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Material Consumption Patterns in India

A Baseline Study of the Automotive and Construction Sectors

EXECUTIVE SUMMARY

Implemented by:

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This document is a brief summary of the full report "Material Consumption Patterns in India: A Baseline Study of the Automotive and Construction Sectors" completed by GIZ-India, with its partners, under the Resource Efficiency project in March, 2016. For more details, or to get a copy of the full report, please contact the designated person listed above.

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Why Resource Efficiency?

Natural resources are critical for every society, but due to rapid economic and population growth, concerns about resource depletion have become acute in the last few decades. Resource supply constraints and price shocks can not only produce potentially severe economic and social consequences, but can also engender political conflict when vital resources are unequally distributed. In addition, resource extraction, utilisation and disposal also typically impose significant environmental burdens, including land degradation, biodiversity loss, as well as air and water pollution.

Moreover, resource extraction and utilisation are extremely energy intensive, thereby utilising a large amount of fossil fuels which even today, remain the main source of energy. This implies a strong correlation between resource use and greenhouse gas (GHG) emissions, which is a matter of urgent global concern. Therefore, judicious use of resources through a combination of conservation and efficiency measures for economic, social and environmental sustainability is in every society's interest.

Integrated, coordinated and collaborative approaches are required, both within and between countries, to reconcile increasing demand for resources with finite supply. Many industrial countries have adopted resource efficiency as a priority in their policy agendas and the G7 countries have committed to resource efficiency in the protocol of their 2015 meeting[1]. Germany, in particular, has developed and notified a national resource efficiency programme called ProgRess[2] which is updated every 4 years.

Learning from such best practices, it is important for India to initiate discussion on resource use and to identify priority areas for action, given its national context. In a resource constrained world, India cannot afford to ignore this issue as it can potentially jeopardise its development plans. Additionally, the enormous social benefits that can accrue from reduced environmental burdens should not be overlooked. Further, GHG emissions reductions resulting from resource efficiency measures will help India to meet its climate change commitments under the Paris global accords, 2015.

Aims and Scope of this Study

This study is a central part of the project titled Resource Efficiency and Sustainable Management of Secondary Raw Materials (in short "Resource Efficiency"). The German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), under its International Climate Initiative, has launched the project as a bilateral cooperation project with the Indian Ministry of Environment, Forest and Climate Change (MoEF&CC).

The project is being implemented by GIZ-India, in cooperation with German and Indian knowledge partners, as well as with external experts. The project aims to enable key Indian institutions responsible for the formulation of environment, climate, industry, and resource policy to aid and establish institutional frameworks that improve resource efficiency.

The project has three interrelated action plans (work packages):

First, material flows in key selected sectors of the Indian economy will be mapped to identify gaps, barriers, and areas of intervention.

Second, options for improving resource efficiency and enhancing the use of secondary raw materials will be demonstrated on a pilot basis for selected industry sectors.

Third, a high-level Indian Resource Panel (InRP) will be set up with renowned experts who will provide recommendations to the Government of India based on the learnings from the project.

This study is part of the first action plan (work package 1). A detailed analysis of material flows, resource needs, utilisation and trends in selected sectors – automotive and construction – will help to achieve a better understanding of these sectors and identify gaps and barriers for resource efficiency and potential areas of intervention.

These findings will inform both the selection of pilot demonstration projects as well as the deliberations of the Indian Resource Panel.

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1 Resource efficiency in the G7. German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB). Available at: http://www.bmub.bund.de/en/topics/economy-products-resources/resource-efficiency/resource-efficiency-in-the-g7/

2 Overview of the German Resource Efficiency Programme (ProgRess). German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB). Available at: http://www.bmub.bund.de/en/topics/economy-products-resources/resource-efficiency/deutsches-ressourceneffizienzprogramm/german-resource-efficiency-programme-progress/

Context of Resource Efficiency in India

Resource efficiency is particularly relevant for India since its economy is going through a period of rapid transformation due to several interlinked factors described below:

a) Growing population and increasing urbanisation: At 1.25 billion, India has the second highest population in the world. Projections show that India will overtake China to become the most populous country by 2030 and its population will keep growing past 2050[3]. Like many other emerging countries, India is witnessing rapid urbanisation. However, India has a relatively lower share of urban population (31% in 2010), and is currently experiencing a much faster rate of urbanisation. By 2050, a majority of India's population is expected to live in cities[4]. In absolute terms, 590 million people will be living in cities by 2030; such an unprecedented scale of urbanisation will require huge investments in housing and infrastructure.

b) Rising income and growing middle class: India has enjoyed one of the fastest economic growth rates over the past decade and is now the 4th largest economy in the world. While per capita income is still low by international standards, it has increased by a remarkable 400% since 1991[5]. The Indian middle class has doubled in size between 2001 and 2010. In terms of middle class consumption, India is currently 12th in the world, but it is expected that by 2050 India will have the world's largest share of middle class consumption[6].

c) Expanding industrial and service-related production: Although the agricultural sector is still dominant in terms of employment, the industrial and service sectors are increasingly contributing higher shares to employment and Gross Domestic Product (GDP). The service sector in particular, contributed 58% of GDP in 2011[7]. These sectors are resource intensive, owing to industrial production and higher consumption patterns due to a rise in disposable incomes.

Per capita consumption of materials in India is still low compared to the rest of the world; at 4.2 tonnes, it was less than half the global average in 2009. However, due to the large population size, India's total resource consumption is quite high, and is expected to increase rapidly, given the trends described above. Between 1980 and 2009, India's total material consumption increased by 184%, making it the world's 3rd largest consumer of materials, accounting for 7.1% of global material consumption. If current trends continue, India's material requirements are projected to be 15 billion tonnes by 2030 and 25 billion tonnes by 2050, with the biggest increases in the shares of fossil fuels, metals and minerals[8].

India currently meets most of its material requirements domestically, and increased domestic resource extraction is likely in response to the massive increase in future resource demand. While insufficient exploration and technological constraints may be one set of factors hindering effective utilisation of domestic mineral resources, environmental and social issues associated with mining are bigger concerns. Extraction per area in India, which could be used as a rough estimate of environmental pressure, is already the highest in the world[9], at 1,579 tonnes/km^2 land area, compared to the global average of 454 tonnes/km^2. Many mineral reserves are located in biodiverse forests, vital watersheds and in lands inhabited by indigenous people.

Environmental degradation, displacement and loss of livelihood associated with mining expansion has resulted in serious strife and conflict in many parts of India, and may be exacerbated with expanded mining[10]. Further, since mining is an energy intensive industry with a high carbon intensity, a massive expansion of mining may conflict with India's GHG reduction commitments under international climate change agreements.

At present, around 97% of all materials consumed are extracted within India, while only 3% are net imports. However, net imports have increased substantially over the past few decades, at a faster rate than that of domestic extraction. As a net importing country in terms of physical dimension of traded commodities, India had a negative trade balance in monetary terms of USD 161 billion in 2011. Of particular concern is the extremely high import dependence for several vital minerals like 95%

[3] World Population Prospects – 2015 Revision. United Nations Population Division.

[4] India's Urban Awakening: Building Inclusive Cities, Sustaining Economic Growth. McKinsey Global Institute, 2010.

[5] World Bank Database – GDP per capita. Available at: http://data.worldbank.org/indicator/NY.GDP.PCAP.CD

[6] Asian Affluence: The Emerging 21st Century Middle Class. Morgan Stanley Smith Barney, LLC. 2011.

[7] Government of India. Open Government Data Platform. Available at: https://data.gov.in/catalog/gdp-india-and-major-sectors-economy-share-each-sector-gdp-and-growth-rate-gdp-and-other

[8] Dittrich, M. (2015). Global Material Flows database. Available at: www.materialflows.net

[9] SERI/WU Vienna. (2012). Global Material Flows database. Available at: www.materialflows.net

[10] Rich Lands Poor People: Is 'Sustainable' Mining Possible? Centre for Science and Environment, New Delhi. 2008.

of copper, and 100% each for cobalt and nickel[11]. Recent experience has shown that mineral import dependent countries have been exposed to several risks, and such trends are only expected to worsen in the 21st century. These include commodity price spikes due to demand-supply mismatch, monopolistic behaviour from exporting companies or countries, export restrictions by countries to fulfill strategic aims as well as supply disruptions due to instability and conflict in exporting countries.

Since both over-extraction and over-dependence on imports have significant associated risks, using resources more efficiently needs to be a major part of India's economic strategy. In 2009, India gained 716 USD (PPP in constant 2005 USD terms) per tonne of used material, while the global average was much higher at 953 USD, and the Organisation for Economic Cooperation and Development (OECD) average was 1,768 USD[12]. Although India currently lags significantly behind in terms of resource productivity, it has made improvements in recent decades. Between 1980 and 2009, India's resource productivity increased more than three times the global average (98% for India versus 27% for global average). However, India's improvements were lower than those of China (118%) and Germany (139%). If India continues to make improvements in resource productivity at the present rate, it could gain around 1,306 USD per tonne of materials by 2030[13]; an even higher level could be achieved with a stronger commitment to resource efficiency.

Rationale for the Choice of Sectors

The automotive and construction sectors were chosen for analysis in this study due to their economic importance as well as their high consumption of materials as inputs.

Automotive Sector:

Mobility is vital for economic development and for the provision of essential services in any country. Unfortunately, the transportation sector also has many down sides – it is resource and energy intensive, and is often one of the highest contributors to pollution, including about 10% of the country's GHG emissions[14]. India being a developing country, public transport still enjoys a high share in terms of transport mode, but car ownership is increasing rapidly and this trend is expected to continue due to rising incomes and a growing middle class. The Indian automotive sector – comprising cars, 2 wheelers, and commercial vehicles – has enjoyed an annual growth rate of 14.4% over the past decade. Currently, it employs 13 million people (about 1% of India's population), directly and indirectly, and contributes nearly 7% to India's GDP. India's automotive production amounts to nearly 5% of world production, placing it 6th in the world[15]. This is a key priority sector for the government, which has future plans to transform India into a regional export hub supplying to the Asia Pacific region.

Analysing the direct and indirect raw material requirements in the Indian automotive sector and comparing them from 1997 and 2007, it was found that the material requirement of the sector doubled in a period of 10 years. If current growth trends continue, the total number of registered cars could exceed 100 million by 2030[16], with a concomitant rise in material requirements. The future distribution of different modes of transport – the modal split – has a significant influence on future resource demand. Heavy reliance on private vehicles would naturally mean much higher levels of resource requirements compared to reliance on public transport options.

Construction Sector:

Provision of housing and related infrastructure plays a crucial role in countries undergoing rapid development and urbanisation. In any country, the construction sector remains one of the largest consumer of resources. Housing and infrastructure investments are typically made for decades; therefore choices about design, location, building materials, etc. have long term implications with respect to resource and energy use.

The Indian construction sector has been growing at an average annual growth rate of 10% over the last decade, with its contribution to GDP increasing from INR 1.5 trillion in 2001-02 to INR 4 trillion in 2011-12, equivalent to 8% of the nation's GDP. The construction sector forms the second largest segment in India's economy in terms of employment, after agriculture, providing employment to about 35 million people[17]. The housing stock in India has been increasing at a remarkable pace, from 250 million units

[11] India's Future Needs for Resources: Dimensions, Challenges and Possible Solutions. Indo-German Environment Partnership. 2013. New Delhi: GIZ-India.
[12] Dittrich, M. (2015). Global Material Flows database. Available at: www.materialflows.net database and Dittrich, Giljum, Lutter and Polzin (2012). Green economies around the world? Available at: http://seri.at/wp-content/uploads/2012/06/green_economies_around_the_world.pdf
[13] Ibid
[14] CAIT Climate Data Explorer (2012 data). World Resources Institute. Available at: http://cait.wri.org/profile/India
[15] Market Evaluation for Resource Efficiency and Re-use of Secondary Raw Materials in the Automotive Sector. New Delhi: GIZ. 2015.
[16] India's Future Needs for Resources: Dimensions, Challenges and Possible Solutions. Indo-German Environment Partnership. 2013. New Delhi: GIZ-India.
[17] Report of the Working Group on Construction Sector for 12th Five Year Plan. Planning Commission. 2011. Government of India, New Delhi.

in 2001 to 330 million units in 2011[18]. However, given the strong demand drivers – population, urbanisation and income growth – the under supply of housing is becoming acute, especially in cities. The built up area in India is expected to increase exponentially; at current rates, about 70% of the buildings that will exist in 2030 are yet to be built[19].

In India, the construction sector was the second largest sector with regard to material consumption in 2007, accounting for around 20% of all material demand. Further, the construction sector was the fastest growing sector with regard to increases in absolute material consumption: between 1997 and 2007, material consumption grew by more than one billion tonnes. If such growth rates continue, the construction sector will surpass the agricultural sector before 2020 and become the highest material consuming sector in India[20].

The predominant materials used in the construction sector are sand, stones (as aggregates), soil (for bricks) and limestone (for cement). The cement industry is one of the largest emitters of CO_2; in India it accounts for approximately 7% of the country's total CO_2 emissions. India is currently the second largest producer of cement in the world, producing 210 million tonnes in 2010, which was 6.3% of global production. India nearly quadrupled its cement production between 1996 and 2010. In India, per capita consumption of cement is still low relative to developed countries at less than 200 kg per person, but at current growth rates, Indian cement production may increase 4-7 times by 2050[21]. While India has considerable limestone reserves, they may run out by 2060 at current growth rates. While domestic production for domestic consumption has been the predominant feature of construction materials in India, recent demand growth is bringing about changes. In recent years, net imports of limestone and gypsum have increased in particular, while net exports of building stones and mineral products such as cement have decreased[22].

It is clear that the Indian construction industry is likely to face serious material supply problems if the predicted growth in demand continues. Supply bottlenecks are already starting to affect prices and construction schedules in some parts of the country. The construction sector is particularly vulnerable to price shocks, since material costs account for roughly 2/3rds of the total cost of a typical building. Therefore, a strong emphasis on resource efficiency and use of secondary and alternate materials is essential for the Indian construction industry going forward.

Analytical Framework for this Study

Economy wide Material Flow Accounting (MFA) is a widely accepted approach to provide information on the quantum of materials coming into and leaving an economy. It is conceptually based on a simple environment-economy model where the economy is embedded in the surrounding environment and connected through material and energy flows. The choice of methodology and indicators depends on the goals of a particular study. While economy-wide MFA is useful for measuring the overall material flow in an economy, analysis of particular sectors requires a more targeted approach. For the two sectors that are the focus of this study, five "priority" materials were identified based on their importance to the resource efficiency debate in India, as explained below. For each identified material, the flows into/out of the economy (e.g., imports and exports), domestic extraction, as well as flows within the economy (for different sectors and applications, waste recycling, etc.) were analysed.

Automotive Sector:

Five important materials used in the sector were shortlisted based on their economic importance and supply risk. The economic importance of a material is determined on the basis of its application in the automobile sector and the extent of its substitutability by other metals or materials. The economic importance of a material in this sector was derived by analysing the composition of the most sold/used auto components in the market. Criticality was determined by: limited geological availability, techno-economic constraints, socio-environmental constraints, high import dependency, and geopolitical and economic constraints.

The five materials thus identified for analysis were:

i. iron and steel
ii. copper
iii. aluminium
iv. zinc and nickel
v. plastics and composites

18 Census of India 2011. Houses, Household Amenities and Assets. Government of India: New Delhi.
19 Constructing Change: Accelerating Energy Efficiency in India's Buildings Market. NRDC-ASCI. 2012.
20 Dittrich, M. (2015). Global Material Flows database. Available at: www.materialflows.net
21 Technology Roadmap: Low-carbon Technology for the Indian Cement Industry. WBCSD & IEA. 2013. Paris and New Delhi.
22 India's Future Needs for Resources: Dimensions, Challenges and Possible Solutions. Indo-German Environment Partnership. 2013. New Delhi: GIZ-India.

Construction Sector:

Five materials were identified for analysis based on their criticality. In order to assess the criticality, a framework was developed and applied to resources used in this sector. Criticality was assessed on the basis of:

- Scarcity of the resource, both physical and economic
- Cost of the material and the transit/carriage
- Environmental impact due to extraction and production
- Embodied energy, i.e., energy consumed during extraction, production and transport
- Supply risk, i.e., political, physical, cultural, legal, etc.
- Reuse and recyclability potential, secondary uses

The five materials thus identified for analysis were:

i. sand
ii. soil
iii. stone (aggregates)
iv. limestone
v. iron and steel

Sand, soil, stone and limestone were shortlisted due to the associated scarcity of the resource as against the projected demand, thus enhancing their supply risk. Another key distinguishing factor was the lack of reuse/recyclability potential, especially compared to metals. On the other hand, iron, though recyclable, was shortlisted due to its growing importance in construction, as well as social, economic and environmental problems associated with extraction and supply.

Analysis of the Automotive Sector

There is a need to shift from the current unsustainable private vehicle led transport approach to a more sustainable public transport (rail and road network) based approach that allows movement and transport activity in a way that helps in mitigating the negative impacts of transport, and strengthens the process of urbanisation in a sustainable manner. However, private and flexible forms of transportation, such as the automobile, are likely to remain an important part of transportation in rapidly industrialising countries like India; hence it is vital to focus on their environmental impacts. Automobile manufacturing and use can be made more sustainable with the help of new technologies such as: bio-fuels, electric engines, hydrogen fuels and low weight materials, and use of secondary raw materials and integrating resource efficiency in the production process of different types of vehicles and components.

Material Flow: Assessing Current and Future Demand

Five categories of automobiles - Trucks, Buses, Four Wheelers, Three Wheelers and Two Wheelers were considered in the context of the selected materials. There is very limited information available on the material composition of vehicles in India due to which estimates were needed in some cases.

An automobile is composed of various material components which are produced by utilising a wide variety of technologies and satisfy customer needs and meet environmental norms. These include conventional steel, high strength steel, stainless steel, other steels, iron, aluminium, rubber, plastics/ composites, glass, copper and brass, zinc die castings, powder metal parts, fluids and lubricants, and other materials. In the past, automobiles have been composed primarily of iron and steel. Steel has remained a major automotive component 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. Iron and steel use has steadily decreased, while plastics and aluminium has steadily increased. Plastics are preferred material for car components not only for their lighter weight, but also because of their inherent corrosion resistance.

Steel is used to manufacture a car's chassis and body including the roof, body and door panels, the beam between doors, mufflers and exhaust pipes. The analysis shows that the aggregate steel demand (for the aforementioned five categories) is projected to increase from 11.11 million tonnes (2015) to 80.66 million tonnes (2030). Among the three most prominent categories, buses will account for 50% of the steel consumption within the sector, followed by 4 wheelers at 33% and 2 wheelers at 10%.

The benefits of recycling steel are manifold. Recycled steel uses 75% less energy than steel made from virgin raw materials. All types of steel are 100% recyclable and can be recycled infinitely without a loss in quality. Recovery of 1 tonne of steel scrap conserves an estimated 1,030 kg of iron ore, 580 kg of coal and 50 kg of limestone[23]. According to the Institute of Scrap Recycling Industries, recycling one car can save around 1,000 kg of iron ore, 560 kg of coal and 48 kg of limestone[24].

[23] Fenton, M. D. (1998). Flow studies for recycling metal commodities in the United States. US Geological Survey. Available at: http://pubs.usgs.gov/of/2001/of01-224/of01-224.pdf

[24] Institute of Scrap Recycling Industries, Washington, DC. (2014). Iron and Steel Fact Sheet. Available at: http://www.isri.org/docs/default-source/recycling-industry/fact-sheet---iron-and-steel.pdf

The use of aluminium in automobiles shows significant variation with developed countries using 140 kg of aluminium per vehicle on average, while in India, the average is around 40 kg per vehicle[25]. The estimated aluminium demand by the automotive industry would increase from its current estimated level of 1.76 million tonnes to more than 10 million tonnes over the next 15 years. Buses will account for 46.7% of the future resource to be consumed in this sector, followed by four wheelers.

Aluminium recycling saves huge economic and environmental costs compared with production from virgin ore. Each tonne of aluminium recycled uses 95% less energy and saves one square meter of land use, 24 barrels of crude oil equivalent of energy, more than 15 tonnes of water use, eliminates more than 9 tonnes of CO_2 equivalent of GHG, avoids 2.5 tonnes of solid waste and hundreds of kg of other air and water-borne emissions and effluents[26]. Recycling of aluminium reduces the mining of bauxite ores as well as use of chemicals such as caustic soda, aluminium fluoride and lime. Aluminium is 100% recyclable and can be recycled numerous times without losing its quality.

The estimated demand for copper by the auto industry in India is expected to increase from its current estimated level of 0.21 million tonnes to about 1.6 million tonnes over the next 15 years. Buses and four wheelers will account for 54% and 36% of the copper usage in the sector by 2030 respectively. There are various economic and environmental benefits associated with recycling copper. Recycled copper uses only about 10% of the energy used for extracting or mining copper. Recycling copper helps to keep the prices of copper and copper products low. In the USA, 43% of copper demand is satisfied by recycled scrap; the corresponding figures for Western Europe and Japan are 41% and 39% respectively[27].

The estimated demand for zinc and nickel by the auto industry in India is expected to increase from its current estimated level of 0.1 million tonnes to about 0.65 million tonnes over the next 15 years. The expected gross consumption of zinc and nickel would be highest for buses (0.3 million tonnes), followed by four wheelers (0.19 million tonnes) and two wheelers (58,000 tonnes).

The estimated plastics demand by the auto industry will increase from its current estimated level of 1.13 million tonnes to more than 8 million tonnes over the next 15 years. Although 13 different high quality plastics are normally used in automobiles, application of 3 types of plastics - polypropylene, polyurethane and polyvinyl chloride - will find major use in the sector. Between 2016 and 2030, total estimated use of composites in the automotive sector would increase from 44,000 tonnes to 131,000 tonnes. Given the growing demand and use of plastics, increased and improved recycling eventually must become a key step towards sustainability in this industry. Recycled plastics will eventually have lesser environmental impacts due to lower energy consumption, reduced GHG emissions, and water use.

The total material demand from 2015 to 2030 in the automotive sector is expected to increase from 14.1 million tonnes to 102.1 million tonnes, given projected demand and assuming existing levels of production efficiency and resource recycling.

Companies in India are recognising the importance of resource efficiency. Some companies have voluntarily adopted practices to efficiently utilise resources and/or minimise wastages. These practices target material consumption, energy consumption, environmental impact and resource efficiency. It is important that the product and component manufacturers focus on increasing the life of the product as well as its efficiency. Some of the by-products or wastage could be a valuable resource for some other process; thus re-utilising and re-using these products should be encouraged rather than disposing them.

Governance Issues and Challenges in Resource Efficiency in Automobile Sector

The automobile sector in India being a major sector in terms of its economic contribution and social implications, a coherent policy framework employing specific and targeted approaches is essential for resource efficient manufacturing, well-organised recycling of products, and competent handling of resources from end-of-life vehicles, among others. Integrating environmental parameters in manufacturing and material purchasing decisions needs to be promoted; this will also lead to economic gains and savings.

The policy framework needs to focus on economic instruments as a tool to regulate automobile manufacturing and help address the associated environmental challenges. Support also needs to be provided for conducting extensive research and development and exploring options for alternate materials and fuels, and accessing clean technologies. All stakeholders can engage in a dialogue to identify and create awareness on solutions for enhancing

25 Ducker Worldwide. (2009). Aluminium Association Light Vehicle Aluminium Content Update. Available at: http://www.drivealuminum.org/researchresources/PDF/Research/2009/2009-Ducker-Report.pdf

26 The Aluminium Association. North American Aluminium Industry Sustainability Report 2011.

27 Copper Development Association. Available at: http://www.copper.org/environment/lifecycle/g_recycl.html

resource efficiency and improving the environmental performance of this sector.

The Indian government currently does not have a specific focus on increasing resource efficiency in the automotive sector. The National Environment Policy[28], introduced by the Government of India in 2006, governs the domain of ensuring responsible use of resources. The policy mainly aims at 'creating incentives to minimise wasteful use and consumption of natural resources' with an overall objective to conserve environmental resources through their efficient use, encourage intergenerational equity, ensure application of principles of good environmental governance and promote ways for environmental protection. Increasing fuel efficiency[29] and decreasing the polluting emissions[30] from the automotive sector have also been active areas of research and regulation in India.

With respect to component manufacturing, Auto Policy 2002[31] was formulated by the Ministry of Heavy Industries and Public Enterprises with an objective to promote integrated, phased, enduring and self-sustained growth of the Indian automotive industry. Measures under this Policy included automatic approval for 100% foreign equity investment in auto component manufacturing facilities and exemption of manufacturing and imports in this sector from licensing and approvals.

An Automotive Mission Plan had been implemented for the duration of 2006-2016 by the Government of India[32]. It initiated setting up of a technology modernisation fund focusing on Small and Medium Enterprises (SMEs) and establishment of automotive training institutes and auto design centres, special auto parks and virtual Special Economic Zones (SEZs) for auto components. But the actual utilisation of such funds and training centres have been inconsistent.

Efficient recovery of materials from end-of-life vehicles after dismantling the automobiles has become an important area for bringing about efficiency improvements. The Ministry of Heavy Industry and the Society of Indian Automobile Manufactures (SIAM) have made efforts to promote the area of resource recovery. The Ministry of Road Transport and Highways has prepared a Draft Voluntary Vehicle Fleet Modernisation Policy for four-wheelers older than 12 years[33]. Once approved and notified, it will provide further impetus to the setting up of dismantling centers and strengthening the business case.

An automobile dismantling center - Global Auto Research Centre (GARC), under the National Automotive Testing and R&D Infrastructure Project (NATRiP)[34] at Oragadam, near Chennai, has been set up with the goal of promoting recycling activities by engaging labour in safe working conditions, managing the hazardous waste, and encouraging recovery of materials which are reusable by Original Equipment Manufacturers (OEMs). The centre, set up in collaboration with SIAM, is also expected to train and help upgrade current units in the unorganised sector. However, currently the sourcing of end-of-life vehicles to such formal dismantling centres remains an issue of concern.

An ambitious initiative has been undertaken by the Government of India in the form of The National Electric Mobility Mission Plan 2020[35]. It is a composite scheme using different policy-levers. Demand side incentives include facilitation of acquisition of hybrid/electric vehicles; promoting R&D in technology including battery technology, power electronics, motors, systems integration, battery management system, testing infrastructure, ensuring industry participation; and promoting charging infrastructure. Supply side incentives include encouraging retro-fitment of on-road vehicles with hybrid kit. Yet, the usage of electrical/hybrid vehicles have their own constraints which need immediate attention such as range limits, lack of awareness among users, lack of promotion of such vehicles, etc.

Further, lack of any proficient methodology for tracking material usage has led to incomplete research in this area. In addition, there is no policy of how to valorise the waste produced in the sector. Without suitable cost and pricing mechanisms, R&D in the sector suffers and in turn, enough investment cannot be argued for in the sector. A comprehensive

28 National Environmental Policy 2006. Ministry of Environment, Forest and Climate Change, Government of India. Available at: http://www.moef.gov.in/sites/default/files/introduction-nep2006e.pdf

29 New fuel efficiency norms in India add pressure to automobile industry. India Transport Portal. March 18, 2015. Available at: http://indiatransportportal.com/new-fuel-efficiency-norms-in-india-adds-pressure-to-automobile-industry-31144

30 Vehicular exhaust emission norms. Central Pollution Control Board. Available at: http://www.cpcb.nic.in/Vehicular_Exhaust.php

31 Auto Policy 2002. Society of Indian Automobile Manufacturers. Available at: http://www.siamindia.com/cpage.aspx?mpgid=16&pgid1=17&pgidtrail=79

32 Automotive Mission Plan 2006-2016. Ministry of Heavy Industries and Public Enterprises, Government of India. Available at: http://www.siamindia.com/uploads/filemanager/20AMP-2006-16.pdf

33 Policy to scrap nearly 28 mission over-11-year-old polluting vehicles submitted to Finance Ministry. The Indian Express, July 6, 2016. Available at: http://indianexpress.com/article/india/india-news-india/policy-to-scrap-nearly-28-million-over-11-year-old-polluting-vehicles-submitted-to-fin-min-nitin-gadkari-2897810/

34 NATRiP homepage: www.natrip.in

35 National Electric Mobility Mission Plan 2020. Department of Heavy Industry, Government of India. Available at: http://dhi.nic.in/UserView/index?mid=1347

and stringent regulatory roadmap would help the automotive sector in India to have better clarity, faster adoption of technology and a sustainable development process for material and resource efficiency.

GHG Saving Potential

India has taken steps to curb expected increases in GHG emissions, including launching efforts to increase the efficiency with which resources are used and by accelerating the adoption of clean technologies. The transport sector in India is a significant emitter of greenhouse gases, already at 10% of the country's GHG emissions[36], and increased transportation demand will further push up GHG emissions in the future. The adoption of measures to improve resource efficiency and reduce energy consumption will lead to reduced GHG emissions in the automobile sector, thereby offering a high mitigation potential and significant improvement in air quality.

Over the last two decades, environmental problems caused by the transport sector has caught the attention of policy makers in India and various steps adopted by the central and state governments have included elimination of lead in petrol, switching to natural gas, particularly in public transport fleets, and adoption of Euro emissions standards for new vehicles. India's Auto Fuel Policy of 2003[37] identified a roadmap for vehicular emissions and fuel quality standards. India's National Action Plan on Climate Change (NAPCC)[38] recognised that GHG emissions from the transport sector can be reduced further by adopting measures that include increased use of public transport, increased use of biofuels, as well as improving fuel efficiency of vehicles.

Reducing the weight of vehicles can help conserve resources, since less material is required, while for users of the vehicles, the reduced weight is reflected in lower fuel consumption and CO_2 emissions. Over the life cycle as a whole, these benefits could far outweigh the increased environmental impacts at the manufacturing stage.

In a world of increased competition, resource efficiency can emerge as the central lever for sustainable value creation in the auto industry, provided a conducive policy environment is developed through informed decision making by policy makers.

Analysis of the Construction Sector

Increasing urbanisation and rising per capita income have fueled a steep growth in the construction sector in India. Recognising these trends, India's Planning Commission has doubled the proposed spending on buildings and infrastructure in the Twelfth Five Year Plan. Buildings, which include residential and commercial, have a share of 6.3% in GDP and this is expected to increase to 13% by 2028[39]. On the infrastructure side, 1,000 km of expressways and 10,000 km of National Highways are planned to be built by the end of 2017. The rail network is also being expanded so that the north-eastern states will be fully connected by 2020[40]. Such ambitious goals will require materials in huge quantities. Some of these materials are already facing scarcity issues. Additionally, their extraction and use have associated environmental and social impacts. Therefore, it is important to understand the conventional flow of these materials in the economy in order to understand the scale and patterns of use and identify points in the flow where interventions could be applied. Understanding the material flow also provides an opportunity to assess the flow of waste that comes out during construction and at the end of life of buildings.

As described above, five critical resources were identified for material flow analysis. The criticality of selected materials was assessed on the basis of their scarcity, cost, environmental impact, embodied energy, supply risk, lack of recyclability and conflict of use. The five materials thus identified for analysis were sand, soil, stone (aggregates), limestone, and iron and steel. The flow of each resource was traced from cradle to grave, i.e., from its extraction to final disposal. Though there are competing uses of these resources in the system, special emphasis was given to the construction sector as an end user of the resource. The material flow follows an input and output approach where inputs are shown in terms of energy and material and outputs are shown in terms of end product and waste. Available statistical data was used to quantify resources along the flow. Wherever data was not available, proxies and assumptions were used

[36] CAIT Climate Data Explorer (2012 data). World Resources Institute. Available at: http://cait.wri.org/profile/India

[37] Auto Fuel Policy. Press Information Bureau, Government of India, Ministry of Petroleum and Natural Gas. Available at: http://pib.nic.in/newsite/Printrelease.aspx?relid=119754

[38] National Action Plan on Climate Change, Government of India. Available at: http://www.moef.nic.in/downloads/home/Pg01-52.pdf

[39] KPMG. (2014). Indian Real Estate - Opening Doors. Available at: https://www.kpmg.com/IN/en/IssuesAndInsights/ArticlesPublications/Documents/Indian-real-estate-Opening-doors.pdf

[40] Planning Commission. (2013). Twelfth Five Year Plan (2012-2017) Economic Sectors Vol II. New Delhi: Government of India.

to quantify the resources. Further, at the end of life of buildings, productivity was assessed for potential alternates to close the loop. Resources were also analysed for their environmental and social impacts and regional differences in prices and availability.

Sand is a resource in high demand from the construction sector; an estimated 1.4 billion tonnes of sand will be required by 2020, compared to 630 million tonnes in 2010[41]. The sources of sand extraction are clearly defined by the MoEF&CC in its recent Draft Sustainable Sand Mining Management Guideline[42]; these include: Rivers (flood plain and river bed), Lakes and Reservoirs, Agricultural fields (Haryana), Coastal and Marine Sand, and Paleo Channels (Rajasthan). River sand is the most preferred choice in the construction and brick sectors due to the presence of silica, which is inert, hard and durable. This type of sand does not require much processing. Thus its mining is an easy and attractive business to small players. This fuels rampant extraction of river sand by the unorganised sector, which leads to the destruction of rivers and river systems. This also makes it difficult for the State to police the activities of the sand mining industry, which proliferates owing to low investments and high returns. Some reports have indicated an amount of INR 10 billion (USD 150 million) being generated from illegal extraction of sand in India in 2011[43].

Due to the unregulated nature of this business, market prices of sand can vary widely from region to region; for example, a truck load of sand (600 ft^3/17 m^3) was available for INR 1,600-2,000 (USD 24–30) in West Bengal, but could go as high as INR 40,000 (USD 598) in Bangalore. River sand has already started to show signs of scarcity in some of the south Indian states while rivers such as Yamuna in north India have already started to degrade due to rampant mining. This has led the central and some state governments to impose temporary or blanket bans on sand mining. However, manufactured sand (m-sand) is emerging as a promising alternative. But preparation of m-sand also uses natural material such as granite. Another potential material that can be used to make m-sand is construction and demolition (C&D) waste. India generated 716 million tonnes of C&D waste per year in 2015. Most of this waste ends up in landfills or is illegally dumped in river beds or road sides. To close the loop, C&D waste should be explored as a source material for m-sand.

In addition, to manage sand mining in India, tracking its extraction becomes very important. Steps taken by Andhra Pradesh and Telangana for online tracking and tendering of sand are a way forward in sustainable management of sand. The Government of Maharashtra is also using a Sand Mining Approval and Tracking System (SMATS) which enables contractors to order sand though their mobile phone and the orders can be tracked online. Such systems lead to transparency in the sand mining business and helps in tracking illegal extraction of sand. They should be promoted in other states as well. The Draft Sustainable Sand Mining Management Guidelines recently issued by MoEF&CC is a positive move to protect rivers and implement sustainable sand mining practices in states. It is imperative that state governments quickly implement these guidelines and promote alternatives to natural sand.

Soil is used by the brick kiln industry for production of clay bricks. The Indo-Gangetic plains covering most of northern India carry the most suitable and fertile soils. Covering about 150 million hectares or about 45.6% of the total land area of the country, alluvial soils constitute the largest share among all soil types found in India. There are other soils such as black cotton soil and red soil in central and south India which are also suitable for brick manufacturing. In addition to brick manufacturing, soils are used for road construction as base material. Soil is also a resource for agriculture and hence there is an overlap of use of soil between brick making and agriculture. This creates food security issues as unchecked soil extraction from agricultural lands degrades its productivity. It is estimated that about 840 million tonnes of soil is extracted every year for brick production denuding 0.17 million km^2 of land[44].

Though soil can theoretically be replenished, it is being utilised much faster than its replenishment rate. Soil mining is an unorganised industry; mining above legal limits is a common practice. Thus inventories are inadequate and are poorly tracked in the market. Prices of soil used for brick making are not compiled by the government, but a survey of contractors in the construction material supply industry suggests that brick kiln owners typically pay landowners between INR 1,500-2,000 (USD 22-30) for 8-10 metric tonnes of soil mined. Brick kilns are also huge contributors of CO_2 emissions. The Central Pollution Control Board (CPCB) estimates emissions from

41 Aggregate Business International. (2013). Booming Indian aggregates market. Available at: http://www.aggbusiness.com/sections/market-reports/features/booming-indian-aggregates-market/

42 MoEF&CC. (2015). Sustainable Sand Mining Management Guideline. New Delhi: Ministry of Environment, Forest & Climate Change. Available at: http://www.moef.nic.in/sites/default/files/Sand%20Mining%20Guideline%2028.08.2015.pdf

43 CSE. (2012). Grains of Despair: Sand Mining in India. Centre for Science and Environment, New Delhi. Available at: http://www.cseindia.org/content/grains-despair-sand-mining-india

44 CPCB. (2015). Brick kilns in India. New Delhi: Central Pollution Control Board. Available at: http://www.cseindia.org/docs/aad2015/11.03.2015%20Brick%20Presentation.pdf

140,000 kilns operating in the country to be about 66 million tonnes[45]. Other harmful gases emitted from brick kilns include carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen oxides (NOx) and suspended particulate matter (SPM). Coal used for brick firing also leaves behind bottom ash as residue. According to the CPCB[46], brick kilns employ 9 million people across India; labour exploitation is widespread.

One of the successful interventions made by the central government was to promote the use of fly ash, vide a notification, S.O. 763 (E) in the year 1999, which mandated the use of fly ash in building materials for construction projects falling within a 100 km radius of coal or lignite based thermal power plants. The subsequent amendments to this notification directed builders to use at least 25% of fly ash in clay bricks and 50% of fly ash by weight in fly ash bricks, blocks, etc. The market responded positively to the sustained efforts of the government, and currently about 12% of total fly ash generated in India is used for the production of bricks and tiles[47]. However fly ash in bricks still competes with cement manufacturers as it is also a popular material used in blended cements such as Pozzolana Portland Cement (PPC).

Use of fly ash in brick manufacturing needs to increase if the pressure on fertile topsoil from brick manufacturing is to be reduced. If a building is demolished properly, most of the bricks can be recovered and reused. Bricks which are broken or are unusable in construction could be utilised as base material for roads, thus replacing soil or primary resources.

Stone aggregates are used by the construction industry for making concrete and road laying. The construction industry prefers igneous rocks like granite and basalt to be used as aggregates due to their durability. With the growing popularity of m-sand, granite already has an emerging competing use. Basalt is mainly used by the railways. Material flow analysis suggests that the total demand of stone for concrete and road making is about 1.1 billion tonnes per annum of which about 99% goes for concrete making. In the foreseeable future, the demand for coarse aggregates is expected to soar as concrete will remain the mainstay of construction. It is estimated that the construction industry will have a demand of more than 2 billion tonnes of coarse aggregates by 2020[48]. Further, the 12th Five Year Plan estimates an additional capacity of 1 billion tonnes of concrete to be created by 2027 to meet demands from road infrastructure and housing. Considering various mix ratios used for concrete, coarse aggregates range from a minimum of 2 to a maximum of 10 parts per unit of cement. Taking this into account, the coarse aggregate requirement in the year 2027 shall range between 2-10.3 billion tonnes. Apart from concrete, the demand for coarse aggregate required as road base material will also increase in view of the recent commitment of the Indian government to build 30 km of roads per day.

Processing of stone for use as aggregate has significant impact on air pollution. Using alternate material for aggregates in place of stones is a way forward in efficient use of this resource. The properties of recycled aggregates made from C&D waste have been established and demonstrated through several experimental and field projects successfully. Recycled aggregates from C&D waste can be readily used in construction of low rise buildings, concrete paving blocks and tiles, flooring, retaining walls, approach lanes, sewerage structures, sub base course of pavements, drainage layer in highways, in dry lean concrete and as base material for roads. Due to lack of standards and lack of marketing, the popularity of recycled aggregates is not growing among builders and contractors. Steps are being taken by the Bureau of Indian Standards (BIS) to formulate standards for the use of C&D waste as coarse aggregates in concrete.

Limestone is the most extracted mineral in the country with the cement industry being the principal user. India has abundant deposits of cement grade limestone and is self-sufficient in its production. However, minable reserves of limestone are concentrated only in 13 states of India. Limestone once used in cement preparation cannot be reused again for the original purpose; however, the cement which comes out with mixed rubble at the end of life of a building can be used as aggregates, thereby ensuring indirect reuse. Currently, India utilises about 226 million tonnes of limestone[49] in cement manufacture, iron and steel, chemical and other industries of which utilisation share of the cement industry is about 93%[50]. Limestone production,

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45 Ibid.

46 Ibid.

47 CEA. (2015). Report on Fly Ash Generation at Coal/Lignite Based Thermal Power Stations and its Utilisation in the Country for the Year 2014-2015. Central Electricity Authority. New Delhi: Ministry of Power, Government of India.

48 Aggregate Business International. (2013). Booming Indian aggregates market. Available at:

http://www.aggbusiness.com/sections/market-reports/features/booming-indian-aggregatesmarket/

49 IBM. (2015). Indian Minerals Yearbook 2015, Limestone and other Calcareous Minerals Part III: Mineral Reviews. Nagpur: Indian Bureau of Mines.

50 Ibid.

consumption, exports and imports are properly documented in the country. It is estimated that limestone resources of India will last for next 35-41 years[51].

Apart from availability concerns, limestone mining also has negative impacts on the environment and human settlements in the vicinity of mines. Ground water contamination and fugitive dust emissions are major environmental threats associated with limestone mining. The global warming potential of limestone mining is 0.0021 kg of CO_2 per kg of limestone mined[52]. Thus in India, it is estimated that limestone mining contributed about 0.6 million tonnes of CO_2 emissions in the year 2012-2013 based on mining data obtained from the Indian Bureau of Mines (IBM). Therefore, it is very important to explore alternatives to limestone such as blended cements for conserving limestone resources. Fly ash is a popular waste from coal based thermal power plants that is used in preparation of cement. Though it does not replace limestone completely, it certainly reduces its use in cement production. Innovative technologies such as the use of china clay in cement production also need to be encouraged to reduce the pressure on limestone resources.

Iron and Steel is a well-established and well regulated industry in India linked to many end use sectors. The construction industry uses steel bars and rods for Reinforced Cement Concrete (RCC) structures. Iron ore, the basic raw material for steel production is abundant in India. However, due to a dip in international prices of high-grade iron ore and inconsistency in domestic supply, India has become a net importer of iron ore in recent years[53]. The cement industry is the only other major consumer of iron ore apart from the iron and steel industry, but its share of consumption is just 1%. India is also a net importer of finished steel, with imports being influenced by changes in international prices[54].

Steel has a very high recyclability potential. Steel scrap in India sells at good prices and is completely recycled. Steel that comes out after demolition of end-of-life buildings is sold in the local market and is reused by local foundries and smelting units. However, steel production and iron ore extraction are extremely polluting activities. There have been instances in the past where iron ore mines have severely polluted surrounding areas and were closed. From the resource efficiency point of view, there are no possible interventions that can be applied as the industry is already streamlined in reusing the iron and steel scrap from the C&D sector.

GHG Mitigation Potential

Apart from resource conservation, use of C&D waste will also help mitigate CO_2 emissions from processing of natural stones into aggregates. Aggregate production from natural stones such as granite and basalt has significant environmental impact, not least in terms of CO_2 emissions from the use of fossil fuels and electricity. It is estimated that about 20 kg of CO_2 is emitted from processing 1,000 kg of natural aggregate. Processing includes quarrying, crushing and transport of aggregates. In contrast, processing 1,000 kg of recycled aggregate (C&D waste) emits about 12 kg of CO_2 (a 40% reduction). Thus, use of 1,000 kg of recycled aggregates translates to CO_2 savings of about 8 kg. Aggregate demand in concrete and road laying in India is estimated to be about 1.1 billion tonnes per annum. If all of the aggregate is replaced by C&D waste there is a potential to save about 8 million tonnes of CO_2 per annum[55].

Natural sand can be replaced by m-sand. However, there is almost no processing required for natural sand and it is mostly locally sourced. Hence CO_2 emissions associated with natural sand are considered negligible. M-sand is an alternative to natural sand, which is now being increasingly adopted in some states of India. It is made from natural stones such as granite. The CO_2 emissions associated with m-sand processing are believed to be more than that from production of aggregates from natural stones. This is because for production of m-sand, stones are crushed to finer particle sizes, which requires more fuel or electricity. If m-sand is produced using C&D waste instead of natural stone, CO_2 savings of about 8 kg per 1,000 kg of C&D waste utilised can be achieved. More importantly, using m-sand from recycled aggregates will help in reducing pressure on rivers for extraction of natural sand.

51 Ministry of Commerce and Industry. (2011). Report of the Working Group on Cement Industry for XII Five Year Plan (2012-2017). Department of Industrial Policy and Promotion. New Delhi: Ministry of Commerce and Industry.

52 Source from Ecoinvent Database of SIMAPRO software

53 Kulkarni, M. (2015, April 23). India likely to remain net importer of iron ore in FY 16. Business Standard. Available at: http://www.business-standard.com/article/economy-policy/india-likely-to-remain-net-importer-of-iron-ore-in-fy16-115042300566_1.html

54 The Hindu. (2015, June 8). Steel imports surge 58% in May. The Hindu. Available at: http://www.thehindu.com/business/Industry/steel-imports-surge-58-per-cent-in-may-consumption-up-68-per-cent/article7294593.ece

55 Based on estimates by USEPA, 2003. For detailed calculations, see Full Report, p. 131.
USEPA. (2003). Background Document for Life-Cycle Greenhouse Gas Emission Factors for Clay Brick Reuse and Concrete Recycling. Washington, DC: Environmental Protection Agency.

Best Practices in Resource Efficiency in the Automotive and Construction Sectors

Automotive Sector:

Design to dematerialise: Under an initiative of Volkswagen, sheets of steel are cut and heated to a temperature of above 900 C. The heated sheets are then placed in a forming liquid where towards the end of the process it changes into high strength steel at a temperature of about 180 C. This results in a reduction of the overall weight of the vehicles and the material consumed. The vehicle used in this process is 100 kg lighter than the earlier model[56].

Recycling and re-use of waste: In 2015, approximately 200,000 end-of-life oil filters and approximately 180,000 end-of-life bumpers were collected and recycled by Honda. Honda Freed's splash guards and other components utilised the recycled bumpers[57].

Design for re-valorisation: To improve the recyclability of metals like steel, aluminium and copper, Toyota has made recyclability a focus in the designing phase of the vehicle itself. The vehicles are now designed in such a way that it is easy to dismantle and separate parts at the end of life. In financial year 2011, the following number of parts were remanufactured from used parts[58]:

Automatic transmission: 4,975
Power steering: 10,919
Torque converters: 4,429

Training and education programme: In the US state of Tennessee, Volkswagen worked with the Chattanooga State Community College to build a staff training center to train its staff on various aspects associated with automotive sector like efficient use of resources, new technological development, sustainable operations, etc. Similar training programmes have been seen at other auto manufacturing companies such as Mercedes with Alabama Industrial Development Training and Kia with Georgia Quick Start[59].

End-of-Life Vehicle (ELV) recycling: In Taiwan, handing over the license plates to the concerned authorities meant deregistration of the vehicles. However, in order to promote recycling, the Waste Act was amended which requires the car owners to get a certificate from authorised recyclers before the vehicle can be deregistered.

Construction Sector:

Regulation: The Fly Ash Notification (S.O. 763 (E)) issued in 1999 by the Government of India, places restrictions on the excavation of top soil for manufacturing of bricks and promotes the utilisation of fly ash for the same. All construction agencies within a radius of 100 km from a coal or lignite based thermal power plant shall use only fly ash based products for construction. These products will have a minimum of 50% of fly ash by weight. It also stipulates that thermal power plants should provide at least 20% of dry fly ash free of charge to units manufacturing fly ash or clay fly ash bricks, blocks and tiles on a priority basis over other users. Other Central and State Government agencies and State Electricity Boards should help manufacturers by making available land, electricity and water and provide access to the ash lifting area for setting up ash based units[60].

Germany's Act for Promoting Closed Substance Cycle Waste Management and Ensuring Environmentally Compatible Waste Disposal, 1994, sets principles for development of waste management in order to transition to a closed loop economy. It emphasises on the prevention of waste generation rather than recycling of waste. However, recycling is more preferable to the disposal of waste, and waste should only be disposed when recycling is not possible or is too expensive. The Federal Cabinet of Germany adopted the German Resource Efficiency Programme (ProgRess) in 2012. ProgRess also promotes recycling of C&D waste[61].

Technology and management: Initiatives are being taken by building administrators or Resident Welfare

[56] Volkswagen. (2015). SEAT Volkswagen Group Annual Report 2014. Available at: http://annualreport2014.volkswagenag.com/divisions/seat.html

[57] Honda Motor Co. Initiatives related to products: Effective utilisation of resources. Available at: http://world.honda.com/sustainability/environment/product/resource/

[58] Toyota Sustainability Report 2012. Toyota Motor Corp. Available at: http://www.toyota-global.com/sustainability/report/sr/

[59] Jacinto, J. (2014). Growing US auto industry drives new hiring, training practices. Available at: http://www.totallyintegratedautomation.com/2014/08/growing-u-s-auto-industry-drives-new-hiring-training-practices/

[60] CEA. (2015). Report on Fly Ash Generation at Coal/Lignite Based Thermal Power Stations and its Utilisation in the Country for the Year 2014-2015. Central Electricity Authority. New Delhi: Ministry of Power, Government of India.

[61] Federal Ministry for the Environment. (2012). German Resource Efficiency Programme (ProgRess). Programme for the Sustainable Use and Conservation of Natural Resources. Germany: BMUB.

Associations (RWA) in townships in India to collect and dispose the C&D waste. RWAs in condominiums in Gurgaon, Haryana have issued notices to home owners not to mix the C&D waste with municipal solid waste (MSW). The waste is collected in separate bins and transported to designated dumpsites by contractors. Such initiatives show the increasing levels of awareness on C&D waste in India.

In Germany, Austria, Switzerland and parts of Northern Italy, before controlled demolition is carried out, a detailed planning, including a concept for controlled demolition and disposal or recovery has to be performed. Detailed planning for deconstruction has also been introduced in Spain[62].

Market mechanisms: Green ratings for buildings and infrastructure and ecolabels are instrumental in popularising the use of secondary raw materials. Green ratings in Australia and the United Kingdom promote the use of C&D waste in construction. The Green Building Council of Australia (GBCA) has developed Green Star tools for rating buildings on sustainability. C&D waste reduction is one of the criteria for rating. The green rating tool for infrastructure by the Australian Green Infrastructure Rating Council specifies the use of low embodied materials in construction[63]. Leadership in Energy and Environmental Design (LEED) is the US based green rating system developed by the United States Green Building Council (USGBC) and is one of the most prominent rating systems for green buildings in the world. The German Sustainable Building Certificate, a voluntary scheme run by the German Sustainable Building Council (DGNB26) sets the criteria to ensure the sustainability of buildings.

Green Rating for Integrated Habitat Assessment (GRIHA) is a national rating system for buildings in India jointly developed by The Energy and Resources Institute (TERI) and the Ministry of New and Renewable Energy (MNRE). GRIHA is a five star rating system to rate commercial, institutional as well as residential green buildings with a built-up area ranging from 2,500 m^2 to 150,000 m^2. A set of 34 criteria categorised under various sections has been developed under GRIHA. In addition to energy efficiency and design and siting parameters, it also looks at the use of sustainable building materials in construction including the use of recycled materials[64].

Research and Development: Research on the use of industrial wastes as secondary raw materials has also been instrumental in developing and mainstreaming resource efficient products and production practices in India. Several academic and research institutes, industry and civil society organisations are engaged in research to utilise wastes like pond ash, foundry waste and marble sludge in brick making. These wastes substitute soil as the raw material in bricks. Research is also being conducted to develop different blended cements like Limestone Calcined Clay Cement (LC3). LC3 is a blend of limestone and calcined clay. It combines the use of abundantly available low-grade kaolinite clay and 15% of limestone, with no reduction in mechanical performance. It can be produced with existing equipment and reduces the clinker content in the cement[65].

62 European Commission (DG ENV). (2011). Service Contract on Management of Construction and Demolition Waste SR-1, Final Task Report 2. Paris.

63 Edge Environment Pvt. Ltd. (2011). Construction and Demolition Waste Guide - Recycling and Re-Use Across the Supply Chain. Department of Sustainability, Environment, Water Populations and Communities, Commonwealth of Australia.

64 GRIHA homepage. Green Rating for Integrated Habitat Assessment. Available at: www.grihaindia.org

65 Bishnoi, S., Maity, S., Mallik, A., Joseph, S., & Krishnan, S. (2014). Pilot scale manufacture of limestone calcined clay cement: The Indian experience. The Indian Concrete Journal, 88(7): 22-28.

Recommendations for Both Sectors

Automotive Sector:

Greater recovery of secondary materials from ELVs

Use of secondary raw materials by way of reuse and recycling is a viable option for enhancing resource efficiency. As per known reuse statistics for India, up to 70% of a vehicle is dismantled and directly reused or sold to other manufacturers[66]; however this is not done in an economically or environmentally optimal way. It is imperative to develop a comprehensive framework for "Environmentally Sound Management" of the ELV sector to enhance resource recovery potential in the automotive sector. The Government of India has taken an initiative in this direction by framing the Draft Guidelines for End-of-Life Vehicle Management[67].

The framework should promote socially inclusive and environmentally safe methods of recycling which also allows the companies for closed loop recycling and recovery. It is well documented that current recycling methods, particularly the handling of ELVs by informal dismantlers, leads to loss of resources and leakages of hazardous constituents like glass wool, waste oils, coolants, etc. Recycling also needs a well-organised collection system and energy-efficient recovery mechanisms to supply the market with competitively-priced, high-quality secondary materials.

Improved material flow management

Material flow management, which refers to the continuous and targeted optimisation of material and energy flows, is another option for enhancing resource efficiency. It helps create transparency by identifying wastage of resources that can be captured, mapped and analysed before being allocated to the relevant process steps, which can enable and support comparison of various scenarios and technologies, thereby optimising the flow of individual materials. Some of the Indian component manufacturing units have adopted principles of lean manufacturing leading to an improvement in flow of material in the production lines, thereby reducing reject rate, but such approaches need to be promoted among smaller units.

Increased product life

It is also important to explore ways to increase the efficiency and life of the product. Iron and steel use has steadily decreased, while plastics and aluminium has steadily increased. The decline in steel used in automobiles is due to use of better and more compact steel components in recent years, particularly the use of the high strength steel plate (High-Tensile Steel), the use of which is rapidly increasing as a means of car body weight reduction. Aluminium and plastics are valuable car components not only for their lighter weight, but also because of their inherent corrosion resistance.

The example showcases that the strategy simultaneously supports three objectives: reduction in material and energy consumption as well as reduced environmental impact. The product and component manufacturers should focus on increasing the life of the product as well as its efficiency. The automobile industry can contribute to resource efficiency by prolonging the service life of the vehicles being produced. Manufacturers should support the longevity of vehicles and its components by ensuring that they can be serviced, repaired and maintained. The extension of the lifetime of a vehicle not only reduces costs for consumers, but also helps in conserving resources and energy.

Improved design to incorporate sustainable materials

Ways should be identified to increase the use of recycled materials and reduce the use of undesirable materials like hazardous metals in automobiles. Innovative usage for recycled materials in the non-metallic portions of the vehicle, which are typically composed of virgin materials, should be explored. For example, the Ford Motor Company had a Voluntary Recycled Content Usage Policy in North America for many years, which set goals for the use of non-metallic recycled content for each vehicle. These targets were increased year by year with each new model by Ford. Under this program, recycled materials are selected for all of Ford's vehicles, whenever technically and economically feasible[68].

Design for Recycling (DfR) focuses on promoting efficient recycling from the production stage itself

66 Akolkar, A., Sharma, M., Puri, M., Chaturvedi, B., Mehra, G., Bhardwaj, S., Mutz, D., Arora, R., & Saluja, M. (2015). The Story of Dying Car in India. Part II. Report prepared on behalf of GIZ, CPCB and Chintan. New Delhi: Central Pollution Control Board.

67 CPCB. (2015). Draft ELV Guidelines. New Delhi: Central Pollution Control Board. Available at: http://cpcb.nic.in/upload/Latest/Latest_113_Draft_Guidelines_ELV-1_.pdf

68 Ford Sustainability Report 2013/14. Sustainable Materials. Available at: http://corporate.ford.com/microsites/sustainability-report-2013-14/environment-products-materials.html

that allows easy dismantling and removal of the hazardous constituents. At the design stage of the product, optimal use of a resource should be taken into consideration that can have dual benefits such as energy conservation as well as time saving and cost reduction. The companies can invest more in improving the quality of recycled material to substitute primary material and thus conserve energy and reduce emissions. Some of the by-products or waste products could be a valuable resource for some other processes; thus re-utilising and re-using these products should be encouraged instead of disposal.

Importance of training and capacity development

It is also important to train the personnel involved in the manufacturing process about the efficient use of resources and motivate/encourage them to adopt skills and knowledge in resource efficient techniques and processes. As resource productivity is a step-wise process, enhanced capacities of industry personnel lead to identification of the key challenges, identification of corrective measures and its implementation mechanism in a phased manner.

Reducing air pollution and GHG emissions

The transport sector in India is a leading emitter of greenhouse gases and increased transportation demand will further push up GHG emissions in future. Growing reliance on personalised modes of transport, particularly in urban areas, leads to negative impacts like road congestion, deterioration in ambient air quality and sound pollution. However, over the last two decades, environmental problems caused by the transport sector has caught the attention of policy makers. During this period, various steps adopted by the central and state governments have included elimination of lead in petrol, switching to natural gas in public transport fleets, and adopting Euro emissions standards for new vehicles.

India's Auto Fuel Policy of 2003 identified a roadmap for vehicular emissions and fuel quality standards. India's National Action Plan on Climate Change recognised that GHG emissions from the transport sector can be reduced further by adopting measures that include increased use of public transport, increased use of biofuels, as well as improving fuel efficiency of vehicles. Since there is likely to be a substantial increase in the share of diesel run vehicles in the short to medium term, it becomes very important to implement Bharat VI emission standards earlier than the proposed timeline[69]. This would help in taking advantage of the fuel savings from the use of latest diesel engine technology without worsening air pollution from diesel vehicles. At the same time, a comprehensive and stringent regulatory roadmap would help the oil and automotive sectors in India have better clarity and enable faster adoption of technology[70].

Developing a broader perspective on mobility

If the automotive sector is considered in a broader context, a comparison should be made between different mobility options. The most environmentally-friendly and resource-efficient mobility options are walking and cycling, followed by mass public transportation. Therefore, urban infrastructure should be developed to support these forms of mobility rather than undermining them. Infrastructure for pedestrians and cyclists, as well as dedicated mass transit corridors, needs comprehensive planning. In India's fast growing megacities, these forms of transport are often threatened and marginalised by motor vehicles and their attendant infrastructure.

Construction Sector:

In order to promote resource efficiency in the construction sector through the use of secondary raw materials, policy and market decision makers should be informed about various available options and models of resource efficiency to create a complete ecosystem. The following measures need to be implemented to promote effective and widespread utilisation of C&D waste in the construction sector.

Accurate inventorisation of C&D waste

One of the first things that need to be addressed in terms of usage of secondary raw materials is to assess and estimate the quantum of waste generated. While the study conducted throws some light on the magnitude of the issues, a more detailed quantification and characterisation is required to better plan an effective waste management strategy. For effective inventorisation, the point of origin as categorised in the C&D Waste Management Rules, 2016 should be considered as the starting point. Therefore, it is recommended that it should be mandatory for every demolition and renovation/retrofitting activity to take a permit from the respective urban local body (ULB). The permit shall necessarily include the estimated quantum of C&D waste generated and the management plan,

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69 Sasi, A. (2016, January 7). Simply put: What needs to be done to upgrade from BS-IV. The Indian Express. Available at: http://indianexpress.com/article/explained/simply-put-what-needs-to-be-done-to-upgrade-from-bs-iv/

70 Bansal, G., & Bandivadekar, A. (2013). Overview of India's Vehicle Emissions Control Program: Past Successes and Future Prospects. International Council on Clean Transportation, Washington, DC. Available at: http://www.theicct.org/sites/default/files/publications/ICCT_IndiaRetrospective_2013.pdf

which will be verified against actual disposal records (at the designated site). Suitable penalty clauses shall be included in case of non-compliance. Such a permitting system will enable ULBs to create a comprehensive and accurate inventory of C&D waste generation. Large infrastructure projects undertaken by public bodies such as Public Works Department (PWD) should also be covered under the system.

Building capacities of ULBs

The responsibility of managing waste including C&D waste is with the ULB. Thus it is important that ULB officials have the technical and managerial capacity to perform effective waste management. This is currently a gap due to the lack of easy access to tools, methodologies and technologies that can aid this process. It is recommended that every ULB should have a designated task force for C&D waste management. Ideally, such a task force should have representation from the ULB, expert institutions, local civil society organisations, as well as the State Pollution Control Board (SPCB). One aspect of future work can be the development of an easy-to-use guide for the taskforce to estimate and plan for the C&D waste generated. Good practice guidelines and manuals for the entire life cycle of waste management ranging from estimation, collection, segregation, processing and final disposal for C&D waste should be developed and shared with the ULBs.

Technical support to new entrepreneurs

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

Building a business case for private entrepreneurs

Weak business models due to uncertainty in the supply of raw material and limited market penetration of the processed product are other barriers entrepreneurs face. Test results[71] show that paving blocks made with C&D waste from Ahmedabad and Bengaluru fulfil the properties of compressive strength (as per BIS 15658:2006) for non-traffic, light-traffic and even medium-traffic uses. In addition, they also offer cost reductions ranging from 19-33% depending on the availability of C&D waste. Thus, it can be an economically viable business for small entrepreneurs. However, potential entrepreneurs should be made aware of the technical and economic viability of the enterprises through activities such as seminars, workshops, one-to-one interactions, advertisements and trade publications.

Large-scale awareness and sensitisation of users

Lack of familiarity with the products and hence inadequate confidence about their quality, are obstacles for potential users. The general perception associated with products made from waste is one of inferior quality, especially when compared to those using virgin resources. This needs to be overcome through large-scale awareness efforts as well as standardisation and certification. It is recommended that demonstration projects should be implemented and properly advertised to sensitise users about products made from secondary materials, especially architects, developers and contractors.

Developing favourable policies for products made from secondary materials

Codes and standards that ensure products meet quality standards will go a long way in building user confidence in the product. BIS codes should be supported by preferential procurement of products made from secondary materials. This can be done through amendments in tenders issued by public enterprises in the construction sector.

Furthermore, incentivising the market, as has been done for fly ash based bricks through preferential procurement policy, will help overcome initial market barriers. Even with current levels of C&D waste generation, there is scope for multiple reprocessing SMEs to come up in each city.

However, in order to safeguard the interests of these SMEs, it is essential to create a favourable policy environment wherein technology, economic and capacity concerns are dealt with. Advocating lessons from demonstrations and studies on the ground with decision makers in the public and private sectors will encourage them to explore, understand, assess and promote good practices that gradually become mainstream.

[71] GIZ. (2015). Resource Efficiency in the Indian Construction Sector: Market Evaluation of the Use of Secondary Raw Materials from Construction and Demolition Waste. New Delhi: GIZ.

Future Outlook

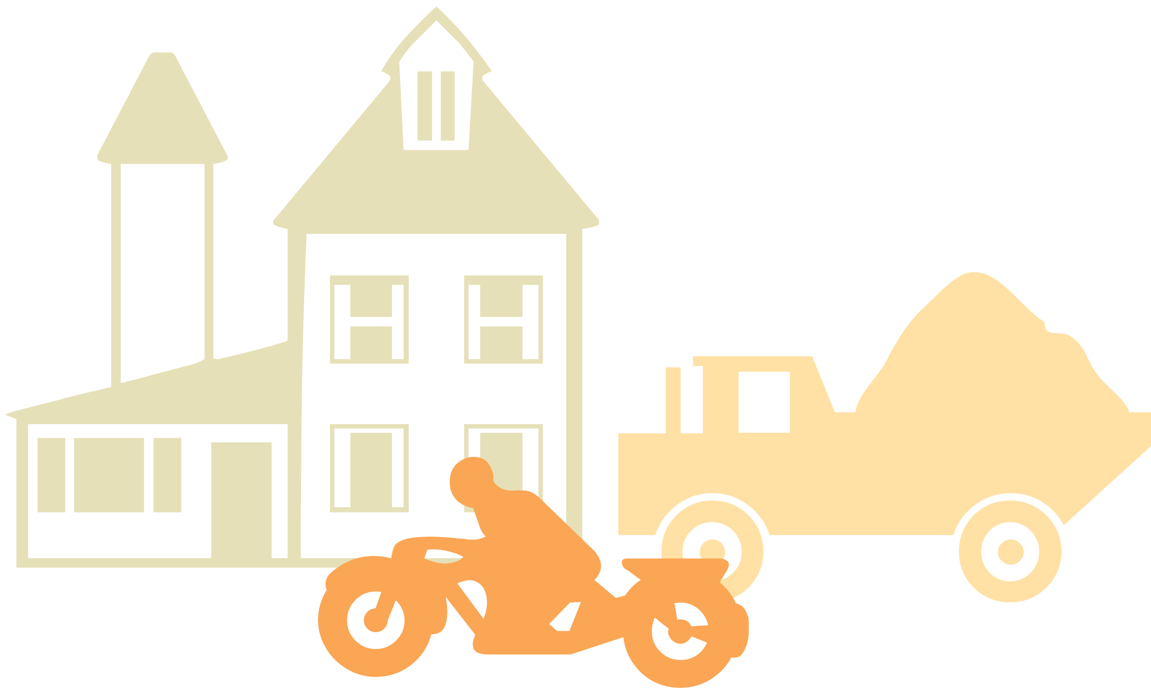
A farsighted and comprehensive resource policy is essential for India going forward in order to meet social, economic and environmental sustainability goals. The lessons coming out from the analysis of the two sectors in this report – automotive and construction – can be extended and applied to the wider economy as well. This is the broader goal of the Indian Resource Panel, set up under the project. A comprehensive resource policy would need to:

a) Involve a wide range of stakeholders, starting from coordination between different government ministries such as mining, transportation, heavy industry, etc., as well as between different levels of government including state and local, to research and standard setting organisations, to the private sector, and finally civil society.

b) Encompass the entire life cycle of resources – from extraction, to transportation, processing, manufacturing, use, disposal as well as recycling/reuse.

c) Emphasise education, awareness, outreach and capacity development at all levels – government, the private sector and civil society – with a special focus on green marketing.

Experience from other countries that have seriously embarked on promoting resource efficiency shows that such strategies, in addition to benefitting the environment, have tangible economic benefits in terms of competitiveness, protection from shocks and macroeconomic stability. Moreover, a circular economy model is typically better in terms of employment generation, a prime concern for all governments. In India, like in many other developing countries, resource recycling in many sectors is often dominated by the informal sector that achieves surprising levels of efficiency and enormous livelihood generation potential. Working with the informal sector to address the many challenges it faces should be the underlying approach of any resource efficiency strategy in India.



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