean manufacturing techniques, primarily the cost of lean manufacturing consultant (80% per cent by Government of India and 20 per cent by beneficiaries).
5	Design Clinic for Design Expertise to MSMEs	Funding support of (1) Rs 60,000 per seminar and 75 per cent subjected to a maximum of Rs 0.37 million/ workshop, and (2) to facilitate the 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)

6.1.3.4 Charter on 'Corporate Responsibility for Environmental Protection, 2016'

The Charter on 'Corporate Responsibility for Environmental Protection (CREP)' was launched in 2003 with the sole objective of going beyond the traditional compliance as governed by regulatory norms, for the purpose of prevention and control of pollution through various measures including waste minimization, in-plant process control, and adoption of clean technologies[49] (MoEF&CC 2003). The charter includes various measures such as waste minimization, in-plant process control, and adoption of clean technologies. Abiding by these standards could have significant positive impact on resource efficiency and SRM. However, it would additionally require appropriate accompanying measures such as dissemination of information regarding resource efficiency and SRM approaches along with awareness generation in partnership with industry bodies and chambers of commerce.

6.1.3.5 Financial support to MSMEs in ZED Certification Scheme, 2017

This is based on the government's objective of promoting Zero Defect Zero Effect 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 Zero Defect Zero Effect rating scheme is a pan-India drive for creating awareness in MSME clusters about the 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 6.1 shows India's Zero Defect Zero Effect rating process.

[49] Details available at http://www.cpcb.nic.in/divisionsofheadoffice/pci3/Important_projects.pdf, last accessed on 8 April 2019

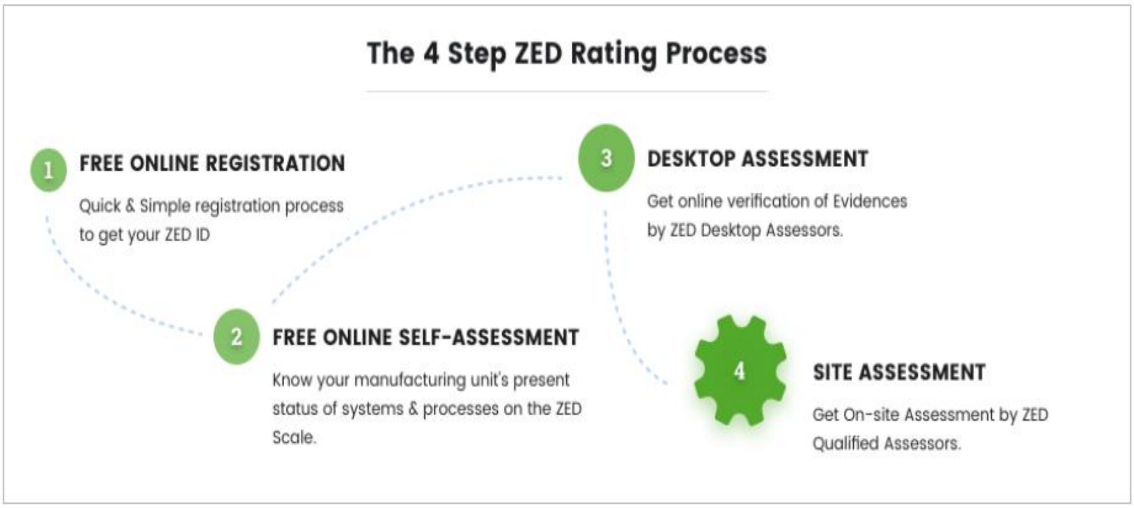

Figure 6.1: The four step rating process

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

6.1.3.6 National Steel Policy, 2017

India's New Steel Policy of 2017, inter alia, emphasizes 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 emphasizes 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 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 resource efficiency and SRM across sectors.

6.1.3.7 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.

6.1.3.8 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 organizational solutions, optimally in a sector-specific way. This can encompass e.g. R&D, standards, active dissemination of resource-efficient technologies, organizational solutions in relevant targets groups, and incentives for the implementation of environmental management systems.

Waste-related information should be provided 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 information technology in India, the inclusion of e-waste awareness demonstrates 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 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, is administered by the 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 with 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, 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 pump sets, microwave oven, etc. (BEE 2017).

6.1.4.2 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 per cent 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 second-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).

6.1.4.3 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) programme 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, that is those states which 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).

6.1.4.4 Perform Achieve and Trade Scheme, 2012

In order to energy efficiency in energy intensive industries in India, the 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 2012–15 that covered 478 facilities and included 8 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 per cent of India's total primary energy consumption (BEE 2015).

6.1.4.5 Auto Fuel Policy, 2015

In 2002, an expert committee on Auto Fuel Policy was formed for laying out the roadmap 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).

6.1.4.6 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 per cent of crude from other oil exporting countries. In order to promote faster adoption of electric vehicles, the Government of India is preparing to offer incentives in cities having population more than 1 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 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, and 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. The 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 in 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 per cent 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 emphasizes 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 authorized 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[50]

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 authorized 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

[50] Details available at http://www.moef.gov.in/sites/default/files/EWM%20Rules%202016%20english%2023.03.2016.pdf, last available on 8 April 2019

The 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 emphasizes 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).

6.1.5.2 Fly Ash Utilization Policy, 1999

The notification on fly ash utilization was first issued in 1999 and since then, the fly ash utilization in the country has increased to almost 60 per cent. Recently, the 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 km. It also mandated cement industries, that are operating within a radius of 300 km of a coal-based thermal power plant, to use fly ash for cement manufacturing as per the 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).

6.1.5.3 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.[51]

6.1.5.4 Reduction in GST on waste products 2017

Recently, the GST council significantly reduced the rates on electronic waste from 28 per cent to 5 per cent 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.

6.1.5.5 Further opportunities

In order to support, facilitate, and operate efficient and effective waste prevention initiatives, the waste management sector has to develop and integrate waste prevention activities, such

[51] Details available at https://cpwd.gov.in/Publication/Guideleines_Sustainable_Habitat.pdf, last accessed on 8 April 2019

as skill building, awareness generation and training, providing feedback to designers and manufacturers as well as reuse and refurbishing, into the business models of the sector.

The waste rules also need to consider developing business models that lead to better implementation, mobilization of financial resources for waste management through EPR, and polluter pays principle. To help the producers implement their EPR mandates, producer responsibility organizations (PROs)[52] have been created which are registered companies that collect and process waste on behalf of manufacturers of products. So with PROs, the producers do not physically take back the end-of-life/waste product. Instead, they support the process financially. However, the producers should also contribute to development of infrastructure for effective EPR implementation.

Since there are different sources of secondary raw materials, it is important to bring them together for effective closed-loop recycling. This can be done by the stakeholders coming together to create a platform (digital or decentralized physical or in and around industrial clusters) where the recovered secondary raw material could be put up and a monetary value created for the secondary material or waste that is recovered. This would require transforming the waste management sector into one that is built around the recovery of secondary materials and integrating it with the manufacturing sector, which remains largely dependent on primary raw materials. The return flow of secondary materials to the manufacturing sector may be expensive due to inadequate infrastructure and limited capacity of current reverse logistics set-ups. So these inadequacies will need to be addressed.

Box 6.3: An innovative service leading to the prevention of waste

Veolia Environment has established a network of four solvent processing units in France, Switzerland, and the United Kingdom and an additional four in North America. This network helps in effective reuse of the solvents of companies through a leasing service rather than continuously purchasing new solvents and creating waste. Several new economic models have been developed for solvent reclamation, reuse, or tolling. In tolling contracts, the solvents are collected directly from the industrial installations, where they are again made available to the same clients after the solvents have been regenerated to their set specifications. The solvents are collected and consolidated for treatment at a unit based in Picardy, France, and redistributed throughout Europe. The benefits (to the companies who use these solvents) of this leasing model include: maximized performance, guaranteed supply and quality, budget management, and reduced environmental impact.

Source: International Solid Waste Association (ISWA)

Besides monetizing the secondary raw material and waste, it is also important to address the market failure linked to the pricing of virgin resources. The environmental costs need to be

[52] In 2018, five PROs registered with the Central Pollution Control Board (CPCB): IPCA, GEM Enviro Management, NEPRA Resource Management, NEPRA Environmental Solutions and Shakti Plastic Industries. Many more are likely to register in the coming months. PROs have undertaken pilot projects in big cities, including New Delhi, Mumbai, Bengaluru, Ahmedabad, and Guwahati. In Delhi, IPCA claims to have diverted 2000 tonnes of plastic from landfills in 2018.

internalized in the pricing of the virgin raw materials and in product prices. Higher taxes could be imposed on products that use virgin materials or/and mandatory environmental standards can be integrated for the development of new products.

Higher cost of secondary raw material compared to competing virgin material can act as a hindrance to the investors in the waste industry from investing in recycling plants and they may prefer concentrating on energy recovery. So to be able to make secondary raw materials as the priority raw materials for the future, it is important to target the production of secondary raw materials in a way to match its price, quality, and quantity to that of virgin materials.

There is a need to also do capacity building of the informal sector which is a major player in the waste sector. National Capacity Building Project under the Clean India Mission (Swachh Bharat Mission) launched in 2017 is a programme by the Ministry of Urban Development (MOUD) and Ministry of Environment, Forests and Climate Change[53] that seeks to strengthen institutional capacities at urban local bodies and amongst stakeholders, towards collection, treatment, disposal, and efficient management of various types and categories of wastes, promote 3Rs (Reduce, Reuse, Recycle) initiatives, and dissemination of good practices, and facilitate integrated efforts towards achieving improvement in general health of the city environment. Since the programme is awareness oriented, the programme curriculum is not able to build specialized or targeted technical skills of stakeholders working at different levels and domains in the waste sector.

Vocational training in the waste sector should be mainstreamed and for this, the Skill Council for Green Jobs (SCGJ) could play an important role. The council has begun to conduct some vocational training with the informal sector through training programmes that tend to enhance skills of unskilled or semiskilled workers involved in cleaning and waste collection jobs. But now the need is also seen for more advanced vocational training for preparing the workforce to handle more and with greater efficiency the end-of-life management operations.

The formalization of the informal sector could happen in many ways including by organizing them in cooperatives or jointly owned private enterprises, so that they can access technology and funding to improve their operations and ensure safe and healthy work environment, and also be able to participate formally in waste management tenders. 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.

Further, 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.

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[53] Details available at http://pib.nic.in/newsite/PrintRelease.aspx?relid=165816, last accessed on 8 April 2019

7 Resource efficiency policy framework for India

7.1 Perspectives for designing resource efficiency policies

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

The first perspective related to the stages of life cycle is discussed in Chapter 6. The life cycle approach is also in line with the idea of closing the loops and reducing dependency on the 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, as discussed in Chapter 5, 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 highlight and 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 considered for designing RE policies is the use of critical and priority materials. These differences between 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.

Finally, though the policy measures have to be adapted to specific characteristics of their diverse subjects, they are also of a cross-cutting nature when their applicability or potential impact is taken into account.

7.2 Policy instruments for resource-efficient India

7.2.1 Economic instruments

As highlighted in Chapter 6, it is fundamental to 'get the prices right' through internalizing 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 their 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 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. 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, such as 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 harmonized with the resource efficiency goals as well as those mandated through various waste management rules in order to make sure that their use is not discouraged and leads to their greater market adoption.

Box 7.1: Example from Sweden

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 natural gravel in parts of the country. The tax encouraged substitution with other materials.

Tax exemptions for components and sub-components made using recycled materials 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. Incentives to manufacturers for making resource-efficient investments and the integration of green production technologies can be provided to corporate tax credits.

It is important to phase out subsidies that are detrimental to promoting a circular economy model, including the withdrawal of market incentives that promote the use of new products and the disposal of used ones. Subsidies or tax holidays could be provided instead to businesses engaged in providing remanufactured/refurbished/recycled products and related services.

Economic instruments can also help make the prices of resource-efficient products more competitive and increase their adoption, for example, in the case 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, and low-carbon cement.

Economic instruments are often contrasted with 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 to meet a certain health or environment objective. Here, market-oriented approaches (e.g. tradable permits) can then be used to allocate the allowable emissions in an efficient manner. Tax incentive structures, including tax breaks, could be designed to incentivize 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: (i) taxes and fees, (ii) recycling credit and other forms of subsidies, (iii) deposit–refund, and (iv) 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 a 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. Therefore, precaution against illegal waste dumping or misuse of recycling facilities is 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 disincentivize landfilling itself by imposing high tipping fees, especially for bulk generators of waste, thereby encouraging the optimal use of material and redirecting waste to appropriate channels for recovery.

For promoting the 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 and Promotion (DIPP), is helping micro, small and 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 7.2: Advanced recycling fee and proper e-waste disposal – how it works

The advanced recycling fee (ARF) acts as a tool that allows both consumers and manufacturers to 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, such as 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 the 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 in 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 set-ups.

Integrating the end-of-life management costs into 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 producers) to contribute towards the recycling industry and consequently provide them with better ways for disposing (or managing) 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) sectors and is aimed to address the end-of-life management of lead acid batteries and deal with 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 as 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 a legislative, cultural, and market framework that has also a major bearing on their effectiveness. Ensuring this framework is coherent and supports the instrument objectives is important to achieve improvements in resource efficiency. In cases where this supporting framework is less coherent, with contradictory or competing goals, or loopholes or gaps in the system, the intended resource efficiency effects can be weakened or lost.

Monitoring and data relating to market-based instruments is typically weak. Quantities can sometimes be derived only 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 a policy.

7.2.2 Regulatory instruments

Regulatory instruments 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 the context of RE, these typically include laws or regulations that stipulate efficiency standards, ban certain products and practices, and mandate the application of certain "best available technologies". In India, many regulatory instruments exist that guide the resource use at different life cycle 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, and implementation are often suboptimal in terms of achieving RE goals. For example, though there are waste legislations in place, there is lagging enforcement of these legislations, and along with absence of end-of-waste criteria for certain product categories, there are resulting inefficiencies in waste management.

At the mining stage, the National Mineral Policy already includes zero-waste mining as a national goal and emphasizes the need to upgrade the mining technology. What is additionally needed is to promote extraction of associated metals (tin, cobalt, lithium, germanium, gallium, indium, etc.) along with major metals, such as copper, lead, and zinc, to enhance resource efficiency in the sector. Just as the Steel Policy aims to increase the extraction rate from the present 93.5% to 98%, there is a need to increase the efficiency in extraction of other minerals to reduce mining and associated environmental impacts.

Standards, developed by specialized standard setting organizations, 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 recognized that there are opportunities to expand the use of standards in the upstream stages of the life cycle, for example, at the design phase. Simple quality standards for the use of secondary materials should be prioritized, followed by more complex standards targeting resource efficiency in the design phase gradually over time. In cases 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.

Bureau of Indian Standards (BIS) is 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 the use of fly ash in concrete (IS 3812) and bricks (IS 12894). In 2016, BIS also amended 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 the 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, as this can be a much shorter and simpler process.. In cases 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 standards for scientific dismantling and recycling of used vehicles that have reached the end of their life.[54] The government can speed up the adoption of many green technologies by using levers like PPP models (e.g. a model proposed for the development of electric and hybrid transportation),

[54] Draft Automotive Industry Standard for End-of-Life Vehicles. Automotive Research Association of India. Details available at https://araiindia.com/hmr/Control/AIS/811201443718PM3_Draft_AIS-129_F4_Aug_2014_ELV.pdf, last accessed on 8 April 2019

creating a dedicated Green Fund to invest in emerging technologies, setting up green science parks that promote collaboration between businesses, research institutions, and universities, and providing fiscal incentives for early adopters.

Sectoral assessment of aluminium has highlighted the need for the quality control of recycled aluminium products and consequently the need for product standards for recycled aluminium to be strengthened and enhanced in consultation with bulk consumers. Standards are also needed for collection, logistics, and treatment to form essential parts of the monitoring and enforcement frameworks of waste categories, especially that of the plastic and e-waste management.

Box 7.3: Example from India

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

There is also a need to promote voluntary standards, such as Green Reporting Initiative and ISO 14062:200212, to develop and strengthen design initiatives for improving resource efficiency and promoting the use of secondary raw materials across sectors. Adoption of voluntary standards by some could trigger a reaction/peer pressure on many others to follow the same and generate more efforts towards resource efficiency and use of secondary raw materials.

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

It is also important to develop more balanced compliance monitoring and compliance promotion programmes, particularly for SMEs. While many State Pollution Control Boards (SPCBs) have relatively good records regarding monitoring the performance of highly polluting units in large-scale sectors, the monitoring and inventory of small-scale units in the category of highly polluting processes are very poor and incomplete.

The government needs to look into more closely the integration of 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 a 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 the implementation of product responsibility in waste management laws and ensuring product recycling across sectors and for different materials.

7.2.3 Information-based instruments

Information-based instruments typically include communication and information campaigns, technical support schemes and eco-audits, training and education, and various eco-labels. Eco-labelling, that is, 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, and several countries introduced eco-labelling schemes in the following decades. Up to 544 eco-labelling schemes covering 197 countries were operating in 2012 (Gruere 2013).

Eco-labels can be the third party certified, self-declaration claims or the quantified product information label. Some labels are also a single issue based that focuses on a specific issue of energy consumption, sourcing of raw materials, and so on. Most reliable labels are those which use objective and transparent criteria/standards and which are awarded by an independent third party and not influenced by the product manufacturer that is seeking the certification.

In 1991, India launched its own eco-labelling scheme called ‘EcoMark’, which is unique as it considers both environmental and quality criteria; product quality has to be certified by the 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 and only a few dozen products have been 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 reorganized 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, use life cycle assessment tools wherever applicable, and take 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 often lack many environmental attributes, and these capabilities need to be built all over the country for the success of an eco-labelling scheme. 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. Public authorities could help create the needed visibility and importance to eco-labels and promote the products that are manufactured using secondary raw materials.

It is important to highlight here 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 are supported by some sort of government mandate.

Green rating systems are also 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 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 the best practice. Further, co-operation between policymakers, statistical offices, and research institutes responsible for producing resource efficiency indicators should be prioritized.

Box 7.4: Resource efficiency indicators in EU

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 a 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 database on the raw material utilization and issued a report on global utilization (UNEP, 2016). It provides information on DMC (domestic material consumption), physical trade balance, and material intensity, as well as raw material equivalents for a selection of countries. While the DMC indicators are based on SEEA's harmonized 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. Data availability is also an essential component to create a successful industrial symbiosis set-up, where matching between by-products is needed. For this, one option could be to create a network of several actors (companies, innovators, entrepreneurs, regulators, academics, sub-national governments) based on the provision and sharing of geo-referred data which allows the identification of possible synergetic exchange of resources, including by-products, among multi-sectoral users.

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 that could be used by ministries and departments to initiate the collection and reporting of RE relevant data and indicators 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 organizations, public or private, can be used to bolster the market demand of goods and services deemed serving a desirable environmental or social goal. Preferential public procurement is 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, and reducing environmental impact.

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, such as 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), promotion of handicrafts from disadvantaged areas/communities, and so on (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.

Thus, green purchasing is about influencing the market. By promoting and using GPP, public authorities can provide the 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, short-term decisions are made to comply with the 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 goals, 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 organizations, such as the Indian Railways, Bharat Heavy Electricals Limited (BHEL), National Thermal Power Corporation (NTPC), and Indian Oil Corporation, have launched 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. However, the green criteria used 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 percentage 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 NITI Aayog (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 programmes at PSUs like the Indian Railways and smart cities
- Prepare training materials and toolkits for the capacity building of procurement officers
- Develop and launch consumer awareness programmes

However, it is important that we first start with a small range of products, for which the market is already reasonably well established, and then gradually expand as the policy matures. Further, experience in 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 facilitates 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 Indian made, resource-efficient products and eco-labelled products in public procurement through green procurement policies. Mandatory targets for green procurement help achieve the desired level of performance; these targets can be graduated and made more ambitious over time depending on the maturity of the programme 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 be a need to develop 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 recycling market in place or not.

So in case of materials for which 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 the seller of the recycled product and the 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 discussed in the previous three sub-sections can be used to support the markets (Finnveden *et al*. 2013). This would include establishment of harmonized quality standards for recycled materials and 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 geographical 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[55] could be set up that can focus on not just economic viability and profits but are also geared towards increasing resource symbiosis and closing the resource loop by enabling utilization of waste of one sector or industry as the 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 far-off isolated areas that limit access to both waste and recovered materials.

Box 7.5: Naroda by-product exchange network – an example of eco-industrial development India

The Naroda industrial estate houses approximately 700 companies in an area of 30 km^2 in Ahmedabad, Gujarat. In December 1998, research funded by the German Ministry for Education and Research surveyed 477 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 tonnes 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 Integrating life cycle aspects to make resource-efficient packaging

Packaging not only plays a role in protecting the final product, but also serves as a medium for attracting customers, thereby assisting in marketing and brand loyalty. It also gives additional information (e.g. reuse and recycling details) about the product. Packaging also has a major role to play in resource efficiency by protecting goods and thus conserving more resources than it uses. Innovations in the package itself, incorporating and improving the sustainable characteristics into the packaging material and design, will bring about efficient use of resources. For example, the ability to recover and recycle the used package at the end of life of the packed product saves resources. The packaging should be designed holistically

[55] 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, namely, Delhi Mumbai Industrial Corridor (DMIC), Bengaluru Mumbai Economic Corridor (BMEC), Amritsar Kolkata Industrial Corridor (AKIC), and Visakhapatnam Chennai Industrial Corridor (VCIC). 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 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).

with the product in order to optimize overall resource use performance, while making it safe and healthy for individuals and communities. The packaging material should be manufactured from recycled or environmentally friendly sourced materials while optimizing the use of renewable or recycled sourced materials (e.g. secondary raw materials). Systems should be put in place to ensure efficient recovery of the packaging material to promote reusability and recyclability.

7.3.3 Creation of RE business models

Resource efficiency-based 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, and regulations to accelerate adoption of certain technologies and practices. Governments can provide support through hard measures such as financial incentives, tax rebates, subsidy, and low interest rate loans or through soft measures such as mandatory green public procurement, generating consumer pressure through awareness campaigns, giving 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) can help businesses meet the high initial cost in their attempt to overcome barriers and become competitive over time by building scale and upgradation of technology. In addition, business models based on sharing services as opposed to owning resources can further aid the shift towards a RE economy.

The following types of RE business models exist:

- **RE products:** These include sale of products that are resource efficient or help users achieve RE. One example is the 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:** These include services such as waste management, consulting for saving resources, and payment per use model for products. The examples include car sharing, end-of-life vehicle management and so on.
- **Cost reduction based business models:** These are RE measures leading to cost savings. For example, Bosch uses electro-winning process to recover copper from plating solution waste.
- **Customer value creation based business model:** It caters 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 are 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 the form of subsides, tax incentives, and so on, and finally lack of internal motivation. Policy can address this awareness gap by providing sectoral and even process-specific information and support to convince businesses that conscious resource management not only reduces the burden on the environment, but also reduces the cost of production by minimizing the material and energy costs, and thus it creates competitive advantages for the company.

7.3.4 Integrating the informal and formal sectors

Informal sector makes a significant contribution to the overall economy and society by reducing the cost of waste management and recycling. The workers engaged in the formal sector constitute nearly 1% of the urban population and belong to the lowest social strata. With a substantial increase in the 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 formalizing it. Towards this end, the informal sector could be organized into cooperatives and jointly owned private enterprises to get access to technology and funding for improving their operations and ensuring safe working environment and health for workers employed in the sector. This will enable the informal sector to participate formally in waste management related tenders, while ensuring that benefits from SRM accrue to workers, resulting in increased earning potentials.

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 minimized. It is important to empower the informal sector through dissemination of low-cost technology and capacity development to increase the efficiency of recovery of key materials from waste. The Centre for Materials for Electronics Technology (C-MET) has developed a low-cost technology to recover key constituents from e-waste with efficiency between 80% and 87% and this technology can also be used by the informal sector. Quality metal scrap would be more in demand, especially as resources become scarce, and this can enable the informal sector to fetch better prices and augment livelihood options.

Different kinds of business models could also be developed that build on the positive aspects of the ways of operation of the informal sector and overcome the existing inefficiencies of the waste management system. For instance, the informal sector's expertise and ability in terms of collecting e-waste or other wastes directly from households and their segregation can be supported through a web platform that could be operated by a formal sector enterprise, thus creating another channel for informal–formal integration.

7.3.5 Research and development and educational initiatives

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

R&D support should be oriented towards producing resource-efficient solutions and developing resource-efficient products and services. R&D is extremely important to improve process efficiency and introduce new processes that can reduce material inputs and generate less waste. For example, as R&D and technological advances continue with a maturing solar industry, the composition of panels is expected to require less raw materials. Currently, two-thirds of globally manufactured PV panels are crystalline silicon (c-Si) that are typically composed of more than 90% glass, polymer, and aluminium, which are classified as non-hazardous waste. However, the same panels also contain 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 the resource recovery potential of end-of-life panels.

R&D is needed to develop innovative technologies to substitute critical raw materials in key industrial sectors, such as automotive, renewables and construction. The scarcity of critical raw materials, together with their economic importance, makes it necessary to explore new avenues towards substitution in order to reduce the consumption of natural resources and decrease the relative dependence upon imports. A lot of research is taking place in India and worldwide on substitutes in the cement industry and energy-efficient production. This research needs further support in the future and identified resource efficiency related innovations need a favoured access into the market.

Infrastructure support to carry out R&D activities 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, Global Auto Research Centre (GARC), under the National Automotive

Testing and R&D Infrastructure Project (NATRiP), was set up at Oragadam near Chennai 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, improve resource recovery and management of hazardous waste, and encourage the use of secondary raw materials by OEMs.

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 resource efficiency 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 R&D and market development for 19 waste management technologies. It is possible to extend similar programmes 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.

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

7.3.6 Creating a dedicated institution for promoting resource efficiency

In order to ensure wider adoption and enforcement of resource efficiency policy in India in a coordinated, integrated, and harmonized manner, there is a need for an overarching authority with relevant legal, administrative, and financial powers.

Section 3.3 of the Environment Protection Act states that '*The Central Government may, if it considers it necessary or expedient so to do for the purposes of this Act, by order, published in the Official Gazette, constitute an authority or authorities by such name or names …*' The allocation of business rules mandates the establishment of any such authority such as CREA under the MoEFCC. So the proposed authority could be housed in the Ministry of Environment Forest and Climate Change (MoEFCC), Government of India and will need to have clearly defined key functions and an implementation plan.

The CREA can be headed by a chairperson to be selected by the members of the steering committee of the already established resource efficiency cell and supported by a small secretariat. A vice-chairperson and a convenor for the proposed CREA could be appointed ex-officio of the Ministry of Environment, Forest and Climate Change. The CREA will also comprise ex-officio members from different central ministries and departments and NITI Aayog.

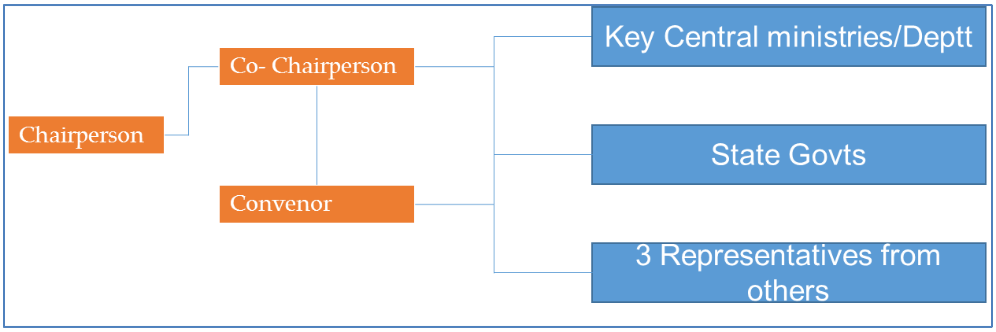

Figure 7.1: Structure of Central Resource Efficiency Authority, Government of India

The CREA members can be appointed for a period of 3 years, while the chairperson, vice-chairperson, and convenor can have a tenure of 4 years each. CREA can also co-opt up to three members, representing industry, academia, and civil society organizations, whose tenure will be fixed for a period of 3 years.

The existing Steering Committee of the RE Cell can be reconstituted to form the advisory board to CREA. The advisory board will initially have a joint meeting with the CREA members every quarter in the first year, and thereafter it is proposed that the board meets jointly with CREA two times a year. The members of the CREA will initially meet once in every two months during the first year, followed by quarterly meetings from the second year.

CREA will come up with short, medium, and long term strategies within six months of the first joint meeting with the advisory board. In the short-term strategy, the focus would be on the hotspot sectors that are covered under the resource efficiency policy (refer chapter 5), and additional sectors/materials including biotic materials of relevance would be incorporated in the medium and long term strategies.

7.3.6.1 Key functions of CREA

- CREA will engage in setting targets for resource efficiency that may be directly related to material use, such as recycling, reuse, and landfilling targets for various sectors, or may also be in the form of expenditures to promote the efficient use of resources. Before setting targets, CREA will have to identify the sectors for which targets will be set.
    - To begin with, the sectors could include households and construction and demolition.
    - This could be followed by the waste prevention targets for municipal, commercial, and industrial waste at the local level.
    - Reduction of marine litter reduction, because of its serious negative impacts on the marine environment, would also be an important target and an explicit definition of marine litter should be included in waste legislations.

- CREA will work with the BIS for setting standards and guidelines for new and resource-efficient products.
    - This would include standards for the reuse of secondary raw materials to address concerns regarding quality, ensure safety, and enable greater uptake by industries.
    - Develop standards for the design aspect of resource efficiency to make products more durable, make use of secondary materials, and make products that are easy to repair and recycle.
    - The standards will need to be consistent with the life cycle thinking approach and avoid the optimization of one life cycle phase at the expense of another.
    - Standards need to include product-specific considerations.
    - There should be industry/sectoral standards for implementation of best available technologies not entailing excessive costs (BATNEEC).

Standards set by CREA may be more politically acceptable than other policy instruments such as taxes. However, compliance and enforcement become a challenge, especially when the number of standards increases.

- CREA will facilitate public procurement of resource-efficient products by maintaining a list of products and manufacturers of approved resource-efficient products that would be referred by government departments at the time of their respective procurements, making it easier for each government agency to procure products without the need to undertake complex assessments with inadequate expertise.

- CREA will provide certifications for resource-efficient products and services, taking into account international best practices, using life cycle assessment tools wherever applicable and using guidance from ISO standards. These certifications are intended to outline and confirm that a product meets a particular standard and offers a resource efficiency linked benefit based on life cycle parameters, thereby making them multi-attribute. These parameters include use of critical virgin resources, recycled content, ease of dismantling, and recoverability of the secondary material. The certification coming from CREA will be considered more respected as CREA is an independent third party that would be conducting the product testing and awarding the certification.

To begin with, the EcoMark scheme should be rejuvenated and should expand into new product categories, especially focusing on products that use secondary resources.

- CREA will maintain database of the resource use across various sectors and selected stages of life cycle of products and materials. An efficient system of data recording that includes data on resource consumption for different resources, across sectors, and with respect to their use efficiency is currently lacking in India. CREA can devise methodology for baseline data collection and monitoring framework for sub-national level resource efficiency interventions and improvements. Based on this data and engagement with sectoral experts, CREA will prepare a list of resource efficiency and circular economy topics for each specific sector and also identify the leading practices for the sectors.

- CREA will also be responsible for registering the different players that are part of the end-of-life management stage such as scrap dealers, aggregators, and dismantlers, including those in the informal sector. The players will then have to abide by the rules set by CREA to engage in sustainable end-of-life management of products. This will also help in formalization of the informal sector and its integration in formal waste management.

- To support the line ministries to develop and implement their sectoral resource efficiency plans, CREA will set up committees headed by the joint secretary of the respective line ministry and develop policy interventions, including regulations for the respective sectors.

- CREA will also establish audit mechanisms and conduct regular inspections regulated by law and impose administrative fines in of the case of non-compliance of resource efficiency standards.

- CREA will also collect periodic data to verify the status of targets and RE initiatives, including use of policy instruments. An independently audited progress report by CREA that reviews the progress made towards the targets set out will be published annually. For verifying the progress of RE initiatives, CREA will develop a measurement and verification (M&V) framework with the objective to 'assess the outcome' of a resource efficiency/circular economy intervention in a transparent, reliable, and consistent manner.

- CREA will support collaborations between different stakeholders, including government, communities, research institutions, and industrial partners. It is also suggested that CREA will facilitate in conducting regular dialogues with relevant government and foreign agencies focused on experience sharing, knowledge transfer and governance models for achieving resource efficiency. Such partnerships will enable the development of new business models and solutions and allow faster adoption in the market.

- CREA will engage in capacity development, particularly in context of mainstreaming a life cycle based thinking across various policies, initiatives, and programmes. The enhancement and support of efforts for technology upgradation, as well as providing training and capacity building for improving the resource efficiency in production stage of life cycle, are extremely important, in the absence of which about 20% of material resources gets wasted. Building capacity of key actors responsible for undertaking or overseeing resource efficiency plans and strategies is an important enabler for fostering resource efficiency. To design a successful capacity building programme, it is important to rely on existing local potentials and place greater emphasis on practice rather than theory.

- CREA will use a holistic and integrated approach to identify and integrate resource efficiency concerns in relevant sectoral and cross-sectoral policies and develop synergies among relevant regulations through review and consultation. It will also identify emerging areas for new legislation, due to better scientific understanding, and economic and social development.

- CREA will collaborate with think tanks, industry associations and chambers, and line ministries to organize sectoral events related to successful resource efficiency projects with a focus on enabling their replication and upscaling. In addition, CREA will serve as a storehouse of best practices and business models that can be referred by those wanting to learn from them and apply in their context.

Besides the above functions, CREA will oversee, administer, and review the implementation of resource efficiency policy in India. It will develop and update, from time to time, national, regional and local resource efficiency plans based on the 6R principles and coordinate with the relevant public and private sector agencies for their inputs. It will comply with relevant stakeholders regarding the provisions of existing policies, rules, and regulations and establish synergies between resource efficiency related policy recommendations and polices with different ministries of central and state governments. This will help in better harmonization of other relevant policies and programmes of the government with the objectives of the resource efficiency policy.

MoEFCC is the apex administrative body in the country for regulating and ensuring environmental protection and lays down the legal and regulatory framework for the same. This is clearly mentioned in the Government of India (Allocation of Business) Amendment Rules, 2017. Since the 1970s, a number of environment legislations have been put in place. The MoEFCC and the pollution control boards, that is, CPCB (Central Pollution Control Board) and SPCBs (State Pollution Control Boards), together form the regulatory and administrative core of the sector. In this context, it will be important to learn from the experience of CPCB and Environment Pollution (Prevention & Control) Authority (EPCA), both of which are constituted under the Environment Protection Act.

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